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GLOBAL STATUS REPORT

2020

KEY FACTS

- Ocean power generation rose substantially in 2019, surpassing 45 GWh.
- The industry began moving from small-scale demonstration and pilot projects towards semi-permanent installations and arrays of devices.
- Maintaining revenue support to ocean power technologies is considered paramount for allowing the industry to achieve greater maturity.

OCEAN POWER

OCEAN POWER MARKETS

Ocean power[i] represents the smallest share of the renewable energy market. Although the resource potential of ocean energy is enormous, the technologies are still in the early stages of development.[1] (→ *See Sidebar 4.*) Net additions[ii] in 2019 were around 3 MW, bringing the total operating installed capacity to an estimated 535 MW at year's end.[2]

Two tidal barrages using mature turbine technologies[iii] – the 240 MW La Rance station in France (installed in 1966) and the 254 MW Sihwa plant in the Republic of Korea (2011) – represent more than 90% of total installed capacity.[3]

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. However, generous revenue support and ambitious R&D programmes in Canada, the United States and China have spurred increased development and deployment.[4]

Tidal stream devices are approaching maturity, with design converging on horizontal-axis turbines mounted on the sea floor or attached to a floating platform.[5] These devices have demonstrated considerable reliability in performance, and electricity generation rose substantially in 2019, owing to an increase in operating hours.[6] Total generation surpassed 45 GWh, with tidal stream devices in European waters alone generating 15 GWh in 2019 (up 50% from 2018).[7]

Wave power devices have not yet seen convergence on design, owing to the complexity of extracting wave energy from a variety of wave conditions and the wide range of possible operating principles.[8] 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).[9]

Although the potential of ocean power is enormous, the technologies are still in the **early stages of development.**

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 or floating solar.

ii A proportion of current installed capacity is removed or redeployed each year as demonstration projects reach their term or advance to a subsequent phase of testing. In Europe, for example, 10.3 MW of wave energy capacity had been decommissioned as of end-2019, following the successful completion of testing programmes.

iii The same in-stream technologies used in some types of hydropower plants.

SIDEBAR 4. The History of Ocean Power

Modern ocean power devices are the product of highly advanced industrial and technological systems, yet their earliest antecedents date back over 200 years. The first patent for an ocean energy device was filed in Paris by French mathematician Pierre-Simon Girard in 1799; the first operational plant was built in 1910 and was used to light and power a home. From 1855 to 1973, the United Kingdom alone granted over 300 patents for wave energy devices. Attempts to develop ocean thermal energy conversion (OTEC) started in the 1880s, and the first plant was built in Cuba in 1930, generating 22 kW of electricity before being destroyed in a storm.

The first large-scale ocean power facility, the La Rance tidal barrage in France, was built in the 1960s using proven hydropower turbine technologies. However, other methods for generating electricity from the ocean did not attract significant interest until the oil crisis of the 1970s. The US government invested USD 260 million in research and committed to producing 10 GW of electricity from OTEC systems by 1999, but ultimately no plants were commissioned[i]. The UK Department of Energy commissioned studies and ran a wave energy programme aimed at upscaling prospective devices, and the University of Edinburgh developed a device prototype and installed the first wave tank. As the oil crisis eased, interest waned and ocean power was largely abandoned, receiving very little funding in the 1980s and 1990s.

From the early 2000s onwards, ocean power experienced a resurgence, spurred by concerns about climate change and by the adoption of ambitious renewable energy objectives and policies. International co-operation was strengthened in 2001 with the establishment of the Ocean Energy Systems technology collaboration programme under the auspices of the International Energy Agency. The European Marine Energy Centre (EMEC) was established in 2003, providing an essential proving ground for devices by allowing for grid-connected testing in harsh weather conditions. More than 20 developers have since tested devices at EMEC.

In 2016, MeyGen deployed the first turbine of a planned 86 MW tidal stream array in the Pentland Firth, Scotland, marking a key milestone on the path to commercialisation. Progress has also been made in developing novel applications for ocean power technologies. In 2017, for example, EMEC began harnessing the excess electricity generated at one of its tidal testing sites to produce hydrogen, which is then used in a variety of fuel, power and heat applications. In 2018, Naval Group deployed a 450 kW Microsoft data centre at an EMEC wave test site, using wave energy to power the device and seawater for cooling.

The trajectory of ocean power has been volatile. On the one hand, a number of countries have invested considerable public funds into R&D, and large companies and private investors have become increasingly involved in device and project development. The EU turned its attention to ocean power for its potential to increase energy security and lower greenhouse gas emissions, while also creating jobs amid an economic downturn. On the other hand, government funding has been inconsistent, while the industry, in a bid to entice investors, overpromised what it could deliver in the near term and underestimated the technical challenges and costs. A number of bankruptcies ensued, large investors and energy companies withdrew, and the momentum generated by past public support slowed as private sector investors lost confidence.

Overall, the outlook for ocean power is positive. Costs are declining, and capital expenditure is lower than expected at this stage of development. Ongoing technological progress and development activity are encouraging, with the industry moving beyond pilot projects towards semi-permanent installations and arrays of devices exporting electricity to the grid, and significant investments and deployments were planned for 2020 and beyond.

i A 50 kW plant was tested for three months in 1979. The Department of Energy was poised to award a contract for a 40 MW pilot plant in 1982, but this did not come to fruition because of a change in the administration.

Source: See endnote 1 for this section.

OCEAN POWER INDUSTRY

Following a turbulent 2018, during which one industry leader ceased operations amid discouraging forecasts and limited development opportunities, the ocean power industry regrouped in 2019 and continued its gradual advance towards commercialisation.[10]

Tidal stream benefited from significant new investments of public funds and policy measures to support development. Three full-scale devices based on novel design principles were deployed for testing, although overall capacity additions were limited as developers prepared for large deployments totalling 9 MW in 2020.[11]

In Canada, the government of Nova Scotia offered a feed-in tariff of between CAD 385 and CAD 530 (USD 295 and USD 405) per MWh for demonstration projects, and as of the end of 2019 five developers were approved for a total of up to 22 MW.[12] During the year, two permits were awarded under Nova Scotia's demonstration permits programme: 2 MW to Jupiter Hydro and 1.5 MW to Nova Innovation.[13] A total of 7 MW (of the 10 MW maximum) was permitted under the programme.[14]

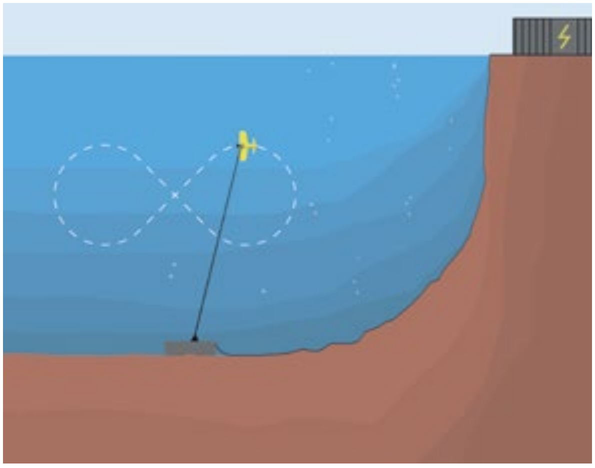
DP Energy and Sustainable Marine Energy continued to advance the Uisce Tapa project under development at the Fundy Ocean Research Centre for Energy (FORCE) in Nova Scotia. The CAD 117 million (USD 85.8 million) project aims to install a 9 MW array of six Andritz Hammerfest turbines and is supported by a Canadian government grant of CAD 29.8 million (USD 21.9 million).[15] Other provinces also are making progress on ocean power, particularly as a means to provide electricity to remote communities in Canada.

In the United Kingdom, a number of innovative cross-border collaborations and test deployments occurred in 2019, and some tidal devices demonstrated their reliability by generating electricity continuously throughout the year. In a large boost for the sector, Interreg France (Channel) England[i] announced that it would contribute EUR 28 million (USD 31 million) to the Tidal Stream Industry Energiser (TIGER) project – 70% of the project's EUR 47 million (USD 52 million) budget.[16] Led by the UK's Offshore Renewable Energy Catapult, TIGER brings together 19 partners from the United Kingdom and France to install 8 MW of capacity in and around the English Channel region.[17] The long-term objective is to cut generating costs from the current EUR 300 (USD 336) per MWh to around EUR 150 (USD 168) per MWh by 2025.[18]

Having entered its 25-year operational phase in 2018, Scotland's MeyGen tidal stream array (the world's largest at 6 MW) generated continuously in 2019, the longest period of uninterrupted generation to date from a commercial-scale tidal array.[19] The developer, SIMEC Atlantis Energy Ltd (United Kingdom), holds a seabed lease that would allow it to build the project out to 398 MW.[20] In 2019, SIMEC announced development of the next phase of the project, which will add a further 80 MW of capacity.[21] The company also was awarded a GBP 1.5 million (USD 1.8 million) government grant to develop a subsea connection hub for the next phase of the project.[22]

Also in Scotland, Nova Innovation's three-turbine 0.3 MW array in the Bluemull Sound of the Shetland Islands continued to generate consistently, with the turbines accumulating more than 20,000 operational hours as of December 2019.[23] Orbital Marine Power (formerly Scotrenewables Tidal Power) began building an optimised model of its SR2000 twin-turbine floating tidal power device, the Orbital O2, which it planned to deploy at EMEC in 2020.[24] Orbital also raised GBP 7 million (USD 9 million) through a crowdfunding campaign.[25]

Minesto (Sweden), which in 2018 successfully demonstrated the ability of its "energy kite"[ii] to harness relatively low-energy tidal streams and ocean currents, signed a power purchase agreement with the Faroe Islands utility for up to 2.2 MW of installed tidal capacity and obtained the required consents.[26] In May 2019, the Welsh government announced its continued support for Minesto's commercial development in Wales, awarding EUR 14.9 million (USD 16.7 million) of EU funding through the Welsh European Funding Office.[27] Minesto's long-term plan is to



i Interreg is a series of programmes to stimulate co-operation between regions in and out of the European Union, funded by the European Regional Development Fund. Interreg France (Channel) England was set up to foster economic development in the south of the United Kingdom and north of France by funding innovative projects that have a sustainable cross-border benefit. See Interreg, "About the programme", https://www.channelmanche.com/en/programme/about-the-programme.

ii 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.

deploy a commercial tidal energy array of up to 80 MW capacity at its Holyhead Deep site, eight kilometres off the coast of north-west Wales.[28] Minesto also was awarded a EUR 2.4 million (USD 2.7 million) grant as part of the TIGER project to install and operate a device at a grid-connected test site off the French coast.[29]

France remains an attractive location for tidal stream development, owing to its competitive grid-connected test centres, active support from regional and local governments, and the potential for scaling up projects in the future.[30] Two turbines were deployed in 2019: a 1 MW vertical-axis turbine at Paimpol-Bréhat (HydroQuest Ocean), which has already surpassed six months of continuous operation, and a short-term test deployment of a 20 kW horizontal-axis turbine at Ria d'Etel (Guinard Energies).[31]

Wave power advanced steadily in 2019, with a range of test deployments hitting the water in Europe and China, the announcement of significant new public funding and a number of developers pursuing novel device designs. More than 4 MW of deployments were planned in 2020, mostly of full-scale, high-capacity devices in Europe.[32]

In Europe, 0.6 MW was added through six individual units in 2019. Ocean Power Technologies (OPT) deployed a 3 kW device in the North Sea, where it supports an autonomous communications and remote monitoring platform used by Premier Oil.[33] The deployment began a nine-month lease that includes a purchase option. Another OPT device in the Adriatic Sea marked a full year of maintenance-free continuous operation in 2019.[34] In Portugal, AW-Energy deployed its 350 kW WaveRoller device, and commissioning work is under way to connect the device to the local electricity network.[35] Deployments also took place in Belgium, France and Italy.[36] In the United Kingdom, Wave Energy Scotland (WES) awarded GBP 9 million (USD 12 million) to 11 wave projects.[37]

In the United States, a 1.25 MW wave energy device was transported to the state of Hawaii for testing.[38] The country continued to provide funding for ocean power, with a focus on wave power devices and associated technology. In 2019, the US Department of Energy's Water Power Technologies Office awarded USD 25 million in research projects with the aim of reducing capital costs and shortening project development times.[39] The three topic areas for funding were early-stage device design, advancement of new power take-off (PTO) devices and control systems, and the consolidation of scientific knowledge and understanding of potential environmental impacts.

In China, the government supported its first megawatt-level test site (the Wanshan Wave Energy Demonstration Project) with an overall budget of RMB 151 million (USD 22 million), and a consortium began building two 500 kW test units.[40] The Guangzhou Institute of Energy Conversion completed the first open-sea test of a floating wave energy platform, which was successfully connected to the power grid of a remote island.

Carnegie Clean Energy (Australia) resumed construction of its CETO 6 device, having entered into voluntary administration in 2018 after a net loss of some AUD 45 million (USD 31 million) in 2018-19.[41] Carnegie continued to operate its Garden Island Microgrid in Western Australia, delivering more than 1,000 MWh to the country's largest naval base.[42] Wave Swell Energy also began construction of its 250 kW wave energy device.[43]

Bombora (United Kingdom) was on schedule to deploy its mWave device in mid-2020 and was progressing through the consenting phase of a proposed 2 MW project in Lanzarote, Spain, which it aimed to commission in 2022.[44] The novel device sits below the water surface and harnesses the pressure of overhead waves, an approach that the company hopes will allow it to overcome the survivability challenges facing wave energy devices.

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. Nonetheless, novel applications continue to be developed. In 2019, for example, the Indian government approved the construction of a new OTEC-powered desalination plant.[45]

Technology improvements and steep cost reductions are still needed for ocean power to become competitive, and the industry is yet to receive the clear market signals it needs to take the final steps to commercialisation.[46] 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.[47]

Uncertainty regarding environmental interactions has often led regulators to require significant data collection and strict impact assessments, which can be costly and threaten the financial viability of projects and developers.[48] Current scientific knowledge suggests that the deployment of single devices poses little risk to the marine environment, but the impacts of multi-device arrays are not well understood.[49]

Continuing revenue support is considered paramount for increasing investment certainty by providing predictable returns until the industry achieves greater maturity.[50] As of 2018, more than EUR 6 billion (USD 6.9 billion) had been invested in ocean power projects worldwide, of which 75% was from private finance.[51] A 2018 European Commission implementation plan estimates that EUR 1.2 billion (USD 1.4 billion) in funding is needed by 2030 to commercialise ocean power technologies in Europe, requiring equal input from private sources, national and regional programmes, and EU funds.[52]

OCEAN POWER

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