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SOWFIA

Streamlining of Ocean Wave Farms Impact Assessment

Deliverable D.2.1
Catalogue of Wave Energy Test Centres

March 2011[1]

[1]Update September 2012

SOWFIA project synopsis

The Streamlining of Ocean Wave Farms Impact Assessment (SOWFIA) Project (IEE/09/809/SI2.558291) is an EU Intelligent Energy Europe (IEE) funded project that draws together ten partners, across eight European countries, who are actively involved with planned wave farm test centres. The SOWFIA project aims to achieve the sharing and consolidation of pan-European experience of consenting processes and environmental and socio-economic impact assessment (IA) best practices for offshore wave energy conversion developments.

Studies of wave farm demonstration projects in each of the collaborating EU nations are contributing to the findings. The study sites comprise a wide range of device technologies, environmental settings and stakeholder interests. Through project workshops, meetings, ongoing communication and networking amongst project partners, ideas and experiences relating to IA and policy are being shared, and co-ordinated studies addressing key questions for wave energy development are being carried out.

The overall goal of the SOWFIA project is to provide recommendations for approval process streamlining and European-wide streamlining of IA processes, thereby helping to remove legal, environmental and socio-economic barriers to the development of offshore power generation from waves. By utilising the findings from technology-specific monitoring at multiple sites, SOWFIA will accelerate knowledge transfer and promote European-wide expertise on environmental and socio-economic impact assessments of wave energy projects. In this way, the development of the future, commercial phase of offshore wave energy installations will benefit from the lessons learned from existing smaller-scale developments.

Grant Agreement number: IEE/09/809/SI2.558291
Project acronym: SOWFIA
Project title: Streamlining of Ocean Wave Farms Impact Assessment

Deliverable D2.1

Catalogue of Wave Energy Test Centres

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March 2011
Annex Updated: September 2012

Executive Summary

The objective of this catalogue is to provide an overview of the development of wave energy projects across Europe. This is framed within the context of the need to address climate change and concerns over security of oil and gas supplies. Both of these have driven European policy-makers to develop and implement a European energy policy. The European Commission has set ambitious targets for all Member States through a Directive promoting the use of energy from renewable sources (2009/28/EC), taken forward at Member State level through a National Renewable Energy Action Plan (NREAP). Many coastal European States have recognised that marine renewable energy developments will play a key role in meeting their targets. This document presents the targets set by each State in their NREAP and specifically identifies the level of ocean energy (tidal or wave) that would be required to meet those targets. Offshore wind is included for comparative purposes. The NREAP targets are supplemented by ocean energy objectives garnered from various other strategies and roadmaps.

This report also addressed the future potential spatial footprint of wave energy developments. The targets set in the NREAPs and other documented scenarios are used to calculate the potential number and spatial extent of wave energy farms required, based on the current state of the technology and operational experience. These predictions will provide an essential contribution to future Maritime Spatial Planning (MSP) systems in EU Member States. The final data section gives an overview of the wave energy development situation in Europe as of early 2011, summarising the wave energy projects that have been tested in the sea to date, those that are currently operational and those that are in the planning stage. These projects range from demonstration type projects to examples of where full-scale devices have been deployed or are planned for deployment in the near future. Information presented relates primarily to the physical characteristics of the site and the technology type in place.

The catalogue concludes with a summary of the main findings from the above work. The document is accompanied by an Annex, with information on devices that have been tested in the sea since 1999, those that are currently operational and those that are in the planning stage. The data contained in the catalogue will act as the foundation for many of the SOWFIA Project's deliverables. Most imminently, an inventory of all available environmental impact data collected, or in the process of collection, at each of the wave energy test centres listed here will be developed.

This catalogue therefore provides a snapshot of the state of the wave energy industry in Europe and its predicted development in the coming decade. It forms a baseline for understanding the developments needed in technology, policy, funding and monitoring. This is essential if the required European-wide device development and testing programmes, technical support infrastructure, and streamlined consenting and permitting regimes are to be developed to facilitate the growth of this industry. Throughout these processes, social, environmental and economic impacts must be considered. The report has four aims: to document the various targets set by coastal Member States for ocean energy; to determine the spatial requirements for these; to provide a methodology for progressing the technology; and to outline the devices that have been tested in the sea since 1999 and those that are in the planning stage.

Contents

1 Introduction

1.1 Rationale

The objective of this catalogue is to provide context for the future development of wave energy. This is achieved by identifying the level of ocean energy that could be introduced in order to achieve the targets set by Member States, what progress has been made to date in this regard, what is needed by 2020, the timeframe associated with achieving this set of targets, and what this will look like in reality. To do this, the document is presented in four key sections, followed by an Annex of physical and technical data.

1.2 Structure

Following this general introduction, the second section presents the targets set by EU Member States to achieve their renewable energy obligations under European law. The options presented here are derived not only from the National Renewable Energy Action Plans (NREAPs), but numerous other industry association roadmaps, government policies and strategies as well as economic 'think-tank' organisations. Some Member States, for example Ireland, had set targets for ocean energy prior to the legal obligation to submit an NREAP to the European Commission. Where this is the case, the associated targets are also presented in this section. An emphasis is, however, placed upon the NREAPs as these are what respective Member State governments have committed to do. It should be noted from the outset that while there is a legal obligation on Member States to reach their renewable energy targets, the path they choose to get there is discretionary and decided at the Member State level.

Where ocean energy[1] has been explicitly included in an NREAP, this would suggest that there is a firm Government commitment made to exploring this as a realistic option. Given that ocean energy is still a nascent industry, some NREAPs do not specifically include ocean energy as a mechanism to achieve their targets. Where this is the case, recourse has been made to the other sources of information. The numbers put forward in these other sources are described here as 'scenarios' to avoid confusion with the legally binding targets. This section also presents a brief synopsis of the Strategic Environmental Assessment (SEA) work that has been conducted in some Member States in relation to ocean energy development plans, as the information contained and knowledge garnered from these experiences will be essential in progressing development of the sector in an environmentally acceptable and sustainable manner. This section of the document therefore highlights the level of effort and commitment that each country has made in order to achieve the ambitious European 2020 targets.

The third section of the report utilises the targets and scenarios derived from the documents reviewed in the previous section to calculate the potential number and spatial extent of wave energy farms needed to meet the anticipated wave energy scenarios, based on the current state of the technology and operational experience. This will be important for the future development of Maritime Spatial Planning (MSP) systems in EU Member States. As a relatively new industry, little is known or accepted about the actual footprint a wave energy

[1] The NREAP template produced by the European Commission for use and completion by individual Member States refers to 'ocean energy' which is taken to include ocean current, wave and tidal.

farm would have. Examples of arrays from various technologies are presented here for illustration purposes.

The fourth section summarises the wave energy projects that have been tested in the sea since 1999, those that are currently operational and those that are in the planning stage. These projects range from test or demonstration type projects to examples of where full-scale devices have been deployed or planned for deployment in the near future. Information presented relates primarily to the physical characteristics of the site and the technology type in place. This section originally gave an overview of the actual situation in Europe in early 2011. An update of this section now gives an overview of the situation in Europe in September 2012.

The catalogue concludes with the main findings from the above work. The document is complemented by an Annex, where all wave energy projects are listed with their main features. The information contained in this catalogue will act as a basis for further work during the lifespan of the SOWFIA project.

This catalogue, and the broader work to be undertaken within the SOWFIA project, is premised on the fact that, to achieve the ambitious wave energy targets already set out, a European wide comprehensive device development and testing programme is required, together with an extensive technical support infrastructure and a consenting and permitting regime that will facilitate the device deployment process. Such a regime must also be cognisant of the local and regional social, environmental and economic conditions and must proceed in a sustainable manner. The report has four aims: to document the various targets set by coastal Member States for ocean energy; to determine the spatial requirements for these; to provide a methodology for progressing the technology; and to outline the devices that have been tested in the sea since 1999 and those that are in the planning stage.

1.3 Terminology

In this document a distinction is made between wave energy farms, parks, test sites and other locations. The International Electrotechnical Commission (IEC) has a Technical Committee (TC114) that continues to work on accepted terminology for marine energy. While the nomenclature has not yet been fully agreed upon, the following definitions, put forward by the IEC, will be used within this document (IEC, in press):

Array - farm of marine energy converters arranged specifically so as to enhance energy capture;

Farm - group of similar marine energy converters of the same type (either WECs or TECs) sharing a connection to the electric grid;

Park - a designated geographical region containing one or more marine energy farms;

As noted by the IEC-TC114 farm spacing will normally be dictated by installation, mooring and access requirements (IEC, *in press*).

The terms test site, pilot zone, pre-commercial and commercial are not defined in the IEC terminology document, however, for the purposes of this catalogue they are defined as follows:

Test site – a location to test solo prototypes, or small arrays, of wave energy devices. These locations tend to be environmentally benign and may accommodate one or more devices of different technology types at any one time, depending on berth availability and capacity. Test sites may or may not be grid-connected as they are intended, first and foremost, to prove operational concepts.

Pilot zone - is usually a single, coherent zone to concentrate activities, facilitate baseline studies, monitoring activities and the construction of associated infrastructure. These tend to be grid connected and operate on a 'one-stop-shop' basis where licensing and permitting have been streamlined. They can accommodate device demonstrations as well as pre-commercial and commercial scale devices.

Pre-commercial – an area with a higher installed capacity per technology and an appropriate term of a licence/lease. These areas are grid connected and have the potential to become commercial scale sites through time.

Commercial – large scale farms of devices that have been suitably proved in test and sea conditions and are ready to supply the market. These areas are grid-connected. In a commercial site a long term lease is usually granted and an appropriate feed-in-tariff agreed.

Large-scale test centre – a national or regional centre established for the testing of pre-prototype (not full-scale) devices, *circa* 1:4.

Full-scale test centre - a national or regional centre established for the testing of prototype devices *circa* 1:1.

Demonstration site – variable scale of devices; not an official national or regional test centre. Device developers and/or project proponents utilise these sites and may previously have used large and/or full scale test centres.

2 Targets

2.1 Legal context

The need to address climate change, and concerns over security of supply, has driven European policy-makers to develop and implement a European energy policy. In 2009, the European Commission set ambitious targets for all Member States through a Directive on the promotion of the use of energy from renewable sources (2009/28/EC). This requires the EU to reach a 20% share of energy from renewable sources by 2020 and a 10% share of renewable energy specifically in the transport sector. The Directive requires Member States to submit National Renewable Energy Action Plans (NREAPs) that establish pathways for the development of renewable energy sources, to the Commission by June 2010.

The NREAPs were prepared in accordance with a template published by the Commission and provide detailed roadmaps of how each Member State expects to reach its legally binding 2020 target for the share of renewable energy in their final energy consumption. Member States must also set out the sectoral targets, the technology mix they expect to use, the trajectory they will follow and the measures and reforms they will undertake to overcome the barriers to developing renewable energy. Table 1 shows the share of energy from renewable sources that Member States consumed in 2005 along with the targets for 2020.

It should be noted that the 2020 targets specified in Table 1, for coastal Member States of the EU, are legally binding on those Member States. The path or mix that a Member States selects to meet these targets is of their own choosing and not binding. The fact that some States have chosen to achieve their targets through the inclusion of ocean energy could however suggest a desire, and more importantly, act as a driver at the national level to progress ocean energy development.

Table 1 National overall share and targets for the proportion of energy from renewable sources in gross final consumption of energy in 2020 (Source: Member State NREAPs)

Member State	Share of energy from renewable sources in gross final consumption of energy, 2005	Target for share of energy from renewable sources in gross final consumption of energy, 2020
Belgium	2.2%	13%
Denmark	17.0%	30%
France	10.3%	23%
Germany	5.8%	18%
Greece	6.9%	18%
Ireland	3.1%	16%
Italy	5.2%	17%
Portugal	20.5%	31%
Spain	8.7%	20%
Sweden	39.8%	49%
The Netherlands	2.4%	14%
United Kingdom	1.3%	15%

Estimation of total contribution (installed capacity, gross electricity generation) expected from ocean (wave and tidal) and offshore wind to meet the binding 2020 targets and the indicative interim trajectory for the shares of energy from renewable resources in electricity for the period between 2010-2014 is presented in Table 2. Offshore wind is included for comparative purposes. From this it is clear that there will be little or no contribution from wave and tidal energy between now and 2015.

Table 2 Estimation of total contribution (installed capacity, gross electricity generation) expected from ocean (wave and tidal) and offshore wind to meet the binding 2020 targets and the indicative interim trajectory for the shares of energy from renewable resources in electricity for 2010-2014 (Source: Member State NREAPs)

Member State	Source	2010 (MW)	2011 (MW)	2012 (MW)	2013 (MW)	2014 (MW)
Belgium	Tide, Wave, Ocean	n/a	n/a	n/a	n/a	n/a
	Offshore wind	n/a	n/a	n/a	n/a	n/a
Denmark	Tide, Wave, Ocean	0	0	0	0	0
	Offshore wind	661	756	856	1256	1256
France	Ocean current, wave, tidal	240	240	256	271	287
	Offshore wind	5542	6830	7598	8512	9572
Germany	Tide, Wave, Ocean	0	0	0	0	0
	Offshore wind	150	432	792	1302	2040
Greece	Tide, Wave, Ocean	0	0	0	0	0
	Offshore wind	0	0	0	0	0
Ireland[1]	Tide, Wave, Ocean (a)	0	0	0	0	0
	(b)	0	0	0	0	0
	Offshore wind (a)	36	36	36	252	252
	(b)	36	36	36	252	252
Italy	Tide, Wave, Ocean	0	0	0	0	0
	Offshore wind	0	0	0	100	129
Portugal	Tide, wave, ocean	5	5	5	10	35
	Offshore wind	0	0	0	0	0
Spain	Tide, wave, ocean	0	0	0	0	0
	Offshore wind	0	0	0	0	50
The Netherlands	Tide, Wave, Ocean	0	0	0	0	0
	Offshore wind	228	228	228	465	940
United Kingdom	Tide, wave, ocean	0	0	0	0	0
	Offshore wind	1390	1980	2650	3470	4450

[1] Both a modelled and a non-modelled scenario are presented in the NREAP for Ireland. Figures (a) relate to the modelled scenario and figures (b) are from the non-modelled scenario. The non-modelled scenario is an ‘export’ scenario illustrating Ireland’s potential to become a net exporter if the appropriate conditions (economic, technical and environmental) existed. It could be considered as aspirational.

Estimation of total contribution (installed capacity, gross electricity generation) expected from ocean (wave and tidal) and offshore wind to meet the binding 2020 targets and the indicative interim trajectory for the shares of energy from renewable resources in electricity for the period between 2015-2020 is presented in Table 3, the figures being derived from associated Member State NREAPs. In contrast to the previous table, it is clear that many Member States predict a significant proportion of their renewable energy mix to come from wave and tidal energy by 2020. This commitment should act as a strong driver at national level to progress the sector. The only exception to this is Denmark where no targets have been set for tide, wave and/or ocean energy.

Table 3 Estimation of total contribution (installed capacity, gross electricity generation) expected from ocean (wave and tidal) and offshore wind to meet the binding 2020 targets and the indicative interim trajectory for the shares of energy from renewable resources in electricity for 2015-2020 (Source: Member State NREAPs)

Member State	Source	2015 (MW)	2016 (MW)	2017 (MW)	2018 (MW)	2019 (MW)	2020 (MW)
Belgium	Tide, Wave, Ocean	n/a	n/a	n/a	n/a	n/a	n/a
	Offshore wind	n/a	n/a	n/a	n/a	n/a	n/a
Denmark	Tide, Wave, Ocean	0	0	0	0	0	0
	Offshore wind	1251	1277	1302	1328	1353	1339
France	Ocean current, wave, tidal	302	318	333	349	364	380
	Offshore wind	2667	3333	4000	4667	5333	6000
Germany	Tide, Wave, Ocean	0	0	0	0	0	0
	Offshore wind	3000	4100	5340	6722	8272	10000
Greece	Tide, Wave, Ocean	0	0	0	0	0	0
	Offshore wind	0	50	100	150	200	300
Ireland	Tide, Wave, Ocean (a) (b)	0 0	0 0	13 125	25 225	38 352	75 500
	Offshore wind (a) (b)	252 539	252 827	416 1352	529 1802	533 2096	555 2408
Italy	Tide, Wave, Ocean	0	1	1	1	2	3
	Offshore wind	168	220	290	385	512	680
Portugal	Tides, waves, oceans	60	75	100	125	175	250
	Offshore wind	25	25	25	25	25	75
Spain	Tide, wave, ocean	0	10	30	50	75	100
	Offshore wind	150	500	1000	1500	2250	3000
The Netherlands	Tide, Wave, Ocean	0	0	0	0	0	0
	Offshore wind	1178	1978	2778	3578	4378	5178
United Kingdom	Tide, wave and ocean	0	200	400	700	1000	1300
	Offshore wind	5500	6810	8310	9800	11300	12990

According to the European Renewable Energy Council (2011), ocean energy will represent 0.15% of electricity consumption in 2020. The Council states that installed capacity is expected to increase from 245 MW in 2010 to 2,543 MW in 2020. It should be noted however that 240 MW of that 245 MW installed capacity can be solely attributed to the Rance tidal power station in France. The EREC Roadmap states that, overall, the NREAPs are "rather satisfying" with respect to ocean energy, considering that the main Member States active in the industry have set firm targets and thus reaffirmed their willingness to invest in and develop these new technologies (EREC, 2011). The Roadmap highlights that Denmark is the only exception as it has not set a target for the ocean energy sector.

In terms of implementation of the Renewable Energy Directive (2009/28/EC), under Article 4(5), the European Commission will evaluate the NREAPs, and the adequacy of the measures contained therein, in relation to reaching the 2020 target. The European Commission may then issue a recommendation in response to a NREAP. Infringement proceedings may also commence before the European Court of Justice for certain failures such as failure to produce a credible NREAP, failure to implement all aspects of the Directive, significant deviation from the plan or trajectory or valid complaints from any EU citizen regarding incorrect implementation or enforcement by Member States.

Articles 22 and 23 of the Directive prescribe the reporting to be carried out by Member States and the Commission respectively. In 2011, Member States will begin to report every two years on progress they have made in reaching their national objectives, as contained in the NREAPs. The European Commission will then report on progress made in achieving the objectives of the over-arching Renewable Energy Directive every alternate year, beginning in 2012. Member States who fail to reach their biannual milestones must submit an amended NREAP by June of the following year. In 2018, the Commission will present a Renewable Energy Roadmap for the post-2020 period. This may be accompanied by proposals for the period after 2020 and will take into account the experience of the implementation of the Directive and technological developments in energy from renewable sources (Article 23(9)).

In November 2010, the European Commission adopted the Communication "Energy 2020 - A strategy for competitive, sustainable and secure energy" (COM(2010) 639 final). The Communication sets out the steps which are required to deliver the EU's medium term policy objectives. This strategy puts forward a range of initial policy decisions which will be needed to meet Europe's 2020 energy objectives as they currently stand. The new energy strategy focuses on five priorities:

1. Achieving an energy-efficient Europe;
2. Building a truly pan-European integrated energy market;
3. Empowering consumers and achieving the highest level of safety and security;
4. Extending Europe's leadership in energy technology and innovation;
5. Strengthening the external dimension of the EU energy market.

Various scenarios in terms of energy mix will be presented in the forthcoming energy roadmap 2050, which will describe ways of achieving the EU's long-term decarbonisation goal and their implications for energy policy decisions.

2.2 Importance of renewables

Renewable sources of energy are essential alternatives to fossil fuels. Their use reduces greenhouse gas emissions, diversifies energy supply and reduces dependence on unreliable and volatile fossil fuel markets (in particular hydrocarbons such as oil and gas). Ocean energy has the potential to be an important component of Europe's renewable energy mix, as part of its longer term energy strategy.

Wave energy has the largest potential in Europe and worldwide and can be captured in a number of different ways through the use of different converters such as point absorbers, attenuators, overtopping, oscillating wave surge convertors, and oscillating water columns. The Marine Institute and Sustainable Energy Ireland (2005) state that "Europe's accessible wave power resource is calculated to be of the order of 320,000 MW with the highest resource available near the west of Ireland". The technology has not yet reached the stage of commercial scale development but progress continues to be made as evidenced through the growing number of test sites and pilot zones being established across Europe. Up to 50 types of wave energy converters have been designed, but less than 20% have reached full scale prototype stage. Wave energy has many advantages over other forms of renewable energy, being much more predictable than, for instance, wind, giving more scope for short term planning of grid usage.

2.3 Progress to date

Numerous Member States are aware of the opportunities surrounding the use of this resource and consequently have established specific targets for wave and tidal energy, separate to the NREAPs above. The associated objectives, in terms of installed capacity, are commonly put forward in 'roadmaps' and associated 'action plans':

- A Roadmap can be defined as a long term strategic planning tool focused on R&D and business investments to accelerate technology development.
- An Action Plan is a specific series of steps taken to accomplish a specified goal. An action plan generally includes steps, milestones, indicators of progress, responsibilities and time frame for delivery.

Action plans and roadmaps can be produced and published by any interested body or potential stakeholder in the industry. For this reason, it is important to specifically identify from where the action plan, roadmap or strategy derives as, arguably, this can give its contents more credibility. In this catalogue a range of action plans, roadmaps and strategies have been sourced, consulted and analysed. The following section of this catalogue seeks to provide an overview of these texts and help make sense of the hundreds of pages of distilled information and advice within them:

- Who wrote the action plan, roadmap and/or strategy
- What are the objectives?
- What are the key targets?
- What are the issues to be resolved?
- What recommendations and actions are put forward?

For convenience the documents are organised according to region (European) and Member State (SOWFIA project partner country), in alphabetical order, along with a few examples from other jurisdictions. The document descriptions are colour-coded by genesis, according to the legend in Table 4. No dedicated strategy, road map document or similar exists for ocean energy in Portugal or Sweden so those countries have been omitted from this section.

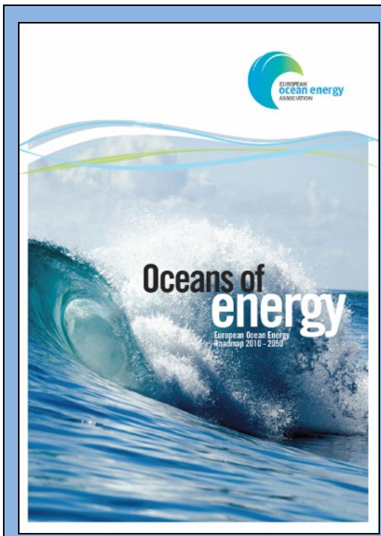
Table 4 Colour codes used in this section

Category	Colour code
Industry associations	
National Governments, public bodies, semi-State agencies	
Research Centres	
Others e.g. forums etc.	

It should be noted that under EU law, a Strategic Environmental Assessment (SEA) is required for plans and programmes prepared or adopted by an authority (at national, regional or local level) and required by legislative, regulatory or administrative provisions.[1] Accordingly many ocean energy development plans and strategies are subject to an SEA, which aims to identify the likely significant effects of the proposed plan/programme on the environment and reasonable alternatives to the proposed plan/programme. This information is contained in a dedicated 'Environmental Report' which can be a useful reference document for strategic level environmental information. A list of pertinent SEAs for ocean energy development across Europe is included here for reference only and will be the focus of more attention later in the SOWFIA project. In the context of this catalogue, it is the development plan or strategy that is of most relevance as it is these documents which should identify a development path to achieve both national and European renewable energy targets.

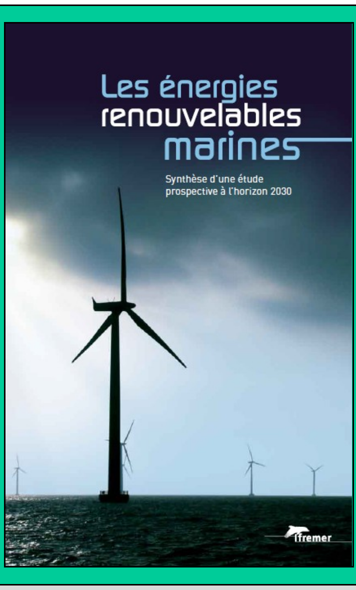
[1] It should be noted that an SEA does not preclude the requirement for a site-level Environmental Impact Assessment.

Europe

	**Reference:** European Ocean Energy Association, 2010, *Oceans of Energy – European Ocean Energy Roadmap 2010-2050*, EU-OEA, Brussels, Belgium. Available from: http://www.eu-oea.com/euoea/files/ccLibraryFiles/Filename/000000000827/ocean%20vectorise%2010%20mai%202010.pdf
	Description: The document is intended to map out the potential development of ocean energy in Europe up to 2020 and beyond to 2050. It identifies issues and barriers surrounding the sector that need to be addressed. It calls on EU Member States and the European Commission to provide strong policy measures and adequate support in order for the sector to reach its full development potential. This will be achieved through implementing a set of steps contained in the Roadmap.
Objectives:	The industrial sector objective is to install 3.6 GW of generating capacity from ocean energy systems by 2020 and reach 188 GW by 2050. The technology objectives to achieve this are: 1. Installation of ocean energy generating facilities with a combined minimum capacity of more than 240 MW; 2. Support for infrastructure and test sites; 3. Grid availability and integration of a variable electricity supply; 4. Resource assessment and spatial planning to support ocean energy deployment.
Key targets:	Development of an ocean energy industry would satisfy 15% of the EU's energy demand, create approximately 470,000 new jobs and avoid 1366 Mt/MWh of CO_2.
Issues to be resolved:	Policy framework for ocean energy; markets and access to financial resources; research & development; and environmental requirements and permitting practices.
Recommendations and actions:	Establishment of a Strategic Ocean Energy Platform to gather key industrial players and achieve the critical mass required to set out the industrial and technological objectives for a joint European Industrial Initiative. Develop full-scale MW range ocean energy devices; Ocean energy development targeting improved generation capabilities; Grid integration techniques for large-scale penetration of variable electrical supply; Resource assessment and spatial planning to support sustainable development of ocean energy; and An R&D programme for forecasting distribution of ocean resources and energy production.

France

The two documents presented here are of relevance as they refer to French targets for marine energy which cannot be traced to any other policy document. They should not, however, be analysed to the same extent as the dedicated strategies from other countries.

<table>
<tr><td rowspan="2">
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Ifremer, 2008, Les énergies renouvelables marines - Synthèse d'une étude prospective à l'horizon 2030, Ifremer, Brest, France. Available from:
http://wwz.ifremer.fr/institut_eng/content/download/39242/536346/file/Ifremer_synthese-etude-prospective-EnRM.pdf</td></tr>
<tr><td>Description:
In March 2007 the President of Ifremer launched a forward-thinking study on marine renewable energy by 2030 with numerous French partners representing major stakeholders including government departments, industry, research institutes and specialised agencies.</td></tr>
<tr><td>Objectives:</td><td>The objective of this work was to provide some answers to three questions: what technologies produce energy from the marine environment; what socio-economic conditions are needed for their development and competitiveness and what are the respective impacts of these technologies on energy and the environment. The work has led a range of contrasting possible futures.</td></tr>
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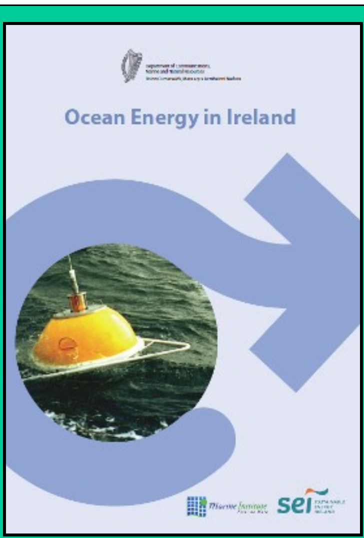
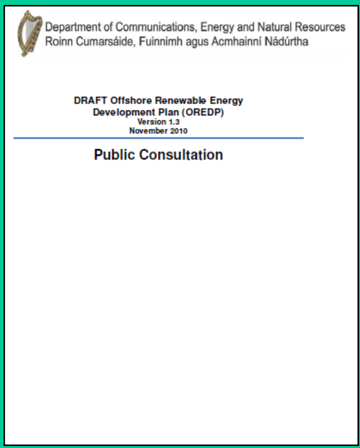
<tr><td rowspan="2">
</td><td>Reference:
Grenelle de la Mer, 2009, Blue Book Commitments of the Oceans Round Table. Ministry for Ecology, Energy, Sustainable Development and Marine Affairs, Paris, France. Available from:
http://www.legrenelle-environnement.fr/IMG/pdf/Livre_bleu_anglais_web.pdf</td></tr>
<tr><td>Description:
The document contains the outcomes of the first meeting of the Oceans Round Table (July 2009) chaired by the French Minister for Ecology, Energy, Sustainable Development and Marine Affairs. It forms part of the broader Environment Round Table. Topics discussed include Marine Protected Areas, ecosystem health, plans for vessels and ports of the future, integrated ocean and coastal management and a 'Blue Plan' for Marine Energy.</td></tr>
</table>

Objectives:	The *Grenelle de la Mer* or Oceans Round Table is France's response to the EU's Integrated Maritime policy. It conveys the Government's decision to commit to new methods of production, exploitation, and protection and use of maritime areas on the basis of strong governance that will unite all those involved.
Key targets:	One of France's objectives is that by 2020, 23% of all energy consumed will be generated from renewable sources (50% in the overseas territories and 30% in Mayotte), which presupposes increasing the production of renewable energy by 20 million TOE by 2020.
Summary of progress to date	In March 2009, the Ministry for Ecology, Energy, Sustainable Development and Marine Affairs requested five *Préfets Coordonnateurs* to identify favourable sites and carry out an individual consultation with a view to delivering a plan in September 2009 relating to the establishment of deep sea wind turbines off the coast. This led to a strengthening of the national partnership initiative for the emergence of marine energy (IPANEMA), financing of test centres open to researchers working on all aspects of marine energy development, and encouraged the development of floating wind turbine technology, which may be more socially and environmentally acceptable. It was recognised that marine energy cannot develop independently of other types of renewable energy and consequently it was decided to reserve a place for marine energy in the national energy package. This would also focus on ensuring proportionality between marine and terrestrial renewable energy and support the development of sources of intermittent renewable energy (wave energy converters and offshore wind farms) by pre-reserving a share (limit set by decree) for intermittent energy in the power supplied to the electricity network, and by systematically preparing risk-benefit impact studies. It was also decided that the regulations applicable to marine renewable energy needed clarification and integration into the various levels of decision-making.

Ireland

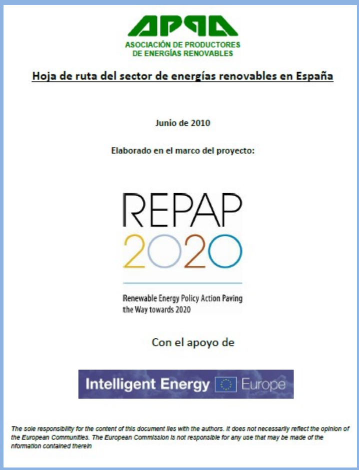
	**Reference:** Sustainable Energy Ireland and Marine Institute, 2005, *Ocean Energy in Ireland*, Submitted to the Department of Communications, Marine & Natural Resources. Sustainable Energy Ireland and Marine Institute, Dublin, Ireland. Available from: http://www.seai.ie/Renewables/Ocean_Energy/Ocean_Energy_Strategy/Ocean_Energy_Strategy_Report_18082006.pdf **Description:** The Ocean Energy Strategy put forward a structured and phased strategy of development supports to enable Ireland to utilise its ocean energy resource within a decade. The strategy was premised on the fact that Ireland had a target of supplying 13.2% of its electricity consumption from renewable sources by 2010. The strategy recognised that targets were likely to increase in the longer term and that this would require large deployments of other forms of renewable energy, including ocean energy.
Objectives:	The objective of the strategy is to advance the speed at which ocean energy technologies are deployed in Ireland by increasing the capacity for research and development, both within academic institutions and commercial entities developing devices in Ireland. Phase 1 (2005 to 2007) focuses on development by supporting product R&D and research facilities. Phase 2 and 3 are pre-commercial phases, relating to single device and 10MW array respectively, with the objective of demonstrating the potential for a cost effective fully functional wave energy converter operating in the Irish electricity market. In Phase 4 large scale market deployment of ocean energy is envisaged.
Key targets:	In this document ocean energy was not expected to play a role in meeting Ireland's targets until well after 2010.
Issues to be resolved:	Technology development was identified as the critical issue for ocean energy systems. Wave converters must be capable of surviving extreme weather loading which may add to the cost of the design. Maintenance costs may be high.
Recommendations and actions:	A four phase strategy to capitalise on Ireland's ocean energy resource was proposed with review procedures and decision gates at the end of each phase. In order to implement the Ocean Energy Strategy, an Advisory Group comprising relevant parties was proposed together with a step-by-step implementation plan. Dedicated funding was allocated for each phase of the Strategy.

 Department of Communications, Energy and Natural Resources Roinn Cumarsáide, Fuinnimh agus Acmhainní Nádúrtha DRAFT Offshore Renewable Energy Development Plan (OREDP) Version 1.3 November 2010 Public Consultation	**Reference:** Department of Communications, Energy and Natural Resources, 2010, *DRAFT Offshore Renewable Energy Development Plan (OREDP)*, Department of Communications, Energy and Natural Resources, Dublin, Ireland. Available from: http://www.seai.ie/Renewables/Ocean_Energy/Offshore_Renewable_SEA/Environmental_Report/Draft_OREDP.pdf
	Description: In 2009, work began on a Strategic Environmental Assessment (SEA) of Ireland's offshore marine environment to examine various development scenarios for offshore wind, wave and tidal energy to ascertain the level of development that appears feasible when environmental considerations are taken on board. This evidence-based approach was taken forward in the draft OREDP which describes the policy context for development of offshore wind, wave and tidal stream energy in Irish waters for the period to 2030.
Objectives:	The policy setting pertaining to the offshore marine renewable energy sector in Ireland is at a developmental stage and is spread across several ministries and state bodies. This document outlines key areas of work that various State bodies are involved in that impact upon the sector.
Key targets:	The Draft OREDP puts forward low and medium scenarios for offshore wind (800 and 2300MW), wave and tidal (75 and 500) development by 2030 which broadly reflect what is in Ireland's NREAP. A high scenario is also put forward which is a more ambitious scenario developed during the SEA scoping (4500 MW for offshore wind and 1500MW for wave and tidal).
Issues to be resolved:	The OREDP states that one of the key challenges in taking the offshore marine renewable energy sector forward is to develop a mechanism for the enhanced co-ordination and collaboration on the sector between the relevant bodies, while respecting each body's individual statutory remit, function and role in delivering and implementing policy.
Recommendations and actions:	The document is still a draft and public consultation is on-going (due to end in March 2011). A range of actions relating to collaboration and coordination; environmental monitoring requirements; addressing data, information and knowledge gaps; consenting and permitting; and dedicated guidance and advice are put forward as recommended actions. There are no dedicated timelines or allocated responsibility associated with any of the actions in the current version of the OREDP.

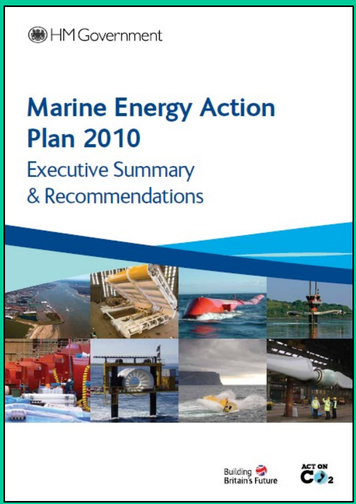
Portugal

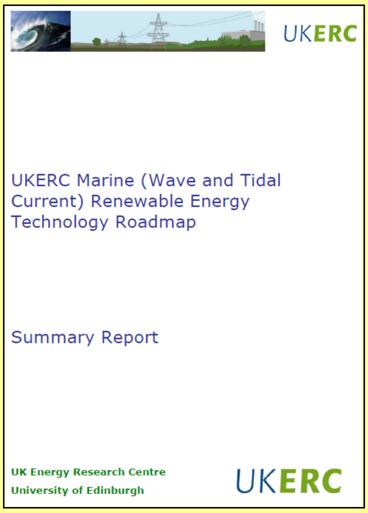
 REPAP 2020 Roteiro Nacional das Energias Renováveis Aplicação da Directiva 2009/28/CE - Versão Final - 12 de Março de 2010 Documento preparado por: apren associação de energias renováveis Coordenador do projecto REPAP2020: EREC Projecto REPAP 2020 financiado por: Intelligent Energy Europe	**Reference:** Associação de Energias Renováveis (APREN). 2010. *Roteiro Nacional das Energias Renovaveis Aplicacao da Directiva 2009/28/CE* (Versao Final). Associação de Energias Renováveis, Lisboa, Portugal. Available from: http://www.repap2020.eu/fileadmin/user_upload/Roadmaps/roadmap_APREN_VFinal.pdf
	Description: This document was prepared by the Portuguese Renewable Energy Association (APREN) as part of the European REPAP 2020 – Renewable Energy Policy Action Paving the way towards 2020 project. The document outlines the past and projected total final energy consumption in Portugal, and like the NREAPs, covers both the transport and heating and cooling sectors. Only the executive summary is available in English.
Objectives:	This document was produced as part of the REPAP project and has the objective of helping the drafting process of the National Renewable Energy Action Plans (NREAP). This document covers all the elements covered in the NREAP but from an industry perspective.
Key targets:	The projection set for tidal, wave and ocean energy in this document is 300 MW installed by 2020. This is slightly higher than the NREAP target of 250 MW.
Issues to be resolved:	The main barriers to be overcome relate to the licensing process. These include hastening the mechanisms to comply with spatial plans, the implementation of a one-stop-shop, an alteration to the composition and operation of the Environmental Evaluation Committee and finally changes to the rules concerning the granting of power connections. For offshore technologies the document states that it is fundamental to perform a characterisation campaign of the existing wave and wind resources, open a funding scheme for these less mature technologies and, of particular importance to wave energy, to catalyse the "current stand-by situation of the pilot zone".
Recommendations and actions:	APREN recommends that the renewable energy industry sector take part in the choice of criteria and administrative procedures to be adopted in the allocation of new power for each technology. In terms of the current Feed-in-Tariffs, APREN proposes the publication of a specific tariff for offshore wind and geothermal power; an increase in the guarantee period for solar technologies and a revision of the wave power tariff.

Spain

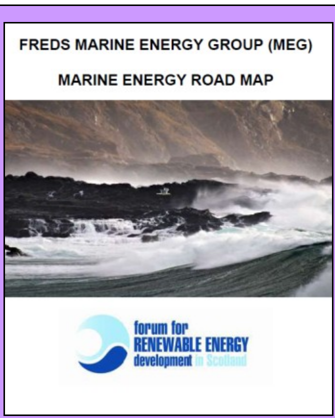
 APPA ASOCIACIÓN DE PRODUCTORES DE ENERGÍAS RENOVABLES Hoja de ruta del sector de energías renovables en España Junio de 2010 Elaborado en el marco del proyecto: REPAP 2020 Renewable Energy Policy Action Paving the Way towards 2020 Con el apoyo de Intelligent Energy Europe The sole responsibility for the content of this document lies with the authors. It does not necessarily reflect the opinion of the European Communities. The European Commission is not responsible for any use that may be made of the information contained therein.	**Reference:** Asociación de Productores de Energías Renovables (APPA). 2010. *Hoja de ruta del sector de energías renovables en España*. APPA, Madrid, Spain. Available from: http://www.repap2020.eu/fileadmin/user_upload/Roadmaps/Hoja_de_ruta_de_EERR_APPA_Proyecto_REPAP_2020__Junio_2010_.pdf
	Description: This document presents the vision of the Spanish renewable energy sector on the development of renewable energy sources (RES) in Spain to 2020, prepared by the Spanish Renewable Energy Association (APPA), which represents all renewable technologies. The goal of this "RES roadmap" is to provide the Spanish government with a compendium of measures deemed necessary to fulfil and surpass the RES targets for Spain in 2020 as laid down in the Directive 2009/28/EC. After a brief summary of the current state of development, the roadmap describes three different scenarios for their possible evolution in Spain up to 2020: from a 'business as usual' perspective to an 'accelerated deployment' scenario.
Objectives:	This document was produced as part of the REPAP project and has the objective of helping the drafting process of the National Renewable Energy Action Plans (NREAP). This document covers all the elements covered in the NREAP but from an industry perspective, in this case the Spanish Renewable Energy Association (APPA).
Key targets:	The projection for tidal, wave and ocean energy in this document is 1000 MW installed by 2020. This vastly exceeds that proposed in the NREAP which has a target of 100 MW.
Issues to be resolved:	Measures proposed in this document to achieve the objectives include defining an action plan for the deployment of smart grids, introducing micro-grids, promoting energy storage technologies, giving priority and preference to renewable energy sources regarding grid access, and establishing public and transparent rules for the sharing/allocation of costs of connecting renewable facilities to the grid taking into account the related benefits.
Recommendations and actions:	A dedicated Renewable Energy law should be adopted as soon as possible and set out the targets and instruments necessary for the fulfilment of the RES Directive commitments (including dedicated timelines).

United Kingdom

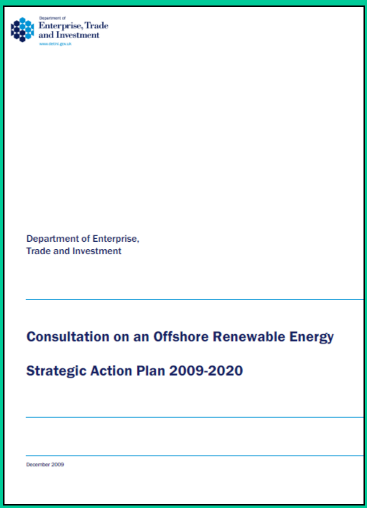
	**Reference:** HM Government/DECC, 2010, *Marine Energy Action Plan 2010 – Executive Summary and Recommendations*, HM Government, London, England. Available from: http://www.decc.gov.uk/en/content/cms/what_we_do/uk_supply/energy_mix/renewable/explained/wave_tidal/funding/marine_action_/marine_action_.aspx
	Description: This document focuses on wave, tidal stream and tidal range technologies and outlines the actions required by private and public sectors to facilitate the development and deployment of marine energy technology. It flags up the main barriers to moving the industry forward into commercial deployment and considers what needs to be done to overcome them. It sets out an agreed vision for the marine energy sector to 2030. Work under the Action Plan was split into five working groups: Technology Road-mapping; Environment, Planning & Consenting; Finance & Funding; Infrastructure, Supply Chain & Skills; and Tidal Range (which acted as a subgroup to include all of these areas of focus).
Objectives:	Five high level themes then emerged which focus on: the need to prove the technology, particularly to stimulate long-term investor confidence; providing the appropriate regulatory frameworks; ensuring appropriate funding is in place for the sector (public and private); co-operation and engagement across the sector and supply chain; and the importance of interdependency of all these themes.
Key targets:	This Government document agrees with the sectors own assessment for wave and tidal stream that 1-2GW installed capacity could be achieved by 2020. It is recognised in the Action Plan that this is aspirational and challenging, but "broadly realistic if all stakeholders are able to put in place the appropriate mechanisms to enable this level of deployment".
Issues to be resolved:	Challenges identified relate to environment, planning and consenting; finance and funding; infrastructure, supply chain and skills as well as the broader need to prove technology. Technology development and deployment will require measures to address the underpinning generic technical challenges. These can be summarized as: predictability, manufacturability, installability, operability, scalability, survivability, reliability, and affordability.
Recommendations and actions:	The Action Plan recommends that UK Government delivery partners continue to support technology development (at both the device and enabling technology level, throughout the RD&D cycle) in the following areas: device and system demonstrators; device components; guidelines and standards and tool development. Create a representative strategic coordination group from all UK States. DECC along with Action Plan members will compile the findings of the initial phase of the Action Plan into a standalone document to form the "Preliminary Findings Of The Marine Energy Action Plan 2010". DECC will also carry out an annual review, update and revision of the Marine Energy Action Plan.

 UKERC UKERC Marine (Wave and Tidal Current) Renewable Energy Technology Roadmap Summary Report UK Energy Research Centre University of Edinburgh UKERC	**Reference:** UK Energy Research Centre, 2008, *UKERC Marine (Wave and Tidal Current) Renewable Energy Technology Roadmap – Summary Report*. UKERC, University of Edinburgh, Edinburgh, Scotland. Available from: http://ukerc.rl.ac.uk/Roadmaps/Marine/Tech_roadmap_summary%20HJMWMM.pdf **Description:** This document is a technology roadmap: it provides a guide for mobilising the wave and tidal energy community in the UK down a deployment pathway towards a target of achieving 2GW installed capacity by 2020. While technically focused it also considers policy, environmental and commercialisation aspects of the marine energy sector, in order to display and put in context these wider influences. The document was developed through consultation at four workshops, as well as over 40 one-to-one interviews. The Roadmap is underpinned by a vision statement, a deployment strategy, commercial strategy and technical strategy.
Objectives:	The roadmap is aimed at providing a focused and coherent approach to technology development in the marine sector, whilst taking into account the needs of other stakeholders. The objective of the document is not to provide a definitive statement on the ultimate route forward for the industry but rather to show how certain deployment scenarios can be applied in the sector. It also details the requirements and timescales involved in achieving them.
Key targets:	The Road Map aims to assist the UK marine and renewable energy community to exploit energy from waves and tidal currents in an environmentally and socially responsible way, aiming for an installed capacity of 2GW by 2020 in UK waters; to stimulate policy and funding instruments to overcome barriers to deployment; to establish a commercially viable industry supported by an extensive supply chain and thereby build skills capacity at all levels and to become competitive with other energy sources by 2020.
Issues to be resolved:	Main challenges to deployment are predictability, manufacturability, installability, operability, survivability, reliability, and affordability. Each of these challenges is addressed in more detail in the commercial and technical strategies, in which activities have been prioritised to meet the deployment scenario. The challenges identified relate very much to the technology, but it is recognised that industrial infrastructure is a major challenge facing the sector. This includes electrical, manufacturing, supply chain and human resources. In relation to manufacturing, for example, it is stated that to meet a target of 2GW by 2020 then by 2012, the sector needs to be able to build 1 unit per week, ramping up to an average of around 4 per week by 2015 to meet the deployment requirements.
Recommendations and actions:	The document does not contain recommendations *per se* but the technical strategy is divided into 12 themes (Technology Working Areas), which represent the technology development chain in marine renewable devices and puts forward a rationale and qualified detailed timelines for each of these. Timelines are accompanied by a list of prioritised actions developed in consultation with the marine community. These are very detailed and relate to technical aspects and, consequently, are not presented here.

Scotland

	**Reference:** Forum for Renewable Energy Development in Scotland (Freds), 2009, *Marine Energy Road Map*, Freds Marine Energy Group (MEG), Scotland. Available from: http://www.scotland.gov.uk/Publications/2009/08/14094700/12
	Description: This document focuses on wave and tidal stream technologies. The rationale for this focus is that Scotland has great potential for the development of wave and tidal stream energy (with around 25% of Europe's tidal stream resource and 10% Europe's wave resource). This Road Map assesses the status and potential of the marine energy industry in Scotland and proposes recommended actions to ensure its continuing growth.
Objectives:	This document sets out scenarios for growth of the industry, to build on what has already been achieved in terms of public revenue support for projects in Scotland, strengthening of test site facilities (EMEC) and completion of an SEA for wave and tidal energy. Existing road mapping work for the UK marine energy sector has been based largely on "target" rather than "scenario" methodology, the former suggesting a possible installed capacity of roughly 1 GW of marine energy in Scottish waters by 2020. This document sets out scenarios demonstrating a range of possible deployment pathways, from low to more aspirational.
Key targets:	The vision is to "create the world's leading marine energy industry, one that will provide a substantial contribution to the sustainable economy and environment of Scotland". To do this, the Group recognises that market opportunities for marine energy generation in Scotland must be promoted and ensure that Scottish companies and communities are well placed to capture these opportunities.
Issues to be resolved:	The Road Map identifies five key issues which will need to be addressed in order to realise the high growth scenarios. These relate to finance, grid, planning, infrastructure/supply chain and the lack of priority status given to the sector in European strategic energy policy. The Road Map states that the pace of advancement for technologies has not been as fast as predicted previously in 2004 (Scottish Executive, 2004). This is attributed to the underestimation of some technical challenges, as well as the fact that it took longer than expected to set in place sufficient financial support streams.
Recommendations and actions:	The document calls on the Scottish Government to launch an open call with an increased budget and an annual allocation which developers must "use or lose" within a 12-month window and should also review the level of ROC banding for tidal stream. DECC are asked to announce the criteria for the Marine Renewables Proving Fund and an associated call for funding proposals. Finally a strategic review of Scottish grid infrastructure for marine energy, identifying longer-term grid infrastructure upgrades on the basis of expected development locations, is needed. MEG will continue with its work programme, set in the context of the recommendations within this Road Map and undertake a review of progress against these recommendations in Summer 2012.

Northern Ireland

 Department of Enterprise, Trade and Investment Consultation on an Offshore Renewable Energy Strategic Action Plan 2009-2020 December 2009	**Reference:** Department of Enterprise, Trade and Investment (DETI), 2009, *Draft Offshore Renewable Energy Strategic Action Plan 2009-2020*, DETI, Belfast, Northern Ireland. Available from: http://www.offshoreenergyni.co.uk/Data/Draft_Strategic_Action_Plan.pdf
	Description: This Strategic Action Plan (SAP) identifies a programme of enabling actions which will be essential to the development of the marine renewable energy resource. It includes actions to maximise the market opportunities to Northern Ireland companies of the development of offshore renewables. It also provides the framework within which offshore renewable energy can be developed through a competitive call, to be undertaken by The Crown Estate, for commercial projects. An SEA has already been completed for this Action Plan. This concluded that between 900 MW and 1200 MW of capacity could be installed by 2020 from offshore wind and marine renewables (tidal arrays) in Northern Ireland waters, without significant adverse effects on the environment.
Objectives:	The overall objective of this draft Strategic Action Plan is to optimise the amount of renewable electricity generated from offshore wind and marine renewable resources in Northern Ireland's waters (to 12M limit) in order to enhance diversity and security of supply, reduce carbon emissions, contribute to the proposed renewable electricity targets by 2020 and beyond and develop business and employment opportunities for NI companies.
Key targets:	To develop at least 600 MW of offshore wind and 300 MW from tidal resources in Northern Ireland waters by 2020. This installed capacity could equate to a contribution of over 50% towards the proposed 40% renewable electricity target for 2020.
Issues to be resolved:	Critical actions which will need to be addressed relate to the electricity grid; infrastructure and supply chain; regulatory and legislative frameworks and support regime.
Recommendations and actions:	These relate specifically to the issues to be resolved above, e.g. develop a reinforcement programme of the NI Grid; develop a practical way forward with Republic of Ireland for handling offshore renewable energy projects in waters in, around or adjacent to the Border Bays and agree appropriate operational arrangements; develop streamlined administrative guidance for developers and officials on the licensing and consenting regimes for offshore renewable energy projects and establish an Offshore Renewable Energy Forum, building on existing cross-departmental group, to engage with relevant external stakeholders. The Plan will be reviewed in 2013-14 to inform decisions on future policy and subject to an overall evaluation post 2020. In the interim, DETI will produce an annual report on progress against the planned actions and any revised plans coming forward.

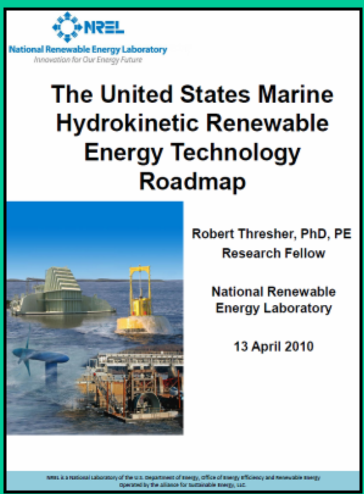
Others

A search for marine renewable energy, ocean energy and wave energy strategies, roadmaps and action plans for Canada, Mexico, Norway, Australia and New Zealand yielded no results despite the fact that all of these countries are contracting parties to the International Energy Agency's Implementing Agreement on Ocean Energy Systems (IEA-OES).

Norway has no special policies or programmes dedicated to ocean energy, but ocean energy is included in more general renewable energy policies and programmes (IEA-OES, 2010). Canada's efforts to date have focussed primarily on tidal energy though the development of a Canadian Marine Renewable Energy Technology Roadmap which is expected to be publically available in 2012 (IEA-OES, 2010).

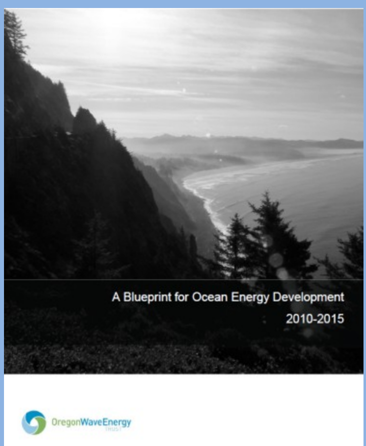
Though there is no government programme specifically for ocean energy in Australia, the Department of Resources, Energy, and Tourism has expressed a desire to see an Australian ocean energy industry association established (IEA-OES, 2010). Some regional efforts at State level are also underway, for example, in Western Australia and Tasmania. In 2010 the Japanese Ocean Energy Association (OEA-J) developed a technology Roadmap for Ocean Energy which includes targets for wave, current and tidal and ocean thermal energy conversion (OTEC) but a copy of this could not be located for consideration in this document. Relevant examples from the United States are presented below.

United States of America - national

	**Reference:** Thresher, R./National Renewable Energy Laboratory, 2010, *The United States Marine Hydrokinetic Renewable Energy Technology Roadmap*, National Renewable Energy Laboratory, Golden, Colorado, U.S.A. Available from: http://www.oceanrenewable.com/wp-content/uploads/2010/05/1st-draft-roadmap-rwt-8april10.pdf
	Description: This roadmap is a working document to be used to facilitate the coordinated development of marine renewable energy technologies and to mobilize the deployment and use of these technologies in the United States. It has a very similar structure to the UKERC document, outlined above, containing a vision statement, deployment, commercial and technical strategies. It is focused primarily on the scientific and technical steps necessary to overcome the barriers to the wide-spread use of these renewable energy technologies. It contains both short term and long term measureable goals, and agreed technical pathways for meeting these goals. The roadmap was developed through consultation with stakeholders through six meetings involving approximately eighty participants.
Objectives:	The vision is to establish a commercially viable marine renewable energy industry that is supplied by a manufacturing chain generating domestic jobs and to facilitate enactment of policies that would make available the funding needed to overcome the barriers and support the development of the

	sector, incentivise early stage deployment, foster responsible siting practices, and ensure sound environmental stewardship. In terms of environmental studies the Roadmap proposes that baseline studies be carried out before installation, impact monitoring is carried out during construction, operational impact monitoring continues after operation and additional special studies are commissioned when needed. According to the roadmap this would be carried out over six years.
Key targets:	To deploy a total of 23 GW of combined marine renewable energy capacity in an economically, environmentally, and socially responsible manner by 2030. No specific target is set for wave energy despite the fact that it is one of the technologies explicitly considered in the Roadmap.
Issues to be resolved:	Identified issues to be overcome are siting and permitting barriers; environmental research needs; technical R&D issues; policy issues; market development barriers; economics and financial issues, and grid integration barriers. The document notes that wave device development from the stage of concept to ocean prototype testing can take 5 or more years, depending on complexity.
Recommendations and actions:	The deployment, commercial and technical strategies are each accompanied by detailed descriptions, scenarios and dedicated timelines. Timelines are accompanied by a list of research needs developed in consultation with the marine community. The document concludes by stating that it is up to each stakeholder to play their particular role by developing and executing their plans and projects so that the vision and goals are fulfilled over the next twenty years.

U.S.A. - Oregon

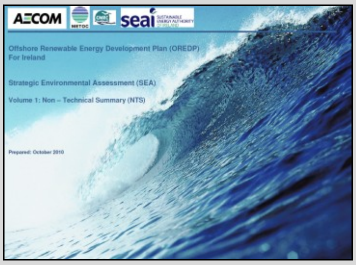
	**Reference:** Oregon Wave Energy Trust (OWET), (2010), *A Blueprint for Ocean Energy Development 2010-2015*, Oregon Wave Energy Trust, Portland, Oregon, U.S.A. Available from: http://www.oregonwave.org/wp-content/uploads/OWET-Blueprint-2010-2015-FINAL-web.pdf
	Description: This document is based on the outcomes of a Summit held in 2010 where there was open dialogue among developers, utilities, and regulatory and policy leaders to develop a strategy to advance ocean energy development in Oregon and the Pacific Northwest of North America by 2015. Approximately 40 attendees gathered for two days of dialogue and brainstorming sessions, information sharing, and discussion about opportunities to advance the industry.

Objectives:	This Blueprint captures the results of the Summit, identifies goals for 2015, and recommends actions discussed at the Summit. It also identifies existing barriers and proposed solutions, and plans for actions to achieve the goals. OWET intends for this Blueprint to be used as a focused action plan to advance a responsible ocean energy industry.
Key targets:	The Blueprint states that pilot and demonstration projects using a phased approach to install 10-to-25 MW, in order to learn more about the cumulative effects of ocean energy, is a realistic and responsible development path that is sensitive to existing users.
Issues to be resolved:	The Summit attendees identified numerous issues, falling under three key topics: connecting to the electrical grid, regulatory and permitting processes and policies to encourage, finance, and advance ocean energy development. For each barrier presented, a range of proposed solutions are put forward. In relation to environmental information the Blueprint recognises that this is collected by individual projects and not necessarily shared with others, resulting in duplicated efforts. The proposed solution is to increase information sharing through use of the Dept. of Energy's Knowledge Management System and conduct more outreach events.
Recommendations and actions:	After a review of the Summit outcomes, OWET developed a list of priority actions representing the most advantageous and achievable objectives. These relate to the electric grid, regulatory and planning issues, and policy and finance. No definite timelines are associated with any of the actions but it is stated that OWET will 'diligently work' on the priority actions.

2.4 Strategic Environmental Assessment (SEA)

A Strategic Environmental Assessment (SEA) involves the systematic identification and evaluation of the impacts of a strategic action (e.g. a plan or programme) on the environment. In other words it provides for strategic environmental information to be considered at an early stage in the decision making process. SEAs tend to cover large geographical areas and the plan/programme being assessed can include a range of different types of project relating to a number of different broad areas for development, in contrast to an Environmental Impact Assessment (EIA) which is site-specific and deals with only one project. An SEA focuses on identifying the 'likely' significance of 'potential' effects, whereas an EIA deals with precise effects and evaluated actual significance.

A number of jurisdictions have completed or are in the process of completing SEAs for the development of marine renewables. The findings of the SEA can assist in guiding development to areas where environmental effects are minimal or can be avoided. The information collated, generated and documented as part of the SEA process often becomes the first source of environmental information for developers when thinking about site selection and project development, pointing developers to sources of further and more detailed information. SEAs are not considered in detail in this catalogue but for reference purposes information on SEAs carried out, key findings and where they are available from, are presented in the Table below.

<table>
<tr><th>SOWFIA partner country</th><th>SEA Details</th></tr>
<tr><td>France</td><td>None available</td></tr>
<tr><td>Ireland


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- SEA on the Draft Offshore Renewable Energy Development Plan currently in the final stages (public consultation phase).
- Coverage: all Irish waters from the Mean High Water Mark out to the 200m water depth contour off the west and south west coast of Ireland and the Irish Exclusive Economic Zone off the north, east and south east coast of Ireland.
- Finding: Overall, the SEA found that, based on the extent of the available offshore renewable energy resource within Irish waters, and the geographical scale of the overall study area, that it would be possible to achieve a high scenario of 4,500MW from offshore wind and 1,500MW from wave and tidal energy without likely significant adverse effects on the environment. This is subject to a number of caveats contained in the final SEA documents.
- SEA Documentation available from: http://www.seai.ie/Renewables/Ocean_Energy/Offshore_Renewable_SEA/

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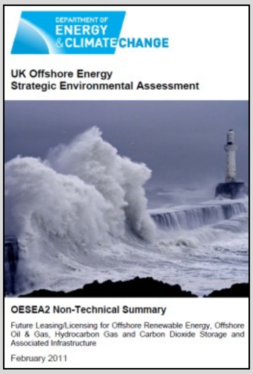
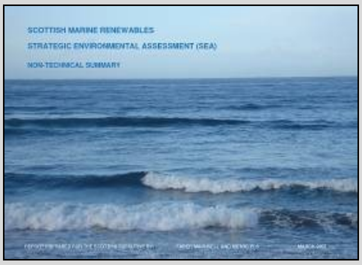
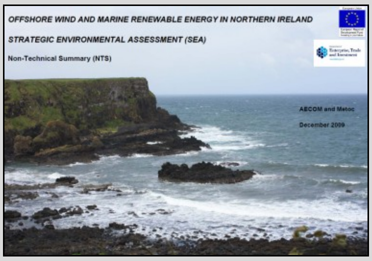
</table>

Portugal	None available
Spain	SEA of the Spanish NREAP is currently underway. An SEA for offshore wind energy was completed in 2009.
Sweden	None available
Portugal	None available
United Kingdom	*See individual jurisdictions detailed below.*
England and Wales 	• SEA for Offshore Energy completed in 2011 on a draft plan/programme to enable future renewable leasing for offshore wind, wave and tidal devices and licensing/leasing for seaward oil and gas rounds, hydrocarbon and carbon dioxide gas storage. • <u>Coverage:</u> It covers parts of the UK Renewable Energy Zone and the territorial waters of England and Wales; for hydrocarbon gas and carbon dioxide storage it applies to UK waters (territorial waters and the UK Gas Importation and Storage Zone); and for hydrocarbon exploration and production it applies to all UK waters. • <u>Finding:</u> The conclusion of the SEA is that the areas offered for licensing and leasing should be restricted spatially through the exclusion of certain areas together with a number of mitigation measures to prevent, reduce and offset significant adverse impacts on the environment and other users of the sea. • SEA Documentation available from: http://www.offshore-sea.org.uk/consultations/Offshore_Energy_SEA_2/index.php
Scotland 	• SEA completed in 2007 on Freds MEG Roadmap. • <u>Coverage:</u> The study area covers the entire west and north coast of Scotland from Shetland to the Solway Firth to a distance of 12 nautical miles offshore. • <u>Finding:</u> between 1,000MW (wave & tidal, low scenario) and 2,600MW (high scenario) generating capacity could potentially be achieved within the SEA study area taking into account environmental effects and depending on the types of technology (including array density) deployed. However, it should be noted that a large proportion of this capacity is located in the Outer Isles, which are remote from the mainland and would require longer cable routes to shore.

	• SEA Documentation available from: http://www.seaenergyscotland.net/SEA_Public_Environmental_Report.htm
Northern Ireland  	• SEA completed in 2010 on Offshore Renewable Energy Strategic Action Plan • Coverage: the full seaward extent of Northern Ireland territorial waters from the mean high water mark to the 12 nautical mile limit. The study area extends from Lough Foyle in the North to Carlingford Lough in the South, the border bays with the Republic of Ireland (not formally delineated). • Finding: the SEA concluded that between 900MW and 1200MW of electricity could be generated by 2020 from offshore wind and tidal arrays in Northern Ireland waters, without significant adverse effects on the environment. As there is limited potential for wave energy, this technology was excluded from the target setting in the related SAP. • SEA Documentation available from: http://www.offshorenergyni.co.uk/EnvironmentalReport.html

2.5 Discussion

While most countries recognise the potential for wave energy in their surrounding waters, relatively few of these have dedicated wave, or indeed ocean, energy strategies, plans or roadmaps. Those that do exist derive from western European countries, around the Atlantic arc. The obligation to produce a National Renewable Energy Action Plan (NREAP) by June 2010 has perhaps raised the profile of renewable energy development at Governmental level, many of them containing explicit targets for wave and tidal energy. A summary table of targets, derived from the preceding information on NREAPs, and scenarios contained in other relevant documents are presented in Table 5.

Table 5 Summary table of targets from NREAPs and other documented scenarios to be achieved by 2020

Country	NREAP target (wave, tidal) (MW)	Ocean energy scenarios (MW)
Europe (Total)	n/a	3600[1]
Denmark	0	500[1]
France	380	800[1]
Ireland	75 500	500[1]
Portugal	250	300[1] 0.4 – 300[2]
Spain	100	600[1]
Sweden	0	0
UK	1300	2000[1]
Scotland	n/a	1300[3]
Northern Ireland	n/a	n/a[4]

1 European Ocean Energy Association, 2010.
2 WavEC Seminar. 2010.
3 Scottish Executive, 2004
4 The Northern Ireland Strategic Action Plan (DETI, 2009) only considers tidal energy at this time.

Denmark is the only country with no dedicated target for tidal, wave and ocean energy within its NREAP. According to the EREC (2011) the Danish Government based its 2020 projections for renewable energy on a "frozen policy" scenario, meaning it is based on the existing policy framework and legislation. While the Danish NREAP states that the over-arching Danish target of 30% renewable energy by 2020 will be met, the EREC state that, for the moment, the financial incentives are in general not high enough to encourage the investment needed to reach the this 30% target (EREC, 2011). France has no dedicated road map or strategy for marine renewable energy or wave energy specifically. The overall French RES target of 23% was enacted in the Grenelle law of 3 August 2009 and each technology target is enshrined in statutory texts[1], yet ocean energy targets and scenarios are difficult to trace to official documents.

In Portugal the projection set for tidal, wave and ocean energy in the industry document is 300 MW installed by 2020 (APREN, 2010). This is slightly higher than the NREAP target of 250 MW. The same is true for Sweden where the industry document has a projection of 100 MW of installed capacity of tidal, wave and ocean energy by 2020 whereas the Swedish NREAP has no target for tidal, wave and ocean energy.

In Spain, there are limited national targets for ocean energy or wave energy specifically at the moment. The Institute for Diversification and Saving of Energy (IDAE), however, has initiated the preparation of a new Renewable Energy Plan for the period 2011 – 2020 which will include wave energy targets for the first time (IEA-OES, 2009). Regional Governments of several areas (the Basque Country, Cantabria, Asturias, Galicia and the Canary Islands) are promoting the installation of test facilities and demonstration projects. Two of them have set targets on ocean energy so far: the Basque Country plans 5 MW of installed power by 2010, and the Canary Islands consider 50 MW by 2015 (IEA-OES, 2009). In relation to wave energy, the NREAP states that Spain is currently initiating the development of the first pilot projects for harnessing wave energy, with different prototypes. These will be in the demonstration phase for the next few years but it is expected that by 2016 the best technology to capture energy from the sea will become apparent. This, in turn, will allow commercial development of the sector with the launch of the first commercial plants becoming operational after this time.

In the United Kingdom, a range of documents all of which have implications for the development of renewable energy, and to a lesser extent wave energy, have been published in recent years. The UK NREAP was published on 1 July 2010, shortly after the election of a new Government in May. While the NREAP includes the new government's commitments, some decisions have not been made on key outstanding issues. The Department of Energy and Climate Change announced a reduction in, and effectively capped the anticipated spend on, feed-in tariffs in October 2010. The Government will publish a detailed report in April 2011 looking at the deployment of renewables post 2020 out to 2030 and 2050 (EREC, 2011).

It is difficult to ascertain with any certainty how realistic the various targets and scenarios are for ocean energy. Part of this is due to the fact that in none of the documents reviewed is ocean energy expressly divided into wave and tidal components with corresponding targets for each. For countries with Atlantic Ocean coastlines, it is more than likely that the majority of their ocean energy will be provided by wave energy and not tidal. Another explanation is the fact that both wave and tidal technologies have not yet reached the commercial scale so their ability to reach the anticipated targets cannot yet be determined.

A review and analysis of ocean energy systems development and supporting strategies, published by the IEA-OES in 2006, recognised that at that time there had not been sufficient demonstration of full-scale prototypes to prove that the technologies work. The review states that this is fundamental and *the* key barrier preventing deployment of ocean energy technologies and must be tackled to ensure that research, development and demonstration progresses to the pre-commercial stage of demonstrating multiple devices in farms (IEA-OES, 2006). Arguably this is still the case and may explain why not every coastal European country has an ocean, wave or tidal development strategy or roadmap.

[1] *Programmations pluriannuelles des investissements.*

Related research initiatives may help address this issue. In Europe, for example, the FP7 funded Off-shore Renewable Energy Conversion platforms Coordinated Action (ORECCA)[1] project aims to create a framework for knowledge sharing and to develop a roadmap for research activities in the context of offshore renewable energy. In particular, the project will stimulate collaboration in research activities leading to innovative, cost efficient and environmentally benign offshore renewable energy conversion platforms for wind, wave and other ocean energy resources.

The next section of this report endeavours to quantify how many wave energy farms are needed to reach the 2020 objectives. This will assist developers, planners and regulators, as well as the wider community, to appreciate the level of effort required to achieve these targets. It will also be of fundamental use in developing a Maritime Spatial Planning (MSP) system. MSP is a planning process that enables integrated, forward-looking, and consistent decision-making on the human uses of the sea, and in doing so facilitates sustainable development (Ehler and Douvere, 2009). The European Commission have advocated that Member States develop an MSP system for their maritime domain and many are already progressing with this, for example, Belgium, Germany and Portugal. It is important that, as a new and developing industry, the wave energy sector can move towards documenting its likely future spatial requirements.

[1] See http://www.orecca.eu/

3 Spatial planning requirements for anticipated wave energy developments

3.1 Context

This part of the catalogue utilises the targets derived from the national NREAPs and ambitious industry documents (reviewed in the previous section) to calculate the potential number and spatial extent of wave energy farms needed to meet the documented scenarios.

Currently, some jurisdictions are in the process of developing and implementing dedicated Maritime Spatial Plans for marine renewable energy, for example, Marine Scotland's Maritime Spatial Planning (MSP) work on Pentland Firth and Orkney Waters (Scottish Government/Marine Scotland, 2009) and Sweden where MSP will be operational in 2012. MSP is seen as a mechanism for the sustainable management of marine activities and increased protection of the marine environment and natural resources. Consequently the European Commission have advocated its use at Member State level and the MSP process will form a specific area of activity for Government departments and agencies in the near future.

MSP must consider all maritime sectors simultaneously and planning for a single development sector in isolation (such as wave energy) contradicts one of the fundamental aims of marine spatial planning. Most maritime sectors, however, are firmly established and their coverage or areas of use well known and documented. This is not the case for wave energy as it is still in the development phase. Accordingly, it would be helpful to explore the potential number of wave energy farms needed to achieved the desired capacity and calculate the spatial area a wave energy farm is likely to occupy.

3.2 Wave farms needed

All the documents reviewed as part of this work combine wave and tidal energy into ocean energy. Consequently it is not possible to emphatically state what proportion of renewables will be derived from wave energy by 2020. Based on the potential wave resource around the western European arc it is probable that the greater proportion of ocean energy will be derived from wave energy in countries such as Ireland, the UK and Portugal where there is a greater wave resource than tidal resource. For the purposes of this work, the numbers put forward in the EU-OEA's Oceans of Energy Roadmap (2010) and the NREAPs have been used. To calculate the amount of farms needed, a number of presumptions have been made here:

1. Developers anticipate wave farms will comprise of between 10 to 250 devices for a full-scale commercial generating station. In this example an early stage wave energy farm composed of 20 devices of 1 MW capacity is used.
2. The figures from the EU-OEA's Oceans of Energy Roadmap (2010) have been used here. In this catalogue it is presumed that *all* ocean energy will come from wave energy to provide the maximum amount of sea space that could be required:
    - Europe: 4700 MW;
    - Denmark: 500 MW;

- France: 800 MW;
- Ireland: 75 MW / 500 MW;
- Portugal: 300 MW;
- Spain: 600 MW;
- UK: 2000 MW.

3. To give a possible range, the NREAP targets, which also use a combined figure for wave and tidal energy, have also been included again presuming ocean energy will be derived from wave energy only;
4. The Pelamis device, a typical wave energy device, has been selected for this example. It is 180m long and 4m diameter. Figure 1 illustrates a theoretical Pelamis wave energy farm. This is comprised of 40 Pelamis devices with a total capacity of 30 MW. For the purposes of SOWFIA, a more conservative figure is adopted. This would equate to 20 devices of 1 MW capacity each but the proposed area is of the same proportion: 2.1km by 0.6km resulting in an area of 1.26km^2. 20 devices of 1 MW gives a power density of 16 MW/km^2 (i.e. 20 / 1.26 = *c*.16).
5. As the technology is still developing, details of array configurations cannot be definitively determined. Current reports quote energy density extraction values between 10 – 28 MW/km^2 therefore in the following example this range giving a minimum and maximum space requirement.

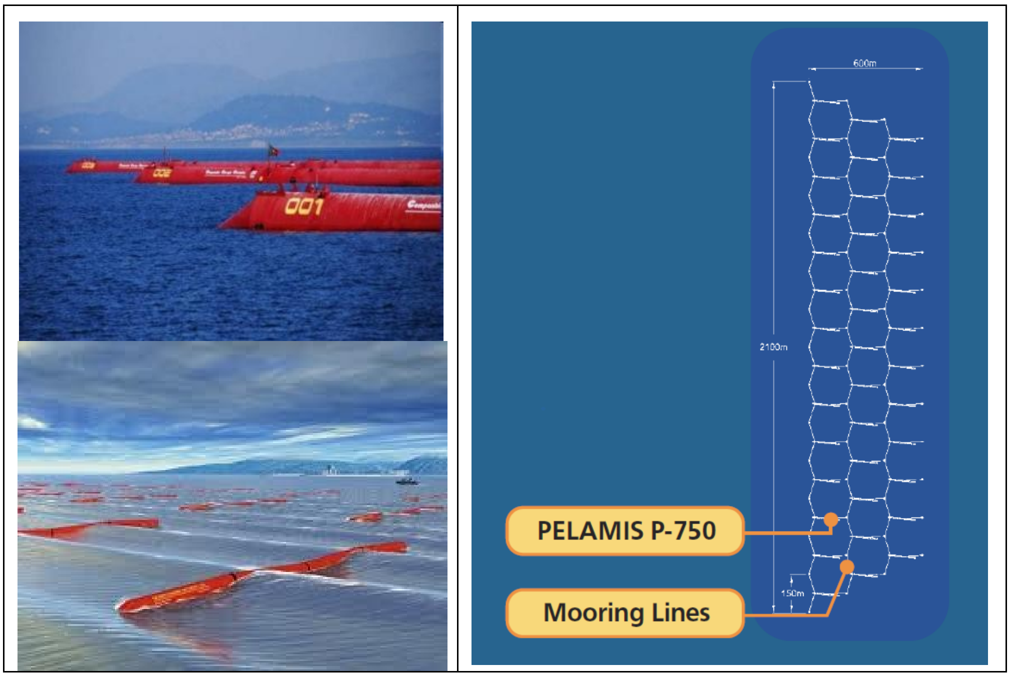


Figure 1 Example of Pelamis array and theoretical wave energy farm for 40 devices with a total capacity of 30 MW (www.pelamiswave.com)

Taking all of the above into account, the estimated number of wave energy farms needed by 2020 to deliver the range of documented scenarios are summarised in Table 6.

Table 6 Wave energy farms needed if 2020 targets for wave energy are achieved

Country	NREAP targets (MW)	EU-OEA figures (MW)	Wave energy farms (20 MW) 10 MW/km^2 Min./Max.	Wave energy farms (20 MW) 28 MW/km^2 Min./Max.
Denmark	0	500	0/50	0/18
France	380	800[1]	38/80	14/29
Ireland	75	500	7.5/50	3/18
Portugal	250	300	25/30	9/11
Spain	100	600	10/60	4/22
UK	1300	2000	130/200	47/72
TOTAL			210.5/470	95/170

On the basis of the above hypotheses, to achieve the objectives described, it would be necessary to install and operate between 95 and 470 wave energy farms in Europe by 2020 depending on the installed capacity and wave energy density. The UK targets are much more ambitious than those put forward by the EU-OEA for Europe as a whole. For the UK, a total of 47-200 wave energy farms of 20 MW (or *pro rata* for larger farms) would be required by 2020. The remainder of the countries listed could potentially contribute to the European target at a lower rate. Theoretically France will need to install a minimum of 14 farms or a maximum of 80 farms; Spain 4-60 (min.-max.) farms, Denmark 18-50 farms, Ireland 3-50 farms and Portugal would require a minimum of 9 and a maximum of 30 wave energy farms.

3.3 Spatial footprint of wave farms

To calculate the spatial extent or footprint of a wave energy farm is difficult as it will depend on the technology being deployed. Similarly, different technologies will have different spacing and mooring requirements which will again have consequences for the sea area occupied. Local, regional, national and international regulations and legislation usually require a buffer zone to be created around any farm development for the purposes of navigational safety. Equally international best practice on cable protection suggests that a buffer of 500m should be created around any cables or pipelines to prevent damage from navigational activities such as shipping and fishing practices.

None of the aforementioned factors can yet be definitely expressed but will still need to be considered in planning the development and management of wave farms. In future this is likely to take place within a dedicated Maritime Spatial Planning system, so this information has the potential to assist in that process.

The results for each country are presented in Table 7.

[1] This figure includes Le Rance tidal power station which has an installed capacity of 240MW.

Table 7 Theoretical spatial extent of wave energy farms needed by 2020

Country	Wave energy farms (20MW) Min. /max.	Spatial extent (km^2) Min./max.
Denmark	0/50	0/63
France	14/80	18/100
Ireland	3/50	4/63
Portugal	9/30	11/38
Spain	4/60	5/76
UK	47/200	59/252
TOTAL	95/470	120/592

To achieve the EU-OEA’s total wave energy for Europe, the area occupied would be between 120 and 592 km^2. In UK alone, the total area necessary for its wave farms would be between 47 and 252 km^2.

4 Progressing Wave Energy

4.1 Advancing to commercial scale

In order to achieve the ambitious targets set out by national governments and industry associations outlined in the previous sections, two important elements must be put in place. These are:

1. A structured funding plan based on the International Energy Association's Ocean Energy Systems (IEA-OES) five stage development schedule;
2. A support infrastructure where companies may quickly and efficiently test their concepts and devices, at a range of stages, from proof of concept, through pre-production to pre-commercial scale.

4.1.1 Five Stage Development Schedule

While substantial knowledge has been gained on the requirements for extracting energy from ocean waves, at the current stage of technical advancement, the development of wave energy devices still requires a cautious and measured methodology to be followed. Commercial scale wave energy can only become a reality following full scale testing of wave energy converters at sea and it is essential that the correct engineering procedures are followed leading up to the first sea trials. The most efficient and effective means of doing this is to proceed according to the Stage Gate development programme. The principle behind this is to sequence design development so that the required knowledge is obtained at different stages to facilitate safe transmission along a course of increasing technical complexity and investment requirements. This approach is now becoming accepted as the best practice and is being formalised in a document under production by the Annex II of the Ocean Energy Systems Implementing Agreement (IEA, 2009).

To accommodate all requirements a five-stage schedule has evolved as the optimum for the development of wave energy devices. Figure 2 shows the overall structure of the programme. Device development should not be regarded as a straight line process and feedback loops and repetition of stages should be expected. The five stages basically align with small (1:50 - 100); medium (1:10 - 25); large (1:3 - 8) and full (1:1 - 2) scale models that can be tested initially in hydraulic laboratories and, at later stages, in the open sea conditions.

Stages 3 to 5 occur in open water conditions. There is a growing agreement that before full scale pre-production prototype WECs are built and deployed, a large scale unit in the region of 1:4 scale, should be tested at a benign outdoor site, which happens at Stage 3. At this stage, sea states are lower, the test sites involve shorter boat trips and the support services required (harbours, support vessels etc) are more readily available. The technical motivation is that it is very difficult to bench test the device's assembled sub-systems so this approach enables the machine to become a serviceable test rig. To reduce the fiscal risk it is recommended that this phase is conducted at an established test site, where licensing and permitting issues together with environmental requirements may be addressed as part of the test site's facilities.

Prototype scale testing commences in Stage 4. Here the device must progress from a pre-production to a pre-commercial machine. The device to be tested at this level would be at, or close to, full size but still a solo machine. The budget required for this scale of testing and the duration of testing both increase significantly in line with the sheer scale of operations. Essentially during this stage, testing should verify the overall design to individual component suitability, through to electrical production and quality of supply. It should take place within one of the established large-scale test centres which should offer easier grid connection that includes performance monitoring instrumentation.

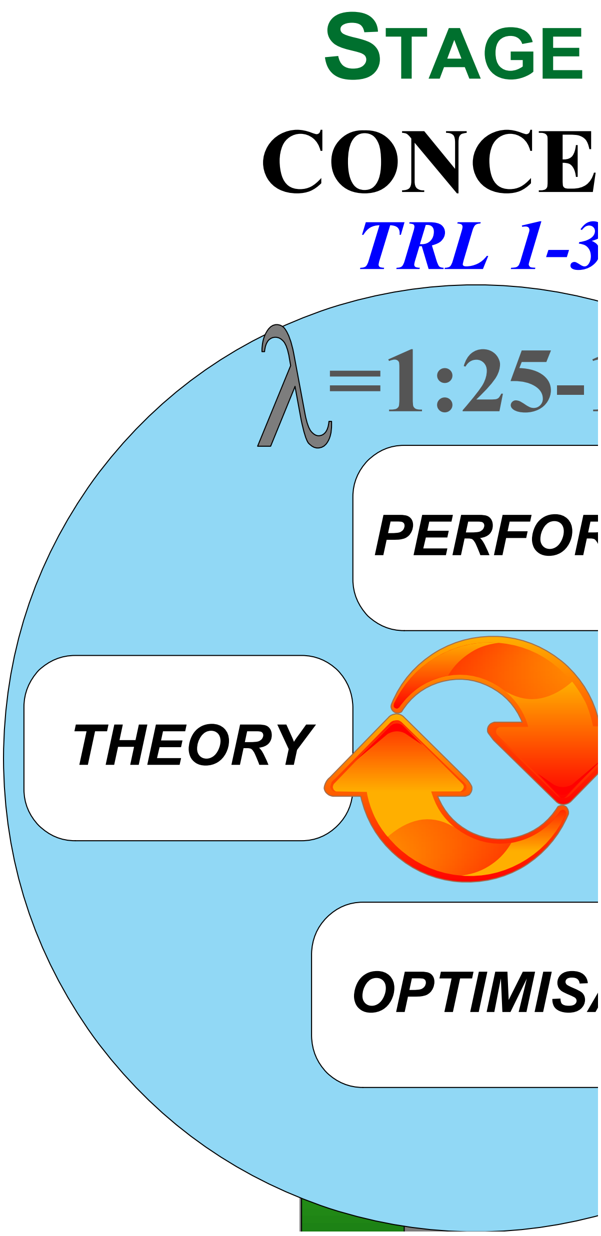


Figure 2 Five stage development schedule (IEA, 2009)

When a device successfully completes the rigorous technical sea trials outlined in the previous stages, the solo pre-production converter should have evolved into a pre-commercial machine ready for economic demonstration in Stage 5. The purpose of this stage is to test small groups of wave energy devices that, if successful, can be expanded into a full electricity generating station. During this stage the power electronics controlling the output and the physical influence of one machine on another will be determined.

4.1.2 Support infrastructure

To enable developers to follow the development schedule approach outlined above, it is essential that funding mechanisms are included in national support policies for wave energy development. The test programme applied at each stage is important but, of equal value, is the Stage Gate decision procedure that should be implemented at the end of each test programme before progression to the next level. While it is not simple or easy to elaborate robust benchmarks to compare devices, such a system is necessary if funds and time are to be invested in the devices offering the greatest potential of large scale deployment. This evaluation is particularly relevant to ocean energy, and in particular wave power, since the possibility of extracting the resource seems to have captured the minds of developers as well as the desires of Government officials.

Test centre infrastructure is crucial to support implementation of the five stage development schedule. In Europe this will be taken forward through the FP7-funded MaRINET project (Marine Renewables Infrastructure Network for Energy Technologies). The aim of this project is to coordinate research and development at all scales (small models through to prototype scales from laboratory through to open sea tests) and to allow access for researchers and developers to facilities which are not available universally in Europe. The linking together of facilities at different scales together with the incorporation of test facilities for components such as power take-off systems, grid integration, moorings, environmental effects, will ensure a focussing of activities in this area.

If these establishments expand with supply and support services, as expected, it would be advisable that the necessary sea trials be conducted at one of these established Centres to reduce the challenges facing heavy engineering operations at sea. As well as alleviating permitting, licensing and singular environmental impact assessment issues the sites should offer easier grid connection that includes performance monitoring instrumentation.

The SOWFIA project will take advantage of the test centres to advance the project objectives. Specifically data from the test centres will increase our understanding of the functioning and environmental impacts of various wave energy devices, thereby informing the development of recommendations for the streamlining of approval process and European-wide streamlining of impact assessment processes. This, in turn, will help to remove legal, environmental and socio-economic barriers to the development of power generation from waves. The next section outlines the test centres that are currently operating and which may help facilitate wider adoption of the five stage development schedule approach.

4.2 Wave energy test centres, pilot zones and commercial projects

This section presents a brief overview of the test centres that are currently operational. Figure 3 shows the distribution of these across Europe. The centres are colour coded according to scale. This is accompanied by more detailed information on each centre in Annex 1.

Test centres can accommodate large scale and/or full scale device testing. Some centres, for example, the European Marine Energy Centre (EMEC) in Orkney, have both nursery and full-scale device berthing facilities. Smaller scale demonstration-type sites are also included in this section.

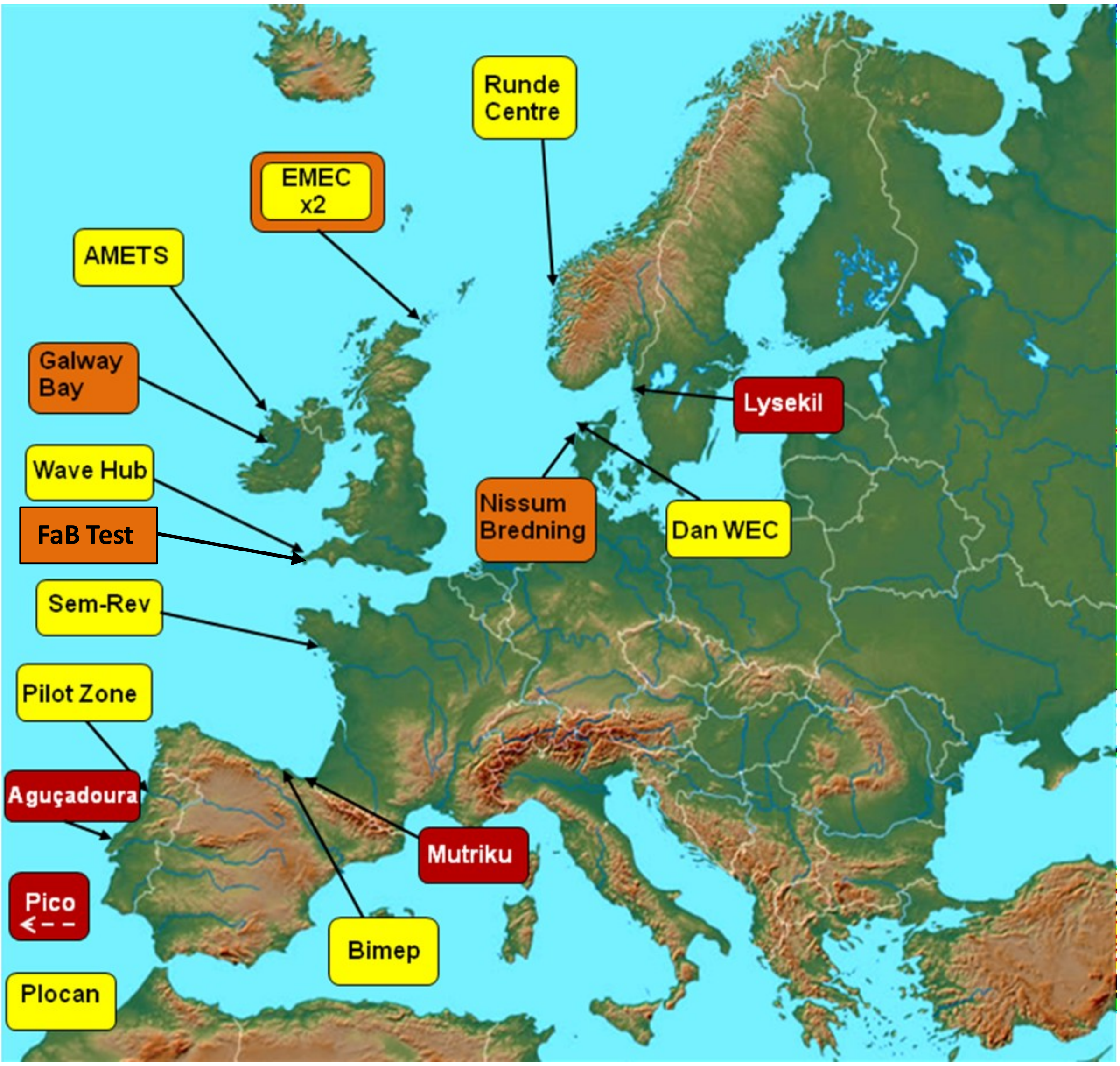


Figure 3 Location of the wave energy test centres and demonstration sites across Europe.

Table 8 European test centres and demonstration sites of various scales (Adapted from Waveplam, 2008)

Country	Location	Name	Est'd	Seabed Area	Water Depth	Energy Flux	Dist. to shore	Port/Harbour Distance	Stage	Grid Connection	Facilities	Devices
FULL SCALE TEST CENTRES												
Denmark	Roshage Pier, Hanstholm	DanWEC	2009	1 km^2	12m	5 kW/m	200m	Hanstholm, 1.5 km	3/4	Yes	Access Pier	Wave Star (in place) Dexawave (in place)
England	St. Ives Bay, Cornwall	WaveHub	2010	8 km^2	50m – 65m	~20kW/m	16 km	Plymouth, 160 km Falmouth, 100 km St. Ives, 9 km	4/5	Yes, 11kV at present, 33kV planned	Wave buoys 4 berths	OE Buoy (planned)
France	Le Croisic, Pays de la Loire	SEMREV	2007	1 km^2	35m	14.4 kW/m	15 km	Le Croisic, 18km	4/5	Yes, 20kV	Wave buoys 3 berths	
Ireland	Belmullet, Co. Mayo	Atlantic Marine Energy Test Site (AMETS)	In planning since 2009	Area A: 10.5km^2 Area B: 6.5km^2	50m – 120m	50 kW/m	7 km	Galway City, 190km Killybegs, 125 km	4/5	Yes, 10kV planned	Wave buoys, 4 berths planned	
Norway	Runde Island, Runde, west Norway	Runde Environmental Centre	2008		30-50m		500m	25 km SW of Aalesund	3/4	Yes, 22kV	Pier	Seabased (in place)
Portugal	Figueira da Foz	Portuguese Pilot Zone	2007	320 km^2	30m – 90m	32 kW/m	5-8 km	Leixoes, 148 km Peniche, 63 km Fig. da Foz, 37 km	4	Yes		

Country	Location	Name	Est'd	Seabed Area	Water Depth	Energy Flux	Dist. to shore	Port/Harbour Distance	Stage	Grid Connection	Facilities	Devices
Scotland 	Orkney	EMEC	2002	5 km^2	20m – 75m	22-25 kW/m	1-2 km	Stromness, 8 km Kirkwall, 23km Lyness, 20km	4	Yes, 11kV	Monitoring station, wave buoys substation 5 cable 1 pipeline connected berths	Pelamis (in place) Oyster (in place) Seatricity (planned) Wello Oy (in place)
Spain 	Armintza, Basque Country	BIMEP	Operational by 2013	5.3 km^2	50m – 90m	21 kW/m	1700 m	Bilbao, 10 km	4/5	Yes 13.2kV	Wave buoys 4 berths	
Spain 	Canary Islands	Canary Islands Oceanic Platform: Plocan	Operational by 2013	40km^2	30-1000m	8-10kW/m	2km	Las Palmas Port, 10km. Arigana Port 21km, Talibarte Port, 8km	3/5	Yes, 20kV	Wave buoys and wind turbines, 6 berrths	
LARGE SCALE TEST CENTRES												
Denmark 	Nissum Bredning	Danish Benign Test Site	2000		4-8m	Hs = 1.2m	200m	Thyboron, 7.5 km	3	Yes	Pier, monitoring station	Wave Dragon (completed) Wavestar (completed)
Ireland 	Spiddal, Co. Galway	Galway Bay	2006	0.37 km^2	21m - 24m	3 kW/m	2.4km	Killybegs, 300 km Foynes, 150 km Galway City, 15 km	3	No	Wave buoys	OE Buoy (completed) Wavebob (completed)
Scotland 	Orkney	EMEC - nursery	2011	0.36km^2	21-25m	Hs = 0.35m	~500m	Stromness, 8 km Kirkwall, 23km Lyness, 20km	3	Yes	Monitoring station, wave buoys substation	

Country	Location	Name	Est'd	Seabed Area	Water Depth	Energy Flux	Dist. to shore	Port/Harbour Distance	Stage	Grid Connection	Facilities	Devices
England	Falmouth Bay, Cornwall	FaB Test	2011	2km^2	20-50m	Unavailable	3-5km	Falmouth, 5km	3	No	3 berths	Fred Olsen BOLT Lifesaver (In place)
DEMONSTRATION SITE												
Portugal	Pico Is. Azores	Pico Test Plant	1999	--	~10m	13.4 kW/m	--	Peniche, 1600 km Horta, 16km	3/4	15kV Grid Connection	1 Substation	PICO OWC (in place)
Portugal	Aguçadoura	Aguçadoura Wave Farm	2007		40-50m	32 kW/m	5 km	Peniche, 240 km Leixoes, 32 km Monserrate, 25 km	5	Yes	Wave Buoys Substation 3 berths	Pelamis (Ended)
Portugal	Peniche	Peniche test site	2007	2km^2	15-20m	30 kW/m	0.5 km	Peniche	3/4	No	n/a	Waveroller (In place)
Spain	Basque country	Mutriku	2011	n/a	<10m	4.8 kW/m (summer) 18kW/m (winter)	onshore	Mutriku	3/4	296kW (16x18.5 kW)	n/a	Mutriku Multi-OWC (In place)
Sweden	Lysekil, near Gothenburg	Lysekil Wave Energy Research Site	2003	0.04km^2	25m	2.6± 0.3 kW/m	2km	Lysekil harbour 10 km		Yes, 10kV	n/a	Seabased (In place)

Denmark

Denmark has a medium-low wave energy resource, but they have one of the best wave energy programmes to develop the power extraction. There are two wave energy test centres installed in Denmark. The Danish Marine Test Site (DanWEC) situated in Hanstholm and the Nissum Bredning Test Station for Wave Energy (NBPB). Several Danish wave energy companies are pursuing their developments: *Wave Star A/S* prototype has been operating in the North Sea in Hanstholm since 2010. The *Dexawave* device has operated for 10 months in Nissum Bredning and is now operating at DanWEC, Hanstholm.

France

France has 3,247 km of coastline and a resource of 420 TWh of wave energy along the Atlantic coast. In 2008, the French Government began investing in the development of a wave energy test centre under the name of SEM-REV (*Site d' Expérimentation en Mer pour la Récupération de l'Energie des Vagues*). This site occupies approximately a 1km^2 test zone area and is fully instrumented and monitored. The test site comprises a 2.5 MVA power cable connected to the national grid through an onshore substation. A new substation will be built on land and will be the connection point to the 20 kV local electricity distribution grid which is connected to the national Electricity Transport Network through an existing substation (Mouslim *et al*., 2009). Several wave energy devices have been under development in France in the last decade. However none of these have yet been tested at full scale in open sea conditions. A national call for tenders was launched in 2010 by the French Energy Development Agency 'ADEME' and this programme will fund the first full scale marine renewable energy prototypes in France including wave energy devices.

Ireland

The west coast of Ireland is recognised as having one of the highest levels of wave power in Europe, reaching up to 76 kW/m. As part of Ireland's Ocean Energy Strategy the Government established the Ocean Energy Development Unit (OEDU) in the Sustainable Energy Authority of Ireland, the State's national energy agency. The OEDU is tasked with coordinating the relevant activities of State agencies and initiating other measures to promote and develop the ocean energy sector. Initially this concentrated on providing support to industry, enhancing research facilities, creating wave and tidal test facilities, supporting reform of the planning and consenting regime and grid development. The OEDU also operate a Prototype Development Fund aimed at stimulating the development and deployment of ocean energy devices and systems.

Ireland has two wave energy test sites. The first of these, located in Galway Bay on Ireland's west coast, was licensed for operation in March 2006. The site is 37 hectares in area, in waters 21-24 metres deep and therefore suitable for the testing of 1/3-1/5 scale devices. To date, two devices have been tested in the site: Wavebob and Ocean Energy's *Seileán* device. The latter most recently concluded a test programme at Galway Bay in 2011 as part of the EU FP7 CORES project.

More recently the creation of a second, full-scale grid-connected test centre was announced. This is known as the Atlantic Marine Energy Test Site (AMETS) and will be located off Annagh Head, in Belmullet, Co. Mayo, also on Ireland's west coast. The purpose of this test site is to provide a location for the temporary mooring and deployment of wave energy devices so that their performance in generating electricity and their survivability can be tested and demonstrated in open ocean conditions. It is proposed for the site to operate for up to 20 years with devices on site intermittently throughout the year. An Environmental Impact Statement (EIS) has been published for the site and a foreshore lease has been applied for. The decision on the foreshore lease will be made in 2012. If the foreshore lease application is successful, the next step in the project will be the installation of cables to connect the test site to the grid. It is hoped that AMETS will be ready for the first full scale wave energy converters in 2014.

Norway

Norway has no special policies or programmes dedicated to ocean energy, but ocean energy is included in more general renewable energy policies and programmes.

Runde Island is the primary wave energy test centre in Norway. The island is the southernmost bird cliff in Norway and designated for conservation purposes. The island is located in a highly productive area with the main spawning grounds for many important North-east Atlantic fish populations occurring in the vicinity.

The FP7 Seewec project is built up around the Fred Olsen FO³, a floating wave energy converter, intended for installation in the near shore environment. The basic concept of the FO³ device consists of several (12 or 21) point absorbers placed under a floating platform. Following sea trials off the southern coast of Norway, the results showed that it was worthwhile to pursue an alternative concept, based on a single point absorber moored directly to the seabed rather than attached to a platform.

Portugal

The Portuguese Government demonstrated its commitment to the development of wave energy through the creation of a dedicated wave energy pilot zone in 2008. The main objective of the pilot zone is to simplify licensing and permitting procedures by allocating these responsibilities to a dedicated Management Body thereby creating a 'one stop shop'. Other objectives of the zone are to attract demonstration and industrial development to Portugal, to create a competitive national cluster supported by R&D and innovation activities and to increase Portugal's renewable energy production. The Pilot Zone covers an area of 320km² located between the 30m and 90m isobaths. The total capacity is 80 MW (medium voltage) and 250 MW (high voltage). The zone can accommodate three types of projects: demonstration (up to 4 MW); pre-commercial (up to 20 MW) and commercial (> 20 MW).

Elsewhere in the Açores, the Pico OWC was built in 1999 and has fed increasing amounts of electricity into the electrical grid, yielding more than 850 operational hours in 2010 (IEA-OES, 2010). The plant is designed to host a second turbo-generation group, which will be facilitated through the European-funded MariNET project on infrastructures.

The technologies tested in Portugal to date have been Pelamis and Waveroller and the Wells turbine in Pico.

Spain

The higher resource levels of wave energy are situated along the north west Spanish coast. Spain is beginning to develop wave energy projects by installing demonstration scale devices. It is expected that commercial scale wave energy will be reached by 2016. Until December

2011, the fixed tariff for wave energy was lower than for hydro or wind energy (7.44c€/kWh). There was, however, the possibility to request a specific tariff for each project on a case-by-case basis. Since January 2012, there is no feed-in tariff for renewable energies but this is a temporary measure. If the feed-in tariffs' program is reopened it will concern those less developed technologies such as the marine energy ones.

The OceanLider R&D project was launched at the end of 2009, funded by the Ministry of Science and Innovation. This €30M project is led by "Iberdrola Ingeniería y Construcción" and covers resource assessment, O&M, technology, grid connection and environmental aspects. The project has duration of 40 months and 20 industrial partners and 24 research centres are participating (IEA-OES, 2010).

Several other wave energy projects continue to progress including the Biscay Marine Energy Platform (Bimep) which is expected to be operational in 2013. The Mutriku OWC breakwater was connected to the grid in May 2011, while the "PIPO" wave energy converter on the PLOCAN's test site in Gran Canaria is also progressing. In Cantabria, the first OPT's Powerbuoy of 40 kW was installed at sea, in September 2008. It has since been removed to incorporate some technical improvements (IEA-OES, 2009).

At a national scale, R&D investment is best represented by the PSE-MAR, a strategic research project funded by the Ministry of Science and Innovation (MICINN). This aims at developing three different wave energy converting technologies, a test and demonstration site and guidance on non-technical issues. This project is comprised of three developers (HIDROFLOT, PIPO Systems and OCEANTEC), industrial companies, R&D centres and universities (IEA-OES, 2009).

Sweden

The Swedish Energy Agency is supporting the wave energy development in Sweden through grant aid and a favourable feed-in-tariff for renewables. The wave energy demonstration project at Lysekil has been running since 2003 and is still continuing. The current permit expires at the end of 2013. A new application for prolonged and extended consent is ongoing. The work is led by Uppsala University, who are also partners in the WESA project, which involves testing a wave energy converter in the Baltic Sea, outside of Hammarudda in Finland. This project was launched in 2012.

United Kingdom

In February 2011, the UK Department of Energy and Climate Change (DECC) published a Strategic Environmental Assessment (SEA) to enable future leasing for offshore wind, wave and tidal devices and licensing/leasing for oil and gas rounds, hydrocarbon and carbon dioxide gas storage. A leasing round for the first commercial wave and tidal leasing round in ten sites in Scotland's Pentland Firth and Orkney waters was held in March 2010. Developers have proposed to have 1.2 GW of installed capacity by 2020. In March 2010, the Crown Estate announced the launch of the Northern Ireland Offshore Renewable Energy Leasing Round. There will be a short industry consultation process starting on 1st April to help shape the Leasing Rounds offered in September 2011, with the potential for development rights to be awarded as soon as Spring 2012. It should be noted that this leasing round applies to offshore wind and tidal only and not wave, given the limited resource around Northern Ireland.

In terms of test centres, in Scotland, the European Marine Energy Centre (EMEC) continues to expand in Orkney with three additional grid-connected berths (2 tidal, 1 wave) and two nursery sites, one for wave and one for tidal, each with two berths, (IEA-OES, 2010). Currently, a number of devices are deployed there namely Aquamarine's Oyster 1, two Pelamis devices and Wello Oy's Penguin. Seatricity are currently preparing to deploy there.

In England, the WaveHub, marine energy project continues to develop. It is located 16 kilometres offshore and is grid-connected by a socket on the seabed off the coast of Cornwall in the south west of England. WaveHub is comprised of four berths each covering two square kilometres. It has an initial maximum capacity of 20 MW but has been designed with the potential to scale up to 50 MW in the future (IEA-OES, 2010).

The Falmouth Bay Test Site (FaB Test) was established in 2011 and is a nursery facility for testing wave energy devices, components and deployment procedures. It is envisaged that it will be a stepping stone for those looking to deploy at Wave Hub. Fred Olsen's BOLT Lifesaver wave energy device was the first to be deployed there in April 2012.

4.3 Analysis

As can be seen from the entries in the Annex there are many different types of wave energy converters in the process of development. At this nascent stage of the industry no single device, or generic type, has proven to be superior to others, indeed there is no reason to believe only a single design will prove successful and it is likely that several different units will suit the various deployment zones that can be exploited. In general these wave farm sites will be:

- On-shore: the structure is in contact with the coastline (typical water depth <10m);
- In-shore: water is too shallow for safe moorings so bottom standing devices are under development (typical water depth between 10m & 25m); and
- Near-shore: water depth is sufficient for safe mooring and too deep for static, bottom standing units (typical water depth between 25m & 100m).

Note the zone boundaries will not be sharp and some devices may defy theses rules. For example, a physically small and limited rated capacity moored device may be moored in intermediate depth water whilst a multiple unit cluster of devices mounted on a single platform may be located in deeper near-shore waters.

Besides the primary converter alternatives, the secondary energy converter, the power take-off sub-system (PTO), also offers a limited number of options from which no preferred type has so far emerged. For example, a twin hull opposing motion hydrodynamic sub-system could be fitted with a hydraulic PTO or a direct drive generator. Again, as can be seen in the Annex data, device developers are pursuing all types at this time.

To assist in the appreciation of the various device combinations, and develop a picture of the technical trends that are establishing for wave energy device design, the Annex data was analysed against several variable base options and are presented in the following graphs.

Figure 4 shows the interest and commitment of EU Member States in the prospects for wave energy contributing to their electricity generation portfolios. The histogram on the left shows the number of devices being developed at the sea trials stage, or in planning. The plot to the right shows how these devices translate into the installed capacity per country.

As can be seen most coastal States have some involvement in ocean energy but the national distributions also offers insight into the support mechanisms these countries are offering. It should be noted that the DGTREN-supported wave energy demonstration projects are included in theses figures against the country the project is to be established in. It should also be noted that it is unlikely that all of these proposed sea trials will take place and, of those that do, not all will pass the completion stage gate criteria.

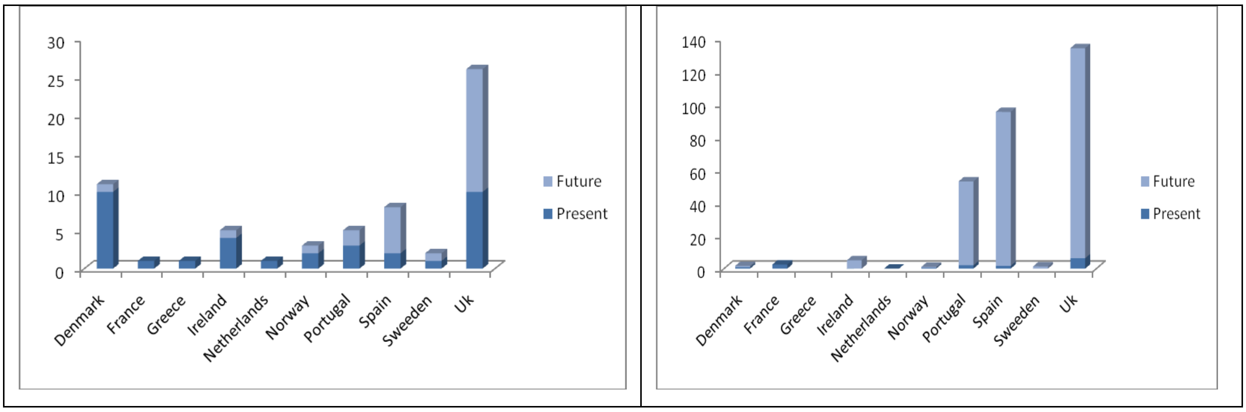


Figure 4 Number of devices deployed (left) and installed capacity (right) in each European state, at present and planned derived from information in the Annex

Figure 5 shows how the power take-off sub-system trend is developing. To some degree the type of primary mover skews these results in that air turbines will, in most cases, be unique to pneumatic devices, such as oscillating water column devices (OWCs). However, the interest in linear generators for translatory reciprocating devices can be seen.

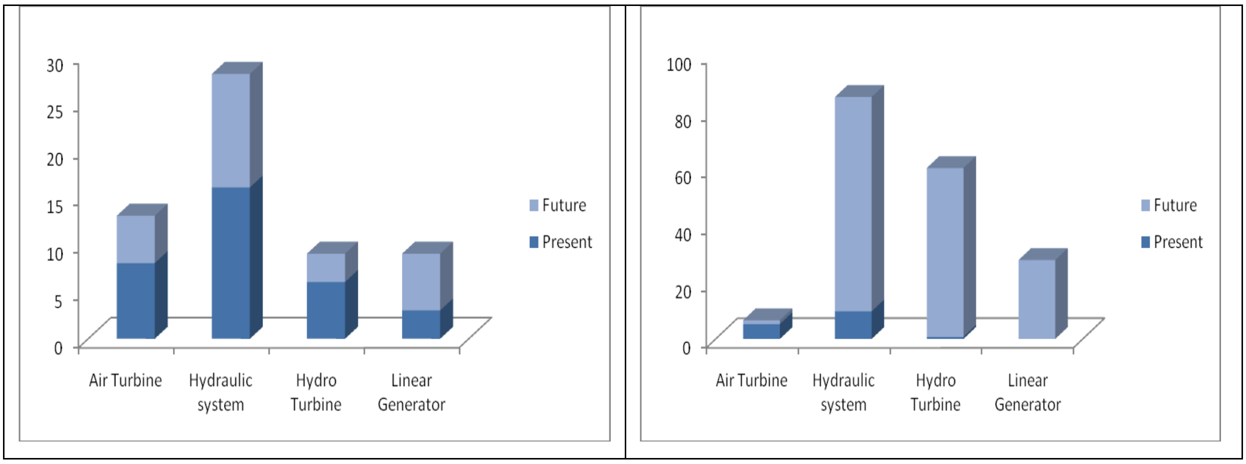


Figure 5 Number of projects by power take-off system (PTO) (left) and installed capacity (MW) (right) derived from information in the Annex

Figure 6 shows the mix of development project by deployment site as described above. The trend towards buoyant moored devices in the near-shore zone (25<depth<100m) is very clear for most countries. This move to the deeper waters is necessary if wave energy is to become a significant source of electricity supply in the multi-megawatt range. Devices designed for the in-shore, and particularly on-shore, zones have the potential for quality niche development projects and local supply potential. Small islands in particular may benefit from this type of energy supply development.

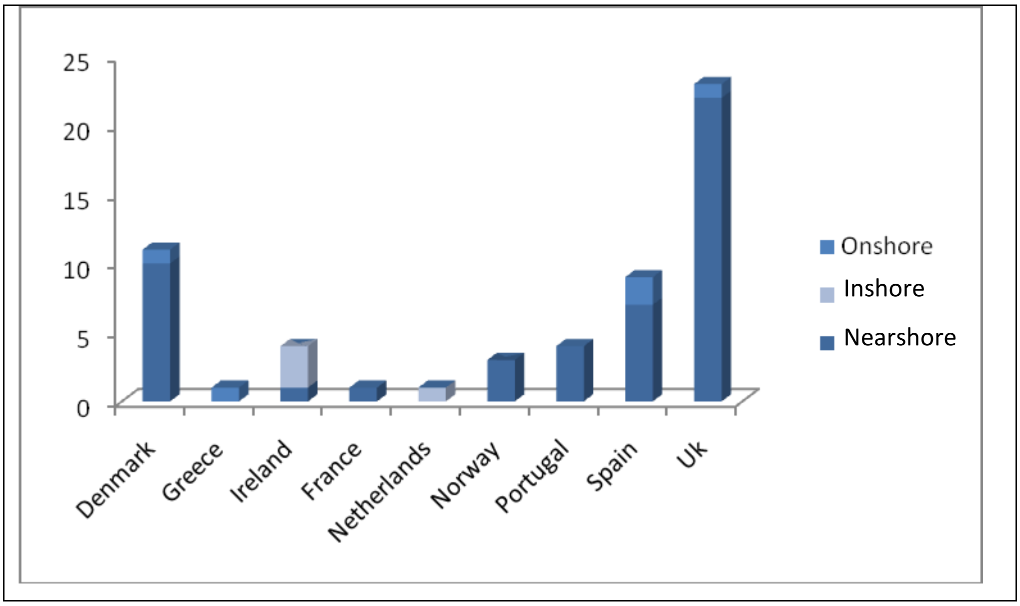


Figure 6 Number of wave energy projects in each European coastal State at various distances (km) from the shore, derived from information in the Annex

The final summary statistics in Figure 7 show how the sea trial projects have, and are continuing to, increase significantly. The ordinate unit is installed capacity (MW) so the move towards larger individual units is incorporated in the yearly trend.

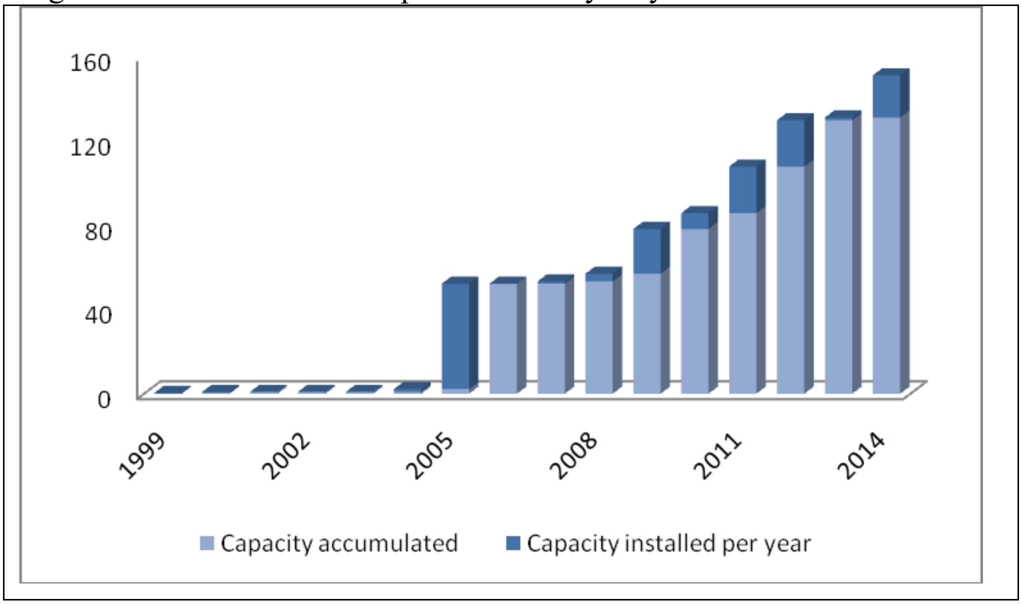


Figure 7 Installed capacity (MW) by year derived from information in the Annex

4.4 Conclusions

This study has presented and analysed the targets and forecasts for installed capacity of the Member States engaged in wave energy development together with the past, present and currently planned projects. This information leads to the following summary:

- It is expected that Europe will have a ocean energy installed capacity of 3.6 GW by 2020 that would avoid 2.61 Mt/yr of carbon dioxide emissions (EU-OEA, 2010);
- France, Ireland, Portugal, Spain and the United Kingdom have set ocean energy targets but none of these countries have separated what proportion will come from the wave resource and what will come from the tidal resource. The United Kingdom has the highest target, of between 1300 and 2000 MW by 2020. Within the United Kingdom, Scotland has the most ambitious objective of achieving 1300 MW by 2020 (Freds, 2009);
- From the calculations in this document, based on the Pelamis example, between 95 and 470 wave energy farms of 20 MW each, depending on energy density, would be required to supply the energy necessary to reach the ambitious European targets by 2020. This equates to a marine spatial area requirement of between 68 and 338km^2.
- Currently there are 16 Wave Energy Test Centres in Europe with varying numbers of operational devices. Alongside this there are a number of *ad hoc* projects progressing outside of the established wave energy test centres.

Projects developed to date have focused on testing and improving the technical aspects of specific devices. It is anticipated that when commercial projects begin, sea trials to improve other device technologies will continue.

Exchange of lessons learned by the pioneering wave energy device development companies are a mechanism that has been promoted and advocated by some Member States as a necessary mechanism to reach targets by the proposed timeline. This mantra was a prime consideration in the EU FP6 project, EquiMar, and will be continued in the SOWFIA project to help overcome permitting, licensing and environmental issues by facilitating exchange of information between project developers and other target audiences. The SOWFIA project's first workshop, to be held in Autumn 2011, will encourage such an exchange of experiences amongst project developers and other industry stakeholders, paving the way for more efficient, streamlined planning and development of wave energy in Europe.

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6 Wave Energy Test Centres Annex

This annex presents the devices under sea trials or planned for testing at wave energy test centres or other *ad hoc* sites around Europe. The Annex is divided into three sections, full scale test centre, large scale test centres and demonstration sites. Important information relating to the sites is given in tables along with information on any projects that are either proposed, planned, in place, completed or were ended prematurely at the sites.

In some cases, all the information relating to the test sites was not found or is not available. Where this is the case, 'Not available' is included in the table.

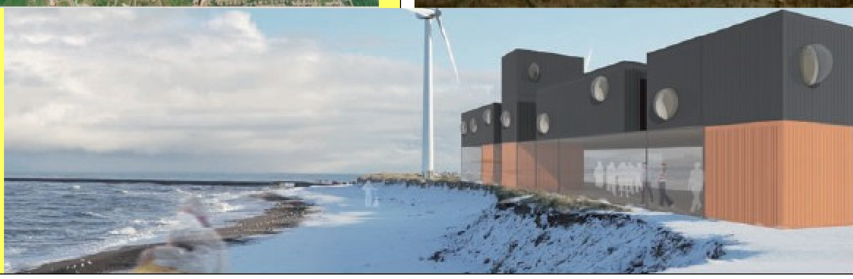
A number of the test centres are partners in the EU FP7 MARINET project. This project is running from 2011 to 2015 and involves test centres offering periods of free access to their facilities to companies, research groups etc. Test centres providing access as part of MARINET are mentioned in the Annex.

6.1 Full-scale test centres

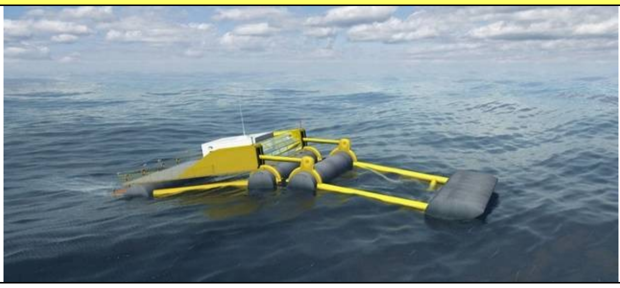
DanWEC, Denmark

The Danish Marine Test Site (DanWEC) is located in Hanstholm, in the north-west of Denmark in the North Sea. It has a fetch of about 600km to the west, sheltered by the UK. The site is grid connected. To date, the devices which have been tested at DanWEC are Wave Star and Dexawave.

Location: Hanstholm, NW part of Denmark	
Name	DanWEC: Danish Marine Test Site
Date	Established in 2009
Device scale	Prototype scale
Distance to shore	200m
Area (m^2)	1 km^2
Depth (m)	12 m
Wave resource	~5kW/m average
Grid connection	Yes
Total power level (MW)	Not available
Number of berths	Not available
Connection voltage (kV)	Not available
Costs	Unknown
Project promoter	Project owner: Port Forum of Hanstolm
Website	http://www.danwec.com/
MARINET Access	No



Name Device	Wave Star	Dexawave
Technology type	Vertical Oscillation	Oscillator
Power Take Off	Hydraulic PTO	Hydraulic PTO
Capacity Project	110kW	5kW
Project Status	In Place	In Place
Start date	2009	2009

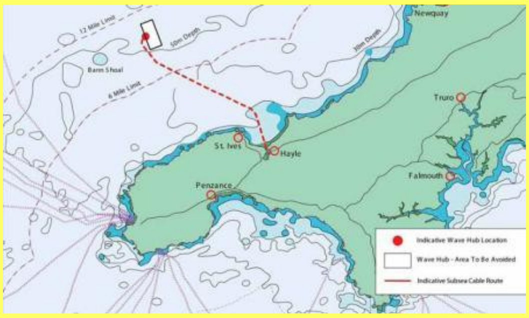
Wave Star	Dexawave
	

Wave Hub, England

Wave Hub is an offshore test centre in Cornwall, for the testing of wave energy devices. The area is 2km by 4km and has a mean depth of 55m. It provides facilities for the simultaneous testing of up to four different technologies with grid connections. Test berths (1km x 2km) are available to lease for a period of 5 years or more. The site will initially operate at 11kV and each developer will be allowed to generate a maximum of 4-5 MW of power (20 MW total capacity). This may be upgraded to 33 kV and 50MW in the future.

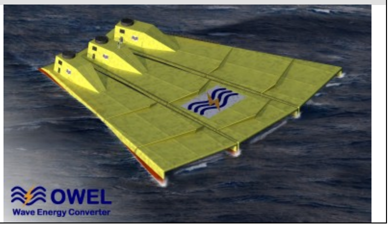
Wave Hub will collect data on incoming waves and purchase the electricity from developers testing there.

Location: St. Ives Bay, Hayle, Cornwall, UK	
Name	Wave Hub
Date	Open for business since November 2010.
Device scale	Prototype scale
Distance to shore	16 km
Area (m^2)	8 km2 (2km by 4km, 4 x 2km2 berths)
Depth (m)	50 - 65 m, 55m mean depth
Wave resource	~20kW/m
Grid connection	Yes
Total power level	Initially 16-20MW. Once grid connection operates at 33kV, the power level will increase to 50MW.
Number of berths	4
Connection voltage (kV)	The Wave Hub system will operate at 11 kV initially. Once subsea components for 33kV have been developed by industry, the Wave Hub system will be capable of operating at 33kV.
Costs	£42m
Project promoter	Wave Hub has been developed by the South West Regional Development Authority in England.
Website	http://www.wavehub.co.uk/
MARINET Access	No



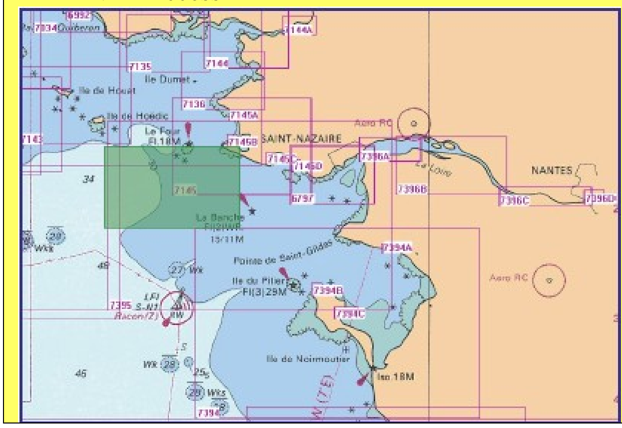
Name Device	OE Buoy
Technology type	Floating OWC
Power Take Off	Air Turbine
Capacity Project (MW)	1.5MW
Project Status	Planned
Start date	Deployment announced for late 2012

Name Device	OWEL
Technology type	Pulsed Air WEC
Power Take Off	Pneumatic
Capacity Project (MW)	0.35MW
Project Status	Planned
Start date	Currently in detailed design phase. Subject to raising suitable finance, the marine demonstrator will be deployed at Wave Hub in 2013



SEM-REV, France

The SEM-REV (*Site d' Expérimentation en Mer pour la Récupération de l'Energie des Vagues*) test site is being developed jointly by the Ecole Centrale de Nantes (ECN) and the French National Centre for Scientific Research (CNRS). The test centre is co-funded by the Pays de la Loire Region, the Loire-Atlantique department, the French Government and the European Regional Development Fund. It is still being developed and to date, no wave energy devices have been deployed there.

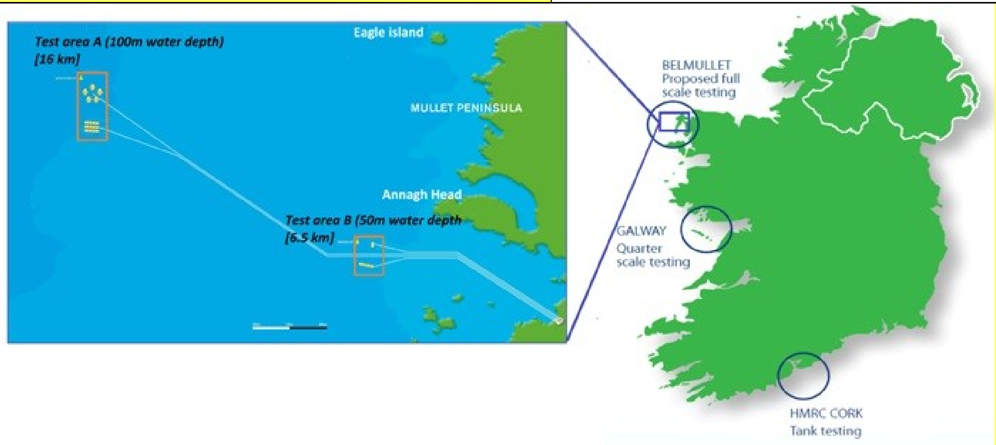
Location: Pays de la Loire, France	
Name	SEM-REV: Site d' Expérimentation en Mer pour la Récupération de l'Energie des Vagues
Date	In development since October 2007
Device scale	Prototype scale
Distance to shore	15 km
Area	1km^2
Depth	35 m
Wave resource	14.4 kW/m (23 year mean)
Grid connection	Under construction – Cable laying operation commenced in May 2012
Total power level (MW)	2.5 MW
Number of berths	4
Connection voltage (kV)	20 kV
Costs	€5.8 million (2008)
Project promoter	Ecole Centrale de Nantes
Website	http://www.semrev.fr/en/
MARINET Access	No
	

Atlantic Marine Energy Test Site (AMETS), Ireland

The Sustainable Energy Authority of Ireland is in the process of developing a national wave energy test site, to be known as the Atlantic Marine Energy Test Site, off Annagh Head, Belmullet, in the west of Ireland (Co. Mayo). This will provide a location for temporary mooring and deployment of full-scale wave energy devices. The purpose of the test site will be to test the performance of pre-commercial wave energy devices in extreme open ocean conditions.

It is expected that the site will operate for up to 20 years with devices on site intermittently throughout the year. The total capacity will be 10 MW. An Environmental Impact Statement (EIS) has been published for the site and a foreshore lease has been applied for. If the foreshore lease application is successful, the next step in the project will be the installation of cables to connect the test site to the grid. It is hoped that AMETS will be ready for the first full scale wave energy converters in 2014.

Location: Belmullet, Co Mayo, Ireland	
Name	Atlantic Marine Energy Test Site (AMETS)
Date	In planning since c. 2009
Device scale	Prototype Scale (Extreme open ocean conditions)
Distance to shore	Two test areas: Test Area A: 10.5km from shore (Cable: 16km) Test Area B: 6.5km from shore (Cable: 6.5km)
Area	Test Area A: 6.9km^2 Test Area B: 1.5km^2
Depth	Test Area A: 100m Test Area B: 50m
Wave resource	Test Area A: 70-75kW/m Test Area B: 55-60kW/m (Source: AMETS Environmental Impact Statement)
Grid connection	Grid connection planned. Application for government funding for grid connection will be made after foreshore license decision (~Sep’ 2012)
Total power level (MW)	10MW total
Number of berths	Test Area A: 2 Test Area B: 2
Connection voltage (kV)	10kV
Costs	Not available
Project promoter	SEAI and Marine Institute
Website	http://www.seai.ie/Renewables/Ocean_Energy/Belmullet_Wave_Energy_Test_Site/
MARINET Access	Yes



Runde Island, Norway

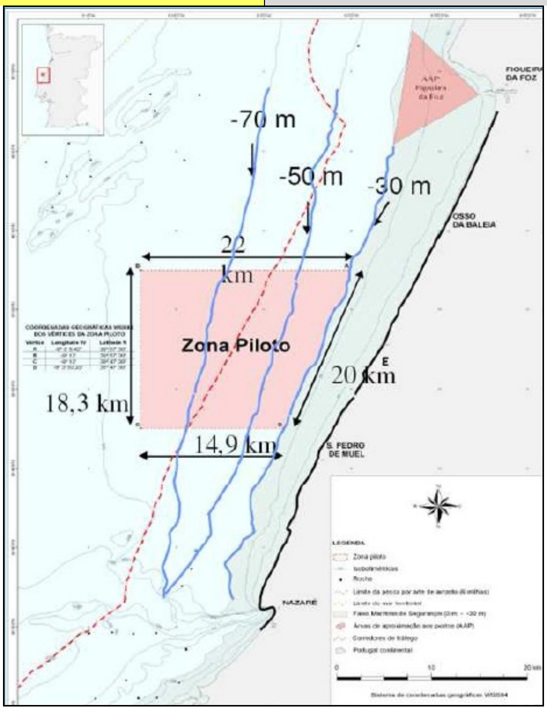
Runde Island is the location of the primary test centre in Norway and is situated on the west coast of the country. Runde Island itself is the southernmost bird cliff in Norway and designated for conservation purposes. It hosts the 'Storwave' wave power plant, which is a fixed, shore-based plant with a chamber for collecting the power. The Centre on Runde promotes the use of renewable energies, particularly ocean energy. Devices can be installed here for demonstration and education, and subsequently for harnessing power.

Location: Runde, Norway	
Name	Runde Environmental Centre and Marine Energy Test Centre
Date	Opened in June, 2009
Device scale	Prototype scale
Distance to shore	~500m
Area	Not available
Depth (m)	30 – 50m
Wave resource	Not available
Grid connection	Yes
Total power level (MW)	Not available
Number of berths	Not available
Connection voltage (kV)	22 kV
Costs	Not available
Project promoter	Runde Environmental Centre
Website	www.rundecentre.no
MARINET Access	No

Pilot Zone, Portugal

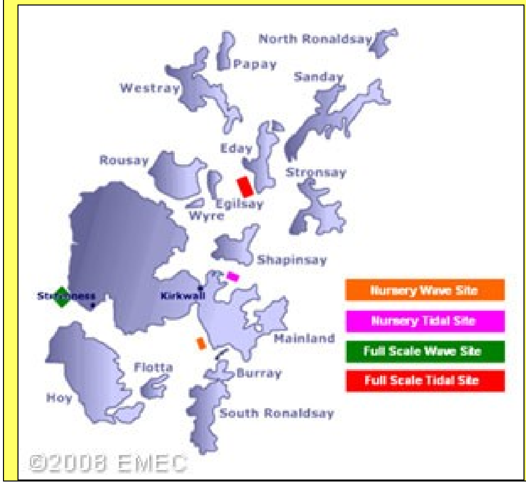
The Pilot Zone is located off the west coast of Portugal, about 130km north of Lisbon. The area test site is 320km^2 in waters between 30m to 90m. So far no wave energy devices have been installed there.

Location: North São Pedro de Moel, Portugal	
Name	Pilot Zone
Date	In planning since 2007
Device scale	Prototype scale
Distance to shore	5-8km.
Area (km^2)	320km^2
Depth (m)	30 - 90m
Wave resource	32kW/m (WERATLAS)
Grid connection	Planned
Total power level (MW)	1st phase 80 MW / 2nd phase 250 MW
Number of berths	Not available
Connection voltage (kV)	Not available
Costs	Not available
Project promoter	Not available
Website	-
MARINET Access	No



European Marine Energy Centre (EMEC), Scotland

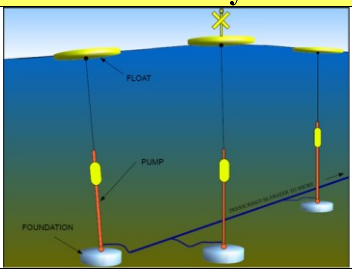
The European Marine Energy Centre (EMEC) on the Orkney Islands in Scotland is one of the first grid connected test sites within Europe and is the first one in the world to create a test base for tidal and wave energy devices. The substation for wave energy is located at Billia Croo. EMEC has 14 full scale test berths (wave and tidal) and two nursery test sites, one wave and one tidal.

Location: Orkney Island, Scotland	
Name	EMEC: European Marine Energy Centre (Billia Croo)
Date	Established in 2003
Device scale	Prototype scale
Distance to shore	5 deepwater berths: 1-2km from shore 2 shallow water berth: <1km from shore
Area	Deepwater berths: ~5 km^2total Shallow water berths: ~0.5km^2 total
Depth	Deepwater berths: 50 – 75m Shallow water berths: ~20m
Wave resource	22-25 kW/m
Grid connection	Yes
Total power level (MW)	Allowed output = 7MW
Number of berths	6 (5 cable connected, 1 pipeline connected)
Connection voltage	11 kV
Costs	Not available
Project promoter	
Website	www.emec.org.uk
MARINET Access	No (Nursery Sites are included)
	

Name Device	**Oyster**		**Pelamis**		**Wello Oy**	**Seatricity**
Technology type	Surge Flap		Attenuator		Rotating Mass	Multiple point absorber
Power Take Off	Hydro turbine		Hydraulic		Rotary	Hydro turbine
Capacity Project (kW)	315	800	750	1500(2 x 750kW)	500	1000
Project Status	Completed	In place (Plans to install further capacity)	Completed	In place	In place	Devices under construction
Start date	2009	2012	2004	2010	2012	2012

Oyster	**Pelamis**	**Wello Oy**
		

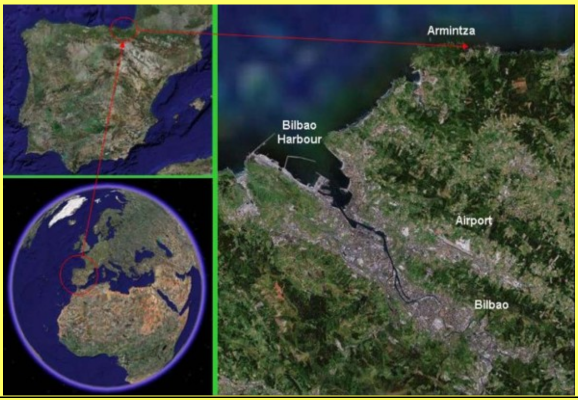
Seatricity

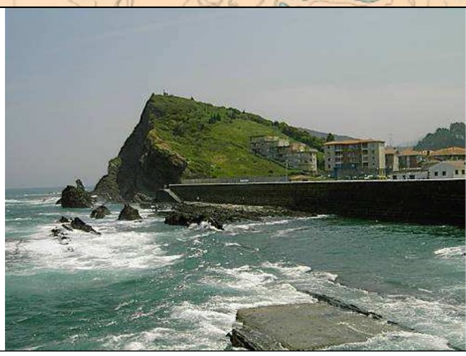


Biscay Marine Energy Platform (Bimep), Spain

The Biscay Marine Energy Platform (Bimep) test centre is being constructed off the coast of the village of Armintza in Northern Spain. It will be a test centre for real scale prototypes. There will be four connection berths for testing wave energy devices and offshore wind turbines. No devices have deployed there yet.

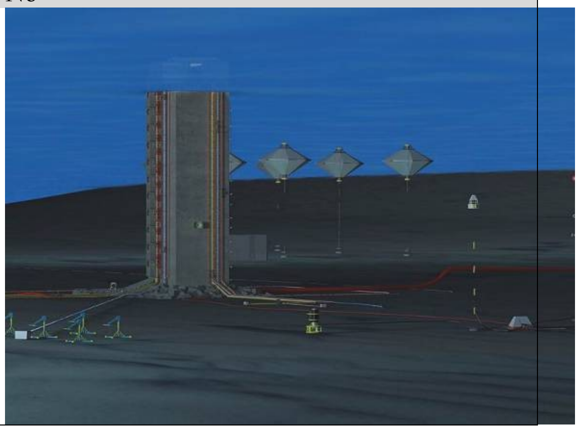
Location: Basque Country, Spain	
Name	Bimep: Biscay Marine Energy Platform
Date	Under development since 2009, expected completion date October 2013.
Device scale	Prototype scale
Distance to shore	1700 m
Area (km^2)	5.3 km^2
Depth (m)	50 to 90m
Wave resource	21 kW/m
Grid connection	Under Construction
Total power level (MW)	20 MW
Number of berths	4 (Each with 5MW power connection)
Connection voltage (kV)	4 x 13 kV connection cables to shore
Costs	€20M estimated
Project promoter	Ente Vasco de la Energia
Website	http://www.eve.es/energia_marina/index_cas.htm
MARINET Access	Yes



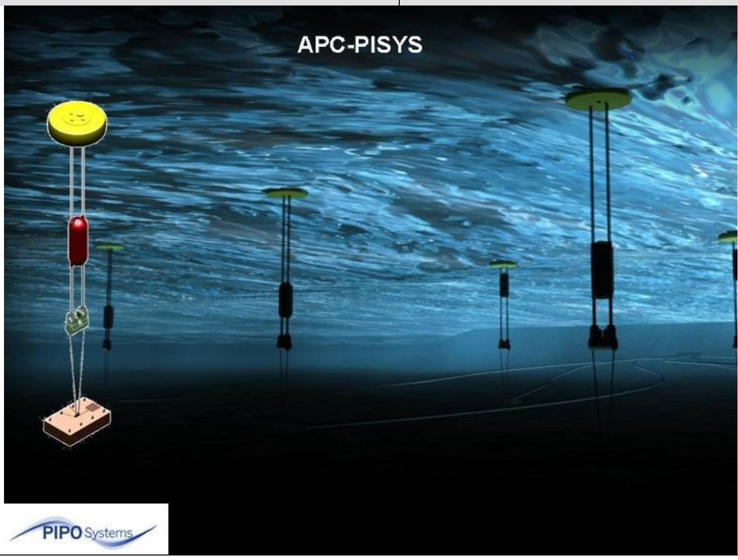


Plocan, Canary Islands, Spain

The Oceanic Platform, located in the Canary Islands, will be a test site for multiple marine renewable energy technologies, including wave and wind energy. It will be installed on the continental shelf boundary.

Location: Canary island, Spain	
Name	Plocan (Oceanic Platform of the Canary Islands)
Date	Created by 2011
Device scale	Prototype scale
Distance to shore	2000m
Area (m^2)	$40km^2$
Depth (m)	30-1000m
Wave resource	8-10kW/m
Grid connection	Existing substation on land
Total power level (MW)	15MW
Number of berths	6
Connection voltage (kV)	1 x 20kV and 5x0.5kV
Costs	€8m
Project promoter	PLOCAN
Website	http://www.plocan.eu/es/
MARINET Access	No
	

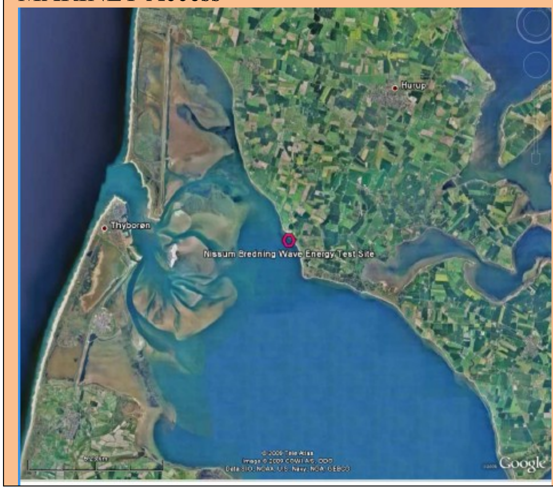
Name Device	APC-Pisys
Technology type	Vertical Oscillation
Power Take Off	Mechanical Transmission
Capacity Project (MW)	0.015
Project Status	Planned
Start date	2013



6.2 Large-scale test centres

Nissum Bredning, Denmark

The Nissum Bredning test centre is located in western Limfjord, not far from the Folkecenter in the north western Jutland peninsula of Denmark. It was built in 2000 at a site of medium wave energy to test technologies in their early stages. It is connected to the grid and can be accessed via a 150m bridge. Thirty wave energy devices have been tested there for varying lengths of time between 1/10 and 1/4 scale.

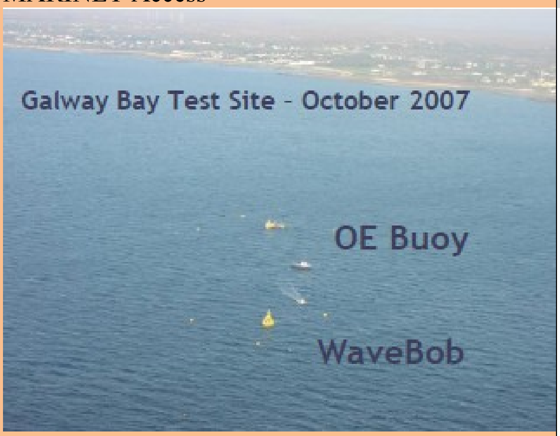
Location: Nissum Bredning, Denmark	
Name	Nissum Bredning Test Station for Wave Energy
Date	Established in 2000
Device scale	Sub-prototype scale (~1/4 – 1/10)
Distance to shore	200m
Area (m^2)	Not available
Depth (m)	4-8m
Wave resource	H_s 1.2m
Grid connection	Yes
Total power level (MW)	0.5 MW
Number of berths	Not available
Connection voltage (kV)	Not available
Costs	Initial grant of over €5 million from Danish Energy Agency
Project promoter	Nordic Folkecenter for Renewable Energy
Website	http://www.folkecenter.net/gb/rd/wave-energy/
MARINET Access	Yes
	

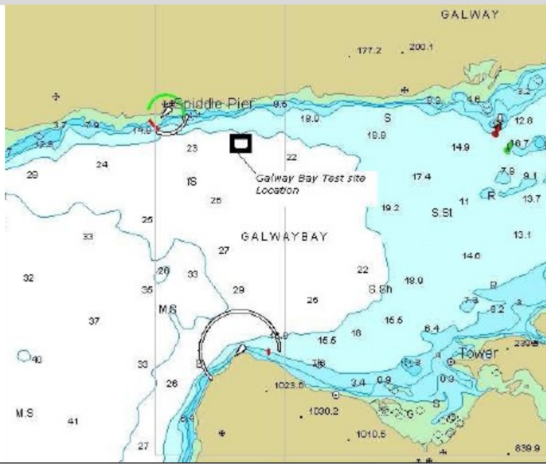
Name Device	**Wave Dragon**		**Wave Star**	**Dexa Wave**
Technology type	Overtopping		Vertical Oscillation	Attenuator
Power Take Off	Hydro Turbine		Hydraulic PTO	Hydraulic PTO
Capacity Project (kW)	20	20	5.5	Not available
Project Status	Completed	Completed	Completed	Completed
Start date	2003	2006	2006	2008
				

Galway Bay, Ireland

The Galway Bay Wave Energy Test Site is a sub-prototype scale, non-grid connected test site, located 2.4km from Spiddal in Galway Bay, Co. Galway, Ireland. The wave conditions at the site give a good representation at one quarter scale of combinations of height and period for exposed north western Atlantic conditions. It can accommodate prototypes of scales 1:3 to 1:5. Two developers have used the test site to date, both on a number of occasions, namely Ocean Energy Ltd and Wavebob. Most recently Ocean Energy Ltd. deployed their device, the OE buoy, for three months as part of the EU FP7 CORES project in 2011.

Location: Spiddal, Co. Galway, Ireland	
Name	Galway Bay Wave Energy Test Site
Date	Established in 2006
Device scale	Sub-prototype scale (c. 1:3 – 1:5)
Distance to shore	2.4 km
Area	0.37 km^2
Depth (m)	21-24m
Wave resource	3 kW/m
Grid connected	No
Total power level (MW)	n/a
Number of berths	2
Connection voltage (kV)	n/a
Costs	Not available
Project promoter	SEAI and Marine Institute
Website	http://www.marine.ie/home/aboutus/organisationstaff/researchfacilities/Ocean+Energy+Test+Site.htm
MARINET Access	Yes

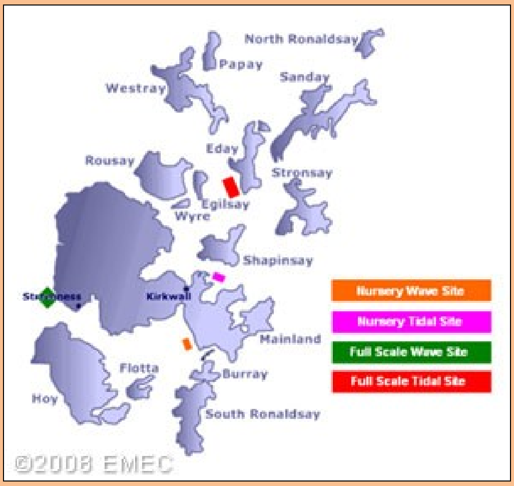




Name Device	OE Buoy			Wavebob	
Technology type	Oscillating Water Column			Vertical Oscillation	
Power Take Off	Air Turbine			Hydraulic PTO	
Capacity Project (MW)	20kW			15kW	
Project Status	Completed (2007)	Completed (2009)	Completed (2011)	Completed (2007)	Completed (2008)
Start date	2006	2007	2011	2006	2007
					

European Marine Energy Centre (EMEC), Scotland

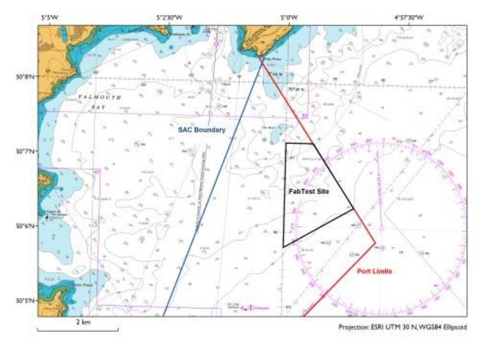
The European Marine Energy Centre (EMEC) on the Orkney Islands in Scotland also hosts two nursery sites for both wave and tidal devices. These were opened for operation in 2011, to allow small scale devices to undergo sea trials in more benign wave conditions. The wave nursery site is located at Scapa Flow off St. Mary's Bay.

Location: Scapa Flow, Orkney Island, Scotland	
Name	EMEC: European Marine Energy Centre (Scapa Flow)
Date	Opened for operation in 2011
Device scale	Sub-prototype scale devices (c. 1/10)
Distance to shore	Approximately 500m
Area	0.36km^2 (0.4km x 0.9km)
Depth	21-25m
Wave resource	Significant wave height of around 0.35m
Grid connection	Yes
Total power level (kW)	Measurement and dissipation of peak load of 75KW
Number of berths	1
Connection voltage	11kV
Costs	Not available
Project promoter	
Website	www.emec.org.uk
MARINET Access	Yes
	

FaB Test, England

Falmouth Bay test site is a nursery facility for wave energy devices, components and deployment procedures to be tested. The sea conditions are more benign and the site closer to shore than Wave Hub and it is being advertised as a stepping stone for those looking to deploy at Wave Hub. Fred Olsen's BOLT Lifesaver wave energy device was the first to be deployed there in April 2012.

Location: Falmouth Bay, Cornwall, England	
Name	FaB Test (Falmouth Bay Test Site)
Date	Started development in 2011
Device scale	Sub-prototype
Distance to shore	3-5km
Area	2km^2
Depth	20-50m
Wave resource	Not available
Grid connection	No
Total power level (kW)	n/a
Number of berths	3
Connection voltage	n/a
Costs	Unknown
Project promoter	Falmouth Harbour Commissioners
Website	-
MARINET Access	No



Name Device	**Fred Olsen BOLT Lifesaver**
Technology type	Point Absorber
Power Take Off	All electric power conversion
Capacity Project (kW)	240kW
Project Status	In Place
Start date	2012

6.3 Demonstration sites

Pico OWC, Portugal

The island of Pico in the Azores has been a European demonstration site since 1999. A fixed OWC was built on the shoreline there in order to demonstrate the technical viability of wave energy on a small island grid. Today the plant continues to be tested and belongs to the Portuguese Wave Energy Centre (WavEC).

Location: Pico, Azores Island, Portugal	
Name	OWC Pico Power Plant
Date	Construction started in 1999 and after several interruptions testing started in 2005.
Device scale	Prototype scale
Distance to shore	Onshore
Area (m^2)	n/a
Depth (m)	Approximately 10m depth in front of plant
Wave resource	13.4 kW/m annual average
Grid connection	Yes
Total power level (kW)	400
Number of berths	2
Connection voltage (kV)	15 kV
Costs	Design and construction (including R&D) approximately 5 M€
Project promoter	Wave Energy Centre (WavEC)
Website	www.pico-owc.net
MARINET Access	Yes

Name Device	**PICO OWC**
Technology type	Oscillating Water Column
Power Take Off	Air Turbine (Wells turbine)
Capacity Project (kW)	0.4
Project Status	In Place
Start date	1999

Aguçadoura, Portugal

Aguçadoura test site is an offshore test centre located near Póvoa de Varzim, north of Oporto, in Portugal. The first wave energy device to be tested at the site was the Archimedes Wave swing in 2004, which was deployed there for a number of months. In 2008, three Pelamis devices were deployed there and connected to the Portuguese grid in what was advertised as the world's first wave farm. This was shut down two months after the official opening of the farm. The site is presently being used for testing offshore wind turbines.

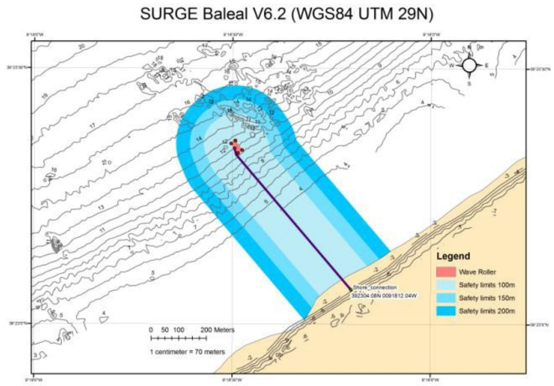
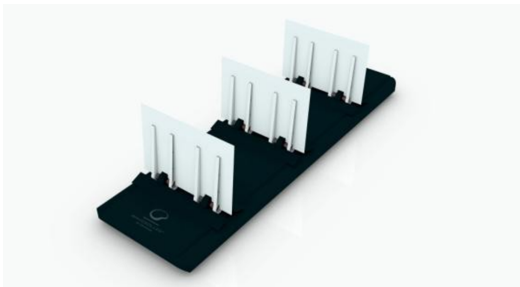
Location: Near Porto, in Portugal	
Name	Aguçadoura test site
Date	2007
Device scale	Prototype scale
Distance to shore	5km
Area (m^2)	Not available
Depth (m)	40-50 m
Wave resource	32 kW/m
Grid connection	Yes
Total power level (MW)	4 MW at present (future 20MW)
Number of berths	3
Connection voltage (kV)	15
Costs	Unknown
Project promoter	
Website	-
MARINET Access	No

Name Device	Pelamis
Technology type	Oscillator
Power Take Off	Hydraulic
Capacity Project (MW)	2.25 MW (3 x 0.75 MW)
Project Status	Ended
Start date	2008
	

Peniche Test Site, Portugal

Peniche, off of the coast of Portugal, is a location where AW Energy have chosen to deploy demonstration projects of their Wave Roller device. The first deployment was for a short duration in the spring of 2007. In August 2012, a 300kW Wave Roller device was installed there. AW Energy have recently been awarded funding for an NER 300 wave energy device array project in Peniche.

Location: Peniche, Portugal	
Name	Peniche test site (Waveroller technology)
Date	2007
Device scale	Prototype scale
Distance to shore	0.5km Offshore
Area (m^2)	2km^2
Depth (m)	15-20m
Wave resource	30 kW/m (WERATLAS)
Grid connection	No
Total power level (MW)	n/a
Number of berths	1
Connection voltage (kV)	n/a
Costs	Not available
Project promoter	
Website	-
MARINET Access	No

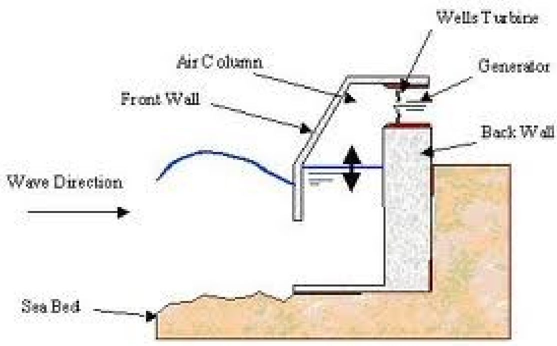
Name Device	**Waveroller**
Technology type	Nearshore (surge)
Power Take Off	Hydraulic
Capacity Project (kW)	300
Project Status	In place, awaiting commissioning (Aug' 2012)
Start date	August 2012
	

Mutriku, Spain

The Mutriku Oscillating Water Column plant is part of an EU-funded project promoted by the Basque energy board, Ente Vasco de Energia (EVE). It comprises of 16 OWCs integrated into a breakwater that was constructed by the local government in Mutriku Harbour. It has been operational since 2011.

Location: Basque Country, Spain	
Name	Mutriku
Date	Officially operational since 2011
Device scale	Prototype scale
Distance to shore	Onshore
Area (m^2)	n/a
Depth (m)	<10m
Wave resource	4.8kW/m in summer to 18kW/m in winter
Grid connection	Yes
Total power level (kW)	296 kW (16 x 18.5 kW)
Number of berths	n/a (Single power plant)
Connection voltage (kV)	13.2 kV
Costs	€6m
Project promoter	Ente Vasco de la Energía (EVE)
Website	www.eve.es
MARINET Access	Yes

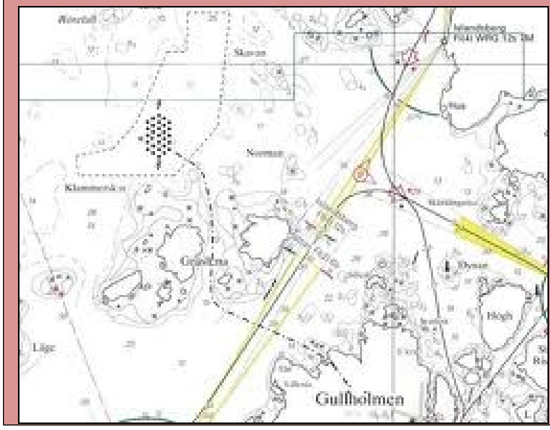
Name Device	**Mutriku Oscillating Water Column**
Technology type	Oscillating Water Column
Power Take Off	16 Wells air turbines
Capacity Project (kW)	296 kW
Project Status	In place
Start date	2011

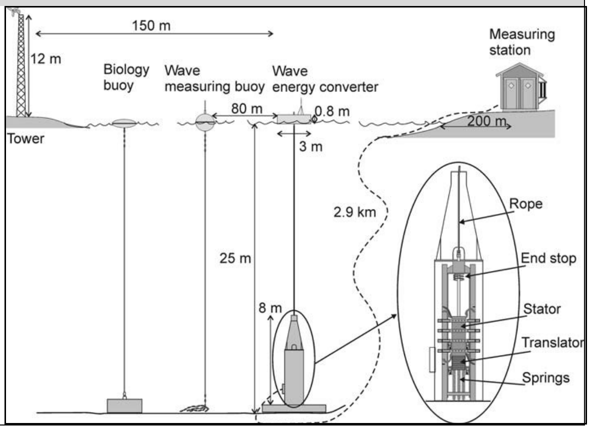


Lysekil, Sweden

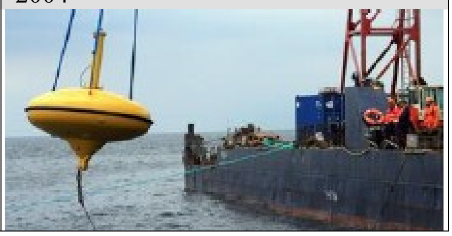
Lysekil Wave Energy Research Site has been developed by Uppsala University to a wave energy device concept in real sea conditions over a long duration. The site is situated to the north west of the city of Gothenburg, Sweden. A technical and biological research project is running there called the Lysekil project. The site can accommodate ten point absorbers, a maximum of ten linear generators, plus 2 sub-bottom substations and also a maximum of 30 environmental buoys for marine environmental studies. It started in 2003 and has permission to operate until 2014.

Location: North west of Gothenburg, Sweden	
Name	Lysekil Wave Energy Research Site
Date	Project started in 2004
Device scale	Prototype Scale
Distance to shore	2 km
Area	40,000 m^2
Depth (m)	25m
Wave resource	2.6 ± 0.3 kW/m
Grid connection	Yes
Total power level (MW)	Total 10MW total planned by end 2015
Number of berths	n/a
Connection voltage (kV)	10kV
Costs	Not available
Project promoter	Uppsala University
Website	http://www.el.angstrom.uu.se/forskningsprojekt/WavePower/Lysekilsprojektet_E.html
MARINET Access	No





Name Device	**Seabased**
Technology type	Vertical oscillation
Power Take Off	Linear generator
Capacity Project	100 kW (10 x 10kW)
Project Status	In Place
Start date	2004



6.4 Other demonstrations

Apart from the projects in test sites, there are other locations where devices are being tested or are planned for deployment. A selection of these projects is included below.

Denmark

Name Device	Leancon	Poseidon FPP
Technology type	OWC	Oscillator
Power Take Off	Air Turbine	Hydro Turbine
Location	Leancon	Onsevig
Capacity Project		0.14 MW
Project Status	In Place	In Place
Start date	2007	2009
		

Netherlands

Name Device	Wave Rotor (c-Energy)
Technology type	Vertical Oscillation
Power Take Off	Hydro Turbine
Location	Borssele
Capacity Project	0.035 MW
Project Status	Completed
Start date	2009

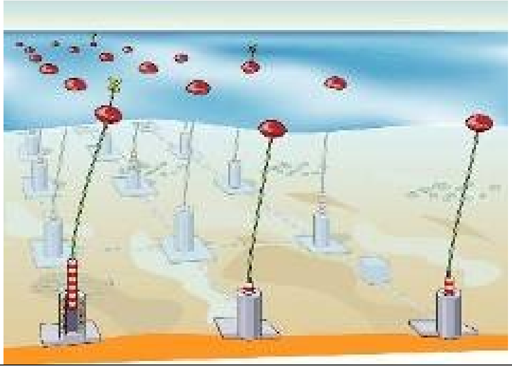
Spain

Name Device	Oceantec WEC	Ocean Power Technologies PB40	Ocean Power Technologies PB40 (WAVEPORT Project)
Technology type	Oscillator	Point Absorber	Point Absorber
Power Take Off	Hydraulic system	Hydraulic system	Hydraulic system
Location	Basque Country	Santoña	Santoña
Capacity Project	500kW	40 kW	40kW
Project Status	Proposed	Completed	Planned
Start date	2013+	2008	2012+

Oceantech WEC

OPT Powerbuoy

Sweden

Name Device	University of Uppsala / Seabased
Technology type	Vertical Oscillation
Power Take Off	Linear Generator
Location	Smögen, Sotenas
Capacity Project	10 x 20 kW
Project Status	Planned
Start date	2011 

UK

Name Device	Pelamis			Oyster
Technology type	Attenuator			Surge flap
Power Take Off	Hydraulic system			Hydro turbine
Location	Shetland	Bernera	Sutherland	North West Lewis
Capacity Project (MW)	10	10	15	40
Project Status	Proposed	Proposed	Proposed	Proposed
Start date	Not available	Not available	Not available	Not available
				

Name Device	Wavegen Wells Turbine	Ocean Power Technologies PB150
Technology type	OWC	Point absorber
Power Take Off	Air Turbine	Hydraulic
Location	Islay Limpet	33 nautical miles from Invergordon, Scotland
Capacity Project	500kW	150kW
Project Status	In Place	Completed (2011)
Start date	2000	2011
		

Portugal

Name Device	Wavebob (EU FP7 STANDPOINT PROJECT)
Technology type	Point Absorber
Power Take Off	Hydraulic
Location	Either Wave Energy Pilot Zone, near Nazare or
Capacity Project	1.5MW
Project Status	Planned
Start date	2012