Ocean energy project spotlight

Investing in tidal and wave energy

March 2017

Ocean Energy Europe

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Cover photo courtesy of Sabella.

Photo courtesy of Atlantis Resources plc.

A global inexhaustible energy source

The world's oceans and seas are an enormous untapped energy reserve. Ocean tides and waves have enough energy to potentially power the whole planet. The ocean energy industry is actively developing and deploying devices to tap this inexhaustible energy source.

100GW of installed wave & tidal energy capacity by 2050…

Recent studies and industry scenarios indicate that 337GW of wave and tidal energy capacity could be deployed around the world by 2050. A third of that, 100GW, in Europe alone.

…generating investments worth €653bn…

The global ocean energy market can generate €653bn in investments by 2050, with an annual market reaching up to €53bn[1].

…covering 10% of EU electricity demand

100GW of wave and tidal capacity can produce around 350 TWh of electricity a year[2]. Consequently, the roll-out of wave and tidal energy over the next 35 years could cover up to 10% of the European Union's energy demand[3].

From small to big: ocean energy's different solutions for different applications

Alongside utility-scale deployment, ocean energy devices plug into local and isolated energy markets. Smaller-scale wave or tidal energy devices can already compete in systems using diesel generators: meeting the power demand of an island, powering a desalinisation plant or fish-farm out at sea.

> *With the creation of DCNS Energies, we have serious assets to succeed in this market: renowned experts, advanced technology, turnkey offers covering the lifetime of projects, and an expanding portfolio of sites.*
>
> Thierry Kalanquin, CEO DCNS Energies

[1] Carbon Trust (2011)
[2] Assuming a plausible capacity factor of 40% (or 3,500 full load hours per year)
[3] Calculation based on Eurostat and European Commission energy models (PRIMES 2016)

What is wave energy?

Waves are created by the wind blowing over the surface of the sea. How much energy can be extracted from waves to produce electricity will depend on their height and wavelength: the distance between two waves.

Wave energy devices produce energy from the movement of the waves and can be designed to operate in different water depths: deep water, shallow water, on the shoreline or coastal constructions, such as port breakwaters. The design of the device will depend on its target location and the characteristics of the waves.

What is tidal energy?

The gravitational forces of the moon and the sun cause the water in the seas and oceans to move creating tides. The flow of water between low and high tide creates currents.

Tidal turbines harness this water flow to produce electricity. They can be mounted on the seabed or moored to it and buoyant. Tidal turbines capacity can range from several tens of kW to two or more MW.

350 TWh of electricity can...

...**power** the whole of the **UK and Greece**.

...**bring electricity** to 230 million people, almost **half the homes in the EU**.

...**replace** 90 average coal power plants, **a third of Europe's coal fleet**.

Ocean energy - take-off in 2016

2016 saw a significant amount of ocean energy activity. Alongside the deployment of several single wave and tidal energy devices, the first tidal energy farms were installed and connected to the electricity grid.

Tidal stream - first farms in the water

By end 2016, 21 tidal turbines of over 100kW were deployed in European waters totalling 13MW. Construction is ongoing on a further 20 turbines adding up to 12MW.

A number of future projects have obtained permits. The roll-out of these will depend on policy frameworks conducive to the development of ocean energy and access to project financing.

Three tidal energy farms were deployed in 2016, in France at a site in Paimpol-Bréhat, and Scotland, in the Shetlands and the Pentland Firth. This latter project, called MeyGen, features four 1.5MW tidal turbines and is the biggest tidal energy farm to date. These come in addition to a multi-turbine project built into an existing sea-wall in the Netherlands.

Wave energy - steady progress

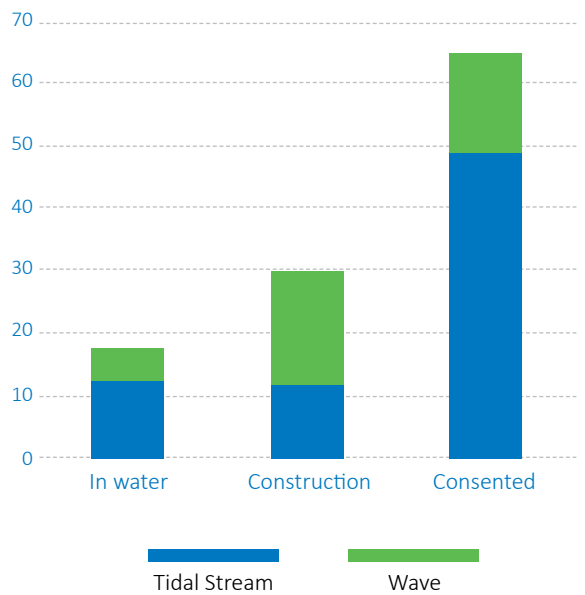
The first experimental wave energy devices were deployed at sea in the late 1990s. Progress in the technology was slow due to a lack of vision for renewable energy and political interest in promoting this new technology. Recently however, renewable and climate policies in Europe and globally prompted increases in research and innovation funding to the sector.

> *I think it would be hard to underestimate the importance of this type of pilot projects that can open up untapped sources of clean energy.*
>
> Jan Vapaavuori Vice-President European Investment Bank, July 2016

> *DEME wishes to be a pioneer in this promising and sustainable technology.*
>
> Alain Bernard CEO DEME, April 2016

Over the past years, 13 wave energy devices of 100kW or bigger have been deployed at sea, totalling almost 5MW. Ten of which were deployed over the last 3 years alone. Whereas most of these devices are experimental or down-scaled versions of the final concept, six further projects totalling 17MW are under construction, including a multi-megawatt device. Another 15MW of wave energy capacity are already permitted.

WAVE AND TIDAL ENERGY PROJECTS IN WATER, UNDER CONSTRUCTION AND CONSENTED AT END 2016 (MW)



Public support for ocean energy is available

The European Union has significantly increased its backing of ocean energy over the past years through grant schemes for both early stage development and deployment. Moreover, ocean energy can tap into risk capital financing through the European Investment Bank.

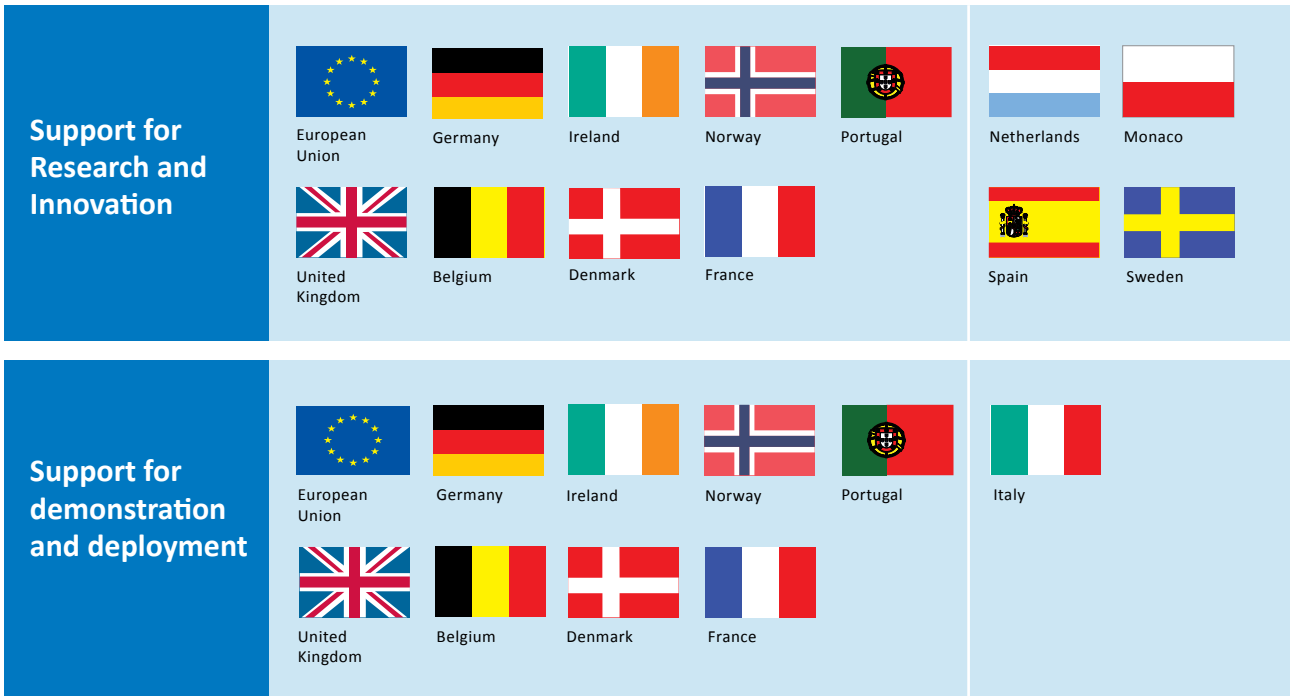
Many European countries have set-up funds to promote ocean energy research and innovation. Alongside these, a number of national support schemes facilitate deployment of pilot ocean energy projects.

ENGIE has been involved in the marine energy sector for over 7 years.

ENGIE believes that Ocean Energy will be part of renewable energy mix in the future.

ENGIE, December 2016

OVERVIEW OF SUPPORT AVAILABLE TO OCEAN ENERGY IN EU AND SELECTED EUROPEAN COUNTRIES

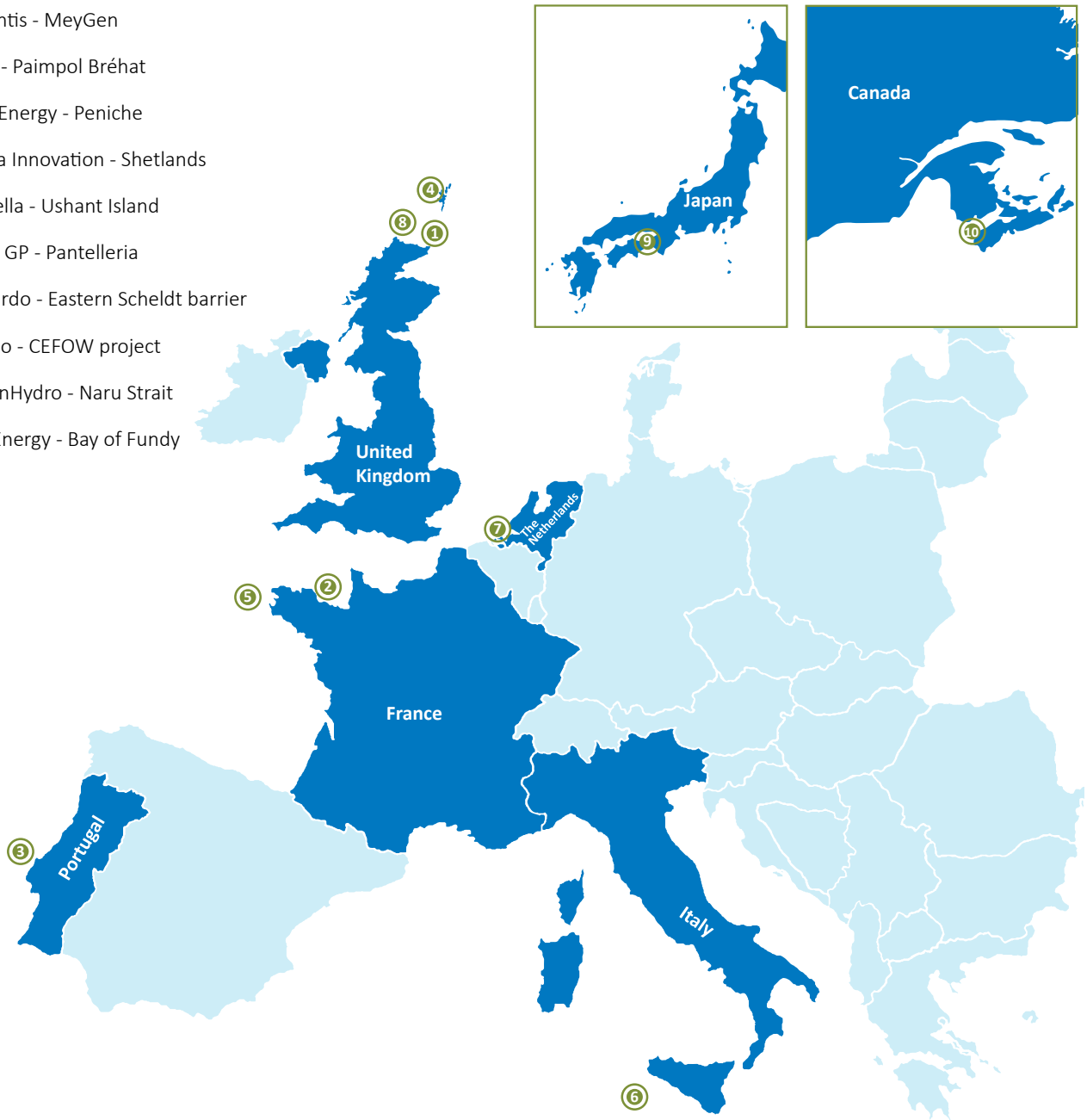


Where the EU is currently world leader, such as in (…) ocean energy, leadership should be maintained. Therefore, the Commission considers that it makes sense to continue to support the development of the next generation of renewables technologies.

European Commission: Towards an Integrated Strategic Energy Technology (SET) Plan (September 2015)

Spotlight on 10 wave and tidal energy projects

1. Atlantis - MeyGen
2. EDF - Paimpol Bréhat
3. AW Energy - Peniche
4. Nova Innovation - Shetlands
5. Sabella - Ushant Island
6. Enel GP - Pantelleria
7. Tocardo - Eastern Scheldt barrier
8. Wello - CEFOW project
9. OpenHydro - Naru Strait
10. DP Energy - Bay of Fundy



Project spotlight

European industry rolling out tidal and wave energy across Europe

1

Atlantis Resources

MeyGen, Pentland Firth (Scotland)

An Andritz Hammerfest turbine ready for loading onto its transport vessel.
Photo courtesy of Atlantis Resources plc.

Total project capacity 398MW total lease capacity	**Number of turbines** Up to 265	**Turbine capacity** 1.5MW	**Turbine stats** 18m rotor diameter
	Grid Connected Yes	**Maximum water speed** 5m/s	**Date of project completion** Phase 1A – January 2017

At 398MW, MeyGen is the world's largest tidal power project. Located in the inner sound of the Pentland Firth in Scotland. Construction commenced in late 2014 soon after achieving financial close in for the project's first phase.

The first phase has a capacity of 6MW, with the first turbine connected to the power grid in December 2016 following a successful construction programme.

Furthermore, A positive final investment decision was achieved in December 2016 for the next phase of the MeyGen project also known as Project Stroma. Construction of this second 6MW phase will begin during 2017.

2

EDF

Paimpol Bréhat, Brittany (France)

Mr François Hollande, President of France, examines DCNS/OpenHydro turbine in Cherbourg, host of the future tidal turbine manufacturing plant. Photo courtesy of DCNS.

Total project capacity 1MW	**Number of turbines** 2	**Turbine capacity** 0.5MW	**Turbine stats** 16m rotor diameter
	Grid Connected Yes	**Maximum water speed** 2.5m/s	**Date of project completion** 2016

In 2015 EDF developed a tidal energy site off the coast of Brittany. The site features an innovative underwater power hub to which up to four tidal turbines can be connected. The hub converts the alternate current from the turbines to continuous current and exports it to the onshore power grid.

Two 0.5MW DCNS/OpenHydro turbines were deployed and connected to the site in early 2016. As a next step, EDF Energies Nouvelles and DCNS/OpenHydro are working to deploy seven similar 2MW turbines in the Raz-Blanchard off the coast of Normandy. This project will be built in 2018.

3

AW Energy
Peniche (Portugal)

The WaveRoller being towed into position off the coast of Portugal. Photo courtesy of AW-Energy Oy.

Total project capacity	Device stats	Average wave height
350kW	Panels 10m by 18m	1.5m
Grid Connected	**Water depth**	**Date of project completion**
Yes	12m to 17m	2017

AW-Energy is deploying a commercial scale WaveRoller® device in Peniche, Portugal. The 350 kW device, financed partly by a loan from the European Investment Bank, will operate under a commercial grid connection license.

Following the success of the demonstration plant on the same site - more than 5,000 operational hours between 2012 and 2014 - the WaveRoller® unit system efficiency and power output performance has been validated by DNV-GL and matched the dry land test facility results. AW-Energy is on track to receive a full Certification of the WaveRoller® technology by Lloyd's Register.

5

A Nova turbine being lifted off the quay.
Photo courtesy of Nova Innovation.

Nova Innovation

Shetland Tidal Array (Scotland)

Total project capacity 500kW	**Number of turbines** 5 x 100kW	**Turbine stats** 9m rotor diameter, 30m water depth
Grid Connected Yes	**Water speed** 2.5m/s	**Date of project completion** Phase 1: 2017

Nova Innovation delivered power from the world's first fully-operational, commercial, grid-connected offshore tidal array. After installing the first device in March 2016, the second in a series of five 100kW turbines was deployed in August 2016.

Phase 1 will be completed with a third turbine during 2017. Two more turbines will follow.

5

Sabella

Ushant island, Brittany (France)

Sabella D10 being lifted into position.
Photo courtesy of Sabella.

Total project capacity	Number of turbines	Turbine stats
1MW	1	10m rotor diameter, 400 tonnes, 55m water depth
Grid Connected	**Maximum water speed**	**Date of project completion**
Yes	4.2m/s	June 2015

The Sabella 1MW D10 turbine was deployed off the island of Ushant, France in June 2015. The turbine was designed building on the smaller D03 model. Before deployment in the Fromveur passage, it was tested at the CNR-INSEAN lab in Italy. Between November 2015 and March 2016 the turbine fed 70MWh of electricity into the grid.

In the water, sensors on the turbine carry out thorough environmental monitoring. To date no particular impact on marine flora or fauna has been identified.

This successful deployment should pave the way for the development of the D12 1MW turbine to be used at a pilot farm scheduled for completion in 2019.

6

ENEL Green Power

Sicily and Western Sardinia (Italy)

Wave for Energy's ISWEC device off the island of Pantelleria. Photo courtesy of Gianpaolo Rampini.

Total project capacity	Device stats	Water depth
200kW	Panels 8m by 15m	35m
Grid Connected	**Average wave height**	**Date of project completion**
Yes	1.2m	2016

ENEL Green Power, in collaboration with an Italian start up Wave for Energy, is proceeding in taking the first steps towards the creation of an industry wholly dedicated to ocean energy technologies. This includes working on bespoke permitting frameworks and obtaining authorisations for the deployment of wave energy devices in Western Sardinia.

Wave for Energy deployed a first full-scale ISWEC wave energy device off the island of Pantelleria in Sicily in August 2015. The device features two power producing gyroscopes for a total of 200kW.

7

Tocardo

Eastern Scheldt barrier, Zeeland (The Netherlands)

Tocardo's Tidal Power Plant being towed into position. Photo courtesy of Tocardo.

Total project capacity	Number of turbines	Turbine stats
1.2MW	5 x 240kW	3m blades, 5.5m rotor diameter, 14.5 tonnes weight
Grid Connected	**Average water speed**	**Date of project completion**
Yes	3.5m/s to 4m/s	December 2016

The Tidal Power Plant was engineered and produced in a record time of nine months. The five 240kW turbines were installed between the pillars under the Eastern Scheldt storm surge barrier in just two hours. The 50 metre-long and 20 metre wide structure was transported over water to the island "Neeltje Jans".

The Eastern Scheldt storm surge barrier is the largest of the Delta Works, a series of dams and barriers, designed to protect the Netherlands from flooding. The project is a unique combination of water safety and renewable energy

8

Wello

CEFOW project, European Marine Energy Centre (Scotland)

Preparing to board Wello's Penguin device. Photo courtesy of Wello Oy.

Total project capacity	Device capacity	Device stats
3MW	1MW	Size: 30m by 20m
Device weight	**Water depth**	**Date of project completion**
250t plus ballast	50m	2020

In partnership with Fortum, Finland's biggest utility, Wello is deploying wave energy devices at the European Marine Energy Center. The project consists of 3 devices in an array. At completion, by 2020, it will constitute the first multi-megawatt wave energy farm in the world. The three "Penguin" wave energy devices will produce continuous power to the grid. The aim of the project is to bring the cost of electricity produced on-par with off-shore wind.

European companies leading global tidal development

9

OpenHydro
Naru Strait (Japan)

Archive photo, courtesy of DCNS.

Total project capacity	Number of turbines	Turbine stats
2MW	1	16m diameter, 27m height, 1,200 tonnes
Grid-connected	**Average water speeds**	**Date of project completion**
Yes	2 to 3.7 m/s	2019

OpenHydro, a DCNS company, is part of a consortium which has been selected by the Japanese Ministry of the Environment to supply a tidal turbine system for installation at Naru Strait, Goto City, Nagasaki Prefecture.

The 2MW Turbine will be built in France and shipped to Japan. The subsea base will be manufactured locally. Local partners will be responsible for all mobilisation and deployment activities.

This deployment is expected to lead to future commercial scale projects.

10

DP Energy
Bay of Fundy
(Canada)

Laying a 2km subsea power cable at the FORCE site, Minas passage, Bay of Fundy. Photo courtesy of FORCE.

Total project capacity 2 projects, 9MW	**Number of turbines** 6 x 1.5MW	**Water speed** 4.8m/s
	Grid Connected Yes	**Water depth** 30m to 35m at low tide

The province of Nova Scotia has taken the lead in North America and has facilitated the development of tidal energy by providing substantial on and off-shore infrastructure and consents for an initial 20MW of power generation through the Fundy Ocean Research Center for Energy (FORCE) site situated in the Minas Passage.

With the award of a feed-in tariff, DP Energy will deploy two projects featuring three 1.5MW (tbc) turbines each during 2018 on two different berths. Berth "C" is being developed by Atlantis Operations (Canada) Limited (AOCL) a firm equally held by Atlantis Resources Limited (ARL) and DP Energy.

Ocean Energy Europe´s Lead partners:

Ocean Energy Europe is the largest network of ocean energy professionals in the world. Its objective is to create a strong environment for the development of ocean energy, improve access to funding and enhance business opportunities for its members. 117 organisations, including Europe's leading utilities, industrialists and research institutes, trust Ocean Energy Europe to represent their interests.

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