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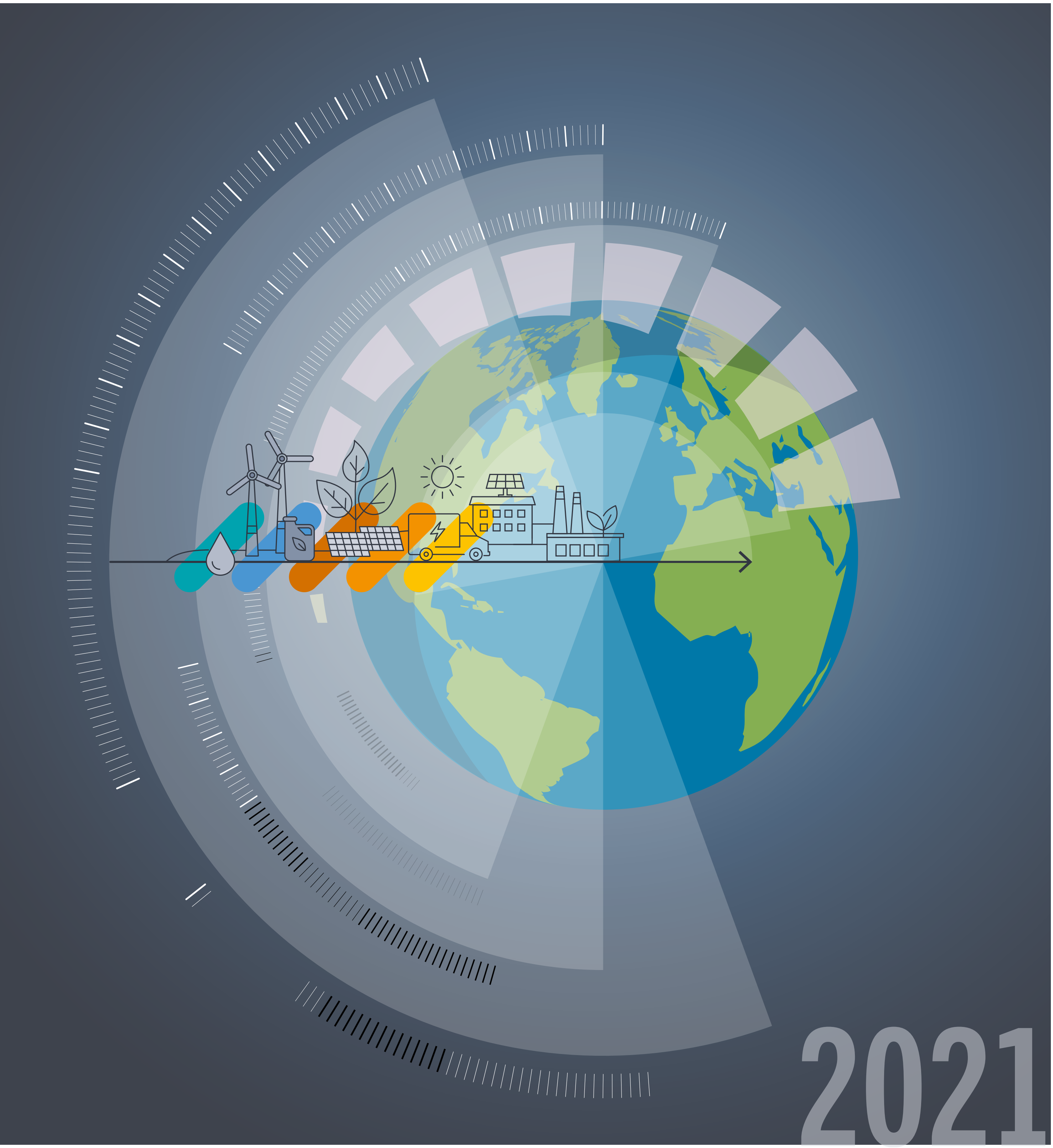
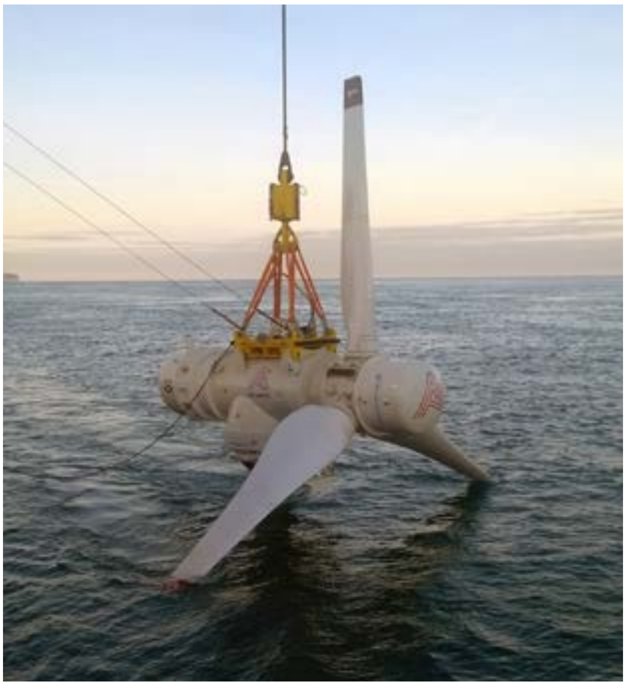
GLOBAL STATUS REPORT



KEY FACTS

- Ocean power **generation continued to rise in 2020**, surpassing 60 GWh.
- The industry is now moving from **small-scale demonstration and pilot projects towards semi-permanent installations** and arrays of devices.
- **Maintaining revenue support** for ocean power technologies is considered paramount if the industry is to achieve greater maturity.



OCEAN POWER

OCEAN POWER MARKETS

The oceans contain the largest untapped source of renewable energy. While ocean power technologies[i] represent the smallest share of the renewable energy market, they are steadily advancing towards commercialisation. Deployments in 2020 added around 2 MW, bringing the total operating installed capacity to an estimated 527 MW at year's end.[1] Two tidal barrages using mature turbine technologies[ii] represent more than 90% of total installed capacity: the 240 MW La Rance station in France (installed in 1966) and the 254 MW Sihwa plant in the Republic of Korea (2011).[2]

Tidal stream and wave power are the main focus of development efforts. Advancements in these technologies have been concentrated largely in Europe, especially the United Kingdom, which has significant resources. However, generous revenue support and ambitious research and development programmes in Canada, the United States and China are spurring increased development and deployment elsewhere.[3] In 2020, the EU set an ambitious target for 40 GW of ocean power capacity by 2050, including at least 100 MW of pilot projects by 2025 and 1 GW by 2030.[4]

Tidal stream devices are approaching maturity, and pre-commercial projects are under way. Device design for utility-scale generation has converged on horizontal-axis turbines mounted on the sea floor or attached to a floating platform.[5] These devices have demonstrated considerable reliability in performance, with total generation surpassing 60 GWh by the end of 2020 (up from 45 GWh the year before).[6] A range of other concepts are under development, designed to meet specific applications or environmental conditions, such as providing power to remote communities or at low-energy sites.

Wave power devices remain in the prototyping phase, and there is no convergence on design yet owing to the complexity of extracting wave energy from a variety of wave conditions and the wide range of possible operating principles.[7] Developers generally have chosen one of two distinct pathways for wave energy development: devices above 100 kW target utility-scale electricity markets, whereas smaller devices, usually below 50 kW, are intended primarily for specialist applications (oil and gas, aquaculture, maritime monitoring and defence).[8]

i Ocean power technologies harness the energy potential of ocean waves, tides, currents, and temperature and salinity gradients. In this report, ocean power does not include offshore wind, marine biomass, floating solar PV or floating wind.

ii These are the same in-stream technologies used in some types of hydropower plants.

OCEAN POWER INDUSTRY

The ocean power industry faced significant challenges in 2020 as the COVID-19 pandemic slowed manufacturing, delayed deployments and interfered with maintenance schedules. Most planned deployments were postponed to 2021, although some deployments took place and power generation continued despite reduced maintenance. In total, seven **tidal stream** devices were successfully deployed in 2020, including a three-turbine array, a large commercial-scale turbine and smaller demonstration deployments.

In China, the China Three Gorges Corporation (CTG) manufactured a 500 kW tidal turbine, designed by SIMEC Atlantis Energy, and deployed it between two islands in Zhoushan archipelago.[9] The CTG also made progress on the Zhoushan tidal current energy project, deploying a 300 kW turbine.[10] Another project, led by Zhejiang Zhoushan LHD New Energy Corporation Limited (LHD), achieved cumulative power generation exceeding 1.95 GWh in October 2020.[11] The modular device currently comprises two vertical-axis turbines of 400 kW and 600 kW, and LHD is working on adding a 1 MW turbine and increasing the capacity of the platform to 4.1 MW.[12] The main structure, now completed, was planned to be deployed in the first quarter of 2021.[13] The project will be the first to benefit from a temporary feed-in tariff of EUR 0.33 (USD 0.40) per kWh, introduced in 2019.[14]

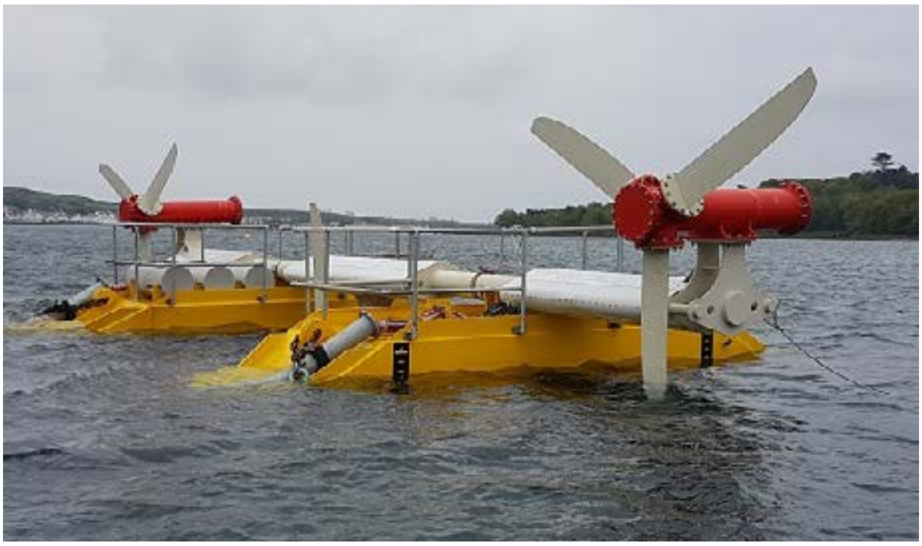
In the United States, Verdant Power installed a 105 kW array of three tidal power turbines at its Roosevelt Island Tidal Energy Project site in New York's East River, marking the first licensed tidal power project in the country.[15] As of January 2020, the array had operated continuously for three months, achieving 100 megawatt-hours (MWh) of generation in its first 85 days.[16] In Igiugig, Alaska, the Ocean Renewable Power Company (ORPC, US) redeployed its 35 kW RivGen Power System, a submerged cross-flow river current turbine.[17] Combined with microgrid electronics and energy storage, the system will reduce diesel use in Igiugig Village by an estimated 90%.[18] OPRC also continued construction on a second RivGen device, targeting deployment in summer 2021, and received USD 3.7 million in funding from the Department of Energy's Advanced Research Projects Agency.[19]

Two deployments took place in the United Kingdom in 2020. Nova Innovation (UK) completed the installation of its 100 kW turbine in the Shetland Islands.[20] This is the first of three turbines deployed as part of the EnFAIT (Enabling Future Arrays in Tidal) project, a EUR 20 million (USD 24.6) effort to demonstrate a viable cost-reduction pathway for tidal energy.[21] Nova Innovation also continued to successfully operate its 0.3 MW array in the Bluemull Sound in Shetland, where the turbines have generated without incident since 2016.[22] DesignPro Renewables (Ireland) successfully completed deployment and testing of its 60 kW DPR60 turbine at Kirkwall in the Orkney Islands, Scotland.[23]

Minesto (Sweden) installed and commissioned its 100 kW DG100 tidal kite system[i] in the Vestmannasund strait, Faroe Islands.[24] By December, it had successfully delivered electricity to the Faroese grid under a 2019 power purchase agreement (signed with the Faroese utility company SEV) for up to 2.2 MW of installed tidal capacity.[25] Minesto also is seeking the necessary permits to deploy a 100 KW device at the EDF-owned Paimpol Bréhat site in France.[26] Minesto received EUR 14.9 million (USD 18.3 million) in EU funding through the Welsh European Funding Office in 2019 and completed work in 2020 on its Holyhead assembly hall, which will serve as a hub for engineering and operational activities.[27] An array of up to 80 MW capacity is planned for the Holyhead Deep site, eight kilometres off the coast of north-west Wales.[28]

Scotland's MeyGen tidal stream array (the world's largest at 6 MW), owned and operated by SIMEC Atlantis Energy (UK), surpassed 35 GWh of electricity generation in 2020.[29] Having entered its 25-year operational phase in 2018, it generated continuously in 2019, the longest period of uninterrupted generation to date from a commercial-scale tidal array.[30] In 2020, the array faced operational challenges, and three turbines were retrieved for servicing in April 2021.[31] SIMEC holds a seabed lease that would allow it to build the project out to 398 MW.[32] SIMEC also shipped a 500 kW turbine to Japan for installation in early 2021 as part of Kyuden Mirai Energy's demonstrator project in the country's Goto islands.[33]

Tidal stream devices generated **15 GWh** of electricity in 2020.



i Minesto's Deep Green device comprises a turbine integrated with a wing, which is tethered to the seabed and operates in a manner similar to an airborne kite.

In Canada, the government of Nova Scotia offered a feed-in tariff of between CAD 385 and CAD 530 (USD 301 and USD 415) per MWh for demonstration projects.[34] As of the end of 2020, five Canadian developers were approved for a total of up to 22 MW.[35] During the year, NewEast Energy obtained an 800 kW permit under Nova Scotia's demonstration permits programme, which issued permits for a total of 9.3 MW of capacity (of the 10 MW available).[36] Canada committed substantial new funding to tidal projects in 2020, investing CAD 28.5 million (USD 22.3 million) in Sustainable Marine Energy's floating tidal array (up to 9 MW) and CAD 4 million (USD 3.1 million) in Nova Innovation's 1.5 MW array in the Bay of Fundy.[37]

DP Energy and Sustainable Marine Energy (both Canada) continued to advance the Uisce Tapa project under development at the Fundy Ocean Research Centre for Energy (FORCE). The CAD 117 million (USD 91.5 million) project aims to install a 9 MW array of six Andritz Hammerfest turbines and is supported by a Canadian government grant of CAD 29.8 million (USD 23.3 million).[38] BigMoon Power successfully applied to occupy a vacant berth at FORCE.[39] Other provinces also are making progress on ocean power, particularly as a means to provide electricity to remote communities.[40]

Several projects have been progressing in France. The HydroQuest 1 MW marine tidal turbine prototype was deployed at Paimpol-Bréhat in April 2019 and connected to the national grid in June 2019, and has operated continuously since then.[41] Featuring a dual vertical-axes design, this cross-flow turbine turns irrespective of the flow direction, enabling the device to be fixed to its foundation without any efficiency loss. DesignPro Renewables continued testing its 25 kW turbine at the dedicated SEENEOH test site on the Garonne River, where it has been deployed since September 2018.[42] SABELLA (France) 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 (France) to deploy two 250 kW turbines in the Gulf of Morbihan.[43] In Normandy, the government approved the transfer of a 12 MW lease in Raz Blanchard to Normandie Hydroliennes, a consortium of partners including SIMEC Atlantis Energy and the Development Agency for Normandy.[44]

In the Netherlands, the Dutch company Tocardo acquired the 1.25 MW Oosterschelde Tidal Power Plant and subsequently resumed full continuous operation.[45] The plant comprises five of Torcado's T-2 tidal turbines mounted on a sluice gate of the Oosterschelde storm surge barrier.

Two **wave power** deployments took place in 2020, with most planned deployments delayed by stalled manufacturing and pandemic-related lockdowns during the year.

In China, a consortium led by the Guangzhou Institute of Energy Conversion deployed a full-scale 500 kW wave energy converter. The Sharp Eagle-Zhoushan converter combines electricity generation with aquaculture and was deployed as part of the Wanshan megawatt-level Wave Energy Demonstration Project, supported by the Ministry of Natural Resources.[46] The Penghu device, based on the Sharp Eagle, completed its 18-month testing period in December 2020.[47] Construction also began on a second 500 kW device, Changshan.[48]

The EU aims to install

40 GW

of ocean power capacity by 2050.

Building on a successful scale test in Denmark, Danish company Wavepiston tested a full-scale device at the Oceanic Platform of the Canary Islands (PLOCAN, Spain). The initial phase of the 200 kW project was deployed in December 2020.[49] The system pressurises sea water, which can then be used to drive a turbine or can be pumped through a reverse osmosis system to obtain desalinated water. A second device that will produce both electricity and fresh water was slated for deployment in 2021.[50]

Existing deployments continued to operate through 2020, passing some significant milestones. The 296 kW Mutriku wave plant in Spain, commissioned in 2011, surpassed a cumulative 2 GWh of electricity production.[51] At the SEM-REV test site in France, the Wavegem hybrid wave and solar platform designed by GEPS Techno reached 18 months of offshore testing, which began in August 2019.[52]

US company Ocean Power Technologies (OPT) reported continuous operation of its device, deployed in the Adriatic Sea, during its first 18 months.[53] The device was leased by Eni, which in March 2020 opted to extend the lease for an additional 18 months.[54] Amid international travel restrictions that delayed deployment of a device in Chile, OPT contracted with SeaTrepid International (US) to conduct a remote installation, training local engineers virtually on technical procedures and installation requirements.[55]

Many companies focused on technology and project development in 2020. For example, Bombora Wavepower (UK) delayed a planned deployment but accelerated design work on a 3 MW project scheduled for deployment in Lanzarote, Spain in 2022.[56] Bombora also entered into an agreement with Technip FMC (UK) to develop a floating offshore wind foundation incorporating wave energy.[57] The first phase of the project will integrate 4 MW of wave power and 8 MW of wind power on a shared floating platform.[58]

Wave Swell Energy (Australia) finalised construction of its 200 kW device, scheduled for deployment on King Island, Tasmania in early 2021.[59] Also in Australia, Carnegie Clean Energy continued to develop its CETO 6 device, after restructuring following the company's entry into voluntary administration in 2018.[60] Carnegie also is developing a wave predictor that uses machine learning to predict wave characteristics up to 30 seconds before they reach the device, thereby increasing efficiency.[61]

US-based company Oscilla Power is finishing construction of a 100 kW device, expected to be installed in Hawaii in 2021.[62] The company also entered the planning stages of a 1 MW demonstration project, targeting deployment off the coast of Kerala in southern India.[63] In the United States, the OEbuoy device developed by Ocean Energy (Ireland), which was transported from the state of Oregon to Hawaii in 2019, is expected to be deployed in 2021.[64]

Other ocean power technologies, such as **ocean thermal energy conversion** (OTEC) and **salinity gradient**, remain well short of commercial deployment, and only a handful of pilot projects have been launched. REDstack (Netherlands) successfully tested its reverse electrodialysis (RED) technology and was planning a first demonstration plant.[65] Akuo Energy (France) announced plans to develop an OTEC plant on Bora Bora, French Polynesia, as part of the EU-funded project, Integrated Solutions for the Decarbonization and Smartification of Islands (IANOS).[66] Puerto Rico (US) is in the early stages of developing the Puerto Rico Ocean Technology Complex (PROtech) and aims to invest an estimated USD 300 million to build a 5 MW to 10 MW OTEC plant by mid-2027.[67]

The Ocean Thermal Energy Association was recently reinvigorated, and a group of member countries of the International Energy Agency's Ocean Energy Systems collaboration are working to assess the current status and global potential of OTEC, with a white paper expected in 2021.[68]

Technology improvements and steep cost reductions are still needed for ocean power to become competitive in utility markets. The industry has not yet received the clear market signals it needs to take the final steps to commercialisation.[69] The lack of consistent support schemes for demonstration projects has proven especially challenging for developers, who have struggled to build a compelling business case, and the sector remains highly dependent on public funding to leverage private investment.[70] Dedicated revenue support is considered paramount for increasing investment certainty by providing predictable returns until the industry achieves greater maturity.

The 2020 announcement of two large private investments provide some positive indications. CorPower Ocean (Sweden) secured EUR 9 million (USD 11 million) in equity funding, and SIMEC Atlantis concluded a share placement agreement, raising an initial investment of GBP 2 million (USD 2.7 million), with the option of increasing this to GBP 12 million (USD 16 million).[71] The UK government is expected to reform its Contract for Difference (CfD) mechanism, separating ocean power from offshore wind, thereby increasing price competitiveness.[72]

As of 2018, more than EUR 6 billion (USD 7.4 billion) had been invested in ocean power projects worldwide, of which 75% was from private finance.[73] A 2018 European Commission implementation plan estimated that EUR 1.2 billion (USD 1.5 billion) in funding was needed by 2030 to commercialise ocean power technologies in Europe, requiring equal input from private sources, national and regional programmes, and EU funds.[74] The industry is collaborating to develop a common evaluation framework for ocean power technologies, aiming to provide clarity for all stakeholders, including public and private investors.[75]

Deploying ocean energy at scale also will require streamlined consenting processes.[76] Uncertainty regarding environmental interactions often has led regulators to mandate significant data collection and strict environmental impact assessments, which can be costly and threaten the financial viability of projects and developers.[77] Current scientific knowledge suggests that the deployment of a single device poses little risk to the marine environment, although the impacts of multi-device arrays are not well understood.[78] This calls for an "adaptive management" approach that responds to new information over time, supported by more long-term data and greater knowledge sharing across projects.[79]

OCEAN POWER

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