European Commission

LOW CARBON ENERGY OBSERVATORY

OCEAN ENERGY
Technology market report

Joint Research Centre

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Foreword about the Low Carbon Energy Observatory

The LCEO is an internal European Commission Administrative Arrangement being executed by the Joint Research Centre for Directorate General Research and Innovation. It aims to provide top-class data, analysis and intelligence on developments in low carbon energy supply technologies. Its reports give a neutral assessment on the state of the art, identification of development trends and market barriers, as well as best practices regarding use private and public funds and policy measures. The LCEO started in April 2015 and runs to 2020.

Which technologies are covered?

- Wind energy
- Photovoltaics
- Solar thermal electricity
- Solar thermal heating and cooling
- Ocean energy
- Geothermal energy
- Hydropower
- Heat and power from biomass
- Carbon capture, utilisation and storage
- Sustainable advanced biofuels
- Battery storage
- Advanced alternative fuels

How is the analysis done?

JRC experts use a broad range of sources to ensure a robust analysis. This includes data and results from EU-funded projects, from selected international, national and regional projects and from patents filings. External experts may also be contacted on specific topics. The project also uses the JRC-EU-TIMES energy system model to explore the impact of technology and market developments on future scenarios up to 2050.

What are the main outputs?

The project produces the following report series:

- Technology Development Reports for each technology sector
- Technology Market Reports for each technology sector
- Future and Emerging Technology Reports (as well as the FET Database).

How to access the reports

Commission staff can access all the internal LCEO reports on the Connected LCEO page. Public reports are available from the Publications Office, the EU Science Hub and the SETIS website.

1 Introduction

The objective of report is to provide an overview of recent market developments in the field of ocean energy and to explore the medium and long-term perspective of these markets. The focus is primarily on Europe and the relative competitive position of the EU ocean energy companies and developers in the global market.

The report takes stock of established JRC work in the area of ocean energy [Magagna et al. 2016, Magagna & Uihlein 2016] and includes results from modelling work performed in the framework of the AA, to provide an outlook for the future deployment of wave and tidal energy and a sensitivity analysis of both techno-economic and external drivers.

The ocean energy market can be divided in five main sectors:

- Tidal stream energy;
- Tidal range and lagoons;
- Wave energy;
- Ocean thermal energy conversion;
- Salinity gradient.

Aside from tidal range technologies, no other ocean energy technology is market ready or commercially deployed worldwide. As discussed in the LCEO Technology Development Reports on Ocean Energy [Magagna & Uihlein 2016, Magagna 2018], tidal energy technology is at pre-commercial scale, with wave energy at demonstration level, whilst ocean thermal energy conversion (OTEC) and salinity gradient technologies are still at early stage of development. All technologies still require R&D efforts to reduce costs and to increase the energy output and reliability of the devices [Magagna 2018], [Magagna et al. 2018].

Ocean energy has the possibility to provide a significant share of electricity generation, both at European and global scale. The estimated technical potential for ocean energy technologies is presented in Table 1.

Table 1. Estimated global and Euopean technical potential of ocean energy technologies.

	Global (TWh/y)	Europe (TWh/y)
Wave power	29500	2800
Tidal power	1200	108
OTEC	44000	n.a.*
Salinity gradient	5177	395

Source: [Lewis et al. 2011][Hammons et al.]

*OTEC has potential in EU overseas countries and territories overseas, such as Curacao, Aruba, Sint Maarten to mention a few.

Given their technological advancement and potential within the EU, tidal stream and wave energy technologies are those expected to provide the greatest contribution to the EU energy system in the near future.

The EU market perspective of ocean thermal energy conversion (OTEC) is limited in continental EU waters, whilst it may present a future an option for outermost and peripheral EU territories.

Currently there are no established markets for Ocean energy worldwide, although some projects are already operating at commercial capacity.

Initiatives to support the creation of ocean energy markets are taking place in the EU, Norway, Canada, USA, Australia, Chile and Korea. Project development is also taking place in East Asia, often through private initiatives.

Large-scale deployment of ocean energy technology requires the successful demonstration and deployment of first-of-a-kind tidal farm projects, and the technological progression of wave energy technology to higher level of reliability and viability.

In the following, this report shows that with current cost estimates, tidal energy may enter the European electricity market in a commercially significant way by 2040. The same cannot be said for wave energy, which may still only play a limited role in the European energy market by 2050.

Policy frameworks and initiatives such as the SET Plan aim to accelerate cost-reduction through the establishment of support mechanisms.

The reduction of costs, along with increased reliability, and higher capacity factors, could drive the uptake of both wave and tidal energy technology.

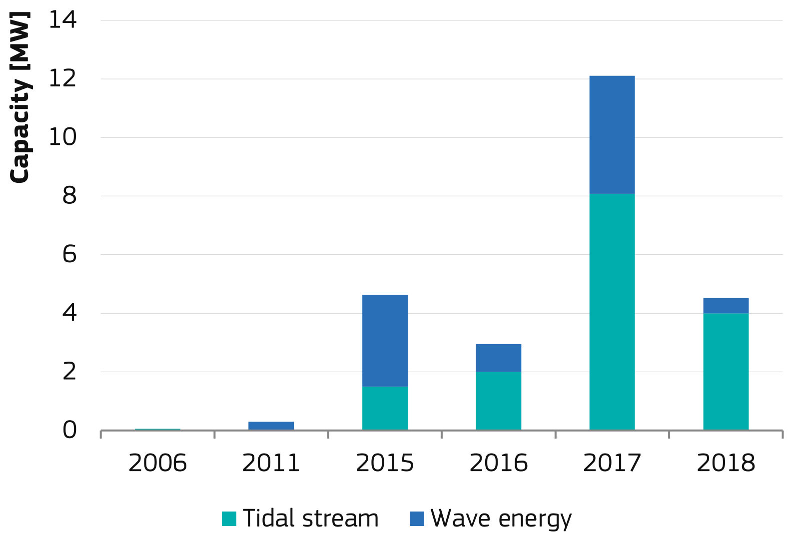
Another critical aspect that would facilitate increased deployment is access to favourable finance for small-projects. Overcoming technological and financial challenges is the key for the sector to increase deployment [Magagna & Uihlein 2015a].

2 Technology trends and prospects

2.1 Deployment trends

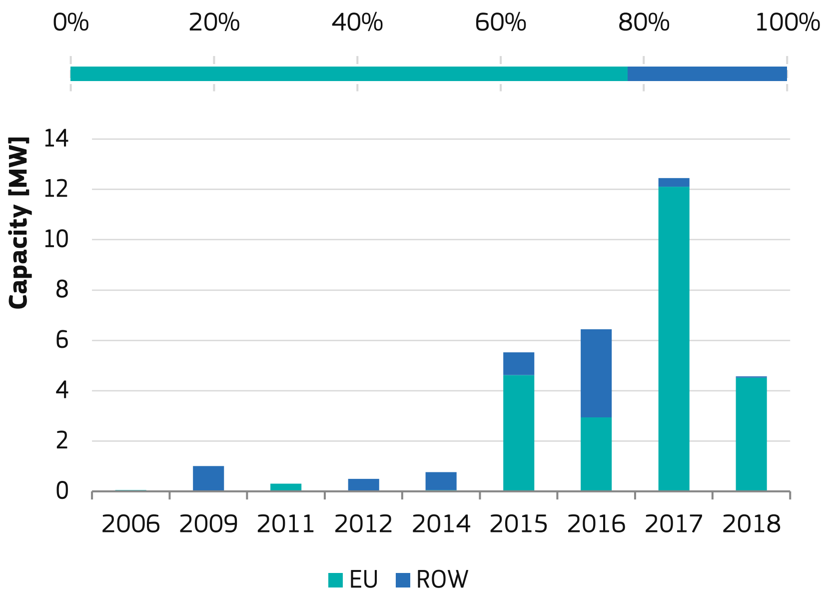
The installed capacity of ocean energy worldwide (excluding tidal range technology) amounted to about 25 MW at the end of 2017, with about 12 MW installed in 2017 alone, an increase of 50 % between 2016 and 2017 [OES 2018a]. At the end of 2018, the total ocean energy installed capacity reached 31.4 MW Figure 1). Taking into account tidal range plants, the total capacity of ocean energy worldwide is in the order of 520 MW.[1] 78 % of the ocean energy installed capacity is located within European waters (24.7 MW), making Europe the global leader in terms of installed capacity and electricity produced by ocean energy (Figure 2).

Figure 1. Global installations of ocean energy capacity from 2006 to 2019



Source: JRC, OES

Figure 2. Wave and tidal energy deployments by region (EU or Rest of the world).



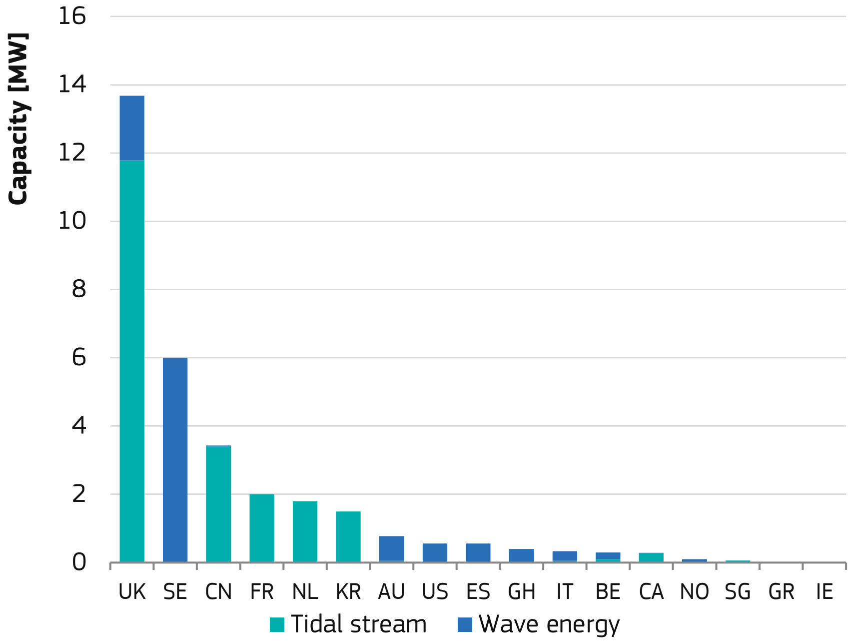
Source: JRC, OES

[1] The two largest tidal range power plants are located in La Rance, France (240 MW) and Sihwa Lake, South Korea 254 MW).

Most of the deployments have taken place in the UK, followed by Sweden, China and France (Figure 3). The majority of the deployments consisted of single-unit technology prototype testing and demonstrators. Small ocean energy farms and arrays have been deployed since 2016. The largest installed capacity of ocean energy is in the United Kingdom, consisting of 11.8 MW of tidal and 1.9 MW of wave energy capacity currently operational.

In Europe, the United Kingdom, France and the Netherlands are the countries with the highest tidal energy capacity installed. For what concerns wave energy, the UK, Sweden, Denmark, Portugal and Spain are the countries with the most capacity installed in Europe. Outside Europe, Australia, China, Ghana and the US are among the countries driving the development of the sector.

Figure 3. Global ocean energy installed capacity in 2018 per country.



Source: JRC, OES

Given the early stage of technology development, the sector has seen the installation of a wide number of technology prototypes that have later been either upgraded or decommissioned.

Figure 4 and Figure 5 show the breakdown of wave and tidal energy in terms of the main developers.

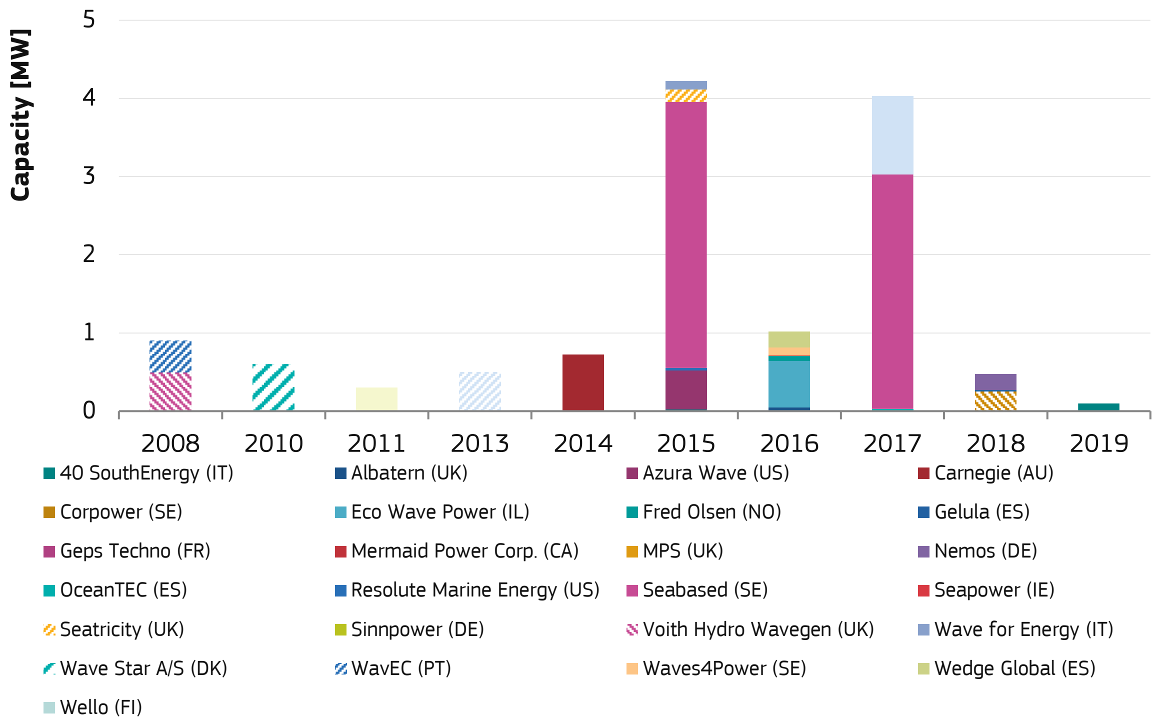
In both cases it can be see that several developers have deployed technologies for validation and demonstration, but only few have managed to follow-up with the deployment of multiple devices of upgraded devices; whilst some have ceased activity since; including 4 MW of OpenHydro turbines that were deployed in 2018 and subsequently stopped operating, following the disinvestment of Naval Energy from tidal energy.

Compared to 2015, when the installed capacity of wave and tidal energy technologies was at similar level (4.6 MW tidal vs 4.8 MW wave), the capacity of tidal energy is now twice that of wave (10 MW wave vs 20 MW tidal).

This due to the more rapid advancement of tidal energy technology to a higher TRL, compared to wave energy technology. Many of the projects proposed for wave energy are prototype, whilst many tidal projects are already grid-connected demonstrators and pre-commercial arrays.

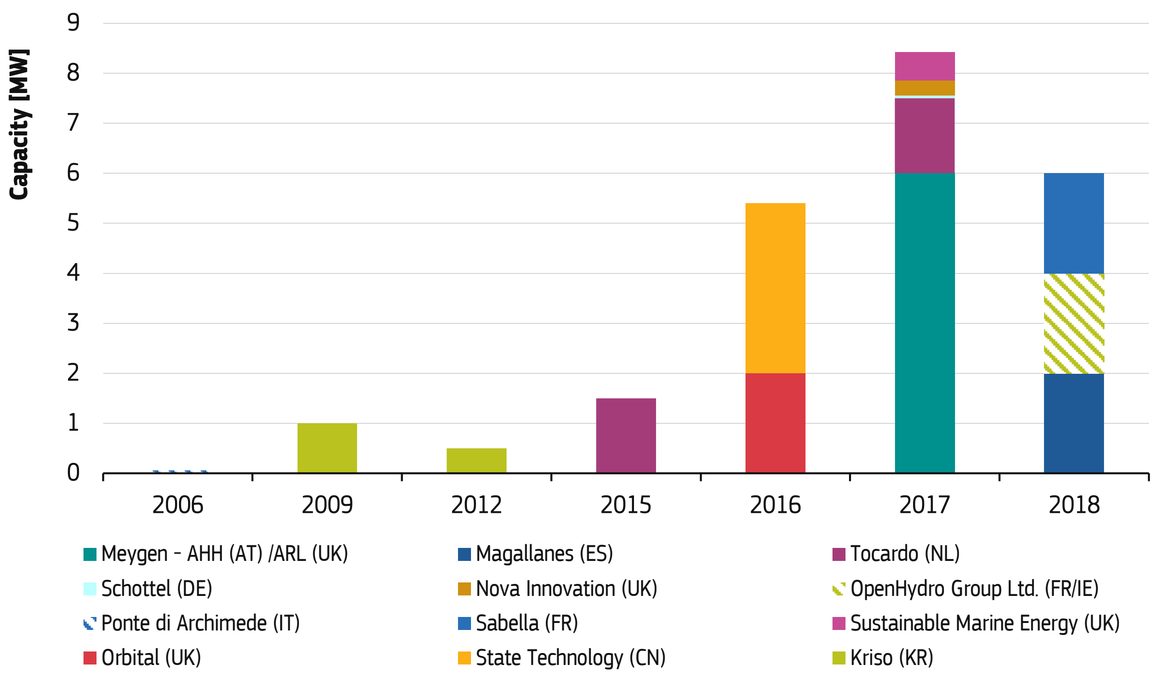
As shown in Figure 6, out of the 20 GWh of electricity generated in the UK between 2010 and 2018, 97 % has come from tidal energy, with only 0.5 GWh coming from wave energy.

Figure 4. Breakdown of wave energy installed capacity per developer. The country of origin of each developer is specified in brackets. Decommissioned projects and developers that have ceased operation since deployment are marked with a



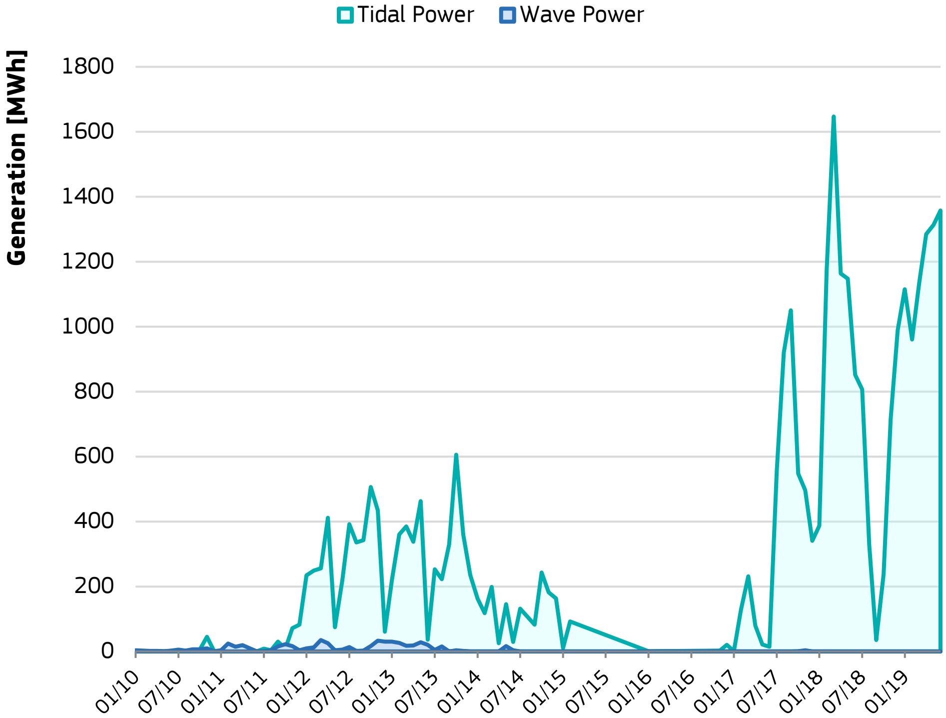
Source JRC, OES

Figure 5. Breakdown of tidal energy installed capacity per developer. The country of origin of each developer is specified in brackets. Decommissioned projects and developers that have ceased operation since deployment are marked with a pattern fill.



Source JRC, OES

Figure 6. Ocean energy electricity power production in the UK between 2010 and 2019. Tidal energy account for 98% of the electricity exported to the grid. Projects such as Meygen and the operation of the Orbital 2MW turbine account for most of ailable.



Source: JRC based on *[OFGEM 2019]*. Last update 31/07/2019

The deployment of a project such as Meygen and the 2 MW demonstrator of the Orbital O2 device are the reasons for the increased generation from tidal energy in 2017 and 2018. Electricity production of wave energy comes mostly from pilot projects, Mutriku power being the most reliable wave energy generator. The 300 kW Mutriku power plant has generated 1.8 GWh since being deployed in May 2011, with an average capacity factor of 9.5 %.

The advancement of tidal energy has been attributed to a greater design convergence, compared to wave energy [SI Ocean 2013, Magagna & Uihlein 2015a, Magagna & Uihlein 2015b]. The tidal energy sector has shown that tidal energy turbines can operate and generate with a higher level of survivability and reliability, compared to wave energy demo projects. The ongoing demonstrations plants are showing that tidal energy devices are becoming more reliable and commercially ready.

2.2 Targets

In 2009 seven member states included ocean energy in their National Renewable Energy Action Plans (NREAP) in accordance with Directive 2009/28/EC [EC 2009]. When the NREAP were launched, it was expected that by 2020 2.25 GW of ocean energy capacity would be operational in the EU. However, the current operational capacity is 264.7 MW[2], including the 240 MW La Rance tidal range barrage (Table 2)

It is clear that the NREAP targets for ocean energy will not be met by 2020. Member States are currently drafting the National Energy and Climate Plans (NECPs), outlining their approach for the design of policies to support innovative energy technologies such as ocean energy

[2] This figure does not include the Openhydro / Naval Energies turbine

Table 2. Ocean energy in the EU: NREAP planning and progress.

Year	Actual Capacity (MW)	NREAP Plan* (MW)
2014	247	322
2016	248	641
2018	264	Not announced
2020		2253

* N.B. The NREAP planning did not differentiate between wave, tidal stream and tidal range technology

Source JRC.

2.3 Policy support

The development of ocean energy is associated with high capital expenditure (CAPEX), high operational expenditure (OPEX), low capacity factors and low reliability of the devices. Currently, the electricity generation from ocean energy is minimal, with an insignificant impact on the overall EU electricity consumption.

Technology developers and advocacy groups have indicated that the lack of policy support instruments is currently hindering the uptake of ocean energy technology. An overview of policy mechanisms supporting ocean energy in the EU and key markets outside the EU is presented in Table 3. Mechanisms available in non-EU countries are included since their availability offer alternative route to markets for EU developers.

The development of technology push and market pull mechanisms is one of the key recommendations of the SET Plan Integrated Plan for ocean energy approved by the European Commission in 2018 [European Commission 2018a]. These include instruments such as risk insurance funds, feed-in-tariffs (FIT), feed-in-premiums (FIP), tradable certificates, tendering, and soft loans.

As seen in Table 3, only a few Member States have dedicated mechanisms to support the development of ocean energy.

The support mechanisms currently available in the EU are not tailored to the current status of ocean energy development. Whilst R&D funds are broadly available to support technology development, thanks mainly to Horizon 2020 and European Regional Development Funds, market support mechanism are mostly aligned to established technologies such as PV and Wind. The result is that emerging technologies at pre-commercial stage, such as ocean energy, cannot make full use of the available market instruments.

In June 2015, the European Commission, together with the European Investment Bank, launched the Energy Demo Projects Risk Finance Facility as a thematic finance instrument under the existing InnovFin-EDP programme. The objective was to bridge the gap from demonstration projects to commercialisation and help further rollout of renewable energy, and hydrogen and fuel cell technologies to the market. By the end of 2018, only one ocean energy project, the Waveroller deployment project in Portugal, had received support through the InnovFIN-EDP.

The SET Plan Implementation plan on Ocean energy has put forward two actions, designed to further bridge the gap to commercialisation for ocean energy technologies, proposing the creation of an Investment Support Fund for ocean energy farms, and of an EU Insurance and Guarantee Fund to underwrite various project risks [European Commission 2018a]. These actions were based on the recommendation of the Ocean Energy Forum Roadmap [Ocean Energy Forum 2016].

In May 2018, DG MARE proposed concrete actions for the design of both the investment support and insurance guarantee fund [European Commission 2018b], suggesting the use of a mix equity and debt design for the funds, taking into consideration the possibility of offering concessional loans at conditions more favourable than current market terms, which may also include a grant component.

In this context, the European Commission has also established the Enhanced European Innovation Council (EIC) to support top-class innovators, start-ups, small companies and researchers with bright ideas that are radically different from existing products, services or business models, are highly risky and have the potential to scale up internationally. The pilot is divided in two main schemes, EIC Pathfinder supporting technology funded by Horizon 2020 FET calls; and EIC Accelerator building on Horizon 2020 SME projects.

Table 3. Policy Mechanisms in key EU and non-EU relevant markets. Non-EU countries are included as the availability of support mechanisms in their jurisdiction offer alternative route to markets for EU developers.

Country	Policy	Detail
France	Specific FIT were provided for the tidal projects in Raz Blanchard; awarded projects could benefit from an older feed-in tariff (173 €/MWh) and reimbursable loans. Commercial scale tenders were expected for 2018, specific for high-energy zones such as Raz Blanchard and the Fromveur Strait in Brittany. Up-front capital grant of €200 million	173 €/MWh for Normandie Hydro
Germany	Fixed feed in tariffs. In the case of ocean energy systems range from 12.4 cEUR/kWh for systems below 500 kW to 3.47 cEUR/kWh for plants above 50 MW.	FIT 12.4 cEUR/KWh <50 MW 3.47 cEUR/Kwh >50 MW
Ireland	Discussion on RESS (Renewable Energy Support Scheme). Floating Feed-In Premium (FIP) selected as the primary financial support mechanism for the new RESS. This support will be allocated through auctions, with potential exceptions for small-scale generation or emerging technologies. A Floating feed-in-premium should be made available for smaller community projects (<6 MW wind, <1 MW other technologies), and development grants should be made available to suitable community-led projects. Currently under review. Additional support is provided in terms of grants through the Prototype development and pre-commercial technology fund, which has provided more than 26 mEUR for ocean energy since being established.	Prototype development and pre-commercial technology fund. 26 cEUR/kWh in 2016
Italy	Feed in Tariff of 30 cEUR/kWh for ocean energy projects (wave and tidal) with capacity of less than 5000 kW for 15 years. For capacity >60 kW also access to registry, but limited so far to 6 MW max (99 kW used)	30 cEUR/kWh for 15 years <5 MW capacity
Netherlands	Generic national subsidy scheme (SDE, stimulating renewable energy) available for tidal current, wave energy and free flow energy at 13 cEUR/kWh	13 cEUR/kWh
Portugal	Feed in Tariffs for micro- and mini-generation (<15 MW) are in place. Recently, the government announced a new FiT of 95 EUR/MWh for capacity up to 250 kW	9.5 cEUR/kWh for 15 years with capacity below 0.25 MW
Spain	There are no specific market incentives for ocean energy in Spain but for renewable energy installations in general.	No incentive. *(Information provided as ES is part of Ocean Energy SET Plan Implementation Group)*
Sweden	There are no instruments in place to specifically incentivise ocean energy deployment.	No incentive. *(Information provided as ES is part of Ocean Energy SET Plan Implementation Group)*
UK	The UK government continues to offer revenue support to a variety of renewable energy technologies through the Contract for Difference (CfD) programme. Based on top-up payments to a strike price, CfDs offer long-term price stabilisation and are awarded via competitive auctions. Strike prices of 310 GBP/MWh for wave and 300 GBP/MWh for tidal stream were quoted for projects due to deploy in 2021/22 in the BEIS 2017 Draft Allocation Framework. Bids for wave and tidal stream CfD allocations are made in competition with other "less established technologies" in a pot that includes offshore wind and biomass. The auction results were considerably lower than the draft administrative strike prices, with offshore wind projects gaining CfDs with strike prices of 74.75 GBP/MW for 2021/2022 and 57.5 GBP/MWh for 2022/23. As yet, no wave or tidal projects have been awarded a contract for difference. The Clean Growth Strategy and Budget confirmed that the 557 mGBP remaining in the former Levy Control Framework would be allocated to further CfD auctions by 2020, with the next auction anticipated for early 2019. The Marine Energy Strategy Board has proposed an Innovative Power Purchase agreement to support tidal energy farms.	CfD – Wave and tidal competing against Offshore wind. Wind CfD at ~8.4 cEUR/kWh (7.5 cGBP/kWh) v the proposed for tidal of ~34 cEUR/kWh (31 cGBP/kWh) Meygen and FLOTEC1 device benefit from ROCs at around 30 cEUR/kWh
Canada	Developers with projects at the Fundy Ocean Research Centre for Energy (FORCE) – Minas Tidal Limited Partnership, Black Rock Tidal Power, Atlantis Operations Canada, Halagonia Tidal Energy Limited, and Cape Sharp Tidal Venture – have approvals for Nova Scotia's Development feed-in tariff (FIT) of 53 cCAD/kWh	Nova Scotia's FIT at 35 cEUR/KWh (53 cCAD/kWh) – 15 year power purchase agreement.

	which allows them to enter into a 15-year power purchase agreement with Nova Scotia Power, the provincial electric utility. Under Nova Scotia's community-based feed-in tariff (COMFIT) program, Digby Gut Limited Partnership has one approval and Fundy Tidal Inc. has two approvals for the COMFIT rate of 65.2 cents/kWh for in-stream tidal devices under 500 kW to be connected at the distribution level. The province of the Ontario FIT Program continues to include waterpower projects, including river hydrokinetic. Projects must have an electricity generating capacity between 10 kW and 5500 kW. The FIT offers a 40 years contract with a rate of 24.6 cCAD/kWh.	COMFIT rate of ~45 cEUR/kWh (65.2 cCAD/kWh) tidal devices under 500 kW (ideal for small islands) Ontario - The FIT for 40 years rate of ~17 cEUR/KWh (24.6 cCAD/kWh) 10<kW<5500
China	New FIT for offshore wind was released by the National Development and Reform Commission (NDRC) in June 2014.	11 cEUR/KWh
Korea	Utility companies with more than 500 MW need to have a given share of renewables (min 5 % in 2018). Market incentives in terms of tradable Renewable Energy Certificate (REC). The values of REC are currently given as 2 for tidal current, 1 for tidal barrage with embankment and 2 for tidal barrage without embankment.	(REC) – 2x for tidal stream
Norway	Green certificate market since 2012. One certificate per MWh has been given to all new renewable energy generation for 15 years, independent of technology, since 2012	Green Certificate
Philippines	In 2012, the Energy Regulation Commission (ERC) granted FIT rates for biomass, hydro, wind and solar project but deferred the issuance of FIT rate (proposed/petitioned by National Renewable Energy Board (NREB) at 17.65 PhP/kWh, specifically for ocean renewable energy, pending further studies on the state of the industry.	~31 cEUR/kWh (17.65 PhP/kWh)
Singapore	The Green-e Renewable Energy Standard for Singapore allows Green-e Energy certification of renewable energy products throughout Singapore	
USA	Clean Renewable Energy Bonds (CREBs). Public Benefits Funds (PBF), which are a state-level market support mechanism designed to provide continued support for renewable energy resources, energy efficiency initiatives and low-income energy programs.	

Source: JRC, OES [OES 2019a].

2.3.1 Projects and existing revenue schemes

In Europe, there are currently 18 MW of tidal capacity installed, most of which are located in the UK. Since 2016, the first tidal energy farm has been installed (Shetland Array), the first pre-commercial farm at utility level started to export power to the grid (Meygen) and pre-commercial demonstrations have been deployed in Scotland (Orbital, Magallanes), England (Minesto), France (Sabella, GKinetic) and in the Netherlands (Tocardo).

Most of the projects mentioned above have benefitted from grant support, both from European (FP7, Horizon 2020) and national R&D programmes. Nevertheless, the availability, especially in the UK, of Renewable Obligations Certificates (ROCs), which provide developers with support for each MWh exported to the grid, has helped the deployment of tidal energy projects. ROCs were in place for the first tidal energy projects deployed by Marine Current Turbines (MCT now part of SIMEC Atlantis), Alstom, and Andritz-Hydro Hammerfest.

However, since 2018, the UK Government has moved from dedicated ROCs for ocean energy projects, to Contract for Difference (CfD) support schemes, where ocean energy technologies have to bid in the same pool of projects with more advanced and established technologies, such as bottom fixed offshore wind, resulting in no ocean energy technology projects being awarded support.

The French government implemented a support scheme for two projects in Normandie, with a capacity of circa 20 MW. The total support amounted to EUR 103 million of capital grants for the two projects, and feed-in support of 179 EUR/MWh for electricity generated. The two projects were awarded to two French developers, Alstom (acquired by GE) and OpenHydro. GE-Alstom has since stopped operations in tidal energy to focus on offshore wind, while Naval Energies closed down its tidal energy activities in June 2018. Naval Energies has cited a study on market perspectives developed by ADEME [ADEME 2018] as one of the reasons to cease activities in tidal energy development. The ADEME study foresees up to 900 MW of tidal energy deployed in the EU by 2030, thus showing only limited business growth for developers.

SIMEC Atlantis has put forward a proposal to the Normandie Region to take over the ownership of the projects, and develop tidal energy technology and supply chain to fill the gap left by Naval Energies, including the grant and revenue support awarded to Alstom and Naval Energy [SIMEC Atlantis].

The identification of revenue support schemes appears necessary in order to facilitate the next wave of ocean energy projects to be deployed. Various proposals have been put forward by developers, and industry representatives, to create a fertile market and support the growth of ocean energy.

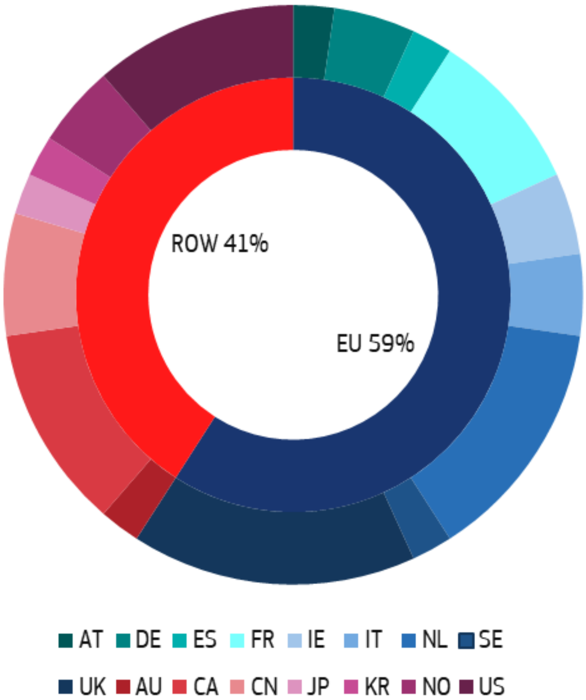
3 Market overview

3.1 Tidal energy

3.1.1 Companies

The development of tidal energy is taking place across the globe, with many companies developing tidal energy devices. 59 % of the tidal energy technology developers are based in the EU (Figure 7), where the country with the highest number of developers is the United Kingdom, followed by the Netherlands, and France. Major non-EU players are the Canada and the USA.

Figure 7. Distribution of tidal energy developers in the world



Source: JRC Ocean Energy Database

The JRC has identified 43 companies active in developing tidal stream energy devices with a TRL>5. It has to be noted, that some developers are developing concepts suitable for both tidal stream and river stream application.

Technological maturity differs amongst developers. 34 % of them have developed technology that is currently at TRL 7 or higher, most of which are located in Europe (87 %).[ESB International 2011][ESB International 2011][ESB International 2011][ESB International 2011][ESB International 2011][ESB International 2011].

Table 4 presents an overview of the leading tidal energy companies at TRL 6 or higher. This shortlist presents the current state of play, but does not provide an indication of future commercialisation or potential success of individual companies and/or devices. A full list of tidal energy developers extracted from the European Marine Energy Centre (EMEC) is presented in Annex 1. This includes all developers that have or still are looking at the development of tidal energy technology.

Compared to 2016, there is an increasing focus on developing technology for niche markets, including off-grid application, river-stream applications and hydrogen-storage options. Tapping into niche markets offers a quick route-to-market for technology developers.

Table 4. Leading tidal energy developers with technology at TRL 6 or higher.

Name	Country	TRL	Operational	Website	Type
Andritz Hydro Hammerfest	Austria	8	Yes	www.andritzhydrohammerfest.co.uk	HAT
SABELLA	France	7	Yes	sabella.fr	HAT
Guinard Energies	France	7	Yes	www.guinard-energies.bzh/	DT
EEL GEN Energy	France	6	Yes	www.eel-energy.fr/en/	OH
SCHOTTEL	Germany	7	Yes	www.schottel.de/schottel-hydro/sit-instream-turbine/	HAT
Openhydro[a]	Ireland	7	No	www.openhydro.com	ET
Design Pro	Ireland	6	Yes	designprorenewables.com/	VAT
Kobold Turbine	Italy	6	No	www.seapowerscrl.com/ocean-and-river-system/kobold	VAT
GEM Ocean Kite	Italy	6	No	bluesharkpower.eu/	HAT
Tocardo	Netherlands	7	Yes	tocardo.com	HAT
Bluewater[b]	Netherlands	7	Yes	www.bluewater.com/	HAT
Water2Energy	Netherlands	6	YES	https://www.bakkersliedrecht.com/en/news/bakker-sliedrecht-and-water2energy-partner-up-to-deliver-high-efficient-water-turbines/	VAT
Magallanes Renovables	Spain	7	Yes	www.magallanesrenovables.com/en/proyecto	HAT
Minesto	Sweden	7	Yes	minesto.com/	TK
Orbital	UK	8	Yes	orbitalmarine.com/	HAT
SIMEC Atlantis	UK	8	Yes	simecatlantis.com	HAT
Nova Innovation	UK	8	Yes	www.novainnovation.com/	HAT
Sustainable Marine Energy	UK	7	Yes	sustainablemarine.com/	HAT
Nautricity	UK	6	Yes	www.nautricity.com/	HAT
Oceanflow / Evopod	UK	6	Yes	www.oceanflowenergy.com/	HAT
Elemental Energy Technologies	Australia	6	Yes	www.mako.energy/projects	ET
Water Wall Turbine Inc	Canada	6	Yes	wwturbine.com/	HAT
New Energy Corporation	Canada	6	Yes	www.newenergycorp.ca/	VAT
Mavi Innovations	Canada	6	Yes	mavi-innovations.ca/project_post/remote-community-tidal-power-project/	HAT
Yourbrook Energy Systems	Canada	6	Yes	www.yourbrookenergy.com	HAT
ZHAIRUOSHAN Tidal Stream energy	China	6	Yes	From OES Report	HAT
Active-Controlled Tidal Current Power Generation System - KIOST	Korea	6	Yes	From OES Report	HAT
Tidetec	Norway	6	Yes	tidetec.com/	HAT
Ocean Renewable power Company	USA	7	Yes	www.orpc.co/	HAT
Verdant Power	USA	7	Yes	www.verdantpower.com/	VAT

Source: JRC

The companies with the most advanced technologies are mainly located in Europe, and have benefitted from the combination of R&D support at national and EU level and by access to research infrastructures and testing facilities that have helped the technology advance to the current pre-commercial state.

In the period between 2004 and 2010, support for the development of tidal energy technology was provided predominantly through national grants, stimulating the initial phases of R&D in the sector. From 2012 funds, including EU mechanisms have focussed more on supporting single demonstration of devices and pre-commercial farms at high TRLs. AndritzHydro-Hammerfest, Magallanes Renewables, Nova Innovation, Openhydro, Orbital Marine, Sabella, SIMEC Atlantis, Sustainable Marine Energy/Schottel, Tocardo have all been part of EU funded projects, and have had access to EU infrastructure testing in projects such as Marinet (FP7), Marinet 2 (H2020), Foresea (Interreg), to name a few. Detail on how EU funds have supported tidal energy developers can be found in the Ocean Energy Technology Development Report [Magagna 2018].

However, the combination of EU, national and regional funds does not necessarily ensure success in the development and commercialisation of tidal energy technology. In July 2018, Naval Energies announced it would cease activities on Openhydro, close the manufacturing facilities opened in Normandy, and stop any ongoing projects, despite a significant support from ADEME to develop the Normandie Hydro project.

3.1.2 Operational Projects

Ongoing tidal energy projects at pre-commercial or demonstration scale worldwide are summarised in Table 5. The majority of those projects are located in the EU, with a few projects taking place in Canada, South Korea, Singapore and China.

The approach to the development and demonstration of tidal technologies is somewhat different for projects in Europe and Canada compared to the projects taking place in Asia, in particular in China and Korea.

In Europe and Canada, public funds support the deployment of a range of technologies, whilst in China and Korea national authorities support the development of technologies with the provision of grants for R&D, funds for deployment, and with national laboratories involved in the designing of the technologies.

For example, the 3.4 MW of capacity installed in China comprises different tidal energy technologies, such as vertical and horizontal axis turbine technologies, on a fixed structure.

Small-scale developments are also taking place in Eastern Asia (Singapore), where projects are supported by a mix of private initiatives and local authority support, focusing on investigating options to offset diesel generation.

Table 5. Ongoing tidal energy pre-commercial and demonstration projects

Project name	Location	Capacity (MW)	Companies and devices	Funding -
Sabella D10 Demonstrator	Ushant (FR)	2	Sabella	Private. Development. Tested with Marinet Support
DP PRO	Bordeaux	0.25	Seenoh	EU H2020
Kobold I	Messina Straight (IT)	0.055	Ponte di Archimede	Private
Eastern Scheldt	Eastern Scheldt (NL)	1.25	Tocardo International BV	Regional Fund
Den Oever	Aflsuitdijk (NL)	0.3	Tocardo International BV	Regional Fund
Texel	Texel (NL)	0.25	Tocardo International BV	Regional
SR2000 @EMEC	EMEC (UK)	2	Orbital	H2020
MeyGen 1A	Pentlad Firth (UK)	6	AndritzHydro-Hammerfest, Simec Atlantis	National, EU
Minesto	Holyhead deep	0.5	Minesto DeepGreen	H2020, ERDF
Shetland Tidal Array	Shetlands (UK)	0.3	Nova Innovation	Regional Fund. Upgrade with support from H2020
InToTidal	EMEC (UK)	1.2	Tocardo International BV	H2020
Magallanes @EMEC	EMEC (UK)	2	Magallanes	H2020 / Foresea
LHD Tidal Current Demo	East China Sea (CN)	3.4	National developer	National
SIT 250 Demonstrator	Singapore Strait (SG)	0.062	SCHOTTEL HYDRO	Private
Uldolmok Tidal Power Station (1)	Yellow Sea (KR)	1	National developer	National

Project name	Location	Capacity (MW)	Companies and devices	Funding -
Uldolmok Tidal Power Station (2)	Yellow Sea (KR)	0.5	National developer	National
Plat-I*	Atlantic Ocean (CA)	0.28	Sustainable Marine Energy	
Water2ENERGY	Belgium	0.15	Water2Energy	Private

*The Plat-I platform was first deployed in Scotland and has since been towed to Canada for deployment there.
**The Openhydro projects are no-longer listed as operational and have thus been removed..

Source: JRC analysis, OES GIS database [OES 2019b], Ocean Energy Europe [Ocean Energy Europe 2019]

3.1.3 Future outlook

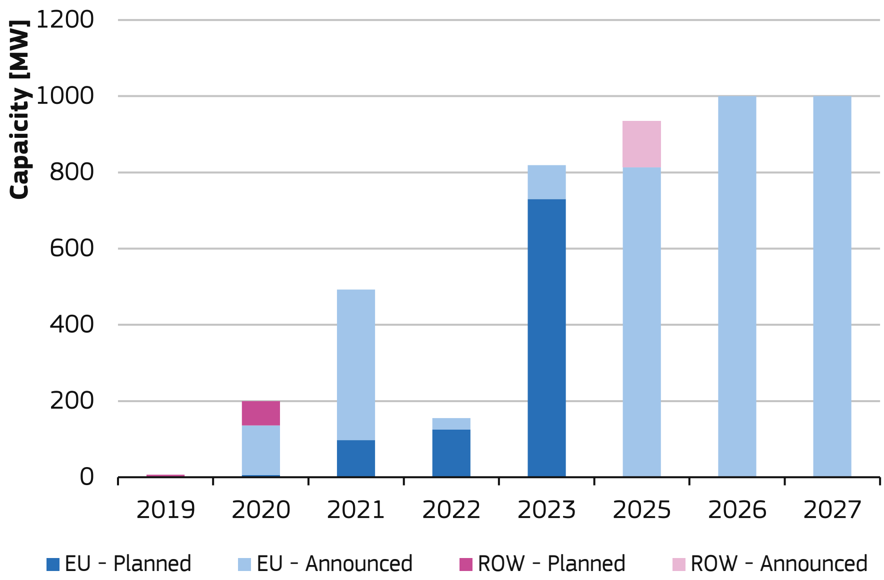
Figure 8 presents the global future deployment outlook for tidal energy projects between 2019 and 2027. The analysis of projects has been carried out by monitoring the websites of key technology developers, advocacy groups and the OES GIS Database [OES 2018b].

This outlook differentiates between two types of projects: planned projects and announced projects, defined as follows:

- Planned projects: Resource potential is identified and assessed. Project planning, licensing and development have already started. Technology options are identified, and in some cases defined.
- Announced projects: Longer-term projects announced by technology developers without an identified deployment plan, where resource potential has not been fully assessed. Project development, licensing and planning has not started.
-

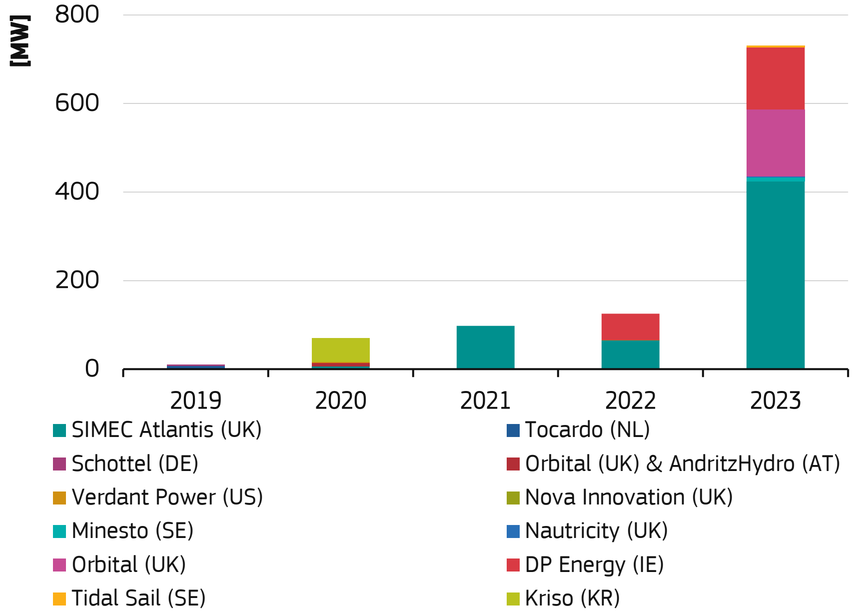
As seen in Figure 8, a total of 4.6 GW of tidal energy projects is in the pipeline and could be deployed between 2019 and 2027. 3.6 GW of projects are announced and another 1 GW are planned. Most of the projects identified are expected to be deployed in the EU (95%). Figure 9 presents an overview of the tidal projects to be deployed between 2019 and 2023 worldwide, a total of 1033 MW, 959 MW of which are expected to be deployed in Europe. This estimate includes, for example, the full deployment of turbines at Meygen (396 MW once completed), and about 140 MW of projects currently being developed by DP Energy, where no technology decision has been made yet.

Figure 8. Announced and planned tidal energy projects in the EU and the rest of the world.



Source: JRC.

Figure 9. Planned tidal deployment worldwide between 2019-2023



Source: JRC

The outlook for tidal energy deployments indicates that there are considerable plans from tidal energy developers for the tidal energy market to take off.

Nevertheless, whilst the ongoing demonstration projects are injecting confidence in the validation of the technology, there is still a lack of support mechanisms to facilitate the deployment of the next wave of array tidal energy farms both in Europe, and globally [Magagna 2018].

The cost of tidal energy, despite showing significant reduction, is still above the cost of other renewable energy sources. The high investment needed to deploy tidal farms does not help attract investors, and hinders the ability of developers to reach final investment decision (FID), thus delaying projects, and effectively stalling the uptake of tidal energy technologies (see section 2.3).

Support instruments, such as feed-in-tariffs, have long been considered necessary to enable the deployment of tidal energy farms and unlock the subsequent cost-reduction. The lack of support, has resulted in the uncertain status of a number of projects that were expected to be deployed by 2018 and 2019, including NER300 supported projects such as Meygen 1B and Sound of Islay.

The availability of feed-in support schemes in other countries, for example in Canada, is attracting EU technology developers outside of the EU. In 2018, tidal energy developer DP Energy announced that it will develop a 9 MW farm in Canada comprising 5 turbines developed by AndritzHydro and 1 floating turbine from Orbital Marine. In order for it to go ahead, the project has received grant funding of ~19 mEUR(29 mCAD) and will benefit of a feed-in-tariff of ~235 EUR/MWh (350 CAD/MWh) [DP-ENERGY 2018].

Whilst Europe maintains a position of leadership in R&D and deployment of tidal energy technologies, the uncertain support framework in the EU, coupled with the availability of instruments elsewhere, may affect the development of the tidal energy market and the subsequent consolidation of the supply chain in Europe.

3.2 Wave energy

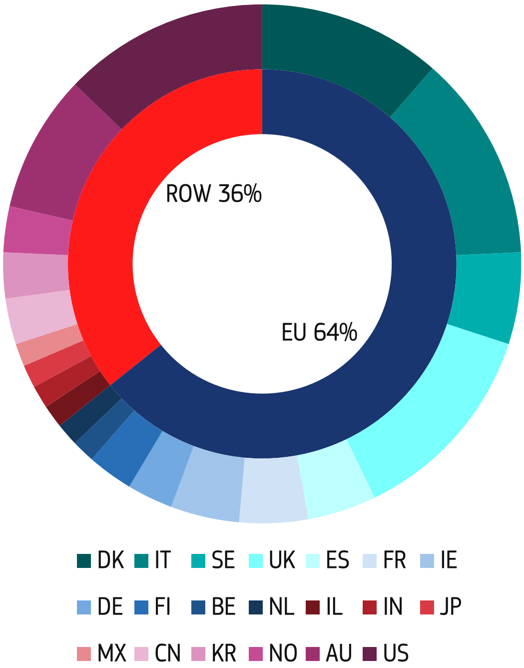
3.2.1 Companies

Similarly to tidal energy, the majority of companies developing wave energy devices are based in the EU (Figure 10). 64 % of active wave energy developers are located in the EU. Denmark has the highest number of developers, followed by Italy, Sweden and the UK. Outside the EU, countries with a large number of wave energy developers are the USA, Australia, and Norway. Nevertheless, a number of developers of technology at low TRL are not included in this analysis. A full list of wave energy developers extracted from the European

Marine Energy Centre (EMEC) is presented in Annex 2. This includes all developers that have or still are looking at the development of wave energy technology.

Compared to 2016, the wave energy sector has shown slow but steady progress in the deployment of wave energy devices, with increasing concertation of devices at TRL 6 and 7, as listed in Table 6. Most of the deployments have taken place in dedicated ocean energy test centres, with an increasing number of deployments taking place at pre-commercial scale (EcoWavePower, Seabased, Sinn Power, Nemo, Wello Penguin and Albatern).

Figure 10. Worldwide distribution of wave energy developers.



Source: JRC

Table 6. Leading wave energy developers.

Name	Country	Website	TRL	Type
Laminaria	Belgium	http://www.laminaria.be/	6	Other
Wave Dragon	Denmark	http://www.wavedragon.net/	7	OT
RESEN Waves	Denmark	www.resenwaves.com/	6	PA
AW-Energy / WaveRoller	Finland	http://aw-energy.com/	7	OWSC
Wello	Finland	https://wello.eu/	7	RM
SBM	France	https://www.sbmoffshore.com/what-we-do/our-products/renewables/	6	BW
SINN Power	Germany	https://www.sinnpower.com/	7	PA
Ocean Energy Ltd	Ireland	http://www.oceanenergy.ie/	7	OWC
SeaPower Ltd.	Ireland	http://www.seapower.ie/	6	ATT
40South Energy	Italy	http://www.40southenergy.com	7	OWSC
Wave for Energy	Italy	http://www.waveforenergy.com/tech/iswec	6	RM
ENI/Fincantieri	Italy	https://www.eni.com/en_IT/innovation/technological-platforms/renewable-energy/iswec-energy-from-the-sea.page	6	RM
Wedge	Spain	https://www.wedgeglobal.com/en/waveenergy	7	PA
CorPower	Sweden	http://www.corpowerocean.com/	6	PA

Name	Country	Website	TRL	Type
Seabased	Sweden	https://www.seabased.com/	7	PA
Waves4Power	Sweden	https://www.waves4power.com/projects/	6	PA
Albatern	United Kingdom	http://albatern.co.uk/	7	PA
Seatricity	United Kingdom	http://seatricity.com/	6	PA
Amog	Australia	ttps://amog.consulting/amog-wave-energy-converter-wec	6	PA
BioWave	Australia	http://bps.energy/projects	7	OWSC
Bombora	Australia	http://www.bomborawave.com/	6	Membrane
Carnegie	Australia	https://www.carnegiece.com/	7	PA
Aquanet Power	Hong Kong	https://www.aquanetpower.com/	6	OWC
EcoWavePower	Israel	https://www.ecowavepower.com/	7	PA
Fred Olsen	Norway	http://boltseapower.com	7	PA
Resolute Marine Energy	USA	http://www.resolutemarine.com/	7	OWSC
Atmocean	USA	https://atmocean.com/	6	PA
Ocean Power Technologies	USA	https://www.oceanpowertechnologies.com/	7	PA
Columbia Power technologies	USA	https://columbiapwr.com/	6	PA
Oscilla Power	USA	https://oscillapower.com/imec-technology/	6	PA
NWEI - Azura Wave	USA / New Zealand	https://azurawave.com/projects/hawaii/	7	PA

Source: JRC

3.2.2 Operational projects

Several wave energy projects at pre-commercial or demonstration scale are currently deployed worldwide (Table 7). In a similar manner to tidal energy deployments, most of the wave energy devices deployed, with the exception of the Wello Penguin, have a capacity below 1 MW. The two Seabased projects comprise multiple 30 kW devices.

A number of deployments have taken place through private initiatives. For example, the SinnPower deployment in Crete, the EcoWave Power in Israel and Gibraltar, and the 40SouthEnergy in Italy have all been developed through private initiatives, thanks to the interest of local stakeholders.

A number of projects are expected to be deployed in the first semester of 2019, including the second 1 MW Wello Penguin, the 350 kW Waveroller device in Peniche, the 500 kW OceanEnergy OWC in Hawaii and the Laminaria device at EMEC.

The short-term outlook of expected projects to be deployed in the EU is shown in Figure 11. In total 182 MW of wave energy capacity are planned. This includes 55 MW of leased projects. In the case of leased projects, no technology decision has been made yet; meaning that the developer has to identify wave energy converters for the realisation of the project. Some of the planned projects have received financial support (e.g. WaveRoller project in Portugal, supported by EIB-InnovFin programme). Other projects are operating on a private bases, and are progressing through power purchase agreements (PPA) as in the case of the Eco Wave Power projects in Israel and Gibraltar.

Additionally, 118 MW of wind-wave capacity can be accounted as announced by Floating Power Plant projects. The Floating Power Plant is a hybrid wind-wave floating system, equipped with a 5 MW wind turbine and 2-3.6 MW wave energy converter. Many of the short-term deployments in the EU are related to R&D projects funded through H2020 or Interreg.

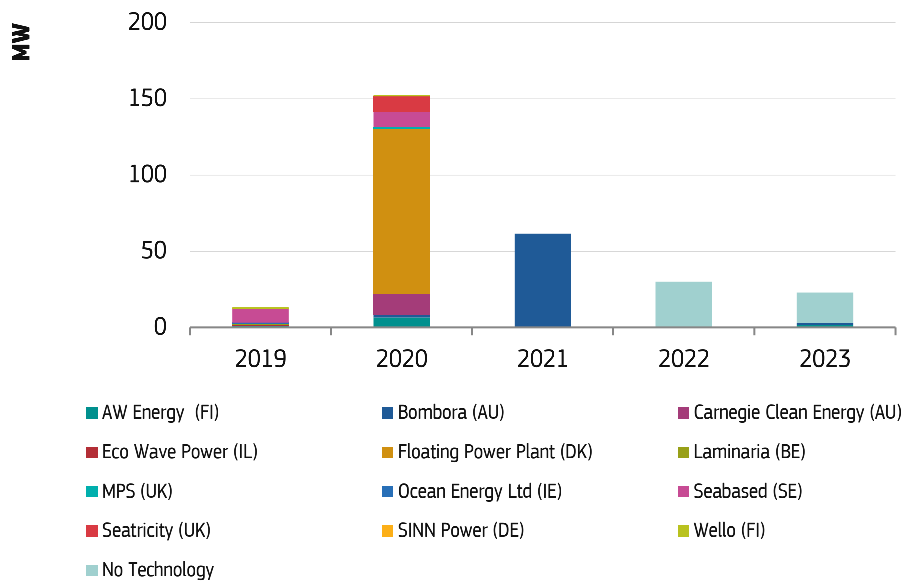
Looking to the mid-term, a total of 490 MW of wave energy projects have been announced for the period 2019-2027. 360 MW are announced in the EU, while 130 MW are expected in the rest of the world.

Table 7. Ongoing wave energy pre-commercial and demonstration projects.

Project name	Location	Capacity (MW)	Companies and devices	Other Info
Mutriku Wave Energy Plant	ES	0.3	Voith Hydro Wavegen	Employed for testing of new turbines as part of the Opera project
Perth project	AU	0.72	Carnegie	Three CETO5 units were deployed in an small array
Marina di Pisa	IT	0.025	40 SouthEnergy	Operational. Device redeployed in 2018
WETS	US	0.5	Azura Wave	Deployed at WETS
Ghana	GH	0.4	Seabased	First 6 converters assembled and grid connection installed
Sotenäs	SE	3	Seabased	Operational
Sinn Power Heraklion	GR	0.002	Sinnpower	Deployed
Pantelleria	IT	0.1	Wave for Energy	Installed
Marine Harvest Salmon Farm	UK	0.045	Albatern	Operates in conjunction with aquaculture farm
Jaffa Port	IL	0.01	Eco Wave Power	Deployed. To be expanded to 1 MW supported by PPA
Gibraltar	UK	0.5	Eco Wave Power	Deployed. To be expanded to 5 MW supported by PPA
WETS	US	0.06	Fred Olsen	Redeployed at WETS and grid connected - 3PTO
Neptune 3 Demonstration	CA	0.011	Mermaid Power Corp.	
Waveel	NO	0.1	Waves4Power	Deployed at Runde
Wedge Global	ES	0.2	Wedge Global	Reliability testing new PA. Currently part of SeaTitan H202
Wave Pendulum	CN	0.03	State	Device developed by national laboratories
Geps	FR	0	Geps Techno	Foresea Interreg
Marmok	ES	0.03	OceanTEC	Opera H2020
Wello WEC 1	UK	1	Wello	CEFOW H2020
Corpower EMEC	UK	0.25	Corpower	Waveboost H2020
Life DemoWave	ES	0.025	Gelula	Life Programme EU
MPS Wales	UK	0	MPS	Welsh Interreg
Nemos	BE	0.2	Nemos	
Seapower	IE	0	Seapower 1/4	1/4 scale device
MaREnergy project	IT	0.1	ENI	ISWEC/Wave Creadle
MaREnergy project	IT	0.05	ENI	Powerbuoy
AMOG	AY	N/A	1:3 scale	AMOG WEC full scale rating 2MW
Wave-tricity	UK	0	Wave-tricity	Pembrokshire
Abatern	UK	0.022	Albatern	WaveNET

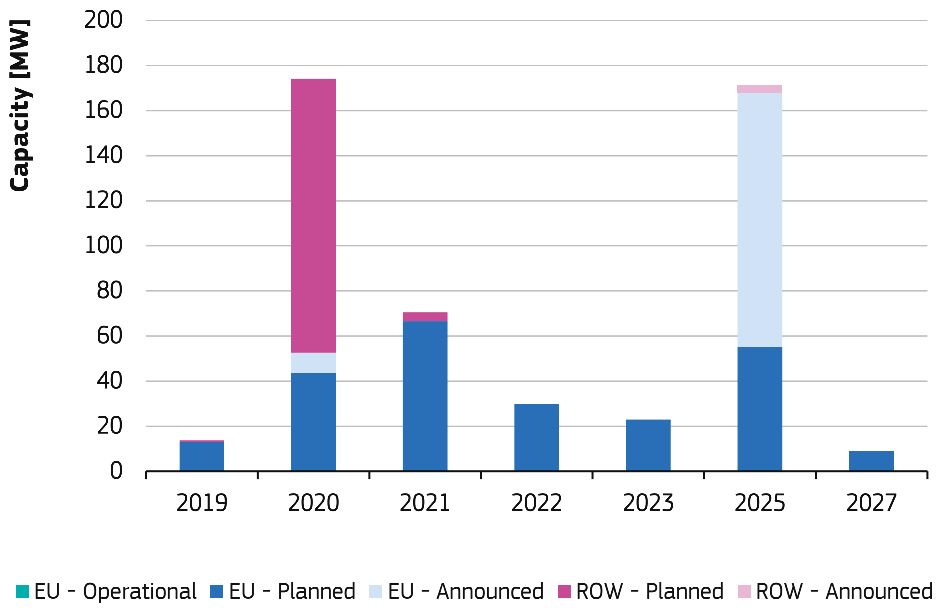
Source: JRC analysis, OES GIS database [OES 2019b], Ocean Energy Europe [Ocean Energy Europe 2019]

Figure 11. Estimated short-term wave deployment in Europe



Source: JRC

Figure 12. Planned and announced wave energy projects in the EU and worldwide.



Source: JRC

Deployment of wave energy is considerably lower than tidal energy, which has about 3.5 GW of capacity in the pipeline up to 2027. The considerable difference between the speed of market uptake is due to the different levels of success of demonstration projects. As mentioned in section 2.1, advanced tidal concepts have already demonstrated increased reliability, both with regards to robustness and the generation of electricity. Whilst a number of wave energy deployments are expected to validate the progress made by the technology, many concepts are still at lower TRL [Magagna et al. 2018]. The deployment of the second Wello Penguin at EMEC, of the AW Energy Wave Roller in Peniche, and of the Ocean Energy Buoy, first in Hawaii and subsequently in Europe, should help the sector overcome the current uncertainties related with the technology.

3.3 Alternative routes to market

The long term goal for ocean energy technologies is to reach cost-competitiveness with other renewable energy sources, so as to become a key player in the energy market.

Currently, with investments being directed to more profitable projects, such as offshore wind, this target does not appear within reach. Developers and policy-makers are exploring different strategies for market entry for ocean energy technologies, to stimulate technology development without having to overcome the constraint of being cost-competitive in the current energy system.

The US Department of Energy has identified 11 market segments that could be a fit for the development of wave and tidal energy technologies [US DOE 2018]:

- Ocean observation and navigation;
- Underwater vehicle charging;
- Desalination, marine aquaculture;
- Marine algal biofuels, seawater mining: minerals and gasses;
- Data centres;
- Constructed waterways;
- Shoreline protection and replenishment;
- Disaster resiliency and recovery;
- Isolated power systems: community scale;
- Isolated power systems: utility scale.

The rationale behind the analysis focuses on the strengths and advantages that ocean energy technologies offer in marine and coastal environments. Furthermore, the near-term applications and market may lead to an increase in the number of development partners.

According to the DOE report, exploring the use of ocean energy technologies for other sectors could offer a valuable avenue for technology development by addressing the relevant challenges of large-scale devices at small scale, and in less price-sensitive environments.

Many ocean energy developers are designing technologies for different uses, from powering ROV vehicles, navigation buoys, oil rigs and fish-farms, to operating desalination and energy storage facilities.

In order to identify successful marine energy drivene desalination technology, the DOE has launched the Waves to Water Prize. A total amount of USD 2.5 million (EUR 2.2 million) has been directed from the DOE to run the prize, which hopes to identify ways to provide clean drinking water for disaster recovery and for remote and coastal communities. The prize is structured in a 4-Stage competition that aims to demonstrate small, modular, cost-competitive desalination systems that use the power of ocean waves.

In mid-2019 Resolute Marine Energy has announced the development of a wave energy plant for electricity production and desalination to be deployed in Cape Verde in 2020-2021. The company has been supported also through Horizon 2020 Blue Growth programme (Wave2O[3] project), and have announced that they could reduce the cost of water supply at nearly a quarter of the price than currently available on the island [Parletta 2019]

Between the end of 2018 and mid 2019 more projects have been deployed exploring the viability of ocean energy for other applications. ENI (Ente Nazionale Idrocarburi) has deployed two projects, one employing OPT PB3 WEC and one employing the Wave 4 Energy ISWEC. Both projects are currently[4] operational in the Adriatic Sea as the company test their viability to supply power to offshore oil platforms. In particular, the PB3 power buoy (3kW rated) has already surpassed 1MWh since deployment in December [Offshore Eenergy Today 2019].

[3] https://cordis.europa.eu/project/rcn/213245/brief/en

[4] As of August 2019.

Table 8 presents an overview of ocean energy developers looking into alternative markets for technology uptake. In particular, EC-OG and OPT have already announced their intention to supply power to oil and gas platforms. Sabella and Nova Innovation have already implemented a solution for energy storage, and many off-grid applications are taking place in Canada, in order to power remote communities.

Table 8. Developers of wave and tidal niche applications.

Developers	Country	Type of technology	Application
Mavi Innovations	Canada	Tidal Stream	Off-grid
New Energy Corporation	Canada	Tidal Stream	Off-grid
Water Wall Turbine Inc	Canada	Tidal Stream	Off-grid
Yourbrook Energy Systems	Canada	Tidal Stream	Off-grid
RESEN Waves	Denmark	Wave	Offshore Powering
Geps Techno	France	Wave - hybrid	Offshore powering
Guinard Energies	France	Tidal Stream	Off-grid
Sabella	France	Tidal Stream	Energy Storage
Nemos	Germany	Wave	Offshore Powering
NIOT OWC (navigation buoy)	India	Wave	Offshore Powering
ENI (Using OPT)	Italy	Wave	Offshore Powering
Fishflow	Netherlands	River	River
Fred Olsen	Norway	Wave	Offshore Powering
Albatern	United Kingdom	Wave	Aquaculture
Aqua Power Technologies	United Kingdom	Wave	Aquaculture
Current2Current	United Kingdom	Tidal Stream	Subsea
EC-OG	United Kingdom	Tidal Stream	Offshore Powering
Nova Innovation	United Kingdom	Tidal Stream	Energy Storage
Wavetricity	United Kingdom	Wave	Desalination
Atmocean	USA	Wave	Desalination
Ocean Power Technologies	USA	Wave	Offshore Powering
Resolute Marine Energy	USA	Wave	Desalination

Source: JRC, OES, Ocean Energy Europe

Box 1. Ocean Energy in Islands

The Ocean Energy System (OES) Technology Collaboration Programme has organised workshops looking at the possibilities of developing ocean energy in insular conditions. Islands are particularly reliant on the import of energy, while they benefit from renewable energy resources. Developing ocean energy in insular territories may offer avenues to offset the reliance on diesel and other fossil fuels and to prove and validate ocean energy technologies.

The most recent OES Workshop on "Ocean Energy in Insular Conditions" has analysed the progress and prospects of ocean energy from the technical, financial and environmental perspective [OES 2018c].

— Technical recommendations: Deployeability and reliability are considered the two main constraints that need to be overcome to ensure the bankability of ocean energy projects in islands. Grid integration of ORE is still to be fully explored. New business models, which may include desalination and energy storage, provide increase value for the deployment of ocean energy pilots in islands.

— Financial recommendations: Cost comparison of ORE vs conventional sources is needed. In some cases the LCOE of ocean energy technology might already be lower than the one of diesel generators.

— Environmental/legislative recommendations: Environmental and licensing barriers pose significant roadblocks in the deployment of ocean energy technologies in islands. These can be overcome through early engagement with stakeholders. Common policies and the implementation of Maritime Spatial Planning should help pave the wave for the deployment of ORE project.

Islands and remote coastal areas represents niche markets for ocean energy, that could help build the necessary confidence for investors and offer an alternative path for commercialisation of ORE technologies, not through direct competitions with other utility market technologies.

It has to be highlighted that a number of initiatives within the EU and outside of the EU exists for developing ocean energy in insular conditions. In the EU, Sabella is developing their turbine to provide electricity and storage option to the highland of Ushant, while in the Canary Islands PLOCAN investigates the use of wave and tidal energy to power their islands (including the deployment of EU Funded WEC Wedge). In the US the Hawaai represents one of regions where most effort have been made to support the development of wave energy technologies, while in Cape Verde Resolute Marine Energy is developing a modular wave-driven desalination facility.

In the EU, the "Clean Energy for EU Islands" initiative provides a legal and policy framework for the uptake of renewable energy technologies in European islands, with the aim of increasing energy security, drive investments and employment and meet climate goals.

3.3.1 Markets for small-size tidal converters

Tidal energy technology developers are not only focussing on the deployment of large, MW-scale machines. Whilst a considerable amount of focus is given to the development of such utility-size projects, a number of developers are also focusing on technology with smaller power-rating, between 25 and 500 kW.

The small–size development is associated with lower risk, from the developer's perspective, both in terms of technology development and demonstration (lower costs). In terms of market this approach provides three main advantages:

- Access to lower-resource sites, opening more market opportunities, especially in eastern Asia;
- Development of decentralised off-grid projects to displace diesel generators on islands and coastal communities;
- Potential application of tidal technology in rivers.

From a technology perspective, the deployment of small-size tidal devices also considerably reduces the associated capital cost, allowing for technological learning at a lower cost than MW-scale devices.

From a market perspective, the development of small-size technologies enables tapping into different resource sites. A comparison between MW-rated turbines and kW-rated turbine is made in Table 9.

Table 9. Technical parameters of MW- and kW-rated tidal energy turbines.

Parameters	Simec Atlantis 2MW	Nova Innovation 100-D
Power Rating	2 MW	100 kw
Rotor diameter	20-24 m	8.5 m
Tidal speed @rated power	3.05 m/s	2 m/s
Cut-in Speed	<1 m/s	0.5 m/s

Source: JRC assessment based on developers' websites.

The tidal energy economic potential in the EU has been estimated at around 108 TWh/year [WEC 2013] [Lewis et al. 2011][Hammons et al.], under the assumption that tidal speed should be in the order of 2.5 m/s or more for projects to become economically viable.

It follows that the development of cost-competitive small-size tidal technology could open different markets for technology developers.

Nevertheless, in both the utility-scale market and in the niche-market the critical aspect for technology and project developers is to ensure the cost-viability of technologies.

As reported in Table 5, eleven of the demonstration projects active in 2018 employed kW-size tidal energy converters; showing that deployment of this type of technologies is somewhat easier to achieve, and may provide an easier route-to-market for developers, especially when revenue support programmes are not implemented.

3.4 Key sensitivities and barriers to market expansion

The progression of ocean energy technologies towards market competiveness is slow, and affected by technological and market barriers, resembling those identified and assessed in the past [MacGillivray et al. 2013, Badcock-Broe et al. 2014, Magagna & Uihlein 2015a].

Despite a the focus of R&D projects in addressing technology shortcomings, targeting in particular the development of PTO, wave energy uptake is still hindered by barriers of technological nature that need to be addressed through further research. Whilst reaching high TRL is key for wave energy technologies, the issues affecting the market uptake of tidal technologies are somewhat different, and more dependent on market design and support mechanisms.

Even though ongoing demonstration projects are showing increased technology reliability, the lack of support mechanisms for emerging technologies is affecting the deployment of tidal energy farms.

Non- technology specific renewable support mechanisms implemented across the EU tend to favour the deployment of technologies such as PV and offshore wind, which are cheaper, more reliable and offer the capacity volume needed to meet climate targets.

Since deployment at scale is required to drive the cost-reduction necessary to become competitive, the inability of deploying more projects risks halting the progress made by the tidal energy technologies, and further increasing the gap to the energy market.

The challenge facing the ocean energy sector is identifying ways to support the deployment of wave and tidal energy farms through innovative support schemes.

An increasing number of developers are exploring the use of crowdfunding either for the fabrication of their new device, to support R&D activities, or to reach the required capital for deployment. Such efforts have mobilised over EUR 20.5 million (USD 23 million) over the past three years [Hume 2018].

The impact of crowdfunding is comparable with public funding for projects, and it is likely to have limited impact, especially in terms of deployment of projects. Nevertheless it is telling of the difficulties being encountered by technology developers.

The actions of the SET Plan, aiming to establish an insurance and investments fund for ocean energy technologies [European Commission 2018a], should address the current gap with the market; however, they require the commitment of Member State in order to be fully delivered.

4 Market outlook

4.1 Modelling

The evolution of wave and tidal energy capacities has been modelled using the JRC-EU-TIMES model [Simoes et al. 2013].

4.1.1 Modelling scenarios

The JRC-EU-TIMES model is a linear optimisation, bottom-up technology rich model, which provides an outlook on the stock and role of energy supply and demand technologies for each country and period as described in [Nijs et al. 2018]

The model examined three main global scenarios:

- Baseline – basic uptake of renewable energy sources.
- Diversified – higher decarbonisation, including nuclear energy and CCUS in the system.
- Pro-RES – higher uptake of renewable energy sources and lower technology costs.

The scenarios are based on a set of inputs and assumptions, associated with uncertainties, which increase when looking at longer time frames (i.e. up to 2050). In this context, and with regards to specific dimensions, (e.g. investment costs or installed capacity) the model results should be viewed as insights on the relevant significance of this dimension relative to the reference, rather than absolute values.

The modelling inputs for ocean energy technology are based on current costs, resulting from a broad literature review as carried out by [Tsiropoulos et al. 2018]. To gain a better understanding of the potential evolution of ocean energy technology, a 'SET Plan technology learning scenario' has been included in the modelling. The 'SET scenario' is based on the assumption that technology innovations will allow the technology to meet the targets of the SET Plan declarations, not only for ocean, but for all technology families. The targets of ocean energy are presented in Table 10.

Table 10. LCoE targets for wave and tidal energy technologies.

Technology	Year	Target
Tidal energy	2025	15 cEUR/kWh
Tidal energy	2030	10 cEUR/kWh
Wave energy	2025	20 cEUR/kWh
Wave energy	2030	15 cEUR/kWh
Wave energy	2035	10 cEUR/kWh

Source: *[European Commission 2016]*

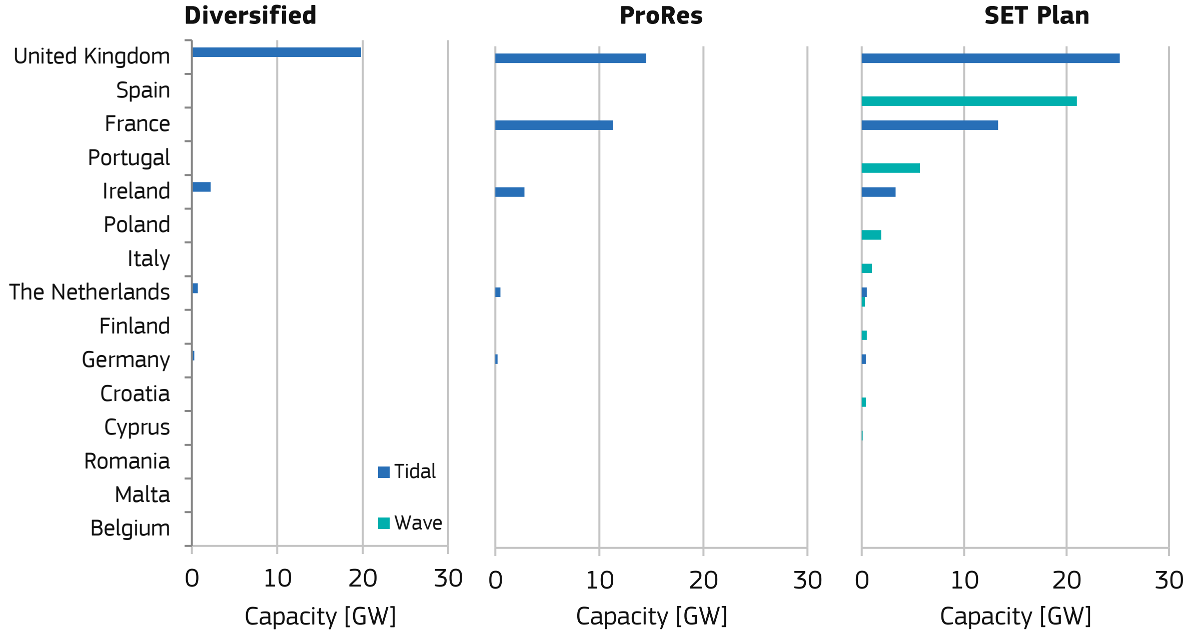
Figure 13 presents the uptake of wave and tidal energy technologies in terms of cumulative capacity (GW) for the year 2050 for the different scenarios modelled.

As shown in Figure 13, meeting the SET Plan targets is fundamental for the uptake of wave, and, to a lesser extent, tidal energy.

Whilst tidal energy would be deployed in UK, France and Ireland under the ProRES scenario and in UK and Ireland only under the diversified scenario, wave energy uptake can only be expected if a significant reduction of the technology cost is achieved.

It is fundamental to highlight that the JRC-EU-TIMES is a cost optimisation model, and therefore cheaper technologies are selected in the creation of the future energy mix. This also explains why in the diversified scenario tidal energy does not appear in France, where nuclear energy is taken up by the model instead.

Figure 13. Cumulative installed capacity by 2050, in GW of wave and tidal energy, according to different JRC-EU-TIMES scenarios. The baseline scenario is excluded since it indicates no wave energy capacity by 2050.

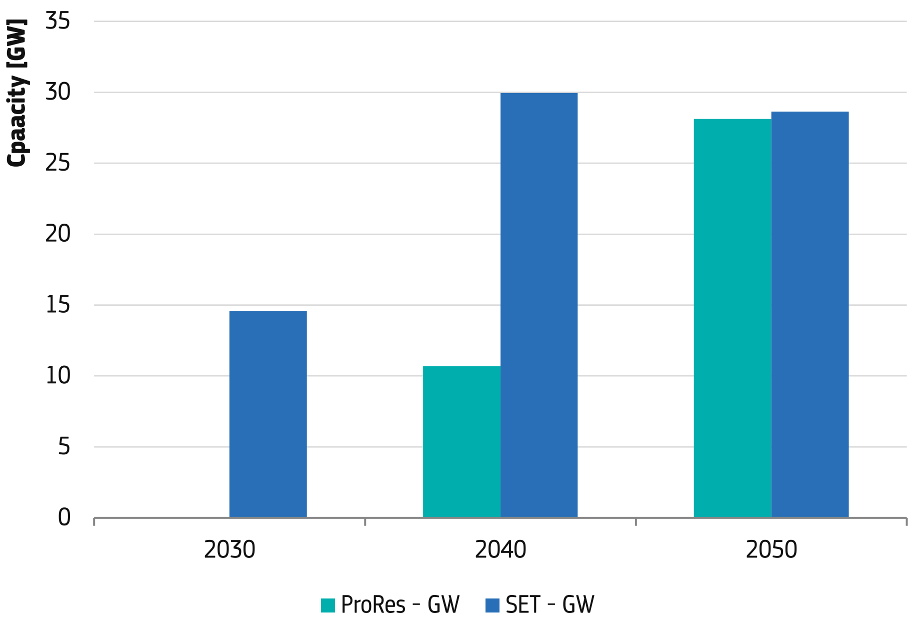


Source: JRC

4.2 Deployment of tidal energy

The cumulative deployment of tidal energy technology under the ProRes and SET Plan scenario is presented in Figure 14. Under the Pro-RES Scenario tidal energy is expected to reach 10.7 GW of installed capacity in 2040, and 28.6 GW in 2050. Under the SET Plan scenario, tidal energy enters the energy system in 2030 as a result of the considerable cost-reduction associated with meeting the SET Plan targets.

Figure 14. Modelled tidal energy deployment under the ProRes (Green) and SET Plan Scenario.



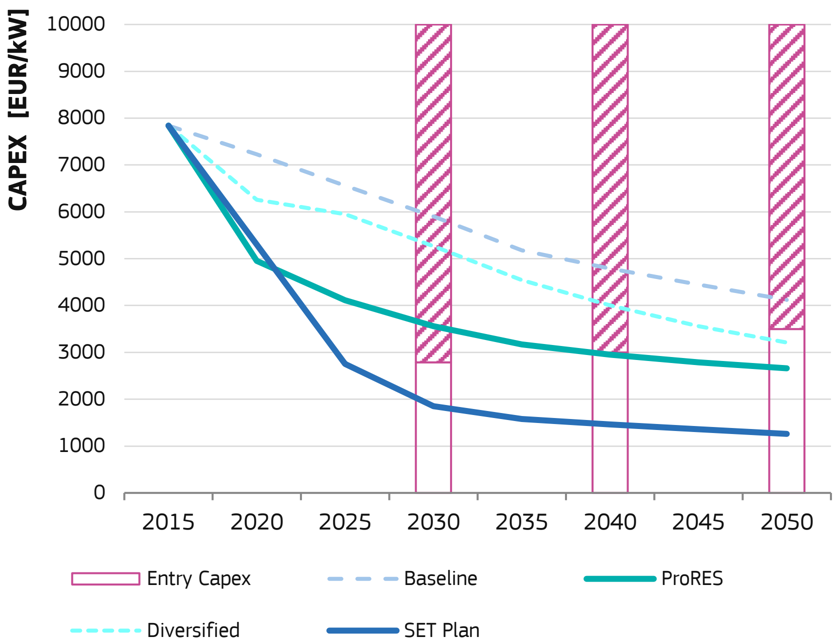
Source: JRC.

Under the SET Plan scenario 14.6 GW of tidal energy could be deployed by the energy system in 2030, with cumulative tidal capacity of 29.9 GW in 2040 and of 28.6 GW in 2050.

The decrease in capacity towards 2050 does not affect the total power of 108 TWh/year generated by tidal energy, which represents the technical potential available in Europe [WEC 2013]. The uptake of tidal technologies in the energy market is based on the assumption of these technologies becoming cost-competitive. Figure 15 presents the evolution of tidal energy Capex under the different scenarios and compares it with the market entry Capex.

The Entry Capex is defined as the threshold Capex which would allow tidal energy to be cost-competitive in the market. Once the Capex of the technology is equal or below the Entry Capex, it is expected that tidal energy technologies will be taken up in the energy system.

Figure 15. Modelled Capex evolution of tidal energy under different JRC-EU-Times scenarios and market entry-capex for tidal technologies.



Source: JRC.

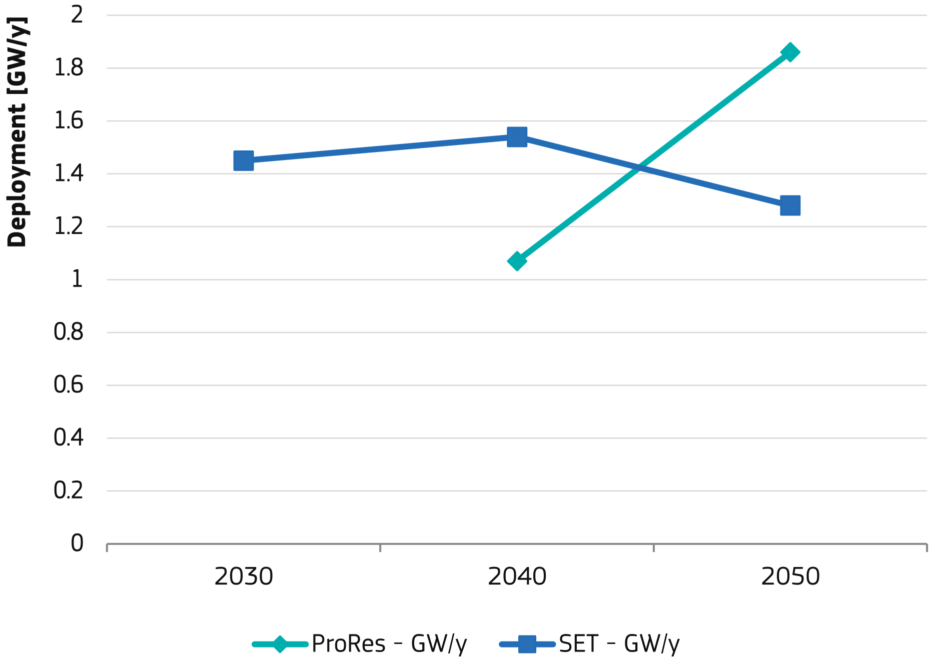
As Figure 15 highlights the modelled Capex reduction in the ProRes, Diversified and SET Plan scenario will reach levels lower than the required Entry Capex by 2050. However, under the conditions of the SET Plan scenario (high learning rate), the CAPEX of tidal energy technology will already be below the required Entry Capex in 2030, thus enabling earlier market uptake of tidal technologies.

Figure 16 presents the indicative annual deployment to meet the modelled capacity for each scenario. In order to reach 14.6 GW installed by 2030 in the SET Plan scenario, annual capacity additions should be of the order of 1.4 GW/y starting from 2020. The respective installation rates of the ProRes scenario are 1.1 GW/y, for the period 2030-2040, and near 1.9 GW/y for the period 2040-2050.

Figure 17 presents the total investments required to meet tidal energy growth under the ProRes and SET Plan Scenario. In total EUR 91 billion of investments would be required under the SET Plan scenario, whilst the ProRes scenario would require investments of EUR 103 billion. The higher investments in the ProRes correspond to the higher cost of tidal technology compared to the SET Plan scenario.

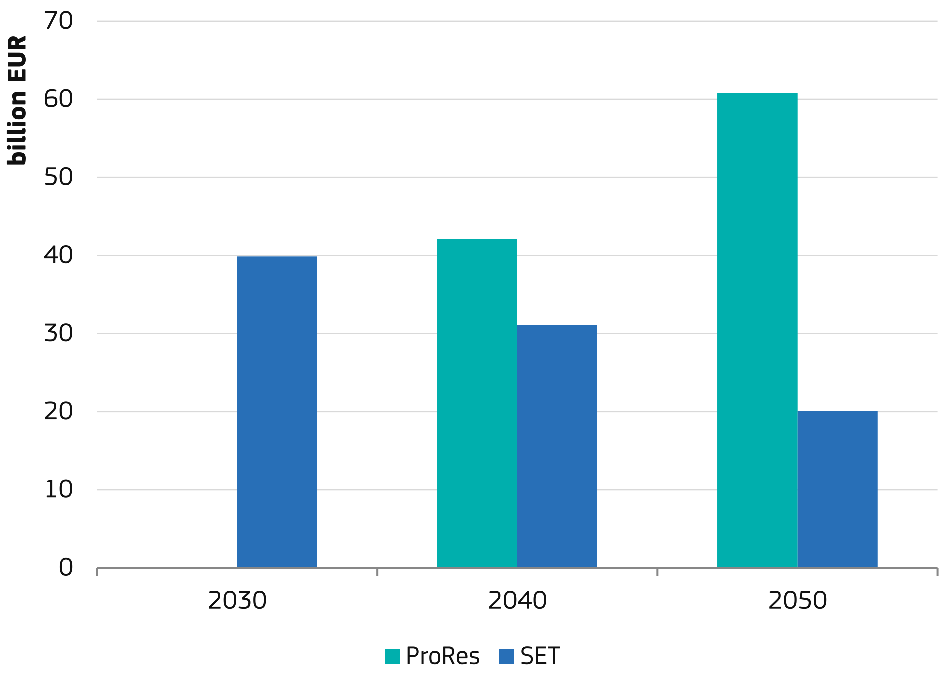
Figure 18 shows the deployed capacity of tidal energy technologies per country according to the ProRes and SET Plan scenario.

Figure 16. Modelled annual capacity deployment under the ProRes (Green) and SET Plan (Blue) scenario for tidal energy.



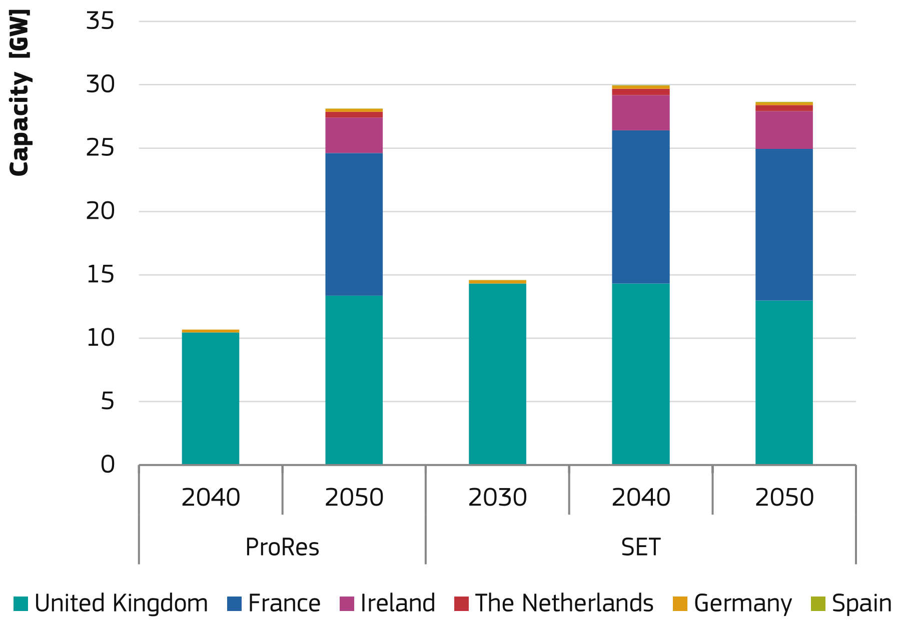
Source: JRC.

Figure 17. Total investments that would be needed to meet the modelled tidal energy capacity under the ProRes (Green) and SET-Plan (Blue) scenario.



Source: JRC

Figure 18. Modelled tidal energy capacity in EU countries under the ProRes and the SET Scenario.



Source: JRC.

Figure 18 shows that in both scenarios the UK is the first country to include tidal energy in the energy system, in both cases reaching 13 GW of capacity by 2050. France could also become a significant market for tidal energy, with up to 12 GW deployed by 2050. Tidal uptake in France is dependent on the renewal of nuclear energy capacities. Other countries who show potential for tidal energy deployment are Ireland, the Netherlands, Spain and Germany.

As mentioned in section 3.3.1, the technical and economic potential of medium-to-low tidal environments (speed <2m/s) is not known, and therefore the market for kW-rated machines is not modelled in the JRC-EU-TIMES model.

4.3 Deployment of wave energy

The modelled cumulative deployment of wave energy technology under the ProRes and SET Plan scenario is presented in Figure 19. Under the Pro-RES Scenario wave energy could to reach 0.04 GW of installed capacity in 2050. Under the SET Plan scenario 0.04 GW of wave energy could already be in the energy system by 2040, with cumulative wave capacity of 30.9 GW by 2050.

The slow uptake of wave technologies is due of the technology being too costly to compete with the alternatives in most of the scenarios.

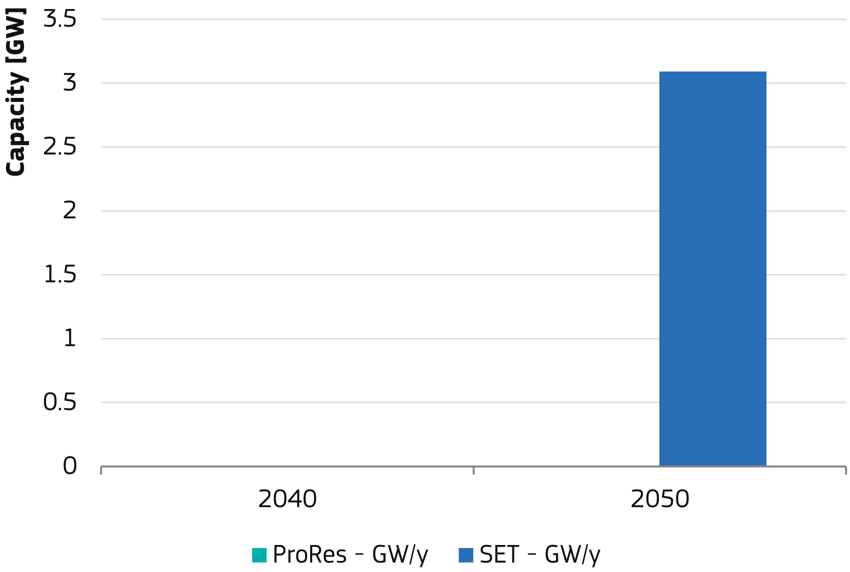
Figure **20** presents the evolution of wave energy Capex under the different scenarios and compares it with the market Entry Capex.

As

Figure **20** highlights, the projected Capex reduction in the SET Plan scenario favours the uptake of wave energy between 2040 and 2050. The high cost reductions required to meet the SET Plan targets, bring the technology cost below the Entry Capex target in 2040 and 2050, thus driving the deployment of wave energy technology. In the ProRes scenario, the expected Capex of wave energy technology reaches the Entry Capex target in 2050, with minimal capacity deployed previously.

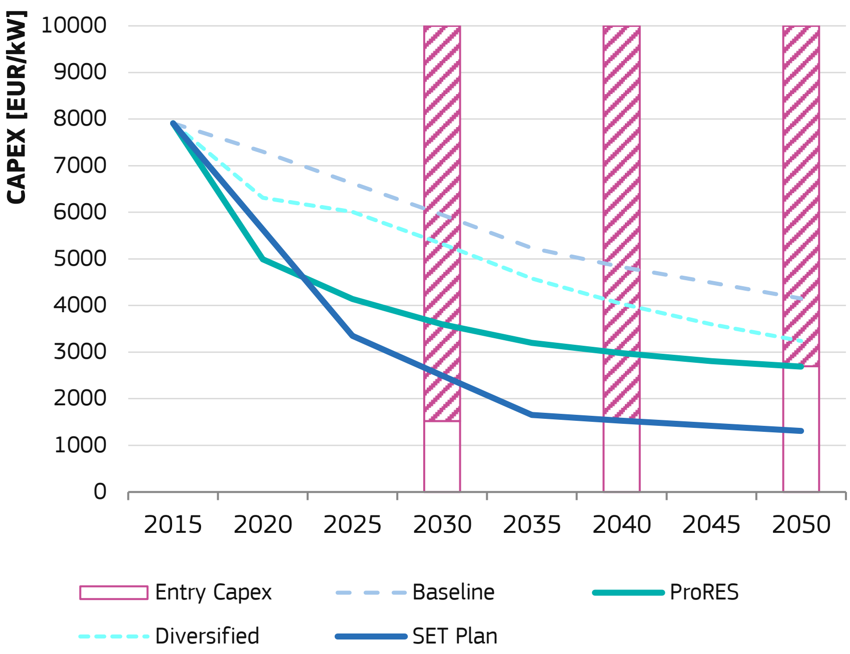
In order to reach 30.9 GW installed by 2050 in the SET Plan scenario, annual capacity additions should be of the order of 3 GW/y from 2040 onwards. This indicates a fast growth of the wave energy markets once costs reduce significantly. The installation rate of the ProRes scenario is considerably slower given the small capacity forecasted by 2050.

Figure 19. Modelled wave energy deployment under the ProRes (Green) and SET Plan Scenario The big increase in capacity between 2040 and 2050 is calculated by the model under the assumption that technology cost-reductions still take place.



Source: JRC.

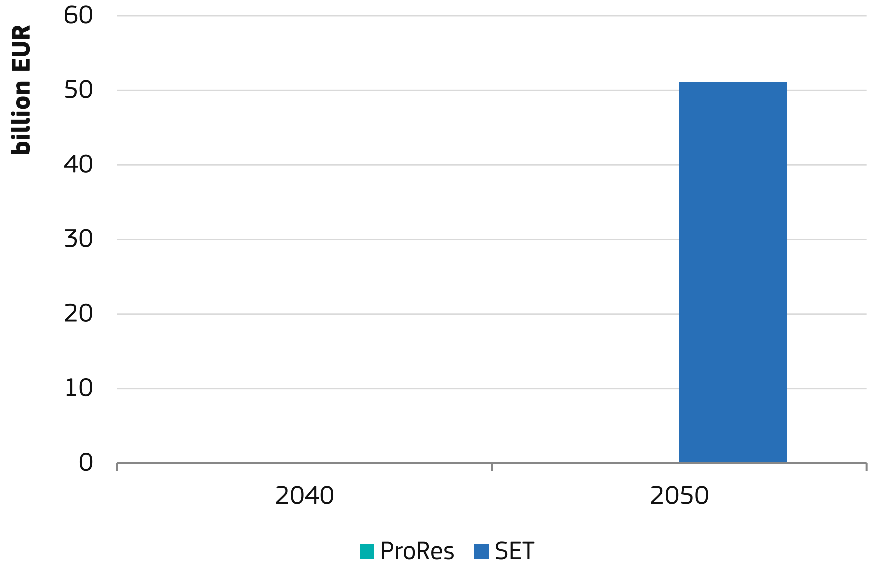
Figure 20. Modelled Capex evolution of wave energy under different JRC-EU-Times scenarios and market entry-capex for wave energy technologies.



Source: JRC.

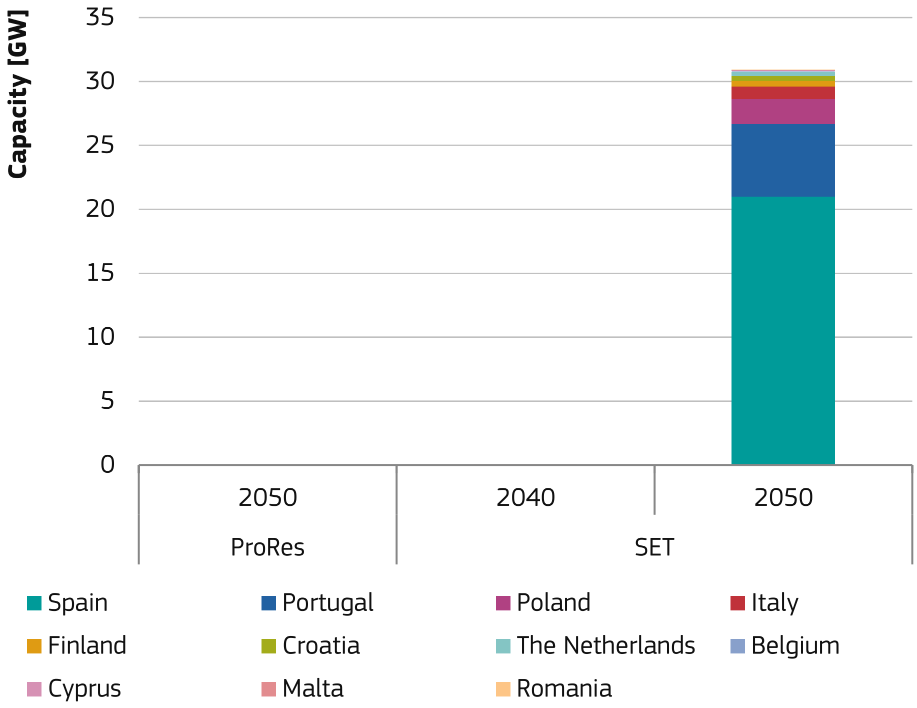
Figure 21 presents the investments required to meet the modelled tidal energy growth under the ProRes and SET Plan Scenario. In total EUR 50 billion of investment would be needed under the SET Plan scenario for wave energy to reach 30 GW of installed capacity by 2050. Figure 22 shows the deployed capacity of wave energy technologies per country according to the ProRes and SET Plan scenario. If cost-reduction targets are met, wave energy will play a significant role in the energy system of Spain and Portugal by 2050, while there is scope capacity to be installed across the EU.

Figure 21. Total investments needed to meet the modelled tidal energy capacity under the ProRes (Green) and SET Plan (Blue) scenario. The big increase in capacity between 2040 and 2050 is calculated by the model under the assumption that technology cost-reductions still take place.



Source: JRC.

Figure 22. Modelled wave energy capacity deployment in EU countries under the ProRes and the SET Plan scenario.



Source: JRC

4.4 Role of ocean energy in other scenarios

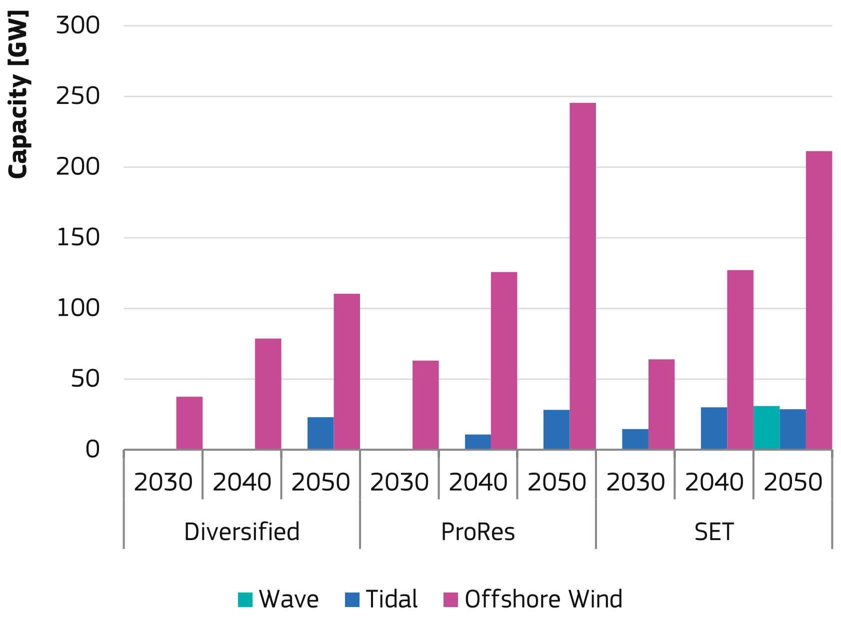
Ocean energy deployment in the EU energy system as modelled in JRC-EU-TIMES depends not only on the assumptions made for tidal and wave energy cost and performance, but also on the assumptions made for the other energy technologies modelled, and their uptake in the energy system.

For example, under the SET Plan scenario, countries with a significant share of tidal energy technologies (UK, France and Ireland) have no uptake of wave energy technologies. The only country where wave and tidal energy technologies are both part of the energy system is The Netherlands.

A more in-depth look at the deployment of offshore renewable energies under different JRC-EU-Times scenarios is shown in Figure 23. By 2050 the uptake of tidal energy is similar between scenarios, with capacity between 25-28 GW. The uptake of offshore wind energy increases significantly between the diversified and ProRes scenario. However, in the SET Plan scenario, when wave energy enters the market (30 GW by 2050) offshore wind capacity is reduced by about 34 GW, indicating that wave energy and offshore wind technology may, in the long term, be competing for a place in the market. It follows, that the long-term viability of wave energy is connected to the cost of the technology being able to compete with offshore wind in the market.

Figure 24 shows the contribution of ocean energy to the energy system of each MS under different scenarios. Competition with other energy sources, such as wind is minimal. In fact, the share of wind energy in countries such as Ireland and UK is only partly affected by the pronounced deployment of ocean energy under the SET Plan scenario. Furthermore, in countries such as Spain and Portugal both ocean and wind energy increase under the SET Plan scenario.

Figure 23. Modelled deployment of marine renewable energies under the diversified, ProRes and SET scenarios.



Source: JRC

Figure 24. Role of ocean energy technology in the energy system under different scenarios.

Source: JRC

4.5 Comparison with other Market studies

One critical aspect driving technology developers towards stopping investments in ocean energy, is the uncertain and often negative market outlook for the near-to-medium term. Delays and difficulties in seeing the projects through, have dampened both market prospective (e.g. Bloomberg New Energy Finance) and the expectations of policy makers (Ademe, [ADEME 2018]). Examples of these difficulties are the two projects funded in Normandie (see section 2.3.1), the NER300 supported projects in the UK, and H2020 projects (Octarray, Demotide), which have been terminated in June 2018 due to the inability of reaching final investment decision.

Investors and policy-makers appear more reluctant to develop support systems, and put trust in forthcoming technology cost-reduction, though in many cases they are not aware of the full-spectrum of innovation and development that is actually taking place.

In 2018, two key market studies were released: one by DG Mare (contracted to COGEA and Wavec) [European Commission 2018b], and one by ADEME in France [ADEME 2018].

These studies are contrasted with the results of the JRC-EU-TIMES modelling. At technical level the studies are very different, driven by different assumptions and underlying calculations.

- **ADEME** – The study addresses tidal energy development in the UK, FR, CA, JP and Indonesia, looking at large tidal turbines (>1.5 MW), using cost data from turbines manufacturers (Including Atlantis, Openhydro, Alstom), including those who have stopped operations. The starting point of the study is a LCOE of about 365 EUR/MWh with the expectations that LCOE could reach a reference value of 165 EUR/MWh in 2030. In the optimal case, LCOE could reach 120 EUR/MWh.

  The study presents 3 scenarios: pessimistic, optimistic and reference. It's not clear how installed capacity and market uptake of the technology is modelled, but it is highly likely that this is done based on costs only. The total potential taken in account is 120 GW globally, and 18 GW in Europe (9 UK, 5 FR, and 4 between Italy, Greece and Spain). No information is provided with regards to floating technology, and tidal kites.

- **DG Mare** – The study is based on a steady technological progression from low TRL to TRL9 for wave and tidal technology, with deployment increasing thanks to technology progression. The study considers that grants form a considerable part of the funds to ensure projects go ahead (capital support). 3 scenarios are presented: pessimistic, medium and optimistic.

In order to compare the different studies the results of the ProRES scenario are compared to the pessimistic and central scenarios of the ADEME and DG Mare. The SET Plan scenario is used for comparison with the optimistic and disruptive scenarios from ADEME and DG Mare. A comparison between the different outlooks for tidal energy up to 2030 is shown in Table 11.

Table 11. Comparison of Market Outlooks provided by ADEME, DG Mare and JRC. Capacity reported in MW.

	Pessimistic		**Central**		**Disruptive**	
Pessimistic	**2025**	**2030**	**2025**	**2030**	**2025**	**2030**
Ademe	11	14	35	83	307	888
DG Mare	200	949	550	1440	800	2232
JRC-EU Times	0	0	0	0	5000	14500

Source: JRC, ADEME, DG MARE

4.5.1 Pessimistic Scenario

In the pessimistic scenario, Ademe foresees a maximum of 14 MW installed in Europe by 2030 (FR and UK only), meaning that no new capacity is installed from now to 2030.

The pessimistic outlook from DG Mare indicates that up to 950 MW of tidal energy installed capacity could take place. No uptake of tidal energy capacity is expected by JRC Times model, indicating that costs are too high for the energy system.

4.5.2 Central Reference Scenario

In the reference scenario, tidal energy capacity could reach 83 MW by 2030 according to Ademe, and 1440 MW according to DG Mare. The JRC-EU-Times model foresees no installed capacity for tidal energy.

4.5.3 Disruptive – Optimistic Scenario

In this scenario, by 2030, tidal energy capacity could range between 888 MW foreseen by ADEME, 2232 MW by DG Mare and 14500 MW from JRC-EU-Times.

The assumptions made by ADEME in this scenario consider that:

- The Normandie Hydro Farm is deployed (14 MW of OpenHydro/Naval Energies);
- Meygen is expanded to 80 MW;
- Offers for Raz Blanchard and Fromvuer are made (not clear if feed-in-tariff).

The projects announced by SIMEC Atlantis in France are not considered.

The JRC-EU-TIMES scenario, which foresees a very high level of penetration of tidal energy by 2030, suggests that cost-reductions of tidal energy technology coupled with foreseeable and reliable generation make the technology competitive in a highly decarbonised EU energy system.

The DG Mare study foresees that most of the tidal energy projects announced (see sections 3.1) will go ahead.

4.5.1 Key takeaways from market forecasts

The different market studies show that tidal energy can grow significantly in Europe.

The main takeaway from the ADEME study is that cost-reduction can take place, even with limited installed capacity. Furthermore, there are reasons believe that the disruptive scenario could lead to technology costs close to the SET Plan targets, allowing the technology to already be competitive in an integrated energy system. This scenario includes the deployment of partly publicly supported projects, such as Normandie Hydro and Meygen 1 (up to 80 MW) and the potential opening of tenders for Fromvuer and Raz Blanchard in France.

The JRC-EU-Times scenario does not include the possibility of supported farms; nevertheless, support mechanisms are needed to ensure that cost-reductions are met.

It is therefore plausible that establishing support mechanisms in the EU, in line with what is presented by the ADEME optimistic scenario, could bring the cost of tidal energy close to targets for commercialisation. Establishing a set of grant and revenue systems towards the target of 300 MW of installed capacity by 2025, as indicated by ADEME in their optimistic scenario, would be feasible with limited funds required.

4.5.2 Quantifying support mechanisms and innovative revenue schemes.

An important aspect of providing revenue mechanisms is the burden on the budget/finance of public authorities. The European Commission has already developed a number of mechanisms designed for developers to:

- test their device (Interreg and H2020);
- improve the performance of their device (H2020);
- unlock low-rate loans (EIB InnovFIN EDP);
- drive inward investments (Blue Invest), and
- support demonstrations (NER300).

The new innovation funds are designed to support the deployment of innovative technologies with large potential that are still emerging. It is expected that ocean energy projects will be well suited to take advantage of these new funds.

Considering the availability of EU funds, the contribution of MS would be considerably smaller than FIT provided in the past to solar PV and wind energy.

In the UK, a new instrument proposed is an Innovative Power Purchase Agreement (IPPA), presented in the UK Marine Energy 2019 report [EMEC 2019]. This instrument is considered the first step to bridge the gap for the commercialisation of tidal technologies, and would be needed to support up to 120 MW of deployed capacity in batches of 5-10 MW per farm.

The proposed IPPA is designed to offer tax rebate to companies that purchase tidal-generated electricity. Following the deployment of the 120 MW at 290 GBP/MWh (circa 320 EUR/MWh), the proposal foresees a further 800 MW of tidal projects support through a CFD system, ensuring that the cost of energy would reach around 90 GBP/MWh with 900 MWh installed (circa 101 EUR/MWh in line with the SET Plan targets).
The overall costs for the IPPA would be 740 mGBP (830 mEUR) to support the IPPA 120 MW, including the CfD scheme, while the annual costs of the scheme would be of about 140 mGBP (152 mEUR) a year for 20 years.

The proposal made by SIMEC Atlantis to take over the two pre-approved projects in France (Nepthyd and Normandie Hydro) would likely increase the speed of deployment and cost-reduction. The proposal made by SIMEC-Atlantis is based on the possibility of having access to the same conditions offered to Alstom and OpenHydro, as presented in their Joint Venture proposal:

- Securing Nepthyd's 8 MW, pending on Engie's approval, transfer of the 51 mEUR grant and a FIT of 173 EUR/MWh.
- Securing Normandy Hydro's 14 MW (EDF and Naval Energies' projects), pending on EDF-EN's approval, work on the consents, transfer of the 51 mEUR and a FIT 173 EUR/MWh.
- Securing a 200 MW (2x100 MW) lease in the Raz Blanchard around these first zones with a LCOE of 116 EUR/MWh by 2024
- Introducing a long-term development plan: 1-2 GW with LCOE of 67 EUR/MWh

In total, considering a FIT scheme with a duration of 10 years, developing the Nepthyd and Normanide Hydro projects would cost EUR 220 million. Supporting the development of further 200 MW at lower FIT (still considering 10 years) would be in the range of 770 mEUR.

Together, the proposals put forward in the UK and in Normandie would be able to deliver 340 MW of tidal projects, for a total cost of roughly EUR 1.7 billion. This deployment would mobilise over EUR 1 billion only for the production and the installation of the turbines. Yet, if part of the capital or revenue scheme is provided through European funds, the burden for the MS could be considerably reduced.

5 Industrial strategies

The market for ocean energy is in its infancy, and device deployment is limited to projects with a small number of devices. The consolidation of the supply chain involving OEMs has still to take place. The slow deployment of projects does not allow the assessment of industrial strategies.

In order to better identify the current R&D focus and positioning of EU players, we analysed the companies that have filed patents in ocean energy[5].

Patents for ocean energy technologies are classified in 6 CPC classes as follows:

- Y02E-10/28 - Tidal stream or damless hydropower, e.g. sea flood and ebb, river, stream;
- Y02E-10/30 - Tidal stream;
- Y02E-10/32 - Oscillating water column [OWC];
- Y02E-10/34 - Ocean thermal energy conversion [OTEC];
- Y02E-10/36 - Salinity gradient;
- Y02E-10/38 - Wave energy or tidal swell, e.g. Pelamis-type.

In total, since 2000, 674 EU companies in 25 Member States have filed patents or have been involved in the filing of patents related to ocean energy. In the EU 50 % of the inventions patented are for wave energy technology, 45 % for tidal energy, 3 % on OWC, and 2% for OTEC.

When countries outside of the EU are accounted for, the share of wave energy increases to 56%, tidal energy decreases to 37%, OWC drops to 2%, OTEC rises to 4% and Salinity gradient to 1%. The 30 most active companies have been classified according to type of activity and positioning in the ocean energy supply chain (Table 12).

Figure **25** shows the countries with the highest patenting activity, led by the United Kingdom, followed by Germany, France and Sweden. R&D focus and specialisation differs significantly between countries; some countries show higher shares of component and parts manufacturers (e.g. Germany) and others are more active in turbine and device manufacturing. In general, patent applications show an increasing trend up to 2014.

Figure 26 provides details on the total number of EU patent applications by country. The United Kingdom (29 %) clearly leads the ranking, followed by Germany (19 %), Sweden (9 %) and France (8 %). These four countries account for 65 % of all EU patent applications in the area of ocean energy.

Table 12. TOP 30 patenting companies in the field of ocean energy in the EU, and focus on CPC classes.

Company	Country	Patents	CPC Class
Robert Bosch Gmbh	DE	42	Predominantly wave
Voith Patent GmbH	DE	26	Predominantly tidal
Tidal Generation Ltd	UK	15	Predominantly tidal
Rolls Royce Plc	UK	9	Predominantly tidal
Skf Ab	SE	8	Predominantly tidal
AW-ENERGY OY	FI	6	Predominantly wave
Marine Current Turbines LTD	UK	6	Predominantly tidal
OPENHYDRO IP LTD	IE	6	Predominantly tidal
IFPEN (IFP ENERGIES NOUVELLES)	FR	6	Predominantly wave
University of A Coruna	ES	6	Predominantly wave
Wello OY	FI	5	Wave only

[5] Complete statistics on patent families are available up to 2014; filings in subsequent years are also considered if they belong to a patent family (or invention) that claims priority in this time period. Patent families are collections of documents referring to the same invention (e.g. filings to different IP offices)

Company	Country	Patents	CPC Class
Instituto Superior Tecnico	PT	5	Wave only
AQUAMARINE POWER LTD	UK	4	Predominantly wave
CMI	FR	4	Predominantly tidal
DCNS SA	FR	4	Predominantly tidal
AWS OCEAN ENERGY LTD	UK	4	Predominantly wave
Lancaster University	UK	4	Predominantly wave
WaveBob Limited	IE	3	Wave only
TidalStream Ltd	UK	3	Predominantly tidal
AVIAT ENTPR LTD	UK	3	Predominantly tidal
Technical University of Madrid	ES	3	Predominantly tidal
VERDERG LTD	UK	3	Predominantly tidal
Siemens Ag	DE	3	Predominantly tidal
Dartmouth Wave Energy Limited	UK	3	Wave only
KLEIN SCHANZLIN & BECKER AG	DE	3	Tidal only
SWEDISH SEABASED ENERGY AB	SE	3	Wave only
SARCO DESIGNS LTD	UK	3	Wave only
SHIFTPLUS DI BUSSOLINO GIUSEPPE	IT	3	Wave and tidal
ABENGOA SEAPOWER S A	ES	3	Wave only
ENERLYT TECHNIK GMBH	DE	3	Wave only
BLUE WAVE CO S.A.	LU	3	Wave only

Source: JRC. Methodology: *[JRC 2017]*

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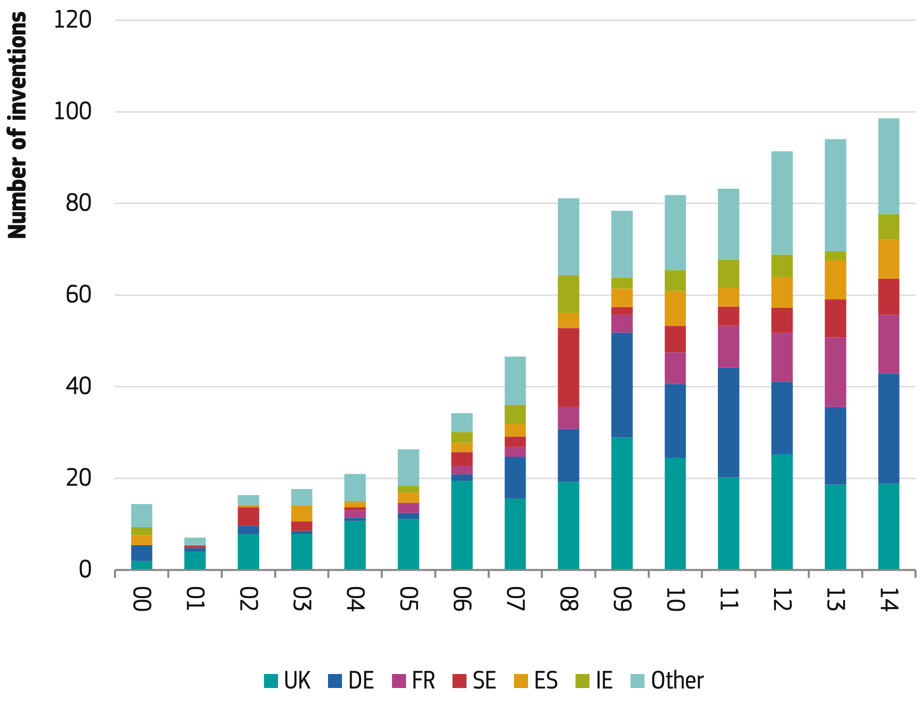
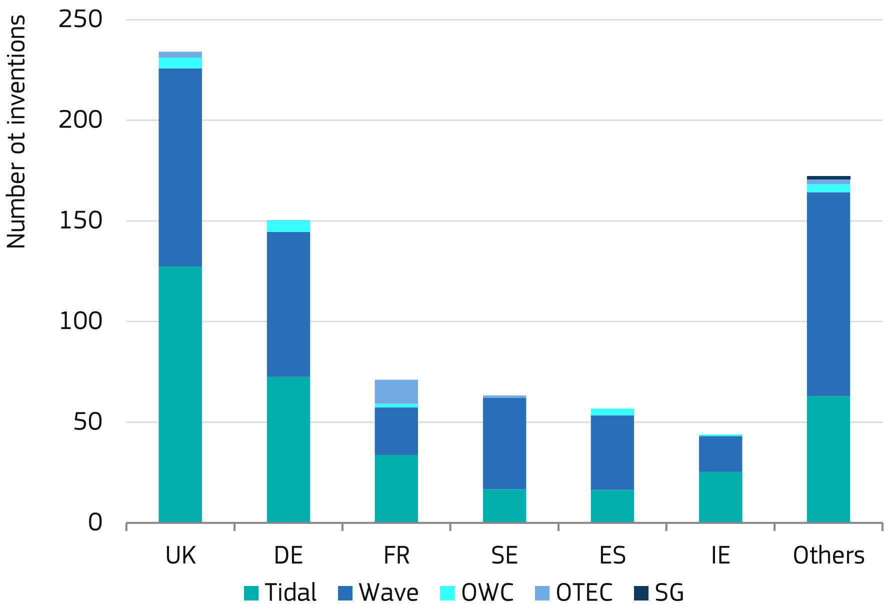
Figure 25. Number of patent families from EU companies most active in patenting.



Source: JRC

Figure 26. Number of the patents families from 2000 to 2014 according to country and CPC classification.



Source: JRC.

5.1 Market protection and competition

The information presented in

Figure **25** and Figure 26 indicates that companies in the EU are investing considerably in the development of ocean energy technology.

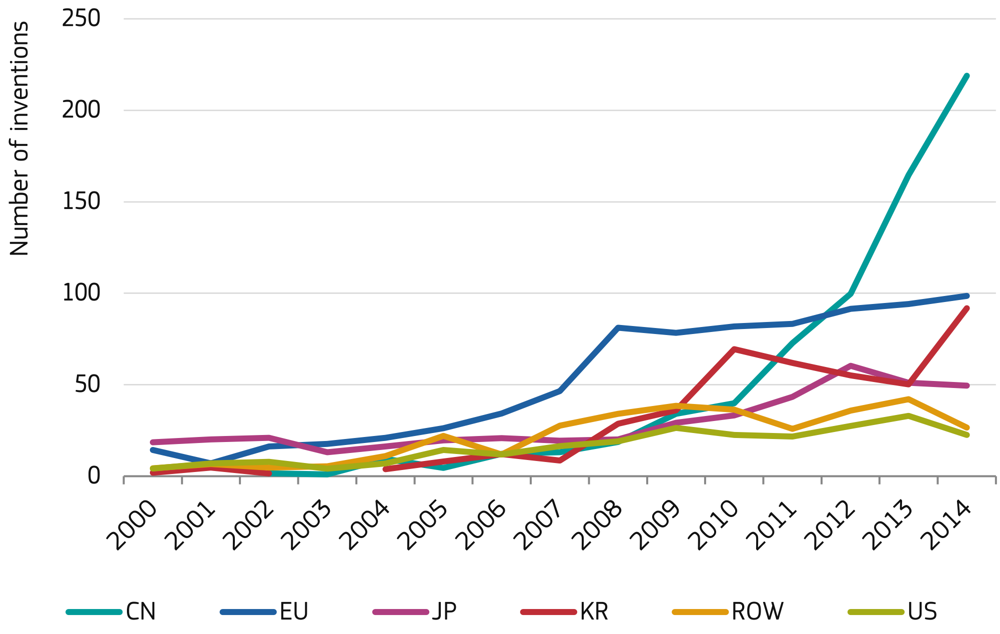
Since 2000, the EU has been the leader in R&D in ocean energy. However, as shown in Figure 27, since 2012 Chinese patenting has increased significantly and has overtaken the EU. Whilst Chinese activity in ocean energy has spiked since 2012, only a limited part of the inventions patented in China have filed for international protection.

Figure 28 presents the global patent trends for the period 2000-2014, taking into account those inventions that were patented in multiple countries, thus offering IP protection of the technology in multiple markets. One can see that only a few Chinese patents have sought international protection; whilst many EU inventors have sought protections in multiple potential markets. Furthermore, only a small part of the patents filed in China are filed by private companies, with the majority of the inventions taking place at universities.

As shown in Figure 29, most of the EU patents come from private R&D, whilst in the case of China universities play a significant role. This situation is possibly due to the higher intervention of the national government in R&D, but may also be related to the market-maturity of the invention, and the related opportunities for commercialisation.

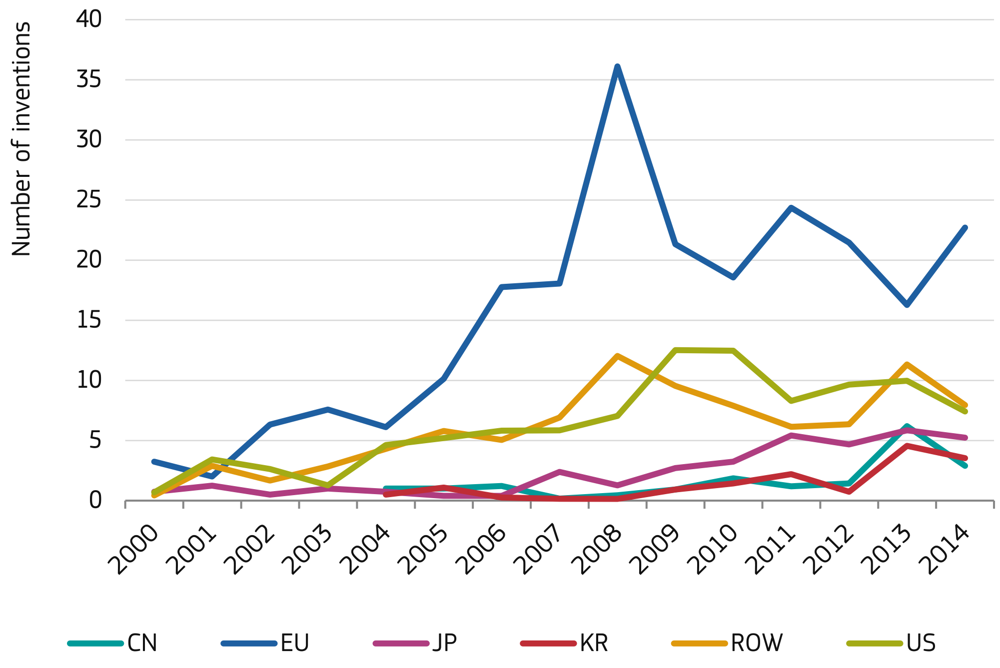
Figure 30 presents where protection for inventions is sought, and provides a link to commercialisation plans of technology developers, who seek to protect a commercial avenue in the country of protection. As seen in Figure 30, European developers are exporting their technologies in all the potential key ocean energy markets, such as the US, China, Japan and Korea. On the other hand, only a small share of non-European developers are seeking protection in Europe. Based on patent filings, Europe is the next exporter of ocean energy technology innovation; and European ocean energy developers are well poised to exploit the growth of the ocean energy sector globally.

Figure 27. Global ocean energy patents trend from 2000 to 2014.



Source: JRC

Figure 28. Global ocean energy patents trend, from 2000 to 2014. In this case only patents with international protection are considered.



Source: JRC, Patstat

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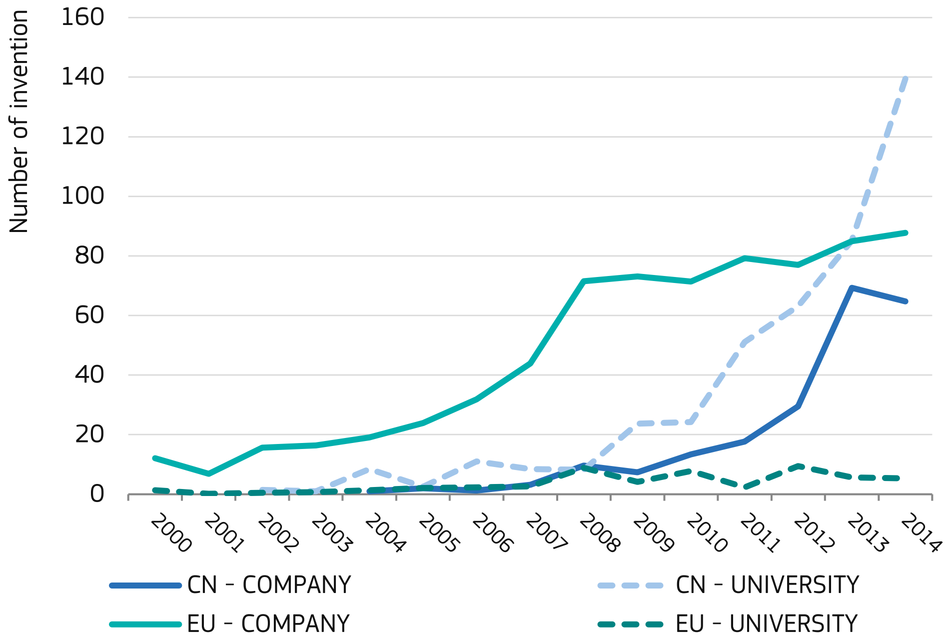
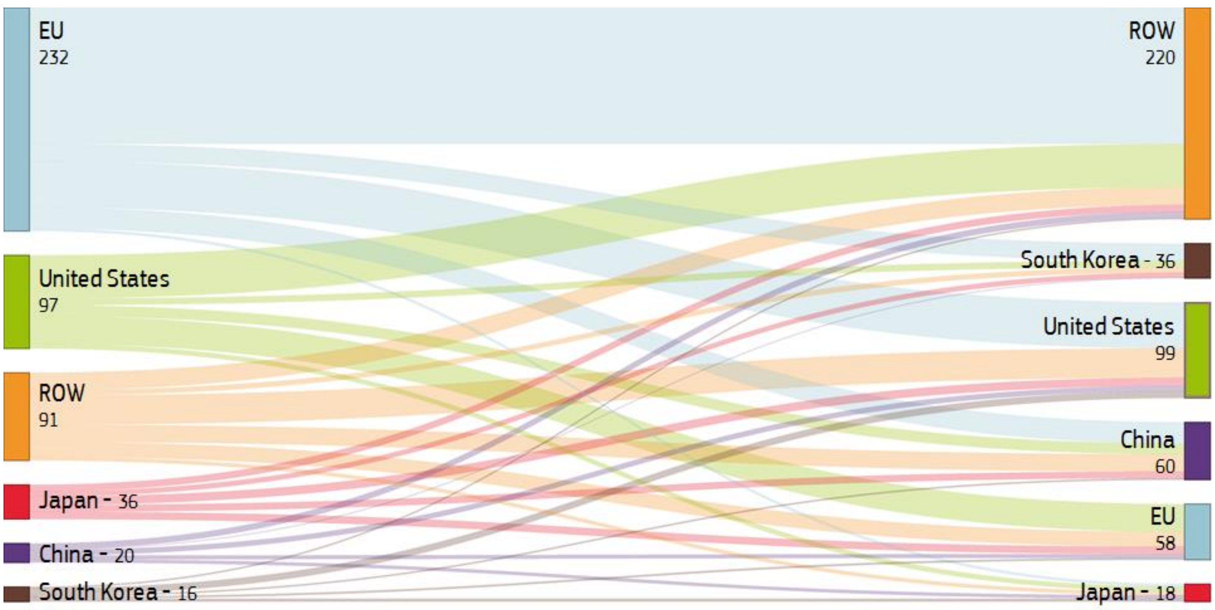
Figure 29. Trends for private company (solid line) and university (dash) filed patents in China and in the EU.



Source: JRC.

Figure 30. Global patents flow. Intra-market patents are excluded.



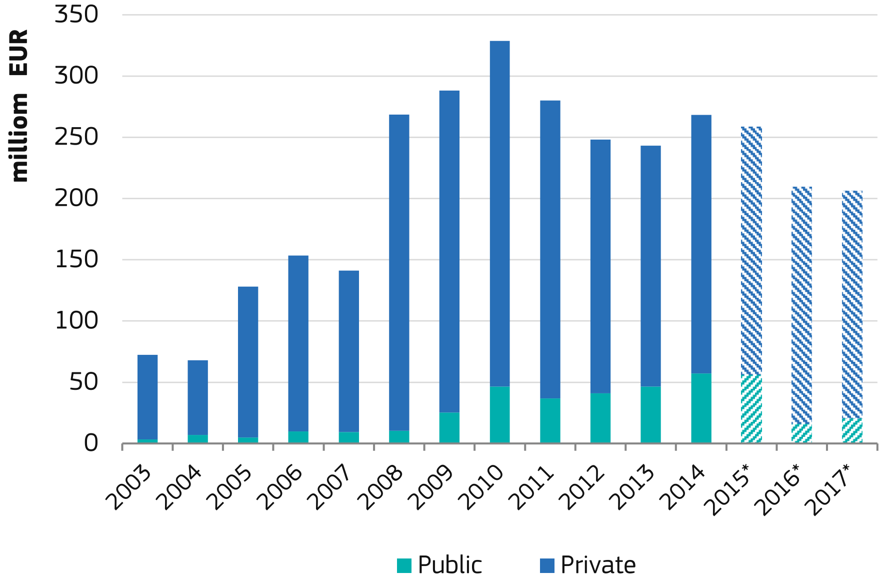
Source: JRC.

5.2 Investments

The breakdown of investment in ocean energy R&D in the EU is shown in Figure 31. National investments in R&D have been growing slowly since 2011, stabilising at EUR 56 million a year in 2014 and 2015, accounting for 21 % of total investment for the same years. Nevertheless, the data available from IEA RD&D Statistics database suggest that national investments have decreased in 2016 and 2017.

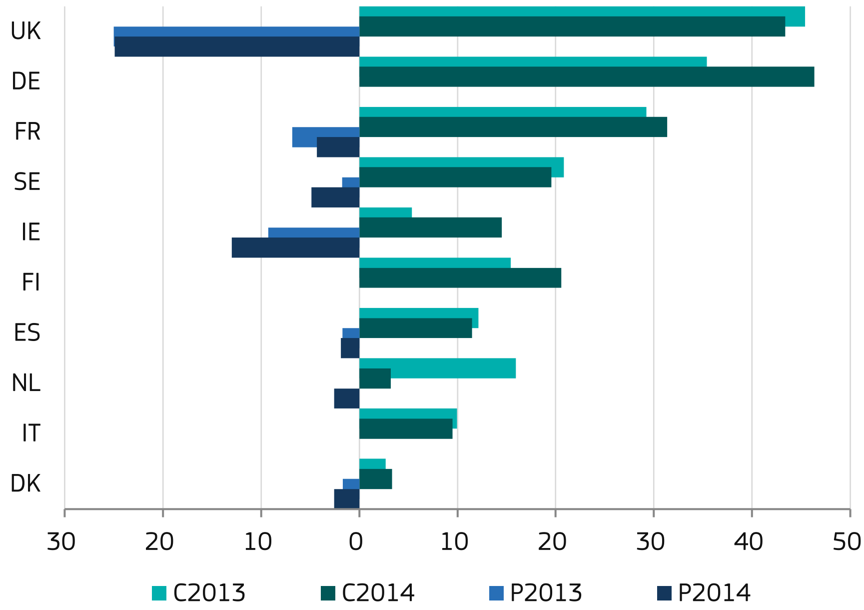
Figure 32 offers a comparison between funding types for the top 10 European investors in terms of corporate and public investments. While in some countries, national and private funds are used to support R&D in ocean energy technologies, in other countries such as Germany, Finland, and the Netherlands the initiative is mainly private. The potential of ocean energy in these countries is limited, however the development of the ocean energy sector may have a positive effect on the manufacturing supply chain in these countries.

Figure 31. Breakdown of ocean energy investments in million EUR between 2003 and 2017 based on type of funding. Years 2015-2017 are incomplete/ based on estimates. Private investment as estimated by JRC SETIS. Detailed methodology available from the JRC. EU and ERDF contributions are not accounted in this analysis.



Source: JRC and International Energy Agency RD&D Statistics database.

Figure 32. Breakdown of national and corporate R&D investments for the TOP10 European investors in 2013 and 2014. C refers to corporate investments and N to national investments.



Source: JRC and IEA [data updated Feb 2019]

6 Conclusions

The ocean energy market is slowly forming; however, its development is hindered by both technological issues that have reduced confidence in the sector, and by the lack of revenue schemes that would be needed for demonstration projects to go ahead.

The highest concentration of wave and tidal energy developers occurs within Europe. Yet, many developers are looking at policy instruments available elsewhere for the deployment of their technologies. In particular, the availability of high feed-in-tariffs in Canada is attractive, especially in light of the competition with offshore wind faced in many European countries.

Patenting and R&D activities show that EU developers are active and working towards establishing a stable market for their technologies, with a clear vision of the potential markets.

Estimated investments in excess of EUR 2.7 billion have been directed to the sector through private capital in the period between 2003 and 2017, with national funds of about EUR 390 million directed to the sector in the same period.

The patenting analysis shows that mobilisation of resource from manufacturers spans across Europe, including areas that may not be able to directly reap the benefits of ocean energy (e.g. Germany) in terms of electricity generated.

R&D activities in ocean energy take place across 25 EU member states, with 674 companies active in the patenting of ocean energy related inventions.

The results obtained from the JRC-EU-TIMES model, indicate that achieving the cost-reductions needed to meet the SET Plan targets will be fundamental for the uptake of tidal and wave energy technology in Europe.

Tidal energy could grow considerably compared to current deployment, and uptake could already be significant by 2030, if cost-reductions continue to take place. On the other hand, deployment of wave energy would be limited under most scenarios and only become visible in 2050.

It is expected that wave energy deployment will face market competition from offshore wind technologies. Significant reduction of CAPEX and OPEX to values comparable or lower to those of offshore wind are needed to ensure higher deployment rates for wave energy. This will require the convergence of technology that is currently experienced in tidal energy, and overcoming a number of technological issues presented in the LCEO Technology development report.

Under the SET Plan scenario, investments of over EUR 140 million will be needed in order to deploy 30 GW of wave and 30 GW of tidal energy capacity.

The comparison of the JRC-EU-TIMES scenario with other market studies, highlights the importance of cost-reductions. The optimistic scenario of the ADEME and the DG MARE market studies suggest that by 2030 capacity of tidal energy could range between 880 and 2200 MW, sufficient to achieve significant cost-reductions to the level required by the SET Plan.

More importantly, these estimates are based on a number of projects announced in the EU. It follows, that the deployment of demonstration farms is fundamental to unlock the necessary cost-reductions and the potential market of ocean energy.

Both wave and tidal energy technologies have a potential pipeline of projects to be deployed in Europe; however, it is critical to identify support that would make the projects viable, particularly at member state level.

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Abbreviations and Acronyms

ADEME	Agence de l'environnement et de la maîtrise de l'énergie
CAPEX	Capital expenditure
CFD	Contract for Difference
CREBs	Clean Renewable Energy Bonds
EMEC	European Marine Energy Centre
ERC	Energy Regulation Commission
EIB	European Investment Bank
EU	European Union
FID	Final investment decision
FIP	Feed-in-premium
FIT	Feed-in-tariff
IPPA	Innovative Power Purchase Agreement
LCOE	Levelised Cost of Energy
MS	Member State
NDRD	National Development and Reform Commission
NECP	National Energy and Climate Plans
NREAP	National Renewable Energy Action Plans
NREB	National Renewable Energy Board
OPEX	Operating expenditure
ORC	Organic Rankine Cycle
OTEC	Ocean Thermal Energy Conversion
OWC	Oscillating Water Column
PPA	Power Purchase Agreement
PBF	Public Benefits Funds
R&D	Research and Development
REC	Renewable Energy Certificate
RESS	Renewable Energy Support Scheme
ROCs	Renewable Obligations Certificates

Monetary Units

The report uses the monetary style guides of the European Commission as presented here. http://publications.europa.eu/code/en/en-370303.htm#million-milliard

Whilst referring to cost of energy (EUR/kWh), and cost of capital (EUR/kW or EUR/MWh), additional abbreviations are used as follows:

cEUR	cents EUR
mEUR	million EUR
bEUR	billion EUR

Annexes

Annex 1. EMEC list of tidal developers

In this Annex the full list of tidal energy developers as listed by the European Marine Energy Centre (EMEC)is presented. Please visit http://www.emec.org.uk/marine-energy/tidal-developers/ for more information.

Developer	Country	Type of device
Andritz Hydro Hammerfest	Norway	Horizontal Axis Turbine
Aquantis Ltd	USA	
Atlantis Resources Corp	UK	Horizontal Axis Turbine
Atlantis Resources Corp	UK	Horizontal Axis Turbine
Atlantisstrom	Germany	Horizontal Axis Turbine
Balkee Tide and Wave Electricity	Mauritius	Horizontal Axis Turbine
BioPower System Pty Ltd	Australia	Other
Bluewater	Netherlands	Other
Bosch Rexroth	Germany	Horizontal Axis Turbine
Bourne Energy	USA	Horizontal Axis Turbine
Centro Tecnologico SOERMAR	Spain	
Cetus Energy	Australia	Horizontal Axis Turbine
Current Power AB	Sweden	Vertical Axis Turbine
Current2Current	UK	Vertical Axis Turbine
Deepwater Energy BV	Netherlands	Vertical Axis Turbine
EC-OG	UK	Vertical Axis Turbine
EEL Energy	France	Oscillating Hydrofoil
Elemental Energy Technology Limited	Australia	Other
Flex Marine Power Ltd	UK	
Flumill	Norway	Archimedes Screw
Free Flow 69	UK	Vertical Axis Turbine
Free Flow Power Corporation	USA	Horizontal Axis Turbine
GCK Technology	USA	Vertical Axis Turbine
Guinard Energies SAS	France	
Hales Water Turbines Ltd	UK	Other
Hydra Tidal AS	Norway	Horizontal Axis Turbine
Hydro Alternative Energy	USA	
Hydro-Gen	France	Horizontal Axis Turbine
HydroQuest	France	Vertical Axis Turbine
Hydrovolts Inc	USA	Horizontal Axis Turbine
Hydrovolts Inc	USA	Other
Hyundai Heavy Industries	Korea	
IHC Tidal Energy	Netherlands	Vertical Axis Turbine
InCurrent Turbines Ltd	Canada	
Instream Energy Systems	Canada	Vertical Axis Turbine
Integrated Power Technology Corporation	USA	Oscillating Hydrofoil
Jupiter Hydro Inc	Canada	Archimedes Screw
Kawasaki Heavy Industries, Ltd	Japan	Horizontal Axis Turbine

Developer	Country	Type of device
Kepler Energy	UK	Other
Leading Edge	US	Oscillating Hydrofoil
Lucid Energy Technologies	USA	Vertical Axis Turbine
Lunar Energy	UK	Enclosed tips (Venturi)
Magallanes Renovables	Spain	Horizontal Axis Turbine
Mako Tidal Turbines	Australia	Horizontal Axis Turbine
Marine Current Turbines	UK	Horizontal Axis Turbine
Marine Current Turbines	UK	Horizontal Axis Turbine
Marine Energy Corporation	USA	Horizontal Axis Turbine
Minesto	Sweden	Tidal Kite
Modec	Japan	Other
Natural Currents	USA	Other
Nautricity Ltd	UK	Horizontal Axis Turbine
New Energy Corporation	Canada	Vertical Axis Turbine
Norwegian Ocean Power	Norway	Vertical Axis Turbine
Nova Innovation Ltd	UK	Horizontal Axis Turbine
Ocean Flow Energy	UK	Horizontal Axis Turbine
Ocean Renewable Power Company (ORPC)	USA	Horizontal Axis Turbine
Ocean Renewable Power Company (ORPC)	USA	Horizontal Axis Turbine
Ocean Renewable Power Company (ORPC)	USA	Horizontal Axis Turbine
Oceana Energy Company	USA	Horizontal Axis Turbine
Offshore Islands Ltd	USA	Horizontal Axis Turbine
Open Ocean Energy Ltd	Ireland	
OpenHydro	Ireland	Enclosed tips (Venturi)
QED Naval	Scotland	Other
REAC Energy GmbH	Germany	Vertical Axis Turbine
Renewable Devices Marine Ltd	UK	Horizontal Axis Turbine
Repetitive Energy Company	UK	Vertical Axis Turbine
ResHydro	USA	Oscillating Hydrofoil
SABELLA SAS	France	Horizontal Axis Turbine
SCHOTTEL group	Germany	Horizontal Axis Turbine
Scotrenewables	UK	Horizontal Axis Turbine
SeaCurrent	The Netherlands	Tidal Kite
SeaPower Gen	UK	
Seapower scrl	Italy	Tidal Kite
SMD Hydrovision	UK	Horizontal Axis Turbine
Straum AS	Norway	Horizontal Axis Turbine
Suanders Energy Ltd	UK	Horizontal Axis Turbine
Sustainable Marine Energy (SME)	UK	Horizontal Axis Turbine
Tidal Energy Ltd	UK	Horizontal Axis Turbine
Tidal Energy Pty Ltd	Australia	Enclosed tips (Venturi)
Tidal Sails AS	Norway	Other
TidalStream Limited	UK	Horizontal Axis Turbine

Developer	Country	Type of device
TidalStream Limited	UK	Horizontal Axis Turbine
Tidalys	France	Horizontal Axis Turbine
Tidalys	France	Horizontal Axis Turbine
Tocardo Tidal Turbines	Netherlands	Horizontal Axis Turbine
Verdant Power	USA	Horizontal Axis Turbine
Vortex Hydro Energy	USA	Other
Vortex Power Drive	USA	
Water Wall Turbine Inc	Canada	Horizontal Axis Turbine

Annex 2. EMEC list of wave energy developers

In this Annex the full list of wave energy developers as listed by the European Marine Energy Centre (EMEC) is presented. Please visit http://www.emec.org.uk/marine-energy/wave-developers/ for more information.

Developer	Country	Type of device
40 South Energy	Italy	Other
Abengoa Seapower	Spain	Point Absorber
Able Technologies LLC	USA	Attenuator
AdapWave	USA	Point Absorber
Advance Ocean Energy @ Virginia Tech	USA	Overtopping/Terminator
AeroVironment Inc	USA	Point Absorber
Aimmer UK	UK	Other
Aker Solutions ASA	Norway	Attenuator
AlbaTERN Ltd	UK	Attenuator
AlbaTERN Ltd	UK	Other
Alternative Energy Engineering Associates	USA	Other
Applied Technologies Company, Ltd (ATC)	Russia	Point Absorber
Aquagen Technologies	Australia	Point Absorber
AquaHarmonics	USA	Point Absorber
Aqua-Magnetics Inc	USA	Point Absorber
Aquanet Power	Hong Kong	Oscillating Water Column
Aqua-Shift	USA	Point Absorber
ATA Engineering	USA	Attenuator
Atargis Energy Corporation	USA	Other
Atlantic Wavepower Partnership	USA	Overtopping/Terminator
Atlas Ocean Systems	USA	Point Absorber
Atmocean Inc	USA	Attenuator
Avium AS	Turkey	Other
AW Energy	Finland	Oscillating Wave Surge Converter
AWECS Attenuator	USA	Attenuator
AWS Ocean Energy	UK	Overtopping/Terminator
Balkee Tide and Wave Electricity Generator	Mauritius	Point Absorber
BioPower Systems Pty Ltd	Australia	Oscillating Wave Surge Converter
Blue Power Energy Ltd	Ireland	Point Absorber
Bombora Wave Power	Australia	Submerged Pressure Differential
Bosch Rexroth	Germany	Other
Brandl Motor	Germany	Point Absorber
Brimes Energy	USA	Overtopping/Terminator
Buoyant Energy	USA	Other
Cal Poly-Protean Wave Energy Inc	USA	Attenuator
Caley Ocean Systems	UK	Other
Calwave	USA	Submerged Pressure

		Differential
Carnegie Wave Energy Ltd	Australia	Point Absorber
Checkmate Seaenergy UK Ltd	UK	Bulge Wave
College of the North Atlantic	Canada	Submerged Pressure Differential
Columbia Power Technologies	USA	Attenuator
Coppe Subsea Technology	Brazil	Other
CorPower Ocean AB	Sweden	Point Absorber
Costas Wave	USA	Oscillating Wave Surge Converter
Crestwing / Danyard Engineering Aps	Denmark	Attenuator
DEXAWAVE A/S	Denmark	Attenuator
Dresser Rand	USA	Oscillating Water Column
Earth by Design	USA	Other
Eco Wave Power	Israel	Attenuator
Ecole Centrale de Nantes	France	Rotating Mass
Ecomerit Technologies	USA	Attenuator
Ecotricity	UK	Point Absorber
ELGEN Wave	USA	Point Absorber
Energystics	USA	Point Absorber
Enorasy Labs	USA	Rotating Mass
Ensea	Italy	Attenuator
Etymol Ocean Power SpA	Chile	Other
Fetzer Wave	USA	Other
Finima-Aimmer	Hong Kong	Point Absorber
FlanSea	Belgium	Point Absorber
Float Inc	USA	Point Absorber
Floating Power Plant AS	Denmark	Attenuator
Fred Olsen Ltd	Norway	Point Absorber
Globalone Sciences	USA	Attenuator
Gmax Tidal Energy	USA	Other
Green Ocean Wave Energy	USA	Point Absorber
Greenfield Techonolgies LLC	USA	Other
Greenheat Systems Ltd	UK	Other
Grey Island Energy Inc	Canada	Attenuator
Group Captain SM Ghouse	India	Attenuator
Gyrogen (DNS)	USA	Other
Havkraft	Norway	Other
Healy's Wave Energy Convertor	USA	Other
Hui Nalu	USA	Other
Hydrocap Energy SAS	France	Point Absorber
Hydrokinetic Energy Solutions	USA	Other
IHC Tidal Energy	Netherlands	Other
Independent Natural Resources	USA	Point Absorber

Indian Wave Energy Device	India	Point Absorber
Ing Arvid Nesheim	Norway	Oscillating Wave Surge Converter
Ingine Inc	South Korea	Point Absorber
Intentium AS	Norway	Other
Interproject Service (IPS) AB	Sweden	Other
IOWEC	USA	Point Absorber
James F Marino	USA	Other
JAMSTEC	Japan	Overtopping/Terminator
Jetty Joule	USA	Other
Jospa Ltd	Ireland	Other
Joules Energy Efficiency Services Ltd	Ireland	Point Absorber
Kinetic Wave Power	USA	Overtopping/Terminator
KN Ocean Energy Science & Development	Denmark	Attenuator
Kneider Innovations	France	Attenuator
Korean Institute of Ocean Science and Technology (KIOST)	Korea	Point Absorber
Kozoriz Franklin California Maglev Inc	USA	Oscillating Wave Surge Converter
Kymogen	USA	Point Absorber
Laminaria	Belgium	Attenuator
Langlee Wave Power	Norway	Oscillating Wave Surge Converter
Leancon Wave Energy	Denmark	Oscillating Water Column
Leviathan Energy Waves	USA	Other
Limerick Wave Ltd	UK	Other
M3 Wave LLC	USA	Submerged Pressure Differential
M4Wave Power	UK	Attenuator
MakerStrong	USA	Point Absorber
Marine Energy Corporation	USA	Point Absorber
Marine Hydroelectric Company	USA	Other
Marine Power Systems	UK	Submerged Pressure Differential
Marine Power Technologies Pty Ltd	Australia	Oscillating Water Column
Martifer Energia	Portugal	Attenuator
Maruthi Power	USA	Point Absorber
Mighty Waves Energy Team	USA	Point Absorber
Mocean Energy	USA	Attenuator
Motor Wave	Hong Kong	Point Absorber
Muroran Institute of Technology	Japan	Other
Navatek Ltd	USA	Attenuator
NEMOS GmbH	Germany	Other
Neptune Renewable Energy Ltd	UK	Point Absorber
Neptune Wave Power	USA	Point Absorber

Next Gen	USA	Point Absorber
Northwest Energy Innovations	New Zealand	Point Absorber
Norvento	Spain	Overtopping/Terminator
Norwegian University of Science and Technology	Norway	Point Absorber
Nualgi Nanobiotech	India	Point Absorber
Ocean Electric Inc	USA	Point Absorber
Ocean Energy Industries Inc	USA	Point Absorber
Ocean Energy Laboratory of Guangzhou Institute of Energy Conversion (GIEC), Chinese Academy of Sciences	China	Point Absorber
Ocean Harvesting Technologies	Sweden	Point Absorber
Ocean Motion International	USA	Point Absorber
Ocean Power Technologies (OPT)	USA	Point Absorber
Ocean RusEnergy	Russia	Other
Ocean Wave and Wind Energy (OWWE)	Norway	Overtopping/Terminator
Ocean Wave and Wind Energy (OWWE)	Norway	Point Absorber
Oceanic Power	Spain	Point Absorber
Oceantec Energias Marinas SL	Spain	Attenuator
Offshore Wave Energy Ltd (OWEL)	UK	Oscillating Wave Surge Converter
ORECon	UK	Submerged Pressure Differential
Oscilla Power, Inc	USA	Point Absorber
Ovsiankin Energy Group	USA	Other
OWEC Ocean Wave Energy Company	USA	Point Absorber
PAULEY (Phil Pauley Innovation)	UK	Other
Pelagic Power AS	Norway	Point Absorber
Perpetuwave	Australia	Attenuator
Pico	Portugal	Oscillating Water Column
PIPO Systems	Spain	Point Absorber
Polygen Ltd	UK	Overtopping/Terminator
Polygen Ltd	UK	Oscillating Wave Surge Converter
Pontoon Power	Norway	Point Absorber
Poseidon’s Kite	USA	Other
Principle Power	USA	Oscillating Water Column
Protean Wave Energy Limited	Australia	Point Absorber
RESEN ENERGY	Denmark	Point Absorber
Resolute Marine Energy Inc	USA	Oscillating Wave Surge Converter
Rotary Wave SL	Spain	Other
Royal Wave	USA	Other
RTI Wave Energy	USA	Other
RTI Wave Power	USA	Overtopping/Terminator
Rutgers Wave Power	USA	Other

Ryokuseisha	Japan	Oscillating Water Column
SARA Inc	USA	Other
SDK Marine	Spain	Oscillating Water Column
Sea Energies Ltd	Ireland	Oscillating Water Column
Sea Green Technologies	USA	Point Absorber
Sea Power International AB	Sweden	Overtopping/Terminator
Sea Power Ltd	Ireland	Attenuator
Sea Wave Energy Ltd (SWEL)	UK	Other
Seabased AB	Sweden	Point Absorber
SeaFoil	USA	Other
SeaNergy	Israel	Submerged Pressure Differential
Seatricity	UK	Point Absorber
Seawood Designs Inc	Canada	Point Absorber
SEEWEC Consortium	UK	Point Absorber
SeWave Ltd	Faroe Islands	Overtopping/Terminator
Sigma Energy	Slovenia	Point Absorber
Sinn Power	Germany	Point Absorber
Slow Mill	Holland	Point Absorber
Snapper Consortium	UK	Point Absorber
Spar Buoy	Portugal	Oscillating Water Column
Spindrift Energy	USA	Point Absorber
Super Watt Wave Catcher	USA	Point Absorber
TAMU-OSSL	USA	Other
Team FLAPPER	USA	Oscillating Wave Surge Converter
Team Treadwater	USA	Other
Tecnalia	Spain	Attenuator
The Bobber Company Ltd	UK	Point Absorber
The CyanWave Wave Energy Converter	Ireland	Overtopping/Terminator
Tremont Electric	USA	Point Absorber
Trident Energy Ltd	UK	Other
Uniturbine Corporation	USA	Other
University of Genoa	Italy	Other
University of Tokyo (UT)	Japan	Oscillating Wave Surge Converter
Uppsala University	Sweden	Other
Vigor Wave Energy AB	Sweden	Bulge Wave
Vortex	USA	Other
Vortex Oscillation Technology Ltd	Russia	Attenuator
Wave Dragon	Denmark	Overtopping/Terminator
Wave Electricity Renewable Power Ocean (WERPO)	Israel	Oscillating Wave Surge Converter

Wave Energy AS	Norway	Overtopping/Terminator
Wave Energy Team at Virginia Tech	USA	Point Absorber
Wave Star Energy ApS	Denmark	Point Absorber
Wave Water Works	USA	Other
Waveberg Development	USA	Point Absorber
WavePiston	Denmark	Attenuator
WavePlane Production	Denmark	Other
Wavepower Technologies Limited	UK	Other
Waves for Energy	Italy	Rotating Mass
Waves Ruiz	France	Attenuator
Waves2Energy	USA	Other
Waves4Power AB	Sweden	Point Absorber
Waveswing America	USA	Point Absorber
Wave-tricity	UK	Other
Wavetube	Sweden	Attenuator
Wavy Turbine	USA	Other
Wello OY	Finland	Rotating Mass
Weptos	Denmark	Other
WITT Ltd	UK	Rotating Mass
Wizards of Energy	USA	Other

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