ONE STEP FURTHER IN UNDERSTANDING

THE CAPITALISATION POTENTIAL FOR PORTS DURING THE DEVELOPMENT OF MARINE RENEWABLE ENERGY

May 2015

The Interreg IVB North Sea Region Programme
Investing in the future by working together for a sustainable and competitive region

BEPPo
Blue Energy Production in Ports

Port Oostende energy port

The contents of the publication reflects its authors' view and do not necessarily reflect the opinions of the institutions of the European Union.

This publication is partly financed by the European Regional Development Fund (ERDF) through the INTERREG IV B North Sea Region Transnational Programme.

ONE STEP FURTHER IN UNDERSTANDING

THE CAPITALISATION POTENTIAL FOR PORTS DURING THE DEVELOPMENT OF MARINE RENEWABLE ENERGY

Listing the main differences among three Marine Renewable Energies:
***off-shore wind, wave and tidal** from a ports perspective.*

AUTHORS

Lucia Margheritini,
Aalborg University

Agathe Rialland,
MARINTEK

Iver Bakken Sperstad,
SINTEF Energy Research

CONTENTS

DISCLAIMER 5

INTRODUCTION 6

UNDERSTANDING MARINE RENEWABLE ENERGY TECHNOLOGIES 8
Overview over wind, tidal and wave technologies 8
Sub-systems 8
Infrastructures 10
Life cycle phases of blue energy installations 12
Case studies 12
Manufacturing, installation, vessels and maintenance procedures 15

TRENDS AND PROSPECTS 18
Trends and technology maturity 18
Challenges and opportunities for funding and development 23

ROLE OF PORTS FOR MARINE RENEWABLE ENERGY 27
Ports functions 27
Port location 28
Service and Infrastructure requirements 28
Port readiness 29

CONCLUSIONS 31

APPENDIX 32
Tables from the case study 32
Projects from BEPPO screening 37
Wave energy projects 37
Wind energy projects 41
Tidal energy projects 42
Other marine renewable energy projects 43
SOURCES 46
AUTHORS 47
BEPPO MANAGEMENT TEAM 47
BEPPO LEAD PARTNER 47
PROJECT MANAGEMENT & COMMUNICATION SUPPORT 47

DISCLAIMER

Parts of this report on the work in WP3 of the BEPPo project – Capitalise on advanced research to foster the introduction & exploitation of innovative marine energy technologies / environments – is based on input from two workshops and meetings in the BEPPo project: 1) a fruitful discussion during and after the second partner meeting in Trondheim, Norway, 2014-07-01, and 2) presentations and discussion during an offshore renewable energy conference and B2B meeting at Gardermoen, Norway, 2014-10-20. Some of the statements herein reflect the statements made by the participants of these events. Whereas these participants are for the most part acknowledged renewable energy experts, it should still be noted that some of these statements are reproduced without references and support from independent sources. When no explicit reference is given, it should be understood that the source is presentations and discussions during one of these events. In addition comes comments and analyses made by the authors; such statements reflecting the authors' (expert) opinion are clearly marked as such. Other parts of the report based on the screening and case studies of relevant projects should be viewed in light of the relatively limited number of projects that was included within the scope of this work. The generality of the conclusions could benefit from more study of tidal energy projects, and for wave energy there is simply very few full-scale projects on which to base the conclusions.

Version	Main responsible	Comments
23/03/2015	Lucia Margheritini	Draft
01/04/2015	Iver Bakken Sperstad, Agathe Rialland	Additional input
04/05/2015	Lucia Margheritini, Iver Bakken Sperstad, Agathe Rialland	Final version

INTRODUCTION

The BEPPo (Blue Energy Production in Ports) project is concerned with Marine Renewable Energies (MRE), building on the innovation capacity of ports to become bases for the exploitation of such energy sources.

MRE includes marine biomass, offshore wind, ocean current, wave energy, tidal energy, salinity gradient and thermal gradient (OTEC), while Ocean Energy includes only the last four in this list. The BEPPo project decided to focus on wave and tidal energy, using offshore wind as an example and a "big brother" to inspire the future development of these technologies.

In light of the exploitation potential of Marine Renewable Energy and increasing R&D activity, this sector may act as a future driver for competitiveness in the North Sea region, whose coastline of 35.696 km and favourable wind, wave and tidal energy resources make it the perfect location to develop and apply new offshore energy technologies. The European targets for 2020 energy mix call also for the exploitation of marine renewable energy.

However, the majority of ocean energy projects all over the world continue to be demonstration pilots, still to be leveraged into full commercial deployment. Moreover, their integration with existing power plants -in or around ports- remains a big challenge.

It is a fact that many ports have spare capacity of land, a direct access to the sea and often proximity to renewable power development zones and power stations. This allows them to be an ideal site for the clustering of industries, technology transfer centres, incubators, research and test centres to service the renewable energy sector, both onshore and offshore.

The intended readers of this report are primarily found in ports authorities and ports-related businesses. For port authorities the organisation of the energy production is not a primary business activity and their relationship with energy companies is largely undefined. As central actors of the maritime logistics sector, it is important for them to understand how they can enter the MRE sector with the adequate capacity and maximum mutual benefit. Ports may play an active role in construction, assembly, installation, monitoring, maintenance and decommission of MREs and capitalise on the idea of Blue Energy Ports such as ports dedicated to marine renewable energy activities.

For this purpose this report wants to summarise the understanding of the BEPPo project on the state of the art of three marine renewable energy (MRE) technologies:

1. offshore wind, particularly floating wind
2. tidal energy
3. wave energy

The objectives are:

- Collect information of MRE existing projects
- Understand the state of development of each technology
- Analyse the differences in activities that may be required for deployment of full scale MRE technologies.

In order to do so, we have in the BEPPo project carried out a screening of relevant MRE projects, and for a handful of well-known MRE projects we have compared installation, maintenance and decommission procedures. We have also analysed the information from project workshops with relevant industry stakeholders and we have completed a brief review (desk study) of technological maturity and market trends for MRE.

The present report should be considered as a preliminary study, given the fact that the analysis is based on a limited number of cases suitable for in depth analysis. The data collected call for deeper investigations and more attention to some clear signals that diagnose the state of development of the MRE industry and market. In addition, given the high pace in innovation activity within the MRE sector, it is important for stakeholders like ports to stay informed and continuously look for potential synergies among the distinct technologies.

UNDERSTANDING MARINE RENEWABLE ENERGY TECHNOLOGIES

OVERVIEW OVER WIND, TIDAL AND WAVE TECHNOLOGIES

The main blue energy sources considered in the BEPPo project, given their relevance for the North Sea region, include Offshore Wind, Wave and Tidal energy. For offshore wind energy one can in turn differentiate between bottom-fixed and floating offshore wind energy. Although still unconventional when compared with many other energy sources, bottom-fixed offshore wind energy is more mature and much more widely deployed than other MREs. The focus of the BEPPo project is therefore on other MREs than bottom-fixed offshore wind energy, but it is included as a reference against which less widely deployed MREs can be compared.

In terms of energy production systems, these three energy categories represent very different technologies as well as different levels of innovation. While tidal energy (especially considering tidal stream) and offshore wind energy do have more than few things in common (rotors, gear mechanism, monopile foundations etc.), wave energy suffers from a lack of technological convergence. Particularly, it is the authors' opinion (shared among other experts in the sector) that the similarities between wind and tidal energy components have been a major drive for the interest of big industrial players such as Siemens and Voith Hydro.

SUB-SYSTEMS

We can divide the energy conversion devices for all the MRE technologies we are considering here in three major sub-systems:

- Support structure, to keep the device in place.
- Fluid-dynamic subsystem, to capture the energy resource
- Power Take Off (PTO) = drive train + generator
-

The fluid-dynamic sub-system is usually the visible part of the device: the rotor, in case of wind turbines or tidal turbines, or the device structure in case of wave energy: overtopping and oscillating water column structures, point absorbers in different configurations and shapes, flaps, sales, carpets. It is the part of the technology that is designed to capture the energy from the resource, being it wind, tidal or wave energy.

The fluid-dynamic subsystem is held into place by the support structure that keeps the devices fixed to the seabed or floating in the vicinity of a given location. In general, the support structures have to be as stable as possible and only movements that do not disturb the production are allowed. In the wave energy case, for most of the point absorbers for instance, the movements may be fundamental for the power production. Support structures can be piled, or drilled and pinned (pin piled), or simply held in place to the seabed by massive gravity base structures. The foundation or support structure can be subsurface or surface penetrating depending on site and seabed conditions and installation and operation costs.

Finally the PTO is the part of the device that transforms the energy into electricity (unique to each device manufacturer) and includes the generator. While for free flow tidal turbines, as for wind turbines, the rotors are connected to the generator with not many furthers steps (by a gear box), for wave energy we may need some extra components. In tidal and wind energy, the PTO and the fluid-dynamic subsystem can be overlapping in this characterization given here.

Tables 1-3 do not want to be exhaustive, but give a general overview on the kind of sub-systems used by the marine renewable energy technologies that are here into consideration. It is clear that the lack of convergence in the wave energy field has a direct consequence on the industry. Despite the existence of innovative wind energy technologies that do not foresee the use of a rotor or blades (such as Sky Sails Power System) (1), we can say that the sector is focussed on bladed concepts.

TABLE 1. SUPPORT STRUCTURES

Technology	mono-piles	tripods	moorings	anchors	semi-submersibles
Off-shore wind (fix)	x	x			
Floating wind			x	x	x
Tidal	x	x	x	x	
Wave energy	x	x	x	x	x

TABLE 2. FLUID-DYNAMIC SYSTEMS
(TO CAPTURE THE ENERGY FROM THE FLOW OF WATER/AIR OR WAVES FORCES)

Technology	blades / rotor	sails	point absorbers	Oscillating water columns	Overtopping structures	Flaps	nets/carpets
Off-shore wind (fix)	x	x					
Floating wind	x						
Tidal	x	x					
Wave energy	x	x	x	x	x	x	x

(1) http://www.skysails.info/english/power/power-system/

TABLE 3. PTO, THAT TAKES THE ENERGY AND TRANSFORM IT INTO ELECTRICITY

Technology	generator	gearbox or control system	hydraulic motor	hydroelectric turbine	air turbine	linear electrical generator	piezoelectric
Off-shore wind (fix)	x	x					
Floating wind	x	x					
Tidal	x	x		x			
Wave energy	x	x	x	x	x	x	x

INFRASTRUCTURES

From an exploitation perspective, it is important to understand the type of infrastructure and related devices and equipment which form the main components of MRE production installations [1]. This is particularly important among others for ports wishing to invest in or prepare for production of MRE and for assessing own infrastructure. The following schemas give a brief picture of offshore-onshore connection infrastructure and components for MRE installations, as well as main logistics components of an offshore wind farm.

The Figure 1 below schematises the offshore-onshore connection of MRE installations, and the most common infrastructure components. Offshore components include energy capture devices (wave, tidal, offshore wind) and cabling from device to shore; onshore infrastructure include cabling for connection offshore-onshore, equipment and facilities, and connection to local grid. [2]

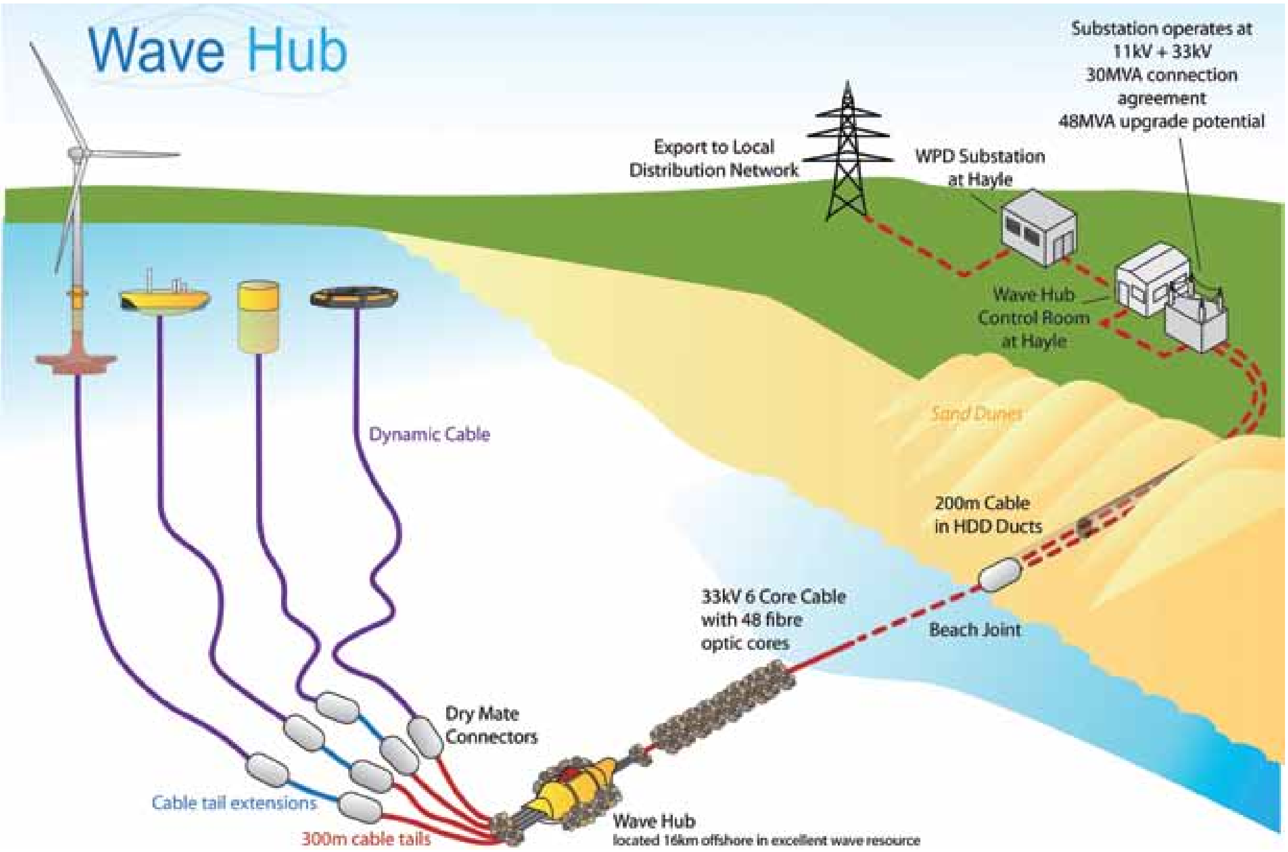


FIGURE 1: ILLUSTRATION OF TYPICAL WAVE/TIDAL PROJECT AND ASSOCIATED INFRASTRUCTURE (SOURCE: WAVE HUB [3])

Figure 2 schematises the main logistics activities related to operation and maintenance of offshore wind farms. Offshore logistics activities are the ones to be served by certain types of vessel and other transportation units which have to be accommodated by ports and require specific infrastructure. Onshore logistics include transport and storage of equipment and devices.

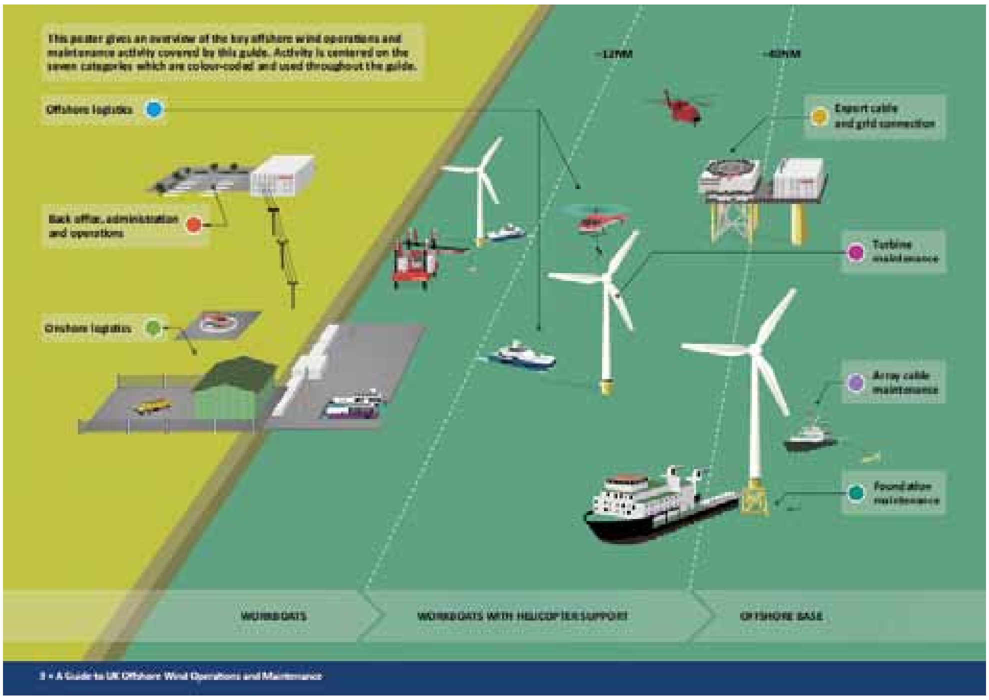


FIGURE 2: MAIN COMPONENTS AND ACTIVITIES OF AN OFFSHORE WIND LOGISTICS SYSTEM (SOURCE: GL GARRAD HASSAN, 2013 [4])

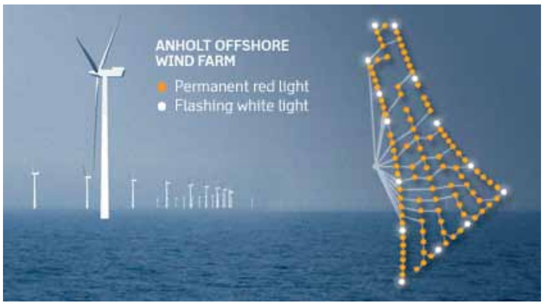
LIFE CYCLE PHASES OF BLUE ENERGY INSTALLATIONS

CASE STUDIES

In order to get a better insight on the type of services, infrastructure, and logistics systems needed to support the development and operation of an MRE farm (here considering offshore wind, wave, tidal), the BEPPo project has examined few case studies of ongoing offshore renewable energy projects. We have collected information on installation, monitoring and decommission for different wind, tide and wave energy installations to compare, if possible, practices and infrastructures and vessels used. This gave us an idea that confirmed what already presented about readiness of the marine renewable energy sector and the differences among the technologies under development.

The most informative projects, given their degree of maturity/commercialization as well as their complementarity and diversity (distinct energy sources and technologies), are summarised below.

- ANHOLT OFFSHORE WIND FARM: full scale wind park with 111 SWT - 3.6-120 wind turbines of 3.6MW, for a total of 400 MW park capacity on monopile foundations.



(Picture: http://www.offshorewind.biz)

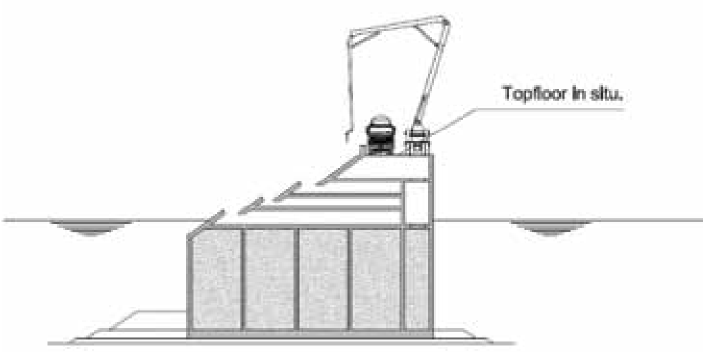
- WAVESTAR WAVE ENERGY DEVICE: 1/10 section of a 1:2 prototype with 2 point absorbers, for a 600 kW installed capacity, bottom based monopole foundation.

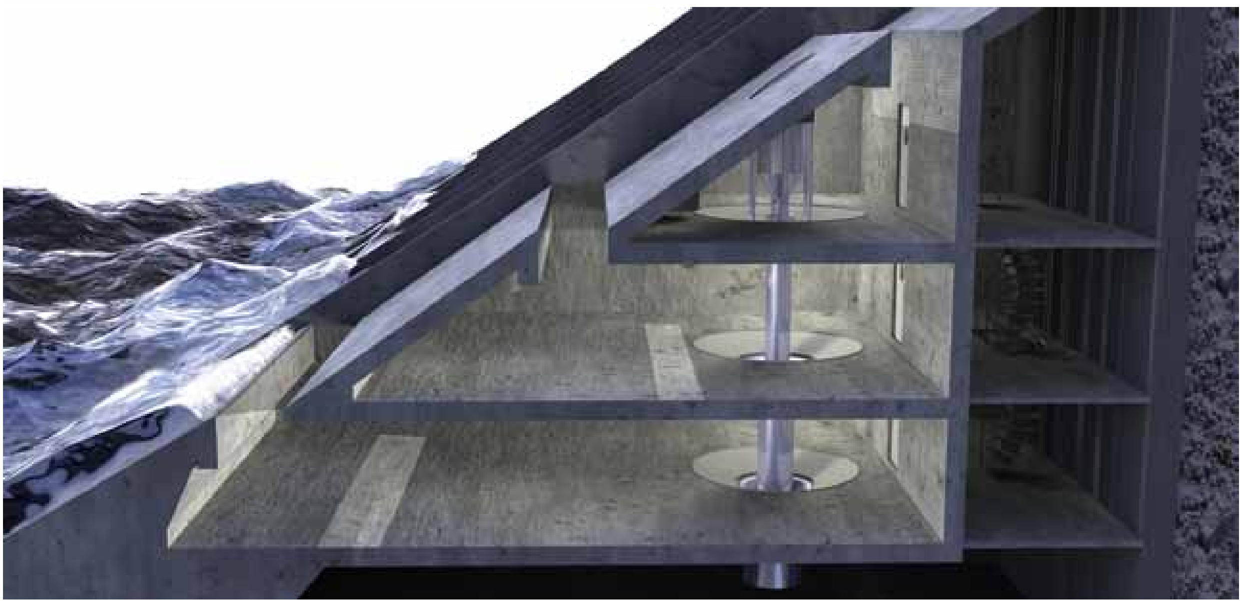
(Picture: http://wavestarenergy.com/)

- HYWIND PILOT FLOATING WIND: one 2.3 MW wind turbine on spar with three moorings lines.

(Picture: Wikipedia – Jarle Vines)

- SSG OVERTOPPING WAVE ENERGY: feasibility study of a harbour breakwater with 56 overtopping caissons each with 70 kW installed low head turbines for a total of 3.9 MW. Gravity bottom based foundations.





- VOITH HYDRO TIDAL TURBINE: one monopole turbine of 1MW, 13 m rotor diameter on a monopile.

(Picture: www.emec.org.uk)

- SEAGEN TIDAL SYSTEM: 1.2 MW capacity, arm-like extensions either side of a tubular steel monopile 3 metres in diameter.

(Picture: www.siemens.co.uk)

MANUFACTURING, INSTALLATION, VESSELS AND MAINTENANCE PROCEDURES

To understand the main operational requirements as well as administrative requirements, the information collection from the case studies was divided into pre-installation, installation, operation and maintenance, decommission and financial and legal issues. Detailed results from this screening work can be found in Appendix (Tables 6-10), and the main findings are described below.

Pre-installation

Common aspects in pre-installation activities are surely the sea bed scan and geological survey. For these kinds of operations standard boats and vessels are used. The preparation of the sea bed is more common in case of gravity foundations, usually in order to level slopes and sand banks, while for tidal energy, due to the strong currents that typically characterize the installation site, this did not seem to be necessary.

In addition to on-sight studies, the pre-installation activities also include preparation work such as manufacturing, construction and assembly of energy production system.

For wind power, having relatively large components, blades in particular, the logistics from the component manufacturing site to the ports is important. The access to qualified workers is very important at production sites, and will hence probably be to an increasing degree in the ports region. Construction and assembly of substructures such as jacket foundations are also tasks that typically have to be done at the installation ports or in other harbour areas.

For wave and tidal there is not yet a common practice. So far the components have not been constructed in the harbours, but only partially assembled there or simply loaded into a barge to be taken into location. As for wave energy device substructures, the trend is moving towards moored systems. The implications are that less steel is needed and that one avoids complications related to gravity-based substructures etc., and this also has implications for the ports requirements.

Installation

During installation, towing to location and cables installation are common activities for all technologies. Laying subsea cable is in itself not a new technique and there are many submarine cables for telecommunications and electricity. However, the challenges in this instance are laying cables in a high tidal energy environment and subsequently protecting the cable from potential damage due to that environment. Careful cable routing utilizing natural seabed features can help keep the armoured cable out of the most aggressive tidal flows until the cable run reaches lower velocity areas. Once in areas with lower tidal movement, and seabed sediment it is normal that the cable would self-bury over time under its own weight. In the high tidal areas where there is high energy and rock seabed, beyond the routing through natural features special techniques may also be required to protect the cable. Inter-array cables (connecting between the individual turbines) will be installed directly onto the rock seabed and configured to utilize localized fissures where possible and to be laid in parallel to the tidal flow where this is not possible. Where necessary, the cables will also be weighed down by the use of cable protectors, concrete mattresses or rock.

Other activities in the installation depend on the technology and characteristics of the structure. It was noticed that for tidal sites, where the use of self-stabilizing barges is necessary, jack up barges may suffer from vibrations if their dimensions are not selected carefully. Therefore dynamic positioning vessels may be preferred, but not mandatory. Tidal, like wind energy, has specialized vessels for installation with companies such as Schottel GmbH or Mojo Maritime. These vessels are designed to carry tidal components, pile or drill the foundation into the seabed and install the cables and lift the other components of the device. The same cannot be said for wave energy that has no dedicated vessels or standard installation procedures. Smaller vessels, which may be sufficient for installing tidal energy conversion devices, are more flexible in the sense that they are cheaper and more readily available than the large vessels needed for offshore wind projects. Tidal projects may also require somewhat smaller and simpler vessels than wave projects. If the vessels are mainly to be used for towing the tidal turbines to site, they may also be less sensitive to weather restrictions due to more complex marine operations necessary to install other marine energy devices.

For the installation of some concepts of wave energy devices, there is also a more extensive use of ROVs (remotely operated underwater vehicle) in the placement of the devices; this may also be the case for some concepts of tidal and floating wind energy devices. Otherwise, a large variety of different vessels have been used for wave energy deployment and testing, and there is no clear trend for which kind of vessels will be required in the future.

For farms of floating wave energy converters one needs to take into account that there should be room for vessels to manoeuvre within the wave farm as well as room for the wave energy devices themselves to move about. For installation, it is believed that larger vessels from the oil and gas industry will typically not be used due to their large cost. Furthermore, as long as the wave energy devices are relatively small compared to offshore wind turbines and there is no lifting involved in installation, there is probably no need for large and very costly jack-up or heavy-lift vessels in the first place. Due to the smaller scale and earlier stage of commercialisation for wave and tidal technology relative to bottom-fixed offshore wind, it is the authors' opinion that it will typically be more important to limit the costs related to installation, by among other avoiding unnecessary investments in too complex and costly installation vessel.

Operation and maintenance (O&M)

Obviously all technologies require maintenance but there are no specialized vessel for this for tidal and wave energy that tend to use what is available in the vicinities. Specialized maintenance vessels do exist for offshore wind (bottom-fixed). Nevertheless from projects such as LEANWIND (€10 million by the European Commission, FP7) it is clear that there is room for improvement even for a mature technology as offshore wind. Indeed, the primary LEANWIND objective is to provide cost reductions across the offshore wind farm lifecycle and supply chain through the application of lean principles and the development of state of the art technologies and tools.

Many of the same considerations as mentioned for installation vessels above also apply for vessels for O&M. As a general note, one could surmise that the differences between vessel requirements for small-scale and large-scale offshore renewable energy deployments may be just as great as the difference between vessel requirements for different technologies. For the daily maintenance of offshore wind farms, a set of relatively specialised vessels have emerged the last several years. For prototype or test devices for wave and tidal energy, there is not the same need to streamline and optimise the logistic support chosen for operation and maintenance as long as there is only a single device that needs maintenance every once in a while. It is therefore the authors' belief that the question of vessel requirements for the O&M phase for wave and tidal energy devices will be more interesting when larger-scale, commercial wave farms or tidal farms are deployed and the logistics challenges become more extensive.

Decommission

Data on decommission have been provided only by WaveStar pilot, but it is logical to say that similar vessels to the ones used for installations are required for offshore wind and tidal and all the other technologies.

Summary

To summarise the activities of each phase of a MRE project, and the necessary support and logistics services to be provided by ports, the following table provides an overview of the technical and operational tasks, and the main support needed from ports, i.e. the type of transport activity to be served, vessels to be accommodated, and facilities and equipment needed. This information is relevant from a port perspective in order to get an idea of the possible roles to be taken by ports.

Phase	Pre-installaiton	Installation	Operation	Decommission
Tasks	Seabed scan, geotechnical and environmental surveys Manufacturing and assembly of production system	Installation of foundations, turbines, grid, substation Towing to location Cable installation	Operation & Maintenance visits	Decommissioning of Turbines Substation
Main logistics support needed	**Port:** small local port; close location to farm site **Support:** crew and material transfer to and from the site **Vessels:** small standard service vessels and tug boats **Equipment:** mobile cranes, geotechnical equipment **Divergence** among MREs: partly on-site manufacturing for wind	**Port:** installation port. maybe located further away from the site **Support:** provide infrastructure for installation and assembly of foundations, energy conversion devices, substations etc. **Vessels:** service and installation vessels: DP3, cable laying vessels, heavy lift, drilling rig, tug boats, barges, work platform **Facilities/equipment:** dry dock, mobile cranes **Divergence** among MREs: - Tidal: maybe suffice with small vessels; self-stabilizing barges - Wave: no need of heavy-lift; possibility for ROVs, no existing dedicated vessels yet	**Port:** small local port; close location to farm site **Support:** crew and material transfer to and from the site **Vessels:** small service vessels **Equipment:** cranes	**Port:** installation-type port. Maybe located further away from the site **Support:** provide infrastructure for decommissioning. Similar to construction but in reverse order. **Vessels:** service and installation vessels, tug boats, barge, suction dredger

TABLE 4: MAIN TASKS OF MRE PROJECTS AND NECESSARY LOGISTICS SUPPORT (BASED ON [5] AND BEPPO CASE STUDIES)

TRENDS AND PROSPECTS

TRENDS AND TECHNOLOGY MATURITY

When considering wave, tidal and floating wind, we can say that there is a gap between these three technologies. One could say that if there was an indicator for the level of innovation among MRE technologies, in terms of novelty of technology, it would rank wave energy as first, then tidal and floating offshore wind. Common challenges are mainly related to survivability and moorings because of the strong wave forces and the harsh sea environment, but tidal and particularly wave energy technologies have to deal also with the design and testing of completely and often radically new power take-off systems (see tables 1-3).

Nonetheless, the total R&D investment in ocean energy (mostly wave end tidal energy) is about 10% of that for offshore wind, therefore a differentiation is necessary.

OFFSHORE WIND

There are currently [6] 69 online offshore wind farms in Europe, mostly located in the North sea - UK, Denmark and Belgium. The trends is larger installations, higher capacity, further from shore, and in deeper water, transferring the technology and competences from onshore, near shore installations as well as from offshore oil and gas industry.

For the floating wind sector, at the end of 2012, there were two full scale grid connected offshore wind turbines on floating sub-structures, Hywind and Windfloat. Both are located in Europe, one in the North Sea and one in the Atlantic: Hywind is developed by Statoil, with a 2.3 MW Siemens turbine. Installed in Norway in 2009, it is the first large scale floating wind structure installed in the world. Windfloat, the second large scale floating system, was installed off the Portuguese coast in 2011 and started to produce energy in 2012. Developed by Principle Power and EDP, it is equipped with a 2 MW Vestas wind turbine. The innovation part regards the support structure, either as a spar or as a semi-submersible. In the authors' view, the deep wind sector could therefore experience seatbacks related to political will, but not relevant technological drawbacks.

TIDAL & WAVE

Wave energy is a highly innovative industry in continuous development, with "wave energy converters deployed at sea today [...] seen as front runners"[7]. So is tidal energy. The tidal stream sector has experienced rapid development in terms of technologies and counts today several large demonstration projects (UK, IR) [8], as well as many prototypes operating a.o. at the EMEC test site [9]. However, despite having received more investments for R&D, the wave energy sector harvested fewer results than the tidal sector. The higher degree of innovation in the wave energy sector may be the reason for difficulties encountered in its development. These difficulties emerge particularly in the comparison between wave and tidal energy, but while the tidal sector also had its seatbacks, they are clearly being overcome. The "solo sea trials by device developers" typical of early scale prototype installations for both wave and tidal, often experiencing challenges regarding administrative and other non-technical requirements, represented a show-stopper for small and isolated actors like in wave energy while the tidal sector could already benefit of the interest of bigger industry player that invested in some tidal technologies that represented for them a smaller risk. Administrative constraints, heavy and little-adapted procedures can in fact be a significant challenge to the development of this energy sector [10].

The rise of this new industry, anyways, had required and still needs robust engineering and investments for open sea trials at a very early stage of development and this can be alone a capitalization opportunity for ports.

TECHNOLOGY MATURITY

When it comes to technology readiness level (TRL), tidal power is ahead of wave power. Tidal technologies appear poised to reach commercial breakthrough earlier than wave technologies, and this is highlighted by the number of concepts that have reached sustained full-scale demonstration. Tidal energy concepts present a greater convergence in design, with the majority of developers opting for horizontal-axis turbine concepts; thus indicating that the tidal energy sector is at a more mature stage of development. On the other hand, wave energy devices have not reached similar technology maturity and may benefit from further R&D, innovation and testing before being able to tap the most resourceful sites available in Europe. Only a few concepts have consistently undergone full-scale testing, and the sector presents a vast number of different concepts, with no clear convergence in design.

There is a need for more R&D activity to demonstrate different operating principles, from components to grid connections [11]. This is well documented in reports such as the "Overview of European innovation activities in marine energy technology" of 2013 from the European Commission or the "Wave and Tidal Energy Strategic Technology Agenda" from the SI OCEAN EU project. In particular, from the first: *«The development of wave energy test and demonstration sites is an indicator of the progress and of the constraint that the sector has faced over the past few years….Wave Hub, developed for array testing, has been ready since 2010 but yet no installation has taken place…. This highlights the technical difficulties encountered in the development and deployment of reliable offshore (wave energy) device."" On the other hand, the development of infrastructure for testing and deployment of tidal technology has followed another route. Many of the (tidal) devices have been tested in the strong and resourceful infrastructure provided by EMEC. Following the successful deployment of technology, tidal farms have been proposed and are currently going through licensing and commissioning."*

There is a race now for tidal concepts, with different projects going through licensing and commissioning. One sign of the relative maturity of tidal power is the fact that there have been numerous takeovers and acquisitions of tidal power developers by larger commercial companies, meaning that the tidal concepts are perceived as commercially viable. Furthermore, for tidal, OEMs are also buying up intellectual property from concept developers, and more mature warranty schemes are coming. This is in contrast with wave power, where investors seem to be leaving the market. This can be regarded as an argument for focusing more on tidal projects in the BEPPo project screening, but the total energy potential for wave and wind power is still substantially larger than for tidal power.

Nevertheless these have been also recently seatback and withdrawal like the case of Siemens who abandoned its ocean power generation business in November 2014 and divested Marine Current Turbines, the Bristol-based tidal turbine development company it acquired in 2010.

Wave energy has been suffering of being coupled to tidal energy and offshore wind. The kind of investments required for wave energy are substantially different due to its immaturity, as explained in different points of this report. During the past years the wave energy industry was pushed to promise too much by the market and competitiveness with other marine renewable energies. This concurred to a number of major failures of prototypes, which have stopped some of the activities and quenched much of the interest in continuing development. In order to counteract this trend, a standardized approach that first requires small scale laboratory testing, then intermediate testing and finally large scale tasting only after success is now in use.

BEPPO PROJECT SCREENING

Within the BEPPo project, we have scanned around 50 existing projects (see Appendix): 23 on wave energy, 10 on floating wind and bottom-fixed offshore wind, 5 on tidal energy. These are primarily Research and Development projects and include demonstration, prototyping, feasibility studies and design and economic analysis. In addition there are 12 large marine renewable energy projects that look into integration aspects, multipurpose platforms, technical and non-technical barriers including environmental impact and logistics. Finally 11 coordination actions (networking, communication and dissemination activities) have also being listed. It is clear that the distribution of research investments by marine energy technology in 2011 that sees 63% of the total going to wave energy technologies is reflected in the number of projects we have encountered.

Fig. 3 summarizes the findings: the wave energy field may be characterized by higher innovation. Wave energy is more technologically challenging than tidal energy. This also means, in this case, that a higher degree of innovation is required to overcome its specific challenges and therefore the path toward commercialization may as a result be longer. This situation has been captured by the survey made by the EU commission [12]: 63% of the R&D money dedicated to ocean energy in the past 5 years went to wave energy and the remaining 37% to tidal. The earlier stage of development of wave energy explains not only the bigger thirst for research investments but also it explains why large scale demonstration struggles to be realized within wave energy. This is documented on the right side of Fig. 3 in the two graphics. The first plots the rated power for tidal infrastructures depending on Spring Tide velocities. It can be seen that infrastructures have been deployed in the full scale range of 2-4 m/s. For wave energy, instead the distance from shore and water depth can be considered as indicative of the state of development of the technology and we can see that all projects in deep water and with considerable distance from shore have not been realized.

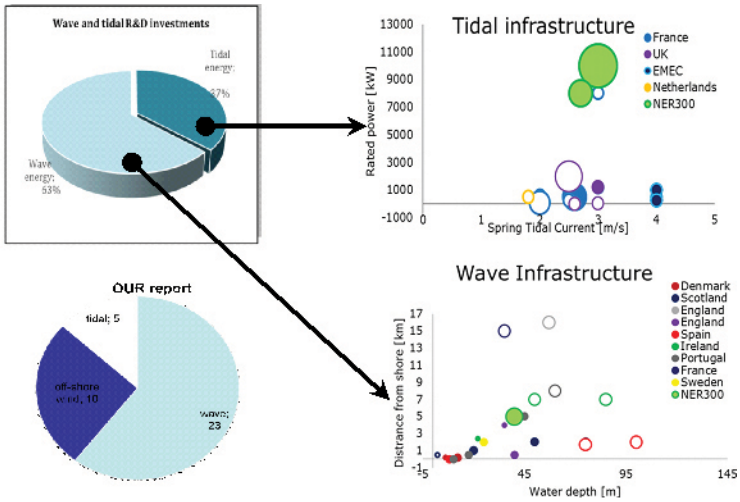


FIGURE 3. SUMMARY OF RESULTS OF THE STATE OF THE ART OF THE TECHNOLOGY.

TOP LEFT: RESULTS FROM THE «OVERVIEW OF EUROPEAN INNOVATION ACTIVITIES" EC, 2013, REPORT EUR 26342, INDICATING HIGHER INVESTMENTS FOR WAVE ENERGY, YEAR 2011. TOP&BOTTOM RIGHT: TIDAL AND WAVE INFRASTRUCTURES – EMPTY CIRCLES ARE NOT REALIZED PROJECTS. THE SIZE OF THE CIRCLE IS PROPORTIONAL TO THE SIZE ON THE TECHNOLOGY. BOTTOM LEFT: NUMBER OF RESEARCH, DEMONSTRATION, COLLABORATION PROJECTS IDENTIFIED WITHIN BEPPO.

Because of their size, it is here worth mentioning the projects approved under the NER300 program. NER300 is a financing instrument managed jointly by the European Commission, European Investment Bank and Member States. NER300 money will be paid out to renewable energy installations as they produce energy and needs only achieve 75% of the total energy production that they bid for the first five years of operation in order to receive their subsidy in full. Origin: Set aside 300 million allowances (rights to emit one tonne of carbon dioxide) in the New Entrants' Reserve of the European Emissions Trading Scheme for subsidizing installations of innovative renewable energy technology and carbon capture and storage (CCS). The approval to NER300 does not grant installation. Developers still need to find investment money. The allowances have been sold on the carbon market and the money raised — 2.1 bn EUR — will be made available to projects as they operate.

Despite the difference among the three energy types mentioned earlier, 2 projects for each of the technologies have been funded under the second call of NER300: two wave energy arrays, two tidal projects and two floating wind projects.

- Irish wave energy project WestWave received €19.8 m of funding under the award. WestWave is a collaborative project between the major players in the Irish wave energy development sector, and aims to install and operate wave energy converters capable of generating 5MW of clean electricity by 2015.
- Swell Project - Peniche, Portugal. The project concerns a large-scale, grid-connected wave farm with a capacity of 5.6 MW that will be built on the coast a few miles north of the Peniche Peninsula, central Portugal. It will consist of sixteen 350 kW modules. Oscillating Wave Surge Converters will be placed on the seabed and only the top part of the flap will be surface piercing. The projects is for € 9.1m
- Of the three ocean energy projects awarded under the programme, the Sound of Islay received the largest amount of funding, with €20.65 million awarded. The tidal array will consist of ten 1MW Andritz Hydro Hammerfest HS1000 Tidal Turbines which will be fully submerged on the seabed just south of Port Askaig, for 30GWh/y of electricity.
- €18.4 million was SeaGeneration (Kyle Rhea) Ltd, a development company set up by Marine Current Turbines (MCT), which is proposing to develop a tidal stream array at the Kyle Rhea site between the Isle of Skye and the west coast of Scotland. The proposed array will consist of four SeaGen devices and have a total capacity of up to 8MW.
- The Spanish BALEA with floating wind power project gets about €34m to place two 5 MW and two 8MW wind turbines on floating foundations in the Bay of Biscay, said the EC.
- FloCan5 will see five 5MW floating wind turbines on semi-submersible concrete foundations up to 3.7km off Grand Canaria, also for €34m.

CHALLENGES AND OPPORTUNITIES FOR FUNDING AND DEVELOPMENT

The total R&D investment in MRE (mostly wave end tidal energy) is about 10% of that for offshore wind. The floating wind sector probably bows in front of the fact that shallow deployment locations that allow the use of proved substructures and bottom based foundations are still available and therefore will probably only sprout when the market will really need it. This could nevertheless be before tidal or wave energy have proved full economic viability or/and competitiveness.

RISK PERCEPTION

The “classical” tenet of finance that diversification reduces the risk is not necessarily valid in the wave power industry. Here, the diversification in a large number of very different concepts is rather confusing the investors, and they rather opt for an entirely different investment option. For instance, having the choice between spreading the investments over a portfolio of different wave energy developers and a single offshore wind energy developer, the investor may choose to make all his investments in the single wind energy developer because the risk associated with that project is still smaller than the combined risk of a portfolio of many wave energy projects.

For companies investing in blue energy, decision makers (boards of large companies, e.g.) typically avoid what they are not able to understand. For wave power, this is complicated by lack of success stories where wave power developers have been promising too much to their investors (return on investment after ten year, for instance), which has contributed to scepticism in the public and investor perception of the commercial viability of wave power. Companies backed by venture capital do not generally focus on basic R&D, which is what wave energy really needs: venture capitalists are less willing to assume technological than institutional risks. Large energy companies fund R&D, but regulations may reduce the ability to recover costs and investors may react negatively to higher perceived risk. Finally, firms in energy related industries may lack a clear business case for replacing their current technologies which are more profitable than the new ones.

Even companies such as Siemens and Alstom are more interested in tidal power due to technical familiarity; they have much experience with other forms of rotating machinery and conventional generators, but not necessarily with the various technical concepts of wave energy conversion devices. Diversification for wave energy devices may be a sign of technical immaturity, but it may also be necessary with a certain degree of diversification because the wave energy devices have to be tailored to the wave conditions to a larger degree than tidal and wind energy devices.

One key to securing funding can be to find niche applications where price is not that important. Examples of such applications are described in the next chapter.

NICHE APPLICATIONS

Special niche applications considered for MRE devices are interesting both for justifying the funding of developing new concepts and from the ports perspective. One important key is to find applications where the price of electricity is not that important. This will typically be areas and applications disconnected from the electricity market, such as remote islands, or in general applications where one is replacing, e.g., diesel generators. For such niche markets a relatively high price will be acceptable for the renewable energy devices.

Examples of applications that have been mentioned would be aquaculture and fisheries, coastal protection (electricity required for rebuilding coral reefs, e.g.), or desalination. The use of floating wind turbines to supply the power needed by oil and gas platforms is an idea that has been highlighted. Also for subsea applications there are a number of ideas, such as floating wind turbines used for water injection in oil and gas wells, and also tidal turbines used for subsea oil and gas installations (both for drilling and production). Other possible subsea applications suggested by concept developers are the powering of marine mining operations, of tsunami warning systems, or of submarines. Some are of the opinion that for many of these niche applications, tidal energy may be preferred to wind and wave energy. The reason that is stated is that sea currents are more consistent and predictable whereas there are often not high enough waves or strong enough winds to generate appreciable amounts of power. For applications needing continuous supply of power, such intermittency of the energy generation would be a disadvantage.

From the ports' perspective, more interesting are applications more closely linked to the harbour area. Examples here are powering docked vessels to reduce the need for ship engines to generate electricity, or powering signal buildings and lighthouses. Wave energy devices could also be integrated into breakwaters, and tidal energy devices could be integrated in bridge structures. A common characteristic to the most promising applications is that they are small-scale and near-shore, and can contribute to avoid the technological risk in scaling up or going further off shore.

Multi-purpose platforms may possibly be a promising option farther into the future. In principle, combining different technologies in one and the same platform may contribute to reducing the risk, but in practice one is likely to increase the risk due to unfamiliarity [cf. section on risk perception].
In addition to combining different energy conversion devices, energy conversion devices can also be combined with aquaculture. Another application is combining blue energy conversion devices with oil installations. This may be interesting because the cost of energy compared to the prices in the electricity market may not be that relevant when the energy is both produced and consumed offshore.

SUPPLY-CHAIN

Much of the necessary competence and services for the MRE sector can be transferred from other industries like shipping and oil and gas. Nevertheless, it is important for MRE to be served by a clearly defined and robust supply chain, where companies work together towards same goal, explore synergies and complementarities, in order to increase efficiency both in technology development and in operations. Furthermore, a well-depicted supply chain is also valuable for supporting the sector in sharing infrastructure, knowledge, experience or even innovations.

The offshore wind sector is definitely the front runner in terms of market penetration and benefit from a strong supply-chain with dedicated infrastructures, services, systems and components. Dedicated vessels for both installation and operation and maintenance is also a strength of this segment, even there is still room for improvement in term of costs reductions and optimization of logistics operations.

The tidal and wave energy segment are still missing a well-dedicated supply chain, including a set of committed major players like the offshore wind segment. However, for the tidal sector it is possible to identify suppliers for different components and sub-components (blades: Designcraft and Norco Ltd, among others; bearings, brakes, shaft: Schottel, among others; gearbox: Orbital2 Wikov, among others; control, generator and electrical: general electrics, ABB, Siemens, among others) [13]. Also as stated previously in this report, the tidal segment also benefits from specialised installation vessels.

For the wave energy segment, on the other hand, no clear supply chain can be identified. While the tidal sector has some clearly identified components suppliers, the scenario for the wave energy sector is clearly more scattered. First of all, regarding the identification of components it is not possible give the differences among the devices, and secondly the supply chain is not consistently engaged. The only significant effort listed is the collaboration started by Aquamarine Power, Albatern and Carnegie to identify a common PTO system with Bosh Rexroth. Finally, no dedicated vessels, neither for installation or maintenance, are available, which may be justified by the lack of technology convergence.

One traditional measure to strengthen the supply chain is the establishment and management of industrial cluster.

One example is the wind power cluster organization in Northern Denmark, which have been organising seminars where major wind energy players such as Siemens are presenting how smaller companies could become sub-suppliers. Similar network organisations and events could conceivably be relevant also for wave and tidal energy actors to build a stronger and more tightly integrated industry and supply chain.

Another example is the Blue Energy Cluster in Belgium, coordinated by the West-Flanders Development Agency. The activities organised by the cluster to strengthen the blue energy supply chain include:

- Developing business network (eg B2B)
- Business opportunities and guidance for SME's
- R&D
- Education
- Infrastructure development
- Branding (through the Greenbridge Incubator)

In Norway, in addition to the large research center NOWITECH dedicated exclusively at offshore wind, another industrial network promoting renewable energy in Norway and representing the interest of both wind, tidal and wave energy sectors is the association NORWEA, counting 130 members.

Not only a strong supply chain is important to serve a domestic market, but also exportation of services and technology requires good collaborations across suppliers. In other words, you don't need a large home market to successfully develop an MRE supply chain. In Norway for instance, the main strategy for offshore renewable energy development has been to export technology that is developed domestically. Although this approach has been fairly successful for important segments of industry and industrial research institutes, the existence of a home market can be crucial for testing and demonstration projects.

Both as test sites for demonstration projects and installation ports for commercial projects, there may be a number of added effects for ports and the ports regions. One effect that has been highlighted is that it draws in increased skills, which may add value in other areas. Renewable energy developments also have implications for the supply chain, creating jobs associated with accommodation, vessels, consultancies, etc. However, if businesses (OEMs, e.g.) from other regions or countries are buying up the technology, much of the business and supply chain development associated with the technology will also move away from the ports region.

ROLE OF PORTS FOR MARINE RENEWABLE ENERGY

Obviously, MRE production is not a primary business activity for ports. Their relationship with energy companies is largely undefined, neither they are listed as main supply chain actors. Looking at the oil and gas sector, the main role of the port is logistics support and host for offshore base activities. On the other hand, actors involved in the MRE market, especially for wave and tidal, often lack logistics competence (clearly not their core business) which is necessary to implement their energy schemes.

PORTS FUNCTIONS

The functions of a port within MRE activity can vary greatly, given distinct locations, infrastructure and facilities, but also depending on the type of activity served by the port (installation, operation, etc.). The main difference is the relatively higher requirements in terms of capacity during the installation and dismantling phase (high activity tempo and larger components to handle). BMT Consult [14] provides a useful classification of offshore wind ports, which can serve as a basis for classifying ports from a broader perspective, including ocean energy like wave and tidal.

Port type	Functions
Construction	The wind turbine can be pre-assembled on site. Capable of providing services during the entire construction process of offshore wind farm. With enough space and routs for the traffic of different offshore wind vessels.
Manufacturing	Involved in the manufacturing of wind turbine, components and BOP items such as foundations and substation platform.
Operantions & Maintenance	Capable of being a base for offshore project developers to provide operation and maintenance services to the wind farms. Services include the deployment of vessels, provision of spare parts for maintenance and etc.
Logistics	Mainly involved in the offshore wind construction phase. It plays a role as a strategic logistic port to facilitate the construction work.
Storage	It can be used for storage of nacelles, major components and BOP items.

TABLE 5: PORT TYPES IN THE OFFSHORE WIND SECTOR (SOURCE [14] AND [15])

PORT LOCATION

In light of the distinct functions to be beard by a port, it is clear that the location of the port is an important decision factor for port involvement in MRE market.

For instance, tidal is a small energy resource in the sense that it is localised to specific areas of the sea where the potential for tidal energy production is high. The location of ports is therefore more important for tidal power than for wave power and wind power.

Furthermore, as mentioned in the analysis of requirements from the case studies, the proximity of facilities for manufacturing large wind turbine components such as blades to the ports is also important to the ports, and vice versa. This is an important driver of decision regarding the location of blade construction facilities at, or very close to, the ports. Wind farm developers often request for turbine producers to specify how the turbines will be transported to site, and turbine producers in turn are asking ports for their capacity for manufacturing and/or assembling the turbines at the ports.

SERVICE AND INFRASTRUCTURE REQUIREMENTS

The main parameters to be taken into consideration when assessing port's capabilities to serves offshore wind activity include the followings ([16], [17]):

- **Access:**
  - Access by sea (vessel draft, vessel length, beam, air draft)
  - Hinterland Access and intermodal connections
- **Quay side**
  - Dock area, Distance Between Docks (m)
  - Berth, Berth Width, RoRo berth
  - Bearing Capacity, bearing pressure Reinforce Seabed
  - Cranes Availability
- **Manufacture and storage facilities**
  - Manufacturing area (ha)
  - Storage area (ha)
  - Floating storage area
  - Workshop area
- **Other**
  - 24/7 fenced Access and Security
  - No restriction to Load/Unloading Activities (labour agreements etc.)
  - Potable water
  - Electrical connection
  - Channels dredged
  - Helipad

This overview is typical to the offshore wind sector, and certain facilities and infrastructure characteristics may be less relevant for wave or tidal technology. Yet, keeping in mind that offshore wind systems and devices are generally bigger and heavier that wave or tidal stream systems, the information above can serve as a basis for analysing port capabilities in a broader context of offshore renewable energy.

A more detailed overview of the port requirements, including specific criteria for quantitative assessment, can be found in the "assessment of ports for offshore wind" conducted by (2). The study also developed an online "Offshore Wind Port Readiness assessment tool", aimed at port authorities and wind farm developers to assess the readiness of U.S. ports for offshore wind farm projects (http://www.offshorewindportreadiness.com). The assessment consists of opportunity analysis, cost-benefit analysis and case studies, and focuses on the suitability of a port to carry out a certain type of operation for an offshore wind farm project with specific installation vessels. Input for analysis includes:

- port identification and location,
- wind farm characteristics (turbine size, number, foundation type, water depth),
- port type (manufacturing, staging or operation and maintenance)
- vessels (suitable for port type and function)

This tool can serve as a useful reference for assessing port suitability for other types of marine renewable energy sectors.

Finally, it is worth pointing out that port requirements do not only concern infrastructure and services, but also administration and organizational capabilities. Certain elements must be in place if a port wants to serve as a "blue energy hub". Taking the example of the Port of Hull and its offshore wind cluster, industry actors can search for ways to cooperate in order to exploit capabilities efficiently and look for synergies across the supply chain. Areas of cooperation include: manufacture and assembly, divers services, research and development, training and education.

PORT READINESS

Considering infrastructure, facilities, equipment, access and quay side, one can say in brief that if a port is ready for wind power, it is also ready for wave and tidal power. This is true both for installation or operation and maintenance activity. That being said, it is likely that larger flexibility is required from ports for wave energy projects due to the large number of different concepts, devices, components and operations that will be involved.

Furthermore, the potential for exploiting certain MRE resource is obviously depending on whether the geography is propitious or not for the type energy, especially in the case of tidal. However, the decision to invest in and launch a marine renewable energy project does not generally involve the port, which means that this criterion of port location or geography is in fact less relevant for a port's own assessment of readiness.

Rather than depending on other actors for creating activity, it is important for ports to acquire knowledge and competence about the MRE sector, its trends, technologies, main actors and supply chain, in order to understand better the type of capabilities that might be required from a port.

(2) Elkinton, C., Blatiak, A. and Ameen, H. (2014) Assessment of Ports for Offshore Wind Development in the United States. No. 700694-USPO-R-03. Garrad Hassan America, 2014

UNCERTAINTY AND CHALLENGES

Ports wishing to prepare for marine energy deployment are facing a dilemma: there may be a while before any marine energy devices are ready to be deployed and tested in their area, but when these are in fact turning up, the ports need to be already ready to accommodate them. Investing with that level of uncertainty is risky.

Ports face also another challenge related to prioritization of offshore activity. Oil and gas vessels generating much revenue, a port may be tempted to give priority to offshore oil and gas rather than prepare for renewable energy exploitation. Renewable energy activity may be less lucrative for ports, and therefore requires the ports to be able to think on the long term and strategically. For ports involved in large-scale offshore wind deployment, however, large wind installation vessels are also generating large revenues, so the preparedness requirements are more comparable to those for oil and gas vessel in this respect.

FINDING A ROBUST STRATEGY

There does not seem to be a strong necessity for ports to prepare for wave power production in the short term, and probably not in the medium-term either. Hence, it may be smarter to be prepared to adapt to the possibility of wave and tidal developments in addition to offshore wind, and looking for possible synergies among several energy type, than to optimise for future wave and tidal developments only.

One possible strategy that has been identified for ports is to focus on pre-installation phase and testing/demonstration activity. This may include the establishment of facilities in ports for tests that are common across different blue energy technologies (e.g., paint and coating).

INNOVATION CLUSTER AT PORT AREA

During the early R&D phase for MRE technologies, the location of research and development activities are often universities, research centers and R&D institutes. Moving to the pre-commercial phase, with the necessity of test sites for the MRE devices, opens the possibility for ports to get involved with their network and engagement with the supply chain. Harbours can be natural bases for developing, testing, exhibiting and commercializing technology. The experience of some marine energy device developers located in the ports area is that support from the ports on logistics is what has been most useful. In addition to good logistics, another key point that has been suggested for ports to prepare is the ability to support development activity, attract visitors and be able to build interest and confidence in the concepts being developed in the ports area.

Having ports as test sites may also have the effect of anchoring the technology and related business locally. Proximity to the local community may be important, especially if test sites also hosts more extensive R&D facilities and satellite campuses for teaching, as this may ensure fruitful interactions between research, development, testing, local businesses and supply chain, and the community at large. Thinking of ports as the location for MRE innovation cluster may be a good strategy to join forces, share costs and risks, strengthen the supply chain and finally attract investors.

CONCLUSIONS

Marine renewable energy includes very different technologies. On one side we have the so-called ocean energy technologies of which tidal and wave energy represent the biggest share and on the other we have offshore wind, including floating. These technologies receive very different public funding (R&D for ocean energy is only 10% of what is given to wind energy) and they are also in very different development stages.

Offshore wind is basically a mature sector that is getting ready for the challenge of deep water with innovative floating concepts. Tidal stream is reaching the market with involvement of relevant industry stakeholders and the engagement of the supply chain. Wave energy falls behind and suffers for the competition with these other technologies. Nevertheless it is important to remember that the energy that can be tapped with wind and wave energy is more interesting than the one that can be harvested with tidal that will suffer, in the long run, of lack of installation sites.

The role of ports in the development of MRE, if it is to be effective, must take into account the differences between the technologies. First of all, one must take into account that the different technologies are at different stages in their development, and different type of support are needed for, e.g., prototype testing than for full-scale deployment. At the moment, given the dimensions achieved by the offshore wind turbines, it can be said that if a port is ready to assist full-scale wind deployment, it is also ready to assist tidal deployment. It should, however, be noted that dedicated vessels for tidal turbine installation are emerging.

For wave energy, the scale of deployment and of the installations is also expected to be much smaller than for wind in the foreseeable future, but here additional flexibility may be required from the ports due to the larger variation in concepts and requirements. Cooperation between ports and organization in some multiple-ports structure may be key to handle the complexity due to this lack of convergence.

In addition to the preparing to fulfil technical requirements to be able to support MRE installations, ports could also seek to develop as innovation clusters in a wider sense. Ports can have an important role in linking the MRE industry with the local supply chain, in turn attracting skill and generating more activity in the ports area. One alternative is to create an association of ports for the development of MRE that can then become the cluster of the industrial knowledge in the sector. They could co-own installation vessels, define monitoring practices and other activities for prototypes, full scale and farm operations. In addition, more than a short term direct turnover from Ocean Energy operations, it seems more possible that ports can start building up now a network of supply chain and services that will benefit the entire sector.

Finally, port could become the natural choice to inherit the baton from research centers, university and small R&D institutions and play the decisive role for the Ocean energy technologies to finally take off.

APPENDIX

TABLES FROM THE CASE STUDY

TABLE 6: PRE-INSTALLATION

Project identification	Pre-installation activities Activities	 Vessels / cranes / facilities
Wavestar prototype	1) Visits to harbors to get knowledge about equipment. 2) Bathymetry survey. 3) Geotechnical investigation. 4) Sea bed preparation and foundations.	Boat with echo sounders, Diver, Surveyor, Geotechnical equipment (CPT and drill), Diver, Mobile crane (60 tons, 28m/3ton outreach capacity), Special suction dredger, High capacity air compressor
Hywind demo	1) Transport substructure 1000 km to Norway. 2) Preassembly of tower, nacelle and rotor.	Done onshore on quay Dusavik near Stavanger
Anholt full scale	1) Transport. 2) Mount transition piece. 3) Install monopiles.	The monopiles were towed by tug boats directly to the site. Ballast Nedsam's Svanen were used. Jumbo shipping's Jumbo Javelin.
SSG feasibility	1) Sea bed scan, bathymetry and geotechnical survey. 2) Wave resource analysis. 3) Sea bed preparation.	Seismic equipment with potential resolution of app. 1 m down to 20-30 m into the seabed. Sidescan sonar would be able to give information on the seabed structures producing detailed data on sand thickness, chalk depth and bathymetry. Buoy data, long term records. The caissons will be placed on a foundation bed of at least 0.5m thick consisting of a gravel bed. Shallower sections may need to be dredged to the required level.
Voith Hydro	-	-
SeaGen	-	-

TABLE 7: INSTALLATION

Project identification	Pre-installation activities Activities	Vessels / cranes / facilities
Wavestar prototype	1) Dry dock tests. 2) Deep water tests. 3)Towing 4) Position and installation 5) Installation of cable	Dry dock, Tug boat (bollard pull 5 tons) Barge (50*18m), Barge (50*18m) Tug boat (bollard pull 18 ton), Two tug boats (bollard pull 5 tons), Four anchors (3 tons), Four winches (16 ton), Mobile crane (60 tons, 28m/3ton outreach capacity) Electrician & diver
Hywind demo	1) Up ending substructure. 2) Ballasting substructure. 3) Assembly of turbine. 4) Tow out to site 5) Install 13,6 km 24 kV. XLPE submarine cable. 6) Final hook-up. 7) Mooring system installation	One crane barge assisted by two tow vessels, Self-unloading bulker, Aker Solutions multi-purpose service barge C/V Conlift was used. (First time wind turbines are installed with and on floating structures). Normand Pioneer and two hold back tugs. Nexans Skagerrak cable laying vessel. Normand Pioneer
Anholt full scale	1) Wind turbine assembly and installation. 2) install offshore transformer-station 3) Install submarine cable. 4) Floating hotel	Sea Power(older converted freighter). Installed 45 turbines Sea Jack(jack-up-rig). Installed 13 turbines. Sea Worker (jack-up rig). Installed 39 turbines. Sea Installer (A2SEA's turbine installation vessel). Installed 14 turbines in approx.. 40 days. (installed a complete turbine in only 7 hours.) HLV Stanislav Yudin transported the transformer station top section from Aalborg and installed it offshore. Transformer station 1800 tons. Fundament: 5000 tons. Stemat 82 laid the cables from the substation. Toisa Wave laid the cables between the turbine positions. Swiber Else Marie buried the cables. The cables were shipped from Grenaa. Wind Perfection was used as base for the technicians to reduce transport time. It arrived at the site in December 2012.
SSG feasibility	1) Dry dock production of concrete elements 2) Floated into position 3) Finalizing in situ 4) Electrical works	Dry dock multiple caissons, estimated time for 1 caisson 1 month. Flooding the dry dock and towed out of the dry dock. Aligned by two tug boats. Electrical works from the breakwaters.

Voith Hydro	1) Drilling and monopile installation 2) Transportation into location 3) Lift	BAUER Renewables Ltd. drilling for monopile installation. Done in one drilling and grounding operation. An underwater drilling rig newly developed and built by BAUER Maschinen GmbH. For the installation the use of a DP vessel was required. For this project in Orkney the "North Sea Giant", a DP3 vessel, has been used successfully. Gross Tonnage: 18151, Deadweight: 12460 t, Length × Breadth: 153.6m × 30m. Challenging conditions: 37 meters water depth, but also by the extremely strong currents running up to 4.5 meters per second, Hi Flo 4 from mojomaritime-specially designed for tidal installation-, capable of positioning dynamically in up to 5.14 m/s current. lift up to 250 tonnes with the removable A-Frame offshore crane.
SeaGen	1) Foundation installation 2) Monopile installation	Quadropod with four piles drilled and grouted into the seabed. Works direct by Fugro Seacore. To install SeaGen S, the device superstructure (which comprised of the quadropod and the monopole) was positioned on location using the crane barge Rambiz. A work platform was then attached to the superstructure. From the work platform, using the quadropod as a guide, Fugro Seacore drilled four piles into the seabed which were then grouted to secure SeaGen S in place. To drill the sockets the complete turbine structure was positioned and levelled on location and a work platform bolted to the top. Conductor tubes were then set through gates in the platform into guides in the quadrapod base. FSCL positioned its B5 drill on top of these and drilled a 7.4 m socket into hard mudstone. Heavy Lift Barge "Rambiz" (DEME) installing SeaGen S foundation in Strangford. Self elevating platform Neptune from GeoSea has also the right size for tidal: Lengh 60m, Width 38 m, depth 6 m, leg lenght 80 m (extendable to 92m), free deck area 1600 m^2, deck capacity 10 ton/m^2. Morring system, winches, anchors, barge and crane.

TABLE 8: OPERATION

Project identification	**Pre-installation activities** **Activities**	**Vessels / cranes / facilities**
Wavestar prototype	1) Access bridge 2) Maintenance and updates 3) Storage of spare parts 4) Remote monitoring	Done by local blacksmith. Mobile crane (60 tons, 28m/3 ton outreach capacity). Rent of storage room at harbour.
Hywind demo	1) Installation base 2) Remote monitoring 3) Maintenance base	Dusavik: More that 200 sensors, incl.Tower motion – Mooring line tension – Strain in tower and substructure – Metocean data (wind, waves and current) – Typical conventional wind turbine measurements like active power production, rotor speed, etc. Skudeneshavn.

Anholt full scale	1) Operation base 2) Maintenance 3) Remote monitoring	Two cold stores have been converted to offices, storage and workshop facilities on the quay of Grenaa. During operation it will house 70 workers. Most of the maintenance will be done during the summer months. During the winter season, only work to repair and start up faulty turbines will be carried out. High speed service vessels are also based at Grenaa.
SSG feasibility	1) Maintenance of the structure 2) Maintenance of electric cables and generators 3) Remote monitoring	From the breakwaters
Voith Hydro	-	-
SeaGen	-	-

TABLE 9: DECOMMISSION

Project identification	Pre-installation activities Activities	Vessels / cranes / facilities
Wavestar prototype	1) Loosening piles from foundations. 2) Removal from site 3) Towing 4) Sea bed preparation in harbour. 5) Positioning and installation in harbour	Diver with explosives. Operated from pier. Two tug boats (bollard pull 5 tons). Four anchors (3 tons). Four winches (16 ton). Barge (75*20m, 4000 tons). Tug boat (bollard pull 18 ton). Diver. Mobile crane (60 tons, 28m/3ton outreach capacity). Special suction dredger. High capacity air compressor. Two tug boats. (bollard pull 5 tons). Four anchors (3 tons). Four winches (16 ton)
Hywind demo	-	-
Anholt full scale	1) Decommissioning of wind turbines, Removed completely 2) Decommissioning of offshore transformer station. 3) Decommissioning of cables	Similar crafts and methods as during construction, but in reversed order. Similar vessel as used for construction. The process will be the reverse of the cable laying process.
SSG feasibility	-	-
Voith Hydro	-	-
SeaGen	-	-

TABLE 10: LEGAL AND FINANCIAL PRACTICES

Project identification	Legal & financial practices
Wavestar prototype	Permits from authorities for the installation at the site, The use of explosives during decommissioning. Permits from authorities for the installation in the harbour.
Hywind demo	-
Anholt full scale	-
SSG feasibility	Which part is owned by the port authority and which part is of the energy company? and which of the developer?
Voith Hydro	-
SeaGen	-

PROJECTS FROM BEPPO SCREENING

As previously described, a screening of relevant MRE projects was conducted in the BEPPo project to select case studies for the comparison of life cycle phases for different MRE technologies. Below follows the list of projects from the project screening with notes made during the work on collecting information during early 2014. Some of the descriptions are copied from the project web sites and may therefore have varying levels of objectivity and accuracy and may no longer be up to date at the publication of this report. Some comments on the relevance for further study in the BEPPo project are also included.

In parenthesis:
W = wave energy related project
Wi = wind energy related project
FlWi = Floating wind energy
T = tidal energy related project

WAVE ENERGY PROJECTS

1. Bombora (W)

Completed stages:

- Preliminary tank testing (in house) and proof of concept
- Numerical analysis (in house)
- Concept CFD modelling (Curtin University)

Surface gravity waves are created by wind (fetch) blowing on the ocean's surface and forcing the water to move in an orbital fashion. Bombora is actively working with the Ocean Energy Industry Australia (OEIA) and Scottish Development International (SDI a subsidiary of Scottish Enterprise) to assess options for a multi-user, common infrastructure testing facility in Australia.

http://www.bomborawavepower.com.au/project

2. Sea Carpet (W)

Laboratory scale completed. Marcus Lehmann, a Ph.D. researcher on Alam's team, added that one potential application for their system could be to lower the high cost of purifying seawater into drinkable water, helping states – and countries – weather periods of drought. *"The benefit of having a system underwater is that there is minimal visual and physical impact on boats and sea life,"* said Alam. *"Our system would work with no problem in stormy conditions because the water column above the carpet buffers the impact momentum of surging waves. In fact, our carpet is even more efficient when ocean waves are stronger."* Alam estimated that one square meter of a seafloor carpet system could generate enough electricity to power two U.S. households. He added that wave energy from just 10 meters of California coastline, or about 100 square meters of a seafloor carpet, could generate the same amount of power as an array of solar panels the size of a soccer field, which covers about 6,400 square meters. Funding for this research was provided by the American Bureau of Shipping. The researchers also set up a project site via Microryza, a crowdsourcing platform for research projects.

http://taflab.berkeley.edu/uc-berkeley-ocean-wave-energy-converter/

3. Oscilla Power, Inc. (W)

Tested its 1:4 scale power take-off (PTO) in Lake Washington. During the week of May 20, 2013 OPI brought the wave energy harvester to Ohmsett for tank testing. "Similar to the Lake Washington testing, the purpose of the tank tests was to validate that the iMEC-enabled PTO of the system performed in a predictable fashion," said Rahul Shendure, OPI's Chief Executive Officer. Based on this success, OPI will partner with the University of New Hampshire's Center for Ocean Renewable Energy to deploy the 1:4 scale PTO in an open ocean test site in July. In addition, open ocean testing of 1:2 scale and full scale PTOs are planned for 2014.

http://oscillapower.com/about-us/news/

4. CORES (W)

European collaborative research project focusing on new components and concepts for power take off, control, moorings, risers, data acquisition and instrumentation for floating wave energy devices, all tested on a floating oscillating water column (OWC) test platform at sea at the Galway Bay Intermediate Wave Energy Test Site. The project focuses on the installation and monitoring of the OE-BUOY and in general OWC systems.

http://www.fp7-cores.eu

5. PICO AZORES (W)

This is the case of the well-known oscillating water column in Pico island, in the Azores. This plant consists of a hollow reinforced concrete structure – pneumatic chamber – above the water free surface that communicates with the sea and the incident waves by a submerged opening (1+3) in its front wall, and with the atmosphere by a fibre duct with an air turbine (2+4).

http://www.pico-owc.net

6. GIANT (W)

Installation prototype multipoint absorber in Venice lagoon, Italy in August 2013.

http://www.veneziaenergia.it/index.php/progetti/75-energia-dalle-onde

7. DanWEC Wavestar (W)

Installation, operation and decommission of scle 1:2 wave start wave energy device. The concept is that of two Ø5 m floats which activated by the waves move up and down and a hydraulic PTO system which drives a generator that produces electricity.

http://www.danwec.com/en/home.htm

8. Danwec Dexa (W)

Installation and operation of scale 1:4 Dexa wave energy device. Dexawave is a slack-moored floating offshore converter. The test unit consists of pontoons interconnected by flexible joints and the motion between the pontoons activates a hydraulic Power take-off system of 5 kW.

www.dexawave.com

9. Danwec Waveplane (W)

Installation and operation and decommission of a scale 1:4 Waveplane device. Waveplane is a floating V-shaped design, with the stern against the incoming waves. The waves roles into funnels over an "artificial beach", and the water is set in a rotating motion exhausted through turbines on each side generating electricity.

www.waveplane.com

10. SSG (W)

Seawave Slot-Cone Generator. Design and economic analysis of a breakwater implemented with wave energy converters. The Seawave Slot-Cone Generator (SSG) concept is an wave energy converter based on the wave overtopping principle. Three reservoirs placed on top of each other, in which the potential energy of the incoming wave will be stored. The water captured in the reservoirs will then run through the multi-stage turbine.

11. Mutriku and EVE (W)

Design, installation and operation of a breakwater implemented with wave energy converters. Mutriku Oscillating Water Column (MOWC) plant is the first multi-turbine wave energy facility in the world.

http://www.eve.es

12. SOWFIA (W)

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. Relevant information on consenting procedures and mapping of wave energy.

http://www.sowfia.eu

13. FlanSea (W)

Research and Development of a Wave Energy Converter Concept Suited for a Moderate Wave Climate
Parnters: DEME Blue Energy, Port of Ostend, Cloostermans, Contec, Electrawinds, Spiromatic, Ghent University

http://flansea.eu

14. Laminaria (W)

Wave energy project at early-demonstration phase. 1/4 scale model with real sea testing.
The principle is that the vertical surface which must interact with the horizontally travelling wave energy. As the result of the horizontal movement in the water the Laminaria will be subjected to a tilting ans translating motion which is transferred through the mooring ropes to the generators

www.laminaria.be

15. The storm buoy (W)

The storm buoy is meant to be use together with a linear generator to harvest wave energy and is developed by the Norwegian company Ocean Energy. The storm buoy is automatically submerged under the sea surface (about 10-15 meter) during bad weather; consequently it does not need to be dimensioned to handle storms. Ocean Energy is working with Seabased AB and uses their linear generators. The buoy is planned tested with two generators on 25 kW and 50 kW at Runde Environmental Centre in Norway during 2013. Tests will also be conducted at PLOCAN in Gran Canaria.

http://www.ocean-energy.no

16. H-WEC (W)

The Norwegian company Havkraft has developed a wave energy converter called H-WEC based on the oscillating water column principle. Building of a 300 kW prototype has started and the plan is to test it at Runde Environmental Center in Norway.

http://www.havkraft.no

17. SURGE (W)

Simple Underwater Renewable Generation of Electricity (SURGE) is financed by the EU FP7 and started in 2009. A wave energy farm consisting of three 100 kW WaveRoller units was deployed in Portugal and has delivered energy to the Portuguese national grid. The performance of the WaveRoller was said to exceed the expectations. Environmental issues were also investigated and it was concluded that the WaveRollers impact on the environment was minimal.

http://fp7-surge.com

18. Sotenäs Wave Power Project (W)

Fortum and Seabased AB are collaborating on the construction of a wave energy park in Sotenäs, off the western coast of Sweden. Once completed it will be the world's largest of its kind with power generation capability of 10 MW and approximately 420 units. Construction started may 2013 on the first 10 % of the units. Once this is completed an evaluation period of 9 months is planned before the rest of the units are installed within 2015. The concept is based on linear generators.

http://www.seabased.com/

19.Lysekil (W)

The Lysekil wave power project is run by the Center for Renewable Energy Conversion at Uppsala University and the goal is to test wave energy converters over a long period of time. The concept is based on linear generators and different buoys are being used. The impact the generators have on the environment is also studied.

http://www.el.angstrom.uu.se/forskningsprojekt/WavePower/Lysekilsprojektet_E.html

20. Pelamis WavePower (W)

Two second-generation full scale machines are now being tested at EMEC.

http://www.pelamiswave.com

21. Aquamarine Power Oyster (W)

Full-scale device in EMEC, projects in USA and Ireland. The system is a buoyant, hinged flap which is attached to the seabed at depths of between 10 and 15 metres, around half a kilometre from the shore. Essentially Oyster is a wave-powered pump which pushes high pressure water to drive an onshore hydro-electric turbine.

http://www.aquamarinepower.com

22. WaveDragon (W)

Scale 1:4,5in Nissum Breadning, DK. Full-scale study in Wales. The system consists of floating, slack-moored energy converter of the overtopping type that can be deployed in a single unit or in arrays of Wave Dragon units in groups resulting in a power plant with a capacity comparable to traditional fossil based power plants. The Wave Dragon overtopping device elevates ocean waves to a reservoir above sea level where water is let out through a number of turbines and in this way transformed into electricity, i.e. a three-step energy conversion: Overtopping (absorption) -> Storage (reservoir) -> power-take-off (low-head hydro turbines).

http://www.wavedragon.net

23. Poseidon floating power (W+FlWi)

FPP's concept consists of a floating power plant that serves as a floating foundation for offshore wind turbines and transforms wave energy into electricity and thus creating a sustainable energy hybrid.

http://www.floatingpowerplant.com WIND ENERGY PROJECTS

WIND ENERGY PROJECTS

24. Hywind (FlWi)

Hywind is a concept for floating offshore wind turbines in development by Statoil. A 2.3 MW pilot turbine has been in operation outside Kramøy since 2009. A wind farm consisting of 5 turbines with a total capacity of 30 MW is now under planning in the Buchan-Deep area outside Scotland

http://innovate.statoil.com/challenges/hywind/Pages/default.aspx

25. W2Power (FlWi)

Floating semi-submerged platform with two 3.6 MW Siemens turbines. Laboratory testing stage.

26. Anholt (Wi)

400 MW capacity, 111 × Siemens SWP 3.6-120 in 2013- DONG, DK

http://www.anholt-windfarm.com/

27. Horns Rev II (Wi)

209 MW capacity, 91 × Siemens SWP 2.3-93 in 2009- DONG, DK

www.hornsrev2.com

28. Rødsand II (Wi)

207MW capacity 90 × Siemens SWP 2.3-93 in 2010 E.ON, DK

www.eon.dk/Rodsand-2

29. Horns Rev I (Wi)

160 MW capacity 80 × Vestas V80-2MW in 2002 Vattenfall 60%, DONG 40%, DK

www.hornsrev.dk

30. 4C offshore database(Wi)

Offshore wind database for vessels, foundations and turbines.

http://www.4coffshore.com

31. STC (FlWi + W)

Spar–Torus Combination, laboratory testing phase, NTNU

32. WindFloat (FlWi)

WindFloat is a floating foundation for offshore wind turbines designed and patented by Principle Power. A full-scale prototype was constructed in 2011 by Windplus, a joint-venture between EDP, Repsol, Principle Power, A. Silva Matos, Inovcapital, and FAI. The complete system was assembled and commissioned onshore including the turbine. The entire structure was then wet-towed some 400 kilometres (250 mi) (from southern to northern Portugal) to its final installed location 5 kilometres (3.1 mi) offshore of Aguçadoura, Portugal, previously the Aguçadoura Wave Farm. The WindFloat was equipped with a Vestas v80 2.0 megawatt turbine and installation was completed on 22 October 2011. A year later, the turbine had produced 3 GWh.

http://www.principlepowerinc.com

33. HiPRwind (FlWi)

The aim of the HiPRwind (pronounced "hyperwind") project is to investigate, develop and validate new solutions for very large wind turbines for future offshore developments.

http://hiprwind.eu

TIDAL ENERGY PROJECTS

34. Morild II (T)

Morild II is a 1.5 MW tidal energy power plant developed by Hydra Tidal. The power plant is a pilot installation located in Lofoten, Norway and is a floating construction with four two-blade turbines.
http://www.hydratidal.no

35. Kvalsundet (T)

Andritz Hydro Hammerfest have installed a 300 kW tidal power turbine, called HS300, in Kvalsund in Finnmark, Norway. The turbine has now proven to be reliable and has an over 1700 hours production track record. The knowledge gained from this project has led to the development of a 1 MW turbine (HS1000) which is now being tested at the European Marine Energy Centre (EMEC). In cooperation with Scottish Power Renewables (SPR) a pre-commercial array project is planned for the Sound of Islay (ten HS1000 devices) and also a large-scale 95MW commercial array in Pentland Firth.
http://www.hammerfeststrom.com

36. Pulse Stream 100 Demonstration Project (T)

The PS100 began generating electricity in May 2009. It is grid-ties and is exporting power to Millennium Chemicals, a large plant on the South bank of the Humber estuary. Funded through the UK Governments technology program, the project has researched and developed a 100 kW prototype Pulse Hydrofoil, which was deployed in 2008. The UK Secretary of State for Energy, John Hutton, granted planning permission for the deployment of a prototype Pulse Stream Tidal power generator at Stallingborough, close to Immingham in the Humber estuary during April 2008. The generator will feed power ashore directly to a large chemicals works.
http://en.openei.org/wiki/MHK_Technologies/Pulse_Stream_100

37. MHK Projects / Seaflow Tidal Energy System (T)

Marine Current Turbines Ltd has been operating the Seaflow Tidal Energy System project since May 2003. This was an experimental test rig – the successor, SeaGen is intended for commercial applications. 1.2MW rated power for SeaGen prototype; production model will be 1.5MW.
www.marineturbines.com

38. MHK Projects / Paimpol-Brehat tidal farm (T)

Project consists of 4 Open Hydro hydrokinetic turbines at a 35 m depth.
www.openhydro.com

OTHER MARINE RENEWABLE ENERGY PROJECTS

39. WAVEPORT (W)

The WAVEPORT project aims to demonstrate a large scale grid connected 200KW peak generator rated point absorber Wave Energy Converter – for which a small scale prototype has been tested. WAVEPORT will also expedite the development of alternative devices by installing a ten port 'open platform' 1.5MW rated underwater substation pod for the validation of future wave energy converters.
http://www.fp7-waveport.eu

40. Marina Platform (W+Wi+T)

Design of floating platforms including a combination of wind and wave – laboratory scale. Good EU ports mapping based on infrastructures from Edinburgh partner.
http://www.marina-platform.info

41. SI Ocean (W+T)

Identifies hotspots, priorities for technology development, market analysis of Atlantic countries in wave and tidal energy. Start June 2012.
SI OCEAN project sets out to deliver a common strategy for ensuring maximal wave and tidal installed capacity by 2020 - paving the way for exponential market growth in the 2030 and 2050 timeframe. The goal of this project is to engage a large number of European stakeholders to identify practical solutions to removing a range of barriers to large scale wave and tidal energy deployment. Quite broad project, reports are: Technology Status Report , Technology Assessment Consultation , Cost & Barriers Report , Gaps & Barriers Report , Regulatory and Policy Report
http://www.si-ocean.eu/

42. WAVEPLAM (W+Wi+T)

The purpose of WAVEPLAM is to develop tools, establish methods and standards, and create conditions to speed up introduction of ocean energy onto the European renewable energy market, tackling in advance non-technological barriers and conditioning factors that may arise when these technologies are available for large-scale development. Focus on non-technical barriers. There is a report with one page mentioning the «highly specific equipment is needed for the installation of wave energy devices which sometimes will not be adaptable from the existing offshore O&G industry components» but not much detail is given.
http://www.waveplam.eu/

43. EMEC (W+Wi+T)

The European Marine Energy Centre Ltd – Testing facilities for full-scale devices.
http://www.emec.org.uk/

44. MARINET (W+Wi+T)

MARINET, the Marine Renewables Infrastructure Network, is a network of research centres and organisations that are working together to accelerate the development of marine renewable energy technologies – transnational access to laboratories, testing standards, networking and training.
http://www.fp7-marinet.eu/

45. EquiMar (W+Wi+T)

EU FP7 project aiming to develop protocols for equitable testing of marine renewable energy – f attempt for standardization and best practices.

http://www.equimar.org/

46. ORECCA (W+Wi+T)

The goals of the ORECCA project (Off-shore Renewable Energy Conversion platforms – Coordination Action) are to create a framework for knowledge sharing and to develop a roadmap for research activities in the context of offshore renewable energy that are a relatively new and challenging field of interest. In particular, the project will stimulate collaboration in research activities leading towards innovative, cost efficient and environmentally benign offshore renewable energy conversion platforms for wind, wave and other ocean energy resources, for their combined use as well as for the complementary use such as aquaculture e.g. biomass and fishes and monitoring of the sea environment e.g. marine mammals, fish and bird life. WP4 and 5 might be interesting for BEPPo.

http://www.orecca.eu

47. TROPOS (W+Wi+T)

TROPOS is a European collaborative project funded by the European Commission under the 7th Framework Programme for Research and Development, more specifically under the "Ocean of Tomorrow" call OCEAN 2011.1 – Multi-use offshore platforms. The TROPOS Project aims at developing a floating modular multi-use platform system for use in deep waters, with an initial geographic focus on the Mediterranean, Tropical and Sub-Tropical regions, but designed to be flexible enough so as to not be limited in geographic scope.

http://www.troposplatform.eu/

48. MERMAID (W+Wi+T)

In the near future, the European oceans will be subjected to a massive development of marine infrastructures. The most obvious structures include offshore wind farms, constructions for marine aquaculture and the exploitation of wave energy.

The development of these facilities will increase the need for marine infrastructures to support their installation and operation and will unavoidably exert environmental pressures on the oceans and marine ecosystems. It is therefore crucial that the economic costs, the use of marine space and the environmental impacts of these activities remain within acceptable limits. Hence, offshore platforms that combine multiple functions within the same infrastructure offer significant economical and environmental benefits.

MERMAID will develop concepts for the next generation of offshore platforms which can be used for multiple purposes, including energy extraction, aquaculture and platform related transport. The project does not envisage building new platforms, but will theoretically examine new concepts, such as combining structures and building new structures on representative sites under different conditions.

http://www.mermaidproject.eu/

49. H2Ocean

Oceans offer good opportunities for sustainable economic development. More and more, energy, fisheries and transport infrastructures are being established offshore. However, this growing demand for maritime transport, resource extraction, offshore energy, fisheries and aquaculture, is threatening marine ecosystems and sustainable maritime activities. The rational exploitation of oceans space and resources is seen as crucial to enhance European competitiveness in key areas such as renewable energy and aquaculture. In particular, offshore platforms that can combine many functions within the same infrastructure could offer significant benefits in terms of economics, optimising spatial planning and minimising the impact on the environment. H2OCEAN is a project aimed at developing an innovative design for an economically and environmentally sustainable multi-use open-sea platform. Wind and wave power will be harvested and part of the energy will be used for multiple applications on-site, including the conversion of energy into hydrogen that can be stored and shipped to shore as green energy carrier and a multi-trophic aquaculture farm.

http://www.h2ocean-project.eu/

50. Port of Hull (Wi)

"We are creating the largest hub of renewable energy manufacturers and their supply chains in the world". Main pillars include: the Humber (designated a Centre for Offshore Renewable Engineering), Enterprise Zone, Green Port Hull and Able Marine Energy Park (port side development sites), strongest logistics, engineering and marine supply chains, and the University Of Hull as main R&D actor.

http://www.hull.co.uk/template01.asp?PageID=253

SOURCES

[1] Parsons Brinckerhoff (2012) Pentland Firth and Orkney Waters, Onshore Infrastructure Information Note, prepared for The Crown Estate, by Parsons Brinckerhoff, assisted by Lucy Parsons & Community Capital Ltd.
[2] Parsons Brinckerhoff (2012) Pentland Firth and Orkney Waters, Onshore Infrastructure Information Note, prepared for The Crown Estate, by Parsons Brinckerhoff, assisted by Lucy Parsons & Community Capital Ltd.
[3] http://www.wavehub.co.uk/
[4] GL Garrad Hassan, 2013 'A Guide to UK Offshore Wind Operations and Maintenance'. Scottish Enterprise and The Crown Estate.
[5] J. Bard and F. Thalemann (2011) ORECCA. Offshore Infrastructure: Ports and Vessels, Report from project ORECCA WorkPackage 4.1 Infrastructure & Innovations,
[6] EWEA, "The European offshore wind industry - key trends and statistics 2013," January 2014.
[7] Nielsen K. (2012) Ocean Energy Technology Study. DanWEC; Technical Report No.1 for The Alliance for Offshore Renewables.
[8] Nielsen K. (2012) Ocean Energy Technology Study. DanWEC; Technical Report No.1 for The Alliance for Offshore Renewables.
[9] Nielsen K. (2012) Ocean Energy Technology Study. DanWEC; Technical Report No.1 for The Alliance for Offshore Renewables.
[10] Greaves D. et al. (2013) Enabling Wave Power: Streamlining processes for progress, September 2013
[11] Nielsen K. (2012) Ocean Energy Technology Study. DanWEC; Technical Report No.1 for The Alliance for Offshore Renewables.
[12] European Commission (2014) 2014 JRC Ocean Energy Status Report Technology, market and economic aspects of ocean energy in Europe. Report EUR 26342. Prepared by Davide Magagna and Andreas Uihlein, European Commission, Joint Research Centre, Institute for Energy and Transport.
[13] European Commission (2014) 2014 JRC Ocean Energy Status Report Technology, market and economic aspects of ocean energy in Europe. Report EUR 26342. Prepared by Davide Magagna and Andreas Uihlein, European Commission, Joint Research Centre, Institute for Energy and Transport.
[14] Navigant Consulting (2013) Global Evaluation of Offshore Wind Shipping Opportunity. Prepared for the Danish Shipowners' Association, by Bruce Hamilton, Navigant Consulting, Inc, Monday, December 2, 2013
[15] J. Bard and F. Thalemann (2011) ORECCA. Offshore Infrastructure: Ports and Vessels, Report from project ORECCA WorkPackage 4.1 Infrastructure & Innovations.
[16] D'Amico, F. (2013) What are the port requirements for future offshore projects and how will port facilities affect vessel choices ?, Offshore Vessels and Access, May 14-16, 2013, London.
[17] Elkinton, C., Blatiak, A. and Ameen, H. (2014) Assessment of Ports for Offshore Wind Development in the United States. No. 700694-USPO-R-03. Garrad Hassan America, 2014.

AUTHORS

Lucia Margheritini is Associate Professor at the Department of Civil Engineering, Aalborg University. She has an MSc in Environmental Engineering with specialization in Coastal Engineering and Ports. She holds a PhD in Wave Energy Development and Commercialization and her work is now focused on multidisciplinary and international activities connected to wave energy and offshore wind.

Aalborg University
Sohngårdsholmsvej 57, 9000, Aalborg (Denmark) - T: +45 9940 2924
www.civil.aau.dk - Lucia Margheritini - lm@civil.aau.dk

Aghate Rialland is a research scientist in the field of maritime logistics, with background in strategic management and organization. At the department of Maritime Transport Systems of MARINTEK since 2006, she´s been working with Norwegian and European research projects within planning, operations, performance and business collaboration towards shipping, ship management and port operations.

MARINTEK
P.O. Box 4125 Valentinlyst, NO-7450 Trondheim (Norway) - +47 4165 2323
www.sintef.no/home/marintek - Agathe Rialland - Agathe.Rialland@marintek.sintef.no

Iver Bakken Sperstad is employed as a research scientist at SINTEF Energy Research in Trondheim, Norway, and has since 2012 been working there in the research group on Power System Asset Management. He holds a PhD in theoretical and numerical physics from the Norwegian University of Science and Technology (NTNU). At SINTEF Energy Research, he has primarily been working on simulation modelling of operation and maintenance and logistics strategies for offshore wind farms.

Sintef Energy Research
P.O. Box 4761 Sluppen, 7465 Trondheim (Norway) - T: +47 73597260
www.sintef.no/home/SINTEF-Energy-Research - Iver Bakken Sperstad - iver.bakken.sperstad@sintef.no

BEPPO PROJECT MANAGEMENT TEAM

Wim Stubbe (Port of Oostende)
Simona Margarino (€ureka Consult)

PROJECT LEAD PARTNER

AG Port of Oostende
Slijkensesteenweg 2, 8400 Oostende (Belgium) - T: +32 59 340 711
www.portofoostende.be - Wim Stubbe - Wim.Stubbe@portofoostende.be

PROJECT MANAGEMENT & COMMUNICATION SUPPORT

€ureka Consult
Friedrichstrasse 102, 40217 Düsseldorf (Germany) - T: +49 1575 6842049
www.eurekaconsult.de - Simona Margarino - simona@eurekaconsult.de

BEPPo (Blue Energy Production in Ports)

The BEPPo project focuses on Blue Energy (wave/tidal) and its complementarity with traditional (gas/oil/coal) & new (wind/biomass) sources of power, building on the innovation capacity of ports to become bases for the production of integrated sustainable renewables, thus ensuring reliable & affordable supplies of clean, green energy. It provides a unique opportunity to understand how to develop marine energy platforms in ports and promote local business opportunities to accelerate economic growth in port regions.

01/06/2013 - 31/05/2015

€597.300

7 PARTNERS FROM BELGIUM, DENMARK, NORWAY, UK:

- AG Port of Oostende (AGHO) – project Leader
- Power-Link, University of Ghent
- Highlands & Islands Enterprise (HIE)
- Wave Energy Research Group, Aalborg University
- Danish Wave Energy Centre (DanWEC)
- Norwegian Marine Technology Research Institute (MARINTEK)
- SINTEF Energy Research

This project is part financed by the EU through the European Regional Development Fund and the North Sea Region cooperation Programme 2007-2013.

The Interreg IVB North Sea Region Programme

Investing in the future by working together for a sustainable and competitive region

BEPPo

Blue Energy Production in Ports

Port Oostende energy port