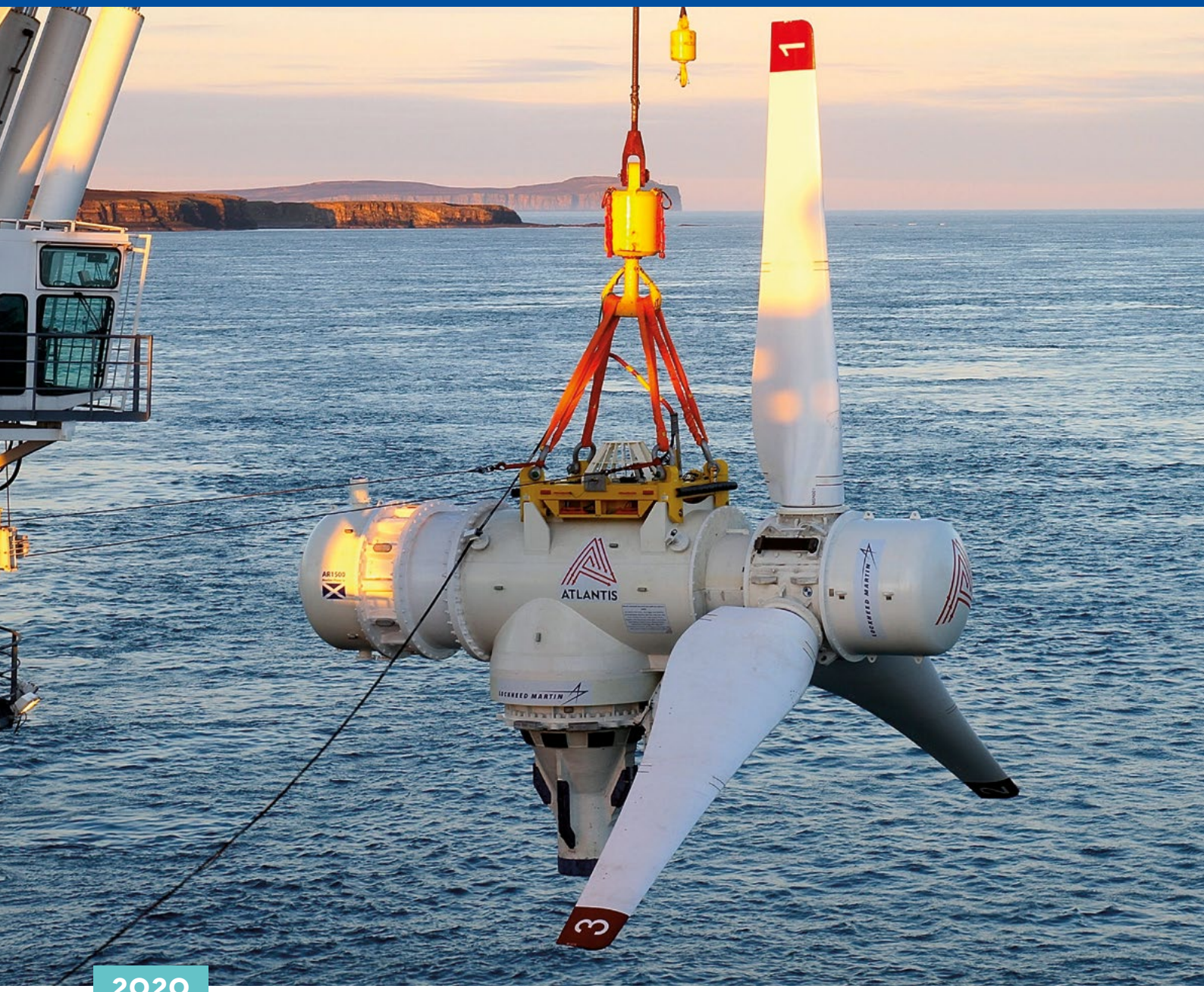
Technology Collaboration Programme
by IEA



2020

ANNUAL REPORT

AN OVERVIEW OF OCEAN ENERGY ACTIVITIES IN 2020

OES OCEAN ENERGY SYSTEMS

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CHAIRMAN'S MESSAGE

Henry Jeffrey
University of Edinburgh, United Kingdom
IEA-OES Chairman (2017 – 2020)

A warm welcome to the 2020 OES Annual Report. The beginning of a new decade brought new challenges and created new opportunities for the ocean energy sector. I trust that, in this unprecedented year, you will find this report valuable and informative.

This year marks also the end of my term as chairman of OES. In the two terms that I have served in this position, the ocean energy sector has achieved important milestones. Cumulative global wave and tidal stream capacity has more than doubled since 2017 reaching approximately 65 MW in 2020 and slowly approaching the OES vision of 300 GW of global capacity by 2050. Successful deployments have taken place in all corners of the world from Australia, through Asia and Europe to North America. Some of these demonstration projects have been grid-connected reaffirming the potential role of ocean energy in the achievement of decarbonisation goals.

In the last four years, more countries have implemented market instruments for the ocean energy industry to progress towards commercialisation, e.g., Feed-in-Tariffs have been introduced in Canada and China, auctions and tenders have taken place in Portugal and Ireland, legally-binding targets have been established in Spain and Ireland and ocean energy technologies have been made eligible for renewable purchase obligations in India. Also, international organisations joined efforts to support the development of the sector. The European Strategic Energy Technology Plan proposed LCOE targets of 10ct€/kWh and 15c€/kWh in 2030 for tidal stream and wave energy respectively while OES began collaborating with the International Renewable Energy Agency and the International Network on Offshore Renewable Energy to promote research and development.

Member countries in all continents have continued fostering technology research and innovation with new funding and projects and have created knowledge exchange opportunities between academia, industry and governments: research centres have opened in Mexico and Australia, a testing facility opened in Oregon, USA, funding programmes and initiatives have started including the Chinese Special Funding Plan for Marine Renewable Energy, Wave Energy Scotland, the Australian Blue Economy Cooperative Research Centre program, Horizon 2020/Horizon Europe, and the American Powering the Blue Economy initiative, among others. Lastly, we have witnessed the creation and implementation of policies to reduce administrative barriers such as Marine Spatial Plans in France and Portugal.

In this very unusual year, the COVID-induced crisis showcased the resilience of renewable energy and has served as a driver for the development of these technologies. The OES member countries have continued to work hard to demonstrate the feasibility and benefits of ocean energy. I would like to heartily thank them for their time and contributions to this year's report. Despite delays due to the global pandemic, our member countries have spared no efforts to aid the development of the ocean energy sector across the globe in 2020. Open-water tests and deployments have been successfully executed in America, Europe and East Asia. These and other achievements and events taking place throughout 2020 are described in this report.

I appreciated very much the open discussions on many different topics in the OES. We have to continue with exchange of experiences and knowledge, and working together. It was for instance very good to see that international collaboration in OTEC increased.

I would like to close my last message as chairman by thanking Ana Brito e Melo for her effort in coordinating and preparing this report every year and Yann-Hervé De Roeck and Matthijs Soede for their work and support as vice-chairs. I would also like to congratulate Yann-Hervé, who has been elected as the new chairman. I am sure that he will lead OES to the development of sound and shared knowledge for the achievement of the goals in the OES international vision. I look forward to continuing as an active member of the ocean energy sector supporting the development and commercialisation of these technologies with my work within OES and the international community.

NEW CHAIRMAN'S MESSAGE

Yann-Hervé De Roeck
France Energies Marines
IEA-OES Chairman (2021 – 2022)

Dr. Yann-Hervé De Roeck has been educated in France as a civil engineer (Ecole Polytechnique, Ecole Nationale des Ponts et Chaussées) and applied mathematician (PhD in numerical analysis, University Paris-Dauphine).

In 1991, he joined Ifremer, the main French oceanographic research institute, contributing to many numerical modelling programs from composite materials for marine usage to geophysics and coastal oceanography. His experience comprises: setting up a system for coastal operational oceanography mixing data and modeling, Previmer; a monitoring program for the coastal environment, Rebent; contributing to marine data policy at the European level, Emodnet.

He is now the Executive Director of France Energies Marines, one of the French Institutes of Technology: a public-private research institute fully dedicated to Offshore Renewable Energies that he created in 2012.

Dr. Yann-Hervé De Roeck is the French delegate to the Ocean Energy Systems Technology Collaboration Program of the International Energy Agency since 2015, Vice-chair since 2017.

In this 2020 OES report, I would like to highlight how challenging it is to step forward for this challenging and demanding position, i.e. to become the next chairman of the IEA-OES, after the brilliant two terms that Henry Jeffrey has conducted. Henry managed to lead us as a tightly united group of experts that have worked together to express to a growing number of stakeholders how confident one should be in the potential, the reliability and the viability of ocean energy technologies by providing benchmarks, reports, methodologies and supporting efforts of complimentary international organizations also involved in the development of the sector.

Indeed, as emerging technologies, ocean energies must express a specific and unified voice of commitment in the urgent worldwide decarbonation of energy production. The natural potential of OE is such that, if in some part of the world, the local situation (economic, regulatory, etc.) is favorable for a successful deployment of wave, tidal range/stream, oceanic current, OTEC or salinity gradient, these solutions can develop rapidly, as long as a group of recognized experts like the IEA-OES is able to shape international communication efforts. We thus have to continue developing tasks that provide a sound and shared knowledge about numerous key issues, such as:

- The potential of technically exploitable resources updated by a state of the art of the various technologies: too many diverging figures exist in currently circulating references;
- Rigorous benchmarking of physical and numerical modelling tools for the design, optimization, and, later on, operations and maintenance of the energy conversion systems;
- Shared recognition of technical criteria and thresholds that enable to assess the level of maturity of any given technology, helping stakeholders to build confidence;
- Contribution to the wide dissemination or interoperability of databases relative to environmental impacts, present and historical deployment of technologies, test centers, etc.
- Transparent access to and comparison of, between countries, regulatory processes, consenting, incentives, etc. in order to benefit from identified innovation and best practices.

Whenever possible, and with transparent discussions between all members that are often solicited by other overarching organizations (professional groups, agencies, scientific committees, etc.) our TCP should also continue to engage in collaborations on selected topics in order to avoid duplication of efforts within a currently limited community of ocean energy experts.

I thus hope that in this 2-year term, readers of the following reports will witness and participate in outstanding progress within the ocean energy sector.

EXECUTIVE SUMMARY

Ana Brito e Melo
IEA-OES Executive Secretary

Ocean Energy Systems (OES) is the short name for the **Technology Collaboration Programme on Ocean Energy Systems** under the International Energy Agency (IEA).

The Technology Collaboration Programme (TCP), a multilateral mechanism established by the International Energy Agency (IEA), was created with a belief that the future of energy security and sustainability starts with global collaboration. The programme is made up of thousands of experts across government, academia and industry in 55 countries dedicated to advancing common research and the application of specific energy technologies.

The Technology Collaboration Programme (TCP) 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.

Currently there are 38 individual technology collaborations working across several technology or sector categories: energy efficiency end-use technologies (buildings, transport, industry and electricity), renewable energy and hydrogen, fossil energies, fusion power, and cross-cutting issues. These technology collaborations are a critical, member-driven part of the IEA family, but they are functionally and legally autonomous from the IEA Secretariat.

As of December 2020, 22 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 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.

The OES international co-operation facilitates:

- Securing access to advanced R&D teams in the participating countries;
- Developing a harmonized set of measures and testing protocols for the testing of prototypes;
- Reducing national costs by collaborating internationally;
- Creating valuable international contacts between government, industry and science;
- Sharing information and networking.

This Annual Report presents an overview of progress made by the IEA-OES in 2020, including summaries of ongoing projects and updated country reviews prepared by the Delegates.

KEY ACHIEVEMENTS IN 2020

Since 2002, members of the OES participate in co-operative research tasks and exchange information on current and future activities at semi-annual meetings. In 2020, OES supported:

4
KEY PROJECTS

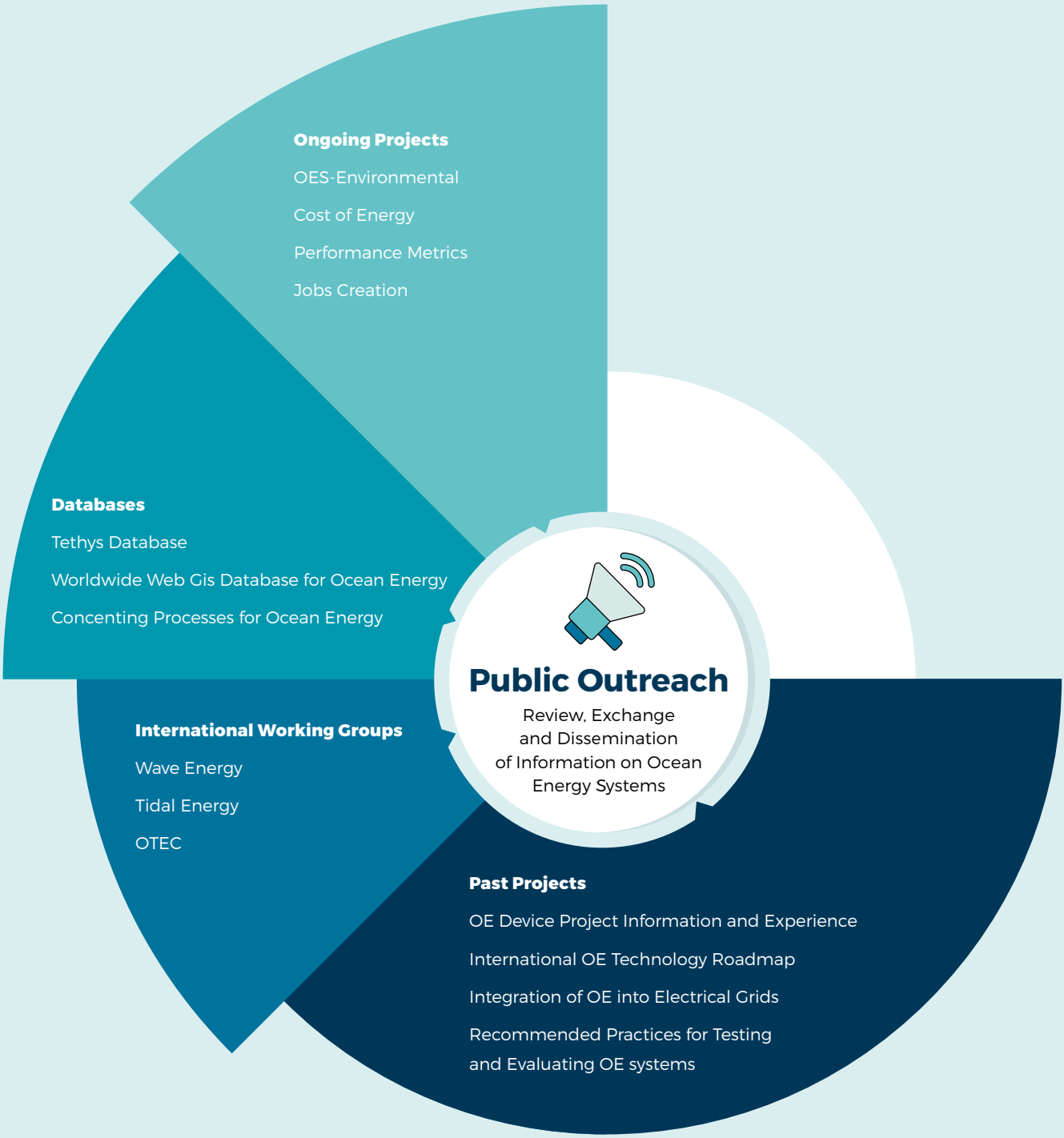
- OES-Environmental
- Cost of Energy
- Performance Metrics
- Assessment of Jobs Creation

3
ACTIVE NETWORKS

- Wave Energy Modelling Group
- Tidal Energy Modelling Group
- OTEC group

3
DATABASES

- Tethys Database on Environmental Issues
- Consenting processes on ocean energy
- World Wide WebGis Database – ocean energy projects



Participation in the IEA-OES continues to represent high value. The work is structured in a number of Tasks, which have well defined objectives, budgets, and time frames.
Through its activities, the IEA-OES aims to increase awareness of ocean energy technology and enhance international cooperation related to sustainable development.

In the course of 2020, the following publications were released:

- *OES-Environmental 2020 State of the Science Report: Environmental Effects of Marine Renewable Energy Development Around the World*, June 2020
- *Ocean Energy in Islands and Remote Coastal Areas: Opportunities and Challenges*, July 2020
- *Six Interviews on the Blue Economy and its Promising Markets for Ocean Energy*, September 2020

The task on environmental issues - **OES-Environmental (OES-E)** – continues to be led by the US Department of Energy (DOE) and implemented by the Pacific Northwest National Laboratory. Fifteen countries have been participating in this task, with three new countries joining OES-E: Mexico, Monaco, and Singapore. Ongoing work to collect, curate, and make accessible existing information on ocean energy environmental effects for *Tethys* continues to expand the platform and reach ever growing audiences. There are currently 3,161 documents that address environmental effects of marine renewable energies available on *Tethys*. OES-E hosted several online workshops during 2020 bringing together experts to further understand key interactions and to work towards consensus on how research and monitoring information can inform consenting processes, and accelerate deployments for the ocean energy industry.

OES has two tasks dedicated to the **modelling verification and validation of ocean energy technologies**, one led by Ramboll in Denmark, focused on wave energy, and a second one, focused on tidal energy, led by the Energy Research Institute at Nanyang Technological University, Singapore. Both groups have been collaborating with a number of experts from universities, research institutions and companies and comparing results among different numerical codes. A group of member countries – Japan, India, China, France and The Netherlands – have been working together on **OTEC** to assess the potential around the world and discuss the present status and plans for OTEC projects. A White Paper on OTEC is expected to be released in 2021.

OES has been developing efforts on the topic of **international performance evaluation of ocean energy technologies** with strong inputs from the European Commission, the U.S. Department of Energy and from Wave Energy Scotland, aiming to support the definition of a fully defined set of metrics and success thresholds for ocean energy technologies and develop an internationally accepted approach. A report was completed discussing the benefits of common evaluation approaches in the ocean energy sector to help build consensus.

Development of safer, more efficient technologies is imperative for energy security, environmental protection and economic growth. Equally essential is the widespread deployment of more economical and environmentally benign technologies. IEA experience has shown that international collaboration on these activities avoids duplication of effort, cuts costs and speeds progress.

Source: IEA Energy Technology Perspectives (ETP)

A new study commissioned in late 2019 to assess the **number of jobs related to the development of the ocean energy sector** is ongoing, coordinated by France Energies Marines. One difficulty to properly assess the number of jobs relies on the methodology applied and so the proposed project provides both a methodology and actual figures of job assessment with an indication of the robustness of the models used, their limitations and the quality of their outputs.

A webinar **on ocean energy in insular conditions** was organised by OES, with three invited speakers: the author of the report published by OES in July 2020, the CEO of Nova Innovation and the Deputy Director of IRENA.

OES commissioned to EMEC the development of a database for **open-sea testing**, in collaboration with the International WaTERS network, to exchange information on open-sea test facilities at a global scale.

Interest and outreach for new membership continued in 2020. IEA-OES is always looking for new members across the globe, and key representatives from potential new member countries are encouraged to attend the Executive Committee meetings as Observers.

COUNTRY HIGHLIGHTS

Policy Landscape

In 2020, the **United States** Department of Energy´s Water Power Technologies Office (WPTO) announced its largest funding opportunity of the year—over $22 million in funding for marine energy R&D, including the support to develop a new Atlantic Marine Energy Center. Also relevant was the launch of the WPTO's Powering the Blue Economy™ initiative that made more than 85 awards to industry and academia to catalyse innovation in ocean energy.

Numerous new funding opportunities have been announced by the WPTO throughout 2020: the Ocean Observing Prize with up to $2.4 million in cash prizes, the Waves to Water prize competition with $3.3 million in cash prizes for wave-powered desalination systems; a $4 million solicitation to organizations to support entrepreneurship and technology commercialization in the blue economy; and TEAMER, a 3-year $9 million testing campaign providing low-cost access to testing infrastructures at certified facilities from several top leading US R&D institutions kicked off its first round of testing. In November 2020 ARPA-E, a separate office within the U.S. Department of Energy, awarded $35 million in funding for 11 projects on tidal and river currents turbines as part of the Submarine Hydrokinetic And Riverine Kilo-megawatt Systems (SHARKS) programme.

The Government of **Canada** also remains committed in supporting the sector: $4 million funding has been awarded for Nova Innovation's project and $28.5 million to Sustainable Marine Energy for their projects at FORCE, the Canada's primary centre for the demonstration of in-stream tidal energy technologies. Further, with support from the Canadian Government, FORCE is leading various research and initiatives to gather knowledge about tidal energy and support technology and project demonstration. In 2020, FORCE was awarded $2 million for a project dedicated to environmental studies to help inform regulatory processes.

A number of ocean energy initiatives have been progressing in **Australia**. This includes the release of a draft regulatory framework a national level for offshore clean energy infrastructure. Policy initiatives relevant for ocean energy have been further introduced by three States during 2020: Victoria released a new marine and coastal policy; Western Australia released a Distributed Energy Infrastructure Roadmap; Tasmania released a Renewable Energy Action Plan becoming the first Australian state to provide specific recognition to ocean energy. The Australian Ocean Energy Group (AOEG) continued to build awareness of ocean energy across a range of potential markets in Australia and launched their Ocean Energy Market Development Programme in 2020. Several public funding programmes continue supporting ocean energy: Since its inception in 2012, ARENA has funded 13 ocean energy projects; State Government public funds have also funded R&D activities for ocean energy technologies.

China released a white paper "Energy in China's New Era" by December 2020 and has proposed to work together with the international community on the sustainable development of global energy, addressing the challenges of climate change. The Government listed renewable energy as a priority area for energy development and is formulating medium and long-term targets. The Government is further preparing relevant financial policies to support the development of renewable energies, including ocean energy. With the support of governmental funds, test sites are under development and many tidal current and wave energy devices have completed sea trials, some of them applied to remote islands.

The Government of **Japan** has put in place policies and funding initiatives to promote and grow the ocean energy sector in the country. NEDO has been supporting research and demonstration of ocean energy power generation and will launch a new programme in 2021. Notable is also the flagship funding programme by the Ministry of the Environment (MOE) on tidal current technologies.

In **Republic of Korea**, the Government established a commercialization plan of ocean energy systems to contribute to the new national renewable energy policy and targets for 2030. In particular, the Government is supporting the development of two open-sea test sites for wave and for tidal energy. A bilateral cooperation project (2018-2020) between Republic of Korea and China, led by Korea Institute of Ocean Science and Technology and by the First Institute of Oceanography (FIO), has been promoting exchange of information on the technology and the utilization of ocean energy systems, and will continue in next years.

Ocean energy has also been identified as one of the prominent alternative energies by ERI@N in **Singapore** specifically towards remote coastal regions and islands. The Government encourages clean technology companies to use Singapore as a 'Living Lab' to testbed and demonstrate innovative solutions. Over the past few years, the Energy Market Authority of Singapore has awarded over $100 million to address industry-relevant challenges and

opportunities in the energy sector that lead to long-term solutions for Singapore's energy challenges. The Singapore Government announced S$49 million in October 2020 to fund low-carbon energy research for the next five years.

In the **United Kingdom**, the Government continues to offer revenue support to a variety of renewable energy technologies through the Contract for Difference (CfD) programme and aims to provide support to less 'established technologies'; the separation of wind technologies into a different category is expected to enable ocean energy technologies to compete more fairly if further CfD reform is undertaken. The Scottish Government continues to champion the ocean energy sector, supporting the research, development, innovation, and demonstration intended to maintain Scotland's position as a world leader in both wave and tidal energy. In 2020 Wave Energy Scotland (WES) awarded £1.4 million to four projects developing quick connection systems for wave energy devices. Marine Energy Wales in its 2020 State of the Sector Report details that a total of 16 developers are actively progressing projects in Wales, driven by a strong policy to support the sector: Over £123.7 million has been spent to date in Wales on the development of the marine energy industry.

Over the course of 2020, there has been significant progress in **Ireland** in relation to policy for offshore renewable development, with ambitious targets set by the Government for offshore renewable energy. A new Offshore Renewable Energy Development Plan is planned to be developed throughout 2021, in continuation of the one that has been in place since 2014. Work is underway to develop Ireland's first marine spatial plan, which will set out the proposed future approach to the adoption of spatial designations for marine activities including offshore renewable energy development. The Sustainable Energy Authority of Ireland continues to support innovative energy RD&D projects and currently 12 offshore energy projects are funded with a new call planned to be open in 2021. Ireland leads the OceanSET initiative, funded by the EC, with the overall goal to support the realisation of the ocean energy SET-Plan and published, in 2020, a comprehensive review of ocean energy projects funded in Europe.

The Spanish Government launched in 2020 a public consultation process for the development of Offshore Wind and Ocean Energies in **Spain**. During 2020 the Spanish Government further continued working in the Energy and Climate National Integrated Plan 2021-2030 (PNIEC), in which administrative procedures are proposed to accelerate the licensing and permits for high TRL R&D grid connected projects.

In **Portugal**, ocean energy goals are supported by the Industrial Strategy for Ocean Renewable Energies published in 2017; the National Energy and Climate Plan (NECP) for the period 2021 - 2030 foresees 70 MW for wave energy reached by 2030. A number of projects for wave energy demonstration have been supported by national funds (Blue Fund).

Some of the policy actions proposed are 'technology-push' mechanisms, typically in terms of capital grants, financial incentives or prizes, that encourage research and innovation in ocean energy and the development of the first demonstration projects. One example is Wave Energy Scotland (WES), established by the Scottish Government, which aims to develop cost competitive wave energy technology in Scotland. WES supports innovation calls, strategic projects, industry engagement and collaboration activities.

In **France**, the recently updated "Pluri-annual Energy Policy", has ambitious targets for offshore wind installed capacity; for ocean energies, objectives remain limited to the availability of public incentives for prototypes and pilot farms until the LCOE of these technologies is demonstrated to be commercially competitive with respect to other renewable sources of energy. Since July 2020, France once again is benefiting from a dedicated Ocean Ministry promoting an efficient marine spatial planning and a public debate on consenting process. Six large completed or ongoing ocean energy projects are benefiting from Environment and Energy Agency (ADEME) support. At the regional level, local authorities have been also supporting the endeavours of this sector.

The sustainable development of the oceans is among the most important political priorities in the State of **Monaco**. In December 2020, Monaco increased his commitment to reduce the greenhouse gas emissions by 55% in 2030 compared to the reference date of 1990 and to achieve carbon neutrality in 2050. In Monaco, the sea is used as a renewable energy source for the development of a heat pump system, with the first seawater heat pump in Monaco dating back to 1963.

In **Italy**, attention is growing for the exploitation of ocean energy. Initiatives in this sector are multiplying, but the most significant at public level concerns 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 the country.

In 2020, **Germany** held the presidency of the North Seas Energy Cooperation (NSEC) a cross-border group, currently comprising nine European states and the European Commission as its members. The focus of the NSEC's work is on the expansion of offshore wind energy and offshore grid infrastructure. Germany's presidency in 2020 focused on the promotion of joint and hybrid projects, where offshore wind farms are linked through an interconnector to at least two member states. On the ocean energy sector, several German R&D institutes and universities continue fully involved into developing wave, tidal current and osmotic power mainly in the framework of National and European research projects.

Throughout 2020, the *Danish Partnership for Wave Energy* proposed a new strategy for the development of wave power in **Denmark**. This strategy envisages that wave power already in 2030 can become a part of the renewable energy mix in the North Sea. The Danish Energy Agency, through its funding scheme EUDP (Energy Technology Development and Demonstration Programme), has been supporting private companies and universities to develop and demonstrate new and innovative energy technologies.

In the **Netherlands**, a study was carried out during 2020 to determine the possible contribution of marine energy to the Dutch 'energy transition', together with research institutes, governments, the marine energy sector and individual developers.

In West Flanders, coastal Western part of **Belgium**, marine renewable energy is seen as a new emerging industry, highly relevant for Flanders. There are several relevant initiatives promoting the development of the blue economy, including marine energies. The Flemish Agency for Innovation and Entrepreneurship (VLAIO) has been supporting the blue economy sector, including marine energies. Moreover, the West Flanders Development Agency (POM West Flanders) is also supporting developments in the blue energy field, promoting the development of ocean energy technology by the academic and private sectors.

In **Sweden**, governmental agencies have been supporting relevant R&D projects at various stages of technology maturity, conducted by the academic and private sector. A €3 million funding call from the Swedish Energy Agency has been focused on the development of cost-efficient, sustainable marine energy systems in Sweden, knowledge exchange and value chain development.

In November 2020 the **European Commission** launched the Offshore Renewable Energy Strategy to support the development of ocean energy in the European Union. The strategy foresees avenues for the creation of an ocean energy industry in the EU, targeting 100 MW installed by 2025, 1 GW by 2030 and 40 GW by 2050.

There are several funding schemes for ocean energy development supported by the European Commission, such the Horizon 2020, the European Maritime and Fisheries Fund (EMFF) and the European Regional Development Fund (ERDF). Currently, 25 R&D projects on ocean energy are funded through these programmes. Under Horizon 2020 the last call was launched in September 2020, funded projects demonstrating at sea critical offshore renewable energy innovations supporting the European Green Deal policy.

The Innovation Fund was launched in 2020 by the European Commission, as one of the world's largest funding programmes for the demonstration of innovative low-carbon technologies, including ocean energy. The Commission also supports the ocean energy sector via BlueInvest, a programme aiming to boost innovation and investment in sustainable technologies for the blue economy, dedicated to early-stage businesses and SMEs. InnovFin Energy Demo Projects (EDP) is another funding scheme being implemented by the European Investment Bank (EIB) together with the European Commission aiming to facilitate and accelerate access to finance for innovative businesses and projects in unproven markets in Europe.

The Offshore Renewable Energy Strategy released in 2020 to support the development of ocean energy in the EU recognises the role of ocean energy to contribute to the decarbonisation goal. The expectation is that by 2030 ocean technologies could make a significant contribution to Europe's energy system and industry, particularly supporting grid stability and playing a crucial role in decarbonising islands in the EU.

Progress on Ocean Energy projects

In the course of 2020, we saw relevant R&D initiatives progressing and ocean energy projects moving forward to the sea, globally:

In the **United States** a few wave and tidal projects have been successfully deployed and tested throughout 2020, with

others progressing with preparations for open sea testing. The Ocean Renewable Power Company (ORPC) redeployed its 35 kW RivGen® Power System, a submerged crossflow river current turbine system, into a river, in Igiugig, Alaska; Verdant Power's deployed the new turbine - Gen5 KHPS - at the East River near New York City. Three wave energy developers are now prepared for deployment at the U.S. Navy's Wave Energy Test Site (WETS) in Hawaii: The 100 kW Triton-C unit from Oscilla Power, the Ocean Energy's 500 kW OWC prototype and two devices from C-Power - StingRAY and SeaRAY - for different applications.

On the East coast of **Canada**, a series of tidal energy projects are underway in the Bay of Fundy: DP Energy continued to develop its 9 MW project, Uisce Tapa, completing the site specific engineering; Jupiter Hydro is planning a non-grid connected 1 MW prototype; Nova Innovation continues the development of its tidal energy project in Petit Passage with the first turbine scheduled for deployment in 2021. Also, next to FORCE, NewEast Energy is in the initial development phase of its floating array, grid connected, the New Energy EnviroGenTM Power Generation system. The Canadian sector remains focused on opportunities for remote and coastal communities, a major market in Canada and globally: Yourbrook Energy Systems, a British Columbia-based tidal energy technology developer, is continuing to develop its 500 kW Kamdis Tidal Power Demonstration Project for remote communities; ORPC Canada is involved in extensive outreach for remote communities across Canada, focused on the transition to a sustainable energy future.

CEMIE-Océano in **Mexico** has been involved in the exploration of sites for testing wave energy devices in Ensenada, Baja California, and ocean current energy devices in the Cozumel Canal, Quintana Roo. Two projects are expected to happen soon, one in each site.

In **Australia**, Wave Swell Energy moved forward with the construction of its 200 kW oscillating water column floating wave energy converter for deployment at King Island, Tasmania, in January 2021.

In **China**, the LHD tidal current energy project has been in continuous operation for several months, with cumulative power generation exceeding 1.95 GWh since 2016 until October 2020. Zhejiang Zhoushan LHD New Energy Corporation Limited (LHD) is moving now to the next upgraded stage of the project with a designed capacity of 4.1 MW; the main structure has been completed and is planned to be deployed in the first quarter of 2021. The Zhoushan tidal current energy project developed by the China Three Gorges (CTG) Corporation has also progressed: a 300 kW turbine was installed near Hulu Island. In the future, this demonstration project can serve as a testing site for tidal current energy prototypes. In 2020, a consortium of Chinese entities, including the Guangzhou Institute of Energy Conversion (GIEC), China Southern Power Grid and China Merchants Heavy Industry completed the construction and deployed at sea the first 500 kW WEC "Zhoushan"; further, a second 500 kW WEC "Changshan" started to be constructed. With this project Wanshan Island will become an important demonstration base and test site for wave energy technology. Another wave energy project completed 18 months of demonstration in December 2020 in a mariculture base of Zhuhai city: Wave Energy Aquaculture Cage "Penghu" was developed by GIEC aiming to combine wave energy (using Sharp Eagle technology) to power an integrated platform for aquaculture, tourism and science. GIEC already signed contracts with several companies.

In 2020, a consortium of Chinese entities, including the Guangzhou Institute of Energy Conversion (GIEC), China Southern Power Grid and China Merchants Heavy Industry completed the construction and deployed at sea the first 500 kW WEC "Zhoushan"; further, a second 500 kW WEC "Changshan" started to be constructed. With this project Wanshan Island will become an important demonstration base and test site for wave energy technology.

In **Korea**, a few R&D wave and tidal energy projects are being carried out by the Korea Research Institute of Ships and Ocean Engineering (KRISO). One of this projects is the 30 kW OWC wave energy converter integrated in a breakwater and combined with an energy storage system designed to provide electricity to remote off-grid islands. KRISO in collaboration with Jeju National University is also developing an arrayed-buoy wave energy converter that was tested in the open sea near Jeju Island. Further, the Korea Institute of Ocean Science and Technology (KIOST) has been developing a tidal energy converter combined with an energy storage system to supply energy to remote off-grid islands and a 1 MW tidal energy converter is already planned to be deployed next year.

In **India**, the wave powered navigational buoy system for oceanographic measurements and navigational aid, developed by NIOT, has been operating successfully in the navigational channel of Kamarajar Port, Chennai. Four of these buoys will be fabricated and deployed at ports in the Andaman & Nicobar Islands, in the north eastern

Indian Ocean, with governmental support. An important initiative has been carried out in OTEC with the design of a desalination plant in the Union Territory of Lakshadweep in India.

Mako Tidal Turbines in collaboration with researcher and industrial partners in **Singapore** is demonstrating their tidal turbine project in Sentosa waters. The offshore renewable energy integration and demonstration project - Offshore REIDS - initiated by ERI@N and funded by the Japanese ClassNK company seeks to pave the way for establishing the world's first scaled marine renewable energy testing facility for tropical needs. This project aims to develop technologies and deployment methodologies for meeting the energy needs of remote islands. Following a call from the Singapore Government for smart grid and renewable energy innovation in April 2020, ERI@N is currently developing an offshore floating solar and tidal turbine hybrid system to be deployed along the coast of Jurong Island, in the southwest of Singapore.

At the end of 2020 the SIMEC Atlantis Energy turbine (500 kW) was shipped from the UK to **Japan** and is ready for installation in the Goto Islands, Nagasaki prefecture. Also, in the sea off the Goto islands, a small scale floating tidal current device has been in continuous operation for one month, a project led by Nagasaki University. On wave energy, major success is the installation of a new wave power plant developed by the University of Tokyo, in front of the Hiratsuka Shinko breakwater in Kanagawa prefecture, already connected to the grid. Saga University has been continuously researching on OTEC and started to develop an experimental project in collaboration with Malaysia.

In 2020, many wave and tidal energy projects in the **United Kingdom** continued to progress towards commercialisation: the MeyGen array, owned and operated by SIMEC Atlantis Energy in Scotland's Pentland Firth has, in December 2020, surpassed 35 GWh since the start of the project. Nova Innovation concluded the installation of its commercial direct-drive tidal turbine "Eunice" on Shetland Islands and is progressing with the installation of two additional M100 turbines at the Shetland site. Orbital Marine Power progressed with the construction of its O2 2 MW tidal turbine for deployment at EMEC in 2021. On the Faroe Islands, Minesto started the commissioning of a 100 kW DG100 tidal kite system. A number of other deployments in UK were planned over 2020, including the 1.5 MW mWave technology from the Australian developer Bombora Wavepower off the coast of Pembrokeshire, Wales; and the redeployment of the ATIR platform from the Spanish tidal developer Magallanes Renovables. EMEC has also signed a key partnership with the Perpetuus Tidal Energy Centre (PTEC) site on the Isle of Wight to develop a multi technology tidal array demonstration facility. This partnership builds on work being carried by the TIGER funded project with 18 partners across the UK and France, in which five sites across these two countries for tidal energy developments will be developed.

Both test sites in **Spain**, BiMEP in the Basque country and PLOCAN on the Canary Islands were very busy in 2020: the Danish wave energy technology Wavepiston deployed its first full scale device at PLOCAN during the autumn of 2020; Arrecife Energy Systems tested at Bimep their floating system adequate for wave, tidal and river currents. The Finnish wave energy developer WELLO OY also signed a contract with BiMEP to test the PENGUIN2 prototype for two years. Several test campaigns were carried out at BiMEP in 2020 by the company ZUNIBAL with its oceanographic buoy to collect data in real time. Mutriku Wave Power Plant, connected to the grid in 2011, reached a record of 2 GWh of cumulative energy generation. A new open sea test site for marine renewable energies in Galicia was authorized in July 2020, located in Punta Langosteira close to the outer harbour of A Coruña.

In **Portugal**, there has been continuous progress with the oscillating water column and air turbines, following decades of research in Portugal with this type of wave energy technology and an air turbine was designed and supplied by the Portuguese company Kymaner and IST to the Australian developer Bombora Wave Power. Two wave energy developers have been much active in Portugal: AW-Energy with its First-Of-A-Kind 350 kW WaveRoller in Peniche and Corpower with its HiWave-5 pilot farm project planning to deploy a first full scale unit in Aguçadoura in 2021.

In **France**, several projects have been progressing: HydroQuest 1 MW marine tidal turbine prototype was deployed at the Paimpol-Bréhat site in the spring of 2019 and exceeded 18 months of operation. The company is now developing a 17.5 MW pilot farm at the Raz-Blanchard, Normandy, one of the most powerful tidal energy sites in the world. At SEENEOH Bordeaux test site, the Irish developer Design Pro Renewables was tested, benefiting from support from the European Bluegif project. At SEM-REV test site the Wavegem platform, a hybrid (wave, solar) autonomous energy production system designed by GEPS Techno has reached 18 months of offshore testing since August 2019. SABELLA is planning to redeploy its grid-connected D10-1000 tidal energy converter on Ushant Island in 2021 and is also working with Morbihan Hydro Energies for the design, construction, and deployment of two tidal turbines of 250 kW in the Gulf of Morbihan within the scope of the Interreg TIGER project. GUINARD Energies Nouvelles is developing its tidal energy technology for isolated community markets, particularly along rivers and estuaries.

SBM Offshore based in **Monaco** is planning the development of wave energy prototype in Monaco territorial waters in partnership with the Government.

In **Italy** there is an increasing interest in the exploitation of wave and tidal current energy. In particular, wave energy converters integrated in breakwaters are gaining interest among port authorities. A number of promising devices have been developed and improved during the last years, including REWEC3 wave energy device integrated in the port of Civitavecchia (Rome) and OBREC integrated in the port of Naples. ISWEC, a point-absorber wave energy converter suitable for mild climate seas has been developed by Polytechnic of Turin and is planned to be deployed in the Strait of Sicily by an industrial partnership. H-WEP1 wave energy device has been deployed off the coast of Marina di Pisa (Tuscany) by 40South Energy and has been operated by Enel Green Power. Kobold tidal current turbine installed in the Strait of Messina is still in operation since 2000 and the GEM Ocean's Kit, deployed in Venice lagoon has plans to progress to a full scale prototype also in the Strait of Messina.

During the course of 2020, we saw in **Germany** relevant involvement of the industry in projects progressing worldwide: SCHOTTEL HYDRO with its partner Sustainable Marine Energy (SME) are continuing the sea trials of the "PLAT-I 4.63" tidal current prototype at Grand Passage in the Bay of Fundy, Canada. The second-generation platform was constructed, planned to be connected to the grid in Grand passage in early 2021. SKF developed, manufactured and delivered two fully integrated power train solutions to the Scottish developer, Orbital Marine Power. Two German wave energy developers - NEMOS and SINN Power - have been active during 2020 reaching significant milestones. MittelrheinStrom, a German start-up, deployed a floating turbine in the Rhein river at St. Goar, Germany, in summer 2020.

Belgian companies have also been involved in relevant projects worldwide: DEME Blue Energy installed four turbines of MeyGen's project in Scotland and is involved in the development of two additional tidal energy parks in Scotland and Northern Ireland. Tractebel was involved in the pre-feasibility study, technical audit and foundation design of the Raz Blanchart tidal energy pilot project in France. The Blue Accelerator test site, close to the port of Ostend, is operational since the spring of 2020, ready for testing new products and technologies in open sea, with easy permitting. Grid connection is planned for 2023.

In **Denmark**, there are eight active Danish wave energy projects today, engaged and exchanging experience via the Partnership for Wave Energy: Crestwing has been testing a half scale wave energy prototype in Kattegat, Wavepiston has moved to the Spanish test site PLOCAN; EXOWAVE granted support to develop and test a small prototype at DanWEC; Resen Waves has been progressing with focus on small scale Smart Power Buoys for autonomous power and data communication; WaveDragon and KNSwing have completed a project focused on the use of concrete for floating wave energy structures.

In the **Netherlands**, Dutch companies are achieving relevant milestones: SeaQurrent which has been developing the underwater TidalKite™ for relatively low tidal current, tested a scale model in the Wadden Sea; Slow Mill Sustainable Projects has now a first wave farm installed in the North Sea, 4 km of the coast of Texel Island. Redstack, after testing the reverse electrodialysis (RED) technology in the pilot facility on the Afsluitdijk is now planning a first demonstration plant at Katwijk (near The Hague), where the salinity gradient is optimal.

In **Sweden**, several developers have progressed significantly in 2020, proving their concepts and moving closer to commercialization. Minesto, in addition to reaching the milestone of delivering electricity to the Faroese grid, has also been working on obtaining the necessary permits for the deployment of 100 KW device at the Paimpol Bréhat site, in France. Novige successfully tested a 1/5 scale unit offshore Stockholm and CorPower has completed the manufacturing of the full scale C4 wave energy converter, as part of the HiWave-5 CorPower's flagship demonstration project, under development in Portugal.

OPEN SEA TEST SITES

Open sea test centres have become a common step in developing ocean energy in countries across the world and are a key milestone in the development of an industry in a region. Open sea test centres are key innovation hubs for the marine energy industry and provide many functions which support its development.

Open sea testing facilities also encourage ocean energy development by enabling practical experience of installation, operation, maintenance and decommissioning activities for prototypes and farms, as well as on services and streamlining procedures.

Today, there are many open sea test sites established across the world. Each has its own challenges, such as consenting issues, resource and operating environments. Test centres also provide very different service offerings to developers. Despite these differences, many are facing the same challenges on a day-to-day basis. The IEA-OES set up a collaboration with the International WATERS network* to create a centralised online database, populated with information on the infrastructure, equipment, services and test programmes available at each test centre. This activity was initiated in 2020 and will be developed in the course of 2021.

NETHERLANDS

TEST SITE NAME	LOCATION
REDstack	Afsluitdijk
Tidal Test Centre (TTC)	Grevelingen barrier

UNITED KINGDOM

TEST SITE NAME	LOCATION
European Marine Energy Centre (EMEC)	Orkney, Scotland
Wave Hub	Cornwall, England
FaBTest	Falmouth Bay in Cornwall
Marine Energy Test Area (META)	Milford Haven Waterway in Pembrokeshire
Morlais Tidal Demonstration Zone	West Anglesey

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
Wave Energy Research Centre (WERC)	Lord's Cove, Newfoundland & Labrador

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

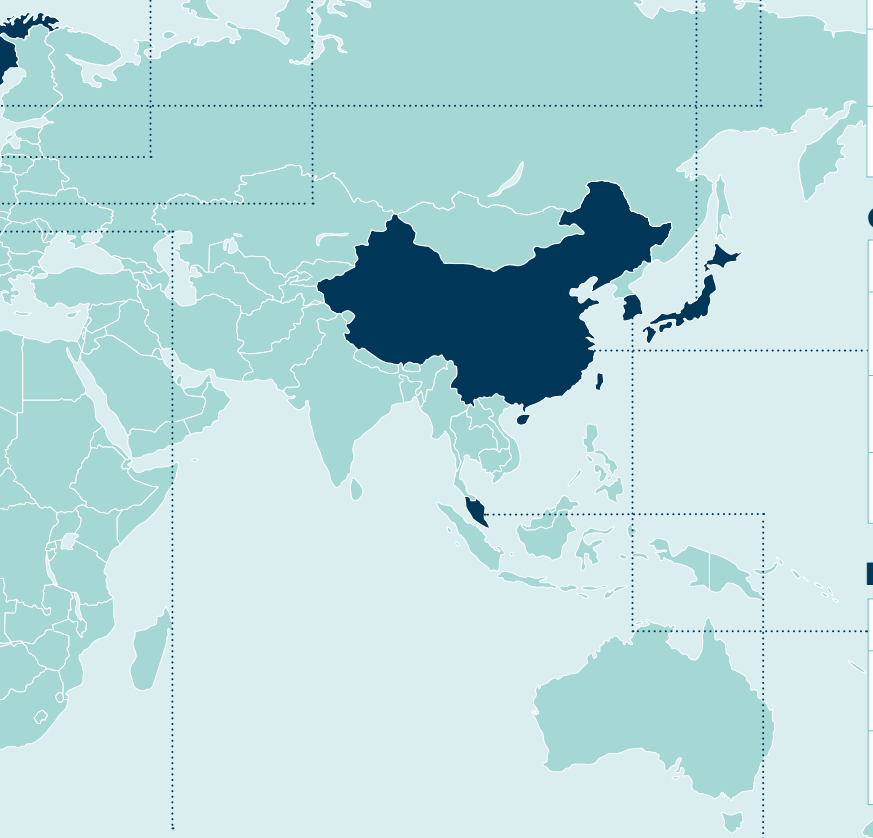
TEST SITE NAME	LOCATION
Viana do Castelo test site	Viana do Castelo
Aguçadora test site	Aguçadora

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



SWEDEN

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

DENMARK

TEST SITE NAME	LOCATION
DanWEC	Hanstholm
DanWEC NB	Nissum Bredning

NORWAY

TEST SITE NAME	LOCATION
Runde Environmental Centre (REC)	Runde Island

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 small scale test site	Weihai, Shandong Province
Zhoushan tidal energy full scale test site	Zhoushan, Zhejiang Province
Wanshan wave energy full scale test site	Wanshan, Guangdong Province

REPUBLIC OF KOREA

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

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

SINGAPORE

TEST SITE NAME	LOCATION
Sentosa Tidal Test Site	Sentosa island

* 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.

1

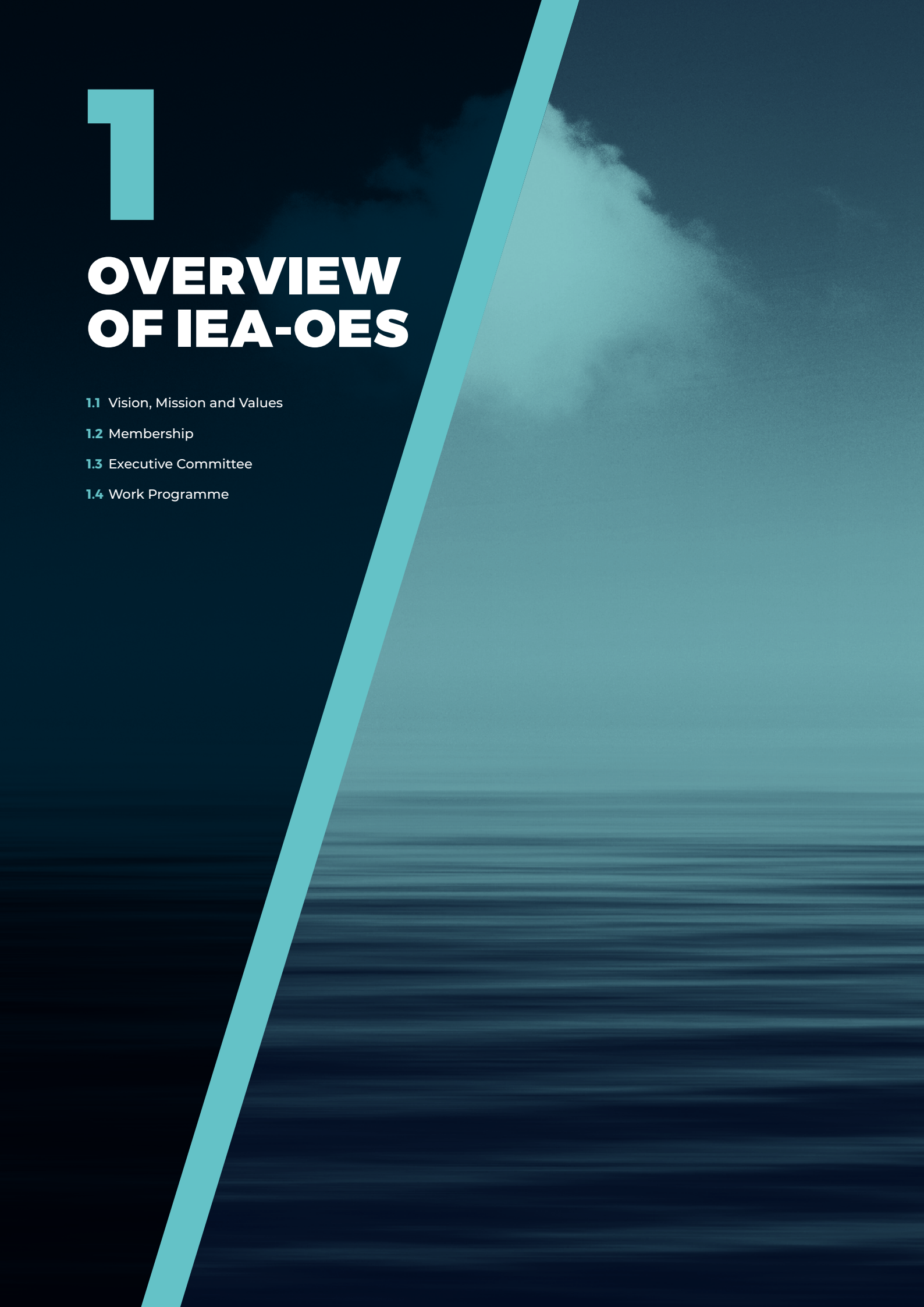
OVERVIEW OF IEA-OES

1.1 Vision, Mission and Values

1.2 Membership

1.3 Executive Committee

1.4 Work Programme



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, MISSION AND VALUES

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 acceptable manner.

ROLE

Using its unique position as an intergovernmental organisation, the OES's role is to:

Connect
with organisations and individuals working in the ocean energy sector to accelerate development and enhance economic and environmental outcomes.

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.

Motivate
governments, agencies, corporate and individuals to become involved with the development and deployment of Ocean Energy Systems.

Facilitate
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.

ORGANISATION VALUES

The OES has also established a set of Organisational Values to its future actions:

Integrity: Any information provided can be relied upon.

Outcome-oriented: We are driven by pragmatic solutions that enhance the global community.

Knowledgeable: All information is based on fact and we strive to ensure that we always have the most relevant and up-to-date researched facts available.

Inspirational: Our performance and our members are committed to providing inspired and collaborative information to accelerate the implementation of environmentally friendly ocean energy systems globally.

Collegial: We are committed to working professionally with each other in the pursuit of our audacious goal.

Surrounding the OES Vision, and influenced by the organisational values of OES and its brand values, the Strategic Plan for OES identified and prioritised four Critical Success Factors, for which an action plan has been prepared.

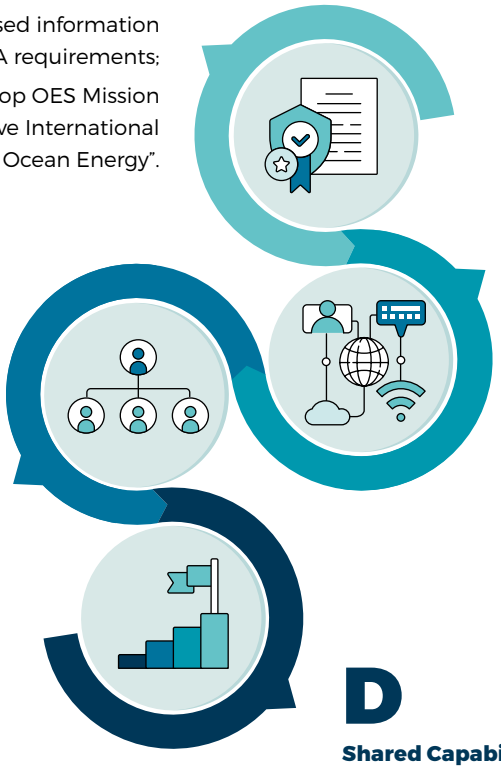
Critical Success Factors and Objectives

A

High-Quality Information

To produce world-leading unbiased information as well as being responsive to IEA requirements;

To maintain and develop OES Mission to become the "Authoritative International Voice for Ocean Energy".



B

Strong Communications Programme

To be recognized as an organisation that delivers exceptional value thereby continuing to grow membership;

To demonstrate OES positioning as a trusted independent voice on ocean energy, developing a brand and broad platform of information channels to connect with all its key audiences.

C

Effective Organization

To develop a professional and business-like approach for the leadership of the organization;

To be committed to the achievement of project timelines and outcomes and ensure the appropriate information is available to all member countries.

D

Shared Capability Growth

To ensure international Governments have a shared understanding of the social, environmental and economic benefits that can be derived from accelerated investment in ocean energy;

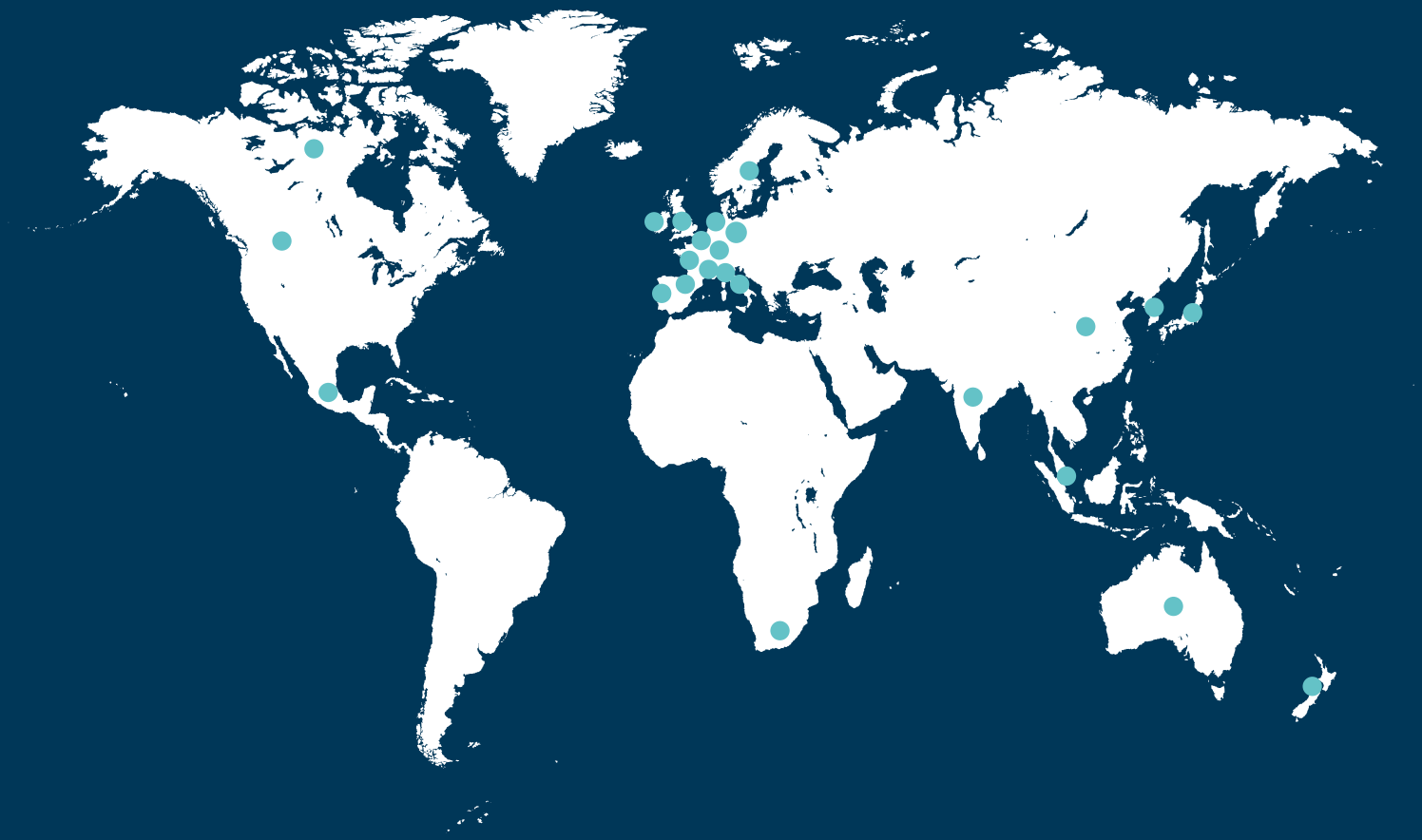
To develop an appropriate technology roadmap with the IEA for ocean energy;

To collaborate with other organisations and to implement a wider range of programmes, in particular with other Technology Collaboration Programmes (TCP).

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 2020, 22 Member Countries and the European Commission are active 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.



Members in 2020

Australia
Belgium
Canada
China
Denmark
France
Germany
Ireland
India
Italy
Republic of Korea
Japan
Mexico
Monaco
The Netherlands
New Zealand
Portugal
South Africa
Singapore
Sweden
Spain
United Kingdom
United States of America
European Commission

Contracting Parties

Year of Signature	Country	Contracting Party
2001	Portugal	Laboratório Nacional de Energia e Geologia (LNEG)
	Denmark	Ministry of Transport and Energy, Danish Energy Authority
	United Kingdom	Department of Energy and Climate Change (DECC)
2002	Japan	Saga University
	Ireland	Sustainable Energy Authority of Ireland (SEAI)
2003	Canada	Natural Resources Canada
2005	United States of America	United States Department of Energy (DOE)
2006	Belgium	Federal Public Service Economy
2007	Germany	The Government of the Federal Republic of Germany
	Norway	The Research Council of Norway
	Mexico	The Government of Mexico
2008	Spain	TECNALIA
	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
	South Africa	South African National Energy Development Institute (SANEDI) (non-active member in 2020)
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	Commonwealth Scientific and Industrial Research Organisation (CSIRO)

WHY SHOULD A COUNTRY JOIN IEA-OES?

IEA-OES facilitates:

- access to advanced R&D teams in participating countries;
- development of a harmonised set of measures and protocols for the testing of prototypes;
- reduction of national costs by collaborating internationally;
- creation of valuable international contacts between government, industry and science.

Through regular meetings, each member provides a well-established platform where high-profile ocean energy issues can be addressed by experts and officials close to government policy making in each member country.

EXECUTIVE COMMITTEE

The overall programme is headed by an Executive Committee (ExCo) composed of representatives from each participating country and organisation. A list of the members of the ExCo is shown in Appendix 1. The ExCo meets twice a year and takes decisions on the management, participation and implementation aspects of the work programme.

All Contracting Parties pay an annual financial contribution to the OES Common Fund used for general administration and communication matters. The common fund may also support coordination of ongoing R&D projects, launch of new projects, organisation of workshops on prioritised topics and commissioning of studies or reports. It does not cover R&D activities; research should be funded by participants involved in a specific task. The annual membership fee is €7000.

Together with the Secretary, the Chairman and Vice-Chairs form the Cabinet, which manages the day-to-day decision-making to implement the annual Work Programme. The ExCo Secretariat is based in Lisbon, Portugal and is run by WavEC Offshore Renewables.

The COVID-19 outbreak has made it difficult for OES to organise the two usual ExCo meetings during the year. The planned 38th and 39th ExCo meetings were therefore replaced by online sessions where relevant tasks of the work programme were discussed and information on national activities was shared among participants.

In the November virtual meeting a new Chairperson was elected: The French delegate, Yann-Hervé De Roeck replaces Henry Jeffrey as Chairman for the period 2021 – 2022. Matthijs Soede (delegate from the European Commission) stands as Vice-Chair for 2021.

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 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.

The initiatives running in 2020 are presented below. OES has an internal prioritisation process for 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.

Work Programme – Current, Completed and Future Tasks

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	Concluded
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	Active
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	Active

2

ACHIEVEMENTS IN 2020

2.1 Communication & Dissemination

2.2 OES-Environmental

2.4 Performance Metrics International Framework for Ocean Energy

2.5 Ocean Energy Jobs Creation

2.7 International Working Group on Wave Energy Converters Modelling

2.8 International Working Group on Tidal Energy Modelling

2.9 Ocean Thermal Energy Conversion Working Group

COMMUNICATION & DISSEMINATION

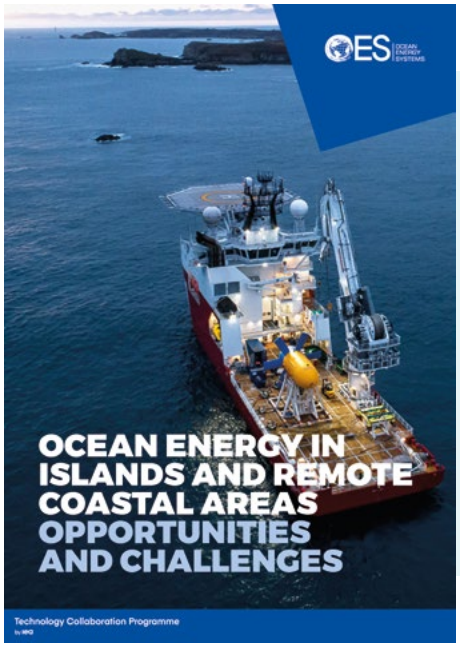
Since 2002, OES has an ongoing task dedicated to collate, review and facilitate the exchange and dissemination of information on the technical, economic, environmental and social aspects of ocean energy systems. The Task ***Review, Exchange and Dissemination of Information on Ocean Energy Systems*** focus on 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 actions are conducted throughout the year:

- The **website** is the primary source of communicating the activities of OES, publications and general outputs of each tasks to a wider audience (www.ocean-energy-systems.org). It includes a restricted area for the ExCo delegates with information to be discussed in each ExCo meeting and repository of all presentations in meetings.
- In order to increase the OES programme's visibility, news are also promoted trough **LinkedIn** and **twitter**.
- A **video** about ocean energy for the general public is available on youtube channel.
- The **Annual Report** is the flagship document of the OES and a marker for industry development; it includes detailed information on national activities from country members.
- Two **publications** were release with a focus on new market opportunities for ocean energy.
- In terms of **international collaboration**, OES has links with a variety of organisations through its delegates, and further looks forward to cooperating with International organisations.
- The Chair, Vice-chairs and individual delegates usually contribute to a number of **events** (conferences, workshops, forums, meetings, etc.) promoting OES.

NEW PUBLICATIONS

Ocean Energy in Islands and Remote Coastal Areas: Opportunities and Challenges

Focusing on islands and remote coastal areas, this report sheds light into the opportunities and challenges posed by the integration of ocean energy technologies into the energy systems in these regions drawing lessons learned from scientific publications, research projects, and a series of workshops organised by the OES. The report highlights potential market opportunities for ocean energy technologies that may be of interest for developers and investors, policymakers, and researchers. Additionally, it aims to inform islands and remote coastal areas and present them with brief descriptions of ocean energy technologies and their contribution to tackling climate change, building resilience, and facing sustainable development challenges while providing a platform for the development of the ocean energy sector.



Acknowledgements:
This report was prepared by the Policy and Innovation Group at the University of Edinburgh and is authored by Maria Vanegas Cantarero.

The report benefited from the input of Dr. Srikanth Narasimalu (NTU) and Simone Meme (PLOCAN), from the three workshop reports organized in Singapore, France and Hawaii.

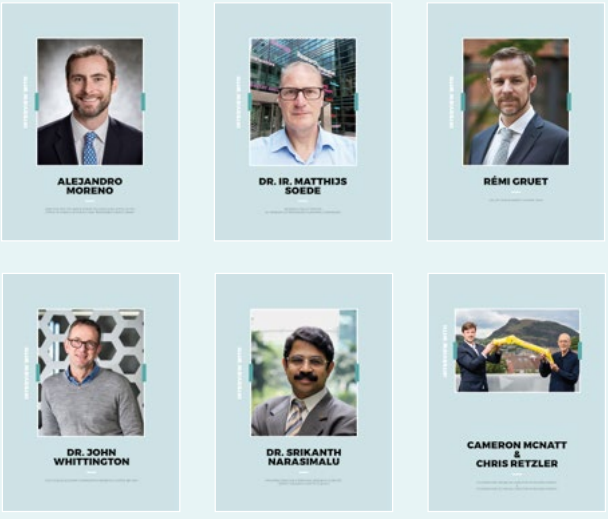
Editors:
Henry Jeffrey, Yann-Hervé De Roeck and Ana Brito e Melo

Blue Economy and its Promising Markets for Ocean Energy

Six in-depth interviews:

- **Alejandro Moreno**, Director for the Water Power Technologies Office in the U.S. Department of Energy
- **Matthijs Soede**, European Commission DG Research & Innovation
- **Rémi Gruet**, CEO of the Ocean Energy Europe
- **Srikanth Narasimalu**, Energy Research Institute at Nanyang Technological University
- **John Whittington**, CEO of the Australian BLUE Economy Cooperative Research Centre
- **Cameron McNatt & Chris Retzler,** Founders of Mocean Energy

Many ocean-based applications and markets are located far from the coast, facing important offshore challenges, such the need for clean power. From the experts interviewed there is a consensus that ocean energy can meet these anticipated needs and unlock the growth potential of the blue economy.



PARTICIPATION IN INTERNATIONAL EVENTS ON BEHALF OF THE EXCO

International Cooperation and Development Forum on Marine Economy 2020
15-16 October 2020

The International Cooperation and Development Forum on Marine Economy 2020, as the strategic forum of China Marine Economy Expo (CMEE), was held on October 15-16, 2020 in China, Shenzhen. The forum discussed the changes and opportunities of marine economy under the background of COVID-19 pandemic, in order to fully develop the potential of the blue economy and flourish from the haze of the epidemic. The Chairman gave an overview of the OES work.

2020 Marine Renewable Energy Conference: On and Off the Grid
12 November 2020

UMass Dartmouth's third annual Marine Renewable Energy Conference was a virtual event with a series of panels addressing ocean wind, wave, and tidal energy from both a grid-scale and an off-grid, purpose-built perspective. Topics included industry updates, innovations, research and development needs, and funding opportunities. The Chairman gave an overview of the OES.

7th edition of the Greening the Islands e_Convention International Conference and Exhibition
24-27 November 2020

The GTI e_Convention is the global event dedicated to the innovative solutions for the self-sufficiency and sustainability of islands. The event was entirely digital and included the international conference, now in its 7th edition, and the exhibition. Vice-Chair Yann-Hervé De Roeck made a presentation focused on the recent study of OES on ocean energy in islands and remote coastal areas.

COLLABORATION WITH INTERNATIONAL INITIATIVES

OES promotes international collaboration fostering and enhancing the development and sustainable use of ocean energy, with a number of organisations, including the International Energy Agency (IEA), the International Renewable Energy Agency (IRENA) and the International Network on Offshore Renewable Energy (INORE).

The following collaborative initiatives in 2020 are highlighted:

International WATERS network

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.

Open sea test centres are key innovation hubs for the marine energy industry and provide many functions which support its development. These include reducing costs for technology developers and streamline testing programmes; breaking down regulatory barriers such as consenting; developing a regional supply-chain; providing a platform for engaging with decisions makers, investors, media etc.; accelerating knowledge sharing; and many more.

Today there are many open sea marine energy test sites established across the world. Each has its own challenges unique to that jurisdiction, such as consenting issues, resource and operating environments. Test centres also provide very different service offerings to industry. Despite these differences, many are facing the same challenges on a day-to-day basis. The OES set up a collaboration with the International WATERS network to create a centralised online database, populated with information on the infrastructure, equipment, services and test programmes available at each test centre globally. This aims to benefit technology developers by giving them an overview of what services and infrastructure are available to them to aid developers to choose relevant sites for testing. This activity was initiated in 2020 and will be developed throughout 2021.

International conference on Ocean Energy (ICOE)

OES has a close link with the International Conference on Ocean Energy (ICOE), held every two years, and leads a competitive process to select the host team for this conference. ICOE focus on the industrial development of ocean energy.

The 8th edition of ICOE was planned for 2020, however, due to the impacts and uncertainty of the COVID-19 pandemic, it was postponed until 28-30 April 2021, as an online event, hosted by the United States National Hydropower Association (NHA), approved by the OES Executive Committee.

The International Steering Committee of ICOE includes the Chairman of the OES and several Delegates. OES manages a dedicated website with past ICOE conference material (www.icoeconference.com), thus providing the historical archive of all papers from previous conferences.

International Electrotechnical Commission (IEC) Technical Committee (TC) 114, Marine Energy – Wave and Tidal Energy Converters

IEA- OES has a formal liaison with the IEC-TC 114 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.

Ocean Renewable Energy Action Coalition (OREAC)

OREAC was formed in response to the 2019 call for ocean-based climate action by the High Level Panel for a Sustainable Ocean Economy (Ocean Panel), aiming to represent marine renewable energies in the global dialogue on a sustainable ocean economy.

OES supports OREAC and has contributed to the report **"The Power of the Ocean"** launched in December 2020. The report outlines the actions needed to support industry and policymakers in achieving the 1,400 GW offshore wind vision and addresses the offshore wind's socioeconomic benefits and role in mitigating climate change; policy, infrastructure and market frameworks; safety considerations; environmental planning; as well as the importance of colocation and coexistence with other ocean-based renewable energy technologies. One chapter is dedicated to ocean energy, showing that emerging ocean-based renewable energy technologies can a play a significant role in maximising the ocean's contribution to carbon reduction.

WECANet COST Action CA1710

WECANet is the first pan-European Network on wave energy providing a platform for dialogue between all stakeholders in wave energy in order to obtain understanding in the main challenges governing the development of the sector. Currently, 31 partner countries are active in the network. This network has been funding the IEA-OES international group on wave energy modelling.

OES-ENVIRONMENTAL ASSESSMENT OF ENVIRONMENTAL EFFECTS AND MONITORING EFFORTS

COORDINATOR

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

PARTNERS

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

OBJECTIVE

This project seeks to be the first international programme engaged in bringing together information and practitioners on environmental effects of marine renewable energy (MRE) development.

ACHIEVEMENTS

Phase 3 of OES-Environmental (OES-E) concluded in May 2020. Phase 4 of OES-E was authorized in September 2020 and will continue through 2024.

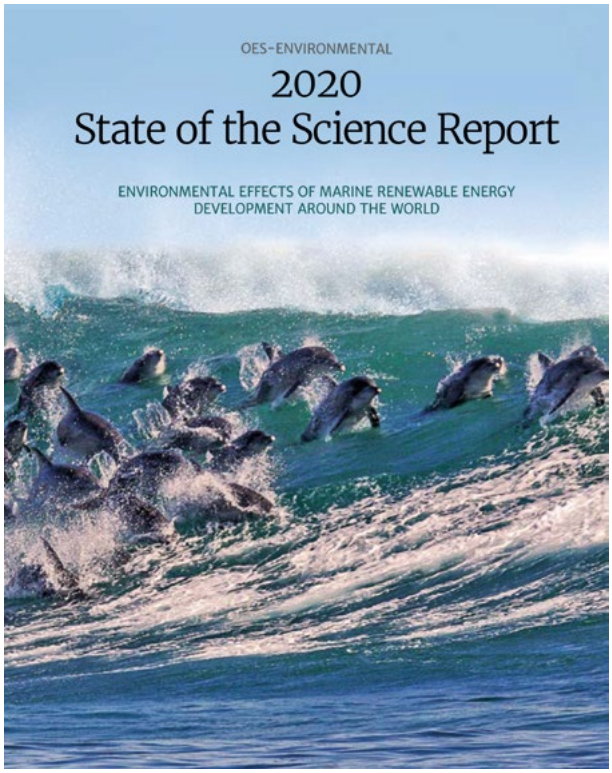
The tasks performed by OES-E during 2020 included:

- Publishing the *2020 State of the Science Report*, holding webinars to discuss the release (Phase 3), and planning a robust outreach plan for the contents of the document. (Phase 4);
- Updating and expanding *Tethys* (https://tethys.pnnl.gov), the publicly accessible knowledge management system, with papers, reports, and other media on environmental effects of marine renewable energy (MRE); (Phases 3 and 4);
- Populating records of baseline data collection and monitoring efforts around deployed MRE devices, and relevant research studies (OES-E metadata forms); (Phases 3 and 4);
- Continuing outreach and engagement to the MRE community through workshops, webinars, and conferences, with particular emphasis on researchers, regulators, advisors, and MRE device developers; (Phases 3 and 4);
- Continuing the development of the risk retirement process for simplifying consenting and licensing; (Phases 3 and 4);
- Beginning to assess environmental effects of MRE in tropical, subtropical, and southern hemisphere waters and other underserved areas that represent OES nations. (Phase 4).

Fifteen nations participated in Phase 3 of OES-E: Australia, Canada, China, Denmark, France, India, Ireland, Japan, Norway, Portugal, South Africa, Spain, Sweden, the United Kingdom (UK), and the United States (US). The US continues to lead the initiative, with Pacific Northwest

National Laboratory (PNNL), one of the Department of Energy's national laboratories, serving as the Operating Agent and implementing the project. Fifteen nations are currently participating in Phase 4 activities, with the additions of three new nations joining OES-E: Mexico, Monaco, and Singapore, while Norway, South Africa, and Sweden are no longer participating. Additional OES nations are in discussion around joining OES-E.

The State of the Science Report



Throughout 2020, writing and publishing the *2020 State of the Science Report* has been the major focus of OES-E. The "*OES-Environmental 2020 State of the Science Report: Environmental Effects of Marine Renewable Energy Development Around the World*" was released as a public draft in June 2020, following three rounds of technical and scientific review involving over 60 international scientists and engineers from 11 countries. Comments from the public draft were incorporated into the final document which was published in September 2020. The report is over 300 pages long and includes 14 chapters written by 40 authors and contributors. The report, the executive summary, each individual chapter, and the supplementary material are all available on *Tethys* (https://tethys.pnnl.gov/about-oesenvironmental) Japanese translation of the executive summary is now available; the French and Spanish translations will be completed in early 2021. Short science summaries for each 2020 *State of the Science* Report chapter were also prepared during 2020 and are also available for download on *Tethys*. As of the end of December 2020, the State of the Science page on *Tethys* has been viewed or downloaded 4754 times (the two metrics cannot be separated).

The *2020 State of the Science* report was announced to the MRE community through direct emails and in several *Tethys Blasts*, added to newsletters of other organizations, and widely publicized including through postings on social media. A 3-day webinar event focusing on the release of the report was held during 2020. An active outreach and engagement process was undertaken that includes activities directed towards sharing the *2020 State of the Science* Report content with key audience groups. The goal of this outreach is to engage a broader constituency in MRE development and to increase visibility of the *2020 State of the Science* report. Key audience groups that will be targeted include existing audiences (MRE regulators, developers, researcher), as well as new audiences: STEM (Science, Technology, Engineering, and Mathematics) students and teachers, researchers and other MRE community members in tropical, subtropical, and southern regions, members of the interested public, and media outlets not commonly addressed in the past (e.g., magazines, podcast audiences).

Working with OES-Environmental Analysts

During 2020, PNNL continued to organize and lead meetings with the OES-E country analysts to coordinate cooperative work, approximately every 2-3 months. The purpose of these meetings is to discuss current OES-E activities, receive input and feedbacks from OES-E country analysts on these activities, and provide an opportunity to learn about current MRE development in each country. Each country analyst is asked to present updates on MRE development and environmental research in her/his respective countries and regions once every two years.

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

During 2020, the country analysts were also heavily involved in the entire development and review process of the *2020 State of the Science Report*, and several analysts served as chapter authors, contributors, and peer reviewers. Following the publication of the report, the country analysts have been asked to provide a translation of the executive summary into the language of their nation (other than English).

Risk Retirement

During 2020, OES-E continued to develop the risk retirement process to facilitate consenting for small numbers of MRE devices, so that each potential risk need not to be investigated for every new MRE project. An important aspect within the risk retirement process is data transferability - transferring data from already consented MRE projects, research studies, or analogous industries to inform potential environmental effects and consenting for future MRE projects. To guide data transfer from existing consented MRE projects to future MRE projects, OES-E continued the acquisition of datasets for the monitoring datasets discoverability matrix during 2020. The initial version of the matrix was released in 2020 on *Tethys* (https://tethys.pnnl.gov/monitoring-datasets-discoverability-matrix). The matrix is an interactive online tool that classifies environmental monitoring datasets for six key environmental stressors (collision, electromagnetic fields, habitat changes, underwater noise, displacement, and oceanographic changes), from already consented projects and research studies. The goal of the matrix is to organize datasets so they are easily discoverable by regulators, developers, and the larger MRE community.

Risk retirement activities carried out during 2019 determined that, with a small number of identified gaps in knowledge, risks from underwater noise from MRE devices and electromagnetic fields from export cables, could be "retired" for small numbers of devices (typically 1-3 devices). Following on this work in 2020, the scientific evidence base that underpins the risk retirement process for habitat changes was developed to describe the current status of knowledge for this stressor. Because in person workshops were not possible during 2020 (as had been carried out in 2019 for the earlier stressors), targeted online workshops and webinars were held to present the risk retirement process and its outcomes, and to bring expert scrutiny to the habitat change stressor. With the identification of some gaps in knowledge for future MRE development, the habitat change stressor was also "retired" for small numbers of MRE devices.

In order to bridge the gap from the science and evidence gathered for risk retirement to regulatory needs, during 2020 a process for developing guidance documents for each stressor was initiated, tailored for regulators, advisors, and developers. The guidance documents are organized around the major types of regulation and legislation governing MRE consenting processes in all nations. The next steps in the process will include the tailoring of the documents for each OES-E nation, which will be the purview of each individual OES-E analyst.

Metadata on Marine Renewable Energy Projects and Research Studies

During 2020, OES-E continued to collect and update information on new wave, tidal, and other MRE technology projects, as well as ongoing research studies, stored as metadata forms on *Tethys*. Existing metadata forms are updated annually by working with the country analysts, developers, and researchers. There are currently 113 project forms and 57 research study forms on *Tethys*. In 2020, there was also a major effort to revamp the metadata project forms to automatically feed the monitoring datasets discoverability matrix.

Regulator Outreach and Engagement

During 2017, OES-E developed a regulator survey to gain an up to date understanding of regulatory knowledge of MRE technologies, challenges, and opinions. The survey has been deployed in eight of the OES-E countries (Canada, France, Ireland, Japan, Spain, Sweden, UK, and US). During 2020, work with OES-E country analysts continued to complete the survey in additional OES-E countries. Results of the survey for France, Canada, and Ireland were compiled in a report in early 2020. Australia started the survey in 2020 and aims to complete it in 2021.

Two workshops were held during 2020 to engage regulators in both the US and the UK to gather feedback on the applicability of the matrix to consenting processes. Feedback received during both workshops was positive and spoke to the usefulness of the matrix, especially as more datasets are collected from deployed MRE projects.

Dissemination of Information on Environmental Effects

Ongoing work to collect, curate, and make accessible existing information on MRE environmental effects for *Tethys* continues to expand the platform and reach ever growing audiences. There are currently 3,161 documents that address environmental effects of MRE available on *Tethys* (an increase of 878 documents from 2019). A biweekly electronic newsletter, *Tethys* Blast, is sent to the broad MRE community of more than 3,500 individuals (an increase of around 2,000 individuals from 2019). During

2020, there was an emphasis on using underutilized social media platforms to promote OES-E events and products through the *Tethys* Instagram, Facebook, and Twitter accounts. Specifically, from 2019 Facebook user engagement increased by 10% each month; Twitter engagement has doubled; and Instagram gained over 80 followers.

Workshops

OES-E hosted one in person and several online workshops during 2020 (in lieu of in person workshops) bringing together experts to further understand key interactions and to work towards consensus on how research and monitoring information can inform consenting processes, and accelerate deployments for the MRE industry:

- An in-person workshop brought together 35 people at the Pan American Marine Energy Conference (PAMEC) in Costa Rica in January 2020 to present environmental effects of MRE knowledge, the OES-E programme, and to examine effects in tropical environments.
- Three online workshops on the monitoring datasets discoverability matrix were held: two in February 2020 to receive feedback on the matrix, one for US and one for UK regulators with 16 people in attendance, and one in July 2020 for the international MRE community to publicly release the matrix, with 48 attendees.
- One international online workshop was held in August 2020 with 18 people in attendance to present the evidence base for habitat change and discuss the ability risk retirement for habitat changes with subject matter experts.

Webinars

Seven webinars were held by OES-E during 2020, each bringing together between 55 and 146 people online to hear about recent research results and plans, and to provide feedback. The webinars are archived on *Tethys* (https://tethys.pnnl.gov/environmental-webinars); each webinar has been downloaded and viewed hundreds of times since the events (up to 1,339 views for one webinar). The webinars included:

- A three-day event hosted by OES-E and ORJIP (the UK Offshore Renewables Joint Industry Programme) as part of an international forum around environmental effects of MRE, with three forum presentations, April 2020
- A three-day event following the release of the *2020 State of the Science*, June 2020
- Risk Retirement for Marine Renewable Energy – September 2020

Conferences

PNNL personnel presented outputs from OES-E work at two in person conferences, and three online conferences, during 2020.

Abstracts that reflect the work of OES-E were submitted for the 2020 International Conference on Ocean Energy (ICOE) to be held in Washington DC, USA, which was postponed due to COVID; the work will now be presented in April 2021. Abstracts were accepted for the European Wave and Tidal Energy Conference (EWTEC) to be held in Plymouth UK in September 2021. Presentations on OES-E work have been invited for the UK SuperGen Assembly and a workshop around the Welsh Marine Energy conference in January 2021.

Conference	Date and Location	Oral Presentation
Pan-American Marine Energy Conference (PAMEC)	January 26-28, 2020 San Jose, Costa Rica	The Road to Risk Retirement: Evaluating and Communicating Environmental Risks
American Geophysical Union (AGU) Ocean Sciences 2020	February 16-21, 2020 San Diego, USA	Establishing Marine Renewable Energy: • Using Risk Retirement and Data • Transferability to Simplify Environmental Permitting
Partnership for Research in Marine Renewable Energy	July 7-8, 2020 Plymouth, UK (virtual conference)	What we know (and don't know) about environmental effects of MRE development
Taiwan Ocean Forum	November 4-5, 2020 Taipei, Taiwan (virtual conference)	Environmental Effects of Marine Renewable Energy
2020 Marine Renewable Energy UMass Dartmouth	November 12, 2020 Dartmouth, Massachusetts, USA	Environmental Effects of Ocean Energy Development

PERFORMANCE METRICS INTERNATIONAL FRAMEWORK FOR OCEAN ENERGY

COORDINATOR

Led by the European Commission and delivered by Wave Energy Scotland (WES), the United States Department of Energy (DOE), Tecnalia (Spain) and other representatives of the OES Executive Committee

BACKGROUND

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, a 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 is 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.

Main objectives are:

- 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.

ACHIEVEMENTS

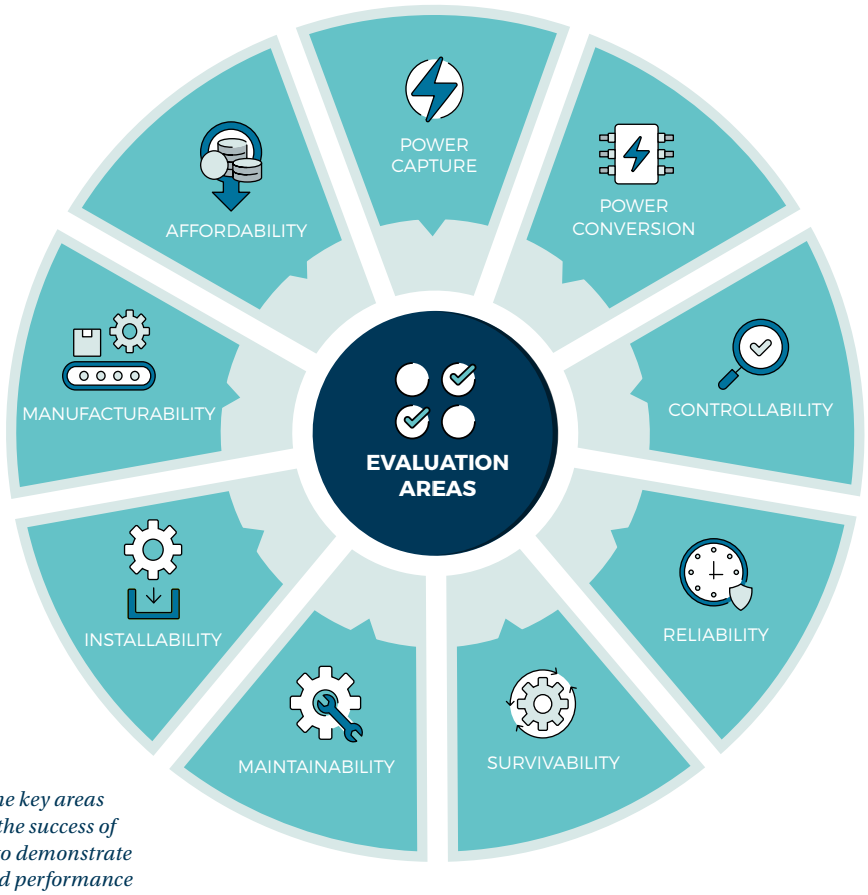
During 2020, a report has been completed, discussing the benefits of common evaluation approaches in the ocean energy sector and the use of common language to help build consensus. The goal of this work was to create a complete and unambiguous process for the development and evaluation of ocean energy technologies throughout all stages of development. This requires clear definition of:

- Stage Activities – the engineering activities carried out by developers,
- Evaluation Criteria – the parameters used to evaluate achievement
- Evaluation Method – the process used to calculate Criteria

Division of the technology development process into Stages provides clarity on expectations for all stakeholders. Public and private investors and technology developers are then aware of the expected Stage Activities throughout the development process and which Evaluation Criteria should be presented. Such clarity in expectations ensures that progress and success can be measured, building confidence in the technology.

Clearly defined Stage Activities allow investors to ensure they place technology developers in the correct stage of a funding scheme and allow technology developers to focus on what is required now, rather than reaching beyond their financial means or technical capabilities. A set of six stages which cover the full path from concept creation to commercial readiness, have been identified, from concept creation to commercial-scale array demonstration.

The report presents nine Evaluation Areas, which have been developed through an iterative process, building on the outputs of a series of workshops held since 2015 which engaged participants from across the ocean energy sector. The Evaluation Areas represent the concerns of key stakeholder groups, including public and private investors and technology developers, all of whom were engaged in the process.



Evaluation Areas - The key areas in which to measure the success of technology, in order to demonstrate progress and achieved performance

OCEAN ENERGY JOBS CREATION: METHODOLOGICAL STUDY AND FIRST GLOBAL ASSESSMENT

COORDINATOR

Yann-Hervé De Roeck, *France Energies Marines*

PARTNERS

LOC Consortium, comprising LOC Renewables (including INNOSEA)
Fraser of Allander Institute from the University of Strathclyde

OBJECTIVE

This project aims at delivering a validated methodology for job assessment in the ocean energy sector and building up from the existing know-how developed on other renewable energies and other maritime sectors.

ACHIEVEMENTS

A state of the art of socio-economic methodologies used to assess the number of jobs created or maintained with the commercial deployment of ocean energy systems has been prepared. There are different approaches used in the calculation of projected impacts, and so it is critical to review existing approaches before producing further quantitative estimates.

A methodology developed will provide a result which relies on the approach used. Different methods would be likely to provide alternative results, which is why it is important that the choice of method is the most robust, transparent for users, and that policymakers and analysts are jointly aware of its limitations.

The report that has been prepared on the state of the art on job assessment methodologies for ocean energy includes the following:

- A review of past works that aimed at assessing the number of jobs and possibly the interview of the leaders of such studies to clarify the methodology being used.
- A critical analysis of state-of-the-art and other used methodologies with regards to the extent and the availability of the required inputs, the robustness of the model and the need for fine-tuning in comparison with the socio-economic framework or the maturity of the industrial sector locally.

- First interactions with IEA and OECD experts as well as OES members to evaluate the adequation between necessary inputs and available data for the selected methodologies.
- Shortlist of one or two models and dataset required.

The main findings can be summarised as follows:

I. There are only a few examples of these methodologies being applied to ocean energy, however applications from renewable energy technologies provide a framework which can be used to evaluate ocean energy technologies;

II. A number of different methods have been used to estimate the number of jobs supported by renewable energy technologies; the necessary inputs to each method has been identified;

III. Each method has properties which make them useful for answering specific questions relating to the employment effects of renewable energy, while each also has limitations.

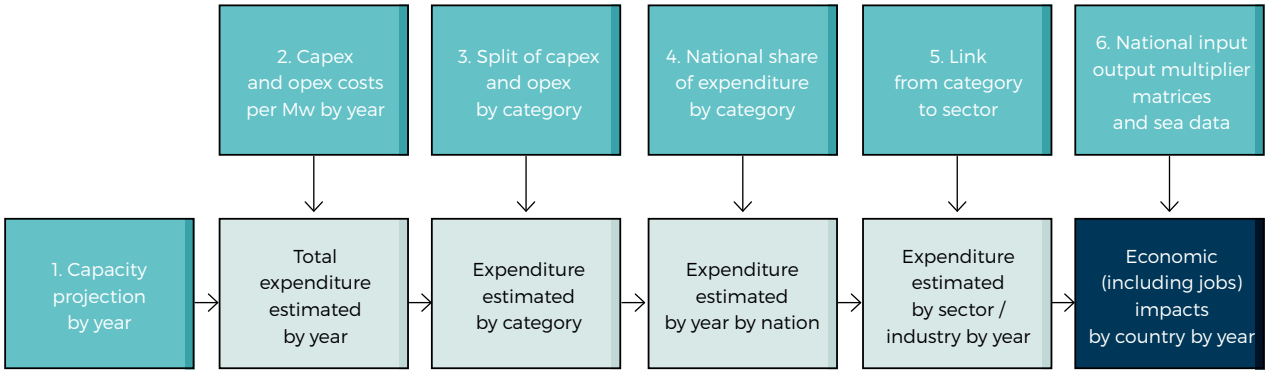
IV. Recommendations for improved data gathering relating to the renewable energy sector and the need for data to be gathered on a consistent basis to economic accounts is provided. This may serve to improve the understanding of the links between ocean energy and the economy and to address how developments in ocean energy can help to meet nations and regions multiple objectives for energy ambitions.

Following the state-of-the-art report, the team suggested the following methodology to be undertaken in this study: numbered items in green boxes are those where data is required, while the results of calculations are shown in black and white boxes.

The process could be separately implemented for each ocean energy technology (tidal, wave, OTEC) and for each country. Some of the required data for the study are explained below:

- National share of expenditures by category: local content achieved by category
- Link from category to sector: allocation from general category to industrial sectors
- National input output multiplier matrices: matrices accounting for inter-industrial flows of goods and services (domestic and imports / exports)
- SEA data: relation between gross output and employment

To date, the jobs study was applied to 3 test countries: UK, USA and France. The data collection for other countries of OES is ongoing and the jobs assessment for other countries will be made in early 2021.



Proposed methodology for estimating ocean energy jobs

CASE STUDY
FRANCE

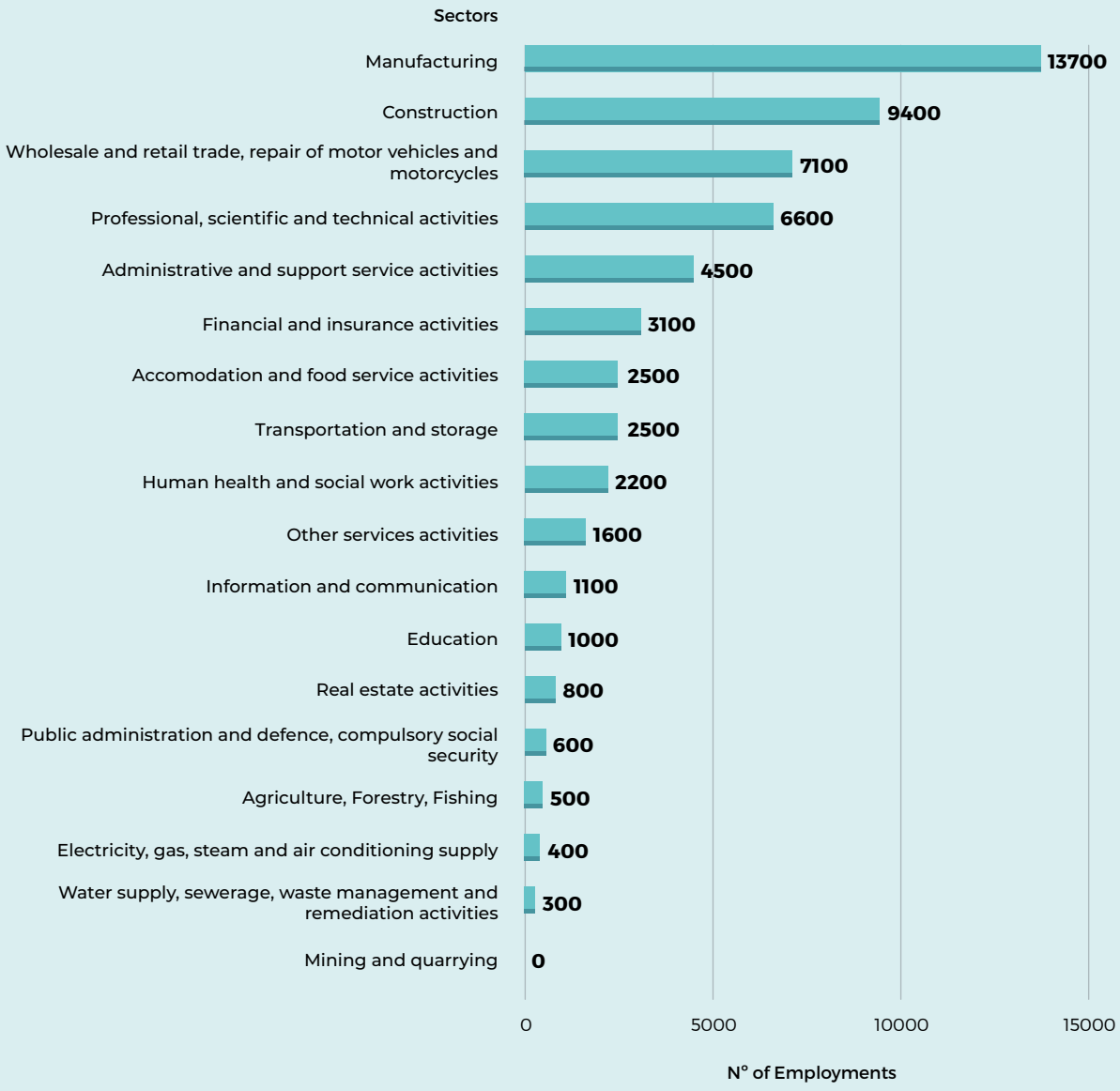
53 MW

Total capacity projection
for ocean energy by 2050

58,200

Estimation of employments
(totalling direct, indirect and induced jobs)

Split of employments by sector:



FRANCE (2050) | Direct, indirect, and induced employments by sector

INTERNATIONAL WORKING GROUP ON WAVE ENERGY CONVERTERS MODELLING

COORDINATOR

Kim Nielsen, Ramboll, Denmark

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 and experts from 13 countries are cooperating with the objective to improve industry confidence in the design and prediction of power production from Wave Energy Converters using numerical tools.

This 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:

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

ACHIEVEMENTS

In general, the validation process adapts the approach of comparing numerical results, as well as comparing numerical results with experimental results. Some numerical models represent reality better than others and some experimental tests are recorded more accurately than others.

To determine the errors associated with each modelling approach, it makes sense to start comparing the output of several numerical simulations, ideally spanning over a range of modelling approaches from different teams. By comparing these results, an understanding of the variation in results and thereby the associated uncertainties are obtained. Also, the speed of the simulation, the cost of the software and skills required to run the simulations are related to the variation of the results. Some simulations

are based on simplified assumptions – and even so give surprisingly realistic results even if the limits for the theory may be broken. This project addresses several topics such as the order of wave theory to use, the influence of water depth – stroke limitations, end-stop forces and the scaling effects of air compressibility in the oscillating water column concept (OWC) and viscous drag on heaving plates.

Numerical results

The work started with the numerical modelling of a sphere with a known theoretical solution, as described in two papers presented at EWTEC [1] and RENEW Proceedings [2]. Following these test cases, work has continued modelling existing experimental data of a heaving float [3] followed by an existing experimental test case, using the KRISO OWC experiments. In the experimental test data from both test cases the uncertainties turned out to be large compared to the spread in the numerical results. However, the comparison between the numerical results with the experiments in these cases, gave a feeling of reality and a guidance on how to best compare numerical models against each other within the confidence bounds of the experiments.

To validate the initial numerical simulations with the sphere, a dedicated experimental set-up was prepared at Aalborg University, using very accurate experimental measurement equipment to assess the accuracy of different numerical models [4].

The sequence of test cases selected for this modelling work was based on the strategy to starting with a simple test case, the heaving sphere, a case studied by Budal and Falnes in the early 1970's when the Point Absorber theory was developed [5]. The work will proceed in 2021 with the simulation of the OWC case.

Acknowledgements

This project has been supported by the NREL team, with thanks to Yi-Hsiang Yu and Thanh Toan Tran. Thanks also Morten Kramer and Jacob Andersen 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.

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INTERNATIONAL WORKING GROUP ON TIDAL ENERGY MODELLING

COORDINATOR

Srikanth Narasimalu, Singapore

PARTICIPATING COUNTRIES

Canada, China, France, India, New Zealand, Sweden and UK

OBJECTIVE

Knowing the fact that majority of the earth is covered with water, the extraction of tidal energy to generate electricity is augmenting interests of the researchers and the method is being further enhanced. In the evaluation of tidal power resources, cataloguing of appropriate sites and estimation of achievable energy are greatly important. Nations with long coastlines, having features like bays, estuaries etc., create a variation in the tidal currents. Also, these coastline properties possess high current velocities making them suitable sites for converting tidal energy in electrical energy.

Models are being developed to identify the locations with high flow velocities and later analysing those areas for the average power density. In this way, sites are being identified for installing tidal power plants. However, the correctness of these models is a function of the accuracy and the resolution of the input data required for these models. Further, the certainty also depends on the hydrodynamic phenomenon being examined by the various models to simulate the ocean flow. Like certain models, does 3-dimensional simulation while other does a 2-dimensional depth-averaged simulation. Still, these models serve the purpose of distinguishing the potential sites for tidal energy extraction which can be later verified by the field data.

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** was thus consequently formed as a part of OES and various international research teams conduct extractable resource studies to share their results and methodology, and work towards creating a standard

report for modelling in harnessing tidal energy. Thus, the main objective of this initiative is to develop a simulation guideline report of tidal energy resource modelling through a common case study with various factors along with code-to-code comparisons of various modelling strategies that exist in different parts of the models. It would also involve comparison of models with experimental data and also discussion on various assumptions made in models such as seabed friction effects, etc.

The main goal of this project is to discuss and develop a standard methodology for modelling in harnessing tidal energy through study of various factors which affects tidal modelling of an ocean site and the various underlying assumptions behind the simulations. The working group was formed as an international team of tidal energy researchers towards a joint exercise effort concentrating on the accurate modelling and reporting the guidelines towards tidal energy resources.

ACHIEVEMENTS

6th and 7th Workshops on Tidal Current Extractable Energy: Modelling, Verification and Validation

The main goal of these workshops was 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.

These workshops were organised and hosted by Energy Research Institute @ NTU (ERI@N), Singapore through teleconferencing on 20th May 2020 and 2nd November 2020. There were attendees from various international tidal energy working teams from all over the world.

Earlier, the International working group identified temperate waters of Alderney race straits, near Cherbourg, France as common case study site. The chosen site case study was simulated by different international tidal energy working group members based on their chosen codes and with their modelling expertise for numerical comparison study. Each team presented their results to other international team members and had a detailed discussion on further improving the accuracy models through inclusion of various parameters. Based on the discussion, the other parameters that need to be included in each model were identified and they are as follows:

- Wind - Wave generation: dominant wave types in terms of wave period/frequency and amplitude. Classification and effects of damping parameters.
- Wave-current interaction and wave breaking to address the following:
  - Resultant water surface elevation
  - Resultant direction of current
  - Basis for coupling between current and waves
  - Influence on tidal energy
- Modelling of the seabed and coastline depicting the quality of the sand in terms of its constituents for addressing the friction/drag force generated over the water flow.
- Effects of salinity and temperature in resultant tidal velocity and direction both qualitatively and quantitatively.

The International Tidal Energy Working Group also prepared and submitted a joint comparison report to OES. Two journal papers were also prepared and submitted to a top tier journal based on the simulation models of the Alderney race case study. As a further work, the international working group identified an Indonesian site of tropical waters with available validation data as a second 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. This would help in further code-to-code comparison of various models along with experimental validation data. It would also help in comparing the prediction accuracy of both tropical and temperate waters using various ocean models.

OCEAN THERMAL ENERGY CONVERSION WORKING GROUP

COORDINATORS
Yasuyuki Ikegami, Saga University, Japan
Purnima Jalihal, NIOT, India

PARTICIPATING COUNTRIES
China, India, Japan, Korea, France and The Netherlands

BACKGROUND

Under the aegis of OES, a task group on OTEC has been formed to promote dissemination and demonstration of OTEC. There are several roadblocks for the progress of OTEC both technologically and commercially. OTEC being a baseload power needs to be pursued and there is a need to disseminate information to all stakeholders. As these issues are of interest to policy makers, it was decided that a white paper on OTEC technologies should be jointly prepared to serve as a guide to international policy makers.

OBJECTIVE

The overall work is carried out by two groups addressing the following topics:

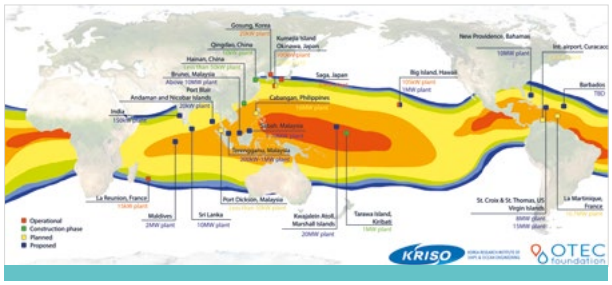
1. Estimation of OTEC potential around the globe (lead by China);
2. Present status and plans of OTEC projects (lead by Korea).

A state-of-the-art report of OTEC activities and projects around the globe has been prepared as a first step to further define a full work programme under this Task. The identification of plans and new developments on OTEC in the various regions of the world would be important for the development of a future roadmap, which is one of the goals of this Task.

ACHIEVEMENTS

Various webinars were organized by the Indian delegate to discuss the contents to be authored by the representatives of the participating countries for the preparation of the white paper. An external expert to collate and formalize the document was also nominated by the Executive Committee. The contents of the document are currently being finalized and the white paper may be ready in early 2021. This document will serve as a short introduction on OTEC to policymakers and other stakeholders. The chapters would touch upon technical issues, costs and scalability.

An independent Ocean Thermal Energy Association (OTEA) was rejuvenated recently to publicize OTEC technology and explore collaborative projects. Various webinars were organized to give shape to this association. Currently more than 300 are registered members of this association. The association hopes to take up collaborative efforts and help in information dissemination.



OTEC power plants

3

INTERNATIONAL ACTIVITIES
ON OCEAN ENERGY

3.1 Australia
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3.22 USA

3.1
AUSTRALIA

AUTHORS
OES Australia Delegation Group, led by Mark Hemer (CSIRO), Tracey Pitman (CSIRO) and Stephanie Thornton (AOEG)

OVERVIEW

In 2020, a number of ocean renewable energy initiatives were progressed in Australia. This included the release of a draft regulatory framework for offshore clean energy infrastructure, in preparation for new policy enactment in 2021; the Australian Ocean Energy Group cluster has continued to build awareness of ocean renewable energy across a range of potential markets in Australia; Wave Swell Energy continued construction of their 200 kW oscillating water column wave energy converter for deployment at King Island, Tasmania in early 2021; launch of the 10-yr, $AUD300m Blue Economy Cooperative Research Centre, which has the vision of growing the Blue Economy with innovation to expand production of seafood and renewable energy offshore, underpinned by a $AUD70m grant from the Australian Commonwealth; launch of the 3-yr, $3.5m Australia-China Joint Research Centre on offshore wind and wave harvesting, led by University of Adelaide; and continued growth of University of Western Australia's Wave Energy Research Centre, centred in Albany, in regional south-west Western Australia. Australia, as a member of the High-Level Panel for a Sustainable Ocean Economy, were also part of the shared vision where the opportunities for offshore renewable energy were increasingly identified, particularly as part of a blue recovery post COVID-19.

More broadly, offshore wind in Australia has increased its profile through 2020, primarily driven by the 2GW 'Star of the South' development proposal on the south-east Australian coast, operating under a current exploration license. Although ocean renewable energy was not identified as an opportunity in the Australian Government Low Emission Technology Roadmap released in September 2020, ocean energy was included in the Tasmanian Renewable Energy Action Plan. This is the first Australian state to provide specific recognition to ocean energy.

COVID-19 unfortunately affected several planned ORE activities in Australia during 2020. The fifth Asian Wave and Tidal Energy Conference, the 3rd Australian Ocean Renewable Energy Symposium, and the 39th Executive Committee meeting of the IEA Ocean Energy Systems Technology Collaboration Programme, were all scheduled to be held in Tasmania in 2020, but unfortunately cancelled owing to border closures which were in place.

SUPPORTING POLICIES FOR OCEAN ENERGY

NATIONAL STRATEGY

A Framework for Offshore Clean Energy Infrastructure

A draft framework for Offshore Clean Energy Infrastructure was released by the Australian national government. A key component of the proposed regulatory process will be the establishment of an enabling Act: The Offshore Clean Energy Infrastructure Act. A process map (shown below) and discussion paper were released in Feb 2020.

The draft bill proposes the Australian Government minister with responsibility for energy matters will make all major decisions under the framework. The process proposed is:

- The Minister would 'consult over an area that may be potentially suitable for offshore clean energy infrastructure development' prior to determining the suitability. The trigger for this consultation to take place is unclear in the discussion paper.
- Following a declaration, the Minister would be able to open applications to seek competitive interest.
- A feasibility licence would be awarded, giving the developer the exclusive right to seek a commercial licence. The feasibility licence would provide a proponent with a period of up to five years to demonstrate their ability to manage safety and environmental risks and impacts.
- If the Minister were satisfied that all conditions and requirements had been met, the proponent could apply for a commercial licence.
- Were an offer for a commercial licence to be made, the proponent would need to demonstrate that a Final Investment Decision for the project had been reached when accepting the offer, and lodge the decommissioning bond security. Decommissioning bonds are expected to equal the amount it would cost government to decommission all infrastructure should the licence holder fail to meet its decommissioning obligations.
- It is proposed to leverage the experience of the National Offshore Petroleum Safety and Environmental Management Authority (NOPSEMA) to operate as the regulator for any new industry. NOPSEMA would be responsible for safety, environment and structural integrity regulation as well as providing technical advice to the Energy Minister to support decision-making.
- Non-exclusive, non-commercial license applications are also accounted for to address requirements of 'truly innovative offshore clean energy technologies, like wave and tidal for example'.

The Offshore Clean Energy Infrastructure Act was to be tabled in Parliament in the winter session of 2020. This timeline was COVID-delayed, and a $5M commitment was made in Australian national budget to finalise the policy over the next year.

Two principles of the proposed Act are worth noting:

- To be flexible and non-prescriptive, to allow for the evolution of the industry over time. A lot of the detail will be left to the supporting policy and regulations, and
- "Co-use" or "co-existence" for any licencing in the marine environment. Separate licences will be required for turbines and transmission infrastructure. This is intended to provide flexibility, for example to allow transmission infrastructure to have separate ownership and to ensure that exclusive use for turbines would not allow a proponent to lock out other transmission infrastructure.

More information:
https://consult.industry.gov.au/offshore-exploration/offshore-clean-energy-infrastructure/

A National Technology Investment Roadmap

A discussion paper titled: First Low Emission Technology Statement - 2020 was released. Key points from the discussion paper include:

- **Hydrogen** is noted as a clean energy transition enabler, with a strong emphasis on green hydrogen, but not exclusively. A price of under $2/kg is targeted.
- **Energy storage**, with the recognition of the high installed capacity of solar PV in Australia (18.5 GW), there is strong emphasis on storage technologies to firm supply, including battery and pumped hydro storage. Australia's Hornsdale 150 MW storage battery is an example of the type of project being encouraged, along with large pumped hydro projects (Snowy Hydro 2.0 and Tasmania's Battery of the Nation) which have strong government support. A price of under $100/MWh is targeted.
- **Low carbon materials** are identified as an opportunity, particularly related to opportunities for low emission steel and aluminium.
- **Carbon capture and sequestration**: recognises Australia's large geological storage basins. Also noted is the global dependence on CCS in negative emission scenarios and opportunity to maintain Australia's coal and gas industries.
- **Soil carbon management**: is seen as an untapped potential for carbon sequestration in Australia's soils, while improving agricultural productivity. Estimated capacity to sequester around 1/5 of Australia's emissions.
- **Offshore renewable projects**: despite an increasing investment portfolio, these projects are being held up by the lack of regulatory framework in place. Offshore renewable energy is not recognised at all in the statement, including amongst watching brief technologies.

More information:
https://www.industry.gov.au/data-and-publications/technology-investment-roadmap-first-low-emissions-technology-statement-2020.

Ocean Energy Policy Initiatives by Australian States

Ocean energy policy initiatives have been introduced by three States during 2020:

Western Australia released a Distributed Energy Infrastructure Roadmap. Despite strong regional growth and support for marine energy in the past, and ongoing market development, the emphasis in this document focuses on PV + storage, and electrification of transport, including rooftop solar, battery storage, EVs / Smart appliances and metering, embedded networks and microgrids

More information:
https://www.wa.gov.au/sites/default/files/2020-04/DER_Roadmap.pdf

Victoria has released a new marine and coastal policy for Victoria (August 2020). The policy includes clear guidelines regarding marine and coastal structures, specific policies relating to marine and coastal industries, and community stewardship and collaborative management practices.

More information:
https://www.marineandcoasts.vic.gov.au/__data/assets/pdf_file/0027/456534/Marine-and-Coastal-Policy_Full.pdf

Tasmania released a Renewable Energy Action Plan (Dec 2020). The plan includes:

- 200% RE Target by 2040. Tasmania is already approximately 100% renewable energy with high penetration achieved via hydroelectricity. The plan is for a new interconnector to mainland Australia, and that the increased renewable capacity will be exported as green energy to mainland Australia. The vision is that Tasmania becomes the battery of the nation.
- Within that scope of new generation, Tasmania's offshore resources, including ocean energy, are acknowledged, and there is a strong support behind the Blue Economy CRC offshore renewable energy program.
- Attract new load and energy intensive industries to Tasmania – jobs growth

More information:
https://www.stategrowth.tas.gov.au/__data/assets/pdf_file/0011/241112/TREAP.PDF

New national Marine Energy Standards Committee – EL066

EL-066 Marine Energy – wave, tidal and other water current converters, is Australia's new mirror committee to the International Electrotechnical Commission on Marine Energy Standards (IEC-TC114). This is a first for the Australian ocean energy development sector.

MARKET INCENTIVES

In 2020, the Australian Ocean Energy Group (AOEG) undertook a strategic shift from a 'coordinating body' to a 'market-driven' organisation. In connecting end users (markets, customers) with ocean energy technology suppliers, AOEG's goal is to accelerate commercialisation of the ocean energy sector through increased market demand. To accomplish this, AOEG launched their **Ocean Energy Market Development Program** in 2020. This comprehensive program is focused on market acceptance of ocean energy systems and includes three core components:

- **Market awareness** of the technologies and how they can integrate with other renewables to provide solutions to market needs.
- **Market accessibility** which addresses how integrated ocean energy systems work and how they can align with specific needs of the market.
- **Market affordability** to address customer concerns about cost, risks and energy system integration.

The focus for the coming year will be on prioritising the key markets for wave and tidal developers in Australia followed by an economic valuation to determine the total potential of that ocean energy market.

PUBLIC FUNDING PROGRAMMES

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

Commonwealth Funding Bodies

The Australian Renewable Energy Agency (ARENA)

http://www.arena.gov.au

ARENA was established by the Australian Government in 2012, with the purpose to improve competitiveness of renewable energy technologies, and improve the supply of renewable energy through innovation that benefits Australian consumers and businesses.

Presently, ARENA has two active ocean energy projects, including support for the design, construction, deployment, installation and operation of WaveSwell Energy's UniWave200 200 kW wave energy converter on King Island, Tasmania; and through its International Engagement Program, supporting Australia's participation in the International Energy Agency Ocean Energy Systems Technology Collaboration Program. Since inception, ARENA has supported 13 ocean energy projects, with a total investment of over $AUD 54m towards total project value of over $AUD 140m.

Current investment priorities for ARENA include Integrating renewables into the electricity system; Accelerating green hydrogen; and Supporting industry to reduce emissions.

Department of Industry, Science, Energy and Resources Co-operative Research Centre Program

The Cooperative Research Centre (CRC) Program supports Australian industries ability to compete and produce, by helping industry partner with the research sector to solve industry identified issues.

The Blue Economy CRC is a 10-yr program launched in 2020, with the purpose of delivering innovation to support growth of Australia's offshore seafood and renewable energy production, underpinned by a $AUD 70m grant from the Commonwealth CRC program.

More information:
https://www.business.gov.au/assistance/cooperative-research-centres-programme

National Energy Resources Australia (NERA)

http://www.nera.org.au

NERA is Australia's Industry growth centre for the energy resources sector, uniquely positioned to support sector-wide transformation and unlock $10b of new value for the Australian economy. NERA's vision is to see Australia as a global energy powerhouse, and a sought after destination for investment and the leading source of knowledge and solutions.

NERA is fast-tracking the formation of an industry-led ocean energy cluster that will strengthen collaboration,

accelerate innovation and increase the current markets for Australia's ocean energy sector. The cluster – the Australian Ocean Energy Group - facilitates industry collaboration of the ocean energy industry to create significant value for Australia.

Australian Research Council (ARC)
http://arc.gov.au

The ARC administers the National Competitive Grants Program accessible to Research Universities, which is a significant component of Australia's investment in R&D. The ARC's purpose is to grow knowledge and innovation for the benefit of the Australian community through funding the highest quality research, assessing the quality, engagement and impact of research, and providing advice on research matters.

The ARC administers several active offshore renewable energy projects across several Universities, including UWA, Curtin University, RMIT, Swinburne University of Technology, University of Melbourne.

Clean Energy Finance Council (CEFC)
http://cefc.com.au

The CEFC has a unique role to increase investment in Australia's transition to lower emissions, to catalyse private sector investment in Australia's clean energy sector with backing from the Commonwealth. The CEFC invest in technologies at higher TRL/CRL than other funding schemes in the innovation sphere, as listed above, investing responsibly and managing risk prudently. To date, CEFC are yet to support any ocean energy technologies, despite it being identified as eligible technology.

State Programmes

In addition to Commonwealth public funding programmes, State Government public funds have also supported R&D for ocean energy technologies. The West Australian State Government is the most notable of these, with the University of Western Australia Wave Energy Research Centre being an example, funded through the "Royalties for Regions" Grant from the WA Govt.

RESEARCH & DEVELOPMENT

BLUE ECONOMY CRC

The Australian Blue Economy Cooperative Research Centre (CRC) http://www.blueeconomycrc.com.au, was launched in January 2020. This is a ten-yr program, with 40 partners from across ten countries. The goal is to enhance development of Australia's sustainable blue economy, embracing engineering, aquaculture and ORE systems.

The Centre has five interlinked Programs underway, with the one of these programs, **RP3: focussing on Offshore Renewable Energy Systems**. Other programs include:

- RP1 Offshore Engineering & Technology
- RP2 Seafood and Marine
- RP4 Environment and Ecosystems
- RP5 Sustainable Offshore Developments

During 2020, 17 scoping projects were completed. Fifteen of the scoping projects had relevance to development of an Australian offshore renewable energy industry, and included:

1. Aquaculture vessel requirements (RP1)
2. Autonomous monitoring of offshore aquaculture and energy operations (RP1)
3. Biofouling challenges (RP1)
4. Multi-purpose platforms (RP1)
5. Offshore Hydrogen storage and distribution (RP3)
6. Offshore sustainable hybrid power systems (RP3)
7. Energy demand assessment of Aquaculture (RP3)
8. Offshore DC microgrids (RP3) General
9. Mooring Tensioner for WECs (RP3) General
10. Monitoring and Assessing effects of offshore production sites (RP4)
11. Offshore industry operational modelling needs (RP4)
12. Risk and opportunities for the Blue Economy (RP4)
13. Economic assessment of Australia's Blue Economy (RP5)
14. Logistics challenges (RP5)
15. Developing a policy and regulatory framework for Australia's Blue Economy (RP5)

With support from the Blue Economy CRC (General Project, 3-yr project commencing October 2020), Carnegie Clean Energy Ltd are leading development and delivery of a reliable, cost-effective Mooring Tensioner design, suitably verified for application to real WEC systems. The

efficient and cost-effective conversion of wave energy into electrical energy has remained an unsolved technological challenge. This project will develop, proof test and demonstrate a novel energy storage element, the Mooring Tensioner, enabling the use of rotary electrical generators for Wave Energy Converters (WEC). The Mooring Tensioner will be delivered in high performance, light weight and durable fibre-reinforced composites, allowing easy integration to the space constrained WEC environment. The project brings together a strong team from across CRC partners, including Carnegie Clean Energy, Advanced Composite Structures Australia Pty Ltd, the University of Queensland, and the Australian Ocean Energy Group.

THE UNIVERSITY OF WESTERN AUSTRALIA

WAVE ENERGY RESEARCH CENTRE

WAVE ENERGY RESEARCH CENTRE

The Australian Wave Energy Research Centre (WERC), hosted by the University of WA, and based in Albany in regional Western Australia, continues to grow. The WERC has a strong multi-disciplinary "surface to seabed" research program, to support the industry to harness and commercialise ocean renewable energy. The research program spans three themes:

- Oceanography / Coastal Processes: investigating and characterising the wave and current conditions for successful deployment of wave energy converters in coastal regions.
- WEC hydrodynamics / wave-structure interactions: development of models to predict wave-WEC interactions and inform optimal WEC design for power generation and survivability
- Geotechnics / Foundation design: developing foundation engineering solutions to meet the specific requirements of the ocean renewable energy industry.

Highlights from 2020 include:

- Completion of UWA's first-ever 'Ocean Renewable Energy' unit. The unit included practical work at the wave flume and wind tunnel facilities.
- Development of a physics-based wave prediction model. This work is synergetic with Carnegie's machine learning approach under investigation; the Centre conducted wave tank testing MARINET2 campaign in Spain, May 2020.
- Performance modelling was undertaken for the M4 WEC at Albany deployment site.
- An industry collaboration project with Fugro was completed; this studied improved the understanding of cyclic loading of suction bucket foundation in sand, for offshore wind projects in the US.

AUSTRALIA-CHINA JOIN RESEARCH CENTRE OF OFFSHORE WIND AND WAVE ENERGY

This Australia-China joint Research Centre for offshore wind and wave energy harvesting was launched in February 2020, led by the University of Adelaide. The Centre has a collaboration with:

- Five Australian partners, supported by the Australian Department of Industry, Science, Energy and Resources, and
- six Chinese partners

The work at the Centre has been heavily COVID impacted, with exchange activities on hold. The research tasks encompassed by the Centre include:

- Wind and wave resource modelling (in collaboration with the national science agency CSIRO)
- Foundations for combined wind/wave harnessing array (in collaboration with the Australian University of Western Australia)
- Grid side characterisation and smooth power output control
- Fluid dynamical and electrical machine coupled models (in collaboration with the Australian Swinburne University of Technology)
- Optimisation of Global real-time control
- Model-scaled experiment of combined arrays (in collaboration with the Australian University of Tasmania)

THE UNIVERSITY of ADELAIDE

Australian Government
Department of Industry, Science, Energy and Resources

PLANNED DEPLOYMENTS

Wave Swell Energy

At a milestone moment for ocean energy development in Australia, Wave Swell Energy set the foundations for deploying their UniWave200 device in King Island, Tasmania. Deployment is planned for January 2021. Following commissioning and throughout 2021, Wave Swell's focus is to validate the models entailed in the various stages of the technology's power conversion process.

More information:
https://www.waveswell.com/king-island-project-expectations/

Other planned developments

With several technology developers active in Australia, addition projects are expected to be announced throughout 2021.

RELEVANT NATIONAL EVENTS AND INITIATIVES

Ocean Energy Market Development Program by AOEG

A key national initiative is the **Ocean Energy Market Development Program** launched by AOEG in 2020.

A new OES Australia Working Group

A new OES Australia Working Group was initiated by the Australian OES delegates in late 2020. The working group has 12 participants from across the OE sector including technology developers, consultants, policy specialists, universities and research agencies. This group will facilitate the contribution of Australian ocean energy expertise, knowledge, and developments into and from OES projects. The objectives of the working group are to:

- strengthen Australia's voice, influence, and contributions to OES
- ensure Australia's ocean energy sector knowledge and expertise are proactively contributed to and incorporated into OES projects, and
- help accelerate development of the Australian ocean energy sector via transfer of global knowledge and expertise generated within the OES

Events in 2020

The 39th OES Executive Committee meeting was scheduled to be held in Tasmania in November 2020 but was held as a virtual meeting instead.

Two other ocean renewable energy events were planned to be held in Australia in 2020, however these were unfortunately postponed owing to COVID-19 travel restrictions and associated border closures. Events that were planned and postponed included:

- The Fifth Asian Wave and Tidal Energy Conference (AWTEC 2020), scheduled to be held in Tasmania in November 2020. This conference has been postponed and new dates are yet to be released, and
- The Third Australian Ocean Renewable Energy Symposium (AORES 2020) scheduled to be held in Tasmania during AWTEC 2020 has been postponed.

Events planned for 2021

2021 Ocean Energy Market Development Summit, date TBC: As an important and integral component of its Ocean Energy Market Development Program, AOEG plans to implement their 2nd annual Ocean Energy Market Development Summit. This event is tentatively planned as an in-person event (pending international travel is open) for 4th quarter 2021. It will bring together customer representatives together with ocean energy leaders to advance market acceptance of integrated ocean energy systems.

3.2
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 pioneer in investigating parks of energy devices.

Ghent University is strategic partner in the H2020 MARINERG-i project coordinated by the MaREI Centre at University College of Cork Ireland, which brings together all the European countries with significant testing capabilities in offshore renewable energy.

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 Blue Energy Cluster of POM West Flanders was established by the province of West Flanders to give businesses in this industry every possibility to grow via innovation. Moreover, POM has introduced TUA West (Technical University Alliance West Flanders) with a focus on improving cooperation between the province's higher education establishments and making knowledge more readily available to the industry and especially the many SMEs in the region.

The Blue Growth Summer School organised by Ghent University is recognized by the European Commission as best practice example of innovative training. Already five years on row, the BGSS has fostered blue knowledge and received a variety of participants. The programme combines fundamental insights with hands on session and site visits. Besides professors also business developers, entrepreneurs and industrial leaders share their expertise with Master and PhD students passionate about the seas and oceans.

SUPPORTING POLICIES FOR OCEAN ENERGY

NATIONAL STRATEGY

Belgium has to increase its share of renewable energy production to 13% of the total consumption by 2020, following the general European Union objective. This share has been growing steadily in the past years. Currently, Belgium's renewable energy share is at around 9%. Main incentives aim at wind energy (onshore and offshore), biomass, biogas and solar energy. The offshore wind energy concessions in the Belgian North Sea will have the biggest impact on renewables, leading up to a total of2.262 MW of offshore wind power installed by end 2020.

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.

In the coastal province of West Flanders, Western part of Belgium, marine renewable energy is seen as a new emerging industry, highly relevant for Flanders. There are several initiatives promoting the development of the blue economy, including marine energies.

The 'Strategic Framework for Smart Specialisation in Flanders', describing the on-going policy process for proprietary areas in the innovation and strategy of Flanders, points out the sectors of Blue Economy, Blue Growth and Blue Energy in Flanders as prioritised areas. WESTDEAL is then focussing on West Flanders.

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 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 Blue Energy Cluster 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 cluster 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 Belgian maritime spatial plan foresees an area for the exploitation for offshore wind, wave and tidal energy. This area has been divided into 9 zones for which the Government has given domanial concessions for renewable energy project development. The last concession (±55 km from the coast) was granted in July 2012 to the temporary trading company Mermaid. This Mermaid concession zone aims at the installation of 232 to 266 MW wind and 5 to 61 MW wave energy (rated power). This hybrid park has a water depth of 35-40 m and an average wave climate of 6.5 kW/m. The project is planned to be finished by 2020 for wind part of it.

The Blue Cluster

The Blue Cluster (https://www.blauwecluster.be) has been established by Jan De Nul, Colruyt, DEME, Econopolis, INVE, Sioen Industries, Tractebel Engineering, Vanbreda Risk & Benefits, Vyncke and ZERI. It was recognized by the Flemish government as a spearhead cluster in March 2018 that focuses on the development and promotion of economic activities at sea.

Highlights about members of the Blue Cluster:

- DEME Blue Energy is a specialized company that focuses on the development of energy generated from waves, tidal movements and tidal currents. DEME Blue Energy installed the four turbines of MeyGen's Phase 1A (Pentland Firth, Scotland) and is involved in the development of two additional tidal energy parks in Scotland and Northern Ireland.
- IMDC is partner in the SE@PORTS project. Funded by OCEANERA-NET, the main goal of the SE@PORTS project is to assess existing WEC's (proven concept TRL 3) on their suitability to be integrated in seaport infrastructures and bring the selected concepts of WEC's to the next TRL.

  More information:
  http://oceaneranet.eu/portfolio/seports/
- Belgian ENGIE affiliate Tractebel was involved in the pre-feasibility study, technical audit and foundation design of the Raz Blanchart tidal energy pilot project in France.

The Blue Energy Cluster

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 Blue Energy cluster, focusing on wind, wave and tidal energy, is situated at the Belgian coast and in the Ostend area. Through a partnership between all relevant actors at the local, provincial and Flemish level, SMEs are supported in their future-oriented and sustainable development: from practical services to promotion, research, training and infrastructure: the cluster platforms aim to create an optimal breeding ground for a future-oriented economy.

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

PUBLIC FUNDING PROGRAMMES

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

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

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

The Energy Transition Fund aims at research and development in the field of energy. The budget of the Energy Transition Fund for the year 2020 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 on innovation by SMEs.

The **Flemish Agency for Innovation and Entrepreneurship (VLAIO)** has been supporting the since 2018 VLAIO set up the 'Blue Cluster' aimed at large companies & SMEs active in the blue economy sector, including marine energies. In the first working year of the Blue Cluster a total of 7 projects have been approved by Flemish Agency for Innovation and Entrepreneurship (VLAIO), representing a total budget of € 10.423.738 (subsidy € 6.995.923). In the second working year of the Blue Cluster a total of 4 projects have been approved by VLAIO, representing a total budget of € 7.676.132 (subsidy € 6.229.277).

RESEARCH & DEVELOPMENT

Coastal & Ocean Basin

The construction of the new Coastal and Ocean Basin (COB) (www.cob.ugent.be) in Ostend has been completed, and various systems (wavemaker, current generating system) are being installed. 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 30m long by 30m wide and has a variable water depth up to 1.4m, allowing for test conditions from coastal to near offshore applications. A pit located in the middle of the basin allows experiments with mooring lines at a depth in excess of 4m.

Ghent University is very active in the Blue Energy - Blue Growth - Blue Economy sectors, with the Coastal Engineering Research Group led by Professor Peter Troch (awww.ugent.be). Ghent University recently presented the new COB facility through a new video:

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)

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). 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 2020, WECANet has funded research collaborations through Short Term Scientific Missions, on-line international meetings, dissemination activities and scientific publications on wave energy. WECANet supports actively IEA-OES activities.

MARINERG-i

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

Research projects at Ghent University dedicated to wave energy

The Research Foundation Flanders (FWO, https://www.fwo.be/) is funding four PhD research projects and two post-doctoral Fellowship, carried out at the Coastal Engineering Research Group of Ghent University. 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) approved funding for developing and constructing WEC array scale models to be tested soon in the Coastal and Ocean Basin in Ostend.

The new "Blue Accelerator" test platform

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

Location of the Blue Accelerator test site; The Blue Accelerator open sea test site at Ostend, Belgium

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

OWI-Lab

OWI-Lab (https://owi-lab.be/about-us) is the continuation of the R&D&I collaboration partnership between wind energy experts from Sirris, Vrije Universiteit Brussel and Ghent University within the IBN-Offshore Energy. The key pillars of the initiative are: (Test / Experiment) -Infrastructure, Expertise and the collaborative R&D&I Platform. Through technology expertise & infrastructure, innovation support services and international collaboration OWI-lab seeks to be a leading expertise centre that is supporting (international) innovation in the offshore energy

sector. The R&D collaboration includes fundamental, applied and industry driven research & development and providing access to testing - and demonstration opportunities in real environments. OWI-lab provides access to unique and real-life test and demonstration infrastructure, operational insights and associated application knowledge to support R&D and innovation in our target group. This target group involves companies active in the onshore –and offshore wind energy business. The testing infrastructures and according expertise services are also available to international partners.

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 ORE sector. With the ambition to become a global industry leader, the 2 Seas ORE sector needs support to successfully scale-up. ENCORE offers advanced technical and business support services to accelerate the ORE 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). To support the four ORE technologies, lead partner Dutch Marine Energy Centre (DMEC) brings together project partners from 4 European countries: the European Marine Energy Centre (UK), Artelia (FR), Bureau Veritas (FR), the Coastal Engineering Research Group and Powerlink from Ghent University (BE), Inyanga (UK) and Deftiq (NL).

More information:
www.energisingcoasts.eu.

BluERA - Blue Energy Resource Assessment (2020 – 2022)

The applied research within the BluERA project will improve understanding of the response of a number of different ocean energy technologies to the variability of the energy source. In addition, it will provide important risk assessment data that will help promoters and investors select potential technologies. The end results of BluERA are two online digital products, a digital ocean energy atlas and an energy yield evaluation tool. The project also provides for a demonstration and verification of this atlas and the tool. Partners: IMDC, Laborelec and Otary RS NV. The Coastal Engineering Research Group (UGent-CERG) of Ghent University participates in the project as subcontractor.

CORDOBA (2021 – 2023)

This project is funded by the Blue Cluster (VLAIO). 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. A number of challenges still have to be overcome in this regard, such as the joint development and coordinated operation of HOV for the provision of network support services to multiple control areas. The partners within the CORDOBA project want to address these challenges 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. Last but not least, the models are validated on two different test cases. 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. Partners: Elicio, Marlinks, Yuso, Enersynt and KUL

H2MHYTIC (2021 – 2023)

This project is funded by the Blue Cluster (VLAIO). Renewable electricity has developed tremendously in recent decades. One of the main challenges in this context concerns the integration of these energy sources into the electricity grid without destabilising this grid.Electrical energy not only needs to be transported in the form of electrical current, but also has to be converted locally into an intermediate form. The conversion to hydrogen is a

promising path to do this on a large scale.This project uses nano-structured materials to build low-cost electrolysers that can convert electrical energy to hydrogen at a higher efficiency. The planned innovations in the field of electrodes and membranes will reduce the production cost of hydrogen and enable electrolysis installations on the scale of MW. The partners in the H2MHYTIC project will develop an electrolysis cell based on a new non-porous 'HEM' membrane and integrate nano-mesh electrodes with an extremely high porosity and internal surface. This new electrolysis cell will have unique properties and can be manufactured using industrially scalable production techniques. Partners: IMEC, VITO and Ghent University.

RAINBOW (2021 – 2023)

This project is funded by the Blue Cluster (VLAIO). The RAINBOW project aims to gain more insight into the erosion of rotor blades as a result of precipitation and lightning as erosion entails significant production losses. This should result in new preventive maintenance opportunities and deliver improved inspection, maintenance and repair strategies. The project partners are committed to thorough monitoring of the turbines and the energy yield on the one hand, and automated inspection of rotor blades by means of drones on the other. Based on the results, coatings and other protective materials will be tested and validated under realistic North Sea conditions. All this also makes it possible to better predict the lifespan of wind turbines and better prepare and plan inspection flights with drones. Ultimately, this will result in a longer life of the wind turbines and a drastic reduction in inspection, maintenance and repair costs. Partners: Otary, Norther, Engie Laborelec, VKI, VUB, Sirris and SABCA.

OPIN

Sirris from Belgium is 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.

NON-STOP

NON-STOP is an abbreviation for *New smart digital Operations Needed for a Sustainable Transition of Ports,* funded by the North Sea Region Programme (2014–2020). Belgian partners are: Port of Oostende, CRESCENT NV and Bluebridge. The project focuses on Small and Mediums sized Ports (SMP) within the North Sea Region, which have been working in complex and rapidly changing world where the society and businesses have experienced a digital transformation in numerous areas. The ultimate goal is to reduce the time of pre-defined logistical/maintenance port operations and lower port energy and pollution.

More information:
https://northsearegion.eu/non-stop/about/

ITEG - Integrating Tidal Energy into the European Grid

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

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

ELBEPlus project

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

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

Soiltwin

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

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

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:
https://ostendsciencepark.be/bluebridge/bluebridge/

TECHNOLOGY DEMONSTRATION

PLANNED DEPLOYMENTS

The Blue Accelerator test site is operational starting in spring 2020. From then on, companies and knowledge institutions active in blue energy, or broader blue growth, can test and demonstrate new products and technologies in real life living conditions, with quick access, easy permitting via POM, access to a large blue energy network and tailor-made support by the involved Flemish partners.

RELEVANT NATIONAL EVENTS AND INITIATIVES

Events in 2020

- **16 January 2020:** Sparta Offshore Wind Benchmarking Workshop, in cooperation with World Class maintenance (Ndl) and ORE Catapult (UK)
- **5 February 2020:** IBN Offshore Energy - Offshore Floating Marine Renewable Energy Technologies.
- **6 February 2020:** 2nd Coastal & Ocean Basin (COB) seminar organised by Ghent University on recent innovations in experimental research in a wave tank facility
- **17-18 March 2020:** Belgian Offshore Days – Conference data driven innovation - Inn2POWER, in cooperation with BOC
- **18 June 2020:** Ancillary services offshore grid, in cooperation with IEEE Benelux and Flux50
- **16 September 2020:** Robotising in offshore wind, in cooperation with World Class Maintenance (Ndl)
- **25 November 2020:** Seminar Internationalisation in cooperation with POM West Flanders – Flanders Investment Trade – ELBEPlus alliance

Events planned for 2021

- **September 2021:** The Blue Growth Summer School organised by Ghent University and the WECANet COST Action CA17105 (http://www.bluegrowth.ugent.be/summerschool/)

3.3
CANADA

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OVERVIEW

Despite the challenges of the global pandemic, Canada's marine renewable energy sector continues to preserve with new R&D activities, new entrants to the market, and ongoing progress of existing initiatives and projects.

On the east coast of Canada, developers working in the Bay of Fundy - DP Energy, Sustainable Marine Energy, BigMoon Power, Jupiter Hydro, and Nova Innovation - continue with planning and development of in-stream tidal energy projects. BigMoon Power joined the Fundy Ocean Research Center for Energy (FORCE) as a new berth holder after being the successful proponent for the vacant berth. NewEast Energy was also awarded a permit by the Government of Nova Scotia for development in the Bay of Fundy. The Government of Canada has also continued it support for the sector with funding support $4 million for Nova Innovation's project and $28.5 million awarded to Sustainable Marine Energy for its 9 MW project at FORCE.

Collaborative efforts amongst industry, research organizations, and government have been launched to address uncertainties around environmental impacts of tidal energy. With the support from the Governments of Canada and Nova Scotia, the Offshore Energy Research Association (OERA) and FORCE are both leading R&D initiatives to help inform environmental monitoring and regulatory processes.

The Canadian sector continues to focus on realizing opportunities in marine renewable energy for remote and coastal communities that are reliant on diesel for electricity generation – a major market in Canada and also globally. The University of Victoria's Pacific Regional Institute for Marine Energy Discovery (PRIMED), Sustainable Oceans Applied Research (SOAR), and the Canadian Hydrokinetic Turbine Test Center (CHTTC) are all working on R&D initiatives to support community-scale marine renewable energy generation. The federal government through the National Research Council has also completed a marine renewable energy resource atlas for British Columbia in western Canada and a river hydrokinetic energy resource assessment is being led by Natural Resources Canada's CanmetENERGY.

SUPPORTING POLICIES FOR OCEAN ENERGY

NATIONAL STRATEGY

Government of Canada

In the fall, Canada joined the High Level Panel for a Sustainable Ocean Economy, which commits to "*Transformations for a Sustainable Ocean Economy: A Vision for Protection, Production and Prosperity*. The action plan prioritizes marine renewable energy as one of the areas of focus. As part of this commitment, the Government of Canada has indicated that they will lead public consultation on Canada's blue economy strategy in 2021.

The Government of Canada has also begun consulting on future offshore renewable energy regulations through the Offshore Renewable Energy Regulations (ORER) Initiative. The ORER initiative aims to develop safety and environmental protection regulations that will apply to exploration, construction, operation and decommissioning activities related to renewable energy projects and power lines in Canada's offshore areas. The ORER will be developed under the Canadian Energy Regulator Act that came into force in August 2019.

This legislation enables the Canada Energy Regulator to review and authorize activities related to offshore renewable energy in Canada's offshore areas. These activities could include:

- Site characterization activities, such as, resource surveys, geoscience and geotechnical studies, and environmental surveys; and,
- Construction, certification, operation, maintenance and decommissioning of offshore renewable energy facilities and offshore power lines.

These regulations will not apply to tidal energy projects in the Canada's Bay of Fundy, as these tidal projects fall primarily under the jurisdiction of the provincial government of Nova Scotia.

Province of Nova Scotia

Nova Scotia continues to be the most active region for marine renewable energy development in Canada, now with seven permitted projects at different stages of planning and development.

The call for proposals for the vacant berth at FORCE initiated in 2019 resulted in an award of the berth to BigMoon Power. This process was led by a third party administrator is conducting the process on behalf of the government and requires that BigMoon also remove the Cape Sharp turbine that remains in the berth after its 2018 deployment.

The Government of Nova Scotia has also issued additional permits under its demonstration permit program that was launched in 2018. Under the program, marine Renewable-energy permits allows project developers test or demonstrate new ways of generating marine renewable energy. Applicants may apply for unconnected permits to test non-grid connected devices or demonstration permits to deploy and connect devices to the electrical grid in the Province. Each demonstration project may be permitted no more than five (5) megawatts of new generating capacity, with a total of no more than ten (10) megawatts available under the program. In August, Neweast Energy was granted a permit for an 800 kW project. Another 7 MW was previously allocated to Big Moon Power (5 MW), Jupiter Hydro (2 MW), and Nova Innovation (1.5 MW).

Numerous permits have been issued for unconnected tests/demonstrations and the Province of Nova Scotia continues to fund and support research dedicated to enabling and advancing tidal energy development. Nova Scotia also remains the only jurisdiction in Canada that has established a regulatory framework exclusively dedicated to marine renewable energy providing both regulatory certainty a management/governance structure to support responsible development of our marine environment (i.e. environmental, social and economic interests).

MARKET INCENTIVES

Under Nova Scotia's *Marine Renewable Energy Act*, projects that receive a permit can also 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.

Two projects at FORCE have approvals for Nova Scotia's feed-in tariff (FIT) for 53 cents/kilowatt hour and allows them to enter into a 15-year power purchase agreement with Nova Scotia Power, the provincial electric utility: 1) DP Energy's Uisce Tapa Project and 2) Spicer Energy's Pempa'q project (a joint venture between Sustainable Marine Energy and Minas Tidal Ltd.).

Projects in other areas of Nova Scotia and the Bay of Fundy are also able to receive a FIT under Nova Scotia's demonstration permit program. In 2020, NewEast Energy was the newest entrant to receive a FIT, with Big Moon Power, Jupiter Hydro, and Nova Innovation having received approvals and a FIT under the permit program in 2018-2019.

PUBLIC FUNDING PROGRAMMES

In late 2020, the Government of Canada released its climate action plan; *"A Healthy Environment and a Healthy Economy"* which outlined a number measures to support renewable energy development of that marine renewable energy could benefit from. These measures include:

- $964 million over four years to advance smart renewable energy and grid modernization projects.
- $300 million over five years to advance the government's commitment to ensure rural, remote and Indigenous communities that currently rely on diesel have the opportunity to be powered by clean, reliable energy by 2030.
- $750 million over five years for Sustainable Development Technology Canada to support clean technologies.

These measures are in addition to an announcement earlier in the year for $2.5 billion to be earmarked for clean energy within the Canada Infrastructure Bank.

RESEARCH & DEVELOPMENT

Canadian Hydrokinetic Turbine Test Centre (CHTTC)

In partnership with SOAR, CHTTC has been working on several work packages to address the realization of community-scale marine renewable energy projects in Canada. R&D activities led by CHTTC have included:

- Demonstration of winter survival by modifying a Smart Hydro turbine mono-float to avoid icing issues.
- Conducting a low-cost resource assessment using a satellite-based approach to identify open waters in rivers during the winter.
- Development of a low-cost instrumented buoy that can be deployed in energetic river areas identified by the satellite method and that can survive multiple years is being developed.
- Testing of turbine interactions using New Energy turbines and H-ADCP and ADV instruments to characterize the flow around the turbines.
- Testing of a 5 kW Waterotor turbine, a low flow turbine that can tap into additional global market opportunities.

Fundy Ocean Research Center for Energy (FORCE)

FORCE is Canada's primary 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 2020, FORCE was awarded $2 million from the Government of Canada for a new project - the Risk Assessment Program (RAP) for Tidal Stream Energy. RAP is designed to create a detailed, credible assessment tool to gauge the probability that fish will encounter a tidal energy device. This project will help to support greater regulatory clarity around tidal project development. Key partners in the RAP project include Acadia University, Marine Renewables Canada (MRC), Mi'kmaw Conservation Group (MCG), Confederacy of Mainland Mi'kmaq, Ocean Tracking Network (OTN), and Dalhousie University.

Other key highlights for FORCE in 2020 included:

- The announcement of BigMoon Power as the successful applicant to fill FORCE's berth D and remove the Cape Sharp turbine presently occupying the berth.
- Collaborative work with the Offshore Energy Research Association (OERA) to advance 'The Pathway Program' to identify effective and regulator approved monitoring solutions for the tidal energy industry in Nova Scotia.
- Continued environmental monitoring baseline studies, analysis of past results, and the development of an updated monitoring plan for 2021 and beyond.
- The development of new methodologies for high resolution eddy mapping.
- Further advancement of the Vectron: the world's first stand-alone instrument to remotely measure turbulence in the mid-water column in high resolution.

Offshore Energy Research Association (OERA)

OERA's marine renewable energy research agenda has evolved over the last decade as the tidal energy sector

River hydrokinetic turbines testing being conducted at CHTTC

advances through progressive stages of development. Since 2006, OERA has funded or co-funded over 100 research projects that – combined with partner leverage – have achieved a total research investment of $23.8M.

In 2020, OERA supported the following marine renewable energy research:

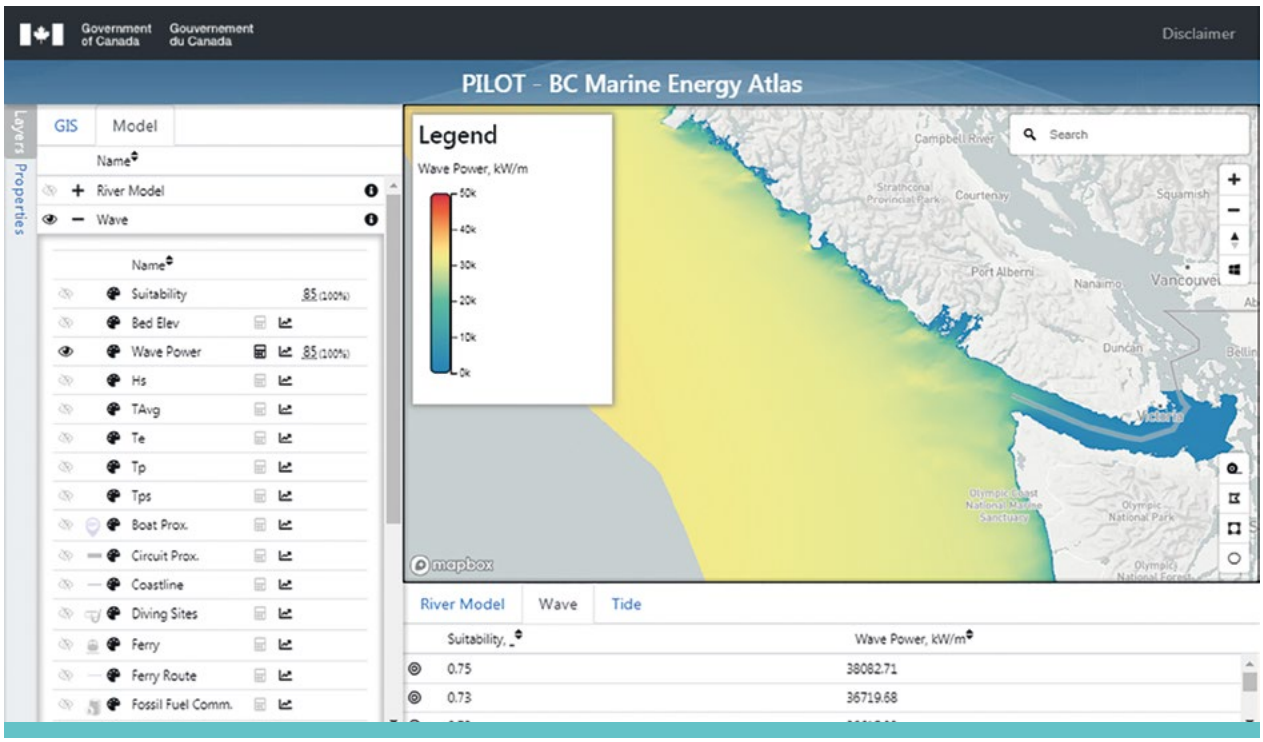
- Field assessment of multi-beam sonar performance in surface and bottom-mount deployments
- Pathway Program – Development of platform and cabling solution
- Testing of 360-degree imaging technologies for improved animal detection around tidal energy installations
- How sounds travel in high energy environments – effectiveness of acoustic monitoring systems and turbine audibility assessment
- Reducing costs of tidal energy through a comprehensive characterization of turbulence in Minas Passage

A major marine renewable energy project led by OERA in 2020 is the Pathway Program. Currently, there is no suite of environmental monitoring tools accepted by regulators as 'field-proven' for the conditions in the Bay of Fundy. To address this, OERA developed the Pathway Program – a $2 million collaborative environmental effects monitoring research program aimed at reducing regulatory uncertainty and compliance costs. This project is supported by the Government of Canada and the Province of Nova Scotia.

National Research Council (NRC)

National Research Council Canada (NRC) is currently developing a Marine Energy Resource Atlas for Canada (the 'Atlas'), based on a pilot web application completed in 2019 (https://www.bc-atlas.ca). The goal of the Atlas program is to support technical assessment of marine energy resources (waves, tidal currents, river flows) and allow various stakeholders to estimate and map energy resources by resource type, by region, and by province.

The Atlas will allow stakeholders to apply a wide range of practical constraints and assumptions so that energy resource investigations can be tailored to address specific needs. The Atlas is currently being developed using Amazon Web Services (AWS) to store, view, query, and host large marine energy datasets (> 25 Terabytes). NRC is collaborating with University of Victoria, University of Ottawa, University of Dalhousie, University of Laval, Polar Knowledge Canada, and NRCan to incorporate new datasets and tool functionalities.



Pilot British Columbia Marine Renewable Energy Atlas

The development encompasses several stages as follows:

1. Developing a methodology and code to upload and download marine resource datasets efficiently through AWS S3 (Spring 2020).
2. Developing an Application Programming Interface (API) to download specific spatial and temporal datasets (Fall 2020).
3. Developing graphical user interface functionalities in the application to extract, view or download marine resource datasets (2021).
4. Creating a user's manual guide for the API and application (2022).

The Atlas will help disseminate detailed information on Canada's most attractive resource opportunities, help accelerate the growth of marine renewable energy technologies, reduce the cost of pilot projects within Canada, and help establish Canadian companies as key players in this emerging industry.

Natural Resources Canada (NRCAN)/ CanmetENERGY-Ottawa

NRCan in continuing collaborative research projects in advancing river hydrokinetic energy with NRC, academia, industry and the Canadian Hydrokinetic Turbine Test Centre (CHTTC). Demonstration of tidal current and river hydrokinetic energy systems (RHE) will support technology and project developers to demonstrate tidal current energy (TCE) and RHE systems, resulting in two to five systems deployed by 2025. Progress made in assessing resources and techno-economic assessment for potential demo with communities in province of Manitoba, Ontario, Quebec, British Columbia and North West Territories.

Simplified models of a RHE turbine has been developed and implemented in various CFD packages, and numerically validated with high-resolution full CFD simulations in collaboration with Laval University and NRC. Based on simplified models preliminary RHE turbine array guideline has been developed.

CanmetENERGY-Ottawa is developing methods for identifying areas of high river hydrokinetic potential in river reaches across Canada through remote sensing techniques. In partnership with the NRCan's Canadian Center for Remote Sensing (CCRS), CHTTC, University of Ottawa, and the National Research Council of Canada (NRC), CanmetENERGY analyzes Synthetic Aperture Radar (SAR) and Optical Satellite data to locate areas of open water within river ice. These areas are indicative of high kinetic energy in the form of turbulence or velocity and may be suitable for energy extraction. The ultimate goal of this project is to create a publicly available database of high potential sites to be leveraged by project developers and remote communities for potential renewable energy projects. Initial SAR datasets from the Radar Constellation Mission (RCM) have been analyzed and field validations of the findings are ongoing.

Ocean Supercluster Projects

Canada's Ocean Supercluster is an industry-led transformative cluster model that is driving cross-sectoral collaboration, accelerating innovation, and growing Canada's ocean economy. By matching industry investment, and facilitating collaboration and close alignment with the ecosystem, academia, science, indigenous communities, and government, the Supercluster supports game-changing projects. In 2020, the Supercluster awarded funding to a number of projects focused on marine renewable energy. These include:

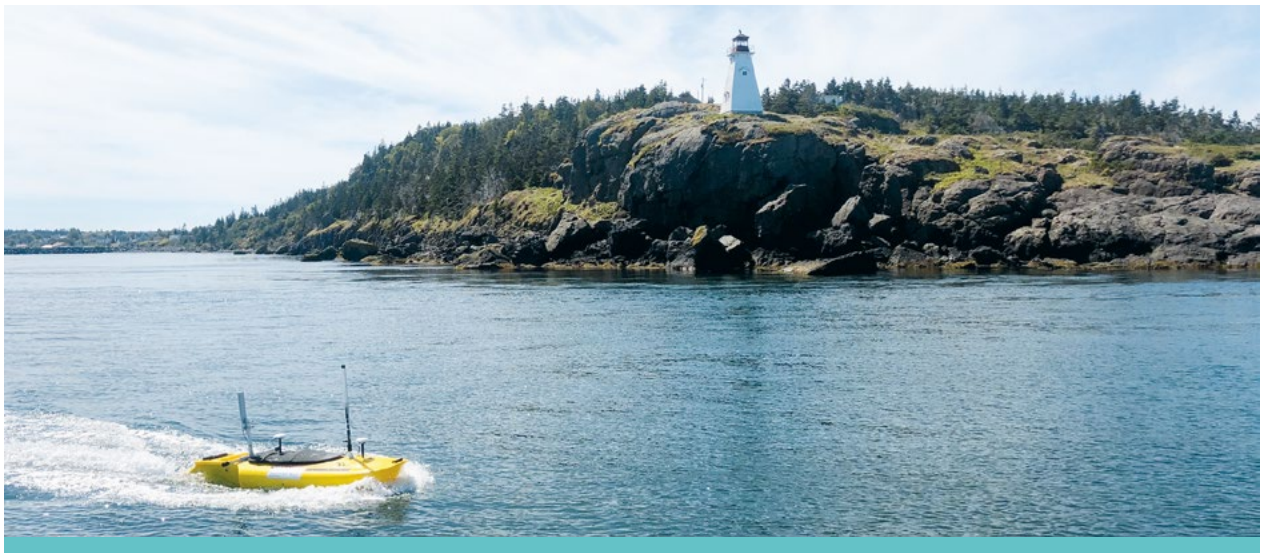
- **Vitality –** A project aimed at capitalizing on Canada's ocean data to deliver definitive commercial outcomes to the businesses involved by advancing ocean data analysis, management and visualization capabilities, and products. This project will see the development of new, applicable low-cost data streams, and the development of tools to manage those streams, as well as software that lowers the barrier to entry for the application of this data. This project will also build tools and linkages between the Canadian Integrated Ocean Observing System (CIOOS) and three emerging environmental technology and data-heavy ocean sectors: aquaculture, tidal power, and offshore wind. Vitality is led by Pisces Research Project Management Inc. together with project partners from across Canada including: Dalhousie University, Perennia Food and Agriculture Inc., FORCE, University of Victoria, St. Lawrence Global Observatory, Tula Foundation and The Hakai Institute, Marine Renewables Canada, and COINAtlantic.
- **Ocean Energy Smart Grid Integration Project –** this project will develop a single controller that has algorithms for different communities, whereas currently there is a bespoke design for each community. With this solution, algorithms are selected and parameterized based on ratings of the equipment. The project will commercialize the integration of ocean energy solutions to help reduce the dependence of diesel power generation in rural and remote communities and increase the opportunity for use of renewable sources of energy. The project is led by BMT partnered with Sustainable Marine, University of Victoria, Rainhouse, and Turtle Island Innovation.

Sustainable Oceans Applied Research (SOAR)

SOAR, has been working closely with OERA and other partners do deliver aspects of the Pathway Program by evaluating the effectiveness of the multibeam imaging sonars for monitoring near-field interactions between marine animals and tidal turbines.

SOAR is also partnered with the University of Manitoba/CHTTC on a project supported by the Government of Canada to advance research on river hydrokinetic and in-stream tidal energy technologies in the Canadian context. As part of this project, SOAR conducted marine animal observations in the Grand Passage area of the Bay of Fundy and worked closely with Dalhousie Ocean Acoustics Laboratory to conduct extensive flow field mapping using vessel mounted and drifting ADCPs to characterize Sustainable Marine Energy's PLAT-I's wake.

Additional work led by SOAR focused on advancing case studies for site assessment at remote indigenous communities in Northern Labrador and British Columbia planned for 2021 in collaboration with Queens University, University of Victoria, and indigenous organizations.



Jetyak in Petit Passage for an OERA funded project - a collaboration between Luna Sea Solutions, Dalhousie Ocean Acoustics Laboratory, and Memorial University to develop and validate software for detecting fish using Acoustic Doppler Current Profilers (ADCP)

University of Victoria (UVic)

The University of Victoria (UVic) has been leading work in 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 its established Pacific Regional Institute for Marine Energy Discovery (PRIMED), which is aimed at eliminating the uncertainty and risk for "first-of-a-kind" community based marine renewable energy projects.

Key project and activities over 2020 included:

- Research methods for extreme wave assessment in coastal waters
- Wave measurement and instrument development - preparing to deploy the first LiDAR based wind profiling offshore buoy in 2021 along with a land-based LiDAR station for buoy calibration near Victoria, British Columbia
- PRIMED collaborative project with BMT to develop hardware in the loop simulation facility for energy system management technology (energy system dispatch hardware) for hybrid energy systems.
- Collaboration with Accumulated Ocean Energy on the development of air pumping wave energy converter concept.
- Muchalaht First Nation project including wave energy FEED study.
- Working with Canadian wave energy Technology Company to develop a control system for point absorber type wave devices.

TECHNOLOGY DEMONSTRATION

PROJECTS IN THE WATER

Sustainable Marine Energy

Sustainable Marine Energy has been operating its PLAT-I 4.63 (280 kW) floating tidal energy platform in Grand Passage since 2018. The demonstrate site has provided the opportunity to collect useful data, test operations and maintenance methods, and support important environmental and technical R&D.

PLANNED DEPLOYMENTS

Big Moon Power

Big Moon Power was the successful proponent for the vacant berth at FORCE. As part of the conditions for occupying the berth, Big Moon is required to remove the Cape Sharp turbine that was deployed at the location in 2018.

DP Energy

DP Energy continued to develop its 9 MW project, Uisce Tapa, at FORCE test site through 2020, finalizing site specific engineering, site characterization activities and the final planning activities. Project-specific marine operations planning work continues to progress. Subsea cable installation is targeted for fall 2022 with subsea structures and turbine installation targeted for 2023.

Jupiter Hydro

Jupiter Hydro has continued planning for the development of its project in the Bay of Fundy, which is in two phases: the testing of a non-grid connected 1 MW prototype and the other for 2MW demonstration.

NewEast Energy

NewEast Energy, a subsidiary of New Energy Corporation was awarded a permit through Nova Scotia's tidal energy demonstration permit program for an 800 kW project in the Minas Passage, as well as a fifteen-year power purchase agreement (PPA). The project will be at a location next to FORCE and will consist of an array of floating grid connected New Energy EnviroGen™ Power Generation systems. Four generators will be installed as part of the array. NewEast Energy is in the initial stages of project development and has a three-year project development window.

Nova Innovation

Nova Innovation has continued the development of its tidal energy project in Petit Passage, Nova Scotia. With the first turbine scheduled for deployment in 2021, Nova Innovation has ramped up engagement with regulators, communities, supply chain and First Nation communities and organizations. In September 2020, Nova Innovation was awarded $4 million from the Government of Canada to support Phase 1 of the project.

Construction of Sustainable Marine's 420 kW PLAT-I platform

Sustainable Marine Energy

Sustainable Marine was awarded $28.5 million by the Government of Canada for the development of its 9 MW Pempa'q project at FORCE. The first phase of the Pempa'q In-stream Tidal Energy Project will begin with the installation of a 420 kW PLAT-I platform that will be launched in early 2021. It will be installed at the Grand Passage site for commissioning and testing throughout the winter and spring. Construction work will then start at the FORCE site where this platform will be installed, alongside two others, to provide a combined capacity of 1.26 MW.

Yourbrook Energy Systems

Yourbrook Energy Systems, a British Columbia based tidal energy technology developer, is continuing development of its 500 kW Kamdis Tidal Power Demonstration Project. Yourbrook's technology is targeting rural and remote communities with a combination of innovative tidal power extraction paired with energy storage capability. The company has recently patented a new highly efficient paddle wheel system to extract more energy from the swept area of the tidal stream.

ORPC Canada

ORPC Canada engaged in extensive outreach in 2020 to potential community, government and supply chain partners across Canada, focusing on supporting remote communities to transition to a sustainable energy future. In addition, ORPC Canada conducted in-depth market analysis and mapping for river hydrokinetic and tidal energy. ORPC Canada's activities have been buoyed by parent company ORPC's success in neighboring Alaska, where the company's RivGen® Power System has been operating continuously for the Igiugig community since October 2019. It is now the longest operating current energy converter device in the Americas and the first one to be successfully produce electricity throughout the Alaskan winter, operating during frazil and ice breakup events.

RELEVANT NATIONAL EVENTS

Events in 2020

Marine Renewables Canada 2020 Annual Conference, November 2020 Halifax, Nova Scotia

3.4
CHINA

AUTHORS
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OVERVIEW

In 2020, China announced further commitments to contribute more to tackling the global climate challenge. China will adopt more vigorous policies and measures, with goals to peak carbon dioxide emissions before 2030 and achieve carbon neutrality before 2060. China released the proposals for formulating the 14th Five-Year Plan (2021-2025), China will further accelerate the development of emerging industries such as new energy, new materials environmental protection and marine equipment. Renewable energy has been listed as a priority area for energy development, China will further formulate relevant financial policies to support the development of renewable energy, including ocean energy. The tidal current energy demonstration project continued to operate steadily, and the 500 kW WEC had been deployed to open sea test in Wanshan. Wanshan wave energy test site and Zhoushan tidal current energy test site will begin operation and provide test services in 2021.

SUPPORTING POLICIES FOR OCEAN ENERGY

NATIONAL STRATEGY

China released a white paper on the country's energy development on December 21, 2020. The document, titled "Energy in China's New Era", was released by the State Council Information Office to provide a full picture of the country's achievements in energy development and major policies and measures for energy reform. China is giving priority to non-fossil energy, and is striving to substitute low-carbon for high-carbon energy and renewable for fossil energy, according to the white paper. The country has been facilitating the use of solar energy, developing wind power, hydropower as well as safe and structured nuclear power while advancing biomass, geothermal and ocean energy development in accordance with local conditions, it noted. China is also proposing for the international community to work together on the sustainable development of global energy, address the challenges of climate change, and build a cleaner and more beautiful world.

The proposals for formulating the 14th Five-Year Plan (2021-2025) for National Economic and Social Development and the Long-Range Objectives Through the Year 2035 was released on October 29. The new China's development plan proposals, which stress innovation, domestic demand, quality of development and high-level opening-up among others, will provide more development opportunities and bring shared prosperity to the world. China will further accelerate the development of emerging industries such as new energy, new materials environmental protection and marine equipment, according to the proposals. China looks to further improve its energy structure by tapping the potential of various types of renewable energy, including solar energy, wind energy, biomass, geothermal and ocean energy.

In April 2020, the National Energy Administration (NEA) issued the draft of the Energy Law of the People's Republic of China and referred to the general public for comments. China has listed renewable energy as a priority area for energy development. China will formulate medium- and long-term targets for the total amount of renewable energy, and formulate a guaranteed purchase system for power generation in accordance with the targets. China will further formulate relevant financial policies to support the development of renewable energy, including ocean energy, it noted.

In March 2020, the National Development and Reform Commission (NDRC), Ministry of Justice issued "on speeding up the establishment of green production and consumption laws and policies of views". According to the views, China will increase policy support for distributed energy, smart grid, energy storage, multi-energy complementary, speed up the formulation of standards and supporting policies for the development of hydrogen energy, ocean energy and other new energy.

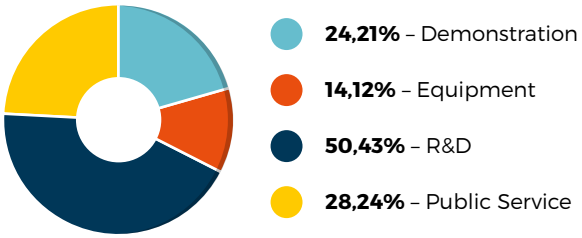
In 2020, the Ministry of Natural Resources (MNR) is working out the National Coastal Zone Protection and Utilization Plan. Ocean energy will be included in the marine functional zoning and supported, to ensure the use of sea areas for ocean energy projects, in order to speed up the industrialization of ocean energy.

MARKET INCENTIVES

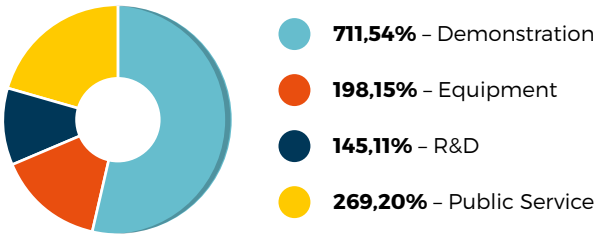
In order to further promote the development of the renewable energy electricity market, China has proposed the establishment of a renewable energy electricity consumption guarantee mechanism to stimulate the potential of local markets. On 18 May, NDRC, NEA issued the Notice on the targets of the Renewable Energy Electricity Consumption of Provincial-level Administrative Regions in 2020. According to the notice, the obligatory targets of renewable energy power consumption for each province in 2020 was proposed.

PUBLIC FUNDING PROGRAMMES

To promote the development of ocean energy, the Chinese Government established the largest special funding programme for marine renewable energy (SFPMRE) in 2010. It mainly focuses on the construction of isolated island power generation systems and grid-connected power stations, industrialization for key technology, research and development for new technology and the public service system. As of 2020, the funding programme of marine renewable energy has invested above 1.3 billion RMB since 2010, and 116 projects were funded.



Projects

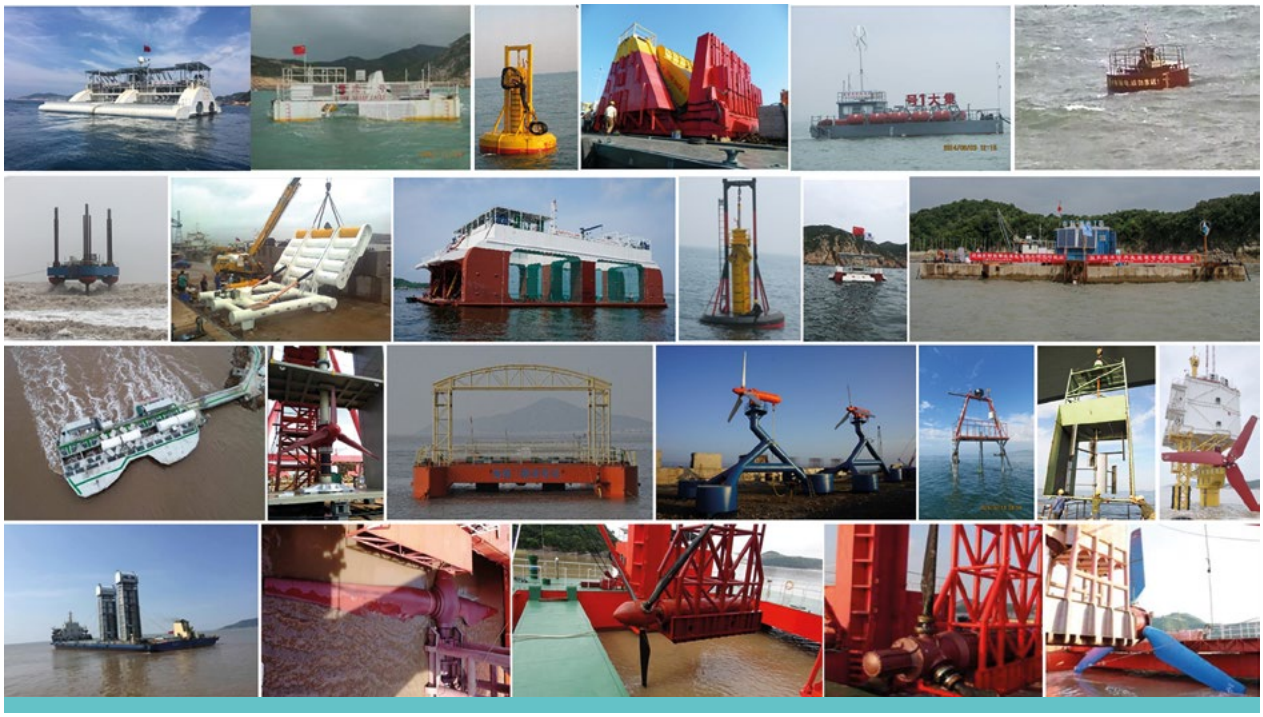


Investment (¥ M)

With the support of special funding programme, the cumulative installation of tidal current turbines is 3.73 MW since 2010, about 3 MW is currently in the water. More than 40 wave energy devices have completed sea trials, with a maximum single power of 500 kW, and Some of WEC technologies have been applied in remote island power supply, mariculture, buoy power supply and other fields.

In order to promote renewable energy technological innovation and development, the Ministry of Science and Technology (MOST) released the National Key Research and Development Program (NKRDP) of 'Renewable Energy and Hydrogen Energy Technology'. There were 2 ocean energy tasks in the programme, task I "Research on ocean energy resources characteristics and high-efficiency energy conversion mechanism" and task II "Research on ocean energy key technology and equipment". The application of projects was started in 2018. So far, 3 R&D projects on ocean energy have been supported.

Research Projects	Period	Funding (¥ M)
High-efficiency Ocean Energy Technology Based on Resources Characteristics	2019.04-2023.03	18.16
MWs High-efficiency and High-reliability Wave Energy Conversion and Island Demonstration	2019.12-2023.11	15.00
Methods and Techniques of OTEC	2019.12-2023.11	8.82



Projects funded by the special funding programme for marine renewable energy

RESEARCH & DEVELOPMENT

High-efficiency Ocean Energy Technology based on Resources Characteristics

In order to promote development in the field of fundamental research of ocean energy, the research team led by Ocean University of China was founded by the NKRDP of 18.16 million RMB, to carry out research on the efficient conversion mechanism of tidal range, tidal current and wave energy based on the characteristics of China's ocean energy resources, and resource assessment, testing methods, development strategies of ocean energy.

MWs High-efficiency and High-reliability Wave Energy Conversion and Island Demonstration

In 2020, the project on "MWs high-efficiency and high-reliability wave energy conversion and island demonstration" was organised by the Guangdong Power Grid Co. Ltd, with the support of NKRDP. The project aims to develop a new 1 MW wave energy conversion suitable for island resource characteristics and demonstration on an island. The project group includes Guangdong Power Grid Co. Ltd, Guangzhou Institute of Energy Conversion (GIEC), National Ocean Technology Center (NOTC), Harbin Engineering University (HEU), and Hainan Power Grid Co. Ltd. The total project investment is 105.5 million RMB, of which 15 million RMB is supported by NKRDP.

Methods and Techniques of OTEC

In 2020, with the support of NKRDP, the research team led by Southeast University is conducting research on key techniques of OTEC such as OTEC turbine, cold seawater pipe, thermal insulation and cold sea lift. The project will deploy a 30 kW island-based OTEC platform in Hainan province in 2022.

Cooperative Study on Comprehensive Evaluation Methods of Wave and Tidal Currents Energy Technology

As Part of NKRDP, MOST published a call for issuing the Guidelines Regarding Application for the Projects in Fields of Intergovernmental International Cooperation on Scientific and Technological Innovation/Cooperation on Scientific and Technological Innovation to support collaborative research under the cooperation framework of the International Energy Agency Technology Collaboration Programme. In 2020, the project "Cooperative study on comprehensive evaluation methods of wave and tidal currents energy technology" organised by NOTC has been approved by NKRDP. The project is carried out jointly by NOTC, GIEC, HEU, Shanghai Jiao Tong University (SJTU), University of Strathclyde, University of Edinburgh and Technical University of Denmark. The object of the project is to conduct cooperative research and laboratory model test verification on the evaluation methods of wave and tidal currents energy technologies, and to promote international cooperation in fields of technology evaluation. The implementation period of the project is from 2020-2022.

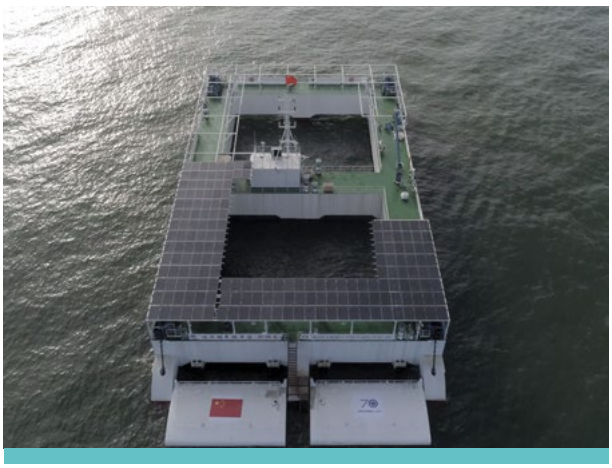
TECHNOLOGY DEMONSTRATION

PROJECTS IN THE WATER

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

To further promote the development of ocean energy industry in China, the construction of China's first MWs level wave energy demonstration project has been started with the support of the Ministry of Finance and MNR in 2017. The total project budget is RMB 151 Million. In 2020, GIEC, China Southern Power Grid, China Merchants Heavy Industry Co. and other units have completed the first 500 kW WEC "Zhoushan" in June and deployed to open sea test. The demonstration project will begin

500 kW WEC "Zhoushan" towed by tugboats to the test sea area



Penghu: Length 66 m, Depth 28 m, Height 16 m; 60 kW wave energy; more than 10,000 m³ aquaculture space

operation in 2021, and it will make Wanshan Island become an important demonstration base and test site for wave energy technology in China.

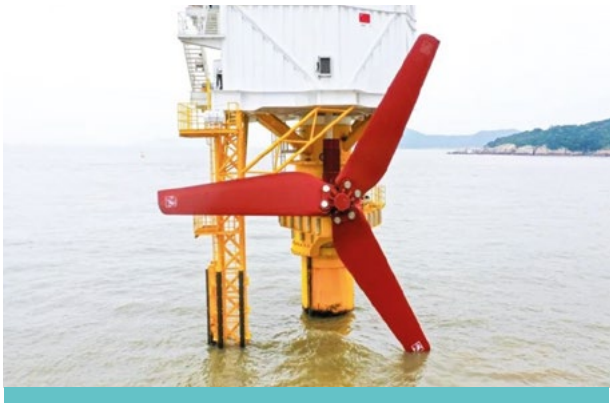
Wave Energy Aquaculture Cage "Penghu"

In order to solve the situation of shortage of energy supply and poor wind-wave resistance of traditional aquaculture cages in China, the GIEC combines Sharp Eagle WEC technology with aquaculture, offshore tourism, science popularization, using wave energy to power the integrated platform of aquaculture, tourism, science popularization. As of December 2020, Penghu have completed 18 months of demonstration operation in mariculture base of Zhuhai city. GIEC has applied patents for the integrated platform in China, European Union, Japan and Canada, and signed sales agreement with several companies.

LHD Tidal Current Energy Demonstration Project

LHD tidal current energy demonstration project has a cumulative power generation exceeding 1.95 GWh since 2016 until October 2020 and continuous operation time exceeds 40 months. In 2018, LHD was funded 72 million RMB by the SFPMRE to press ahead with the next project phase, including #2 platform (designed capacity is 4.1 MW) and 1 MW for the new turbine). At present, the main structure of #2 platform has been completed and will be deployed in the first quarter of 2021.

#2 platform assembled at the dock



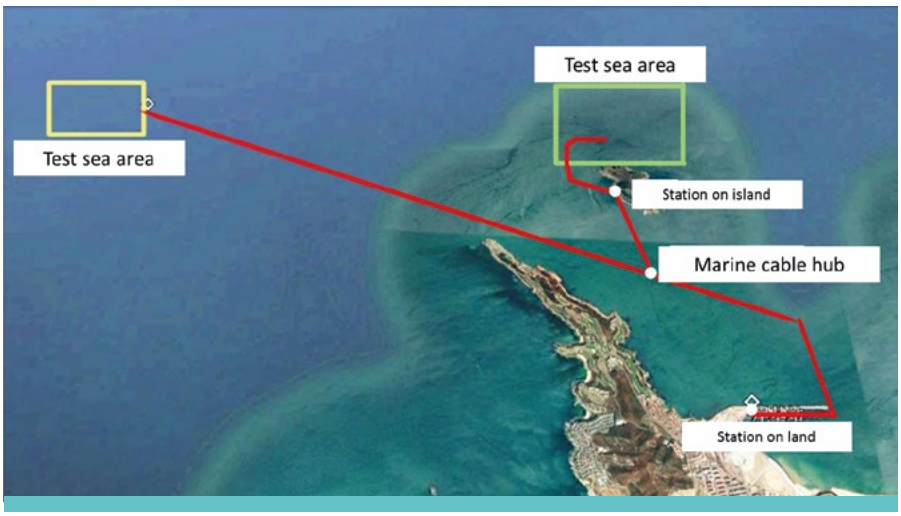
Offshore Step-up Station and 300 kW Turbine

Zhoushan Tidal Current Energy Demonstration Project

The Zhoushan tidal current energy demonstration project was developed by the China Three Gorges (CTG) Corporation with the support of SFPMRE. In April, the offshore step-up station and 300 kW turbine have been installed near Hulu island to test run. The 300 kW prototype was built by the group including China State Ship Building Corporation, IT Power and other units. In the future, the demonstration project can serve as a testing site for tidal current energy prototypes, auxiliary project will be constructed and delivered for use synchronously with the demonstration project. As part of the Zhoushan tidal current energy test site, the platform will be able to provide testing services for 3×600 kW turbines. The Zhoushan tidal current energy test site will begin operation and be able to provide test services for tidal current energy prototype in 2021.

Weihai Test Site

The Weihai test site was developed by NOTC with the support of SFPMRE. As the important part of the national open sea test site, the Weihai test site has the ability to provide test services for ocean energy small-scale prototype since 2020.



Weihai Test Site

PLANNED DEPLOYMENTS

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

The project group launched the construction of the second 500 kW WEC "Changshan" in 2020, expecting to complete and deploy on Wanshan Island to open sea test in the first half of 2020.

RELEVANT NATIONAL EVENTS

Events in 2020

On 15-18 October, the China Marine Economy Expo 2020 (CMEE2020) was held in Shenzhen.
As part of CMEE2020, the Marine Renewable Energy Industry Development Forum was held on 15 October.
More than 200 delegates participated in the forum, and the number of online visits to the forum exceeded 1000.

3.5

DENMARK

AUTHORS
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OVERVIEW

For almost a decade the wave energy activities in Denmark has been guided by the Strategy for Wave Power published in 2012 and the Danish Wave Power Roadmap from 2015. The year 2020 the Danish Partnership for wave energy initiated describing a new strategy for the development of wave power in Denmark. This strategy proposes that wave power already in 2030 can become a part of the renewable energy mix in the North Sea. Wave energy in Denmark is funded mainly through the funding program EUDP, which is a part of the Danish Energy Agency.

The eight active Danish Wave Energy projects today are developed to stage between TRL 3 – 6 and the group of Danish developers engage and exchange experience via the **Partnership for Wave Energy**. Crestwing was during 2020 testing a half scale WEC in Kattegat based on the principle of a hinged raft with an installed power of about 20 kW. Wavepiston has moved from the Danish test site DanWEC to the test site PLOCAN at Gran Canaria where several power modules will pump seawater to the PLOCAN platform for further processing. EXOWAVE is a relatively new Danish WEC company that in 2020 was granted project support to develop and test a small prototype at DanWEC. The WEC concepts is based on the principle of bottom mounted surging plates. Floating Power Plant is combining 2.5 MW wave and 10 MW wind power on a common floating platform is involved in several development tracks including Power-to-X. Resen Waves have been funding to test and validate a numerical model of the floating WEC focused on the commercial market providing small scale Smart Power Buoys for autonomous power and data communication. WaveDragon and KNSwing have completed a project focused on the use of concrete for floating WEC structures, looking at production methods, cost, and reliability. Danish developers are also participating in the Interreg projects OESA and MEA. The Danish test site DanWEC is engaged in the OESA project and developing new activities to broaden the spectrum of clients that can benefit from testing in relation to the extended Port of Hanstholm.

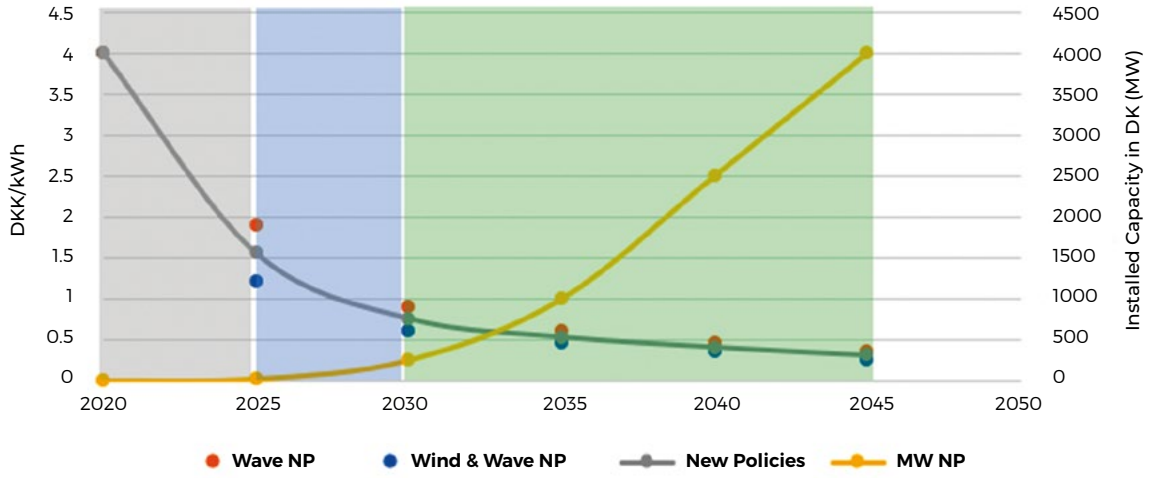
SUPPORTING POLICIES FOR OCEAN ENERGY

NATIONAL STRATEGY

In the beginning of 2020, the Danish Parliament approved a national Climate Act with legally binding target to reduce greenhouse gas emissions by 70% in 2030 compared to 1990 levels and towards net zero by 2050. In May 2020, Danish government published its first climate plan. A key component of the plan is to build two energy islands placed in the North Sea and by the Danish Island of Bornholm.

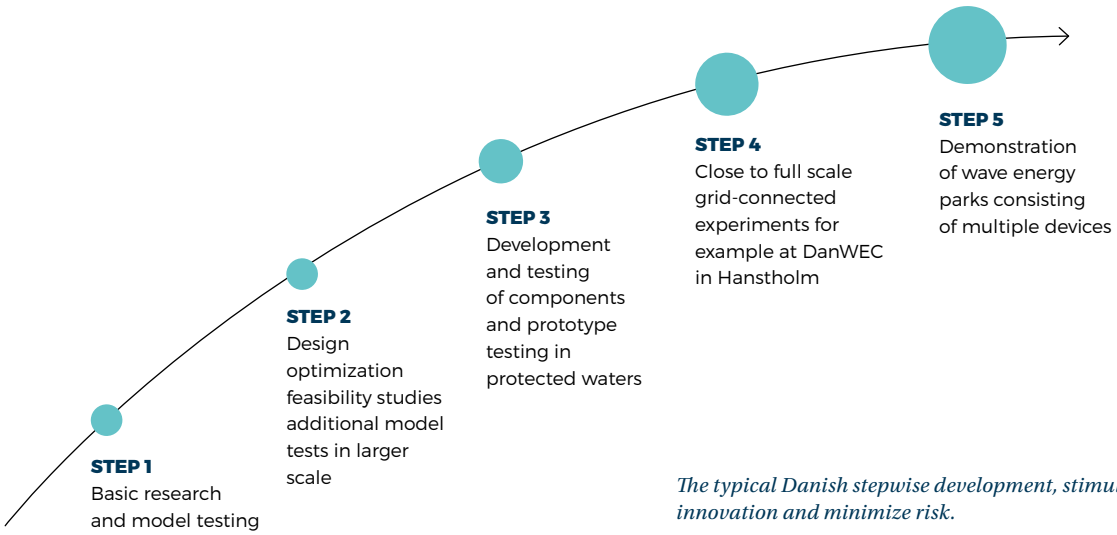
Despite the Climate Act and high focus on reducing greenhouse gas emissions, Denmark has no official targets for wave energy, however, the Danish industry organisation "the Danish Partnership for Wave Power" have set new targets that they expect can be achieved, provided enough incentives are available. The targets are shown on the figure below.

New Policies
Wave Energy Denmark - LCOE and MW Over Time



New targets for installed capacity and implemented combined with LCOE estimates

The Partnership for Wave Power have in 2020 engaged with the Danish Politicians to highlight the need for a long-term development support of wave power. The Danish stepwise development process is implemented which combine LCOE estimates for each as Technology Readiness Level (TRL).



The typical Danish stepwise development, stimulating innovation and minimize risk.

MARKET INCENTIVES

In Denmark there are no incentives dedicated for ocean energy. Ocean energy and wind energy are competing on commercial conditions.

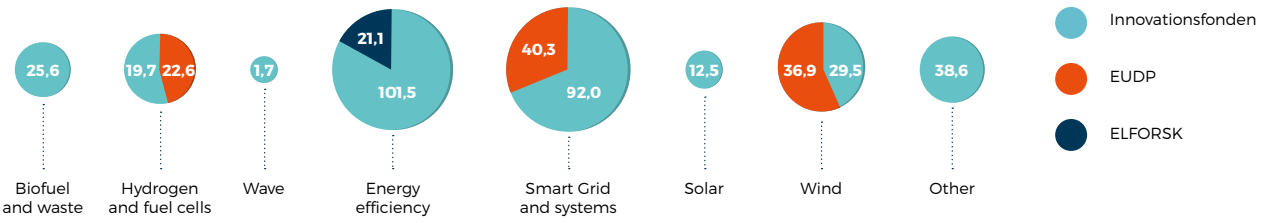
PUBLIC FUNDING PROGRAMMES

There are three national funding programmes that support ocean energy, including:

- Energy Technology Development and Demonstration Program – EUDP
- Innovation Fund Denmark
- ELFORSK

Each of these funding programmes supports a wide range of renewable and clean energy activities, and therefore ocean energy initiatives and proposals are competing with other technologies as wind energy for funding. As shown in figure below few grants have been given to wave energy compared to other energy activities. In 2019 6.7 Mio. DKK. were granted to wave energy, and in 2020 the amount was increased to almost 17 Mio. DKK from EUDP alone.

Programme Grants by technology - 2017 (DKK MILL)



The category "Other" includes: sustainable transport projects, geothermal energy, administrative and social analyses.

Grants from EUDP, Innovation Fund Denmark and ELFORSK in 2019

R&D initiatives and proposals within ocean energy are mainly supported by EUDP and private companies. Examples of projects supported are given in the next section.

RESEARCH & DEVELOPMENT

The key research institutions in Denmark are the universities: Aalborg University and DTU. Both universities have researchers and test facilities such as basins and flumes for development of wave energy.

The test site at DanWEC located next to the Port of Hanstholm is becoming a part of the Danish R&D infrastructure related to wave energy, gradually being expanded to align with the needs from the developers.

In the following sections some examples of R&D projects are given.

Resen Waves

Resen Waves are developing a Small-scale Smart Power buoy for providing autonomous power and data communication in the oceans for applications with resident AUV´s on the seabed and providing real-time data access to sensors on the seabed like ADCP´s. With the support from EUDP Project Resen Waves had, in 2020, focus on:

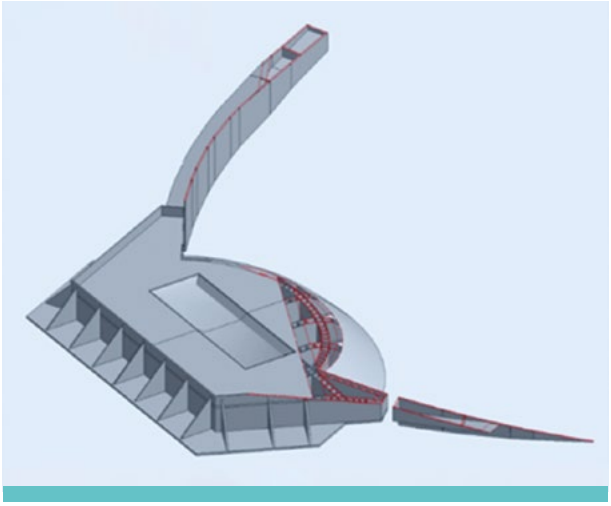
1. Develop a general and verified numerical model of the buoy power production through tank testing.
2. Improve and document minimum 12 months of testing in sheltered water as well as in the North Sea to verify reliability.
3. Certification of the buoy which "blue stamps" the buoy technology.
4. Optimize manufacturing methods for an important carbon-fibre spring and
5. Develop a 1st stage converter which turns a fluctuating voltage, into a stable output voltage

Floating Power Plant FPP

Floating Power Plant (FPP) is involved in a project supported by EUDP on De-carbonisation of Oil & Gas Production by cost effective Floating Renewable Technologies. Carbon emissions can be the reduced by combining renewable energy with the extraction of hydrocarbons. This is an emerging market with significant growth potential, but technology adaptation and development are needed to penetrate and accelerate this market entry. Floating Power Plants (FPP's) renewable technology is in this project combined with the knowhow from the oil and gas industry. The aim is to develop solutions for 3 oil and gas market segments: 1) Production Support Power, 2) Enhanced Oil Recovery, and 3) Service/Decom. The project partners will develop designs and business cases for each application and select one, which will be taken to full Front End Engineering Design, including a basin test to validate the design. Floating Power Plant has won a 1.5 Mio. EUR grant from the Danish funding programme (EUDP) to upscale and complete a detailed design of a full-scale wave energy power take off (PTO) system. The full-scale PTO system will be built and tested in a new test rig, which is also designed and built within the project.

Project "Concrete for Wave Energy Converters"

The two wave energy converters, overtopping system Wave Dragon and OWC attenuator system KNSwing are both suitable to be built in concrete. Both systems are passive structures with a few moving parts. Because of the substantial structural weight, the unit cost of concrete is important, and future low cost will require mass production. The project "Concrete for Wave Energy Converters" was supported by EUDP and finalized in 2020. Optimization of the KNSwing and Integration of OWC systems on floating concrete breakwaters is investigated as part of the MEA Interreg project.



Overtopping system Wave Dragon

Wave Star

Wave Star is in contact with an Oil & Gas company to establish a framework to build a scaled-up version of the prototype previously tested in the North Sea at DanWEC in Hanstholm (visited by the ExCo in 2012). A full-scale demonstration 6 MW Wave Star wave machine, consisting of twenty floaters, each with a diameter of 10 meters and an arm of 20 meters, will be 120 meters long and 50 meters wide. There is an ongoing research project at Aalborg University on optimising the PTO system.

WEPTOS

Weptos has been negotiating with potential investors, during 2020.

OES Task 10 on numerical modeling of Wave Energy Converters

The Danish Partners in the OES Task 10 on Numerical Modeling of Wave Energy Converters received support from the EUDP to Phase II of the project. A separate progress report on "Wave Energy Modelling Task" has been prepared for the OES ExCo, available at the OES website at:

https://www.ocean-energy-systems.org/oes-projects/wave-energy-converters-modelling-verification-and-validation/

PROJECTS IN THE WATER

Crest Wing

Tordenskiold was towed back in Frederikshavn after the second offshore test phase (February-November 2020) near the Hirsholm Islands. For a total of 14 months, data has been collected regarding the plant's capacity and efficiency in all kinds of weather, from small waves to storms and hurricanes. The Danish Consulting Engineering Company, NIRAS A/S, has analyzed and compared the offshore data with previous pool tests data. Next step to test the durability of the mooring system and the hinges of Tordenskiold in a more challenging wave environment in the North Sea of Hanstholm, and to further develop the PTO and generator system.

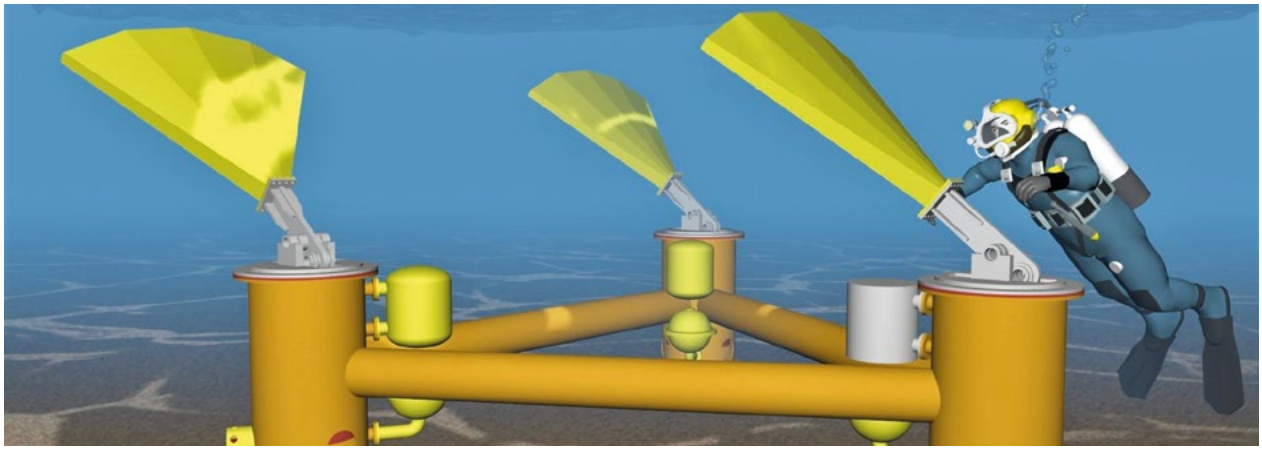
Wavepiston

Wavepiston is running two EU supported demonstration projects (SME Phase 2 and Fast Track to Innovation). The *SME Phase 2* project focuses on electricity conversion from a full-scale demonstration system at PLOCAN, Gran Canaria. It consists of a single Wavepiston WEC with 24 energy collectors (length 200 m, width 8 m) and a turbine generator. In the *Fast Track to Innovation* project the consortium of Vryhof, Fiellberg, Energia Mediterranea and Wavepiston focuses on delivering power and desalinated water to island communities. A full-scale Wavepiston WEC will be connected to a combined desalination and power generation system. In December 2020 the first system was installed at the PLOCAN test site, Gran Canaria.

PLANNED DEPLOYMENTS

EXOWAVE

EXOWAVE has won a +600.000 EUR grant from the Danish EUDP program for its innovative cleantech project Exowave, Water, Electricity and PtX. The project will develop and demonstrate the Exowave WEC in combination with a desalination system. The demonstration offshore will take place in late summer 2021 in the North Sea at the north west coast of Denmark at DanWEC.



3.6 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 Blue Growth Strategy.

In November 2020 the European Commission launched the Offshore Renewable Energy Strategy, highlighting the role that offshore wind and ocean energy technologies are expected to play to contribute to the EU's goal of climate neutrality by 2050. The Strategy proposes to increase Europe's offshore wind capacity, including floating wind, from its current level of 12 GW to at least 60 GW by 2030 and to 300 GW by 2050. The strategy foresees avenues for the creation of an ocean energy industry in the EU, targeting 100 MW installed by 2025, 1 GW by 2030 and 40 GW by 2050.

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 its funding programmes like Horizon 2020 and the European Regional Development Fund. The new Innovation Fund support programme has been launched in 2020. The new Horizon Europe programme for Research, Demonstration and Innovation will commence in 2021.

EUROPEAN STRATEGY

The European Commission presented the European Green Deal[1] in 2019. It will be the most ambitious package of measures that should enable European citizens and businesses to benefit from sustainable green transition. In follow up of this package the Commission presented in 2020 an EU strategy on energy system integration, an Industrial Strategy for a green and digital Europe, and the offshore renewable energy strategy. The Offshore Renewable Energy Strategy is the key policy initiative released in 2020 to support the development of ocean energy in the EU. The strategy was released in the context of the European Green Deal and its ambition to drive the EU towards climate neutrality by 2050. The strategy recognises the role of ocean energy to contribute to the decarbonisation goal. The expectation is that by 2030 ocean technologies could make a significant contribution to Europe's energy system and industry, particularly supporting grid stability and playing a crucial role in decarbonising islands in the EU. The Offshore Renewable Energy Strategy 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. As foreseen by the strategy a crucial but feasible step to reach commercial size by 2030 would be implementing the existing pipeline of 100 MW pilot-farms projects by 2025.

It is expected that EU Islands can play a key role in the development of ocean energy technologies in the EU. EU Islands in fact provide attractive testing and demonstration grounds for innovative offshore electricity generation technologies. The Clean Energy for EU Islands Initiative provides a long-term cooperation framework to promote replicable and scalable projects with funding from private sector investors, relevant EU support instruments, and technical assistance, in order to accelerate clean energy transition on all EU islands.

The offshore renewable energy strategy places a strong emphasis on the importance of integrating ocean energy technologies safely in the environment. As such, to facilitate dialogue on the environmental, economic and social sustainability of offshore renewable energy, the Commission is ready to facilitate and promote a 'community of practice' where all stakeholders, industry, social partners, NGOs and scientists can exchange views, share experience and work on joint projects.

To meet the EU's energy and climate targets for 2030, EU Member States need to establish a 10-year integrated national energy and climate plan (NECP) for the period from 2021 to 2030 (See annual report 2020). The national plans outline how the EU Member States intend to address energy efficiency, renewables, emissions reductions, interconnections, and research and innovation and have been submitted in 2020.

The European Commission has also included an analysis of the role of Ocean Energy in the first report on the progress of clean energy competitiveness, with recommendations on exploring specific business cases for ocean energy such as it value in the grid (beyond the LCOE) and its potential for decarbonising small communities and EU islands.

MARKET INCENTIVES

The NER300 programme was the main market incentive scheme supporting first-of-a-kind commercial-scale renewable energy projects in previous years. Information about projects awarded can be found in previous annual reports. The programme was already not anymore open for new projects since 2014. 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 around EUR 10 billion of support over 2020-2030 for the commercial demonstration of innovative low-carbon technologies, aiming to bring to the market industrial solutions to decarbonise Europe and support its transition to climate neutrality. The Innovation Fund improves the risk-sharing for projects by giving more

1 https://ec.europa.eu/info/publications/communication-european-green-deal_en

funding in a more flexible way through a simpler selection process and is also open to projects from energy-intensive industries. The Innovation Fund focuses on highly innovative technologies, such as ocean energy, and big flagship projects within Europe that can bring on significant emission reductions. It is about sharing the risk with project promoters to help with the demonstration of first-of-a-kind highly innovative projects. The first call for large-scale project proposals (capital costs >7.5 million EUR) was open in 2020. The first call for small scale projects (capital costs between EUR 2.5 and 7.5 million) was launched at the end of 2020 and will close in March 2021.

The Commission supports the ocean energy sector via BleuInvest. 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. It is enabled by the European Maritime and Fisheries Fund.

PUBLIC FUNDING PROGRAMMES

2020 was the last year for Horizon 2020 to publish calls for R&I projects. The last call was to support Green Deal and included a specific topic asking for projects demonstrating at sea critical offshore renewable energy innovations. Horizon Europe will be the successor of Horizon 2020 and the budget proposal for Research and Innovation is 95.5 billion EUR. After adoption the programme will commence in 2021 and will include topics on ocean energy development under the Climate, Energy and Mobility subprogramme.

The European Investment Bank (EIB) together with the European Commission is implementing the InnovFin Energy Demo Projects (EDP) scheme which provides support in the form of loans for first-of-a kind projects. InnovFin aims to facilitate and accelerate access to finance for innovative businesses and projects in unproven markets in Europe. The scheme helps reducing the financial risk of demonstration projects, offering equity and debts tailored to the need of the project.

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

The European Commission supports different activities addressing the development of ocean energy technologies. In particular, since 2014, the year when the Horizon 2020 (H2020) Framework Programme was launched, the EC has supported 47 projects addressing different technologies at various stages of the development. Currently 12 projects are still active.

EU support is fundamental for ocean energy R&D, supporting a wide range of tidal and wave energy technologies. EU projects aimed at the development of tidal technology have contributed to the progression of technology to higher TRL. The R&D undertaken has led to the development of new components, namely PTO, umbilical and tethers that can assist the cost-reduction of tidal energy technology and drive it towards the targets of the SET Plan.

In terms of wave energy, most projects put significant emphasis on the development of a reliable PTO. Results from EU funded TRL 5 experiments indicate that performances are on par or even better than expectation, providing a positive outlook for the development of wave energy technology and their progression to higher TRL.

An overview of awarded H2020 R&D projects in the last three years and which are still ongoing, is presented in the table below, focusing on the objective of the newly announced projects. Information about projects in previous years can be found in earlier IEA-OES annual reports.

A detailed assessment of the projects is to be provided in the upcoming JRC report "Ocean Energy Technology Development Report 2020".

Ocean Energy R&D H2020 projects awarded since 2018

Year	Acronym	Title	Technology developer	Focus
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.
2019	LiftWEC	Development of a novel wave energy converter based on hydrodynamic lift forces		Development of LiftWEC, a novel type of wave energy converter, based on the exploitation of lift forces generated by wave-induced water velocities.
2019	Element	Effective Lifetime Extension in the Marine Environment for Tidal Energy	Nova Innovation	Focus on the development of blades for tidal turbines
2019	NEMMO	Next Evolution in Materials and Models for Ocean energy		The project aims to drive down costs by designing larger, lighter and more durable composite turbine blades
2018	The Blue Growth Farm	Development and demonstration of an automated, modular and environmentally friendly multi-functional platform for open sea farm installations of the Blue Growth Industry	WAVENERGY. IT SRL	To produce advanced industrial knowledge with a fully integrated & efficient offshore multipurpose floating platform hosting a commercial 10 MW wind turbine and a number of wave energy converters (WEC).
2018	RealTide	Advanced monitoring, simulation and control of tidal devices in unsteady, highly turbulent realistic tide environments	Sabella, EnerOcean	The projects aims to identify failure caused o tidal turbines at sea whilst providing a step-change in the design of key components such as blades and PTO.
2018	Imagine	Innovative Method for Affordable Generation IN ocean Energy	Innovative Method for Affordable Generation IN ocean Energy	The Imagine project aims at developing a new Electro-Mechanical Generator (EMG)
2018	MegaRoller	Developing the PTO of the first MW-level Oscillating Wave Surge Converter	AW-Energy	The MegaRoller project aims to develop and demonstrate a next-generation Power Take-Off (PTO) solution for wave energy converters.

2018	Sea-titan	SEA-TITAN: Surging Energy Absorption Through Increasing Thrust And efficiency	Wedge, Corpower	The SEA-TITAN project aims at designing, building, testing and validating a direct drive PTO solution to be used with multiple types of wave energy converter.
2018	DTOceanPlus	Advanced Design Tools for Ocean Energy Systems Innovation, Development and Deployment	Corpower, EDF, Enel Green Power, Naval Energies, Nova Innovation, OceanTEC	Development of second generation open source design tool for ocean energy technologies including sub-systems, energy capture devices and arrays from concept, through development, to deployment.

More information about the projects and results can be found via the CORDIS project database https://cordis.europa.eu/projects/en

The European Maritime and Fisheries Fund (2014-2020) seek to promote a growth and job based recovery in Europe 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.

Ocean Energy EMFF projects awarded since 2018

Year	Acronym	Title	Technology developer	Focus
2018	WESE	Wave Energy in Southern Europe	AW-energy	To contribute to increase the current knowledge on environmental impacts of Wave Energy (WE). This knowledge will better inform decision-makers and managers on environmental risks and reduce environmental consenting uncertainty of ocean WE projects across Europe.
2018	SEA wave	Strategic Environmental Assessment of Wave energy technologies	CorPower Laminaria, Wello Oy, New Wave Technologies	To address the long-term environmental concerns around the development of wave energy technology.
2019	VPSTTG	VPSTTG: VPS for Tidal Turbine Generators	Atlantis	To manufacture and test an improved tidal turbine's pitch system – an important component enabling technology for more cost-effective tidal energy turbines.
2019	SIMBIOSE	Sustainable Innovation in la Martinique: BIOfouling Solution for clean Energy	Naval Energies	To find solutions for biofouling which will contribute to maintain heat exchangers' energy performance (OTEC)
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.

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

REGIONAL COOPERATION PROGRAMMES

Interreg projects aim at fostering transnational cooperation among neighbouring countries, encouraging collaboration to improve economic, social and territorial development of European regions. Since 2016, 16 Interreg projects have supported exclusively or partly ocean energy development for a total of EUR 132 million.

List of Interreg projects supporting ocean energy development and demonstrations in Europe

Project Name	Sea Basin	Specific to ocean energy	Total project cost	Start Year
Renewable energy projects in the countries of north-west Europe	North West Europe	No	€5,000,000	2018
Blue-GIFT (Blue Growth and Innovation Fast Tracked)	Atlantic	No	€2,500,000	2018
Marine Energy Alliance	North West Europe	Yes	€6,000,000	2018
OPIN (Ocean Power Innovation Network)	North West Europe	Yes	€2,570,000	2018
Tiger (Tidal Stream Industry Energiser Project)	Channel Manche	Yes	€46,800,000	2019
OceanDEMO (Demonstraton Programme for Ocean Energy)	North West Europe	Yes	€12,850,000	2019
OESA (Ocean Energy Scale-Up Alliance)	North Sea	Yes	€6,200,000	2019

RELEVANT PUBLICATIONS

Report on Progress of clean energy competitiveness
https://ec.europa.eu/energy/sites/ener/files/report_on_clean_energy_competitiveness_com_2020_953.pdf

EU strategy on energy system integration
https://ec.europa.eu/energy/topics/energy-system-integration/eu-strategy-energy-system-integration_en

A new Industrial Strategy for a green and digital Europe
https://ec.europa.eu/info/strategy/priorities-2019-2024/europe-fit-digital-age/european-industrial-strategy_en

An EU Strategy to harness the potential of offshore renewable energy for a climate neutral future
https://ec.europa.eu/energy/sites/ener/files/offshore_renewable_energy_strategy.pdf

Clean Energy Transition –Technologies and Innovations Report
https://ec.europa.eu/energy/sites/ener/files/documents/swd2020_953_-_1_en_autre_document_travail_service_part2_v2.pdf

Promising new technologies to help Europe achieve its ambitious climate goals - Results Pack on ocean energy
https://ec.europa.eu/inea/sites/inea/files/innovationfunds/cordis_rp_oceanenergy_brochureen_v1.pdf

National energy and climate plans (NECPs)
https://ec.europa.eu/energy/topics/energy-strategy/national-energy-climate-plans_en

JRC Ocean Energy Technology Development 2020 Update Report – to be released Feb 2021

RELEVANT NATIONAL EVENTS

2020 SET Plan Conference – Session specific on Offshore Renewable Energy Technologies.

3.7
FRANCE

AUTHORS
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OVERVIEW

In 2020, French activity in Ocean Energy was mainly supported through publicly funded projects at the European, national or regional levels. However, the national Pluri-annual Energy Policy does not set targets for ocean energy technologies as it does for offshore wind. Despite this, long-lasting experiments (> 1 year) reveal ambitions for grid-connected tidal electricity generation, with the two consented pilot tidal sites back on track in the Raz Blanchard which is one of the most significant potential tidal energy sites in the world. At the same time, testing continues for specific turbines, wave energy converters and hybrid systems designed for non-interconnected sites or for alternative usage. It is also clear that many R&D projects are addressing technological issues that will be immediately useful for offshore wind, with a strong focus on floating technologies. Many of these coming advances have potential applications for ocean energy technologies so no time will be lost! The current pandemic has not diminished the fast growing community of engineers, researchers and skilled professionals that firmly supports the deployment of ORE in the country.

SUPPORTING POLICIES FOR OCEAN ENERGY

NATIONAL STRATEGY

In France, the Energy Act (*Loi de Transition Energétique pour la Croissance Verte*), adopted in August 2015, defines an aim of 40% renewable energy in the electricity mix by 2030. The application decree called "Pluri-annual Energy Policy", which sets 10-year targets for installed capacity for all types of energy used in electricity production, was updated in 2020. Separate but comparable documents are defined for the mainland as well as overseas regions and territories. In the present document, distinct and ambitious figures of installed capacities and timing for calls for tenders are given for both bottom-fixed and floating offshore wind energy. However, for ocean energies, objectives remain limited to the availability of public incentives for prototypes and pilot farms of converters until the LCOE of these technologies is demonstrated to be commercially competitive with respect to other renewable sources of energy.

Since July 2020, France, after a prolonged absence, is once again benefitting from a dedicated Ocean Ministry which is in charge of a planning guideline called the Strategic Seaboard Document (DSF). Although the policies, permitting and incentives for offshore energies depend on the Ministry of Ecological Transition, the new Ocean Ministry provides a good impetus to their deployment by prioritizing a fair and efficient marine spatial planning, as well as promoting an enlightened public debate in the consenting process involving fisheries and other stakeholders. As a reminder, a set of laws and decrees in recent years have been enacted supporting offshore renewable energies by simplifying their deployment, namely:

- most of the legal obligations (preliminary technical studies, initial environmental assessment, public participation) are performed upstream of the actual permit issuance, thereby considerably reducing the risk for project developers;
- this process is secured as long as the technical details of the project do not diverge from the initial plan. An "envelope permit" is issued allowing for technological flexibility if developers have provided an impact assessment based on the worst-case scenario;
- for commercial farms, the cost of the export cable is to be supported by the French Transmission System Operator, which also shoulders more legal and financial responsibilities with respect to the availability of electricity exportation.

MARKET INCENTIVES

Although an incentive programme had awarded 2 demonstration pilot farms of tidal energy converters with partial support, allowing these projects to benefit from a feed-in tariff (173 €/MWh), grants and reimbursable loans, both projects are still on hold in the Alderney Race. This demonstrates that the initial support scheme was not considered supportive enough for the developers. However, new consortia are lining up for demonstrations in the Alderney Race, with HydroQuest and SIMEC as turbine manufacturers.

Also, in compliance with EU regulations on competitiveness, in the case of a call for tenders at a commercial scale, as is potentially foreseen for two high-energy tidal zones which have already been identified (Alderney Race and the Fromveur Strait in Brittany), a major part of the selection criteria will rely on the assessed electricity price per MWh. However, the present LCOE of tidal energy is considered too high to enable such a call, and present projects are supported by regional and

PUBLIC FUNDING PROGRAMMES

The "Investment for the Future" program managed by the Prime Minister and, on energy topics, by the Ministry for the Ecological and Solidary Transition, is the major provider of the above mentioned incentives through grants and loans, with the selective help of three main agencies, depending on the TRL of the project (from higher to lower): Public Investment Bank (BPI), Environment and Energy Agency (ADEME), National Research Agency (ANR). Regional local authorities also provide substantial support for prototypes and pilot projects. Since 2020, a labelling process involves the maritime industrial sector in order to identify projects that might have a significant economic impact thanks to innovation breakthroughs: ocean energy projects are included in a "smart offshore industry" subset, and one project has already been promoted: the DeMHy project which is devoted to precise resource assessment of tidal energy in marine and estuarine environments.

At the time being, this support begins with the ADEME which has an estimated cumulative budget for ocean energy projects (any type of offshore wind excluded) awarded in or before 2020 of 73 M€, which includes 6 large completed or ongoing projects. These projects involve the development of technological bricks for tidal energy, the development of tidal energy converters, wave energy converters, salinity gradient and hybrid systems for insular applications (combined renewable energies and storage systems). Ongoing projects issued from calls for tenders of previous years also involve ocean thermal energy converters, prototypes for all ocean energy technology types and technological bricks like subsea connectors or hubs, foundation concepts, specific dredging or installation tools, etc.

In 2020, the ANR officially awarded France Energies Marines (FEM), one of the seven "Institutes for the Energy Transition" and dedicated to offshore renewable energies, with 16 M€ over the period 2019-2024, for innovative research and development projects. Since this support is meant for public-private collaborative R&D projects, a 1€ public for 1€ private rule implies that more than 30 M€ is thus devoted

to this large sector, helping tackle technological bottlenecks and environmental issues.

All along the French coastline, at the regional level, local authorities also support the endeavours of the marine renewable energy sector. In addition to grants allocated to R&D federative programmes like the national institute France Energies Marines, or to local initiatives like WEAMEC (Pays de la Loire region), they invest in harbour facilities in order to enable the development of offshore wind and tidal industries, thus providing enough space to build plants along new quays, e.g. in Cherbourg, Brest and St-Nazaire.

The two French competitive Sea Clusters, Pôle Mer Bretagne-Atlantique and Pôle Mer Méditerranée, have marine renewable energies in their roadmaps. Through a labelling process, they foster interest in collaborative projects that can apply for national funding, as long as the expected results of those projects can quickly be brought to market.

RESEARCH & DEVELOPMENT

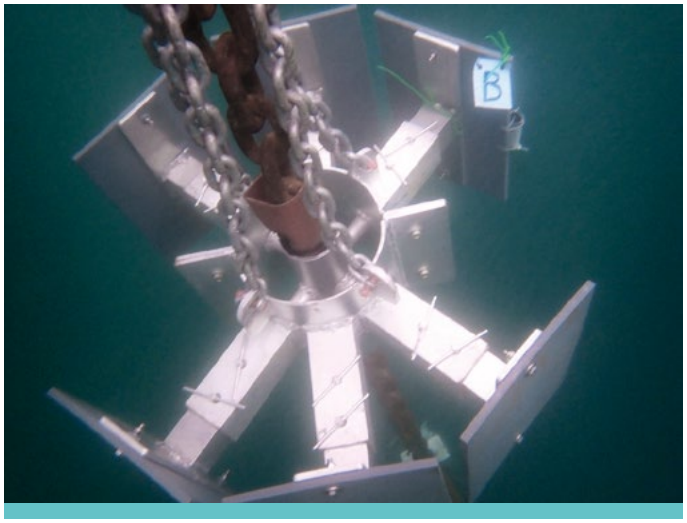
Collaborative projects of the Institute for the Energy Transition FEM

As a national public-private research centre (teams in Brest, Nantes and Marseille) France Energies Marines initiates collaborative ocean energy R&D projects with the support of the ANR. Following, is a list of selected projects running in 2020, producing data, software and publications useful for the development of ocean energy systems (offshore wind projects are not mentioned here):

DIMPACT – Design of floating platforms for ORE and impacts of energetic steep and breaking waves
RESCORE – Resources centre for offshore renewable energies
MONAMOOR – Monitoring of polyamide mooring lines (for ORE platforms)
DYNAMO – Dynamic cable monitoring (export cable for ORE platforms)
MOSISS – Monitoring strategies for innovative substations
COME3T – Committee of experts for offshore renewable energies environmental issues

France Energies Marines is also partner of several European projects, that are even more focused on Ocean Energies, namely:

DTOcean+ – 2nd generation advanced design tools for the selection, development and deployment of OES (also with Sabella as end-user beta-testing the tools);
ELEMENT – Effective lifetime extension in the marine environment for tidal energy (also with Chantiers Bretagne Sud for a better assessment of resources and environmental conditions);
OCEANSET – Support implementation of the OE component of the SET-Plan.



Immersion at the Etel's estuarine tidal site of biofouling probes for assessing marine growth (FEM)

WEAMEC (West Atlantic Marine Energy Community) federating the ORE ecosystem of Pays de la Loire Region

In the field of Research, Education and Innovation activities, WEAMEC brings together around 30 institutions and research laboratories (such as Centrale Nantes, University of Nantes, Jules Verne Technological Research Institute, Sea cluster…) and more than 75 partner companies and SMEs at the regional level. More than 250 companies at the French and international level collaborate with the academic and industrial stakeholders of WEAMEC. Since 2016, this program has cumulated 6.5 M€ of awarded funding for projects dedicated to local academic teams in conjunction with industrial stakeholders. More than 20 ongoing projects cover a broad range of topics, with the following applicable to OES:

ECOSFARM – Generic control-command tool for testing operating strategies of tidal farms
FRYDOM – Flexible and rigid bodies dynamic modelling for marine operations
LEHERO, TOCCME, BIODYTHERM, BIODYTHERM_8 – Marine growth
FIRMAIN, CEAUCOMP – Composite aging
OMCEND, BRAGGMETER – Structural health monitoring
ORIGAMI, QR CONNECT – Electrical connection
REDENVEOL, ANCRE-EMR – Mooring

Easing access to test sites and tanks

THeoRem, Marinet2, Marinerg-I, OceanDemo, Foresea and BlueGift

The Research Infrastructure THeoREM bringing together the ECN and IFREMER hydrodynamics testing facilities has recently been joined by the Gustave Eiffel University which will contribute complementary testing means for materials (tensile test benches) and foundations (geotechnical centrifuge). THeoREM pursues the major objective of becoming the French node of the future MARINERG-i ERIC aiming at developing and supporting research for the development and deployment of Offshore Renewable Energy. The goal of this Distributed Research Infrastructure is to allow the sustainability of experimental research activities for the development and deployment of OE technologies undertaken in the MaRINET (FP7) and MaRINET2 (H2020) projects. For the latter, IFREMER coordinates the trans-national access program.

Since 2016, the SEM-REV wave and floating wind test site of ECN is involved in the Interreg projects Foresea, OceanDemo and BlueGift which aim to help bring ocean energy technologies to market by providing access to Europe's world-leading network of test centres. Through these projects, the performance of innovative ocean renewable energy technologies are demonstrated in real sea conditions, helping to leverage the investment needed to take new products to market.

SEENEOH, the estuarine tidal test site running in Bordeaux, also belongs to the set of test sites, access to which is facilitated for SMEs thanks to the OceanDemo and BlueGift Interreg projects.

Advance monitoring, simulation and control in unsteady tidal environment

RealTide project

Partnering with LORIMA, SABELLA has finalised the construction of a prototype for a new generation of composite tidal turbine blades with integrated fixations, innovating in the manufacturing and assembling processes. With a 30% reduction in costs, the prototype is now optimized for the two tidal turbines to be deployed in the framework of the PHARES project, a multi-energy project for the non-grid connected Ushant Island.

Optimized composite blade for Sabella's new generation of turbines

Tidal demonstrations across the Channel

TIGER project

The Tidal Stream Industry Energiser Project, known as TIGER, is the biggest ever Interreg project (46 M€) that will prove game-changing for the European tidal stream energy sector. The TIGER project will drive the growth of tidal stream energy in France and the UK (Channel Manche region) with significant economic benefits for coastal communities. On the French side, three sites are involved:

- Raz Blanchard in Normandy, on the very place where 2 pilot projects were already planned, Hydroquest and SIMEC will prepare new multi-MW deployments;
- Paimpol-Bréhat (North of Brittany), whose transition towards an open test site for different tidal turbine technologies is managed by EDF, BDI and SEENEOH, will invite MINESTO for demonstration;
- Morbihan Gulf (South of Brittany), on a site consented in 2020, where Sabella will deploy two 250 kW turbines.

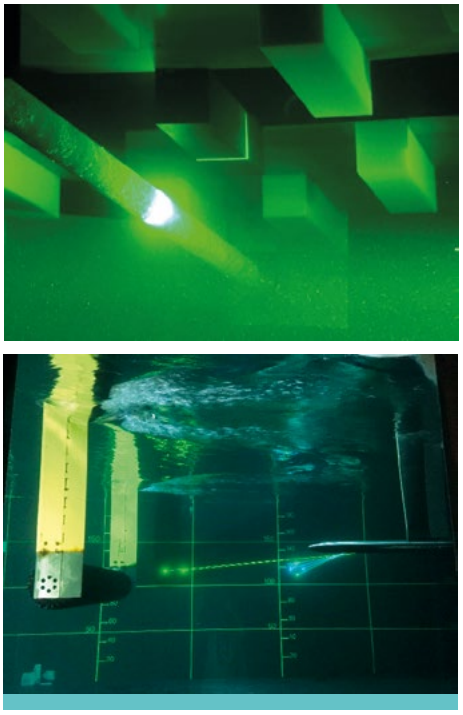
Physical simulations in tank tests for tidal energy converters

Ifremer, the national research centre for the sustainable exploitation of the seas, performs studies and experiments in close collaborations with many OE developers. Numerical and physical simulations complement each other, before scaled or real-size demonstration at sea. At the Boulogne test tank, numerous experiments have enriched a database comprising results of:

- Wake effects between tidal turbines, 3 scaled models being deployed for assessing induced turbulence and impact on performance;
- Turbulence effects generated by several geometries, bathymetry, flow regimes, observed by PIV monitoring;
- Wave-current interactions generating dynamic loads on blades, analysis of control strategies;
- Simulated rugosity of marine growth and of natural seabed that impact the hydrodynamical behaviour of submarine cables.

EEL ENERGY

EEL ENERGY has pursued its tests on its 3 kW bio-inspired membrane-based prototype in a channel serving as water output for an industrial fish farm in Gravelines (North of France). Over the last 6 months, this EEL prototype has proved its robustness with stable power production in a range of 0,5 to 1 MWh per month. 2021 project plans are to test the 30 KW-scale prototype at the SEENEOH field test site in Bordeaux.



Flow measurements around a 1/5 cable close to a rough seabed, and behind a full scale cable colonized by mussels

TECHNOLOGY DEMONSTRATION

PROJECTS IN THE WATER

Four grid-connected test sites for ocean energy are now operational in France for validating prototypes and subsystems.

Paimpol-Bréhat

The tests of the HydroQuest 1 MW marine tidal turbine prototype with a dual vertical contra-rotating axis have continued in 2020. The turbine was deployed at the Paimpol-Bréhat site in the spring of 2019, with the first MWh exported to the grid in June 2019. The turbine has now exceeded 18 months of operation, and BUREAU VERITAS certified the power curve in July 2020. "OceanQuest", name of the demonstration project, is supported by the ADEME as part of the "Investment for the Future " program. The turbine will be decommissioned during the summer of 2021 after 2 years of continuous operation.

HydroQuest turbine, presently tested at Paimpol-Bréhat

River flow interception by the Design Pro energy converter

SEENEOH Bordeaux

As part of the European project Blue-Gift (INTERREG Atlantic Area), SEENEOH has made available 3 "vouchers" to provide a preferential access to SEENEOH facilities for turbine developers to test their devices in real conditions. The project has allowed Design Pro Renewables tidal turbine exploitation to be extended to reach a total of 24 months of operation. This system consists of a pair of vertical axis tidal turbines and aims at river and estuarine markets. The SEENEOH test site on the Garonne river in Bordeaux is therefore fully representative of the targeted operational environment.

SEM-REV test site

On the Atlantic coast offshore Le Croisic, run by Centrale Nantes, this test site is dedicated to wave and floating offshore wind.

The Wavegem platform is a hybrid (wave, solar) autonomous energy production platform which is designed to supply marine or island installations without access to the electricity grid. Wavegem is designed by GEPS Techno. The 21m x 14m and 7m high platform derives its energy from waves by converting the movements of the float into electrical energy through a closed loop circulation of seawater employing a low-speed turbine. PV solar panels also cover the platform. The overall installed capacity reaches 150 kW. 18 months of offshore testing began in August 2019. The platform is secured with a four-point synthetic mooring system.

Wavegem hybrid wave-solar platform at SEM-REV (© Jacques Vapillon / Geps Techno)

PLANNED DEPLOYMENTS

SABELLA

SABELLA is planning to redeploy its grid-connected D10-1000 tidal energy converter at Ushant Island in the summer of 2021. The known issues relating to the electrical connectors have been clearly identified through deep testing and a new design of connectors is currently being investigated and constructed. SABELLA is also working with Morbihan Hydro Energies for the design, construction, and deployment of two tidal turbines of 250 kW in the Gulf of Morbihan within the scope of the Interreg TIGER project.

HYDROQUEST

HYDROQUEST and its partners are now developing a 17.5MW pilot farm at the Raz-Blanchard (Normandy, France), one of the most powerful tidal energy sites in the world. This pilot farm will consist of 7 next generation tidal turbines. The project is already pre-consented, and the construction phase is planned for 2022.

GUINARD Energies Nouvelles

GUINARD Energies Nouvelles is pursuing a policy of developing their tidal energy technology in isolated community markets, and particularly along rivers and estuaries such as the Ria d'Etel in France, Togo and French Guyana.

RELEVANT NATIONAL EVENTS

A yearly survey of the sector

The assessment of jobs and business data for the entire ocean renewable energy sector is performed yearly by the **Observatoire des Energies de la Me**r, through a questionnaire issued at the end of the year. Hence, at this date, only 2019 figures are available. The main results focusing on ocean energies are:

- 350 full-time equivalents (12% of the ORE sector);
- 5.7 M€ of turn-over (2% of the ORE sector);
- 7.0 M€ of investments (2% of the ORE sector).

Tidal remains the most significant technology for the economic development of the sector in France, followed by wave, OTEC and a number of emerging activities in salinity gradient.

A yearly forum for the sector

SEANERGY, the international forum dedicated to Offshore Renewable Energy (ORE), is the largest of the sector in France covering all ORE technologies. The event gathers each year more than 3,500 international players (politicians, contractors (energy operators and industrials), technological experts, NGOs, researchers, investors and subcontractors) - around an exhibition space with 250 exhibitors, industrial and technical conferences, B2B meetings, job-dating sessions, pitches, an interview stage, research area and local technical visits. The 5th edition of SEANERGY will take place on 8 – 11 June 2021, in Nantes and Saint-Nazaire.

3.8 GERMANY

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ENERGY POLICY & MARKET UPDATE

In 2020 electricity from renewable energy contributed around 46% of electricity consumption in Germany - an increase of 3.8 percentage points compared with the previous year. According to Agora's analysis, gas, coal and nuclear power plants lost 6 percentage points in the generation mix last year, supplying only 50% of German electricity for the first time. Without corona and the resulting 3.6 % drop in electricity demand, the share of renewables would have been only 44.6 % in 2020. Two-thirds of the increase in renewables is attributable to a good wind year and more offshore wind power; one-third to PV which benefited from both sunny conditions and 4.4 gigawatts of capacity additions in 2020. At 51 terawatt-hours, solar energy supplied more electricity than hard coal (42.5 terawatt-hours) for the first time. (Source: Agora-Energiewende.de)

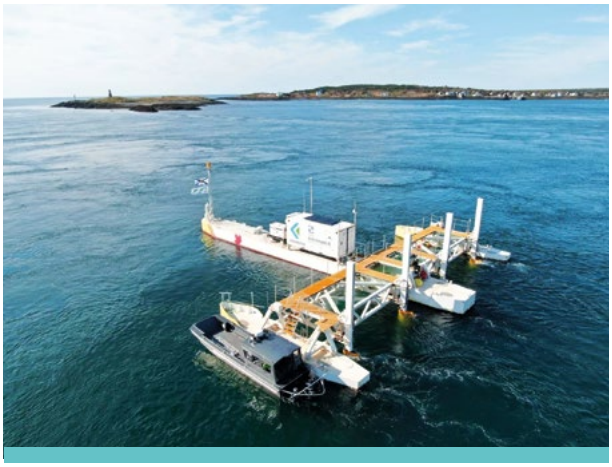
As a result of the pandemic, Germany's greenhouse gas emissions fell significantly in 2020, coming in 42.3% below the reference year of 1990. Germany thus met its 2020 climate protection target of a 40 % reduction. One main driver was recession-induced declines in energy consumption, industrial production and transport. In addition, carbon prices were relatively high and gas prices low. A mild winter also led to low heating energy consumption. Two thirds of this reduction are corona effects; without them, the reduction would have been around 25 million metric tons. The reduction in emissions compared with 1990 would then have been 37.8%. "Real climate protection effects were only seen... in the electricity sector, because here the CO2 reductions are due to the replacement of coal by gas and renewables," says Dr. Patrick Graichen, director of Agora Energiewende.

Wind turbines in the North Sea accounted for 17.2% of Germany's total wind power output of 132 TWh, including 4 TWh from wind parks in the Baltic Sea. TenneT's offshore transmission capacity in the German North Sea has reached 7.13 GW. By 2030 Germany aims to have 20 GW of offshore wind and TenneT will be responsible for connecting 17 GW of that. In its overview of 2020, the TSO points out that the power grid will not be the only tool to distribute the "ever-growing addition of renewables" in the future. Power-to-X technologies, including the use of electrolysers for hydrogen production, and sector coupling will limit the grid expansion (source: renewablesnow.com).

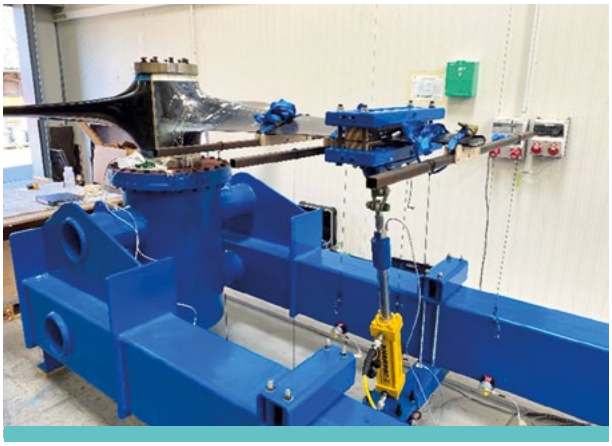
In 2020, Germany held the presidency of the North Seas Energy Cooperation (NSEC) a cross-border group, currently comprising nine European states (following the UK's withdrawal) and the European Commission as its members. Apart from Germany, Belgium, Denmark, France, Ireland, Luxemburg, the Netherlands, Norway and Sweden are members of the NSEC. The focus of the NSEC's work is on the expansion of offshore wind energy and offshore grid infrastructure. Germany's presidency in 2020 focussed on the promotion of joint and hybrid projects, where offshore wind farms are linked through an interconnector to at least two member states. This allows not only for the transport of electricity generated in wind farms, but also the mutual exchange of electricity (source: BMWi).

In the public sector, around 15 R&D institutes and universities have been involved into developing wave, tidal current and osmotic power mainly in the framework of National and European research projects over the last decade.

Tidal power developer SCHOTTEL HYDRO with its partner Sustainable Marine Energy (SME) are continuing the sea trials of the "PLAT-I 4.63" prototype at Grand Passage in the Bay of Fundy, Canada. The floating trimaran platform is rated at 280 kW and carries four of SCHOTTEL's Instream Turbines "SIT" with 6.3 m rotor diameter. During the course of 2020 a substation has been constructed to connect the platform to the Nova Scotian grid in early 2021.



PLAT-I 4.63 installed at Grand Passage



SIT drivetrain test rig at CWD Aachen (top) and SIT blade test rig (bottom)

The second-generation "PLAT-I 6.40" platform was constructed during the course of 2020 utilising key suppliers within Germany. It will be equipped with six SIT tidal turbines with 4 m rotor diameter, rated at 420 kW in total. The new platform will be connected to the grid in Grand passage in early 2021 and later in the year moved to the Fundy Ocean Research Center for Energy (FORCE) in Nova Scotia, Canada, as the first unit of a 1.26 MW floating array project. This will be the first phase of the 9 MW "Pempa'q" Tidal Energy project at FORCE.

SCHOTTEL HYDRO is currently conducting a research project called "Optimization of a Floating Turbine System for Harnessing Tidal Energy". Partners are Potsdam Model Basin (SVA), Fraunhofer IEE, the Institute of Fluid Mechanics and Hydraulic Machinery (IHS) at the University of Stuttgart and the Center for Wind Power Drives (CWD) at RWTH Aachen University. As part of this project, a blade test rig as well as drivetrain test rig have been commissioned in 2020 alongside a hardware-in-the-loop setup. These installations have been utilized to perform critical sub-system testing prior to field-testing of the next generation SIT turbine.

In 2020, SKF developed, manufactured and delivered two fully integrated power train solutions for Orbital Marine Power's O2-2000, the world's most powerful tidal stream turbine. The landmark powertrain supply brings the industrial capabilities of SKF in behind Orbital Marine's world leading floating tidal technology. It also provides Orbital with access to the resources and capabilities of one of Europe's largest OEMs. SKF has an annual turnover of over £6bn in global equipment sales and services. Orbital has been working with SKF for the supply of critical bearing and sealing components since 2011; in both its 250 kW unit and the SR2000-2MW unit, which produced an excess of 3 GWh of electricity over its initial 12-month continuous test programme at EMEC. The new commercial O2 2000 houses two 1 MW drivetrains, each supporting rotor diameters of 20 m, to give an overall 2 MW rating to the turbine. Each 80-tonne drivetrain represents a holistic SKF power train solution, which includes both rotor pitching hubs and nacelle assemblies.

Power train for Orbital Marine Power's O2-2000, developed and manufactured by SKF

The turbine will be commissioned in Q1 2021 and deployed at the European Marine Energy Centre (EMEC) in Orkney later thereafter. Thus, the installation will enter commercial service as the world's most powerful tidal turbine, where it will also validate industry leading technical and commercial performance metrics. Looking to further advance their success and expand the commercial tidal sector Orbital is already progressing multiple enabling project opportunities, focusing on commercial arrays, which would see multi-turbine installations be constructed and operational within the next 3-4 years. This scenario would afford the ability to expand to large-scale installations within a timeframe of 2030.

Within the H2020 Space@Sea Project, German wave energy developer NEMOS GmbH, together with its partners from the project consortium, designed, built and tested wave energy converter (WEC) modules that can be connected to a large modular floating island. In this application, the wave energy converters serve a double purpose: the obvious one is the production of electricity by converting the energy of the waves. This electricity can be used to power the island's infrastructure. Apart from energy conversion, the excitation forces acting on the rest of the island's modules are reduced, as they are protected by the surrounding WEC modules which dampen the motion. This leads to lower forces in the connecting links of the island's modules and therefore lower costs. The motion of the modules is reduced as well which improves the comfort of people living and working on such islands.

Wave power developer SINN Power GmbH's project "Testing of a Modular Concept for the Generation of Grid Conform Electricity from Irregular Ocean Waves in a Generator Array" concluded at the end of 2020. Their energy system at a breakwater at the port of Iraklio, Greece, now consists of several wave energy module prototypes, each equipped with up to eight self-developed generators with integrated power electronics, the SINN PowerTrain 3.4. The system was furthermore supplemented with a small wind turbine that is also equipped with the SINN PowerTrain to test a complete off-grid energy system. The wave energy modules were put back in operation a few weeks after storms hit the site in early 2020. The company announced plans for 2020 to upgrade the modules' powertrains to generation 4.0, which has a higher nominal power and can be individually expanded modularly. Additionally, the company installed an Ocean Hybrid Platform (OHP) in the port of Iraklio, which features the possibility to combine wave, wind and solar power converters. The goal is to internationalize this platform technology as a complete off-grid energy solution to provide people near coasts worldwide with renewable energy. Furthermore, SINN Power announced the implementation of „ModTroniX"

Tank testing of a modular floating island, WEC module with PTO. ©MARIN

SINN Power OHP at the port of Iraklio, Greece (source: SINN Power)

components, the worldwide only power electronics product family specifically designed for application in maritime environments. ModTroniX comprises electric machines and controllers for wave, wind and PV converters, as well as LFP storage and hybrid grid converters, consequently covering all aspects from wave to grid connection point.

German energy start-up MittelrheinStrom 560 KG deployed a floating hydrokinetic turbine in the Rhein river at St. Goar, Germany, in summer of 2020. The "Strom-Boje 3.2" technology is a two-bladed, gearless horizontal axis turbine rated at 70 kW, placed in a diffusor and floating body housing, which is chained to the river bed. The technology is being developed by Austrian company Aqua Libre, who operates an earlier version of the system in the Donau river since 2011. The installed system is the first of a hydro energy farm of at first 8 and finally 16 "Strom-Boje" devices at St. Goar.

The "Strom-Boje" being transported to its deployment site (source: MittelrheinStrom)

Other German suppliers, such as Bosch Rexroth, Schaeffler, Contitech, Thyssen Krupp, Hunger Hydraulik and Hydac deliver components and parts for a number of ocean energy devices – for wave as well as tidal turbine technologies, mainly in Europe. Certification companies such as the DNV GL-Group and consultants are contributing to the technology and project development in the sector. This international collaboration demonstrates the technology export opportunities, which exist in ocean energy for the German industry.

3.9 INDIA

AUTHORS
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OVERVIEW

The design of OTEC powered desalination plant of 100 m^3/day capacity in Kavaratti, UT Lakshadweep was completed. Request for proposals (RFPs) are being invited separately for various project components towards establishment of the 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. National Institute of Ocean Technology (NIOT), an autonomous institute under Ministry of Earth Sciences (MoES) has been entrusted to develop technologies pertaining to ocean energy. NIOT also evaluates ocean renewable energy technologies for MNRE as and when required.

MARKET INCENTIVES

Ocean energy is now accorded the status of renewable energy and thus is eligible for meeting the non-solar Renewable Purchase Obligations (RPO). Stakeholders desirous of utilizing Ocean Energy are invited by MNRE for demonstration projects of proven technologies under Research, Design, Development and Demonstration (RDD&D) policy of the Ministry.

PUBLIC FUNDING PROGRAMMES

The Ministry of Earth Sciences under Government of India supports the programme on Ocean Energy and Desalination at NIOT.

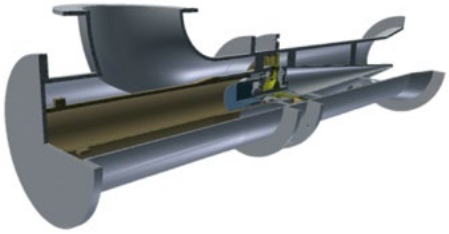
RESEARCH & DEVELOPMENT

Wave Energy

IIT Madras in collaboration with University of Hawaii is working on wave powered desalination for disaster affected people under Wave to Water scheme of DoE, USA. IIT Madras is also working on point absorber wave conversion and has developed a facility for design and testing of various kinds of power module with support from NIOT.

Energy from ocean thermal gradient

Performance assessment studies are continuously being carried out in the laboratory at NIOT on Open cycle OTEC and Low Temperature Thermal Desalination (LTTD) system. This facility is equipped with a heater and a chiller to maintain requisite temperatures for warm and cold water supply respectively. Recently developed power module was evaluated and it was found that the system met the design target of electricity and fresh water generation. These studies will be helpful for understanding the performance of the large capacity OTEC and Desalination plant at Lakshadweep.



Open cycle OTEC turbine (dia. 268 mm) testing in OTEC-desalination laboratory at NIOT

TECHNOLOGY DEMONSTRATION

PROJECTS IN THE WATER

Wave powered navigational buoy system is being operated in the navigational channel of Kamarajar Port, Chennai for oceanographic measurements and navigational aid.

PLANNED DEPLOYMENTS

As per request from Andaman & Nicobar (A&N) UT Administration, 4 nos. of wave powered navigational buoy will be fabricated and deployed at ports in A&N islands with funding from A&N Administration.

RELEVANT NATIONAL EVENTS

As part of the Govt. of India initiative, Vaishwik Bharatiya Vaigyanik (VAIBHAV), a global summit of overseas and resident Indian scientists and academicians, to bring out a comprehensive roadmap to leverage the expertise and knowledge of global Indian researchers for solving emerging challenges, NIOT hosted a thematic session on virtual platform on Desalination and Ocean Renewable Energy (DORE) to explore collaborative opportunities in ocean energy systems. Persons of Indian origin who are residing in other countries with experience in ocean energy and desalination participated and gave their suggestion for cooperation. Possible collaborative work may include:

- Modelling, resource assessment, site potential assessment
- Studies on compact heat exchangers with low costs and high heat transfer coefficient
- Small and medium scale deployments of ocean renewable energy devices.

An international Ocean Thermal Energy Association (OTEA) has been rejuvenated recently with active participation from NIOT to publicize OTEC technology and explore collaborative projects. Currently more than 300 are registered members of this association. Some of the Executive Committee members of IEA-OES are also Executive Committee members of OTEA.

3.10 IRELAND

AUTHORS
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OVERVIEW

Ireland has one of the best offshore renewable energy resources in the world with a sea area of 900,000 square kilometres which is approximately 10 times the size of our landmass. Because of Ireland's location at the Atlantic edge of the EU, we have more offshore energy potential than most other countries in Europe, with an estimated long-term potential of 70 GW of ocean energy opportunity (wind, wave and tidal) within 100 km of the coastline.

In 2019, Ireland launched the Climate Action Plan[2] which significantly stepped-up Ireland's commitments to tackle climate disruption. The plan outlines over 150 actions to address climate change and charts a course towards ambitious decarbonization targets including achieving 70% renewable electricity by 2030. There are three actions that are specifically relevant to the development of offshore renewables and require Ireland to develop policy supports and build out significant infrastructures to integrate new technologies such as wave and tidal energy.

In 2020, a new Programme for Government[3] set ambitious targets to progress offshore energy in Ireland including a target to achieve 5 GW capacity in offshore wind by 2030 off Ireland's Eastern and Southern coasts. The Programme also included a plan to introduce a *'transformational programme of research and development, to ensure that Ireland is at the cutting edge of scientific and technological innovation in meeting our climate change targets, including: in the bioeconomy, in marine sequestration, in green hydrogen, in wave technology, in developing floating offshore wind turbines to take advantage of the Atlantic coastline'*.

2 Climate Action Plan https://www.gov.ie/en/publication/ccb2e0-the-climate-action-plan-2019/
3 Programme for Government Our Share Future 2020 https://www.gov.ie/en/publication/7e05d-programme-for-government-our-shared-future/

NATIONAL STRATEGY

The Offshore Renewable Energy Development Plan (OREDP)

Ireland's Offshore Renewable Energy Development Plan (OREDP) published in 2014 highlights Ireland's focus on stimulating industry-led projects for the development and deployment of ocean energy devices and systems. The OREDP identifies resources for increasing indigenous production of renewable electricity, contributing to reductions in our greenhouse gas emissions, improving the security of our energy supply and creating jobs in the green economy. The OREDP sets out key principles, policy actions and enablers for the delivery of Ireland's significant potential in this area. The development of a new Offshore Renewable Energy Development Plan is due to commence in 2021. The new OREDP will set out the Government's policy for the sustainable development of our abundant offshore renewable energy resources.

Policy development for Marine Consenting

Over the course of 2020, there has been significant progress made in relation to policy for offshore renewable development. Ireland's ambitions for the offshore renewable energy sector are contingent on delivering a licensing and regulatory regime for offshore renewable energy. This will provide certainty to project promoters and provide a pathway to realising the necessary investment in offshore renewable energy. Work is underway to develop Ireland's first marine spatial plan. The plan, which will be known as the National Marine Planning Framework (NMPF)[4], will set out the Irish Government's long-term planning objectives and priorities for the management of our seas over a 20-year time frame. The plan will set out specific objectives and marine planning policies for all the activities taking place in Ireland's seas, from aquaculture through to waste water treatment. All these activities will be contextualised within the pillars of their economic, environmental and social considerations. The NMPF will also set out the proposed future approach to the adoption of spatial designations for marine activities including offshore renewable energy development, or designated marine protected areas, and taking account of the existing network of designated European sites under the Birds and Habitat Directives by the Minister for Culture, Heritage and the Gaeltacht. It is intended that the plan will be submitted to the Commission by Q1 2021.

The Department of Housing, Local Government & Heritage are currently preparing the Marine Planning and Development Management (MPDM) Bill[5]. The MPDM Bill seeks to establish 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 MPDM will also streamline procedures using a single consent principle: one state consent (Maritime Area Consent (MAC)) to enable occupation of the Maritime Area and one development consent (planning permission), with a single environmental assessment. The passage of the legislation has been prioritised to ensure that the new consenting model, as well as implementation of a new offshore grid connection policy that lines up with the RESS auction timeframes will ultimately deliver our 2030 targets.

National Energy and Climate Plan[6]

Ireland's draft National Energy & Climate Plan (NECP) 2021-2030 was submitted to the European Commission in December 2018. The draft NECP took into account energy and climate policies developed up to that point, the levels of demographic and economic growth identified in the Project 2040 process and included all of the climate and energy measures set out in the National Development Plan 2018-2027.

4 National Marine Planning Framework https://www.gov.ie/en/publication/a4a9a-national-marine-planning-framework/?referrer=http://www.housing.gov.ie/planning/maritime-spatial-planning/maritime-spatial-planning-directive/maritime-spatial-planning

5 The Marine Planning and Development Management Bill https://www.gov.ie/en/publication/91aab-the-marine-planning-and-development-management-bill/

6 Irelands National Energy Climate Plan 2021-2030 https://www.gov.ie/en/publication/0015c-irelands-national-energy-climate-plan-2021-2030/

In 2019, the NECP was updated to incorporate all planned policies and measures that were identified up to the end of 2019 and which collectively deliver a 30% reduction by 2030 in non-ETS greenhouse gas emissions (from 2005 levels). Trajectories for ocean energy production in Ireland of 30 MW by 2030 and 110 MW by 2040 are included in the most recent version of this Plan.

Under the Programme for Government, Our Shared Future, which was published in 2020, Ireland committed to achieving a 7% annual average reduction in greenhouse gas emissions between 2021 and 2030. Ireland is currently developing policies and measures to meet this target via the Climate Action Plan and intend to integrate these into a revision of the NECP.

Currently there is no relevant roadmap or legislation in place governing ocean energy development in Ireland. The OREDP (outlined above) is considered the most appropriate guiding policy. The OREDP is underpinned by a Strategic Environmental Assessment and is due for comprehensive review in 2021.

The Department of the Environment, Climate and Communications (DECC) has responsibility for Ocean Energy in Ireland. The Sustainable Energy Authority of Ireland (SEAI) was established as Ireland's national energy authority under the Sustainable Energy Act 2002[7]. SEAI is an agency under the DECC that supports the sustainable development of Ireland's ocean energy potential. The national action priorities for Ocean in Ireland are set out in the OREDP as described above. In 2020, €2.090M was spent on Ocean Energy development by SEAI and the budget for 2021 is €3M. Expenditure in 2020 was significantly less than expected due to restrictions in activities and projects as a result of the COVID 19 pandemic.

MARKET INCENTIVES

The new Renewable Electricity Support Scheme (RESS) is being developed under the aegis of the Climate Action Plan and commits to 70% of electricity from renewable sources by 2030. The RESS has been designed within a competitive auction-based, cost effective framework and the Scheme will provide for a renewable electricity (RES-E) ambition of 70% by 2030.

The new RESS is already expected to support up to an additional 4.5 GW of renewable electricity by 2030, while ensuring citizens and communities can fully participate in the future energy transition in Ireland. The Scheme aims to deliver a broader range of objectives including:

- Providing pathways and supports for communities to participate in renewable energy projects
- Broadening the renewable technology mix (the diversity of technologies)
- Increasing energy security, energy sustainability and ensuring the cost effectiveness of energy policy.

Ireland will increase the volumes and frequencies of the RESS auctions to deliver on the 70% renewable electricity target by 2030. Reaching 70% renewable electricity on the grid will be one of the world's highest levels of renewable penetration.

The terms and conditions of the first RESS auction were published in February 2020 and final selected projects were published in September 2020. There were 82 successful projects in total (63 solar and 19 onshore wind). There were no ORE eligible to enter the first auction.

The RESS will include a range of measures to support community participation including a proposed category for community owned projects and a citizen investment scheme. There will be approximately six RESS auctions up to 2030. These auctions are expected to connect circa 13,000 GWh of renewable electricity.

Various technology specific levers will be applied in the individual auctions to facilitate diversity of renewable technologies and also increased community participation and offshore projects. Terms and conditions will be prepared for auctions to provide a route to market for offshore wind. The second RESS auction is scheduled to commence qualification in 2021.

7 http://www.irishstatutebook.ie/2002/en/act/pub/0002/index.html

PUBLIC FUNDING PROGRAMMES

SEAI Prototype Development Fund

The prototype development fund (PDF) was developed by SEAI in order to provide funding specific to ocean energy developers. The programme operated from 2009 to 2019 and during this time supported over 125 projects with +€21m grant funding. Many projects supported through the programme have utilised Ireland's suite of test facilities, particularly development of small-scale physical models in the wave basins at the National Ocean Test Facility at University College Cork and sea trials in Galway Bay. Since the PDF closed, opportunities to fund ocean energy technologies has been maintained via the SEAI Research, Development and Demonstration fund. The final projects awarded under the PDF are winding down and it is anticipated that all projects will be closed in 2021.

SEAI Research, Development 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 learning from supported energy projects

There are currently 12 offshore energy projects funded under the RD&D. There was no call for funding in 2020, however a call is planned in 2021.

OCEANERA-NET Cofund

The Ocean Energy ERA-NET Cofund (OCEANERA-NET COFUND) project is a five-year action that secured support through the European Union's Horizon 2020 Programme for Research and Innovation in 2016. This programme has built on the work of OCEANERA-NET and with an increased budget and financial support from the EU Commission, the COFUND programme focuses on collaborative projects that demonstrate and validate innovative technologies for ocean energy.

The first joint call was launched in 2017 and was open to applicants from three European countries (Ireland, Spain, Sweden) and four regions (Brittany, Pays de la Loire, the Basque Country, and Scotland). Three projects, with four Irish partners, were awarded grants in the COFUND joint call. A second call was issued in 2019 and contracts for projects were awarded in 2020. Three projects with Irish partners were awarded funding under this final call. All projects commenced operation in 2020 and it is anticipated that projects will run to 2022.

RESEARCH & DEVELOPMENT

MaREI, the SFI Research Centre for Energy, Climate and Marine

MaREI is the Science Foundation Ireland Research Centre for energy, climate and marine, coordinated by the Environmental Research Institute (ERI) at University College Cork. MaREI has over 200 researchers across 13 partner institutes in Ireland working with over 75 industry partners focussing on the energy transition, climate action and the blue economy. MaREI's research capabilities cover a wide range of cross-cutting topics in marine renewable energy technologies, materials and structures, observation and operations, coastal and marine systems, bioenergy, energy policy and modelling, and energy management. MaREI researchers work with collaborators in more than 36 countries and this research increasingly underpins energy and climate policies of the Irish Government and the European Union. Through engaged research and dialogue with stakeholders and communities, MaREI also supports the human and societal dimensions of climate action and marine conservation.

More information can be found on MaREI at
www.marei.ie

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 which features upgraded and expanded tanks and equipment for the testing of small-scale ocean energy renewable devices. 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.

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.

More information can be found on Lir at
www.lir-notf.com

EU Projects

Ocean Energy projects that Irish partners are participating in through European-funded programmes include:

- **H2020 INFRARIA MaRINET2** project will provide and co-ordinate free access to ocean energy developers to test infrastructure throughout Europe. MaRINET2 has built upon the previously successful MaRINET programme. UCC are project co-ordinators. Facilities at NUI Galway and the University of Limerick are also included, as well as the Galway Bay Marine and Renewable Energy Test Site.
- **H2020 TAOIDE** proposal is to develop a fully-integrated generator to grid energy delivery system with high reliability and availability, suitable for use in multiple architectures of marine renewable energy systems. This work will provide the basis for development of a power production system certified for use in marine renewable energy applications – a system designed for the specific environments and regulations of the European Union market, utilising skills, expertise and capabilities of European partners. The Irish partners in these projects are ORPC Ireland, UCC, and Letterkenny Institute of Technology.
- **H2020 FloTEC** Project (Floating Tidal Energy Commercialisation): The FloTEC project will demonstrate the potential for floating tidal stream turbines to provide low-cost, high-value energy to the European grid mix. The project will entail the construction of a turbine device that will be deployed alongside an existing floating tidal array which will serve as a demonstration platform for commercially viable tidal stream energy. Irish partners include UCC/MaREI and Eirecomposites.
- **H2020 LiftWEC** has the objective of developing a new type of wave energy convertor. Irish Partners are MaREI-UCC and MaREI- MU (led by QUB).
- **H2020 MUSICA** project involves the deployment of a multi-purpose renewable energy platform in the Mediterranean. Irish Partner is MaREI-UCC.
- **H2020 OceanSET** (Support to the Realisation of the Ocean Energy Implementation Plan of the SET-Plan) project will run from February 2019 to December 2021. The project was developed to support the Implementation of the European Strategic Energy Technology Plan (SET Plan) for Ocean Energy. The Implementation Plan focuses on the key challenges for wave and tidal energy technologies. Its ambition is to outline a structured approach that will enable wave and tidal technologies to follow a credible development path, with the ultimate destination of a commercially viable wave and tidal industry. SEAI is the lead partner in this project.
- **H2020 IMPACT** Development of new test rigs for the development of wave energy convertors. Irish Partner is MaREI-UCC.
- **H2020 Saturn** Testing of innovative solutions for reducing the most harmful effects of underwater noise. Irish Partner is MaREI-UCC.
- **Interreg ProtoAtlantic** Innovation in the marine environment including testing of various offshore renewable energy technologies. Irish Partner is MaREI-UCC.

- **INTERREG NWE MEA** project (Marine Energy Alliance) is a 4 year project running from May 2018 to May 2022. The aim of MEA is to progress the technical and commercial maturity level of early-stage (TRL 3 – 4) marine energy technology companies with the overall goal of reducing the risk of device failure in subsequent demonstration phases. Irish Partners include Exceedence Ltd and MaREI-UCC.
- **INTERREG AA PORTOS** project works on developing offshore renewable energy solutions (wave and tidal) for European ports. Irish Partners are MaREI-UCC and Shannon Foynes Port.
- **INTERREG Ireland-Wales Selkie** Project addresses identified gaps that are slowing the progression of the wave and tidal energy sectors. Irish Partners are MaREI-UCC, GDG ltd and DP Energy.
- **Interreg EERES4WATER** Development and promotion of energy-water nexus resource efficiency through renewable energy and energy efficiency. Irish Partner is MaREI-UCC.
- **INTERREG Northern Ireland, Ireland and Scotland BRYDEN PHD Programme**. This programme offers fully funded PhD Studentships in Marine renewable energy and Bioenergy. Using a Doctoral Training Centre model, the BRYDEN CENTRE project will recruit 34 PhD students and 6 PDRAs; each of whom will work with industry to produce industrially relevant research with the potential for commercial exploitation and resulting economic growth within the region. Letterkenny IT are the Irish Partners in this project.
- **INTERREG NWE OPIN** project (Ocean Power Innovation Network) is a 3-year project running from October 2018 to December 2021. OPIN will design, test and deliver an innovation model to build cross-sectoral collaboration, to accelerate growth of the Ocean Energy sector and its supply chains. Irish partners include SEAI, as lead partner, with MRIA, ESB and Enterprise Ireland as associate partners.
- **INTERREG AA Blue-GIFT Project**: The €2.5 million Blue-GIFT (Blue Growth and Innovation Fast Tracked) project kicked off in 2019 and announced its 3rd call for applications in December 2020. Funded by Interreg Atlantic Area, the Blue-GIFT project is a coordinated ocean energy technology demonstration programme encouraging longer-term demonstration and technology de-risking across the Atlantic Area regions. The calls offer support package vouchers to ocean energy companies for access to demonstration sites across the Atlantic Area, lowering costs for testing and validating technologies in real sea environments. The project aims to support a minimum of eight floating wind, wave or tidal demonstration related projects across the Atlantic Area region. BlueWise Marine's (formerly SmartBay Ireland) role in the project is to transfer know how gained from the very successful FORESEA project and to coordinate and administer the applications and call procedure in the project. The access to the test sites is only available for the southern test site in PLOCAN, WavEC, Bi-MEP and Seeneoh.
- **INTERREG NWE OceanDemo**: This is a follow on project from the successful FORESEA project, which targets multi-machine ocean energy demonstrations. OceanDEMO recognises that the transition from single machine to pilot farm scale is critical for the future of the ocean energy sector. The project aims to ease the transition towards pilot farms by providing free access to Europe's network of open sea test centres: EMEC – European Marine Energy Centre, UK; DMEC– Dutch Marine Energy Centre, Netherlands; Centrale Nantes/SEM-REV – Site d'Expérimentation en Mer pour la Récupération de l'Énergie des Vagues, France; and the SmartBay Marine and Renewable Energy Test Site. The project released its Third call for applications in June 2020 and devices will be installed from 2020 to 2023. In the third call, OceanDemo recommended one Irish organisation for support to trial and validate their wave powered sensor buoy developed for the offshore wind sector. The fourth call for applications will open in June 2021.

TECHNOLOGY DEMONSTRATION

PROJECTS IN THE WATER

Due to COVID restrictions there were no projects in the water in 2020 in Ireland.

PLANNED DEPLOYMENTS

New Wave Technology trading as Ocean Energy plan to deploy a half scale model to test in US Navy WETS facility in Hawaii in 2021. The project is co-funded by both SEAI and DOE in the US. The project has been in place since 2016 and up to now has focussed on, build, transport and access to the site. The technology was transported from Oregon to Hawaii in November 2019 and in now awaiting access to the test site. It is anticipated that a year testing regime will follow.

This project is stage/phase 4 of the Development & Evaluation Protocol for Ocean Energy technology, the prior stages having been completed with financial assistance from SEAI, the Marine Institute, Enterprise Ireland and EU funding. The prior stage included several deployments at the Galway Bay Quarter Scale test site – during which the device accumulated over 24,000 hours of open water testing.

OTHER ACTIVITIES

Ocean Power Innovation Network – building a collaborative network and innovative supports for OE companies

The Ocean Power Innovation Network (OPIN) is a 3-year cross European initiative, supported by Interreg North West Europe (NWE). Irish partner SEAI is leading the project with partners from UK; France; Germany; Netherlands and Belgium. OPIN's objective is to build cross-sectoral and cross-regional collaboration, to accelerate growth of the Ocean Energy sector and its supply chains. OPIN activities include the growth of a transnational cross-sector network, challenge calls for cross-sectoral collaborative innovation projects, and tailored support to SMEs. To date OPIN has grown a network of 397 companies; has run 19 events and has supported 14 OE technologies directly to explore markets and next stages of development. The OPIN network is free to join and all events and supports can be accessed freely by its members.

https://www.nweurope.eu/projects/project-search/opin-ocean-power-innovation-network/

OceanSET's first annual report- a comprehensive review of Ocean Energy projects funded in Europe

The OceanSET project is a H2020 funded initiative with the overall goal to support the realisation of the ocean energy SET-Plan. An Implementation Plan has been devised which identifies 11 actions for Member States and EU Commission to follow in order to help tidal and wave technologies realise LCOE of 10c/kWh by 2030 and 2035 respectively. OceanSET published its first annual report in 2020 which gave an overview of progress against these actions. Key findings from this first annual data collection exercise are presented below:

- Six Member States (out of 11) have an ocean energy policy.
- Ocean Energy received €26.3M funding from Member States in 2018.
- 90 ocean energy projects were funded by Member States in 2018, two-thirds of which are supporting wave energy devices.
- Twelve ocean energy projects, operational in 2018, were identified as TRL 7 or above.
- Three Member States consented wave or tidal projects in 2018.
- Test sites enabling demonstration can be found in almost all of the Member States.
- The supply chain in most Member States is considered robust.

At times, accurate information on the performance and costs of the different technologies has been difficult to assess via the surveys undertaken, as developers were unwilling to share this level of critical information. This issue will need to be resolved if progress in cost reductions and increased power output in the sector is to be measured precisely.

In 2020 the OceanSET project carried out its second annual review and data will be published in Q1 2021. The annual reviews will be maintained so that support for the sector can be appropriately tracked and analysed. This project is led by Ireland and has 9 partners from UK, France, Spain, Italy, Portugal and Belgium.

All reports are published here:
https://www.oceanset.eu.

The Ocean Energy Ireland Portal

The portal, designed by SEAI and the Marine Institute with input from numerous other groups, acts as a 'one stop shop' to guide developers through the supports available in Ireland for the marine renewable energy sector. All information is aligned under six axes of activity that provide access to marine data, maps, tools, and funding support information.

www.oceanenergyireland.com

3.11
ITALY

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OVERVIEW

Despite 2020 was characterized by the sudden outbreak of the Coronavirus pandemic, which effectively paralyzed various production sectors for many months, some relevant developments concerning ocean energy occurred, especially regarding research infrastructures and technological innovations. These changes are described in the report, together with the annotation of the main 2020 relevant events.

SUPPORTING POLICIES FOR OCEAN ENERGY

NATIONAL STRATEGY

In January 2020 Italy has presented to the EU Commission the National integrated Energy and Climate Plan (NECP), setting challenging energy and environmental targets for 2030. NECP was presented by the Ministry of Economic Development, the Ministry of Environment and the Ministry of Transport and Infrastructures, but it was prepared with the collaboration of various high level technical and research bodies. Renewables are expected to grow remarkably, getting to very high levels of penetration in the electricity sector, around 55%. A key role will be played by mature technologies such as photovoltaic and wind plants, which will be promoted through competitive mechanisms and regulatory actions, however innovative and promising technologies, including marine, are also encouraged to give a contribution to 2030 targets. In that context the NECP announced that *ad hoc* measurements will be put in force for such innovative technologies, evaluating different supporting schemes.

The Blue Italian Growth Technology Cluster (BIG) led by the Italian National Research Council (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.

To restart Europe after the Coronavirus pandemic, last July the EU approved the Next Generation EU, known in

Italy as the Recovery Fund. This is a special fund aimed at financing the economic recovery of the EU in the three-year period 2021-2023 with European government bonds, that will be used to support structural reform projects envisaged by the national reform plans of each country. The total allocation is 750 billion euros, to be divided between the various countries and Italy is among the major beneficiaries of this measure. Digitization, research and innovation represent one of the three strategic axes of the Recovery Plan, but the largest share of the resources of the Italian Recovery and Resilience Plan goes to the macro-sector "Green revolution and ecological transition" (about 70 billion euros), a large ambit in which the growth of RES (including ocean energy), hydrogen and sustainable mobility emerges. In the Recovery Plan, it is proposed to increase the share of energy produced from renewable sources in line with European objectives, stimulating the development of a green industrial chain, through investments of 8,6 billion euros and interventions on several scopes.

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, on shore wind turbines, hydroelectric plants and those with purification gas; according to NECP, 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. The Decree defines the criteria to access the registries and the Dutch Auctions and establishes specific limits for the annual capacity eligible to incentives. These limits are set up differently for each kind of renewable energy source and for all the different ways of access to incentives (registries or bid auctions).

In general, the Decree grants a fixed tariff plus, in some cases, a specific premium, to provide incentives to net electricity fed into the grid. The fixed tariff is different according to each source, technology, and capacity range considered. Power plants with a capacity > 500 kW can only receive the incentive (fixed tariff minus electricity hourly zonal price, plus premiums if foreseen). Power plants with a capacity ≤ 500 kW can alternatively receive a Feed-in Tariff composed by the fixed tariff plus, in some cases, a specific premium.

The incentives last for the average conventional plant life of each typology of power plant. All the support schemes are managed by the Italian Energy Service Operator (Gestore Servizi Energetici, GSE), the body in charge of managing incentives to renewable energy.

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. The direct access to incentive was in force up to the end of 2017, but no plant has benefited from this incentive.

From 2013 to 2016, the total annual capacity eligible for access to registries, and therefore for granting incentives, amounted to 6 MW. To this day, only one project, with capacity of 50 kW, located in Tuscany, participated to the registry. The plant was then realized and presented formal request to access incentives, but such request was rejected.

The Decree does not provide for Dutch Auctions for wave and tidal energy power plants. For new wave and tidal energy power plants, DM 23/6/2016 has confirmed the previous tariff, as follows:

Source (Typology)	**Capacity** (kW)	**Conventional Plant's Life** (years)	**Fixed Tariff €/MWh**
Oceanic (tides and waves)	1< P ≤ 5000	15	300

The Directive 2014/89/EU on Marine Spatial Planning is also relevant for the specific Blue Energy Sector and it has been recently transposed into the Italian legislation via the D. Lgs 201/2016.

PUBLIC FUNDING PROGRAMMES

With about 5 million euros a year, Italy ranks first among Mediterranean countries and second in all of Europe, immediately after the United Kingdom, for public funding for energy from the sea. This was revealed by the first report of the European project OceanSET 2020, which analysed investments and technological development of 11 European countries (Belgium, Finland, France, Ireland, Italy, Norway, Netherlands, Portugal, United Kingdom, Spain).

Thanks to two innovative models developed by ENEA it is now possible to estimate the production of energy from the sea:

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

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 technology has a higher level of maturity. Initiatives in this sector are multiplying, but the most significant at public level concerns 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.

Italy relies on a public research programme aimed at maintaining and improving the national energy system, including the still limited marine energy sector. Such programme, named *Ricerca di Sistema* (System Research), purses as its main objective the promotion, organization and management, of basic and industrial research, and of the related technological development, finally ensuring maximum fruition of results to all citizens and end users.

The Committee of Research Experts for the Electricity Sector (CERSE) plays a strategic role in orienteering R&D activities towards the innovation of the electrical system, through funding under the EU principles that regulate State aid for Research and Development and Innovation. The CERSE is composed of five members, appointed by the Minister of Economic Development, and is responsible for regulating public funding for research projects of general interest in the electricity sector.

RESEARCH & DEVELOPMENT

Research Infrastructures

Marine Renewable Energy Lab (MORE)

ENI's inaugurated a joint research laboratory with the Polytechnic of Turin, named Marine Renewable Energy Lab (MORE). The MORE laboratory allows to deepen the study of all marine energy sources, investigating not only wave motion but also wind and offshore solar, ocean and tidal currents and the saline gradient. The MORE Lab is based at the Polytechnic of Turin but triangulates with two important Eni structures: the Marine Virtual Lab and the offshore test area in Ravenna.

Design and installation of the SeaPower Natural Laboratory in Villa San Giovanni (RC)

The University of Naples "Federico II" has a long-standing experience in the design and testing of tidal energy converters. The university spin-off SeaPower s.c.r.l., a non-profit private consortium that already patented new marine energy converters, is also bound to implant a natural laboratory offshore Villa San Giovanni (RC), for the development, optimization and monitoring of innovative devices for the exploitation of tidal currents. Its location in the Strait of Messina is ideal for the significant intensity of local currents and the extremely favourable climatic conditions offered throughout the year, two requirements that are rarely simultaneously met in the Mediterranean Sea. The authorization process for the construction of the laboratory is in progress. Due to the peculiar hydraulic characteristics of its location (Punta Pezzo), the SeaPower laboratory will represent a unique facility in the Mediterranean, offering the opportunity to test both full-scale and reduced-scale prototypes in a fully monitored natural environment. The laboratory will consist of five areas, permanently designated

for the monitoring and testing of prototypal turbines, of a test area on the existing artificial pier and of an onshore laboratory to host the related infrastructure assets. An additional artificial breakwater will be built in proximity of the marine test areas for logistic support to operations at sea. Submerged cables will connect the converters at sea and the monitoring equipment to a submarine hub, from which a single cable will carry both the electric current produced and the acquired data to the onshore lab.

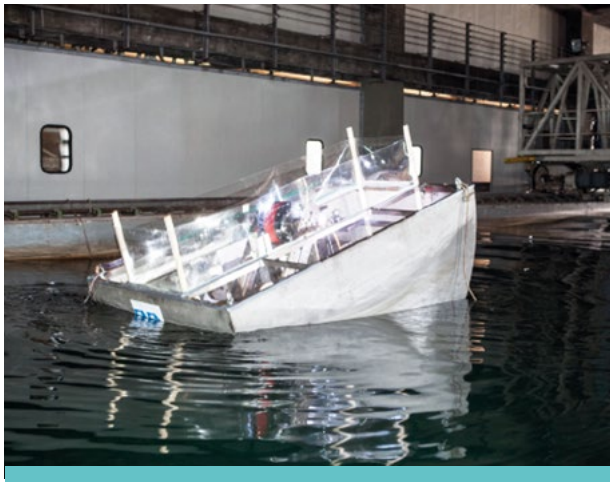
Towing tanks

Small and medium scale prototypes are used in wave flumes and wave tanks where a specific sea state can be artificially created, and power production and device survival assessed. While scaling down the system, the wave tank/flume features are also to be taken into account, so as to scale the prototype according to the characteristics of the facility that is going to be used. In particular, the CNR-INSEAN offers research infrastructures that include world-class towing tanks and flume tanks, thus providing a relevant testing environment for wave, tidal, offshore wind energy systems. The facilities provided are among the largest worldwide and are used to test large-scale models of concepts with TRL up to 5, allowing the simulation of real operating conditions at sea, accounting for the combined effects of winds, currents and waves.

Innovative Converters

PeWEC

The Pendulum Wave Energy Converter (PeWEC) is, according to usual classifications, an offshore, floating, single-body, point-absorber, pendulum-based device. The PeWEC is mainly composed of a floating hull moored on the seabed and a pendulum connected to the shaft of an electrical generator, which is integral with the hull structure. In other words, the generator shaft constitutes the pendulum hinge. The pendulum, the electrical generator and all the other equipment necessary for the device functioning are enclosed in the hull and protected against the corrosive action of sea water. The PeWEC project, initiated born in 2014 from the collaboration between ENEA (the Italian National agency for new technologies, energy and sustainable economic development) and the Politecnico di Torino, was initially financed by the Italian Government. A 1:12 scaled prototype has been already designed and widely tested at the INSEAN wave basin. Moreover, the numerical model validation against the experimental results carried out at the INSEAN tank testing on the intermediate scale prototype allowed to create a design and optimization methodology, suitable for the development of a full scale PeWEC device.



Testing phase of the 1:12 prototype at the INSEAN naval tank

W.e.l.s.

The wave energy device called W.e.l.s. (Wave energy light system) is the result of long studies that start from the first turbine created in order to exploit wave energy. Two turbines were installed in Lipari island (150 W and 1,3 kW) to properly prove that these turbines can start to produce electricity with a minimum wave. These are particular turbines able to produce electricity using very low waves and can find application especially in docks, breakwaters and breakwater barriers. 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 only for demonstration purposes and have already been dismantled. There are plans to build a 300 kW power plant.

PIVOT Wave Converter

The PIVOT system is a wave energy converter that consists in a hinged floating body oscillating under the effect of wave motion and an electric generator, connected via hi-tech components. It has been developed from the GEL prototype by SeaPower s.c.r.l. in collaboration with the University of Naples "Federico II". The conversion of mechanical energy can be achieved through a variety of technical solutions. The PTO currently consists of an electric generator coupled to a recirculating-ball screw that was designed in collaboration with the manufacturer, Umbra Group Spa. Both reduced-scale and full-scale prototypes of the system have been tank tested, reaching TRL 5. The PIVOT concept can be exploited in different configurations, by using alternative PTOs or by adapting the mobile and fixed structures to specific requirements. In particular, a system based on an oscillating floating body is currently under development, in which the mechanical transmission of motion to the generator is achieved via an innovative system that reduces the criticalities deriving from the alternating wave-induced motion.

The E-WAVE 100 converter (TRL 4) for near-shore installation

The E-WAVE 100 converter consists in a dual-chamber Oscillating Water Column (OWC) device, designed for being integrated into vertical-wall breakwaters. The two chambers that constitute the device act in charge/discharge mode respectively and are both equipped with specifically adapted non-return valves. Electro-mechanic conversion is achieved via a low-head hydraulic turbine. A scale model 1:20 was tested in the Aalborg University tank in 2017, while in 2018 the 1:2 model was tank-tested in the Large Wave Flume (GWK) of Hannover University, in the context of the MARINET2 EU project.

The IMPETUS-UNIPA device (TRL 4) for near-shore installation

The IMPETUS-UNIPA device was developed and patented by the Department of Energy, Information Engineering and Mathematical Models of the University of Palermo. It is a point absorber that consists in a cylindrical body containing a linear electric generator. The stator is integrated into an inner cylinder while the rotor is connected to an external cylinder that moves along with vertical wave motion.

The ECOMar 100 wave energy converter for near-shore installation (TRL 4)

The ECOMar system by Kuma Energy is a wave energy converter that can be integrated into any vertical structure and installed on any seabed. The project is based on a system which, by means of a float, captures the movement of the waves by feeding a hydraulic circuit which in turn operates an electric motor (cimoelectric system). It can be installed adjacent to both existing and newly built maritime protection works (marinas and breakwaters). ECOMar is a versatile hybrid system that combines a hydraulic and an electromagnetic converter, allowing energy production at both low and high frequency and for different wavelengths. ECOMar can be easily equipped with a system for the collection of plastic or other floating waste. A 1:8 prototype has been tank tested in the AM3Spin-off laboratory of the University of Florence, while a pilot plant is under development. On 13 December 2019, the Apulia Region Economic Development Department and the company Kuma Energy signed a contract which provides for the construction of a pilot plant for the measurement of wave motion in the harbour of Taranto, preparatory to the construction of plants to produce energy from the sea. In March 2020, the Port System Authority of the Southern Adriatic Sea and Kuma Energy srl, have signed a memorandum of understanding aimed at starting the first pilot plant of the ECOMar system.

The ECOMar 100 wave prototype

WAVESAX

RSE S.P.A. (*Ricerca sul Sistema Energetico - Research on the Energy System*) developed WAVESAX (TRL 5/6), an innovative wave converter within the OWC category (Patent Document N. 2 848 802 B1, European Patent Bulletin 2016/23). This device has been conceived for its integration in coastal structures. 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, that transforms the energy of the moving water into electricity. The turbine is of a bi-directional type. 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. Laboratory test studies have been performed on a 1:20 scale model in the ocean wave basin of the HMRC - Hydraulic Marine Research Centre (Cork, Ireland). A second 1:5 scale prototype has been tested at the ECN Hydrodynamic and Ocean Engineering Tank (Nantes, France).

WAVESAX 1:5 scale prototype

TECHNOLOGY DEMONSTRATION

In Italy there is an increasing interest in the exploitation of wave and tidal energy. 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-techno steps of the design and production process. The most promising devices that have been developed and improved in the last years are reported below.

Main projects in Italy to 2020

Project name	Project type	Project status	Location	Capacity (MW)
REWEC3 @ Civitavecchia	wave energy	consent authorised	Tyrrhenian Sea Civitavecchia	2,5
Overtopping Breakwater for Energy Conversion (OBREC)	wave energy	fully operational	Tyrrhenian Sea Napoli	0,008
ISWEC demonstration	wave energy	fully installed - missing grid connection	Mediterranean Sea	0,1
MaREnergy	wave energy	fully operational	Adriatic Sea Ravenna	0,003
Marina di Pisa H-WEP 1	wave energy	fully operational	Tyrrhenian Sea Marina di Pisa	0,05
Kobold I	current energy	fully operational	Mediterranean Sea	0,055
GEMSTAR Demonstration II	current energy	early planning	Mediterranean Sea	0,3

REsonant Wave Energy Converter (REWEC3)

The Mediterranea University of Reggio Calabria has been developing the REsonant Wave Energy Converter (REWEC3), which is a particular type of the Oscillating Water Column (OWC) incorporated into a traditional vertical breakwater. This activity is being carried out in cooperation with Wavenergy.it, an academic spin-off of the Mediterranean University. The Rewec3 has already been installed in the port of Civitavecchia (Rome) and the famous architect Renzo Piano plans to insert it in the new port of Genoa. It will soon also be built in the Port of Salerno and Roccella Ionica (Reggio Calabria) and its installation will be evaluated both in the Principality of Monaco and in Belgium to defend the artificial islands. About the first full-scale prototype built in the port of Civitavecchia, the Port Authority of Civitavecchia decided to upgrade its infrastructure and adopted the REWEC3 technology for the realization of 17 new caisson breakwaters. The total length of REWEC3 caissons is 578 m. A first Wells turbine of 20 kW, without any optimization, has been installed, while the total installed power will be 2.5 MW.

OBREC (Overtopping BReakwater for Energy Conversion)

The University of Campania Luigi Vanvitelli has developed a device denominated OBREC (Overtopping BReakwater for Energy Conversion), embedded into a breakwater and based on the wave overtopping process. A small-scale (1:30) prototype of the OBREC was tested at Aalborg University (Denmark) during two complementary experimental test campaigns in 2012 and 2014. A full-scale, 6 metres long prototype has been installed in the port of Naples in 2015, along the San Vincenzo rubble mound breakwater. The overall performance of the device is being monitored.

ISWEC (Inertial Sea Wave Energy Converter)

The Polytechnic of Turin developed ISWEC (Inertial Sea Wave Energy Converter, TRL 7), a point-absorber wave energy converter suitable for mild climate seas such as the Mediterranean. It is based on the gyroscopic technology. On 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 capacity of 50 kW. The plant is located in the Adriatic Sea off the coast of Ravenna and was created thanks to the partnership between Eni and the Polytechnic of Turin (PoliTO) and Wave for Energy, a spin-off of the Polytechnic of Turin. The unit is part of a hybrid system that integrates photovoltaics and storage. The plant has reached a peak of power exceeding 51 kW, or 103% of its nominal capacity. In October 2019, Fincantieri, Cassa depositi e Prestiti, ENI and Terna joined their forces to launch the first phase of a joint project to convert ISWEC into an industrial scale power station. At the same time, the first ISWEC industrial installation will be completed near ENI's Prezioso platform in the Strait of Sicily, in the Gela offshore.

Ocean Power Technologies (OPT)

Ocean Power Technologies (OPT) PowerBuoy has been deployed in the Adriatic Sea since November 2018 by the oil and gas company Eni in a project aiming to demonstrate suitability of wave energy technologies in oil and gas operations. Operating continuously for six months, as part of Eni's MaREnergy project, PB3 PowerBuoy has produced more than 1 MWh cumulative energy to date. The OPT PowerBuoy will be used to advance Eni's research and development of proprietary integrated subsea technology systems to allow future applications for remotely controlled field developments powered by wave energy, environmental monitoring and offshore asset inspection using autonomous underwater vehicles (AUVs).

Deployment of OPT PowerBuoy in the Adriatic Sea

H-WEP 1

H-WEP 1 was first deployed off the coast of Marina di Pisa (Tuscany) by 40South Energy since September 2018 and it is operated and managed by Enel Green Power. The H24-50kW is a sort of large mobile body that runs on a horizontal guide that collects the energy of the waves and put it directly into the grid. H24 has the shape of a large table about two meters high and 20 meters long. The plant was installed 6 meters deep and sheltered from storms, responsible for making previous attempts fail.

Kobold

The Aircaft Design & AeroflightDynamics Group (ADAG) of the University of Naples "Federico II", in cooperation with SeaPower Scrl, developed and patented the KOBOLD turbine (TRL 7), a rotor mounted on a vertical shaft, which produces mechanical energy by exploiting marine currents. A platform equipped with a Kobold turbine of the diameter of 6 m with three blades, built by the Ponte di Archimede

Company, has been installed in the Strait of Messina in the year 2000 and is still in operation and gird connected, with a nominal power output of 30 kW.

GEM, the Ocean's Kite

ADAG and SeaPower s.c.r.l., in cooperation with Ing. Morrone, also designed GEM, the Ocean's Kite (TRL 7), an ocean current energy conversion system that consists of a submerged body with two horizontal axis hydro turbines. It is tethered to the seabed and free to self-orienting to the current. A first full-scale prototype has been deployed in Venice lagoon. The nominal power of the device is 100 kW with 5 knots of current speed; in the Venetian lagoon, where the maximum flow current speed is around 3 knots the power that can be produced is about 20 kW. A full-scale prototype of 300 kW will be installed in the Strait of Messina. GEMSTAR, an evolution of GEM turbine, is at TRL 7 being the first prototype tested in real field.

RELEVANT NATIONAL EVENTS

March 2020 - The Port System Authority of the Southern Adriatic Sea of Brindisi and Kuma Energy ltd, signed a memorandum of understanding aimed at starting the first pilot plant of the ECOMar system.

September 2020 - ENI's Marine Renewable Energy Lab (MORE) inaugurated a joint research laboratory with the Polytechnic of Turin.

3.12

JAPAN

AUTHORS
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OVERVIEW

Surrounded by the sea, Japan has great potential for ocean energy including wave energy, tidal energy, ocean current and ocean thermal energy conversion. Ocean energy is well distributed across all the regions of Japan and is expected to play an important role as a geographically distributed power source and to help decarbonize the energy system. Government renewable energy policies continue to be supportive of renewables with specific ocean energy related programmes enabling large scale demonstration projects to progress towards deployment.

SUPPORTING POLICIES FOR OCEAN ENERGY

NATIONAL STRATEGY

The 5th Strategic Energy Plan for Japan announced in 2018 has set a target of 22-24% renewable energy in the energy mix by 2030. The Government of Japan has put in place policies and funding initiatives to promote and grow the ocean energy sector in Japan. Notable is the Action Plan for Cooperation of Related Ministries and Agencies for Expanding the Introduction of Renewable Energy announced by the Japanese Government in 2017 and was followed by the Third Basic Plan on Ocean Policy announced in 2018 committing work towards establishing this new low-carbon energy resource. In Japan, whilst offshore wind has revenue support, ocean energy has yet to be established within a revenue support scheme such as a feed in tariff until the policy maker understand more about its potential from the demonstration activities being undertaken. The departments and agencies of the Government of Japan are managing a programme to support the development, demonstration, testing and environment assessment of ocean energy technologies.

The New Energy and Industrial Technology Development Organization (NEDO)

Demonstration of Ocean Energy Power Generation from 2018-2021 is supporting research and demonstration ocean energy power generation by providing grant funding. The project aims to achieve the commercialization of ocean energy power generation technology and implement long-term demonstration research in actual ocean areas. The aim of these efforts is to develop commercially viable ocean energy power generation technology by 2030. NEDO has also been preparing a new programme that will launch in 2021 supporting start-ups, small and medium enterprises to develop future new energy technologies. For large companies, new demonstration funding will also open up in 2021.

Ministry of the Environment (MOE)

Practical Realization Project of Tidal Current Power Technologies is the flagship funding programme supporting a large scale tidal energy demonstration project. The successful project will deploy Japan's first large-scale (500 kW class) tidal generator at a test site off the coast of the Goto Islands, Nagasaki Prefecture. The project aims to develop and demonstrate tidal current power generation that is suitable for the seas of Japan with high potential for widespread use whilst having minimal environmental impact.

The MOE is also supporting a wave power demonstration project. The Hiratsuka wave power plant was selected in 2018 and the project was installed, grid connected and commissioned in 2020 for a one-year demonstration.

RESEARCH, DEVELOPMENT AND TECHNOLOGY DEMONSTRATION

The main research and demonstration projects that have been progressing during 2020 are as follows.

Goto Islands tidal demonstration field

Japan's first large-scale (500KW) tidal power device demonstration including installation on the seabed, operations and decommissioning is planned for a site in the Goto Islands, Nagasaki prefecture. The site surveys and preparation have been completed and the SIMEC Atlantis Energy AR500 turbine was shipped from the UK at the end of 2020 ready for installation in early 2021. The project is led Kyuden Mirai Energy Co Ltd in partnership with Nagasaki Marine Industry Cluster Promotion Association with funding support by the Ministry of Environment.

SIMEC Atlantis Energy AR500 turbine delivered to Nagasaki Port

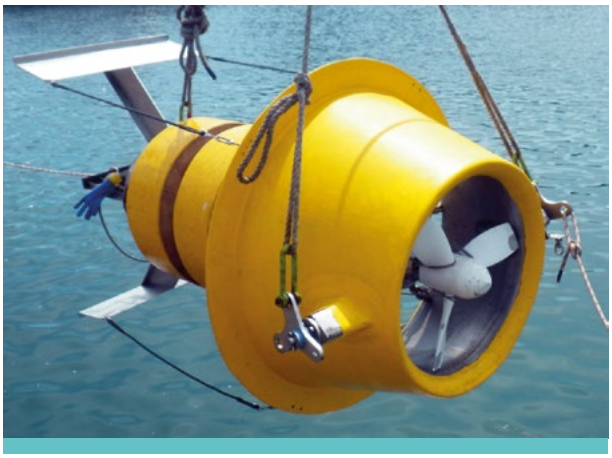
Hiratsuka Wave Power Plant

Hiratsuka wave power plant

The Institute of Industrial Science, The University of Tokyo, has completed a new wave power generation device and in February 2020, the device was installed in front of the Hiratsuka Shinko breakwater in Kanagawa prefecture and connected to the grid. After passing the pre-use inspection by the Ministry of Economy, Trade and Industry, it officially started operation as the Hiratsuka wave power plant and started a one-year sea area verification test. The project partners include Kawasaki Heavy Industries, Ltd. Precision Equipment and Robot Company, Tokyo Kuei Co., and Yoshida Gumi Co and is funded by the Ministry of Environment.

Nagasaki University small scale demo

The Organization for Marine Science and Technology, Nagasaki University, has developed a small scale floating tidal current power generation system that can handle low flow currents. The new system that automatically rises and falls and changes direction according to the direction change of the tidal current due to the flood and ebbing tides. They have succeeded in continuous power generation for one month in the sea off the Goto islands, and will continue further research towards practical use.



Nagasaki University tidal current power generator (Dimensions: L = 2m, B = D = 1.25m, turbine diameter = 0.64m)

Ocean Thermal

Saga University has been continuously researching and developing ocean thermal energy conversion systems for many years. Latest developments include an innovative ocean thermal energy conversion (H-OTEC: Hybrid Ocean Thermal Energy Conversion) system that simultaneously realizes power generation and desalination of seawater, and further technical demonstrations will be carried out in collaboration with Malaysia. Saga University is participating in a project for to develop the “First Experimental OTEC Plant of Malaysia," by 2024. This effort is supported by Okinawa Prefecture’s Ocean Thermal Energy Conversion (OTEC) Demonstration Test Facility that was opened in 2013.

RELEVANT NATIONAL EVENTS

Nagasaki Ocean Academy

Nagasaki Ocean Academy

In 2020 Asia's First Academy for Professionals in Ocean Energy Development Industry was established and opened at Nagasaki University.

In order to promote nationwide efforts to cultivate marine development engineers required in the marine development market, with the cooperation of Japanese companies, universities, public organizations and governments who intend to enter and expand the marine development market, the Nagasaki Ocean Academy was established as part of Nippon Foundation Ocean Innovation Project. The NOA provides an educational curriculum for marine energy development such as offshore wind power generation, aim to train 1,600 people in five years, and in collaboration with universities, marine renewable energy demonstration field.

3.13
MEXICO

AUTHORS
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OVERVIEW

A program for the implementation of the Technological Roadmaps for ocean energies published in 2017 by the Ministry of Energy is being continually updated as technological developments take place and public policies are improved. In line with the program, a theoretical assessment of wave, current, saline gradient and thermal gradient energy resources in Mexico has been elaborated by CEMIE-Océano. Among the objectives of developing ocean energy in Mexico is extending off-grid access to electricity. Another objective concerns the challenges around clean energy materials (e.g. superhydrophobic, nanostructured ceramic and polymeric coatings). Progress has been made in the instrumentation of two natural laboratories, the updating of laboratory facilities, the development of prototypes, materials and technical bases for environmental and social regulation. Joint projects have been approved to optimize resources for the use of marine bioenergy and wave energy. The OTEC group of CEMIE-Océano is organizing the 8th International OTEC Symposium (virtual).

SUPPORTING POLICIES FOR OCEAN ENERGY

NATIONAL STRATEGY

Short- and medium-term goals have been set for the generation of electricity from clean energy sources. The Energy Transition Law (LTE) establishes a minimum share of clean energy electricity generation of 25% by 2018, 30% by 2021 and 35% by 2024.

To strengthen the operation of the Mexican Energy Innovation Centres (CEMIEs), the Technological Roadmap (TRM) for ocean energy is focused on strengthening the technological capabilities required, including infrastructure, specialized human resources and technological services. It also prioritizes the actions required to reach the 2030 goals for installed capacity, as well as detailed activities, identification of stakeholders, targets and milestones in a specific timeframe. It is therefore estimated now that Ocean Energy can contribute 500 to 1000 MW of installed capacity by 2030.

The main National Priority Actions for ocean energy are training and capacity building, development of the regulatory frameworks for ocean renewable energy and development of innovative technologies. The approximate budget of the CEMIE-Océano for 2020 was around 2.5 million euros.

MARKET INCENTIVES

In 2020 no new incentives have been implemented.

PUBLIC FUNDING PROGRAMMES

The Fund for Energy Transition and the Sustainable Use of Energy was created by the Ministry of Energy (SENER) and the National Science and Technology Council (CONACYT) to promote and support projects and initiatives which contribute to the fulfilment of the National Strategy for Energy Transition and the Sustainable Use of Energy. The objectives of this fund are to:

- promote, encourage and disseminate the use and application of clean energy
- promote the diversification of primary sources of energy.
- establish a standardization program for energy efficiency.
- promote and disseminate measures for energy efficiency, as well as for saving energy.
- propose the necessary measures so that the population has access to reliable, timely and easily accessible information regarding the energy consumption of equipment, devices and vehicles, which operate with electricity.

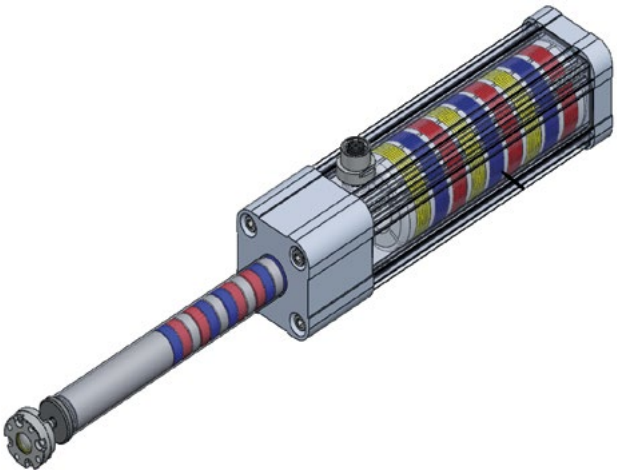
This fund is intended to develop the national energy sector in energy efficiency, renewable sources, use of clean technologies and diversification of primary sources of energy through:

1. **Capacity Building:** develop scientific, technological and innovation capacities in academia, industry, society and government; promote the link between the stakeholders from the energy sector.
2. **Research, development and innovation:** Identify and prioritize technological development opportunities and promote research to transfer this into commercial applications.
3. **Training:** Promote the coordination and information acquisition for timely decision-making; to encourage personnel to apply and generate knowledge, products and services of high value and; ensure that the energy sector attracts talented individuals.
4. **International agenda:** Promote international collaboration in the programs, projects and activities of the fund.

RESEARCH & DEVELOPMENT

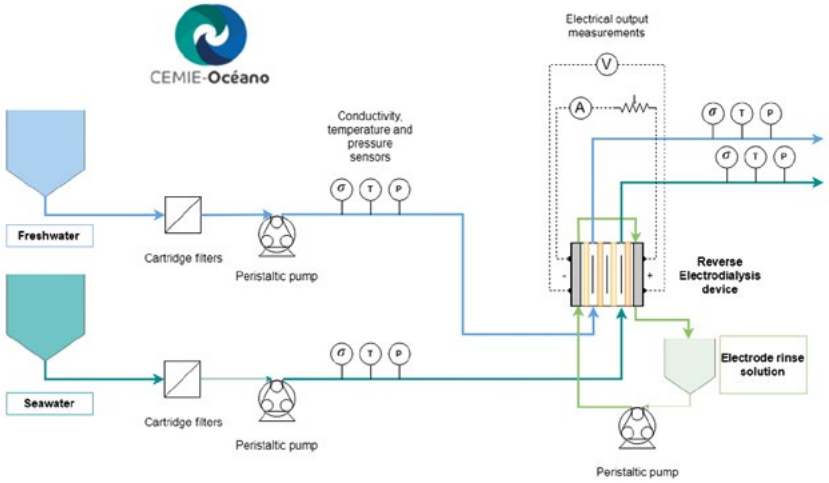
CEMIE-Océano has been conducted several R&D activities related with ocean energy:

The Wave Energy Group has improved a WEC prototype, which is currently undergoing laboratory testing. This first version has mechanical actuators where the waves move a transmission or rotational motion mechanism, which activates an electric generator. A linear generator with permanent magnets is also being developed, which will act as electrical generator in our prototype. This new design includes a mechanism for the generation of electricity, without a motion conversion or transmission mechanism.



WEC developed by the CEMIE-Océano

The Tidal and Currents Energy Group is carrying out: a) Assessment of the vulnerability of turbines in hurricane conditions, to determine the depth at which installations are undamaged. b) Assessments of energy resources are continuing with in situ measurements and numerical models focusing on sites previously identified as having high potential in the Cozumel Channel and in the Gulf of



Schematic representation of the Reverse Electrodialysis system implemented

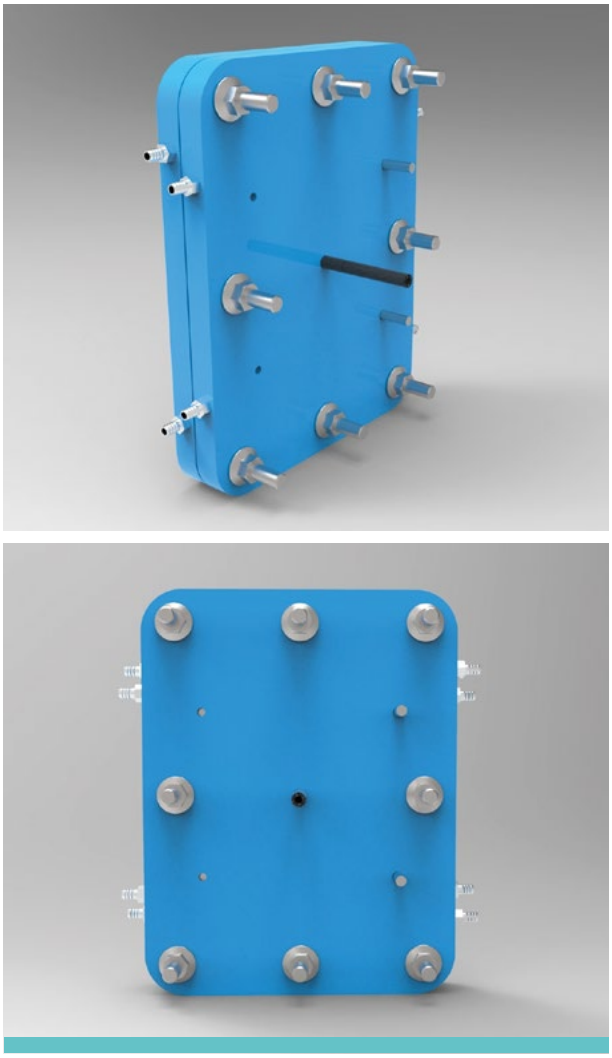
California. c) Detailed evaluation of environmental impacts, considering noise pollution (measurements and modelling) and changes to habitats. Aspects such as larval dispersion patterns, effects of mixing and stratification, effects on morphodynamics, are all being assessed with numerical models. d) An interactive digital Atlas of Marine Current Energy is underway.

Hydrogenators for slow speeds and accessories to improve their efficiency are being developed and tested. These include vertical and horizontal axis turbines, and a flux concentrator. Blades and shafts are being specifically designed and manufactured.

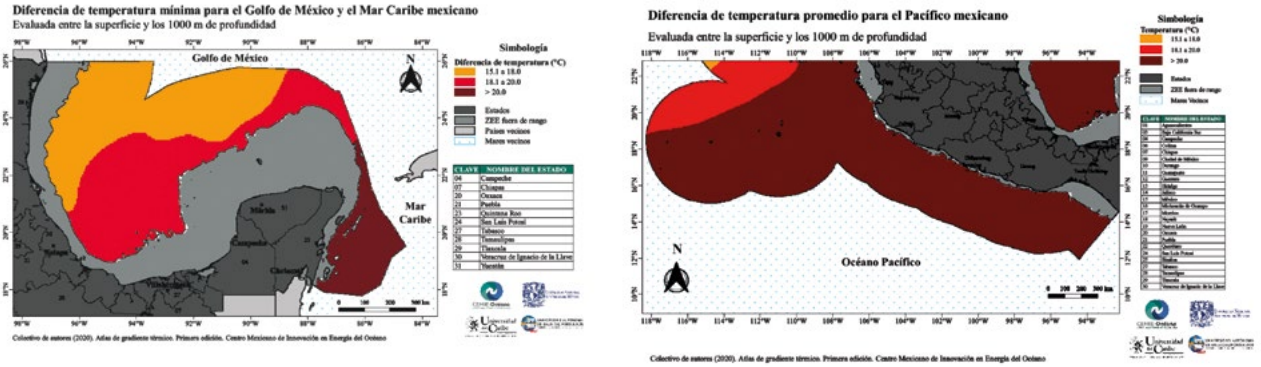
The Salinity Gradient Energy Group has made more field measurements of thermohaline variables in two of the sites under study; a hypersaline coastal lagoon and a river mouth. Advances were made in the analysis of physical, biological and ecological variables for holistic characterization. The database and the development of a GIS in the Resource Atlas containing all the information on Mexico was strengthened. In this area, the first book (in Spanish) was published, along with the first scientific paper in this research line. In technology development, after laboratory scale experiences with synthetic waters in 2019, improving the prototypes with CFD and numerical modelling was the main focus in 2020.

A RED device is being optimized and instrumented. Electricity generation has been achieved and the possibility for water desalination is under development. The device is being characterized to get a better selection of inner fluxes, membranes and electrodes. The development of a non-storage PRO device is under investigation.

The Thermal Gradient Energy Group completed the atlas: Spatial distribution of the Thermal Gradient energy resource in Mexican seas (in Spanish).



RED device

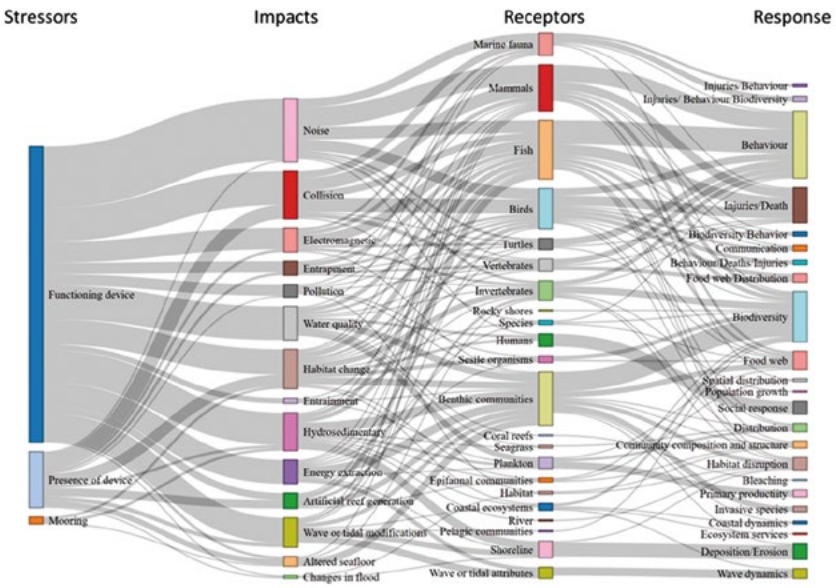


Two maps from the Thermal Gradient atlas (in Spanish)

The Ecology Group has been working on: 1) a diagnosis of potential ocean power generation zones, based on the geomorphological characteristics of the coast; 2) the generation of information on the structure, composition and functioning of coastal and marine ecosystems and species, to determine the potential socio-environmental impact of the installation of new energy generating devices. This group has generated inventories of flora and fauna at the potential sites of ocean power generation and explored the potential environmental consequences of harvesting this energy where sites have very important environmental assets, including fragile ecosystems such as coral reefs, and endangered species (vaquita and totoaba). The environmental assessment was investigated in a systemic manner, considering the interactions between stressors, their impact in the environment, receptors and their responses.

The Grid Code for Marine Power Plants has been published. This document establishes the minimum technical requirements that the Members of the Electricity Industry must comply with in relation to the planning and operation of the National Electricity System (NES), as well as the measurement, the control, access and use of electricity infrastructure. All forms of energy extraction and conversion are variable, therefore they must satisfy the Grid Code, if their nominal installed power is greater than 500 KW.

Science dissemination and communication activities of the CEMIE-Océano included the publishing of five books: Salinity Gradient Energy, Design of Foundations for Marine Turbines on Rocky Soils, Birds of the Land of the Swallows: Cozumel Island, Impact of the Sea Breeze and Wind on the Climate of Mexico (in Spanish); and the Atlas of the Distribution and Abundance of Mammals in Mexico (in English). Two editions of the CEMIE-Océano bulletin and 21 infographics were published, complemented by the website www.cemieoceano.mx and publications on the social networks @cemieoceano and Facebook/cemieoceano. Consultations increased 40% compared with 2019.



Iinteractions between stressors, their impact in the environment, receptors and their responses

TECHNOLOGY DEMONSTRATION

PROJECTS IN THE WATER

CEMIE-Océano continues to work in natural sites for testing wave energy devices in Ensenada, Baja California, and to test ocean current energy devices in the Cozumel Canal, Quintana Roo. Studies are being made and oceanographic measuring equipment has been acquired and deployed.

PLANNED DEPLOYMENTS

CEMIE-Océano is planning two installations soon:

- A wave energy device - Baja California
- An ocean current turbine – Cozumel Channel

RELEVANT NATIONAL EVENTS

An international workshop was organized by CEMIE-OCÉANO on Ecological Impact Indicators of Marine Energy Devices at the Instituto de Ingeniería UNAM, Mexico City, Mexico. 13-17 January 2020.

In 27-29 January 2021, the 8th International OTEC Symposium will take place, virtually. This event is being organized by the 8th International OTEC Symposium Executive and Local Committee (Mexico). The Chairman of the committee is Dr. Miguel Angel Alatorre Mendieta of the Institute of Marine Sciences and Limnology, National Autonomous University of Mexico (UNAM).

3.14 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 gases and also a specific policy towards the establishment of a sustainable city.

The Principality of Monaco joined the OES in June 2013. This action was part of the Government targets for combating climate change and recognizing the relevance of international cooperation.

Monaco is a coastal country with 2,08 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.

Monaco has set itself, in the Climate and Energy Plan 2020, the target to 2020 of improving energy efficiency by 20% (compared to 2007), achieving 20% of final energy consumption from renewable sources (compared to 2007) and reducing the GHG emissions by 30% (compared to 1990). This document is under revision and the Climate Air Energy Plan 2030 targets will be increased. The document will be finalized soon.

On 2020, December, in the National Determined Contribution, in line with the provisions of the United Nations Framework Convention on Climate Change and the Paris Agreement, Monaco increased his commitment to reduce the greenhouse gas emissions by 55% in 2030 compared to the reference date of 1990 and to achieve carbon neutrality in 2050.

PUBLIC FUNDING PROGRAMMES

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

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

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

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.

RESEARCH & DEVELOPMENT

A prototype of the society SBM Offshore of a wave-powered machine should be set up in the Monaco territorial waters in partnership with the Government Services in 2021.

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.

PLANNED DEPLOYMENTS

Two new thalossothermal loops connected to seawater heat pumps are under construction. They should supply 3500 homes and eliminate 6ktCO2eq of GHG emissions (approx. 8% of the total emissions of Monaco).

RELEVANT NATIONAL EVENTS

5 - 7 May 2021: EVER Monaco (Ecologic Vehicles/Renewable Energies)

3.15 NETHERLANDS

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SUPPORTING POLICIES FOR OCEAN ENERGY

NATIONAL STRATEGY

In 2020, a reconnaissance study was carried out to determine the possible contribution of marine energy to the Dutch 'energy transition'. The study also included an assessment of the export potential of the Dutch technology developers. Together with research institutes, governments, the marine energy sector and individual developers the possible potential was inventoried.

During the issue of this country report, the results of the reconnaissance study and the export potential were still unknown.

The Netherlands has a national target of 16% renewables in 2023 and a 49% overall CO2 reduction target in 2030. There is no specific target for ocean energy. The marine spatial planning is focused on offshore wind, special areas have been appointed for offshore wind (3500 MW).

The North Sea Spatial Agenda indicates a potential of up to 2000 MW of tidal current and wave energy to be possible, if techniques are developed further to fit the Dutch situation, with relatively low tidal heads and speeds. Although in some cases there is fast flowing water of estuaries, and near barriers there are places with high speeds up to 5 m/sec. There are no commercial offshore ocean energy projects planned yet.

Although there is a central permitting system, in practise consenting requires engagement with a wide range of permitting bodies such as central government, province, municipality, The Netherlands' Department of Waterways and Public Works (Rijkswaterstaat), local harbour authorities, ministry of defence and the regional water board. Rijkswaterstaat supports initiatives to generate energy while ensuring safety of its waterworks protecting the Netherlands from flooding from the North Sea.

MARKET INCENTIVES

In 2021, the generic national subsidy scheme (SDE, stimulating renewable energy) will continue for tidal current, salinity gradient and free flow energy. The maximum subsidy for renewables is limited to € 0,13/kWh, due to the decreased costs of offshore wind, which is considered as the benchmark.

Business, research institutes and other organizations joined forces in DMEC, the Dutch Marine Energy Centre. DMEC collaborates with clients in various market segments to identify, explore and realise tailored solutions using innovative ocean energy technologies.

PUBLIC FUNDING PROGRAMMES

In addition to the feed-in tariff (OPEX subsidy) mentioned above, there are generic funding programmes (CAPEX subsidy) for all relevant types of renewable energy. The Ministry of Economical Affairs initiated a number of grants via generic R&D instruments, these are also available for ocean energy research. These programmes have a tender system in which projects compete with each other, and have a general condition that a cost reduction must be achieved by innovation.

RESEARCH & DEVELOPMENT - NEW PROJECTS IN 2020

OceanDEMO is a 4-year Interreg North West Europe project running from 2019 to 2022. The aim is to bring offshore renewable energy technologies to the market by providing free access to North-West Europe's world-leading network of offshore test centres. Ocean DEMO specifically targets multi-device ocean energy installations to prove their technology at full commercial scale. In 2020 the Dutch developers SeaQurrent and Oceans-of-Energy were selected to receive support from DMEC via OceanDemo to demonstrate a scaled system in the Wadden Sea and the NorthSea respectively in 2020/2021.

VALID is a 3-year H2020 project that kicked off at the end of 2020. It will 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). The methodology for accelerated hybrid testing combines both physical testing (physical test rigs) and virtual testing (simulated environment, numerical models and data). The VALID Hybrid Test Platform (VHTP) will become the interface that allows for seamless accelerated hybrid testing. With the long-term goal of establishing a standard for future use and making a step-change impact on the sector, the new test rig platform and methodology will be validated for a variety of WECs, critical components and subsystems through three different user cases. TU Delft is one of the academic partners contributing to the development of the new hybrid testing platform with open access for models, testbeds and improved data management to lower the cost on future technologies.

TECHNOLOGY DEMONSTRATION

OPEN SEA TEST SITES

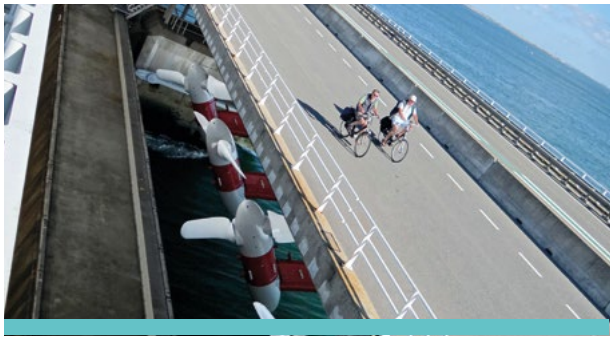
Main developments in test sites during 2020.

Test Site Name	Location	Promoter/ manager	Grid Connection (Y/N)	Status (operational, under development, planned)
REDstack	Afsluitdijk	REDstack	Y, 4-50 kW	Operational
Tidal Test Centre (TTC)	Grevelingen barrier	BT Projects	No	Delayed

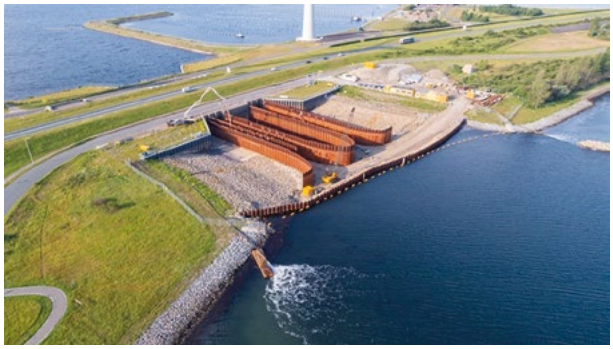
OPERATIONAL PROJECTS

2020 was a stormy and turbulent year in many ways.

Begin 2020, QED Naval and HydroWing acquired Tocardo, a Dutch specialist developer in tidal energy. Together they restarted the 1.25 MW tidal power plant in the Eastern Scheldt. After a year of shutdown, the 5 turbines were put into use again and connected to the grid. Tocardo went bankrupt end 2019 and the tidal power plant was shut down as a result.

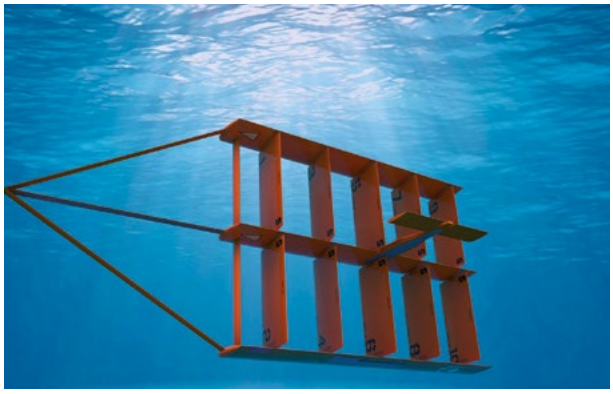


Tocardo, 1.25 MW tidal power plant in the Eastern Scheldt, operational since 2015.



Begin 2020 the construction of the **Tidal Test Centre Grevelingendam (TTC GD)** was stopped due to financial problems, the licence was revoked. A public auction is being held to attract new investors. A new business plan and capital is needed to finalise the tidal technology test centre. If no candidates are found, the construction site must be restored in its original state to guarantee the safety from flooding.

SeaQurrent operated and tested a pilot on the Wadden Sea. Their tidal kite aims at moderate water speeds. A following project will focus on marine operations related to the handling, installation and operation of the Tidalkite, as well as disconnecting and demounting the system. The project also includes assessing the correct working and its performance. The Tidalkite at the picture below is tethered to the power take off (PTO) at the bottom of the sea.



After testing the technology in the pilot facility on the Afsluitdijk, **Redstack** now aims at a first demonstration plant at Katwijk (near The Hague), where the salinity gradient is optimal. Unfortunately, in 2020, the financing of this project has still not been completed.

Blue energy is energy generated from the difference in salinity between river water and sea water, for example at the point where a river naturally empties into the sea. Reverse Electro Dialysis (RED) is a salinity gradient power technology that makes use of two types of membranes: one allows only positive ions to pass through, and the other allows only negative ions to pass through. Electricity can be generated by arranging these two types of membranes in a RED stack. The amount of energy generated is related to the difference in salt concentration of the two solutions – the larger the salinity difference between the two solutions, the more energy can be generated. Blue Energy is a good candidate for base-load energy production and application in the energy-mix.

Slow Mill is realising the first Northsea wave farm 4 km of the coast of Texel. In 2020 they assembled and tested the floater of the scale model for deployment. Additionally, they finalised the construction of their installation deck and launched it from the Port of Den Helder. Slowmill's wave device is able to harness the short and irregular North Sea waves and protect itself in storms by letting large waves partly wash over while producing optimum output and avoiding peak loads.

The **Brouwersdam tidal power plant** (25 MW) has further been studied in 2020. The challenge is to combine the production of energy with the safety function of the barrier, and take into account the rising sea level and protecting the ecosystem. The Brouwersdam was built in 1971 as a defence barrier, it closes the Grevelingen lake off from the North Sea. Over the years this resulted in a reduced water quality disturbing the ecosystem, the main reason to re-open the Brouwersdam. The re-opening offers an additional opportunity to generate electricity, but the current options do not seem financially feasible.

PLANNED DEPLOYMENTS

- SeaQurrent kite demonstrator (500 kW) at the Wadden Islands (2021)
- Slowmill wave demonstrator (25 kW) off the coast of Texel (2021)
- REDstack demoplant (0.5-1 MW) at Katwijk (near the Hague); planning delayed
- Tocardo in Eastern Scheldt (2 MW) (further future)
- Brouwers Barrier tidal range plant of 25 MW (after 2021, various scenario's)
- Several arrays in Afsluitdijk discharge gates (further future)

RELEVANT NATIONAL EVENTS

Offshore Energy Exhibition & Conference (OEEC)

On 27 & 28 October 2020, the virtual Offshore Energy Exhibition & Conference (OEEC) took place. The OEEC is Europe's leading event for the entire offshore energy industry, connecting the maritime and offshore world for sustainable solutions. This year, DMEC/EWA organized a program full of Marine Energy content. Next to the session: Marine Energy: The Next Big Thing in Energy, ocean energy companies contributed within several Talkshows, Offshore Energy Talks and Round Tables.

The North Sea Conference 'Towards New Horizons'

On 10 November 2020, DMEC participated in The North Sea Conference 'Towards New Horizons', marking the launch of the North Sea Commission's North Sea Strategy 2030. The event provided an excellent opportunity to virtually connect with North Sea stakeholders focused on transitioning to a greener and smarter North Sea Region. The conference was hosted by the North Sea Commission and supported by the North Sea Region Programme.

Offshore Industry 2020

In cooperation with Port of Amsterdam, the 11th edition of Offshore Industry took place on the 26th of November 2020. At the Offshore Industry conference, the entire offshore energy industry came together online to discuss global themes. DMEC was one of the key speakers at the conference, providing insights into the opportunities of Marine Energy.

ImpactFest

On 27, 28 and 29 October the virtual ImpactFest took place: Europe's biggest impact meetup, with the mission of 'doing good & doing business' and to drive innovations for a better world. As a partner of the ImpactFest 2020, DMEC organised the session: Marine Energy, the next big thing in energy.

Dutch Marine Energy Community Strategic Session

On 14 December 2020, DMEC organized a strategic session for the Dutch Marine Energy Community, focusing on marine energy technology developers. The goal of the session was to establish a shared vision for the public affairs strategy for the Dutch Marine Energy sector in 2021 and beyond.

3.16
PORTUGAL

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OVERVIEW

In 2020, a number of research centres and SMEs were active partners in R&D projects related to marine renewable energies. There has been continuous progress with the oscillating water column and air turbines, following decades of research in Portugal with this type of wave energy technology. Two wave energy developers have been progressing in Portugal: AW-Energy with its First-Of-A-Kind 350 kW WaveRoller in Peniche and Corpower with its HiWave-5 pilot farm project planning to deploy a first full scale unit in Aguçadoura in 2021.

SUPPORTING POLICIES FOR OCEAN ENERGY

NATIONAL STRATEGY

National Strategy for the Sea 2021-2030

The Ministry of the Sea, created by the Portuguese Government in 2015, is responsible for the coordination of maritime affairs, the promotion of a sustainable ocean economy, and the creation and monitoring of ocean policies based on scientific knowledge, innovation and technological development. They are also responsible for the licensing of all activities in the sea, including ocean energy projects, by issuing the title for the private use of the maritime space.

During 2020, the National Strategy for the Sea 2021-2030, was in public consultation until November. It is foreseen that Portugal will continue its transition in order to achieve the national objectives of the Portuguese Roadmap for Carbon Neutrality 2050, first in the lowest cost-effective sectors and technologies, and then progressively in more expensive sectors and technologies until the desired emission reductions are achieved.

Regarding ocean energies, the goals are supported by Portugal's Industrial Strategy for Ocean Renewable Energies (EI-ERO) published in 2017.

Roadmap for Carbon Neutrality 2050

The Government of Portugal submitted in September 2019 its long-term strategy for low-emission development (LTS) to the United Nations Framework Convention on Climate Change (UNFCCC), highlighting its intention to achieve carbon neutrality by 2050. Portugal's LTS titled '*Roadmap for Carbon Neutrality 2050 (RCN2050): Long-term Strategy for Carbon Neutrality of the Portuguese Economy by 2050*' elaborates a path to carbon neutrality and identifies guidelines for policies and measures required to achieve this goal. It explains that carbon neutrality is economically and technologically feasible and is based on reducing emissions between 85% and 90% by 2050, compared with 2005.

National energy and climate plan (NECP) for 2021 to 2030

To meet the EU's energy and climate targets for 2030, EU Member States established a 10-year integrated National Energy and Climate Plan (NECP) for the period from 2021 to 2030. In Portugal, it is foreseen that wave energy will reach 70 MW by 2030 and offshore wind power can reach 300 MW in the same period.

Marine Spatial Planning Situation Plan (PSOEM)

The Portuguese MSP Situation Plan (PSOEM) was approved in December 2019 aiming to promote compatibility between competing uses or activities. The Geoportal Maritime Spatial Plan was designed to spatially display existing and potential areas for different uses of the sea, providing a visual perspective of the main Portuguese maritime spatial data (including the environmental data, as well as information on activities, regulations and jurisdictions). This geoportal is now available in English and includes the latest information from PSOEM: https://www.psoem.pt/geoportal_psoem/.

Collaboration with the European Strategic Energy Technology Plan

Portugal, trough the Directorate General of Energy and Geology (DGEG), is participating in the OceanSET project, which has the overall goal to support the implementation of the European Strategic Energy Technology Plan (SET Plan) aiming to accelerate the development and deployment of low-carbon technologies. Partners in this project are working together to facilitate the implementation of the technology development actions of the Implementation Plan, promoting knowledge sharing across the European Commission, Member States and other stakeholders in the ocean energy sector, and investigating collaborative funding mechanisms. The Portuguese partner of this project, DGEG, is the public administration body responsible for designing, implementing and evaluating policies on energy and geological resources, in a perspective of sustainable development and security of energy supply.

PUBLIC FUNDING PROGRAMMES

Fundação para a Ciência e a Tecnologia (FCT)

FCT is the national funding agency that supports science, technology and innovation in all scientific domains. In November 2020 it was published a call for project grants in all scientific fields, with a maximum funding limit for each project of 250 000 EUR, and maximum duration of 3 years. This call is open until March 2021 for research and technological development projects exploring innovative concepts, for which marine renewable energies can apply.

Sea Policy General Directorate (DGPM) - BLUE FUND

Blue Fund is an innovative public financial instrument, managed by the Ministry of the Sea, which started in 2017 focused on the development of the ocean economy, scientific research and protection of the sea environment. It prioritizes the development of sea biotech start-ups, underwater robotics, innovative shipbuilding, ocean energy, aquaculture technology and innovative solutions for ocean protection, safety, monitoring and surveillance. Six projects for wave energy demonstration and robotic equipment for operations in the sea, have been developed using these funds, led by the following Portuguese institutions and SMEs: WavEC, IST, inanoEnergy (University of Porto), In2sea, Composite Solutions and Abyssal.

OTHER INITIATIVES TO STIMULATE MARITIME SECTORS

OceanACT, Atlantic Lab for Future Technologies

A new initiative aiming to be a test and demonstration center for future technologies and solutions that require validation in an ocean environment. The Aguçadoura Test Site and Viana do Castelo Demonstration Site, as well as the Atlantic Testing Platform for Maritime Robotics (the TEC4SEA Research Infrastructure) and the oceanographic radar network from the Portuguese Hydrographic Institute are among the candidates to be integrated in the OceanACT. This will enable the attraction of highly innovative projects in the Blue Economy area. This initiative initiated in 2020 is being promoted by the Collaborative Laboratory +Atlantic, Forum Oceano, CEIIA, INESC TEC and WavEC.

Atlantic Strategy Committee (ASC)

Portugal is one of the four EU Member States represented in this committee. The ASC is the governing body of the Atlantic Strategy aiming to ensure the political and operational coordination of the Atlantic Action Plan and provide the framework for its implementation. The revised Atlantic Action Plan 2.0 was communicated by the European Commission on July 2020 with the main objective to unlock the potential of blue economy in the Atlantic area while preserving marine ecosystems and contributing to climate change adaptation and mitigation. One of the four pillars is dedicated to Marine Renewable Energies.

Oceaninvest

An online platform for the promotion of products and services of the Portuguese Blue Economy, to attract potential investments and construct partnerships contributing to the development of the blue economy, aligned with the UN Sustainable Development Goals.

More information at:
https://www.oceaninvest.pt/

Bluetech Accelerator

A Startup Programme inviting startups to bring innovation to the Blue Economy. The first edition of the programme was strategically focused in the Port & Shipping industry and benefits from a partnership with the Luso-American Development Foundation (FLAD).

Portugal Blue

A new initiative for blue economy investments launched in 2020 by the European Investment Fund (EIF) and the Portuguese national promotional institution, Instituição Financeira de Desenvolvimento (IFD), co-financed by the Portuguese Ministry of Sea with resources from Fundo Azul (Blue Fund). The EIF and IFD each contribute €25 million to this joint programme to support Portuguese companies active in the area of blue economy.

MARKET INCENTIVES

Since 2012 no feed-in tariff (FiT)has been approved for new projects.

RESEARCH & DEVELOPMENT

KEY R&D PROJECTS

Portuguese companies, universities and research institutions have been involved in several research and development projects related with wave energy during 2020. Below are a few examples.

Projects funded by the national "Fundo Azul" programme of the Portuguese Ministry of the Sea

BLUECAO

Aiming to develop an offshore platform concept to supply energy and feed offshore aquaculture farms based on a wave energy system, consisting of an aggregation of coaxial oscillating water columns (OWCs) assembled to a central food deposit. The project is conducted by a Portuguese consortium coordinated by WavEC and involving one university - Instituto Superior Técnico – and three companies - Secil, Rota Grega and Kymaner.

JUMP

A pioneering initiative in Portugal to monitor underwater noise. The project coordinated by WavEC brings together ten Portuguese partners from academia and public administration. The project started in January 2020 and will last for two years collecting and promoting information regarding noise pollution and further supporting the implementation of the Marine Strategy Framework Directive in Portugal.

BASEPOINT

In2sea Lda has partnered with Sines Tecnopolo, Mecwide AS and the Dutch technology developer Teamwork Technology to validate a new water turbine PTO concept for heaving point absorbers, as part of the Symphony WEC development. Symphony is an evolution of the Archimedes Wave Swing technology invented and initially developed by Teamwork Technology, resulting in full-scale sea trials in 2004. The new turbine is key to the pressurised closed-loop water PTO with a structural membrane and an air/water spring tank, which allows to put into practice an endstop-less PTO and permanently submerged operation, both potential advantages versus other point absorbers. The results feed into a full test rig validation INTERREG project, preparing Symphony for sea trials.

i.nano.WEC

This project concerns the development of a marine buoy incorporating a highly efficient energy harvesting system based on triboelectric nanogenerators (TENGs). It further aims to optimize the TENG's performance for selected marine applications (e.g., oceanic buoys used in aquaculture, signaling and metocean monitoring) by using a composite modelling approach that combines numerical simulations and experimental testing in a multidirectional wave basin (scaled model tests). The main promoter of the project is inanoEnergy a startup based in Porto, which has the strategic support of two research centres, CIIMAR and INEGI.

Projects funded by the European Maritime and Fisheries Fund (EMFF)

WESE

Led by the RD&I Basque center AZT, this project aims to develop environmental monitoring around wave energy devices operating at sea and further to develop efficient guidance for planning and consenting procedures in Spain and Portugal. The consortium is includes, from Portugal, WavEC and the Portuguese company, Hidromod.

SAFEWAVE

Co-ordinated by EMEC, with a diverse range of project partners across six European countries, this project aims to address long-term environmental concerns around the deployment of wave and tidal energy converters in the marine environment. WavEC is participating in this project through the collection, processing, analysis and sharing of environmental data around devices operating at sea.

Projects funded by EU Horizon 2020

LIFTWEC

Coordinated by the Queen's University of Belfast focusing on the development of LiftWEC, a novel type of wave energy converter, based on the exploitation of lift forces generated by wave-induced water velocities. WavEC is contributing to the identification of promising configurations of the LiftWEC concept that may minimise environmental impacts and ensure social acceptance

ETIP OCEAN 2

This project funds the European Technology and Innovation Platform for Ocean Energy (ETIP Ocean), the European Commission's advisory body for research and innovation. ETIP Ocean2 is led by Ocean Energy Europe and aims to define ocean energy research and innovation priorities, discuss solutions with the industry, and European and national policy makers. WavEC coordinates

all overall environmental questions and licensing tasks of the project.

MEGAROLLER

Aiming to develop and demonstrate a next-generation Power Take-Off (PTO) solution for wave energy converters. The proposed PTO technology for a 1 MW oscillating wave surge converters (OWSC) device is based on multiple hardware and software innovations. The project is led by AW-Energy, with the participation of WavEC on the coordination of the environmental and socioeconomic aspects of the project.

SEA-TITAN

Led by the Spanish company Wedge Global, the project aims to designing, building, testing and validating a crosscutting and innovative Direct Drive Power Take-Off (PTO) solution to be used with multiple types of wave energy converters. The design was based on the Wedge Global W200 PTO prototype. WavEC is one of the European partners involved in this project contributing to the development of the numerical modelling work.

MARINET2

Providing free access to a network of 57 research facilities across Europe, through a series of competitive calls open to offshore energy technology developers (offshore wind, wave and tidal energy). WavEC has been involved in the development of standardized procedures and metrics for the financial assessment of offshore renewable energy projects, development of physical modelling and engineering evaluation processes for ecofriendly anti-fouling coatings and coordination of the training programme comprising a set of short-courses and webinars.

DTOceanPlus

Led by Tecnalia and comprising 18 European partners. The consortium has been developing, since 2018, a second-generation open-source design tool for ocean energy technologies including sub-systems, energy capture devices and arrays planned to be concluded in April 2021. WavEC coordinates the development of the modules to assess the design of each technology (sub-system, device and array), to assess the logistics and marine operations planning, as well as the system lifetime costs and the legal, institutional and political frameworks of the marine energy projects.

BLUEGIFT

Launched in 2018, the Blue-GIFT project aims to support at least eight floating wind, wave or tidal demonstration projects across the Atlantic Arc region, by providing free access to key European test centres. WavEC participates in the project, offering Aguçadora test site in Portugal as an open sea testing facility.

TECHNOLOGY DEMONSTRATION

TEST CENTRES & DEMONSTRATION ZONES

In the Portuguese Atlantic coast there are three grid-connected open sea test sites, in exposed areas. Peniche site, at intermediate water depths, has a private use by the Finish company AW-Energy for the development of their wave energy project. The other two sites are open to developers willing to test wave energy and floating offshore wind projects. Viana do Castelo test site is available for pré-commercial projects (TRL 8 - 9), while Aguçadora test site is more adequate for research and demonstration projects (TRL 6 - 8). In Aguçadora, Corpower Ocean is starting to develop their wave energy project, and in Viana do Castelo the Windfloat Atlantic project has been deployed in 2020.

DEMONSTRATION PROJECTS

The Portuguese company **Kymaner** and **IST** designed and supplied a unidirectional air turbine for integration into the fully submerged bottom-standing 1.5 MW mWave wave energy converter of the Australian company Bombora Wave Power for installation off the coast of Pembrokeshire, Wales, UK.

A wave-powered oceanographic buoy, based on the OWC spar-buoy concept developed by the Mechanical Engineering Institute (IDMEC) at **IST** was tested off the island of Faial, in the Azores Archipelago, in 2020.

AW-Energy completed the final assembly and deployment of the First-Of-A-Kind 350 kW WaveRoller in Peniche, Portugal during the autumn 2019. The unit was successfully connected to Portuguese national grid and started energy production in mid-November 2019. AW-Energy Oy received Prototype Certification by Lloyd's Register (LR) for its WaveRoller device on 16 January 2020. A two-day monitoring campaign was undertaken by WavEC around the WaveRoller device during October 2020 to assess the noise emitted during the activities. The acoustic monitoring was performed simultaneously with the decommissioning of WaveRoller. A field campaign with ROV was undertaken for the seafloor integrity to allow evaluating the alterations of the seafloor due to the presence of the device and mooring cables.

PLANNED DEPLOYMENTS

In November 2020 **CorPower Ocean** has secured a 10-year licence from the Portuguese authorities to establish a wave energy project in the Atlantic Ocean, the company's flagship HiWave-5 wave energy converter (WEC). The Tupem license – awarded by the national Directorate-General for Natural Resources (DGRM) – provides a 'Permit for the Private Use of the Maritime Space' up to 10km off the coast of Aguçadoura in northern Portugal. The HiWave-5 project aims at having at least three operational devices demonstrated in a pilot farm, delivering electricity to the grid with certification of availability and performance. In 2021, the first full scale unit 'C4' is planned to be deployed, taking the technology from TRL 6 to TRL 7.

RELEVANT NATIONAL EVENTS

WavEC Annual Seminar 2020 was organized on December 9th in collaboration with the Embassy of Canada to Portugal. The event usually organized in Lisbon, took place, this year online, with one session dedicated to wave and marine current projects.

http://wavec.org/en/events/seminar-2020

3.17

REPUBLIC OF KOREA

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OVERVIEW

The Ministry of Oceans and Fisheries (MOF) established a commercialization plan of ocean energy systems to contribute to the new national renewable energy policy of providing 20% of electricity from renewable sectors by 2030. Many R&D projects are being carried out to support this ministry's commercialization plan. Korea Research Institute of Ships and Ocean Engineering (KRISO) is developing 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. KRISO and Jeju National University are developing an arrayed-buoy WEC, and the arrayed-buoy WEC was tested in the open sea near Jeju Island and the southern coast of Korea. Two R&D projects for developing tidal energy converters (TEC) were initiated in 2019: (1) the development of a tidal energy converter combined with ESS to supply energy to remote off-grid islands, and (2) the development of a 1 MW class commercially available tidal energy converter by Korea Institute of Ocean Science and Technology (KIOST). The TEC-ESS combined system is being manufactured and will be installed in October 2021.

The KRISO-Wave Energy Test Site (KRISO-WETS) was open in July 2020. The Korea Tidal Current Energy Center (KTEC), established by KIOST, is under development since May 2017 and will be open by December 2022. A bilateral cooperation project (2018-2020) 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. This bilateral cooperation project will be continued for more than 3 years as the Second Phase.

SUPPORTING POLICIES FOR OCEAN ENERGY

NATIONAL STRATEGY

Within the 2030 Ocean Energy Development Plan, the ministry's action plan for developing and disseminating ocean energy systems, a strategic plan has been established in the field of 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 will be extended for the Carbon Neural in 2050 and the roadmap will be prepared in 2021.

MARKET INCENTIVES

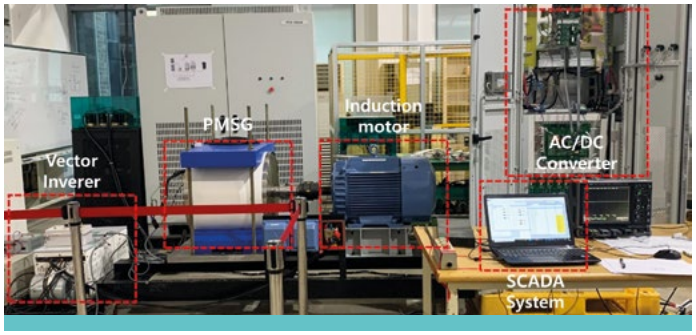
The renewable portfolio standard (RPS) was established in 2012 to compel utility companies with a capacity greater than 500 MW to provide obligatory portions of their total electricity production from renewable energy, based on the Acts on the Development, Utilization, and Supply Promotion of Renewable 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, while the value of REC for wave and ocean thermal energy has not been assigned. In the REC market, the REC price has gradually reduced from 140 USD/REC in 2016 to 40 USD/REC in 2020 due to the expansion of renewable energy supply as well as the stagnation of demand for REC by energy companies.

PUBLIC FUNDING PROGRAMMES

MOF provides public funding for ocean energy R&D projects, including demonstration projects, and 20.4 million USD was invested in the development of ocean energy systems in 2020. The main two programs will be continued by 2022, and the remaining budget for ocean energy R&D projects is about 27.3 million USD in 2021 and 2022.

RESEARCH & DEVELOPMENT

As a part of a KRISO-led R&D project focusing on the development of 30 kW wave energy converters applicable to breakwaters in remote islands, ESS and PCS systems were manufactured, and the performance was tested by integrating with the generator in 2020. The conditions of regular and irregular waves were generated and it was confirmed that power is stably produced according to the PCS control algorithm. The switchgear and the ESS system for grid connection were completed and installed on site. The OWC concrete structure has been built and is scheduled to be installed on the breakwater in early 2021.

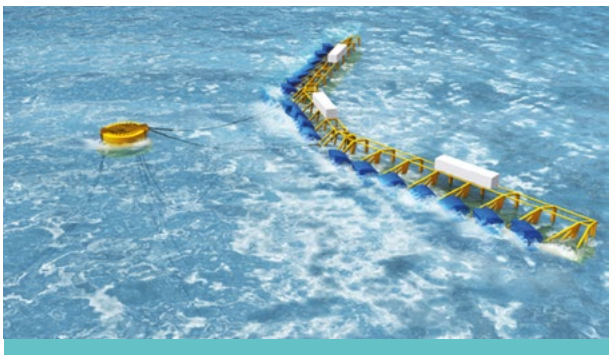


Integrated performance test on prototype of generator & PCS (Courtesy: KRISO)

KRISO and Jeju National University are developing an arrayed-buoy wave energy converter, which arranges a number of floating bodies(rotors) on the floating platform's body to absorb the wave energy in the form of electrical energy and transmits it to the land through the cylindrical mooring buoy. Optimal design of salter's duck type rotor as the primary energy converter was carried out and secured durability and stable power generation performance of the entire system by applying a rotary hydraulic transmission system as a power take-off system.

In summer to fall 2020, actual sea demonstrations for rotor and hydraulic PTO systems were conducted in the Jeju and southern coast of the Korean Peninsula, and continuous operation performance was achieved for more than 24 hours through automatic control of power generation loads.

TEC-ESS hybrid system for remote off-grid islands is being developed utilizing dual vertical axis Darrius (outside) and Savonius (inside) turbines with venturi walls to increase inflow speed. The generators and maintenance facilities such as an overhead crane will be located on top of a steel frame supporting structure, and ESS will be installed on an island's landside. This hybrid system is currently being manufactured, and KIOST plans to test its performance under open sea conditions in October 2021.



Arrayed-buoy wave energy converter (Courtesy: KRISO)

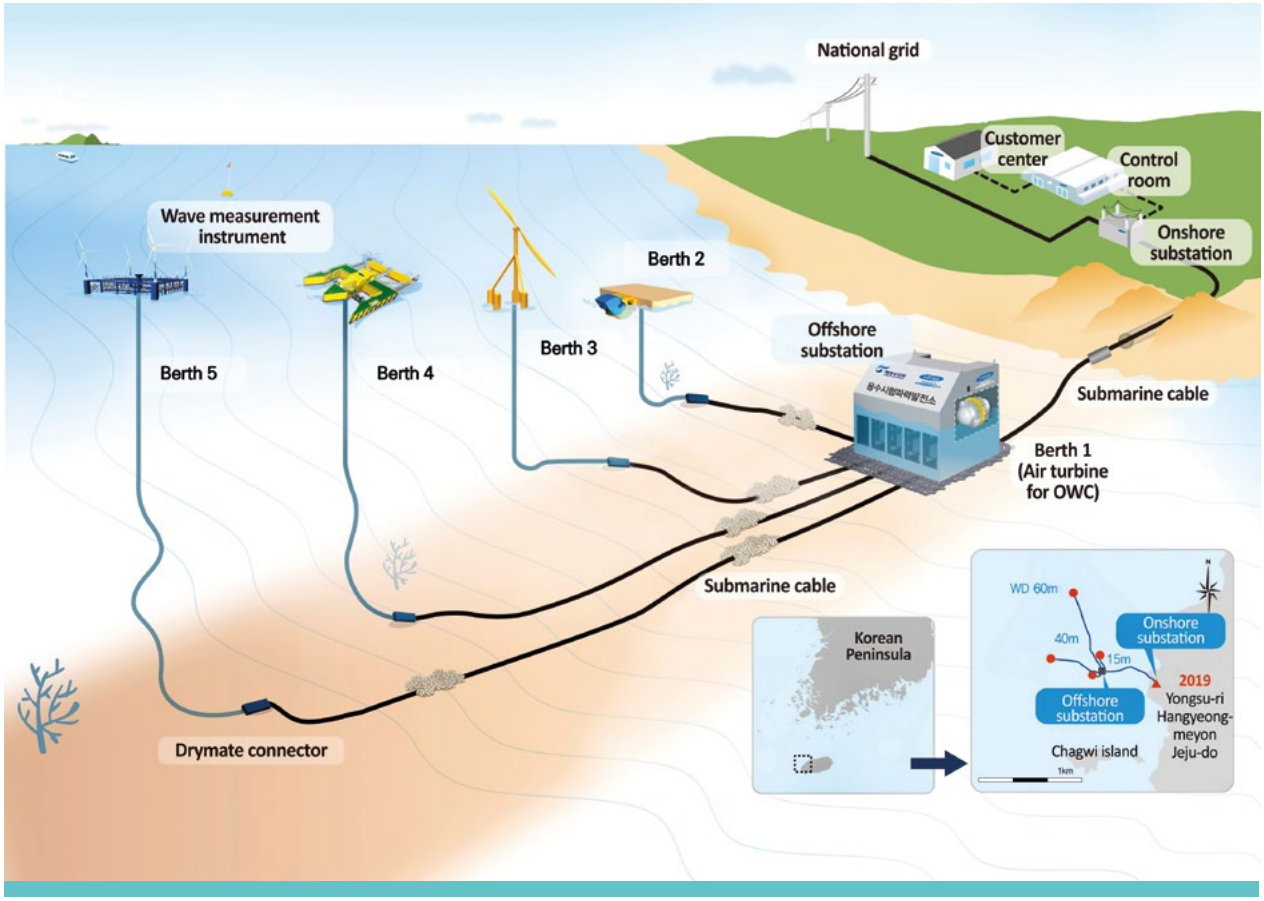
Actual sea demonstrations for rotor and hydraulic PTO system of (Courtesy: KRISO)

TECHNOLOGY DEMONSTRATION

Open-Sea Test Sites

MOF is supporting two construction projects for open-sea test sites for WECs and TECs. The **KRISO-WETS** (Wave Energy Test Site) located on the western side of Jeju Island, was officially opened the last September 2020. There are five berths including the existing Yongsoo OWC-type WEC, which is working as the first berth for the OWC-type WECs and also as the offshore substation for the open-sea test site. KRISO led this construction project, and the total budget is about 17.3 million USD. Four more berths, two in shallow water (about 20 meters) and two in deep water (about 40-60 meters), are connected to the offshore substation and grid system, with a total capacity of 5 MW. The fifth berth, 60 meters deep, is expected to be used for floating offshore wind turbines as well.

The **K-TEC** (Korea Tidal Current Energy Center) led by KIOST, will run five berths of 4.5 MW installed capacity connected to the grid and is going to open by December 2022. The onshore component performance test facility for rotor blades and other structural parts is under construction and will be completed by March 2021 at the KIOST Busan Headquarter as a part of this project. About the open sea test sites, the Uldolmok Tidal Current Power Plant will be utilized as the test site for small- and medium-size TECs under 500 kW due to the limited water depth of about 25-30 meters. The other four berths will be located in JangJuk Strait, and an extensive consenting process was carried out, including environmental impact and navigational safety assessments in 2020.



KRISO-WETS (Courtesy: KRISO)

KTEC (Courtesy: KIOST)

3.18

SINGAPORE

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SUPPORTING POLICIES FOR OCEAN ENERGY

NATIONAL STRATEGY

Singapore is an islandic nation located in the heart of South East Asia with a total land area of about 728 km² and with a population of about 5.7 million as per data provided by Department of Statistics Singapore on 2020. In 2015, Singapore pledged to reduce its Emissions Intensity (EI, or GHG emissions per unit of GDP) by 36 per cent from 2005 levels by 2030 and stabilise emissions with the aim of peaking around 2030. The Government's strategy to enable Singapore's low-carbon transition consists of three thrusts.

a. Transformations in industry, economy, and society.
b. Adoption of advanced low-carbon technologies.
c. Effective international collaboration.

This makes the country more determined to establish different energy efficiency measures and to harness alternative sources of energy.

MARKET INCENTIVES

The Green-e Renewable Energy Standard for Singapore allows Green-e Energy certification of renewable energy products throughout Singapore, 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 the 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 PROGRAMMES

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, of which S$140 million is allocated for research into clean energy technologies under the banner of the Energy Innovation Programme Office (EIPO) (EDB, 2015). Ocean renewable energy has been identified as one of the prominent alternative energy 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. In 2017, the Singapore Economic Development Board (EDB) has also secured investments from six clean energy companies worth $500 million for next five years (EDB, 2017). Over the past few years, Energy Market Authority of Singapore (EMA) has also awarded over $100 million to address industry-relevant challenges and opportunities in the energy sector that lead to long-term solutions for Singapore's energy challenges (EMA, 2019). The Singapore Government has also set aside S$49 million on Oct 2020 to fund low-carbon energy research for next five years (NCCS, 2020).

RESEARCH & DEVELOPMENT

ERI@N, supported mainly by the 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 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.

TEST SITES

ERI@N developed Tidal turbine system

Sentosa – ERI@N Tidal Site

The Sentosa Tidal Test Site is a joint collaboration between Sentosa Development Corporation (SDC) and ERI@N, funded by the Ministry of Trade and Industry's Core Innovation Fund. This project aims to showcase tidal energy extraction as a feasible and sustainable energy generating technology in Singapore and to provide opportunities to develop local technologies to harness the energy available in the narrow channel between Singapore and Sentosa. In November 2013, ERI@N and SDC officially launched the Sentosa Tidal Test Site (NTU, 2013).

Recent developments on the test site include the deployments of customized tidal turbines supported from the floating barges. Also, novel concepts such as floating solar system, anti-biofouling coatings are being evaluated for better field performance. The power developed is used for electric lighting on the boardwalk. This was further developed towards floating tidal turbine system. For feasible power capture, tidal generators are preferably located at natural coastal features which can converge and amplify water flow, such as channels and estuaries. The current test bed benefits from amplified flow due to the narrowed channel between Singapore and Sentosa islands and bridge piers which provides manmade flow convergence.

Ocean Basin Facility – TCOMS

Technology Centre for Offshore and Marine Singapore (TCOMS) is a joint venture between the National University of Singapore (NUS) and the Agency for Science Technology and Research (A*STAR). A key feature of the TCOMS is the state-of-the-art Deepwater Ocean Basin, a massive water containment facility that can simulate the harsh environment of Deepwater oceans. The Deepwater Ocean Basin can hold a volume of water equal to over 20 Olympic-sized swimming pools and has a 50 m deep centre pit. Armed with smart sensing, modelling and data analytics capabilities, the next-generation Deepwater Ocean Basin can reproduce the wave and current systems of ultra-deep waters. This enable researchers to study the complex ocean state and understand the deep-sea challenges facing the M&OE industry. Ultimately, this helps researchers to develop innovative solutions such as intelligent floating platforms, marine robotics and subsea systems to help the M&OE industry improve safety and enhance efficiency in the rough ocean waters.

TCOMS is currently working with its industry partners to solve real-world problems in the Marine & Offshore Engineering operations using state-of-the-art simulation techniques to better predict the behaviour and response of marine and offshore systems, such as rigs, smart vessels, and underwater systems.

Key Research Thrust areas of TCOMS are:

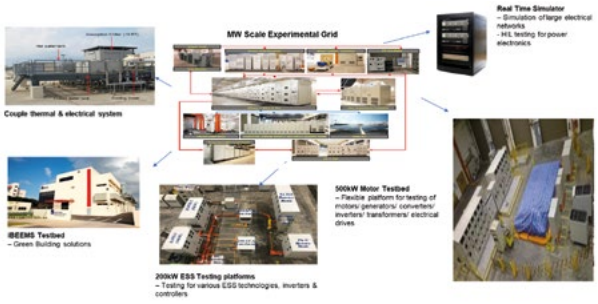
- To enhance the predictability of the operating environment and the behavior and response of ocean systems in challenging and complex sea states.
- To advance research and technological innovation in maritime autonomous surface ships.
- a digital twin of the metocean environment for the waters around 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 is home to Singapore's petrochemical hub, the Experimental Power Grid Centre (EPGC) houses one of the largest and most comprehensive integrated energy facilities. It consists of a comprehensive range of generation sources, energy storage systems, and loads, which allows equipment manufacturers and system integrators to test out their technology or configuration at actual power before deployment. The experimental power grid has been valuable to industry partners to develop and demonstrate concepts such as microgrids for rural electrification. Throughout the years, ERI@N/ EPGC have built up various testing platforms:

- 200 kW ESS testing platform
- 500 kW motor testing platform
- Real-time simulation and HIL testing platform
- 100 kW PV inverter testing platform
- Intelligent Building Energy and Environmental
- Monitoring and Control System (iBEEMS) testing platform

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

OPERATIONAL PROJECTS

Turbine Demonstration Project – MAKO Tidal Turbines

In June 2017, MAKO Tidal Turbines commenced research in collaboration with Energy Research Institute @ Nanyang Technological University (ERI@N) Singapore to evaluate the performance of its MAKO.4 tidal energy turbine in Singapore tropical water conditions. Singapore was selected by MAKO turbines because of its government's active support for hosting and nurturing the development of renewable energy, availability of suitable tidal flow and its proximity to Asian markets. ERI@N tidal site was used for this turbine demonstration project. ERI@N actively involved in this project in deployment and in evaluating the performance of the MAKO.4 tidal energy turbine. ERI@N also performed studies related to the impact of tropical environment on tidal turbine as well as on its performance. As a next phase of the project, Mako Tidal Turbines in collaboration with Sentosa Development Corporation, Enterprise Singapore, Energy Research Institute @ NTU (ERI@N) and other industrial partners demonstrated a MAKO tidal turbine that is integrated with a Pylon of Sentosa Boardwalk on September 2019.

MAKO tidal turbine system demonstration in Sentosa waters

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 electricity distribution. REIDS fosters systemic research and development in the broad energy arena in support of Singapore corporate and public stakeholders, thereby strengthening their position on the rapidly growing renewable energy and microgrids markets. Key technology developments include smart grid architecture, power electronics based on wide band devices, novel energy storage technologies such as reflow batteries, hydrogen, etc. The main development, test and demonstration site for REIDS is a 6.4 ha plot, designated as P2, on Semakau Landfill In effect, the Semakau Landfill constitutes the REIDS in-the-field laboratory and provides for REIDS to develop and demonstrate the operation of actual-sized off-grid microgrids. Till date, the university has setup collaborations with around 30 local and international companies. Presently, The Fish farm in the island is currently 100% powered by Clean energy harnessed from multiple renewable sources with an energy integration system.

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 on 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 acts 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 government is planning to deploy 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 of renewables and water generation system is in progress.

Southern Islands of Singapore

Singapore Decarbonization efforts

Jurong Town Corporation, a Singapore government agency has launched a Request for Information (RFI) for technical / conceptual ideas for smart grid and renewable energy innovation on Jurong Island in April 2020. This RFI requested for proposals and innovative ideas to:

- Maximize solar deployment on Jurong Island (JI) and explore creative deployment of Energy Storage Systems.
- Pilot and subsequently develop and operate a JI-wide smart grid management system or network of smart grid management systems.
- Test-bed innovative low-carbon technologies and other renewable technologies.

ERI@N is currently developing an offshore floating solar and tidal turbine hybrid systems that can be deployed along the coast of Jurong island.

Jurong Island, Singapore

Floating Solar Deployment

- Construction of a 60-megawatt peak (MWp) floating solar photovoltaic (PV) system on Tengeh Reservoir was started by Sembcorp on Aug 2020. This will offset 7% of PUB's 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.
- Singapore's Economic Development Board (EDB) has issued a request for information to explore the feasibility of a 100 MW floating solar project. The proposed facility will generate electricity for private sector consumption after construction. Such a facility will save 52,000 tonnes of carbon dioxide (CO2) emissions per year.
- Two smaller floating solar PV systems will also be deployed by the PUB at the reservoirs in Bedok and Lower Seletar in the second half of this year.
- ERI@N is also currently developing and deploying 100 kW offshore floating solar system for deployment in waters in depth of 20 – 30 m. Initial testbed is being planned for deployment in a seawater lake near Sentosa, Singapore.

Floating solar in Singapore

RELEVANT NATIONAL EVENTS

6th and 7th Workshops on Tidal Current Extractable Energy: Modelling, Verification and Validation

These two workshops were organised and hosted by Energy Research Institute @ NTU (ERI@N), Singapore through teleconferencing on 20th May 2020 and 2nd November 2020. The main goal of these workshops was 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.

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 13th edition of SIEW 2020 addressed the theme of "Creating Our Low Carbon Energy Future Together", underlining the importance of all energy stakeholders from governments, international organizations and societies in building a low-carbon energy system.

ERI@N also organized a roundtable session on "Low Carbon Innovation and New Technologies".

International Floating Solar Symposium (IFSS 2020)

International Floating Solar Symposium was organised by Solar Energy Research Institute of Singapore (SERIS) as a part of Asia Clean Energy Summit (ACES) and was held in conjunction with Singapore International Energy Week (SIEW 2020) in October 2020 as a virtual conference. Various industry players, innovators, developers and other stakeholders of floating solar were brought together. Highlights of IFSS 2020 include:

- Announcement of a large, multi-national testbed for near-shore FPV
- Launch of the "International Floating Solar Society" (IFS^2)
- Upcoming business opportunities (future projects on reservoirs and near-shore)
- Comparison of different energy yield models
- Real-world O&M experiences
- Standards in Floating Solar

3.19
SPAIN

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OVERVIEW

2020 has been a hard year for ocean energy in Spain due to COVID-19 pandemic. Several ongoing projects were delayed, and work has slowed down. Anyway 2020 can show progress on reliability of ocean energy (a new full year operation at Mutriku Wave Power Plant feeding electricity to the grid, reaching the milestone of 2 GWh purchased to the grid), open sea operating experience gained with the deployment of WAVEPISTON in PLOCAN, some new European R&D projects, several developments on corrosion and fouling resistant coatings being tested at the Marine Corrosion Test Site "El Bocal", one additional year of operation of the materials and components offshore laboratory – HarshLab – placed at BiMEP, and Punta Langosteira Test Site (a new test site at the Galician coast) being authorized in July 2020.

2020 can also show some changes in the legal field to make easier in the short term to develop research and demonstration projects. Anyway, there are still several barriers to remove, some of them due to the technology development stage of Ocean energy and some others due to the lack of a stable and proactive policy and legal framework in the past to push forward the development of the sector.

SUPPORTING POLICIES FOR OCEAN ENERGY

NATIONAL STRATEGY

During 2020 the Spanish Government continued working in the Energy and Climate National Integrated Plan 2021-2030 (PNIEC), and the Energy Transition and Climate Change Law. Both documents will fix the framework to develop new energy infrastructures, the energy source targets for 2030 and new rules to boost renewable energy in general and, hopefully, ocean energy specifically.

The Ministry for the Ecological Transition has also opened a public consultation process of the Roadmap for the development of Offshore Wind and Ocean Energies in Spain. In a first step, the roadmap establishes the need of high TRL development support programs, to help the sector reach a certain maturity prior to support. In a second step, the roadmap bid for demonstration projects. Additionally,

the PNIEC proposes to adapt the administrative procedure to accelerate the obtaining of licenses and permits for high TRL R&D grid connected projects. The elaboration of this document contributes to the fulfilment of the PNIEC and is in line with the route marked in the draft of the Climate Change and Energy Transition Law. The energy policy relays on the new Ministry for the Ecological Transition and the main permits needed to develop an ocean energy power plant (environmental, use of the marine space, energy production) have to be approved by this Ministry. The PNIEC, still at draft stage, sets for ocean energy the target of reaching 25 MW of installed capacity for 2025 and 50 MW for 2030. The renewable energy contribution is expected to reach 42% in 2030. The Basque Government approved in 2016 its Energy Strategy for 2030, which included a specific initiative to speed up technology and commercial development for marine energy and set a target of 10 MW by 2030.

Regarding the use of marine space, the Government is writing the maritime space management plan. It is comprised by five management plans must be developed, one for each of the five marine areas established in Law 41/2010, on the protection of the marine environment. A first draft has been written and went under public consultation (still ongoing) during 2020. It is currently being reviewed by the Ministry, together with the Autonomous Regions. The cartographic information contained in these documents can be consulted in the InfoMAR geographic viewer, Marine Environment Information System, also currently under construction http://infomar.cedex.es.

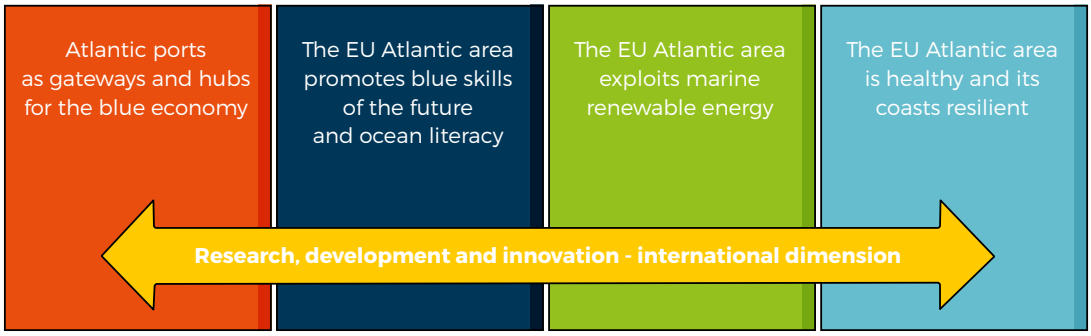
Regarding the regulatory framework, no dedicated consenting process exists for ocean energy technologies in Spain but there are several legal documents affecting ocean energy projects and in June 2020 a new one was approved to start the change to a new legal framework. The most important are the following ones:

- Royal Decree 1028/2007 establishes the administrative procedure for processing applications for electricity generating facilities in territorial waters. Although it focuses on offshore wind, it also includes electricity generation from other marine renewable technologies.
- Law 2/2013, of 29 May, for protection and sustainable use of coastal and amending the previous Coastal Law of 1988. It provides the legal framework for occupation of the territorial sea, as well as governing issues affecting the fishing sector and safety conditions for maritime navigation.
- Law 21/2013, of December 9th, establishes a simplified process on Environmental Impact Assessment for all marine energy projects.
- Royal Decree-Law 23/2020, of June 23, which approves measures in the field of energy and in other areas for economic reactivation.
- Royal Decree 960/2020, of November 3, which regulates the economic regime of renewable energies for electricity production facilities.

In 2013 the European Commission put forward an Atlantic Action Plan to implement the Atlantic Maritime Strategy. The Action Plan went through a mid-term review and identified seven goals under four thematic pillars through concrete actions mobilising all relevant Atlantic stakeholders.

The coordination of the pillar III – Marine Reneable Energy – was awarded to EVE (Basque Energy Agency). The result for this nomination for two years is expected to be concrete projects on MREs for the Atlantic Area with the aim of accelerating the deployment pace. EVE has presented a roadmap and will receive contributions from Atlantic Area regions and Member States.

Ocean energy is also a priority for Xunta de Galicia (regional government), and it is included in its energy strategy. INEGA, the Energy Agency of Xunta de Galicia, takes part into Pillar III MRE of the Atlantic Action Plan 2.0.



MARKET INCENTIVES

There are no specific market incentives for ocean energy in Spain but for renewable energy installations in general.

Royal Decree 413/2014 established that the support for new renewable facilities is granted through competitive public tender processes. Through these auction processes, bidders propose the initial value for the investment that they will be willing to accept, and the MW auctioned are allocated to the most competitive offers (the lower ones).

Royal Decree 960/2020, of November 3, which regulates the economic regime of renewable energies for electricity production facilities and Order TED / 1161/2020, of December 4, which regulates the first auction mechanism for the granting of the economic regime of renewable energies and establishes the indicative calendar for the period 2020-2025, will allow to start the tender calendar for the next five years.

The above mentioned Order TED / 1161/2020 stablishes a tender of 20 MW every two years focused on "Other Technologies", where ocean energy is included, reaching 60 MW for 2025. If PNIEC is fulfilled, 25 MW of those 60 MW should be ocean energy.

PUBLIC FUNDING PROGRAMMES

There are several national and regional funding programmes to support R&D and demonstration projects in Spain but most of them are no specific for ocean energy. The only two programmes focused on ocean energy are:

- OCEANERA-NET COFUND (2017-2021) is an initiative of eight national and regional government agencies from six European countries, which has received funding from the European Union under the Horizon 2020 Programme for Research and Innovation. The participating countries/regions are: the Basque Country, Brittany, Ireland, Pays de la Loire, Portugal, Scotland, Spain and Sweden. The aim is to coordinate support for research and development in ocean energy, to encourage collaborative projects that tackle some of the key challenges identified for the sector as it progresses towards commercialisation.
- The Basque Energy Agency (EVE) launched a new call of its "Demonstration and validation of emerging marine renewable energy technologies" programme in 2020. As previous calls, the programme has a budget of 2,5 M€ for a maximum of 3-year duration projects.

RESEARCH & DEVELOPMENT

EuropeWAVE

Horizon 2020 project EuropeWAVE wants to bridge the gap to commercialisation of wave energy technology using pre-commercial procurement. The Grant Agreement of the project was signed in December 2020 and the project will be launched in January 2021. WES (Wave Energy Scotland) will be the coordinator of the proposed EuropeWave project and lead a 'Buyers Group' of public authorities from the UK (Scotland - WES) and the Basque Country (EVE). 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 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. This will be achieved by procuring a phased competitive programme of R&D to pull forward those technologies that can demonstrate the best potential to achieve the technical and economic performance metrics that will make them investor-ready. During 2020, the fifth call for trans-national access to European offshore renewable energy test facilities were assessed within the MARINET2 project, a H2020 programme project. This project, funded by the European Commission under the Research Infrastructure section of H2020, has the participation of 7 Spanish partners: BiMEP, CENER, CTC, EVE, IH Cantabria, PLOCAN and TECNALIA.

BLUEGIFT

BLUEGIFT, Blue Growth and Innovation Fast Tracked, is a €2.5 M European Regional Development Fund project that aims to help Atlantic Area companies test the next generation of Marine Renewable Energy (MRE) technology in real sea environments and prove power can be economically generated from the ocean. The project will result in a minimum of 8 MRE floating wind, wave or tidal pre-commercial demonstrations, over 24,000 hrs of operation, work with over 20 SME's, sustaining 30+ jobs and helping to secure €15 M investment into MRE companies. The BLUEGIFT consortium is integrated by test centres covering the major geographical spread and resource types and are evenly distributed across the Atlantic Area programme area: EMEC (wave and tidal) in Orkney, UK; SEENEOH (hydrokinetic and tidal) in Bordeaux, France; SmartBay (wave and floating wind) from Galway, Ireland; Centrale Nantes / SEM-REV (wave and floating wind) in Nantes, France; PLOCAN (wave and floating wind) in the Canary Islands; WavEC (wave and floating wind) in Portugal; and BiMEP (wave and floating wind) in Spain.

Strategic Research and Innovation Agenda (SRIA)

TECNALIA has led, in collaboration with Ocean Energy Europe and the University of Edinburgh, the Strategic Research and Innovation Agenda (SRIA) for Ocean Energy within the context of ETIP Ocean, the European Technology and Innovation Platform on Ocean Energy. The SRIA was officially launched in June 2020 with the purpose of being a reference document for the whole ocean energy sector and specifically for public funding organisations aiming at inspiring research calls.

DTOceanPlus

The DTOceanPlus project, funded under the H2020 programme and coordinated by TECNALIA, is developing an integrated open-source suite of design tools to support the entire innovation and development process for ocean energy sub-systems, devices and arrays. By the end of 2020, this three-year project has successfully verified the standalone versions of the set of design tools and modules (beta versions), and produced a comprehensive analysis of the potential markets and supply chain for ocean energy technologies.

More information on website:
https://www.dtoceanplus.eu/

NEMMO

The NEMMO project (2019-2022), funded under the H2020 programme and coordinated by TECNALIA, is working on boosting the competitiveness of tidal energy by optimising tidal turbine blade design and performance. The project aims to create a larger, lighter and more durable composite blade for floating tidal turbines, enabling devices to reach capacities of over 2 MW. Magallanes Renovables also participates in the project as key end-user partner and beneficiary of the prototype of blades to be manufactured in NEMMO. During 2020 the project produced several public deliverables that can be downloaded from the project website http://nemmo.eu/

VALID

A new H2020 project started at the end of 2020 with the participation of three Spanish partners (BiMEP, IDOM and TECNALIA). VALID (Verification through Accelerated testing Leading to Improved wave energy Designs) is a three-year project specifically designed to develop a Hybrid Testing Platform for accelerated testing with methodologies by combining the virtual and physical environment, reducing cost in the product developing process, tackling scaling challenges and lowering uncertainties once fully demonstrated in the ocean.

SEA-TITAN

SEA-TITAN project (2018-2021) funded under the H2020 programme (ID 764014) comprises a consortium of 11 European entities coordinated by the Spanish company WEDGE GLOBAL. The project objectives include the design, manufacturing, validation and standardization of a 2nd generation direct drive Power Take-Off (PTO), conceptual design of a 1st generation superconductive Power Take-Off and the development of an innovative exploitation strategy through open business model. In 2020, the project started the manufacturing of the 2nd generation PTO in collaboration with Siemens-Gamesa, one active unit has been completely assembled, second active unit partially assembled, passive unit elements manufactured but not assembled yet, the manufacturing has been extended to 2021 given the COVID-19 impact over the year.

More information on website:
http://seatitan.eu

OCEANERA-NET Cofund

OCEANERA-NET Cofund project is now in its fourth year and has successfully implemented two Joint Call for collaborative, trans-national research, development and demonstration projects to tackle some of the key challenges and opportunities for ocean energy. In 2020, 3 new projects funded under the Second Joint Call 2019 were announced: SeaSnake, WEC4PORTS and EVOLVE.

WESE - Wave Energy in Southern Europe

Funded by the European Maritime and Fisheries Fund (EMFF) through is Executive Agency for Small and Medium-sized Enterprises (EASME) and launched in November 2018, aims to improve the current knowledge of the potential environmental impacts of ocean wave energy projects and consequently reduce the uncertainty about these impacts in order to better inform decision-makers and managers on environmental real risks and reduce environmental consenting across Spain and Portugal. The WESE Consortium, led by the RD&I Basque center AZTI, includes a multidisciplinary team of partners bringing together technology device developers (BiMEP and IDOM from Spain and AW-Energy from Finland), Environmental Impact Assessment consultants (WavEC from Portugal and CTN from Spain), academic experts and data managers (HIDROMOD from Portugal), aiming to involve the wider community of ocean energy key stakeholders from across Portugal and Spain. The project will run until October 2021 and specific details can be found in its recently launched website: http://wese-project.eu/.

SafeWAVE - Streamlining the Assessment of Environmental Effects of Wave Energy

Funded by the European Maritime and Fisheries Fund (EMFF) through is Executive Agency for Small and Medium-sized Enterprises (EASME) and launched in November 2020, 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 (WE) projects in EU. The SafeWAVE Consortium, led by the RD&I Basque center AZTI, includes a multidisciplinary team of partners bringing together technology device developers (BiMEP from Spain, WELLO from Finland, CorPower Ocean from Sweden and GEPS Techno from France), Environmental Impact Assessment consultants (WavEC from Portugal, CTN from Spain and RTSYS from France), academic experts (University College Cork – National University of Ireland, Cork (UCC) from Ireland and Ecole Centrale de Nantes (ECN) from France) and data managers (HIDROMOD from Portugal), aiming to involve the wider community of ocean energy key stakeholders from across Portugal, Spain, France and Ireland. The project will run until September 2023.

ELBE PLUS

The ELBE PLUS project is part of the European Union's COSME "Cluster Go International" programme. ELBE aims to develop an internationalization strategy to contribute positioning Europe as a world technological and industrial leader in Blue Energy, witha focus on emerging areas such as offshore wind, wave and tidal energy. The consortium gathers seven European clusters in Scotland, Belgium, Sweden, Denmark, France and Norway, under the coordination of the Basque Energy Cluster. In the case of ocean energy, it specifically targets promotion of international cooperation with five countries: US, Canada, Japan, Taiwan and South Korea.

FLOTANT

FLOTANT is a H2020 funded project led by PLOCAN as a Project Coordinator. The main objective of the project is to develop the conceptual and basic engineering, including performance tests of the mooring and anchoring systems and the dynamic cable to improve cost-efficiency, increased flexibility and robustness to a hybrid concrete-plastic floating structure implemented for DWWF. Innovative solutions will be designed to be deployed in water depths from 100 m to 600 m, optimizing the LCOE of the floating solution (85-95 €/MWh by 2030). Prototypes testing of this offshore wind floating platform and its associated mooring, anchoring and dynamic cable systems are foreseen in relevant environment and real sea conditions within the scope of the project. Moreover, the assessment and optimisation of the construction, installation and decommissioning techniques will also contribute to bring down the current cost of offshore wind energy, as well as, increasing its deployment. The tests which will be performed in the test site area of PLOCAN will follow the appropriate standards (ASTM D3623 and ASTM D6990) for testing and evaluating antifouling resistance of selected materials containing different percentages of additives in the marine environment.

Galician Innovation Agency

The Galician Innovation Agency is an agency that aims to promote and structure innovation policies in the Galician public administrations, and to support and boost the growth and competitiveness of Galician companies, through the implementation of efficient innovation strategies and programmes. Currently, it is working in the new Smart Specialization Strategy 2021-2027, that will include the main challenges facing marine renewable energies.

TECHNOLOGY DEMONSTRATION

PROJECTS IN THE WATER

Open Sea Test Sites

A new open sea test site for MRE in Galicia was authorized in July 2020. The site is located in Punta Langosteira (Arteixo), close to the outer harbour of A Coruña. It provides a location for the temporary anchoring and the deployment of marine energy devices to test and validate them under real operating conditions in the open sea.

The Galicia test site is an ocean research, demonstration and operation of marine energy converters under real conditions in open waters, mainly wave energy converters. The test site allows to validate designs, components and materials of the devices, and to assess the technical and economic feasibility of the energy converters.

The main features of the Galicia MRE ocean site:

- Annual average energy flow: 20-30 kW/m
- Surface: 2.2 km²
- Depth: 20-60 m
- Distance from dock: 500 m
- Total electrical capacity: 20 MW (to be installed)

BiMEP

BiMEP is an open sea test area located off the coast of Armintza, in the province of Bizkaia. 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. In 2020 the company **WELLO OY** (from Finland) signed a contract to test its prototype PENGUIN2 at BiMEP for two years. The project has been delayed firstly due to the COVID19 pandemic and later due to winter weather.

HarshLab

HarshLab is an advanced floating laboratory for the evaluation of standardized probes and components in an offshore environment developed by TECNALIA. It is suitable to test new materials and solutions against corrosion, ageing and fouling in real and monitored conditions. The first version of HarshLab was installed at BiMEP in September 2018. It can handle up to 125 samples in atmospheric zone, 320 in splash and 320 in immersion (765 probes in total). Since its commissioning in September 2018, HarshLab hosted more than 500 samples coming from 19 industrial companies, including materials from H2020 projects, such MARINET2, NEWSKIN and NEMMO. TECNALIA is working on a bigger and more complex second version, with more functionalities for testing components and subsystems applicable to offshore technologies, including ocean energy. Detail design of this second version was performed in 2020 and the structure will be commissioned in BiMEP during summer 2021.

HarshLab deployed by TECNALIA at BIMEP during an inspection

Other test campaigns were carried out at BiMEP in 2020 by the company **ZUNIBAL**, its oceanographic buoy ANTEIA obtaining very good results to collect, in real time, height, direction and period data, as well as the water temperature.

Arrecife

Arrecife is a floating system whose functioning is based on several cross-flow turbines; for that reason, it is able to work with waves, tidal and river currents. Its turbines are strategically disposed to oppose the waves and to break them in order to capture both the horizontal (kinetic) and vertical (potential) energy components of the wave, imitating the behavior of a coral reef. Throughout the summer of 2019, Arrecife Energy Systems tested its 1:3 scale prototype at the BIMEP area and in real sea conditions for the first time. That was a key highlight that set the path and led the start-up to test, during 2020, small units at sea and rivers. These units offer a solution for small power needs, such as houses located in remote areas. COVID19 pandemic has delayed the works planned for 2020.

Mutriku Wave Power Plant

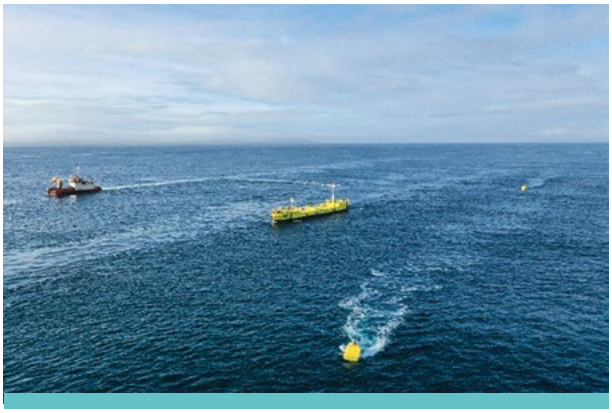
Mutriku Wave Power Plant, the first multi-turbine wave energy facility in the world, has been integrated in BiMEP infrastructure, being now a second facility of BiMEP. The plant was connected to the grid in July 2011, reaching a record of cumulative energy from waves powered to the grid of more than 2 GWh, milestone that was reached in February 2020. Two of the air chambers are prepared to test OWC components (air turbines, electrical generators, power converters and control systems).

PLOCAN

PLOCAN offers a 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 around a test tank to facilitate sea trials and launching vehicle to the sea. In autumn 2020 WAVEPISTON deployed its first full scale device at PLOCAN. Going for full scale demonstration Wavepiston reaches a new milestone in its development of a commercial wave energy device. The first short test string with two energy collectors attached have been assembled in the Port of Las Palmas Gran Canaria and has been installed at the test site at Plataforma Oceánica de Canarias, being now ready for the first round of testing and to deliver the desired results, demonstrating that it works in real-life conditions.

Magallanes Renovables

Galicia-based company Magallanes Renovables with its 1.7 MW power platform has been installed since February 2019 in Fall of Warness, in Orkney. Since 2019 August 1, continuous and autonomous energy is being produced, pouring into the UK network. During the year 2019, Magallanes Renovables was been able to validate the operability in real conditions and the performance obtained, demonstrating that the model is ready to begin its commercialization. During the year 2020, Magallanes Renovables has continued validating the generation and maintenance model and start commercialization in projects such as Morlais and in the EMEC.



Source: Magallanes Renovables

PLANNED DEPLOYMENTS

PENGUIN2

During 2021 the arrival of PENGUIN2, wave energy device of WELLO OY, is expected at BiMEP. The device is going to be tested in the frame of an alliance of WELLO OY and SAIPEM. The device started in autumn 2020 the travel from Scotland to the Port of Bilbao, close to BiMEP, but bad weather conditions forced to suspend the towing and wait to spring for better sea conditions. PENGUIN2 is expected to be at BiMEP in Spring and will start its two year test campaign. This campaign will receive the support of MARINET2, BLUEGIFT and Basque Energy Agency (EVE) support program.

RELEVANT NATIONAL EVENTS

Due to COVID19 pandemic 2020 has been a difficult year for events. In some cases they have been substituted by webinars adapting the sessions into different days and formats. The first part of 2021 is not going to be different. And hopefully during the last part of the year some events would start to become a reality.

EVE together with BEC (Bilbao Exhibition Centre), and the collaboration of TECNALIA, will organise in 2021 the fifth edition of Marine Energy Week as part of a wider maritime event “World Maritime Week”, if the pandemic situation allows it.

3.20 SWEDEN

AUTHORS
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OVERVIEW

In 2020, the Swedish ocean energy research community has taken crucial development steps, furthering e.g. the understanding of key components (such as cables, mooring and anchoring systems), array design and optimization as well as techno-economic optimization. Furthermore, several Swedish developers have progressed significantly with their respective technologies, proving their concepts and moving closer to commercialization. For example, Minesto has reached the milestone of delivering electricity to the Faroese grid, while CorPower has completed manufacturing of their full-scale C4 WEC module. Funding for research and innovation was provided e.g. by means of a €3 million funding call from the Swedish Energy Agency, which focused on the development of cost-efficient, sustainable marine energy systems in Sweden, knowledge exchange and value chain development.

SUPPORTING POLICIES FOR OCEAN ENERGY

NATIONAL STRATEGY

In 2016, the government together with several other political parties agreed on a long-term bipartisan energy policy for Sweden. The agreement includes a target of 100 percent renewable electricity production by 2040 and no net emissions of greenhouse gases in the atmosphere by 2045. Furthermore, a new Climate Act was introduced in 2018, which states that each government has an obligation to pursue a climate policy based on the climate goals adopted by the Riksdag. In the beginning of 2020, the government additionally published Sweden's integrated national energy and climate plan[8], which presents how Sweden contributes to reaching the European Union's goals in renewable energy and energy efficiency by 2030.

8 The complete document in English can be found here:
https://ec.europa.eu/energy/sites/ener/files/documents/se_final_necp_main_en.pdf

In 2015, the Ministry of Enterprises, Energy and Communications enacted a national maritime strategy[9] which identifies areas where action is needed to promote a sustainable development in the Swedish maritime sector. Ocean energy is one of many areas included. However, there is no national energy policy specifically for ocean energy.

In December 2019 Swedish Agency for Marine and Water Management submitted the Swedish marine spatial plan proposals to the Swedish government. The government will decide on the plans by March 2021 the latest. Marine spatial planning will form the basis for governmental agency and municipal decisions regarding the most appropriate usage of a marine area, taking into account the character and location of the area and the existing needs. No specific area has been designated for ocean energy usage to date.

MARKET INCENTIVES

The long-term Swedish energy policy relies on economic policy instruments, including a carbon tax, international emissions trading and a renewable electricity certificate system. These instruments provide incentives for renewable energy while remaining technology neutral. 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 program was started. The activities and priorities of the program are formulated in the Swedish Energy Agency's strategy for ocean energy, which was finalised in 2017[10]. The programme ends in 2024 and has a total budget of around 10,2 MEuro. Since 2018 there has been a research call each year, resulting in a total number of 21 funded projects. The programme supports research, experimental development and demonstration of technical solutions within the following focus areas:

- Improved knowledge regarding environmental impact during installation, operation and decommissioning
- Improved reliability and durability
- Development of systems, subsystems and components for cost-effective conversion of marine energy
- Tests and demonstration of systems in marine environments
- Improved installation, operation and maintenance strategies

The Swedish Energy Agency is also involved in OCEANERA-Net Cofund, which is a collaboration between national/regional funding organisations and the EU to support the ocean energy sector and fund transnational projects.

9 A summary in English can be found here: http://www.government.se/contentassets/9e9c9007f0944165855630ab4f59de01/a-swedish-maritime-strategy-for-people-jobs-and-the-environment

10 http://www.energimyndigheten.se/nyhetsarkiv/2017/energimyndigheten-antar-strategi-for-havsenergi/

RESEARCH & DEVELOPMENT

Swedish companies, universities and institutes have been involved with several research and development projects during 2020. Below are just a few examples.

Untapping Blue Energy – Improving water pre-treatment for harvesting osmotic power

Current methods to utilize the osmotic energy that is released when two streams with different salinity mix are membrane-based technologies that suffer from membrane fouling. To overcome this issue, pre-treatment processes, that are highly energy intensive, are employed prior to the membranes. In this project, the pre-treatment processes are improved to reduce the power demand by exploring different membrane materials and mitigating the fouling issue by ozonation. In the current phase of the project, a test rig is being built to evaluate the interaction of dissolved ozone with membrane materials under controlled lab conditions. Also, tests with simulated sea water and fresh water are being used to determine the dosage of ozone required for reducing membrane fouling. Results of the lab tests will be used for designing a membrane based osmotic power generation process and to evaluate the system performance taking into account the energy demand for the pre-treatment and pumping of sea water and fresh water. Based on this, the effectiveness of the ozonation pre-treatment on the overall power generation capacity will be investigated and quantified. The project is being carried out by KTH Royal Institute of Technology in collaboration with Ozone Tech Systems AB.

Uncertainty analysis of numerical wave energy simulations - IEA OES Task 10

A large number of computational methods for wave energy simulations have been benchmarked in a code-to-code comparison study in the IEA OES Task 10. A group of Swedish participants (Chalmers University of Technology, RISE, SSPA and Uppsala university) is contributing to the study with the uncertainty analysis of advanced non-linear methods. The results from the uncertainty study will be included in a best practice guide for advanced non-linear methods.

INTERACT - Analysis of array systems of wave energy converters (WECs)

This project is developing new design and assessment methods together with advanced simulation models that can be used to design array farms, accounting for interaction effects for optimum system performance e.g. power, fatigue life, LCoE. This is achieved by systems engineering, risk analyses and fully coupled hydrodynamic and structure response simulations. Several show cases of different WEC technologies, sites of operation and array systems are simulated, analysed and optimised. The project is carried out by Chalmers University of Technology, NKT Cables AB, RISE Research Institutes of Sweden, CorPower Ocean AB, Waves4Power AB, Novige AB and Seaflex AB.

WAVEMEASURE - Control of wave energy converters based on wave measurements, for optimal energy absorption

By placing three wave measuring buoys (Wave-rider buoys) in a triangle at a suitable distance from each other with a wave power buoy in the middle, the wave field between the Waverider buoys and the spread of the wave field will be defined. This information, combined with information about the radiating waves emitted by the wave buoy itself, will form the basis for developing statistical methods for control algorithms for parameters in the wave power buoy's control system. This will define when the power plant is switched on and off, which pressure is to be selected at any time regarding incoming waves and when the system is to be storm-proofed due to risk of overload. The project participants are Chalmers University of Technology, Waves4Power AB, BlueOrbis AB, Delacroy IT-consult AB, Lund University and Siemens AB.

SEASNAKE (OCEANERA-Net Cofund)

This project aims to provide a step change in the overall performance of medium voltage cable systems - ensuring that they are highly reliable while reducing the risks of ocean energy installations. Project objectives are:

- to increase the economic viability of OWC systems by reducing the LCOE by at least 20%.
- to prove that 95% availability can be achieved with an improved design for reliability, maintainability and survivability of all cable sub-systems, validated in a relevant environment, reaching TRL7.
- de-risk and optimise the offshore operations.
- demonstrate dynamic cable solutions.
- minimise environmental impact.

The project is carried out by RISE Research Institutes of Sweden, Chalmers University of Technology, CorPower Ocean AB, I-Tech, MWA Coatings, NKT Cables AB, Ocean Harvesting Technologies, Université Gustave Eiffel, WavEC, Waves4Power AB and WaveVenture.

WECs in Survival Conditions: Augmenting Linear Models Using Machine Learning.

The project aims to improve the performance of linear hydrodynamic models in the survival design of WECs. This will be achieved by establishing novel procedures to extract nonlinear terms using machine learning based on data obtained from hierarchical hydrodynamic modelling. Participants are RISE and Sigma Energy & Marine AB.

De-Risk PTO by control the marine biofouling and corrosion

The project aims to validate solutions for the piston rod and sealing system within wave energy devices which handle marine growth, corrosion and wear to ensure the operational life expectancy of the internal protective seals. Tests will be carried out in accelerated forms in lab environments as well as in field environments at Kristineberg innovation and research stations, the Corpower test facility in Stockholm and WavEC´s test site in Portugal. The results will contribute to increased knowledge and optimisation of suitable protective coatings and their durability in environments relevant for wave energy converters to predict service intervals. The project is conducted by RISE and CorPower.

Cost-competitive foundations for tidal turbines - CF2T

The project aims to develop, manufacture and monitor a hybrid concrete/steel turbine foundation for tidal turbines. The gravity-based foundation will be designed to decrease construction and deployment costs, with modular interfaces to allow an offshore installation in several packages in order to limit the required crane capacity on ships. Alternatives to reduce the structure construction costs and modularity will be evaluated. During 2020, RISE has developed the concrete mix, made a sensor literature study, developed a monitoring system and started durability tests in the laboratory. The foundation shall be manufactured during 2021. The project is carried out by SABELLA, ALLIA, SAITEC, RISE and ALKIT.

Improved reliability and survivability of mechanical wave energy subsystems

In this project the wave loads on mechanical wave energy components are measured and computed, and the impact on the survivability of the system is analysed. During 2020, several important steps were taken in the project:

- The experimental equipment of a 1:30 scale wave energy converter with linear damping was finalized and dry-testing showed expected performance at the wave tank facility at Ålborg University, Denmark.
- To investigate the mooring line dynamics and its impact on the survivability, the MooDy code was implemented in OpenFOAM and WEC-Sim.
- Failure mode effect analysis (FMEA) was conducted as a foundation for VMEA analysis. The severity and likelihood of failure of critical components of the Uppsala University WEC has been identified, and different load scenarios have been analysed.

The project is carried out by Uppsala University, Chalmers University of Technology, Plymouth University, RISE Research Institutes of Sweden and Ålborg University.

OESA – Ocean Energy Scale-up Alliance

The project's objective is to realize a transnational Pilot Accelerator Program by promoting a new Scale-up Service Offer, accelerating the deployment of five ocean energy pilots and engaging relevant stakeholders to stimulate greening of North Sea region. In this project, Uppsala University is collaborating with three technology developers Seabased Group (Norway), Floating Power Plant (Denmark) and Nemos (Germany), supporting the companies' development in different areas such as hydrodynamic modelling and optimisation, generator design, techno-economic optimisation of electrical infrastructure and grid integration, planning and implementation of tests (lab and offshore), experimental data analysis and numerical model validation.

Dragon park – optimisation of tidal energy arrays

This project aims to develop general simulation tools for the study of intra-array effects of tidal energy converters, and for the layout optimisation of tidal energy converters in an array. The project is carried out by the University of Gothenburg, with support from Minesto AB and Chalmers University of Technology.

UMACK - Universal Mooring, Anchor & Connectivity Kit Demonstration

The UMACK project addresses ocean energy affordability, survivability, reliability and installation through the demonstration of a generic anchor-foundation-mooring-connectivity system. The project aims to reduce capital and installation costs by up to 50% and is tailored for offshore installations in sites with sand and clay soil. UMACK brings together wave and tidal energy developers, CorPower (wave) and SME (tidal), mooring experts TTI Marine Renewables, Ternan Energy (offshore geotechnical experts), EMEC (an ocean energy test and verification facility), and University of Edinburgh (marine renewable energy modelling experts).

In 2020 the project has:

- completed several tank tests at the COAST wave tank in University of Plymouth.
- concluded design studies on a highly innovative anchor design optimised for cyclic loading of wave devices, allowing high structural efficiency and rapid low-cost installation.
- completed the detailed design of mooring and anchor, including full scale anchor and 1:3 scale test plan
- completed the tidal regulation concept and progressed with the detailed design.

The anchors, the foundation structure and the mooring system will be installed during the summer 2021.

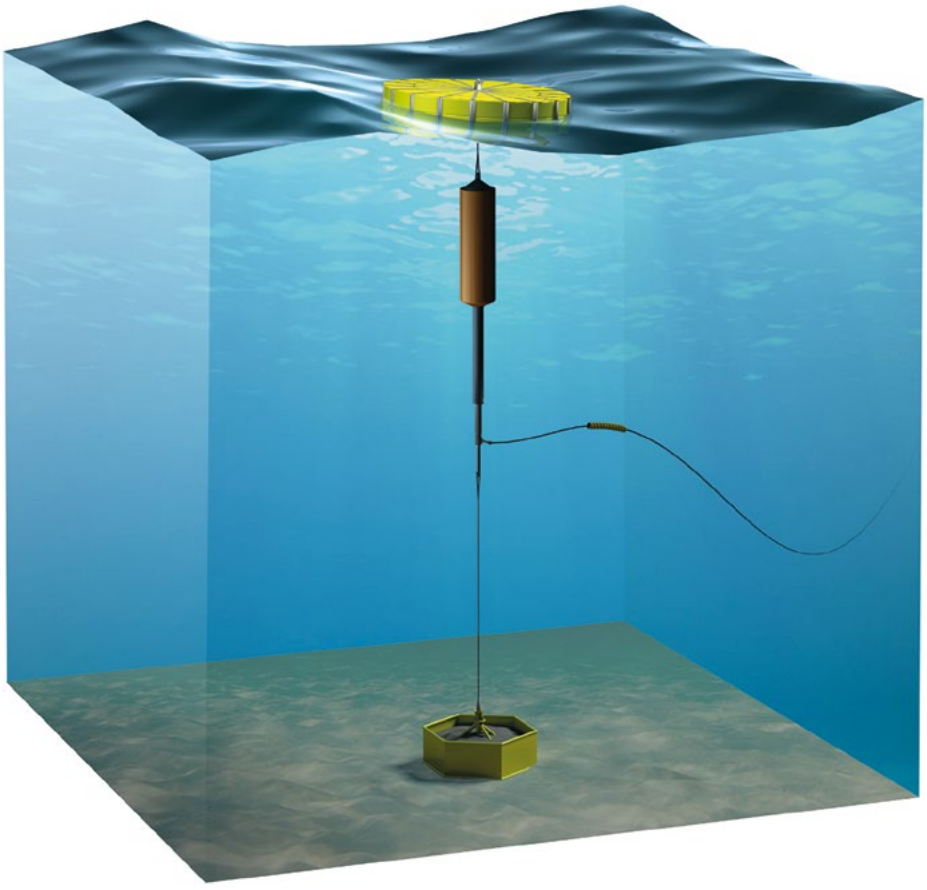
IWEC – Cost optimisation for the InfinityWEC Wave Energy Converter

Ocean Harvesting Technologies (OHT) is developing the InfinityWEC, a point absorber with a novel power take-off (PTO), using advanced reactive force control technology to achieve very high annual energy production relative to the size and cost of the WEC, and to provide a survivable and reliable system by detuning to limit loads.

This simulation driven and LCoE based design optimisation project was completed in 2020. The project started with a design update to generation 3 of the InfinityWEC, introducing major improvements. A time efficient simulation model (WEC-Sim) was first calibrated with CFD simulations, and then used to optimise design parameters such as buoy geometry and maximum PTO force for lowest CAPEX per average output. Finally, the annual energy and LCoE was calculated for 6 different sites. The result was an LCoE between 93 – 162 EUR/MWh at 100 MW deployed capacity, well in line with the 100 EUR/MWh objective.

Design validation of InfinityWEC´s power take-off in a HIL test rig at scale 1/10

OHT is now working on generation 4 of the InfinityWEC technology, with further improvements relating to using more standardised components and end-stop handling in the pre-tension system, and a more compact design of the PTO that fits in standard containers for road transportation. In August 2020, Ocean Harvesting started designing and building a test rig at scale 1:10 to validate the PTO and control system.



InfinityWEC wave energy converter

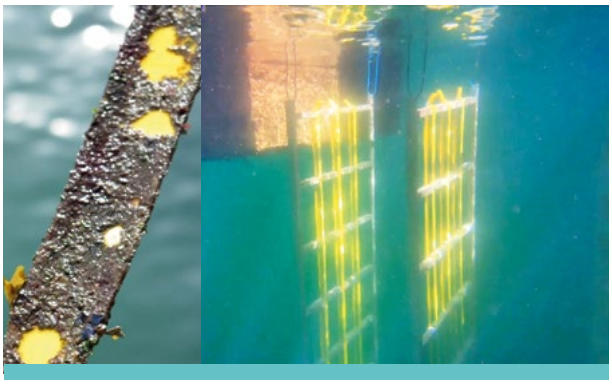
PROJECTS IN THE WATER

Uppsala university – Lysekil test site

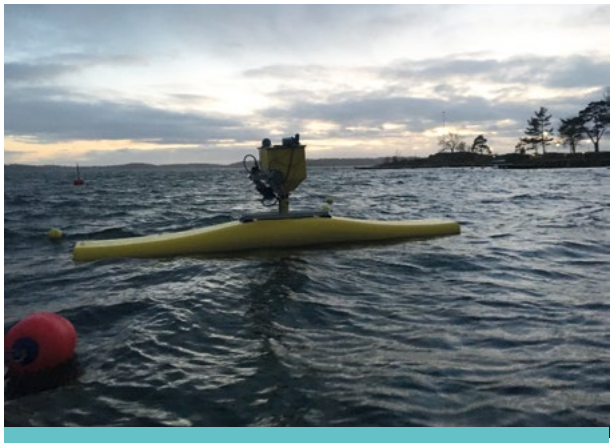
Data from a force measurement buoy deployed at the Lysekil test site in 2019 has been analysed by Uppsala university using extreme value methods and the results have been submitted to a scientific journal. The force measurement buoy was deployed again in November 2020 to collect data during the winter season and is currently in operation.

Seasnake project

Anti-fouling and coating tests have taken place at the Kristineberg test site in Sweden as well as in Lisbon, Portugal. Further, laboratory testing of the cable has been conducted in France (Université de Gustaf Eiffel).



Efficacy test of I-Tech Selectope biocide and MWA easy clean coating on a cable outer shell as tested in the Seasnake project at the test site in Lisbon Portugal and Kristineberg, Sweden.



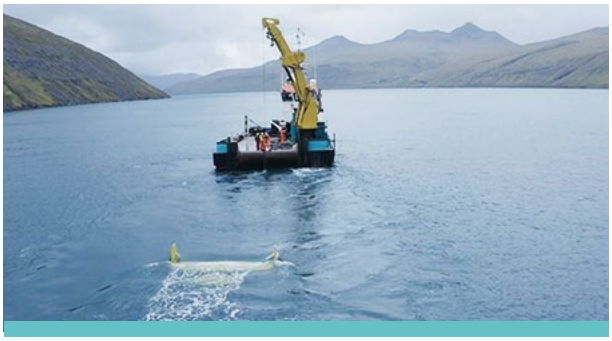
NoviOcean tested outside Stockholm

Novige/NoviOcean

Novige is developing a point absorber that via a basic hydraulic cylinder pumps high pressure water up to a Pelton turbine that runs a generator. From end of November 2019 to January 2020 a 1/5 scale unit was successfully tested offshore outside Stockholm, showing expected functionality, surviving one million cycles, as well as relatively harsh conditions, including ice and snow. In February/March the system was tested successfully for two weeks in Plymouth, COAST Laboratory, where the PTO was seen to be fully functional. These tests were followed by the construction of a new test rig.

Minesto - Deep Green Island Mode 2 (DGIM/2)

Minesto is developing a technology, called Deep Green, that can produce electricity from low-velocity tidal and ocean currents. This project aims to install two commercially viable tidal energy converters in a production and customer environment on the Faroe Islands. During 2020, the foundation and the onshore control station were installed, the export cable laid, and the Alpha power plant launched and connected to the Faroese grid at Minesto's open sea test site in Vestmannasund (the Faroe Islands). Minesto has reached the milestone of delivering electricity to the Faroese grid facilitated by the Power Purchase Agreement with the utility company SEV.



Deep Green tidal kite system in Vestmannasund, Faroe Islands

PLANNED DEPLOYMENTS

Novige/NoviOcean will continue fine-tuning their test rig during the first half of 2020 with new wave tank testing taking place most likely in the summer. This will be followed by offshore testing during the fall and winter of 2021.

Minesto will through the project **Deep Green Phase 2** fund the design, construction and operation of the second-generation utilities-scale device at Holyhead Deep in 2022. (In 2018-2019 Minesto's phase 1 demonstration project was implemented at the Holyhead Deep site, with the installation of a 500 kW turbine.) Minesto is additionally working on obtaining the necessary permits for the deployment of 1x 100 KW device at the EDF owned Paimpol Bréhat site (**TIGER - Tidal Stream Industry Energiser Project**). The deployment is scheduled to take place in Q2 of 2022, with the testing period scheduled to run until the Q3 2022. The TIGER project aims to install up to 8 MW of new tidal capacity at sites in and around the Channel region while delivering new designs for improved performance and lower cost tidal turbines, as well as associated infrastructure and ancillary equipment.

CorPower Ocean is developing compact high-efficiency WECs, inspired by the pumping principles of the human heart. The project **HiWave-5** is CorPower's flagship demonstration project. It is designed to prove the survivability, performance and economics of a grid-connected array consisting of four full scale devices, with type certification from DNV-GL. HiWave-5 is performed in two stages:

- Stage 4 (2020-2022): Demonstration and prototype certification of a single device full scale C4 WEC, taking the technology from TRL 6 to TRL 7.
- Stage 5 (2022-2024): Demonstration and type-certification of a pilot array with three additional C5 WECs, taking the technology from TRL 7 to TRL 8.

CorPower PTO assembly & dry-test facility in Stockholm

The activities and deliverables of HiWave-5 have been carefully designed in dialogue with customers and stakeholders including EDP, Simply Blue Energy, ENEL, and oil & gas companies. The Agucadoura site in northern Portugal is the same site that was used by EDP and Principle Power to demonstrate Windfloat.

During 2020 the C4 WEC modules were manufactured, and system assembly started in CorPower's new full-scale PTO facilities in southern Stockholm. In parallel the installation and commissioning of a large dry test rig with 7.2 MW of simulated waves has been completed in collaboration with ABB. Towards the end of 2020 a temporary machine hall facility in Portugal was completed, which is designed to support the fabrication of full-scale composite hulls as well as assembly and maintenance work of WECs.

RELEVANT NATIONAL EVENTS

OffshoreVäst Annual Conference 23 & 24 January 2020, Gothenburg

The theme for the conference was "From Innovations to International Business" and laid the foundation for new research projects, collaborations and the future course for OffshoreVäst.

3.21

UNITED KINGDOM

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OVERVIEW

Despite being a challenging year, 2020 saw continuous innovative cross-border collaborations, deployment of state-of-the-art projects and offshore tests being undertaken for the ocean energy sector. The UK is home to the first tidal stream arrays in the world and has already deployed more wave and tidal energy devices than the rest of the world. The UK ocean energy sector continued to reach new milestones this year, with the European Marine Energy Centre (EMEC) achieving the world's first ocean energy Renewable Energy Testing Laboratory (RETL) designation, the highest international appointment for marine energy test laboratories awarded by the International Electrotechnical Commission – Renewable Energy System (IECRE). 2020 also marked the 1st year of the TIGER project (Interreg's largest ever project, led by ORE Catapult) to evidence tidal stream cost reduction and Nova Innovation's world first tidal array successfully powering the Shetland Islands for over five years. With the fourth round of the Contracts for Difference (CfD) scheme of 2021 to be open for bids from the tidal sector, a dedicated policy and revenue support for ocean energy would deliver significant sustainable economic benefits. Also, separation of wind technologies into a separate category (Pot II) shall create more opportunities for ocean energy technologies. However, a reduction in technology costs is still required for the sector to compete with alternative low-carbon technologies and contribute towards achieving the UK's net-zero target.

Wave

In 2020, the wave energy sector continued to engage in innovative R&D to drive the sector towards design convergence and commercialisation:

- Wave Energy Scotland (WES) continues to be the focus for wave energy R&D activity in the UK in terms of funding provision for wave energy innovation and demonstration. In 2020, the programme awarded £1.4 million to four projects developing quick connection systems to improve the installation efficiency and infrastructure of wave power devices.
- EMEC worked closely with the WES Novel Wave Energy Converter developers AWS and Mocean who are gearing up to test at EMEC in 2021. Throughout 2020, EMEC also partnered with Seabased Group to design and implement a testing programme which will support Seabased's certification goal, crucial to driving quality-controlled manufacture whilst reducing sectoral costs.
- The Welsh European Funding Office (WEFO) in Wales also continues to contribute significantly to wave R&D with £30.4M being allocated for wave energy development since 2014.
- In July 2020, Bombora transported the full scale 'cell module' structure, a key component part of the 75-meter-long subsea mWave, from the fabrication workshop to the assembly workshop.

Tidal Stream

In 2020, many tidal stream projects continued to progress towards commercialisation:

- Orbital Marine Power has been busy manufacturing the next generation technology, the O2, its first commercial turbine, due to be installed and tested at EMEC in 2021.
- Magallanes' test of their second generation, 2 MW tidal platform 'ATIR', as part of the H2020 Ocean_2G project led them to secure additional test site access support via the MaRINET2 and OceanDEMO projects. Following some routine maintenance taking place at Leith Imperial Dry Docks, the ATIR will return to EMEC's Fall of Warness tidal test site in early 2021.
- Towards the end of 2020 EMEC and Perpetuus Tidal Energy Centre (PTEC) signed a partnership to develop a large-scale tidal energy site off the Isle of Wight in England. The project provides a clear market signal to the tidal stream sector in the UK, committing resources and time to further the development and commercialisation of tidal stream devices. The partnership builds on work towards the development of the £41 million Interreg Channel funded TIGER project, which will ready five sites in France and the UK for tidal energy developments.
- Nova Innovation celebrated its 10th birthday with the successful expansion of the Shetland Tidal Array. In October 2020, the company confirmed the installation of its commercial direct-drive tidal turbine "Eunice", the first of three turbines set to double the size of the world's first Tidal Array as part of the EnFAIT project, making tidal energy a commercial reality. Additionally, in September 2020 the Scottish tidal developer also announced a $4 million investment from Natural Resources Canada for Phase 1 of its 1.5 MW tidal array in the Bay of Fundy area of Nova Scotia, Canada.
- In October 2020, Minesto installed and commenced commissioning activities of its 100 kW DG100 tidal kite system in the Vestmannasund strait, Faroe Islands. By December, it successfully delivered electricity to the Faroese grid facilitated by Power Purchase Agreement with the utility company SEV.

SUPPORTING POLICIES FOR OCEAN ENERGY

NATIONAL STRATEGY

The UK Government's Department for Business, Energy, and Industrial Strategy (BEIS) retains overall responsibility for energy policy in the UK while powers related to planning, fisheries and the promotion of energy efficiency are devolved to the governments of Scotland, Wales, and Northern Ireland.

While preparing to host the 26th UN Climate Change Conference (COP26) in 2021, the UK has set out new plans to establish itself as the world leader in clean wind energy by creating jobs, slashing carbon emissions, and boosting exports. To accelerate the progress towards the UK's net zero emissions by 2050, the government has announced "The Ten Point Plan for a Green Industrial revolution" in November 2020, which plans to mobilise £12 billion of government investment and three times as much of private investment to create and support up to 250,000 green jobs. As a part of the Green Industrial revolution, the government also mentioned that the fourth round of the Contracts for Difference (CfD) scheme of 2021 will be open to bids from the tidal sector. This is expected to not only double the capacity of renewable energy but also extend the investment and policy support provided to multiple technologies. Absence of a capacity specifically ringfenced for marine energy, makes it difficult for the sector to compete with the more advanced technologies. But the government has committed to look into the role of wave and tidal in the "Energy White Paper" published in December 2020.

In June 2020, the Committee on Climate Change (CCC), the UK's independent climate advisory body published a series of very important publications. This includes the 2020 Progress Report to the UK Parliament, the 2020 Progress Report to the Scottish Parliament and the Sixth Carbon Budget report. Following the COVID-19 pandemic, the report to the UK Parliament, "Reducing UK emissions: 2020 Progress Report to Parliament", sets out series of recommendations to the UK Government on securing a green and resilient recovery. Assessing the progress made by the UK since 2008, it prioritises the need for climate policy and investments to be made in the coming year to achieve the net zero ambitions across the whole UK economy.

Scotland

Scotland's climate change legislation includes a commitment to reduce Scotland's emissions by 75% by 2030 (compared with 1990) and to net zero by 2045. An update to Scotland's Climate Change Plan, published in December 2020, charts a pathway to emissions reduction targets out to 2032 and outlines the Scottish Government's approach to delivering a green recovery from the COVID-19 pandemic. The Scottish Energy Strategy sets out the Scottish Government's vision for the future of the energy sector to 2050 and maps out a transition which is consistent with the ambitions in Scotland's climate change legislation. The Energy Strategy is defined by a whole-system approach and includes a target to meet the equivalent of 50% of Scotland's heat, transport, and electricity consumption from renewable sources by 2030.

The Scottish Government continues to champion the ocean energy sector, supporting the research, development, innovation, and demonstration intended to maintain Scotland's position as a world leader in both wave and tidal energy. Since 2014 the Scottish Government has invested nearly £50 million in its internationally recognised Wave Energy Scotland programme which will see the deployment of two prototype wave energy convertors in real-sea conditions in Scotland in 2021. In 2019-20 the Scottish Government awarded around £5 million from the Saltire Tidal Energy Challenge Fund to two innovative tidal energy projects which will be deployed in Scottish waters. The Scottish Government also continues to support a working group which enables industry, academia, and the public sector to work together towards the further development of Scotland's marine energy sector.

Marine Scotland, the Directorate of the Scottish Government responsible for the management of Scottish seas, including planning and licencing of marine energy projects, published "The 2020 Sectoral Marine Plan for Offshore Wind Energy". This document sets out the most sustainable plan options for the future development of commercial offshore wind energy in Scotland. The draft Plan Options provide the spatial footprint for the ScotWind Leasing round, managed by Crown Estate Scotland.

Crown Estate Scotland (CES) is a public corporation which, as part of its duties, manages Scottish seabed leasing for renewable energy projects out to 200 nautical miles (nm). It delivered £12m for Scotland's communities in the 2019/20 financial year, which will be returned to The Scottish Government for public spending and to aid Scotland's green economic recovery. Crown Estate Scotland currently operates an open leasing application process for wave and tidal developers, for non-competitive sites up to a maximum of 30 MWs. Additionally, in 2020 the Crown Estate launched the first cycle of ScotWind leasing, which will potentially award up to 8,600km2 of the seabed for bids from offshore wind developers.

Wales

The Welsh Government is committed to unlocking the renewable energy potential from Welsh waters by supporting the delivery of marine energy projects. The Welsh Government has a 70% renewable electricity mix contribution target by 2030, a proportion of which should come from marine sources. For this, the Welsh Government has allocated £100.4m of European Union (EU) structural funding over the next 5 years for marine energy through the Welsh European Funding Office (WEFO). The fund is aimed at establishing Wales as a centre for marine energy production by increasing the number of wave and tidal energy devices being tested including multi-device array deployments.

Marine Energy Wales (MEW) is the industry led stakeholder group representing the wave, tidal (stream and range) and floating offshore wind industries in Wales. MEW brings together project and technology developers, test centres, wider sectoral alliances, the supply chain, academia, and the public sector to establish Wales as a global leader in sustainable emerging offshore energy generation. Their vision is to create a thriving and diverse emerging offshore renewables industry in Wales that brings with it the combined benefits of climate change mitigation, reliable contributions to the national energy mix, jobs, and economic development in coastal, peripheral zones along with large-scale future export potential.

Over £123.7 million has been spent to date in Wales on the development of the marine energy industry. This figure is increasing annually with rising interest to invest in Wales and a strong policy drive to support the sector. The MEW 2020 State of the Sector Report details that a total of 16 developers are actively progressing projects in Wales with seabed agreements in place for over 532 MW of sites. Through the Morlais energy project in North Wales, the Marine Energy Test Area in Milford Haven and TIGER's Ramsey Sound site along with the ORE Catapult Marine Energy Engineering Centre of Excellence, Wales has an excellent world-class suite of Test and Innovation Sites. These will continue to attract not only the interests of UK based technology developers, but also further the inward investment successes already achieved from countries including Sweden, Canada, France, and Spain.

The 2020 developments recently announced through this organisation include:

- The Welsh Government, through the European Regional Development Fund (ERDF), will provide funding of £1.2 million to Nova Innovation towards its ground-breaking Enlli tidal energy project. The project will potentially transition "The Island in the Currents" to be the world's first blue energy island.
- Swansea-based Marine Power Systems (MPS) has secured a crowd funding support of over £2m in August 2020 apart from the £12.8m of EU funding awarded last year to support the next stage of project phase. With this, MPS is now set to build their first commercial wave demonstrator device in Wales.
- In June 2020, Pembrokeshire received the green light for a £60m funding for a marine energy project. The Swansea Bay City Deal project as part of the North Wales Growth Deal, will seek to deliver; The Marine Energy Test Area led by Marine Energy Wales and supported on the ground by EMEC from April 2020, a 90 square kilometre Pembrokeshire Demonstration Zone led by Wave Hub, modernised port facilities by the Port of Milford Haven and the Marine Energy and Engineering Centre of Excellence (MEECE) by ORE Catapult.

Marine Energy Council

The UK Marine Energy Council (MEC) was formed in 2018 by a collaboration of the leading wave and tidal developers, to engage with the Government and other stakeholders as a unified sector. Apart from technology and project developers, MEC members include supply chain companies, consultants, as well as leading industry associations, e.g., Renewable UK, Scottish Renewables, Marine Energy Wales, and the Offshore Renewable Energy Catapult (OREC). The objectives of the MEC, which was formally incorporated in 2020, are to:

- progress from the OREC cost reduction advisory group, encouraging collaboration across the sector and supporting the policy positions for delivery of marine renewables; and
- lead the development of the sector both in the UK and internationally, as well as delivering a work programme to support the growth of the wave and tidal sector through the development of a UK market.

On September 2020, the MEC presented a detailed response to the UK Secretary of State for BEIS stating how the wave and tidal stream sector could generate a net cumulative benefit of £4.0bn by 2040 and £1.4bn by 2030, respectively. Moreover, strategic support for the wave and tidal sector would result in achieving three key objectives: a boost to UK manufacturing and jobs; practical application of the 'Green Transition' as a route to post-pandemic recovery; and a major export opportunity in technologies where the UK currently leads the world. Urging the need for strong support, the MEC put forward three measures that would be influential in realising these opportunities: Contract for Difference (CfD) reforms, a strategic vision and support to technology developers through the *Innovation Power Purchase Agreement (IPPA)*.

MARKET INCENTIVES

Contracts for Difference (CfDs)

The UK Government continues to offer revenue support to a variety of renewable energy technologies through the Contract for Difference (CfD) programme. Based on top-up payments to a strike price, CfDs offer long-term price stabilisation and are awarded via competitive auctions. Ocean energy technologies are however yet to gain a CfD through the competitive auction process, primarily because they have been in the same CfD 'pot' as established, mature technologies such as offshore wind.

Last year during the third round of auctions in May 2019, twelve projects, of which six offshore wind, four remote islands wind and two-advanced conversion technology projects secured the contracts. For the upcoming fourth round of CFD auction in 2021, BEIS has decided to allocate support for up to 12 GW of new renewables projects. Through this, the government aims to double the capacity of renewable projects deployed and provide support to the less 'established technologies' including floating offshore wind, Advanced Conversion Technologies and tidal stream. Also, separation of wind technologies into a separate category (Pot II) will enable ocean energy technologies to compete more fairly if further CfD reform is undertaken.

Seeking views from stakeholders and interested parties on proposed changes to the scheme, the government published its "Contracts for Difference (CfD): proposed amendments to the scheme" consultation document. Building on the consultation and the significant number of responses, a further 'Call for Evidence' was issued that sought views on the scope for deploying other innovative marine energy technologies such as floating offshore wind, wave energy and tidal stream energy.

PUBLIC FUNDING PROGRAMMES

In the last few years, the UK Government has made available some public funding alternatives to support the development of the ocean energy sector. Some of these programmes and initiatives are described in this section.

UK Research and Innovation (UKRI)

In operation since April 2018, UKRI brings together seven research councils to support and coordinate research and innovation in the UK. Independently chaired, UKRI has a £6 billion budget funded primarily through the Science Budget by BEIS. The research councils and bodies operating within UKRI are the Engineering and Physical Sciences Research Council (EPSRC), Innovate UK, Arts and Humanities Research Council (AHRC), Biotechnology and Biological Sciences Research Council (BBSRC), Economic and Social Research Council (ESRC), Medical Research Council (MRC), National Environment Research Council (NERC), Research England, and the Science and Technology Facilities Council (STFC). In May 2020, NERC and ESRC together announced research applications to address the objectives of the new Sustainable Management of UK Marine Resources (SMMR) research programme. Worth £12.4m, the programme is run in partnership with the Department for Environment, Food and Rural Affairs (Defra) and Marine Scotland. In June 2020, the EPSRC announced another call to fund research proposals in Marine Wave Energy with an approximate funding of £4.5 available to support 4-5 grant proposals. The two calls closed in October and September 2020, respectively.

https://www.ukri.org/

Innovate UK

A member of UKRI, Innovate UK is a funding body that supports businesses in their development of new technologies and concepts, helping them to reach commercial success. Innovate UK awards grant and loan funding across all sectors to business-led and high-value innovation in the UK. The organisation also cultivates networks between innovators and investors, researchers, industry, policymakers, and future customers on a domestic and international scale.

https://www.gov.uk/government/organisations/innovate-uk

Wave Energy Scotland (WES)

WES continues to use Scottish Government funding to support an innovative and unique approach to the development of wave technology. The WES programmes drive innovative technology projects towards commercialisation through a competitive stage gate process. The stages of R&D activities guide projects from concept to prototype testing. Funding calls have targeted development of wave energy devices, power take-off systems, control systems, quick connection systems and materials. Subsystem hardware from the programme has been demonstrated in Scottish waters during 2020, and preparations are being made for the deployment of two half-scale wave energy converters around Orkney, in Northern Scotland, in early 2021.

https://www.waveenergyscotland.co.uk/

RESEARCH & DEVELOPMENT

This section contains an overview of the primary research institutions and their core project activity in 2020.

KEY R&D INSTITUTIONS

Supergen Offshore Renewable Energy (ORE) Hub

The Supergen ORE Hub was established in July 2018 with £5million of funding from the Engineering and Physical Sciences Research Council (EPSRC), and subsequently was awarded a further £4m in June 2019. Led by the University of Plymouth the Supergen ORE Hub brings together expertise from multiple UK institutions including University of Edinburgh, University of Aberdeen, University of Exeter, University of Hull, University of Manchester, University of Oxford, University of Southampton, University of Strathclyde, and University of Warwick. The mission of

the Supergen ORE Hub is to provide research leadership to connect stakeholders, inspire innovation and maximise societal value in offshore renewable energy. Some key updates as announced by the organisation are as follows:

- In January 2020, the Supergen ORE Hub organised a workshop to develop a sector roadmap for wave energy, bringing the wave energy sector to the attention of policymakers and setting out suggested routes for its development considering the UK's net-zero carbon targets. The wave energy sector roadmap was subsequently cited in a £4.5m funding call on Marine Energy from EPSRC in Spring 2020.
- In July 2020, the Hub, through its second Flexible Funding programme, awarded almost £1.2m to UK universities to support ambitious research projects investigating all aspects of offshore renewable energy (ORE). This second round of funding follows the £1 million awarded by the Hub in 2019 to ten projects in its first round of Flexible Funding.
- In autumn of 2020, the Hub, with the Supergen Energy Networks Hub and Supergen Energy Storage Network+, hosted a round of cross-hub workshops. The workshops focussed on bringing together cross-disciplinary researchers and industry to discuss potential new research proposals that would address new challenges in Offshore Renewable Energy Transmission & Storage (Technology & Pathways) and Co-Design of Offshore Renewables with Network & Storage Vectors (Future systems). The three Hubs are subsequently providing seedcorn funding, via a competitive application process, to cross-discipline research groups to carry out pilot studies to enable new and adventurous research, ultimately leading to further grant applications through existing funding bodies.
- In October 2020, the Hub together with Aura, an initiative from the University of Hull, published a report that outlines an action plan centring on short, medium and longer-term initiatives to help improve equality, diversity and inclusion in the engineering sector, with a focus on the offshore renewable energy industry and academia.

https://www.supergen-ore.net/

ORE Catapult

Offshore Renewable Energy (ORE) ORE Catapult is the UK's flagship technology and innovation research centre, combining research, development, demonstration and testing facilities with leadership, industrial reach, and engineering expertise. ORE Catapult accelerates design, deployment, and commercialization of renewable energy technology innovation. By the end of financial year 2019/2020, ORE Catapult had supported 803 Small Medium Enterprises (SMEs) and engaged in 556 academic collaborations and 802 industry collaborations. Currently, ORE is involved in the Tidal Stream Industry Energiser (TIGER) project, ELEMENT (Effective Lifetime Extension in the Marine Environment for Tidal Energy) project, MONITOR (Multi-model investigation of tidal energy converter reliability) project and the Ocean Energy Scale-Up Alliance (OESA) partnership. All these projects are accelerating development and cost reduction.

https://ore.catapult.org.uk/

KEY R&D PROJECTS

Funding Ocean Renewable Energy through Strategic European Action (FORESEA)

EMEC has led the €11m Interreg NWE project, FORESEA, since it was launched in 2016. The project, closed on March 2020, has been hailed an overwhelming success and was nominated for the 2019 EU Sustainable Energy Week Citizens' Awards. Having enabled 30 technologies to deploy across four European test centres (EMEC, DMEC, SEM-REV and SmartBay), FORESEA has enabled more ocean energy technologies to be tested offshore than any other project, including CorPower Ocean, Orbital Marine Power, Naval Group and Whitford.

https://www.nweurope.eu/projects/project-search/funding-ocean-renewable-energy-through-strategic-european-action/

Floating Tidal Energy Commercialisation (FloTEC)

The FloTEC project, led by Orbital Marine Power and funded by the EC's H2020 programme, is an ongoing project running from January 2016 to August 2021. Building on the success of their 2 MW floating tidal technology, the SR2000, the FloTEC project is focussed on the design, construction, and deployment of Orbital's commercial 'O2' technology and progressing a range of complementary innovations and activities including mooring load dampers, co-located energy storage design and environmental monitoring.

www.flotectidal.eu

Second Generation Technologies in Ocean Energies (Ocean_2G)

Funded by the EC's Horizon 2020 programme and managed by Magallanes Renovables, the Ocean_2G project was focused on testing, validating, and pre-certifying Magallanes' second generation 2 MW tidal energy platform solution, the ATIR. Launched in 2017, the project undertook several key innovations followed by a series of test programmes to demonstrate the operational performance of the prototype in open water conditions in Vigo, and then at EMEC where it was deployed in early 2019.

www.ocean-2g.eu

Enabling Future Arrays in Tidal (EnFAIT)

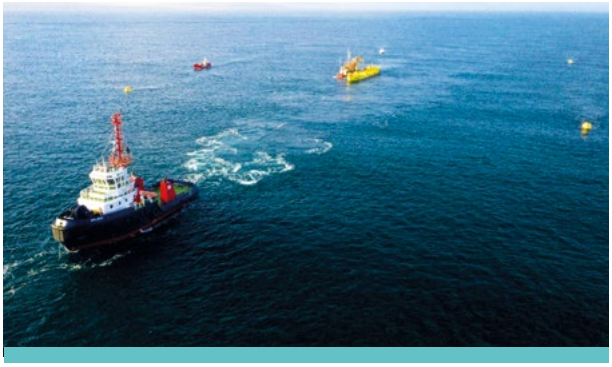
Funded by EU Horizon (H2020), the Enabling Future Arrays in Tidal (EnFAIT) project is a €20.2m project, which began in July 2017 and will run until June 2022. Led by Scottish tidal energy developer Nova Innovation, the project is a partnership of seven European companies and academic partners. EnFAIT builds on Nova Innovation's existing operational tidal array in the Bluemull Sound, in Scotland's Shetland Islands. It will extend the Bluemull Sound array from three to six turbines and demonstrate that high array reliability and availability can be achieved using best practice maintenance regimes. In 2020, with three turbines already operating, the fourth next generation direct drive turbine was deployed. Two of the three operating turbines were recovered for maintenance and redeployed this year. The next two direct drive turbines will be installed in 2021/2022.

https://www.enfait.eu/

Integrating Tidal Energy into the European Grid (ITEG)

Funded by the Interreg NWE programme, part of ERDF, the ITEG project has a total budget of €11m and is led by EMEC in Orkney. With EU funding of €6.46m, the project runs from 2017 to 2021 and aims to provide an integrated tidal and hydrogen solution for generating clean energy and, tackling grid export limitations faced in remote areas. Hydrogen will be produced from excess tidal capacity. With project partners from the UK, France, Belgium and the Netherlands, the project aims to drive down the costs of pre-commercial ocean energy demonstration by producing hydrogen using an AREVA H2Gen electrolyser, powered by Orbital's 2 MW O2 - the next generation floating tidal energy converter. In June 2020, Clean energy solutions provider, H2Tec Limited was chosen to perform program upgrades to EMEC's hydrogen production plant in Orkney that will in turn improve efficiency between the hydrogen plant and storage facilities at the Caldale site on Eday.

www.nweurope.eu/ITEG



Magallanes Renovables ATIR installation (Source: Colin Keldie)

DTOceanPlus

The EC H2020 funded DTOceanPlus is a €8m project running from May 2018 to April 2021. It is developing a suite of second-generation advanced design tools for the selection, development, and deployment of ocean energy systems. The project is led by Tecnalia and comprises 16 EU partners, including, from the UK: The University of Edinburgh, Wave Energy Scotland, Energy Systems Catapult, Orbital Marine Power, and Nova Innovation.

https://www.dtoceanplus.eu

Strategic Environmental Assessment of Wave energy technologies (SEAWave)

The SEAWave project, co-ordinated by EMEC, aims to address long-term environmental concerns around the deployment of wave and tidal energy converters in the marine environment. Launched in 2018, the 3-year project aims to adopt multi-WEC environmental monitoring campaigns developed through gap analysis on WECs demonstrated in Scotland. The project is co-funded by the European Maritime and Fisheries Fund (EMFF) of the EU and is supported by a diverse range of project partners across UK, Portugal, Finland, Belgium, Sweden, and Ireland. In March 2020, a dedicated platform called MARENDATA was launched that will host range of information on resource characterisation, underwater noise, and video capturing seabed ecology and species behaviour from various marine energy test sites.

www.seawaveproject.com

Marine Energy Alliance

The Marine Energy Alliance (MEA) is a four-year European Territorial Cooperation project running from May 2018 to May 2022. The project has a total budget of €6 million and is financially supported by Interreg North West Europe, who provides €3.6 million of ERDF funding. The aim of MEA is to progress the technical and commercial maturity level of early-stage (TRL 3 – 4) marine energy technology

companies with the overall goal of reducing the risk of device failure in subsequent demonstration phases. In 2020, MEA reached another important milestone by awarding services to 23 SMEs.

NWE MEA - North West Europe Marine Energy Alliance | Interreg NWE (nweurope.eu)

Ocean Power Innovation Network (OPIN)

A cross-sectoral and cross-regional collaboration for offshore renewable energy SMEs, the OPIN project is a 3-year initiative from 2019 to 2021. It is led by the Sustainable Energy Authority of Ireland (SEAI) and is represented by Scottish Enterprise (SE) and ORE Catapult as the UK partners. It has a total budget of €2.6m, where Interreg North West Europe (NWE) from the European Research and Development Fund (ERDF) provides €1.5m of financial support. The OPIN project plans to support around 100 companies by transferring already established expertise, capabilities, and products from mature proven sectors into the ocean energy sector and thus reduce cost and initiate technology development. The partnering countries involved in this project include the UK, Belgium, France, Netherlands, and Germany.

https://www.nweurope.eu/projects/project-search/opin-ocean-power-innovation-network/

Ocean Energy Scale-Up Alliance (OESA)

Led by the Dutch Marine Energy Centre (DMEC), the OESA is a 3-year project running from January 2019 to December 2021. With a total budget of €6.2m, where Interreg NWE provides €3.1m of financial support, it is a European partnership of 13 international organisations specialising in offshore engineering, market development, ocean energy testing and technology development. In 2020, developers such as Floating Power Plant and Seabased worked with EMEC through the programme to align their current test campaign with IECRE standards and to prepare for certification, respectively.

https://www.dutchmarineenergy.com/our-projects/ocean-energy-scale-up-alliance-oesa

Tidal Stream Industry Energiser (TIGER)

The Tidal Stream Industry Energiser Project, known as TIGER, is an ambitious €45.4m project funded by ERDF via the Interreg France (Channel) England Programme, running from July 2019 to June 2023. The TIGER consortium comprises of 18 partners from across the UK and France spanning turbine developers, ocean energy demonstration sites, research organisations, as well local and regional authorities. The 4-year project aims to develop cross-regional partnerships while developing, testing, and demonstrating new technologies, installing up to 8 MW of new tidal capacity around the Channel region leading to new product and service development. As the biggest project across all Interreg programmes, it will establish tidal stream energy as a cost-effective source while driving growth within the energy mixes of France and the UK.

www.InterregTIGER.com

Ocean DEMO

Launched in January 2019 and funded by Interreg North-West Europe, the Ocean DEMO project is a €13m project. Built upon the FORESEA project, it aims to accelerate ocean energy's transition from single prototype to multi-device farms by providing free access to key European test centres: EMEC, DMEC, SEM-REV and SmartBay. The OceanDEMO programme had a successful Call 3 for applications in 2020, adding 11 technology developers to the project pipeline. Amongst them, AquaPower, Inyanga Maritime, Leask Marine, Mocean Energy and Tidetec AS will be supported by EMEC.

www.oceandemo.eu

Selkie

Launched in 2019, Selkie is funded by the EU's Ireland-Wales co-operation programme and is led by University College Cork in partnership with Swansea University, Marine Energy Wales, Menter Môn, DP Energy Ireland and Dublin-based Gavin and Doherty Geosolutions. The €4.2m project will see the development of a streamlined commercialisation pathway for the marine energy industry by establishing a cross-border network of developers and supply chain companies in Ireland and Wales. Multi-use technology tools and models will be created and trialled on pilot projects before being shared across the sector. In June and in August 2020, Ocean Energy and Sabella were announced as successful wave and tidal energy developers respectively, to collaborate on the demonstration project.

Home - Selkie Project (selkie-project.eu)

SEACAMS2

The SEACAMS2 project supports developing economic opportunities in Low Carbon, Energy and Environment through specialisation in commercial application of research and innovation in marine renewable energy (MRE), climate change resilience and resource efficiency in Wales. The £17m project, a partnership between Bangor University and Swansea University, is part-funded by the European Regional Development Fund and focuses on the convergence region of Wales.

ELEMENT

ELEMENT is a €5m EU H2020 project running from June 2019 to May 2022. It is led by tidal energy experts Nova Innovation, with the participation of ORE Catapult and University of Strathclyde, as UK partners of an 11-strong international consortium. As part of the rapid progress being made with tidal energy technologies, the consortium has identified an opportunity to improve performance using artificial intelligence. In a world-first, the ELEMENT team is using behavioural modelling and machine learning to control tidal energy turbines to improve efficiency and reduce costs. This approach will reduce the dependency on external instrumentation and sensors which can struggle to withstand the immense forces exerted by the tides.

(element-project.eu)

MONITOR

MONITOR is an Interreg Atlantic Area project, led by Swansea University, and bringing together EMEC, ORE Catapult, Magallanes Renovables S.L., Région Normandie, Sabella S.A.S., Universidade do Algarve, Université Le Havre Normandie and University College Cork. The project will identify critical parameters for blades and support structures and design a monitoring system aiming to lower engineering safety factors.

https://www.monitoratlantic.eu/

Wave Energy Scotland (WES)

2020 saw continued progress in the WES stage gate research, development, and innovation programmes. Five power take-off projects have now completed large-scale testing, while the construction of two half-scale wave energy devices by Scottish companies is nearing completion. These devices will be deployed in the waters around Orkney in early 2021, representing a key milestone of the WES programme and utilising technologies developed in the other WES programmes. Elsewhere, development of two control systems is continuing with pace and novel structural materials have been demonstrated in various on and offshore tests. In summer 2020, WES announced £1.4 million to support four projects developing Quick Connection Systems - an important opportunity to improve the speed, cost, and safety of operations at sea. The WES programme has awarded nearly £41.6m to 95 projects and will now partner with EVE the Basque Energy Agency and Ocean Energy Europe to deliver EuropeWave - a new five-year collaborative programme that will channel €20m to the most promising wave energy concepts. The initiative is match-funded by the European Commission via its Horizon 2020 programme.

TECHNOLOGY DEMONSTRATION

TEST CENTRES & DEMONSTRATION ZONES

Offshore test centres and demonstration zones enable the deployment of wave and tidal energy devices for R&D. A selection of these facilities is described below.

The European Marine Energy Centre (EMEC)

Established in 2003, EMEC remains the world's only United Kingdom Accreditation Service (UKAS) accredited test and research centre focusing on wave and tidal power development. With 13 grid connected test berths across 5 sites, EMEC has to date hosted the highest numbers of marine energy converters around the world. In 2020 EMEC achieved the world's first ocean energy RETL designation, the highest international designation for marine energy test laboratories awarded in August by the International Electrotechnical Commission – Renewable Energy System.

With regards to wave energy, EMEC continues working closely with AWS and Mocean who are gearing up to test their devices in 2021 at EMEC through the Wave Energy Scotland programme. On the tidal energy front, EMEC continues to work with Orbital Marine Power through FloTEC, ITEG and OceanDEMO to progress the commercialisation of the tidal sector. Orbital signed up to a second EMEC tidal berth in March, with the aim of delivering their first floating tidal turbine farm by 2022. Moreover, Magallanes Renovables will return in 2021 to continue testing their ATIR platform. Over the summer of 2020, EMEC also signed a key partnership with The Perpetuus Tidal Energy Centre (PTEC) site, to develop a large-scale tidal energy site off the Isle of Wight, England.

The EMEC-led OceanDEMO and BlueGIFT projects, as well as MaRINET2, have continued to award opportunities for testing technologies in the sea at EMEC and other

European test sites. Through the Marine Energy Alliance (MEA) project, EMEC has been working with 16 early-stage technology developers to de-risk development prior to demonstration at sea. The RESOURCECODE project, led by EMEC, aims to support investment and growth in the wave and tidal energy sector through the creation of an integrated marine data toolbox, which is due to be launched in 2021.

In addition, EMEC has continued to diversify into innovative waters. At EMEC's Billia Croo wave test site, Microsoft continued testing their subsea data centre through Project Natick, powered by Orkney's renewable electricity, and cooled by the ocean. 2020 saw the launch of ReFLEX Orkney, a project in which EMEC is lead partner and which is developing an integrated smart energy system in Orkney, increasing the system-wide use of clean energies. In December 2020, ReFLEX Orkney inaugurated a range of new low-carbon transport and power services exclusive to Orkney residents and businesses to further decarbonise the island's energy system, a major milestone for the project.

http://www.emec.org.uk/

Wave Hub

Wave Hub is a pre-installed grid-connected site approximately 10 nautical miles (16km) off the north coast of Cornwall for the testing of large-scale offshore renewable energy devices. Wave Hub is owned by Cornwall Council and operated by Wave Hub Limited. The site consent has been reconsented for floating offshore wind and is being sold off to a private buyer. As a partner to the £60m Pembroke Dock Marine project announced in June 2020, Wave Hub Ltd will deliver the Pembrokeshire Demonstration Zone (PDZ), a consented and grid connected offshore test site.

https://www.wavehub.co.uk/

FaBTest

FaBTest is a 2.8km2 test site in Falmouth Bay on the south coast of Cornwall with 10 years proven track record. The relatively sheltered location of the bay from the west allows for marine energy converter concept devices and components to be tested, whilst being occasionally exposed to more significant weather form the east. The pre-consented site, leased from the Crown Estate, has a 9 metre 1-in-100-year return period significant wave height, and is highly accessible from Falmouth Harbour. Most recently Marine Power Systems, followed by AMOG Consulting Ltd., demonstrated their 'WaveSub' and 'AEP' wave energy converters, completing power production and survivability tests in 2019.

http://www.fabtest.com/

Marine Energy Test Area (META)

META is a test site led by the Marine Energy Wales in the Milford Haven Waterway in Pembrokeshire. The Area comprises a variety of sites with consent and grid connection, which will facilitate testing of component, sub-assembly, and single-device stages. As one of the partners in the £60m Pembroke Dock Marine Project, META will enable technology developers to test their marine energy devices close to their base of operation.

META Wales - META Wales

Morlais Tidal Demonstration Zone

The site in West Anglesey was primarily setup for its tidal resource and access to local infrastructure. At its full deployment it will allow 240 MW of tidal energy to be transported to National grid. This is enough to supply, on average, 180,000 homes. The 35 km2 site is being sub-let for testing and commercial demonstrating activities as one of the first array scale projects. The project is funded by the EU and Welsh Government funds. There are in total 10 developers signed up to deploy their technology in the MDZ. The project is at present in the consenting process.

http://www.morlaisenergy.com/

FASTBLADE

FASTBLADE is an innovative research facility that uses regenerative hydraulic technology to allow high-quality, low-cost accelerated testing of composite and metal structures including tidal blades, composite bridge sections and carbon fibre aircraft wing boxes. Developed by the University of Edinburgh, the facility will use a Digital Displacement regenerative hydraulic actuation system to reduce the energy requirements of fatigue testing. As the world's first dedicated fatigue test facility for tidal blades, it will help secure Scotland's leadership role in marine energy.

FASTBLADE - World's First Regenerative Fatigue Test Facility | FASTBLADE (ed.ac.uk)

ARRAYS AND DEMONSTRATION PROJECTS IN THE WATER

This section is a non-exhaustive list of key projects tested, installed in the sea, and operating in 2020.

MeyGen

The MeyGen array is owned and operated by SIMEC Atlantis Energy in Scotland's Pentland Firth. In December 2020, the MeyGen project confirmed it has surpassed 35GWh of generation onto the grid since project commencement. In August 2020, under the Saltire Tidal Energy project, a subsea hub was installed on our site, this will facilitate the buildout of the next generation of grid connected tidal turbines. The project aims to continue its success in 2021 and increase generation, availability and learning from the array.

https://simecatlantis.com/projects/meygen/

MeyGen Subsea Hub being lifted (Source: SIMEC Atlantis Energy)

Minesto

Swedish marine energy developer Minesto received €14.9m of EU funding in May 2019, for the commercial development of Minesto's tidal energy scheme in Wales. After being upgraded to an enhanced PTO system, Minesto's DG500 kite system was commissioned at Holyhead Deep site offshore North Wales in September 2019. Minesto later retrieved the system back to carry out further tests and improvements at the site. In October 2020, Minesto installed and commenced commissioning activities of its 100 kW DG100 tidal kite system in the Vestmannasund strait, Faroe Islands. In December 2020, it successfully delivered electricity to the Faroese grid facilitated by Power Purchase Agreement with the utility company SEV.

https://minesto.com/

Minesto initiates DG500 commissioning program (Credit: Minesto)

Magallanes Renovables

Spanish tidal developer Magallanes Renovables' second-generation tidal turbine device, the ATIR, was successfully deployed at EMEC's grid-connected Fall of Warness tidal test site in February 2019. Funded by the Fast Track to Innovation pilot scheme, part of the EU's H2020 research and innovation programme, the device generated its first electricity into the UK national grid at EMEC in March 2019. and the device was temporarily removed from the site in 2020 to undergo maintenance in Leith and will be returning to EMEC's Fall of Warness tidal test site in 2021 for further testing.

https://www.magallanesrenovables.com

Nova Innovation

Nova Innovation was granted an extension to their existing seabed lease by Crown Estate Scotland, significantly increasing the capacity of the Shetland Tidal Array site from 0.5 MW to 2 MW. This extension will enable Nova Innovation to progress their EnFAIT project with the installation of three additional Nova M100 turbines, each rated at 0.1 MW. This installation will double the generating capacity deployed at the site and increase the number of turbines in the water from three to six. In October 2018, Nova Innovation installed a Tesla battery in the Shetland Tidal Array to create the world's first baseload tidal power plant, capable of providing predictable, controllable, and renewable power to the grid. In July 2020, the developer also won a second contract with Wave Energy Scotland (WES) to deliver its innovative subsea electrical connector. In October 2020, Nova Innovation successfully installed its state-of-the-art direct drive tidal turbine in Shetland that eliminates the need for a gear box and reduces the cost of tidal energy by 30 percent. By December 2020, Nova Innovation's turbines had accumulated over 30,000 hours generating energy to the Shetland grid. Internationally, in late 2019 the Scottish tidal developer was granted licence to deploy a 1.5 MW array in the Bay of Fundy area of Nova Scotia. In September 2020, the developer announced an investment of $4 million from the Canadian government for Phase 1 of the Nova Scotia tidal energy project. The Nova Scotia project will feature 15 of Nova's novel direct drive turbines.

https://www.novainnovation.com/post/nova-innovation-celebrates-birthday-with-shetland-tidal-array-expansion

PLANNED DEPLOYMENTS

This section contains a non-exhaustive summary of wave and tidal projects expected to be deployed in 2021.

Bombora Wavepower

Australian wave energy developer Bombora Wavepower secured a £10.3m ERDF grant in 2018 to support the design and testing of a fully submerged membrane-style wave energy convertor at Pembroke Dock. In October 2019, the developer received the first Marine Licence for a wave energy device in Wales, for the deployment and testing of 1.5 MW mWave wave energy converter technology off the coast of Pembrokeshire, Wales. Initially scheduled to be deployed in mid-2020, the project had placed more than 70% of contract by January 2020 but was delayed due to the pandemic. In July 2020, the full scale 'cell module' structure, a key component part of the 75-meter-long subsea mWave, was transported from the fabrication workshop to the assembly workshop. The Pembrokeshire Demonstration Project is currently scheduled to be deployed in the first half of 2021.

https://www.bomborawave.com/

AWS Ocean Energy

AWS has developed a fully submerged pressure differential absorber named the 'Archimedes Waveswing'. AWS was awarded £3.4m from the WES programme to develop a prototype and deploy and test in Orkney. AWS has been working closely with EMEC through 2020 in preparation to begin testing in 2021. Alongside validation of the device performance and reliability, this large-scale project will provide valuable experience of manufacture, installation, operations, and maintenance for this promising technology.

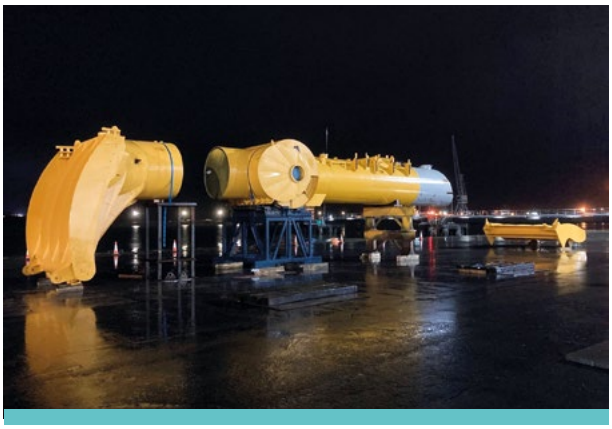
http://www.awsocean.com/

Archimedes Wave Swing being fabricated by Malin Group in Renfrewshire (Credit AWS Ocean Energy)

Mocean Energy

Mocean will deploy its "Blue X" prototype in early 2021 at EMEC in Orkney; the project is funded through the Wave Energy Scotland Novel WEC programme. Blue X provides learning towards Mocean's "Blue Horizon" technology for utility-scale power and "Blue Star" device for subsea power applications. Following the WES testing, Blue X will be used to demonstrate power to real subsea equipment including a residential AUV in the OGTC-funded Renewables for Subsea Power project. Mocean Energy's innovation is in the WEC geometry – using AI-optimisation to design hull-shapes that significantly increase performance.

https://www.mocean.energy/



Mocean's Blue X prototype in Scotland, prior to final fabrication and wet commissioning (Credit: Mocean Energy)

Marine Power Systems (MPS)

In August 2020, Swansea-based wave developer Marine Power Systems (MPS) obtained over £2m through a crowdfunding campaign, to build their first commercial demonstrator device in Wales. This is in addition to the £12.8m EU funds it was awarded in 2019 to support the manufacture and testing of the full-scale WaveSub wave energy converter that would assist the development of the full-scale prototype for providing renewable energy in and around Wales.

https://www.marinepowersystems.co.uk/

Orbital Marine Power

In 2020, Orbital Marine Power progressed construction of the world's most powerful tidal stream turbine, the O2 2 MW for deployment at EMEC in 2021. The O2 will feature

a range of innovations focussed on driving down the cost of tidal stream energy, including twin 20m rotor diameters - the largest swept area on a single tidal energy converter to date, pitching hubs for floating tidal energy and a new 'gull wing' leg retraction system to allow low cost, onsite access to the entire generating unit. The O2 project has received funding from the Horizon2020 Research and Innovation Programme, the Scottish Government's Saltire Tidal Energy Challenge Fund, and Interreg North-West Europe. The company also announced a new €5 million R&D programme, supported by the INTERREG France (Channel) England TIGER project. Orbital also secured a second berth at EMEC in March 2020 to support its technology development and commercialisation programme.

https://orbitalmarine.com/

Nova Innovation

After the successful installation of their fourth tidal turbine 'Eunice' into the Shetland Tidal Array in 2020, Nova Innovation plans to install two more M100 0.1 MW turbines at Bluemull Sound in Shetland in 2021/22. After a period of operation, the device positions will be moved within the array in order to investigate turbine wake interactions for the first time in an in-sea tidal array.

https://www.novainnovation.com/

Orbital O2 Turbine (Credit: Orbital Marine Power)

Eunice at Belmont Pier in Shetland prior to deployment and commissioning in October 2020 (Credit: Nova Innovation)

RELEVANT NATIONAL EVENTS

Some relevant events for the ocean energy sector that took place in the UK in 2020 include:

- **29 – 30 April 2020 –** Marine Energy Wales Annual Conference, Virtual
- **8 June 2020 –** OPIN Intro to EU Tidal Stream Projects, Virtual
- **9 July 2020 –** TIGER Supply Chain Opportunities Webinar, Virtual
- **3 – 9 September 2020 –** Orkney International Science Festival, Virtual
- **1 – 3 September 2020 –** Scottish Renewables Annual Conference 2020, Virtual
- **13 – 14 May 2020 –** All Energy 2020, Virtual
- **26 November 2020 –** Scottish Renewables: Green Energy Awards, Virtual

The UK will also be hosting some important events in 2021, such as:

- **18 – 23 January 2021 –** Supergen Offshore Renewable Energy Hub Annual Assembly, Virtual
- **27 – 29 January 2021 –** Marine Energy Wales Conference 2021, Virtual
- **23 – 24 March 2021 –** Scottish Renewables Annual Conference 2021, Virtual
- **18 – 19 August 2021 –** All Energy 2021, Glasgow
- **5 – 10 September 2021 –** 14th European Wave and Tidal Energy Conference, Portsmouth, England
- **1 – 12 November 2021 –** Conference of the Parties 26 (COP 26), Glasgow

3.22

UNITED STATES OF AMERICA

AUTHORS
David Hume, *Pacific Northwest National Lab*
Tim Ramsey, *U.S. Department of Energy*

OVERVIEW

In 2020, the U.S. marine energy sector made progress in key research efforts and prepared for additional deployments in 2021. While a few industry events and research activities were delayed due to the global pandemic, a number of open-water tests were executed safely and successfully. Research and development (R&D) collaboration in the U.S.—led by the Department of Energy (DOE), national laboratories, academia, industry, and federal partners—continued mostly uninterrupted. These efforts have prepared the sector for exciting developments in 2021.

In April, the U.S. Department of Energy (DOE) Water Power Technologies Office (WPTO) announced its largest funding opportunity of the year—over $22 million in funding for marine energy R&D at research institutions. Included in this opportunity are funds to add a new Atlantic Marine Energy Center to its network as well as a Foundational Research Network Facilitator to maximize the impact of WPTO's investments in these research centers. DOE expects to be able to announce the selections soon. Representing the suite of sustainable ocean-based economic opportunities that can lead to commercial growth, improved livelihoods, and new jobs while preserving the health of ocean ecosystems, the Blue Economy is a space of increasing focus for WPTO. After its launch in 2019, WPTO's Powering the Blue Economy™ initiative has since made more than 85 awards to industry and academia and built new partnerships to catalyze innovation in marine energy and connect more closely with future customers and end-users in the blue economy. These investments are intended to help jumpstart some of these Blue Economy markets and build new commercialization pathways for marine energy technologies.

In the United States, one tidal energy project and one river current project were safely deployed and began testing this year despite work and travel restrictions. Wave energy developers have made progress in their preparations for open-water deployments, with five devices anticipated to be tested in 2021. Smaller scale tests in lab and tank settings have also taken place, and many more are getting started with support from the new TEAMER program. The new wave energy test facility, PacWave, has passed additional regulatory milestones and is nearing the construction phase.

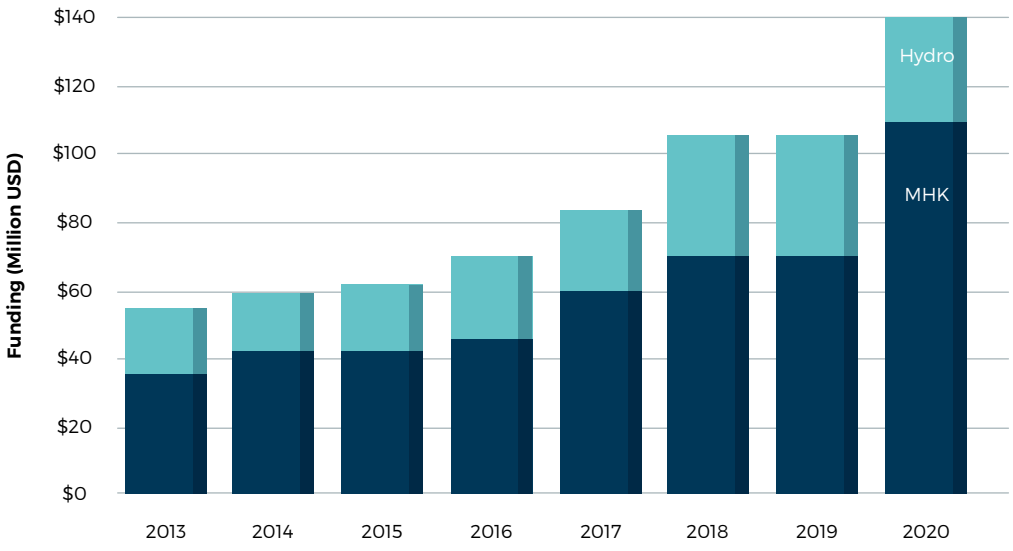
NATIONAL STRATEGY

The WPTO Marine and Hydrokinetics (MHK) Program envisions a U.S. MHK industry that expands and diversifies the nation's energy portfolio by responsibly delivering power from ocean and river resources. To help realize this vision, the MHK Program conducts transformative early-stage research that advances the development of reliable, cost-competitive MHK technologies and reduces barriers to testing. WPTO aligns itself with federal goals for ocean science and works with other agencies, such as the National Science Foundation, the U.S. Navy, and the National Oceanic and Atmospheric Administration, to advance federal ocean priorities. Many of these priorities are encapsulated in a report released in November 2018 by the White House Subcommittee on Ocean Science and Technology, under the National Science and Technology Council, titled "Science and Technology for America's Oceans: A Decadal Vision". Marine energy is featured frequently throughout the report. At the time of this writing a new presidential administration is preparing to take over the executive branch of the federal government which will likely bring changes to national ocean policy.

WPTO makes investments that support key technology innovations, mitigate risks, and assists in creating a robust U.S. marine renewable industry by providing funding and technical assistance. WPTO funds research in four main topic areas: (1) foundational R&D, (2) technology-specific system design and validation, (3) reducing barriers to testing, and (4) data access and analytics. Work in each topic area provides the industry with tools, services, and technologies that tackle specific challenges hindering development and commercial adoption. An additional research priority for WPTO is the Powering the Blue Economy initiative whose purpose is to understand the power requirements of emerging coastal and off-grid markets that are well-suited to integrate with marine renewable energy to relieve power constraints and promote economic growth within the blue economy.

More information on WPTO can be found at:
www.water.energy.gov

Federal funding for WPTO has maintained an upward trend, and this past FY 2020 funding for WPTO was $148M. As of this writing, the office is awaiting congressional appropriation of the FY 2021 budget.



MARKET INCENTIVES

While there are no dedicated marine renewable energy market incentives in the U.S., there are clean energy incentives which may be applicable in some regions. These include:

- Clean Renewable Energy Bonds (CREBs)
- Qualified Energy Conservation Bonds (QECBs)
- Renewable Portfolio Standards (RPS) and other voluntary renewable energy goals
- Public Benefit Funds (PBF)

For more information on these funding mechanisms please consult the 2018 and 2019 OES Annual Report.

PUBLIC FUNDING PROGRAMMES

There are several sources of public funding for marine energy R&D. WPTO is the primary group covered under this country report as it provides the bulk of federal funding that supports marine energy R&D, but this work could not be done without the help from other federal agencies and offices. For example, the Naval Facilities Engineering and Expeditionary Warfare Center (NAVFAC EXWC) actively supports R&D of various renewable energy conversion technologies, including wave energy. NAVFAC EXWC's funding efforts focus on advancing technology development to harness marine energy resources to ensure energy security and for powering U.S. Navy and Marine Corps assets both on- and off-shore. NAVFAC is funding and actively managing the Navy's Wave Energy Test Site (WETS) in Hawaii, including the Hawaii Natural Energy Institute's on-site monitoring and support of the test site, as well as marine renewable energy development efforts at the University of Washington, Applied Physics Laboratory. Other federal offices such as the Advanced Research Projects Agency – Energy (ARPA-E), the Bureau of Ocean Energy Management (BOEM), National Oceanographic and Atmospheric Administration (NOAA), and the Federal Energy Regulatory Committee also support marine energy projects.

Marine energy technology developers can seek DOE WPTO funding through several different competitive funding mechanisms. **Funding Opportunity Announcements (FOAs)** are topic-specific competitive grants for industry, academia, or national laboratories to form partnerships in conducting research and testing. Some FOAs are available to international applicants.

Small Business Innovation Research (SBIR) and **Small Business Technology Transfer (STTR)** programs are methods through which federal agencies with large R&D budgets set aside a fraction of their funding for competitions among small businesses to pursue early stage research. Small businesses that win awards in these programs keep the rights to any technology developed and are encouraged to commercialize the technology. DOE also has a **Technology Commercialization Fund (TCF)** which leverages R&D funding in the applied energy programs, paired with private partners, to mature promising energy technologies with high impact potential. Lastly, DOE administers **prizes and competitions** which can attract new innovators and investment to specific challenge areas. Since 2019, the MHK Program has launched several prizes and competition, as part of Powering the Blue Economy portfolio, which have attracted more than 400 applications to date.

WPTO identifies and funds qualified projects within specific topics that support program objectives, depending on available funds. In evaluating all proposals for new energy developments or new adaptations of existing technology, WPTO assesses whether individual applications clearly meet the goals of the topic area and their potential to advance the industry.

More information on available funding opportunities can be found at:

https://energy.gov/eere/water/water-power-funding-opportunities

To see other examples of all WPTO funded projects, visit the online project database map at:

https://www.energy.gov/eere/water/water-power-technologies-office-projects-map

There are numerous universities, private companies, organizations, non-profits, and national laboratories that actively support research on marine renewable energy in the United States. Collectively, these institutions represent approximately 40 unique testing facilities for marine energy research. To foster marine energy technology research, education, and outreach, WPTO has partnered with five universities to operate three National Marine Renewable Energy Centers (NMRECs). These NMRECs are:

- Pacific Marine Energy Center (PMEC)
- Hawaii National Marine Renewable Energy Center (HINMREC)
- Southeast National Marine Renewable Energy Center (SNMREC)

As previously mentioned, WPTO looks forward to announcing a new NMREC—the Atlantic Marine Energy Center—very soon.

DOE's national laboratories possess unique instruments and facilities capable of addressing large-scale, complex R&D challenges with research expertise and an approach emphasizing translating basic science to innovation. WPTO partners with several of these laboratories to support R&D in marine renewable energy, including:

- National Renewable Energy Laboratory (NREL)
- Pacific Northwest National Laboratory (PNNL)
- Sandia National Laboratories (SNL)

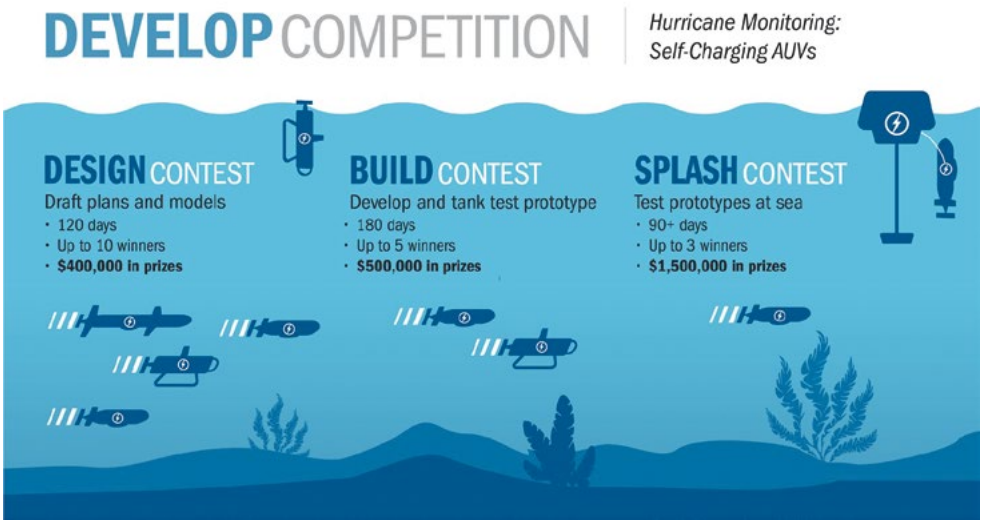
There are numerous other R&D institutions within the US that work on related ocean technologies such as the Applied Physics Laboratories, US Navy Research Lab, US Navy Office of Naval Research, and the Marine Environmental Laboratories operated by the National Oceanographic and Atmospheric Administration (NOAA).

WPTO FUNDED R&D ACTIVITIES

WPTO has had an active year with numerous new funding announcements and R&D projects launched. Highlights include:

Prizes and Challenges

- **Ocean Observing Prize –** This prize competition is jointly offered by the WPTO and NOAA and includes two separate competitions that will award up to $2.4 million in cash prizes. In October 2020 the first phase of the DEVELOP Competition was launched and it tasks contestants to design a wave energy harvesting autonomous underwater vehicle for hurricane monitoring.



- **Waves to Water –** This prize competition will accelerate the development of wave-powered desalination systems to provide drinking water in disaster relief and coastal locations. $3.3 million in cash prizes will be provided over five different stages or contests.
- **Marine Energy Collegiate Competition –** University teams submit a preliminary technical design and a business plan to explore opportunities for marine energy. A virtual pitch contest for contestants was held in summer of 2020 and $15k was awarded to 15 teams. The 2021 competition, involving 17 teams, is now underway.
- **Build to Scale - Blue Economy Industry Challenge –** WPTO in partnership with the U.S. Economic Development Administration (EDA) offered a $4 million solicitation to organizations to support entrepreneurship and technology commercialization in the blue economy. Seven grants were issued in Fall 2020 ranging from $300k - $650k each.

Testing Infrastructure

- **PacWave –** This grid-connected, pre-permitted test site for wave energy devices and arrays with a combined capacities of up to 20 MW. The site will have four test berths located approximately seven miles offshore of Oregon. This past year the DOE released a 'Finding of No Significant Impact', a critical step in the regulatory approval and permitting process.
- **Testing & Expertise for Marine Energy (TEAMER) –** Recently launched this past year, TEAMER is a 3-year testing campaign that will provide low-cost access to testing infrastructure at pre-certified facilities and subject matter experts from the nation's leading marine energy R&D institutions. This $16 million program is anticipated to fund testing of over 100 projects.

Competitive Funding Opportunity Solicitations

$22 million was announced in 2020 for marine energy R&D. Topic areas include:

- **Foundational Research and Development (R&D) –** $10.5 million will be made available to no more than seven awardees
- **Atlantic Marine Energy Center (AMEC) –** $5 million will be made available to one awardee
- **Foundational Research Network Facilitator (FRNF) –** $1.5 million will be made available to one awardee
- **Current Energy Technology Testing Infrastructure –** $5 million will be made available to one awardee

Other Projects and Initiatives

- **Energy Transitions Initiative Partnership Program (ETIPP) –** Launched in Fall 2020, WPTO, in partnership with six other institutions and national labs, will work alongside remote and islanded communities interested in pursuing energy transition efforts to address energy challenges, build capacity, accelerate the sharing of best practices and innovations between similarly-situated regions, and leverage specialized, local expertise.
- **OES – Environmental, State of the Science Report –** In September 2020, on behalf of the IEA-OES, PNNL released the 2020 State of the Science report, summarizing scientific progress to date on marine energy devices and their potential interactions with the marine environment, including the animals that live there and the habitats that support them.

OTHER FUNDED R&D ACTIVITIES

In November 2020 the **Advanced Research Projects Agency – Energy (ARPA-E)** announced $35 million in funding for 11 projects as part of the Submarine Hydrokinetic And Riverine Kilo-megawatt Systems (SHARKS) program. SHARKS teams will develop new economically competitive Hydrokinetic Turbines (HKT) designs for tidal and riverine currents. SHARKS projects address at least one of four generation use-cases: remote riverine energy, remote tidal energy, utility scale riverine energy, and utility scale tidal energy. Projects are encouraged to apply concurrent (as opposed to sequential) design methodologies: control co-design, co-design, and designing for operation and maintenance.

TECHNOLOGY DEMONSTRATION

PROJECTS IN THE WATER

Ocean Renewable Power Company (ORPC)

ORPC deployed a 35 kW submerged crossflow river current turbine system (RivGen® Power System) into the Kvichak River in Igiugig, Alaska. This single system could provide up to half of the community's electricity and greatly reduce its dependency on costly diesel fuel. The system was deployed in Summer 2019 and was redeployed in October 2020.

Verdant Power

Verdant's Fifth Generation Kinetic Hydropower System (Gen5 KHPS) is an axial flow turbine that incorporates a TriFrame for optimized turbine spacing to allow for cost-effective installation, operation, maintenance, and retrieval. The system was recently deployed in the East River near New York City, NY in October 2020.

Verdant Power

PLANNED DEPLOYMENTS

CalWave is anticipating aiming to deploying their submerged pressure differential WEC off the coast of San Diego, California near Scripps Institute of Oceanography for six months starting in Spring/Summer 2021.

C-Power is preparing for deployment of its 1 kW non-grid SeaRAY WEC at the U.S. Navy's Wave Energy Test Site (WETS) in Hawaii, USA. Anticipated deployment in Spring 2021.

C-Power is preparing for deployment of its StingRAY H3 WEC at the U.S. Navy's Wave Energy Test Site (WETS) in Hawaii, USA. Anticipated deployment in Fall 2021.

Ocean Energy recently constructed a 500 kW Ocean Energy Buoy which was towed across the Pacific to the U.S. Navy's Wave Energy Test Site (WETS) in Hawaii in December 2019. The device is currently in port undergoing system preparation for its pending deployment.

Oscilla Power is developing a two body multi-mode point absorber WEC called the Triton. The company is finalizing construction of a 10 m x 7 m 100 kW variant called Triton-C which is scheduled for a year-long test commencing in Spring 2021 at WETS in Hawaii.

RELEVANT NATIONAL EVENTS

The United States recently held a presidential election on November 3, 2020, the new president will be inaugurated on January 20, 2021. New policies around energy, climate, and the ocean are expected.

The U.S. will host the International Conference on Ocean Energy (ICOE) in 2021. Originally slated to take place in Washington, DC in 2020, the event will now take place virtually in April 2021.

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APPENDICES

APPENDIX 1

MEMBERSHIP OF THE EXECUTIVE COMMITTEE

CABINET 2020

CHAIRMAN
Mr. Henry Jeffrey
The University of Edinburgh
United Kingdom

VICE-CHAIR (Elected Chair for 2021)
Dr. Yann-Hervé De Roeck
France Energies Marines
France

VICE-CHAIR
Dr. Ir. Matthijs SOEDE
EC DG Research & Innovation
European Commission

SECRETARY
Dr. Ana Brito e Melo
WavEC Offshore Renewables
Portugal

DELEGATES

Country	Delegate	Alternate
Australia	**Dr. Mark Hemer** CSIRO Oceans and Atmosphere	**Mrs. Stephanie Thornton** Australian marine Energy Taskforce (AMET)
Belgium	**Dr. Ludovic Mouffe** Federal Public Service Economy	**Dr. Vicky Stratigaki** Ghent University
Canada	**Mr. Ghanashyam Ranjitkar** Natural Resources Canada	**Mrs. Monika Knowles** Natural Resources Canada
China	**Mr. Peng Wei** National Ocean Technology Center, SOA	**Mr. Wang Ji** National Ocean Technology Center
Denmark	**Mrs. Karina Remler** Energistyrelsen, EUDP	**Dr. Kim Nielsen** Ramboll
European Commission	**Dr. Ir. Matthijs SOEDE** EC DG Research & Innovation	**Dr. Davide Magagna** EC DG Joint Research Centre
France	**Dr. Yann-Hervé De Roeck** France Energies Marines	**Mr. Kelly Cayocca** France Energies Marines

Germany		**Mr. Jochen Bard** Fraunhofer Institute for Energy Economics and Energy Systems Technology IEE
India	**Dr. M. A. Atmanand** National Institute of Ocean Technology	**Dr. Purnima Jalihal** National Institute of Ocean Technology
Ireland	**Mr. Declan Meally** Sustainable Energy Authority of Ireland	**Mrs. Patricia Comiskey** Sustainable Energy Authority of Ireland
Italy	**Mr. Luca Benedetti** Gestore dei Servizi Energetici (GSE)	
Japan	**Dr. Yasuyuki Ikegami** Institute of Ocean Energy, Saga University	**Dr. Shuichi Nagata** Institute of Ocean Energy, Saga University
Korea	**Mr. Man Wook Hoe** Ministry of Oceans and Fisheries	**Dr. Jin-Hak Yi** Korea Institute of Ocean Science & Technology
Mexico	**Dr. Rodolfo Silva Casarín** CEMIE – Océano	**Dr. Juan Carlos Alcéreca Huerta** CEMIE – Océano
Monaco	**HE Bernard Fautrier** Government of the Principality of Monaco	**Mr. Jérémie Carles** Fondation Prince Albert II de Monaco
Netherlands	**Mr. H.W.Boomsma** Ministry of Economic Affairs	**Mr. H.P.E.M. Reijnders** Netherlands Entreprise Agency
New Zealand	**Dr. Craig Stevens** National Institute for Water and Atmospheric Research (NIWA)	**Mr. Gareth Gretton** AWATEA
Portugal	**Prof. Luis Gato** Instituto Superior Técnico (IST)	**Prof. António Falcão** Instituto Superior Técnico (IST)
Singapore	**Prof. Subodh Mhaisalkar** Energy Research Institute	**Dr. Srikanth Narasimalu** Energy Research Institute
Spain	**Mr. Luis Hilario Alonso Mijares** Ministry of Industry, Energy and Tourism	**Mr. Yago Torre-Enciso** BIMEP - Biscay Marine Energy Platform
Sweden	**Ms. Maria Olsson** Swedish Energy Agency	**Mr. Lars Karlbom** Swedish Energy Agency
UK	**Mr. Tim Warham** Department for Business, Energy and Industrial Strategy (BEIS)	**Mr. Henry Jeffrey** The University of Edinburgh
USA	**Mr. Tim Ramsey** U.S. Department of Energy	**Mr. David Hume** U.S. 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	

CONTACTS

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Portugal
E-Mail: info@ocean-energy-systems.org

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 co-ordinate 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).