The marine turbine developed by the Scottish engineering firm Orbital Marine Power is moored in the Orkneys, the subarctic archipelago located north of Scotland. It has 2 MW of installed capacity and will be connected to the European Marine Energy Centre (EMEC) to be tested there.

ORBITAL MARINE POWER

249.2 MW

Projects using ocean energies having been active during the year 2021 in EU 27

OCEAN ENERGY BAROMETER

A study carried out by EurObserv'ER.

Marine energy, also known as ocean energy, offers coastal countries significant diversification potential for their electricity mixes. Competition in the European sector is rife with companies trying to outdo each other and impose their marine turbine or wave energy converter concepts for mass production. The tidal stream sector, which uses ocean current energy, has opened up a slight lead by launching its first commercial projects to benefit from power purchase agreements. It is currently collecting feedback on its full-scale prototypes, i.e., MW "commercial" size turbines. The wave energy converter (WEC) sector is hard on its heels, testing prototypes dimensioned at several hundred kW adapted to deal with differing European coastal wave conditions.

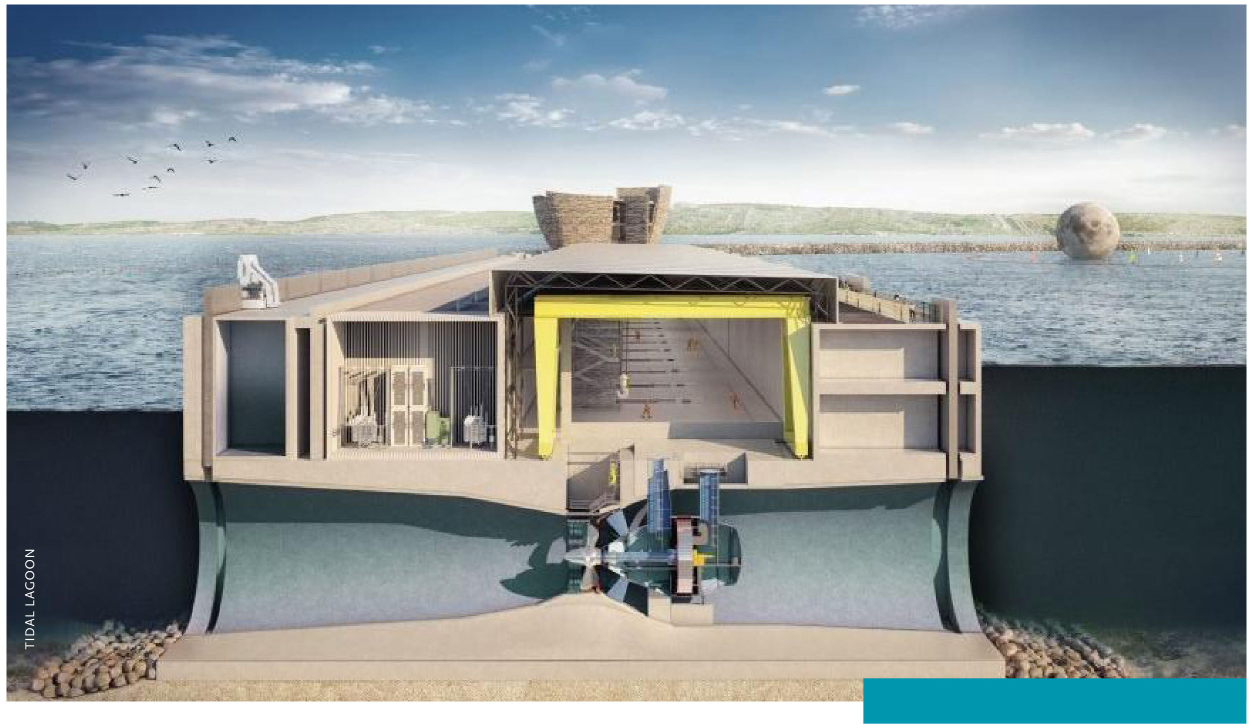
The oceans and seas, that cover over 70% of the planet's surface, harbour enormous quantities of energy flows that originate, partly from solar energy that causes winds, wave swell, major marine currents and temperature differences in the sea and, partly by gravitation variations due to the respective positions of the Earth, Moon and Sun that give rise to tides. The European Union is in a unique position to develop renewable energies in the sea because of the diversity and complementarity of its maritime basins: from the Baltic to the North Sea, the Atlantic Ocean, the Mediterranean, through to the Black Sea. Now while offshore wind energy makes the headlines with its capacity to harness sea winds … the latest wind turbines have unit capacities of over 10 MW, blades of around one hundred metres in length, and annual load factors of about 60%. Alternative technologies using the other sea energy flows, that complement wind and solar energy, are likely to contribute to the diversification of the European and world energy mix. Marine energy in the forms of current energy or tidal ranges (see below) in particular, offer high predictability. Tide energy is linked to the moon and sun's gravitational force and is independent of climate conditions and hence contrasts with wind or solar energy. Accurate forecasts of tidal current electricity output can be made for any hour of the year, which enables forward planning of its use. A particular phenomenon of wave energy is that it is stronger in winter when the wave heights are at their steepest (winter swell) and thus in perfect phase with the season's higher electricity needs. Last but not least, another asset of marine energy is that its production capacities can be installed in areas or outlying shore areas underserved with electricity, such as Brittany and the islands.

OVERVIEW OF EUROPEAN PROJECTS

Marine energy breaks down into five distinct families that each has its own technologies that are at different stages of development – tidal range energy (or tidal power), tidal stream energy (or hydrokinetic energy), wave energy (wave energy converter energy), ocean thermal energy conversion (OTEC – that exploits the temperature difference between the seabed and the surface water) and osmotic energy that exploits the difference in salinity between freshwater and seawater. The two most active sectors at industrial scale use the energy of tidal currents and wave energy. Other projects are being developed in the remaining three sectors, including a particularly innovative osmotic energy project (see below). We should make clear that the offshore wind energy sector is not covered by this barometer. You can follow it up in the wind energy barometer that was last published online in February 2022.

Historically, **tidal range energy** was the first ocean energy to have been deployed in Europe. It is the energy potential created by tidal movement, and in particular the difference (tidal range) between high water and low water levels. It is harnessed by constructing a barrage in a bay or across an estuary equipped with turbines (the same as those used in hydropower dams). The tide's ebb and flow in turn fill and drain the reservoir driving the turbines to generate electricity. Tidal range plants, like hydroelectricity dams, may also feature pumped storage units to increase the head of stored water to boost production when the tide ebbs. This system operates at the European Union's only tidal range power plant in service, across the La Rance estuary, Brittany, a stone's throw from the bustling port of Saint-Malo. The 240-MW capacity site inaugurated in 1966 is still in service and supplies enough electricity to satisfy the city of Rennes' demand. There are four other tidal range power plants operating across the world. The most recent construction, commissioned in 2009, is South Korea's Sihwa Lake Tidal Power Station with 254 MW of installed capacity, making it the world's largest. The third largest, the Annapolis Royal Generating Station in Canada (20 MW), went on stream in 1984. It no longer generates electricity following the breakdown of a generator in 2019. As its operator has decided against repairing the installation, it will be mothballed. Small tidal range power plants operate in Jiangxia, China (3.2 MW, commissioned in 1980), Kislaya Guba in Russia (1.7 MW, commissioned in 1968), and at Uldolmok in South Korea (1.5 MW, commissioned in 2009). South Korea is intent on developing more ambitious projects such as that of Garolim (with about 520 MW of capacity), while Russia and the Philippines have even bigger projects on their drawing boards. Europe has been developing projects based on artificial lagoons, such as the Swansea Bay Tidal lagoon (320 MW) project in South Wales. Artificial lagoons offer the advantage of limiting the environmental impact of a barrage in a river estuary. They would act as artificial lakes, filling with water at high tide, then emptying through sluice gates fitted with turbines. However the Welsh project suffered a major setback in June 2018 when the Department for Business, Innovation and Skills (BEIS) rejected an electricity contract for difference (CfD) needed to finance the £ 1.3 billion proposal, in favour of offshore wind energy and nuclear power plant projects. There are other artificial lagoon projects being developed in Wales, primarily in the Severn Estuary, but their prospects look uncertain.

Tidal stream energy harnesses the kinetic energy of both tide and ocean currents. It is generally captured by marine turbines, placed or anchored on the seabed or, in the case of floating marine turbines, moored under a barge or platform, usually in pairs. Technologies capable of developing tidal currents' potential abound, such as axial flow turbines, crossflow turbines and oscillating profiles such as underwater wings. Marine turbines are much smaller than wind turbines at equivalent capacity, because the density of water is 833 times higher than that of air. Another advantage is their low visual impact which is limited for completely submerged or low height models, while turbines placed or anchored on the seabed that are not exposed above the surface level present fewer navigational constraints. According to Ocean Energy Europe, in its Ocean Energy, Key trend and statistics 2021 publication, published in March 2022, Europe has amassed 30.2 MW of marine turbine capacity since 2010 using tidal



Artificial lagoon based projects are currently under way in Europe, such as the Swansea Bay Tidal Lagoon project (320 MW) in South Wales.

streams, 11.5 MW of which are currently submerged in European waters (European Union, the UK and Norway). A further three new turbines with combined capacity of 2.2 MW were submerged in European waters in 2021and another 1.5-MW turbine returned to the water following maintenance and modification to improve its performance.

One of them, the horizontal-axis 2-MW marine turbine called O2, developed by Scottish engineering firm **Orbital Marine Power**, was anchored off Orkney on the European Marine Energy Centre's (EMEC) Fall of Warness site, a test and research centre specializing in the development of wave and tidal energy based on the Orkney Islands, north of Scotland. This model is currently the world's most powerful tidal turbine. It comprises two rotors 20 metres in diameter, that each develop 1 MW, connected to a 72-metre floating platform by two 18-meter long articulated arms, capable of sweeping up 600 sqm of water. The turbines can go into reverse between tide cycles to maximize energy production regardless of the current's direction and the generated electricity is sent to land through subsea cables. Commercial development of this O2 marine turbine is right on track as it secured its operating funding in July 2022 backed by private and public funds. **Orbital Marine Power** has secured £ 4 m of funding from the **Scottish National Investment Bank**, supplemented by a 12-year debenture from **Abundance Investment**, an online crowdfunding enterprise, which raised the sum from 1 000 individual investors, and financial participation from **TechnipFMC**. (Note: a debenture is a negotiable bond that businesses can issue to obtain long-term financing without having to secure it with a collateral or dilute their equity). TechnipFMC is a UK-based multinational energy industry player formed by merging FMC Technologies of the United States with Technip, in France. The Scottish engineering firm also revealed in its 13 September 2021 press release, that this O2 tidal turbine project is part of the **Forward-2030** project (see inset) that will benefit from a € 21.5 million European Union grant as part of the Horizon 2020 research programme. The project will integrate the next Orbital turbine into a hydrogen production and battery storage plant at the European Marine Energy Centre (EMEC). The project partners will design options for large-scale incorporation of tidal range energy in future net zero energy systems, while developing environmental monitoring and marine spatial planning tools for the major floating tidal networks. Although the UK has left the European Union, its companies and researchers still benefit from pre-Brexit programme funding. This financial base allowed Orbital Marine Power to take up two Contracts for Difference (CfD) in July 2022, allotted through the UK Government's 4th auction round for low-carbon emission power at a strike price of £ 178.54/MWh (about € 200/MWh) for 7.2 MW of capacity on EMEC's Fall of Warness site.

Another turbine in European Union waters (the Netherlands) is a 100-kW vertical axis water turbine **VAWT**, developed by the Dutch start-up **Water2Energy**. This turbine was installed in the recesses of an outfall channel by the sea locks of the Flushing marina in Zeeland, the Netherlands' most westerly province. The vertical axis water turbines are of the Darrieus type. The design, construction and installation of this prototype were developed under the framework of the **INTERREG 2 SEAS European ENCORE project**, for Zeeland ↘

Table No. 1

List of projects* using ocean energies having been active **during the year 2021 in the European Union and in Europe**

Summary	Device Developper	Device Name	Technology	Location	Date	Total capacity (in MW)
France						
Rance tidal power plant (EDF)	Alstom	Bulb Turbine (La Rance)	Tidal range	Brittany – La Rance	1966	240
Wavegame – Test at SEM REV	GEPS Techno	Wavegame (prototype)	Wave energy	SEM REV	2019	0,12
Paimpol Brehat	Hydroquest	HydroQuest	Tidal current	Brittany – Paimpol Brehat	2019	1
Total France						241,12
Spain						
Enagas Huelva plant**	Enagas	Enagas Huelva plant	OTEC***	Huelva, Andalousia	2013	4,5
Ente Vasco de la Energia (EVE)	Voith Hydro	Mutriku	Wave energy	Pais Vasco	2011	0,296
WavePiston – Plocan test	Wavepiston	Wavepiston	Wave energy	Plocan, Gran Canaria	2020	0,2
Biscay - BiMEP Platform	Wello Oy	Penguin 2	Wave energy	Bay of Biscay	2021	0,6
Total Spain						5,60
Netherlands						
Oosterscheldedam	Tocardo	T2	Tidal current	Oosterschelde-dam	2015	1,25
Port of Den Helden	Slow Mill	Slow Mill	Wave energy	Port of Helden	2021	0,04
100 kW VAWT for Vlissingen	Water2Energy	VAWT	Tidal current	Vlissingen	2021	0,1
Total Netherlands						1,39
Denmark						
Pilot plant at the Afsluitdijk	Redstack	TRL7	Salinity Gradient	Breezanddijk on the Afsluitdijk	2014	0,05
Port of Fredrikshaven	Crestwing	Tordenskiold	Wave energy	Port of Fredriks-haven	2018	0,3
First commercial project SEV	Minesto	DG100	Tidal current	Vestmannasund (Faroe Islands)	2020	0,1
Second commercial project SEV	Minesto	DG100	Tidal current	Vestmannasund (Faroe Islands)	2021	0,1
Total Denmark						0,55
Portugal						
Swell Project	AW-Energy	WaveRoller	Wave energy	Peniche	2019	0,35
Total Portugal						0,35
Italy						
Messina Strait test project	ADAG	Kobold	Tidal current	Strait of Messina	2000	0,05
Civittavecchia test project	Wavenergy	REWEC3	Wave energy	Civittavecchia	2016	0,02
PC80 Platform (Eni)	Wave for Energy	ISWEC	Wave energy	Ravenna	2019	0,05
Total Italy						0,12
Greece						
Port of Heraklion test project	SINN Power	SP WEC 3rd Gen	Wave energy	Heraklion	2017	0,036
Port of Heraklion test project	SINN Power	SP WEC 4rd Gen	Wave energy	Heraklion	2018	0,072
Total Greece						0,11
Cyprus						
Larnaca Bay project	SWEL	WLM	Wave energy	Larnaca Bay	2021	0,001
Total Cyprus						0,001
Total UE 27						**249,2**
Norway						
Projet Haddal	Havkraft	HWEC	Wave energy	Haddal	2021	0,03
Total Norway						0,03
United Kingdom						
Projet Eco Wave Power – Gibraltar	Eco Wave Power	Wave Clapper	Wave energy	Gibraltar	2016	0,1
Projet MeyGen phase 1A	Andritz	HS1500	Tidal current	Pentland Firth	2016	4,5
Projet Shetland tidal array	Nova Innovation	M100	Tidal current	Bluemull Sound, Shetland	2016	0,3
Projet MeyGen phase 1A	SIMEC Atlantis Energy	AR1500	Tidal current	Pentland Firth	2016	1,5
Projet Shetland tidal array	Nova Innovation	M100	Tidal current	Bluemull Sound, Shetland	2020	0,1
Projet Nemmo – EMEC Platform	Magallanes Renovables	ATIR	Tidal current	Orkney (Scotland)- EMEC	2021****	1,5
Orbital Marine Power – EMEC Platform	Orbital Marine Power	O2	Tidal current	Orkney (Scotland)- EMEC	2021	2
Mocean - EMEC Platform	MOCEAN	Blue X	Wave energy	Orkney (Scotland)- EMEC	2021	0,01
Total United Kingdom						10,01

** Including demonstrators and prototypes during the test phase. ** The Huelva project exploits the temperature difference between the ocean and liquefied natural gas. *** Ocean Thermal Energy Conversion. **** Redeployment of the Magallanes Renovables ATIR platform previously tested at EMEC in 2019 – now rated at 1.5 MW*
Source: EurObserv'ER 2022

province. The designer claims that the possibility of using an existing infrastructure such as a lock not only radically slashes the installation costs but enables many other projects to be envisaged all over the world in big and small locks and outfall channels.
Swedish developer **Minesto** has added a second 100-kW **DG 100** (Deep Green 100) marine turbine of the "underwater tidal kite" type at Vestmannasund on the site of its first commercial project on the Faroe Islands. In November 2018, Minesto signed collaboration and power purchase agreements with **SEV**, the Faroe Islands' main electricity producer and distributor, for the installation, commissioning and operation of two grid-connected units of Minesto's DG100 model. The first turbine started delivering electricity to the Faroe Island grid in December 2020, and **Minesto** installed its second turbine in March 2021. Minesto has developed its own specific technology based on an underwater wing tethered to the seabed by a cable along which the electricity is delivered. This wing carries a turbine at the front directly connected to a generator, the rudder at the back steers the kite along a pre-set trajectory. The wing moves in the sea forming eights in the same way as a kite flyer makes looping figures with the wind. These figures of eight make the machine move faster than the current and accelerate the water's movement on the turbine. Minesto has announced upcoming projects in Sweden, Northern Ireland and Taiwan in addition to its on-going development projects on the Faroes and in Wales. The company, which has been listed on the Stockholm stock exchange since 2015 signed a protocol agreement with the French multinational **Schneider Electric** in March 2021 to work on the development and construction of ocean energy farms based on its **Deep Green** technology.
In April 2021, Spanish tidal turbine developer **Magallanes Renovables** refloated its second-generation double-rotor ATIR floating platform with a combined capacity of 1.5 MW on the EMEC test site. The platform was initially tested in 2017 in Spain, then was transferred and connected to the Scottish EMEC test site in 2019 before undergoing drydock maintenance in Edinburgh. **Magallanes** also successfully bid for 5.6 MW at the UK's fourth CfD auction round, at the same strike price of £ 178.54/MWh for a project at Morlais, Wales. It should be pointed out that during this auction round, the lion's share of CfDs – 28 MW – was awarded to the developer **Simec Atlantis** to pursue the development of the **MeyGen tidal stream energy** project at Caithness, where four vertical axis water turbines of commercial size of 1.5 MW (1 AR-1500 and 3 HS-1500) have been in service since 2016, excluding maintenance periods. That was true of the AR-1500 turbine that was redeployed on the site in March 2022. Two other HS-1500 turbines are still undergoing maintenance and repairs and should be redeployed in the coming months. New tidal range turbines of the AR2000 type – a 2-MW water turbine –should be deployed in the **MeyGen** project's next development phase. More recently, in April 2022, the French turbine designer

The Swedish developer Minesto tests a submarine glider attached to the seabed by a cable in the waters of the Faroes. The force of the currents will get the "kite" to make figures of eight in the water and generate electricity.

Sabella resubmerged its **D10** water turbine and reconnected it to the Ushant Island power grid in June 2022, starting a third test and production campaign for the water turbine model. The D10 wind turbine is a gravity-based water turbine with maximum capacity of 1 MW, a rotor diameter of 10 m, it is 17 m high and weighs 450 tonnes. The main innovation tested during this new campaign is geared to smoothing the electricity production required to guarantee constant quality of the electricity injected into the Ushant Island grid to the grid operator **ENEDIS**. On 1 June 2022, **Sabella** successfully completed its fundraising effort for 2.5 million euros via the **GwenneG** funding platform, in the form of the issue of bonds not convertible into shares. The funds will be used for the company's R&D industrialization projects including this year's construction of its future assembly shop at the port of Brest with the installation of a 50-tonne gantry. This operational site will be used to assemble the water turbines of its two ongoing commercial projects: the one led by Morbihan Hydro Energies in the Gulf of Morbihan as part of the European TIGRE programme (two 250-kW D08 water turbines in 2023-2024), and the PHARES project to supply Ushant Island (two 500-kW water turbines in 2024-2025). The Phares project is a multi-energy project that combines two 500-kW Sabella D12 water turbines, one 900-kW wind turbine, 500 kW from an innovative solar photovoltaic mix with 2 MWh of storage capacity, for 2.4 MW of total installed capacity. At the start of 2021, SABELLA took over the water turbine business of GE Renewable Energy. Under the terms of their 18 January 2021 agreement, GE Renewable Energy holds 15% of SABELLA's share capital and is a member of its board.
Many technologies convert **wave energy** into electricity by using point or linear floaters, swell systems and even oscillating columns of water. The Ocean Energy Europe association data for 2021 records that a total capacity of 12.7 MW of wave energy converter projects have been tested in Europe since 2010, and that at the end of 2021, 1.4 MW of projects were being tested in European waters. The year 2021 was particularly active with 681 kW new projects – three in the European Union (for a total of 641.4 kW), one in Scotland on the EMEC test site and another in Norway. They include Europe's most powerful project, that was submerged in August 2021. It is the second generation of the 600-kW, commercially sized **Penguin WEC 2** wave energy converter, developed by the Finnish firm **Wello Oy**, a decade after it launched its first full-scale prototype that it tested in 2012 on the Orkney test site (Scotland). This 44 metre-long wave energy converter with off-centre rotating mass and direct drive has been deployed on the Biscay Marine Energy Platform (BiMEP), Spain on the Basque coast. The Penguin is designed to capture the rotation energy generated by the movement of its asymmetrical hull that rises and rolls as each wave passes and can operate with full storm height waves of over 18 metres. The Penguin **WEC 2** will undergo tests and trials in real ocean conditions for two years. Wello Oy hopes it will be able to validate its wave conversion technology fully during this time. In December 2021, it was towed away for its first inspection, maintenance, and repairs. Wello Oy claims that during the first test period, it had supplied electricity to the Basque Country's grid at power and production levels in line with the expectations raised during the preliminary wave tank trials. Wello Oy has the technical expertise backing of **Saipem**, a world-leading offshore industry player specializing in developing major energy and infrastructure projects. The company recently received financial backing from the Basque energy agency EVE. According to Wello Oy, the Penguin WEC 2 can come in 0.5 to 1-MW versions ranging from 30-56 metres in size. It has its sights set on the European and global markets. In August 2022, Wello Oy signed an agreement with the BIDC (Barbados Investment and Development Corporation) to develop a 5-MW farm in Barbados, and also a Memorandum of Understanding (MoU) with the National Taiwan Ocean University's Centre for Ocean Energy Systems (NTOU) to design and deploy a WEC in Taiwan.
A wave energy converter (WEC) of the "Point absorber" type was installed in August 2021 in the Dutch North Sea Port of Helden. It uses the **Slow Mill** concept developed by the Dutch firm **Slow Mill Sustainable Project** bv. The prototype, on a tenth scale, has 40 kW of installed capacity. The Slow Mill WEC comprises a floater with blades linked variably to an anchor on the seabed. The waves push the floater upwards and the blades far away from the anchor. Thus, it uses not only the waves' up-down movement, but also their to and fro movement. The blades dip up to 3-4 m under water to harness the subsurface wave energy as well. When the wave draws back, it takes the "Slow Mill" to its original position. **Slow Mill** now aims to design its technology for the moderate wave climate typical of the North Sea at a commercial size of 400 kW. **Mocean**, another Scottish WEC developer deployed its Blue X prototype on a tenth scale (i.e., 10 kW), at the EMEC centre for testing from June to November 2021. This demonstration project is of the "attenuator" type, a sort of articulated raft that converts the waves into electricity by flexing in response to the swell. It has been financed by the **Interreg North-West Europe Ocean DEMO project** and by **Wave Energy Scotland**.
The WEC sector should be busier in 2022 than in 2021 with, according to Ocean Energy Europe forecasts, up to 2.8 MW of wave energy capacity deployed, including at least 4 commercially sized machines manufactured by **CorPower Ocean, Eni SpA, Bombora** and **Wavepiston**. These deployments will be sited around the UK, Spain and Portugal. The most eagerly awaited prototype is the **Bombora** mWave wave converter of the Pembrokeshire Demonstration project in Wales – a € 23.5 million project, which is funded by the **European Regional Development Fund (FEDER)** via the Welsh government. Boasting 1.5 MW of capacity, the mWave will be the world's most powerful wave energy converter. It weighs 900 tonnes, its dimensions are 75 metres long, 15 metres wide and 6 metres high. According to **Bombora**, the Pembrokeshire mWave Demonstration Project aims to provide a plan for the multi-megawatt wave energy projects of the future. Also awaited is the **CorPower** C4, with 300 kW of capacity

which should be launched as part of the HiWave-5 Project off Portugal's northern coast at the end of the year. In France, the company **Legendre** has joined forces with **Ifremer** and the engineering firm Geps Techno, to develop the first positive energy breakwater with the **DIKWE project**. A prototype on a quarter scale was installed in the water in July 2022 on a sea trial site at Sainte Anne-du-Portzic, near Brest. The machine looks like a container equipped with an oscillating flap. It measures almost 4.5 m high by 4.5 m wide and 6 m deep. It is installed on a fixed support and is completely submerged at high tide. This project aims to produce energy while protecting harbours and coastlines in the future as sea levels rise. The idea is to design and construct port breakwaters to stop the surge energy. Rather than lose this energy, the port breakwaters could be used to produce electricity in addition to offering protection. The schedule includes a third phase in 2024 with a full-scale 1-MW prototype incorporated into the breakwater concrete.

Salinity gradient uses the energy that can be exploited from the difference in salinity between seawater and freshwater. The natural phenomenon of osmosis is characterized by the transfer, through a semi-permeable membrane (water permeable only), of the water from the environment with the lowest salt concentration (freshwater) to where it is the most concentrated (seawater), to the point where concentration equilibrium is reached either side of the membrane. The difference in salinity makes the water move, which exerts pressure in the saltwater compartment. The resulting water pressure drives a power generating turbine. In April 2021, **Sweetch Energy**, a French start-up at the vanguard of osmotic power plants announced that it had secured € 5.2 million of funding to finance its first prototype. After validating the technology in laboratory conditions, the firm decided to initiate the industrialization phase with the design of a prototype in the next three years, primarily by signing a technology partnership (for € 2.7 million) with the **Compagnie Nationale du Rhône (CNR)** for the construction of an initial demonstrator in the Rhône delta. **Sweetch Energy**'s exclusive "INOD® technology" system is based on a new generation of nano-scale membranes specially designed to harvest osmotic energy, built with environmentally friendly bio-sourced materials. Sweetch Energy has identified the main market as being desalination plants, offering the possibility of slashing their operating costs. An osmotic power plant is already in service in Europe. The Dutch firm RedStack has been operating a pilot Reversed Electro Dialysis type osmotic power plant (TRL7) with 50 kW of installed capacity on the Afsluitdijk dike with the sea on one side and freshwater on the other since 2014. The process uses 1 m3/s of freshwater and the same amount of seawater. Sweetch Energy also aims to use its process to produce hydrogen directly and increase capacity to 1 MW.

Table No. 2

Capacity* and electricity production from ocean energy in European Union in 2020 and 2021 (in MW and GWh)

	2020		2021	
	MW	GWh	MW	GWh
France**	211.8	481.8	211.4	483.8
Spain	4.8	27.0	4.8	19.0
Total EU 27	216.6	508.8	216.2	502.8

Net maximum electrical capacity. ** Electricity production excluding pumped storage. For information, production from pumping of the Rance tidal power plant was 65 GWh in 2020, 66 GWh in 2021. Note: Most countries with marine energy demonstrators or prototypes do not officially include them in the capacity and production data communicated to Eurostat.* ***Sources: EurObserv'ER 2022*

Ocean Thermal Energy Conversion (OTEC) exploits the temperature difference in a classic thermodynamic cycle, between the warm surface water available in some of the world's oceans (at 25–30°C) and the cold deep seawater (at about 4°C from a depth of 800 m and below). Few sizeable projects remain across the globe since the NEMO project that aimed to build a 10.7-MW plant on Martinique, that at the time was led by Naval Energie, a company that no longer exists, was abandoned in 2018. Another project led by the UK's **Global Otec** aims to install a 1.5-MW floating OTEC platform called **Dominique** to supply electricity to São Tomé Island, the main island of São Tomé and Príncipe, a small country off the Gabon coast. The sea's thermal energy can also be recovered by other processes. Spain's gas supplier, Enagas, has hit on the idea of using its liquified natural gas (LNG) methane offloading terminal regasification plant in the port of Huelva in Southern Spain. It operates a 4.5-MW plant that uses the temperature difference between the seawater (which acts as the hot spot) and the liquified natural gas (which acts as the cold spot) to generate electricity. The announced construction of new LNG terminals in the European Union opens up new development potential for this type of plant.

THE EU WAS HOME TO ALMOST 250 MW OF PROJECTS IN SERVICE AT THE END OF 2021

Because of the number of projects currently being tested, drawing up an inventory of the capacity of marine energy projects in service is no mean task. The official organizations do not systematically monitor the prototypes, be they on- or off-grid, and the incessant turnover of prototypes (immersion, improvement, maintenance decommissioning phases), sometimes tested over relatively short periods (about one to two years), does nothing to simplify the production of an accurate project count. Eurostat and the International Energy Agency carry out official statistical monitoring of the net capacity of projects using wave, tide and sea current energy, as defined by the international "tide, wave and ocean" classification. As it stands, only two EU-27 countries – France and Spain – monitor net marine energy capacity and the resulting gross electricity output. Only the capacity and electricity output of the La Rance tidal range power plant are recorded in the data released by the SDES (Monitoring and Statistics Directorate) of the French ministries of the environment, energy, construction, housing and transport. In 2021, its capacity was recorded at 211.4 MW for 483.8 GWh of output. The power plant has a pumped storage unit that added 66 GWh to this total in 2021 (65 GWh in 2020). Spain's Ministry for Ecological Transition only produced accounts for the capacity and electricity output of the Enagas ocean thermal plant and the 296-kW capacity of the Mitriku wave energy plant, giving total capacity of 4.8 MW and output of 19 GWh at the end of 2021. The other EU countries with demonstrators and prototypes that were approached for the purpose of this barometer, have so far decided against monitoring, because of the low output levels and statistical confidentiality rules.

Table 1 shows another installed marine energy capacity monitoring indicator, that includes prototypes and pre-commercial demonstrators that were in service in 2021. The EurObserv'ER marine energy capacity figure for the EU-27, including the 240 MW capacity of the La Rance tidal range plant in France and the 4.5 MW of the Enagas LNG terminal's ocean thermal plant, rose to 249.2 MW. Furthermore, EurObserv'ER puts the EU and Faroe Islands' tidal stream project capacity running in 2021 at more than 2.6 MW and the capacity of wave energy converters at 2.1 MW. The UK, whose test centres accommodate many projects funded by European programmes, add a further 10 MW, including 9.9 MW of projects using tidal stream energy.

The 100-kW, vertical axis water turbine VAWT, developed by the Dutch start-up Water2Energy. This turbine was installed in the recesses of an outfall channel by the sea locks of the Flushing marina in Zeeland, the Netherlands' most westerly province.

THE MEMBER STATES ARE WAITING FOR THE LIGHTS TO TURN GREEN

The European marine energy industry is not short of ambition. According to Ocean Energy Europe, that represents 120 tidal stream, wave energy and other marine energy manufacturers and organizations, 100 GW of capacity using wave energy and tidal currents could be deployed in Europe by 2050 and satisfy 10% of Europe's current electricity needs. Thus, marine energy has the potential to cover the electricity needs

WELLO

COMMERCIAL DEPLOYMENT GETS THE GO-AHEAD IN THE UNITED KINGDOM

In July 2022, the fourth allocation round results of the UK Government's renewable energies auctions were published. For the first time, almost 11 GW of clean energy including tidal stream and floating offshore wind energy was included. The Contracts for Difference (CfD) scheme is the UK Government's main mechanism for supporting low-carbon emission electricity production, as CfDs give project developers the certainty of investing in new renewable energy infrastructures by protecting them from wholesale price volatility. In fact, 41 MW of tidal stream projects have clinched contracts at a strike price of £ 178.54/MWh. Of these, Orbital Marine has been awarded two CfDs totalling 7.2 MW of tidal stream energy deployments on EMEC's Fall of Warness site, Simec Atlantis was awarded 28 MW to continue developing the MeyGen site at Caithness, and Magallanes was awarded 5.6 MW for a tidal stream energy project at Morlais, Wales. At the end of 2021, the UK Government announced the launch of a specific £ 20 m per annum auction for tidal stream projects for 15 years, in addition to new CfD allocation rounds to be launched on an annual basis from 2023 onwards.

of 94 million households, which is tantamount to hydropower's current contribution. The deployment of 100 GW of marine energy would also create a new industrial sector firmly rooted in Europe, and 400 000 skilled jobs along the supply chain. Europe's marine energy companies are the global leaders in their technologies just like their offshore wind energy industry counterparts, even though Chinese, Australian and American players have entered the fray. Proof of this leadership is that most of the demonstration projects outside Europe, in Canada, Japan, Indonesia and Chile use European technology. Ocean Energy Europe asserts that this puts European firms in a privileged position to conquer the global market put at € 53 billion per annum in 2050. Following over a decade of developing demonstrators and prototypes and having invested over € 1 billion in R&D and production plants, the sector now declares itself ready for industrialization, mass production, which is the only route it can travel to bring down production costs. In its **Ocean Energy, Key trends and statistics 2021** publication, OEE points out that the publicly announced public- and private-sector investments in marine energy, such as capital raising, crowdfunding and public investments at national level, increased by 50% in 2021 to € 70 million. One of the largest funding

The Penguin WEC-2 developed by Wello Oy on the Bimep marine testing site, off the Spanish Basque Country coast of Armintza (Bay of Biscay).

FORWARD2030 PROJECT

The EU-funded FORWARD2030 project that kicked off on 1 September 2021, aims to accelerate the commercial deployment of floating tidal energy, in line with the European Green Deal. Specifically, the project must develop a multi-vector energy system to combine predictable floating tidal energy, wind energy generation, grid export, battery storage and green hydrogen production. Furthermore, it aims to create an integrated environmental monitoring system, an energy management system and an operational forecasting tool. In time, FORWARD2030 will be a societal cost of energy assessment tool and also provide marine spatial planning and life-cycle carbon reduction assessment. The total budget project is € 28 million including a € 21.5 million input from the European Union's Horizon 2020 research and innovation programme and will be coordinated by the Scottish firm Orbital Marine Power Limited. The programme's end date is 31 August 2025, and it has five specific objectives:

1. Reducing the Levelized Cost of Energy (LCOE) from € 200 to € 150/MWh,
2. Enhancing environmental and societal acceptance,
3. Complete industrial design for volume manufacture rollout for 10 and >100 MW projects,
4. Reducing life cycle carbon emissions by 33% from 18 g to 12 g CO_2 eq/kWh,
5. Enhancing commercial returns and energy system integration (with battery storage and green hydrogen production).

programmes is that of the Swedish developer **CorPower** which secured € 16.3 million for its flagship CorPower HiWave-5 demonstration project off the north coast of Portugal, with public-private funding from the Portuguese authorities, the Swedish Energy Agency, **EIT InnoEnergy** and other private investors. This development attracted full European Union support through its research and development programmes which strives to ensure that the commercial development of tidal stream and wave energy and cuts in production costs should come as soon as possible so that the sector can contribute fully to the EU's 2030 renewable energy production targets. If we are to cite some of the biggest projects, we should mention TIGRE (Tidal Stream Industry Energiser Project), an ambitious € 45.4 million project launched in 2019, part of the Interreg France (Manche) England programme and the recent FORWARD2030 project launched in September 2021 that aims to accelerate the commercial deployment of floating tidal stream energy, with targets such as 2030 MW of tidal stream energy by 2030 and a reduction in the levelized cost of electricity (LCOE) from € 200 to € 150/MWh (see inset). This industrialization phase, which is vital for cutting production costs, also requires the implementation of guaranteed remuneration systems, such as Feed-in Tariffs and tenders allocated to marine energy. The proliferation of agreements entered into with the major industrial partners in the field of energy accustomed to large offshore, primarily oil and wind energy projects, such as Saipem, TechnipFMC, Schneider Electric, Kawasaki Kisen Kaisha, SKF and General Electric, is another harbinger of the imminence of the industrialization phase. These major groups get involved in different ways, such as through direct investment in technology developers, signing protocol agreements to explore future opportunities or joint development agreements for specific projects.

What matters now is that the marine energy sector ensures that all its investments, research and development programmes produce concrete results through large-scale industrialization. The sector believes that it is contingent on the European Union adhering to the trajectory it set itself in its renewable energy strategy for marine energies presented on 19 November 2020. Ocean Energy Europe published **"Last Stop to 2025"**, its action plan for 2022 in June 2022 with this in mind. In that publication, it emphasizes that government services' and original equipment manufacturers' (OEM) funding and production capacities are crucial if marine energy is to develop. The organization stresses that the experience of the 2010s demonstrated that continuous industrial interest depends on clear government actions to establish markets, without which newcomers will leave the sector and the industrial partnerships will come to an end.

IS THIS THE LULL BEFORE THE STORM IN EU WATERS?

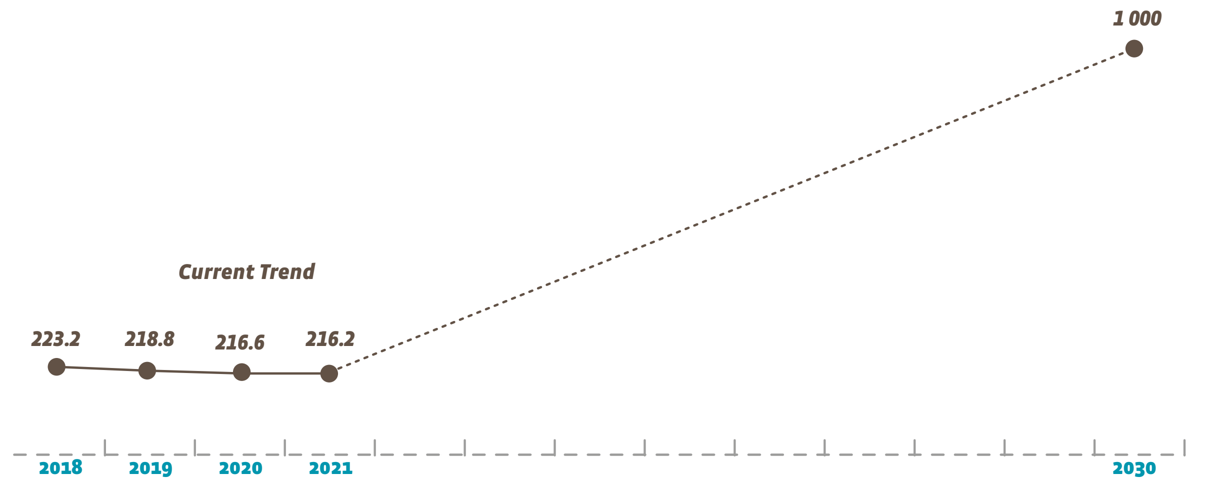
The commercial phase is in the offing after years of testing and the proliferation of full-scale prototypes in Europe. The UK, which has taken and is still taking full advantage of the European Union's policies, has shown the way by guaranteeing revenues for electricity production likely to deploy more than forty MW. Other non-EU countries, such as Canada, have already announced generous guaranteed Feed-in Tariffs for marine energy for projects in Nova Scotia (up to € 350/MWh) and China (up to € 330/MWh). However, the Ocean Energy Europe association observes that project deployment in European Union waters seems to be losing speed and falling short of its Offshore Renewable Energy Strategy targets published on 19 November 2020. The strategy's medium- and long-term targets for ocean energy are to achieve total capacity of 100 MW in the EU by 2025 (on top of the La Rance Tidal Power Plant's capacity) then about 1 GW by 2030 and finally 40 GW by 2050. Progress has been made but has not yet resulted in decisions guaranteeing fast development of ongoing projects. The French Government recently took a step in the right direction when it launched a new opportunity for renewable energy developers to discuss income support bilaterally with the Energy Agency and the French Energy Regulatory Commission. Spain also appears to have good intentions, as it has published a new roadmap for offshore renewables with a 2030 target of 60 MW for wave and tidal energy. Italy's recovery and resilience plan sets aside a budget worth € 700 m for developing innovative renewable energy technologies, explicitly including wave energy. The European Commission also anticipates that it will play its role with the Horizon Europe 2023-24 work project that includes four auction rounds for marine energy with a proposed envelope of € 94 m. Ocean Energy Europe fears that the European Union runs a high risk of missing its 2025 deadline. However, it considers that a significant number of commercial projects could be launched before 2025 and that many more will get to the "Final Investment Decision" (FID) stage by the same timeline. OEE suggests that this decision practically guarantees subsequent deployment and can be considered as reaching the Commission's target, with the caveat that the project funding and guarantee of remuneration for electricity must be finalized before the end of 2023 to enable the FID to be secured before the end of 2025. So, time is of the essence. ☐

Sources : SDES (France), Ministry for the Ecological Transition (Spain), ENS (Denmark), AGEE-Stat (Germany), Statistics Sweden, DGEG (Portugal), Statistics Netherlands, EurObserv'ER, Ocean Energy Europe.

The next barometer will be about renewable energies in transport.

Graph. No. 1

EurObserv'ER projection of the evolution of ocean energy net capacity* in the EU 27 (in MW)



** Net maximum electrical capacity. Note: Most countries with marine energy demonstrators or prototypes do not officially include them in the capacity and production data communicated to Eurostat. Source: EurObserv'ER 2022.*

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