

# Ocean Energy Forum

## DRAFT OCEAN ENERGY STRATEGIC ROADMAP BUILDING OCEAN ENERGY FOR EUROPE



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This Strategic Roadmap was commissioned by the European Commission Directorate-General for Maritime Affairs and Fisheries, Atlantic, Outermost Regions and Arctic and produced in collaboration with the Ocean Energy Forum.

The Ocean Energy Forum has been set up to bring together stakeholders to develop a shared understanding of the problems faced by the Ocean Energy sector and to collectively devise workable solutions.

The Forum is formed of three workstreams: Environment & Consenting, Finance and Technology. Each workstream has a Steering Committee and a Chair. The three workstreams allow consensus building to take place at a topic-specific level.

The Forum is supported by a Secretariat, appointed April 2015, whose main role is to help ensure the production and timely delivery of the Strategic Roadmap. The Secretariat services form part of a Programme whose implementation has been delegated to the Executive Agency for Small and Medium-sized Enterprises (EASME).

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# Ocean Energy Forum

## **DRAFT OCEAN ENERGY STRATEGIC ROADMAP**

BUILDING OCEAN ENERGY FOR EUROPE

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# EXECUTIVE SUMMARY

## EXECUTIVE SUMMARY

Ocean energy is abundant, geographically diverse and renewable. Under the right regulatory and economic conditions, ocean energy could meet 10%<sup>1</sup> of the European Union's (EU) power demand by 2050. Europe's seas and oceans, therefore, could play an important role in one of the biggest challenges facing the EU today; an energy transition from a system based on imported fossil fuels to a flexible and interconnected system based on clean and renewable infinite domestic resources.

Policy in Europe has been very successful in taking the first generation of renewable energy technologies, such as solar and wind, to commercially competitive levels. The EU will however need other technologies to further diversify its low-carbon generation capacity, if it is to meet its objective of reducing greenhouse gas emissions to 80–95% below 1990 levels by 2050<sup>2</sup>. By 2050 power generated by the ocean energy sector could avoid the equivalent of 276 m tonnes of CO<sub>2</sub> emissions annually<sup>3</sup>.

Investments are required (Europe needs to continue to invest and support ocean energy) to yield significant rewards: a new industrial sector developed in Europe, creating jobs in its regions throughout the local supply chain. Spurred by ambitious renewable energy policies, the European ocean energy sector is a world leader today, home to the most advanced technology so far. This technological advantage, as well as the need to stay close to the resource to reduce costs, ensures that this manufacturing remains European.

The EU needs industrial success stories, and ocean energy can be one of those. With the right support over the coming decade, Europe will maintain leadership in a global market, worth a potential €653 bn (cumulative, undiscounted) for 2010–2050<sup>4</sup>, and an annual market of up to €53 bn, hugely benefiting the European economy. Successful development of a competitive European ocean energy industry would also place European industry in a prime position to seize export opportunities in the global market.

Ocean energy technologies are at varying stages of development in Europe; each uses a different ocean resource, and each has its own specific electricity production pattern. To reach a stage where ocean energy technologies can be rolled out industrially and to truly reap the rewards of Europe's early investments, the technologies need to go from R&D and prototype through to demonstration and pre-commercial phases.

During each development phase, all ocean energy technologies have to overcome similar challenges. Demonstration and validation of the technology is fundamental to the sector's development, as commercial lenders and financiers are often reluctant to invest in unproven or little understood technologies. This reflects the current situation, as power producers have moved from strategic investments in new technologies to a focus on returns.

Six priority areas have been identified to allow technology to progress and decrease its risk profile:

- 1 **Testing** sub-system components and devices in real sea conditions;
- 2 Increasing the **reliability and performance** of ocean energy devices allowing for future design improvements;

1 Ocean Energy Europe has estimated that 100GW of ocean energy capacity could be deployed in Europe by 2050, producing around 350TWh of electricity. The European Commission's EU Energy, transport and GHG emissions: trends to 2050 reference scenario 2013 estimates total EU power generation in 2050 at 3.844TWh.

2 European Commission (2011). Communication for the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions. 'Energy Roadmap 2050' (COM(2011)885 final of 15 December 2015)

3 Calculations based on Ocean Energy Europe and European Commission's EU Energy, transport and GHG emissions trends to 2050 reference scenario 2013

4 Carbon Trust (2011). Marine Renewables Green Growth Paper

- 3 Stimulating a dedicated *installation and operation and maintenance* value chain, to reduce costs;
- 4 Delivering *power to the grid*, with hubs to collect cables from ocean energy farms and bring power to shore;
- 5 *Devising standards and certification*, to facilitate access to commercial financing; and
- 6 *Reducing costs and increasing performance* through innovation and testing.

For each development phase the technological, financing and regulatory challenges to address these six priority areas are different. They will require bespoke actions from all stakeholders as well as fit-for-purpose public and private funding and financing solutions.

#### **RESEARCH AND DEVELOPMENT AND PROTOTYPES: TESTING AND VALIDATION THROUGH GRANT PUBLIC FUNDING**

Further device innovation and component improvements, plus rigorous testing are required before larger investments can be made. Several technologies have reached this stage of development.

R&D and prototypes projects offer little revenue in terms of electricity sales, so require grant funding. Early R&D can be funded from companies' balance sheets and research grants, but larger budgets are required to leverage enough private capital for prototypes. Public authorities should supply appropriate levels of funding to ensure that enough technologies reach demonstration stage and Europe's technology leadership is maintained.

Public funding ensures collaboration between otherwise competing companies, as well as data and knowledge sharing to the benefit of the entire industry, thus accelerating the sector's pace to industrial roll-out.

As test centres for R&D and prototypes are spread across the EU, a common language for test results is required. EU-wide standardised testing would help developers access finance by enabling investors to compare the different technologies based on objective measurable criteria.

#### **RECOMMENDATIONS FOR R&D AND PROTOTYPES**

- Member States and the EU to maintain a high level of innovation and R&D support.
- Industry to define and adopt standards for testing devices and components.
- Industry and Member States to establish a European scheme to validate components and subsystems in the less mature ocean energy technologies.
- Member states to fully engage with the European Energy Research Alliance (EERA) Ocean Energy Joint Programme.

#### **DEMONSTRATION AND PRE-COMMERCIAL: CONTRACTING FOR THE FIRST ELECTRICITY FROM THE OCEAN**

Proven prototypes must demonstrate their technical viability then identify cost reduction pathways in order to become financially viable through industrial roll-out.

Single devices are well understood, yet uncertainties on production level and maintenance requirements remain. These uncertainties imply a higher financial risk, preventing access to commercial bank loans.

The pressing need for upfront finance requires that investment support schemes remain key for demonstration and pre-commercial ocean energy projects. As projects begin to generate and export electricity to the grid, it will be possible to complement investment support and ocean industry balance sheets with a mix of revenue support and risk financing.

European state aid guidelines should also better accommodate the funding requirements of emerging technologies such as ocean energy, and national authorities offer guidance to the industry on combining diverse sources of funding, thus ensuring better access to existing finance. The EIB and national investment banks should also support the development of ocean energy by unlocking risk capital.

## RECOMMENDATIONS

- National programmes
- National authorities should leverage available EU finance e.g. European Structural and Investment Funds, ERA-Net co-fund, Innovation Fund (NER400), European Fund for Strategic Investment – to fund 10 demonstration and pre-commercial ocean energy projects.
- National authorities should cover the cost of infrastructure to connect at least 300MW of ocean energy devices EU-wide, with installed cable and secured grid connection, thus reducing the risks and costs to industry associated with site selection and development. Areas for smaller, close to shore devices and farms should also be considered.

## INDUSTRIAL ROLL-OUT: PROVEN TECHNOLOGY, DECLINING COSTS, COMMERCIAL FINANCE

As ocean energy technologies begin developing industrially, project costs will start to fall, generating cheaper electricity. With enhanced knowledge, ocean energy deployments will increasingly be financed on the basis of revenues from the sale of electricity. Public support, therefore, can shift from upfront investment support (grants) to power production-based support such as green certificates or feed-in premium tariffs.

Industry can, moreover, reduce its balance sheet investments as the technologies are better understood by commercial lenders. Public support schemes will help leverage commercial loans at competitive rates.

## RECOMMENDATIONS

- The ocean energy sector to develop guidance and standards on optimal device performance and farm lay-out as more farms are put in the water.
- The ocean energy industry to cooperate with insurers and finance institutions to develop appropriate financial products.
- Governments to establish long-term revenue support schemes ensuring predictability of income for ocean energy projects.

## PLANNING, CONSENTING AND ENVIRONMENT

Social acceptance of ocean energy is currently strong. However, forward planning is necessary to prevent future conflicts with other sea users and to ensure minimal impact of ocean energy deployment on the marine environment.

Obtaining consent for an ocean energy project can be time consuming and costly. Consenting processes need to be tailored to the characteristics of ocean energy and be proportionate to the potential environmental risks posed. A risk-based approach to ocean energy licensing, using the findings from existing studies and deployed projects, should be considered. Licensing should also take into account the size of projects and devices to ensure small-scale projects are not overburdened with irrelevant procedures. Good practice suggests that a one stop approach to consenting is preferable.

## RECOMMENDATION

- National consenting authorities, the European Commission and the ocean energy industry to set up a planning and consenting working group to develop licensing guidance. This will ensure that best practice and experience in consenting ocean energy projects is shared and used to improve and streamline processes.



SECTION 1  
INTRODUCTION

## SECTION 1 INTRODUCTION

### 1.1 Europe needs ocean energy

The Ocean Energy Draft Strategic Roadmap reflects the common vision of the ocean energy sector, through a series of meetings, workshops and open-session conferences, and reflects the preliminary analysis undertaken in October 2015. It aims to identify a path forwards, building on European leadership in ocean energy, and developing technologies that can meet a significant amount of Europe's power demand over the next 35 years.

#### TECHNOLOGY LEADERSHIP AND INDUSTRIAL SUCCESS

Ocean energy is abundant, geographically diverse and renewable. Developing technology to exploit this potential offers opportunities for Europe to develop a new industrial sector, create jobs and capitalise on its first mover status to cultivate significant export opportunities.

The global market for ocean energy could see 337 GW<sup>5</sup> of installed capacity by 2050. The aspiration stated by the ocean energy sector is to install up to 100 GW in Europe<sup>6</sup>. A techno-economic scenario study for EU power supply in 2050<sup>7</sup> projects 14–26 GW of wave and tidal technology installation if not all technological barriers are overcome.

Today 45% of wave energy companies and 50% of tidal energy companies are from the EU<sup>8</sup>. The EU is in need of industrial success stories, and ocean energy can be one of those. The right support over the coming decade will enable Europe to maintain leadership in a global market, worth a potential €653 bn (cumulative, undiscounted) for 2010–2050<sup>9</sup>, and an annual market of up to €53 bn, hugely benefiting the European economy.

#### OCEAN ENERGY WILL BRING MUCH NEEDED INVESTMENTS AND JOBS TO THE ECONOMY

The ocean energy supply chain is truly pan-European, with both leading companies and supply chain SMEs spread across the EU's Member States, including landlocked countries like Austria, with long experience in hydro equipment manufacturing.

Moreover, ocean energy is deployed in coastal areas, some of which have been affected by economic restructuring in recent decades. Putting ocean energy farms in the water will complement Europe's regional growth agenda by creating high-skilled jobs and sustainable economic development. Ocean energy also provides under-used ports and harbours with an opportunity to innovate and specialise as hubs for blue growth.

#### OCEAN ENERGY PROVIDES A SOLUTION FOR EUROPE'S OVER-RELIANCE ON FOSSIL FUEL IMPORTS

The EU is in a precarious energy position. The bloc continues to rely on imports for 53% of its energy needs, costing €400bn a year<sup>10</sup>. Dependence on a handful of exporting countries is becoming increasingly problematic.

5 Ocean Energy Systems (2014). Annual Report, 2013

6 Target ambition estimated by members of Ocean Energy Europe, stated in European Ocean Energy Association (2013). Industry Vision Paper, 2013

7 Pfluger *et al.* 2011. Fraunhofer ISI. Tangible ways towards climate protection in the European Union (EU Long-term scenarios 2050)

8 Joint Research Centre (2015). 2014 JRC Ocean Energy Status Report

9 Carbon Trust (2011). Marine Renewables Green Growth Paper

10 European Commission (2011). Communication for the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions. 'Energy Roadmap 2050' (COM(2011)885 final of 15 December 2015)

Renewables are the only viable source to power Europe in the coming decades. Based on projections, ocean energy has the potential to generate 350 TWh of electricity meeting up to 10% of Europe's demand by 2050<sup>11</sup>.

#### **OCEAN ENERGY CAN PLAY A CENTRAL ROLE IN THE TRANSITION TO A LOW-CARBON ECONOMY AND THE FIGHT AGAINST CLIMATE CHANGE**

Policy in Europe has been very successful in taking the first generation of renewable energy technologies, such as solar and wind, to commercially competitive levels. The EU will however need other technologies to further diversify its low-carbon generation capacity, if it is to meet its objective of reducing greenhouse gas emissions to 80 – 95% below 1990 levels by 2050<sup>12</sup>. Power generated by the ocean energy sector could avoid the equivalent of 276m tonnes of CO<sub>2</sub> emissions annually<sup>13</sup> by 2050.

#### **OCEAN ENERGY CAN LEVERAGE EXTRA VALUE BY EXPLOITING SYNERGIES AND KNOWLEDGE TRANSFER ACROSS THE BLUE ECONOMY**

Other marine sectors have both a lot to offer and a lot to gain from the development of the ocean renewable energy sector. Today, companies from sectors such as naval construction, offshore oil & gas, offshore wind and dredging are amongst the leading players in the ocean energy sector. These companies are creating extra value from their existing knowledge by using it to exploit new growth opportunities in the emerging ocean energy industry.

#### **OCEAN ENERGY CAN REDUCE ISLANDS' DEPENDENCE ON COSTLY GENERATION**

The remoteness of small islands and other locations can mean high electricity costs due to reliance on oil generators; ocean energy can provide a viable, more competitive solution. The higher price paid for electricity in these locations, will allow ocean energy to be deployed with less support whilst ensuring a return on investment.

### **1.2 Ocean energy: The technologies**

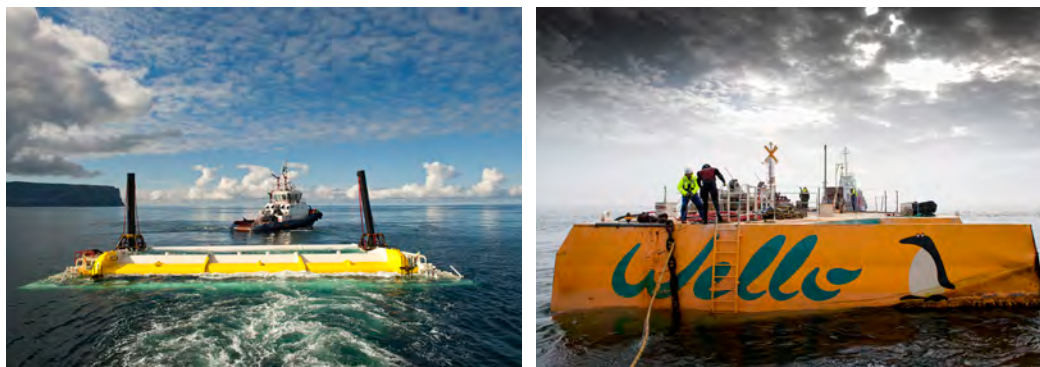
Ocean energy comprises five distinct technologies. The variations in ocean resource and location will require different technological concepts and solutions.

**Wave energy** converters derive energy from the movement of waves and can be located flexibly, on the shoreline, the nearshore or offshore at depths of over 100m – in order to harness the available energy most efficiently. A range of full-scale prototypes have been deployed, however, further technology development, testing and demonstration are required prior to commercialisation and industrial roll-out.

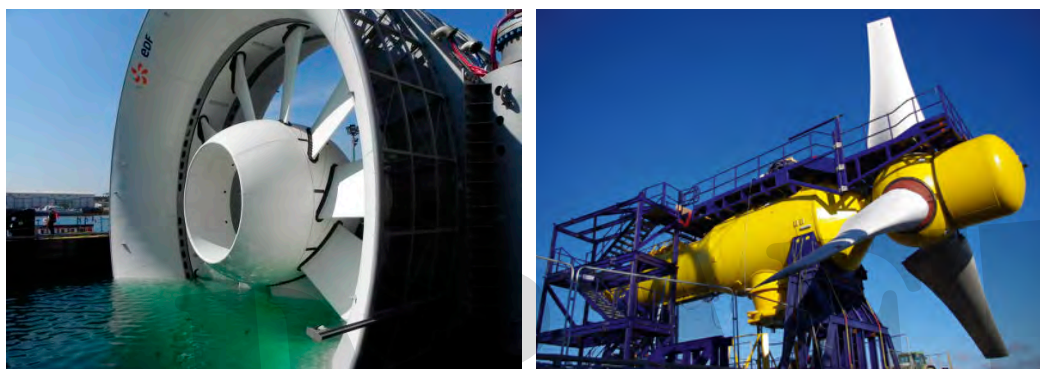
11 Ocean Energy Europe has estimated that 100 GW of ocean energy capacity could be deployed in Europe by 2050, producing around 350 TWh of electricity. The European Commission's EU Energy, transport and GHG emissions: trends to 2050 reference scenario 2013 estimates total EU power generation in 2050 at 3,844 TWh.

12 European Commission (2012). Energy Roadmap 2050

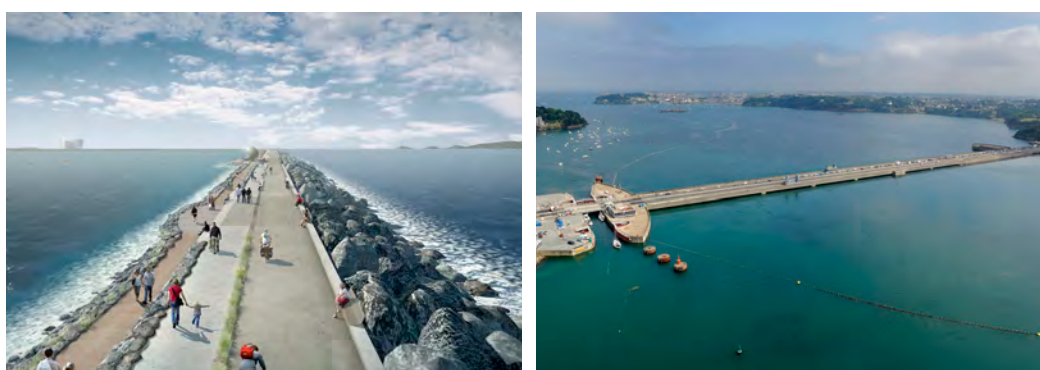
13 Calculations based on Ocean Energy Europe and European Commission (2013). EU Energy, transport and GHG emissions trends to 2050, reference scenario 2013



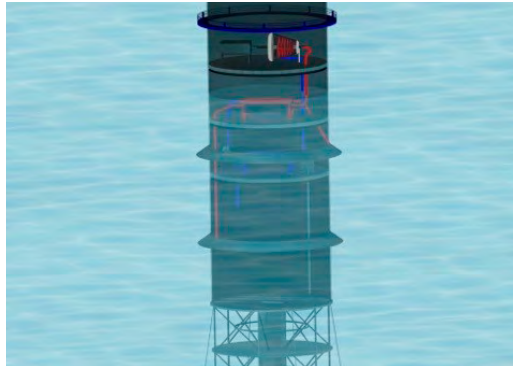
**Tidal stream** turbines harness the flow of the currents to produce electricity. Tidal turbines can be fixed directly to and mounted on the seabed, or tethered/moored to the seabed and buoyant, floating on surface or in mid water.



**Tidal range** uses the difference in sea level between high and low tides to create power. Tidal range technology uses the same principles as conventional hydropower, and requires a barrier to impound a large body of water, driving turbines generating electricity. Tidal range is the more established ocean energy technology, with several projects generating power around the world.



**Ocean Thermal Energy Conversion (OTEC)** exploits the temperature difference between deep cold ocean water and warm surface waters to produce electricity via heat-exchangers. OTEC is suited to oceans where high temperature differences will yield the most electricity. A number of demonstration plants are being developed in EU overseas territories opening up export opportunities.



**Salinity gradient** power generation utilises the difference in salt content between freshwater and saltwater, found in areas such as deltas or fjords, to provide a steady flow of electricity via osmosis. Deployment potential is significant around Europe, however, further technology development is required to bring salinity gradient to maturity.



### 1.3 Ocean energy outlook: 850 MW cumulative capacity by 2020

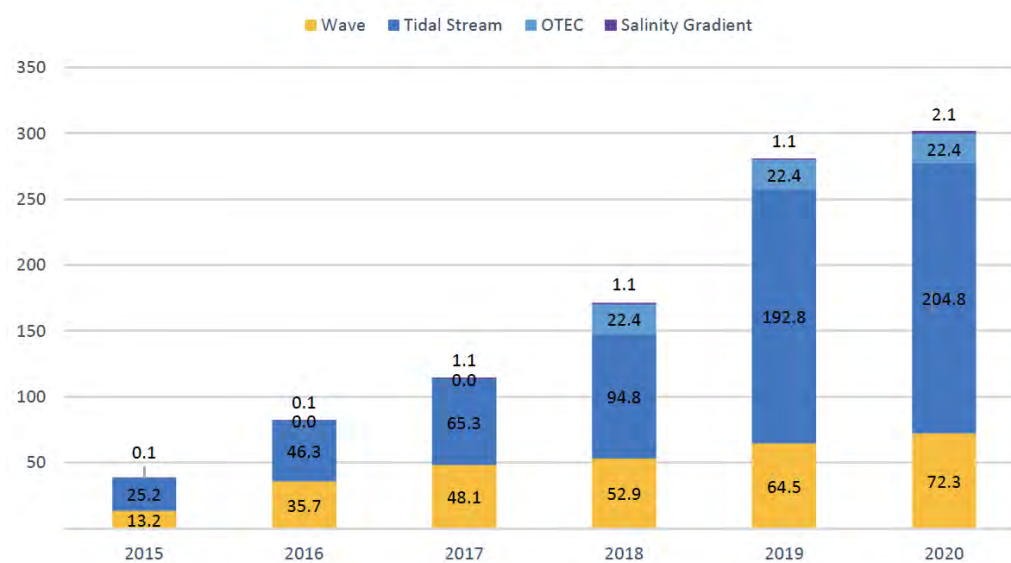
Over the past 10 years the ocean energy industry has invested an estimated €1 bn in capital to move concepts from the drawing board to deployment in EU waters. It is estimated that ocean energy deployment will reach a cumulative capacity of 850 MW by 2020, which will require further investment to be unlocked.

Ocean energy's first deployment in Europe was in 1966 when a 240 MW tidal range project was built in La Rance, France. For three decades there was little deployment of ocean energy technologies until 1999, when a wave energy device was tested in Portugal.

By mid-2015, 11 MW of tidal stream and 8 MW of wave energy had been deployed, bringing cumulative deployed capacity to 261 MW. It is expected that by the end of 2015, cumulative deployed capacity will be over 270 MW, showing that ocean energy technologies are now ready to accelerate their deployment.

The industry association Ocean Energy Europe has identified projects at different stages of development (excluding tidal range) that would lead to a cumulative capacity of 302 MW by 2020 (Figure 1). Total deployed ocean energy capacity in 2020 including tidal range could therefore be 853 MW.

Figure 1. Expected cumulative deployed ocean energy capacity in Europe by technology (excluding tidal range<sup>14</sup>)



Source: Ocean Energy Europe, Kit in the water database.

National and EU funds have been instrumental in leveraging private investments in the industry. It is expected that between 2015 and 2020 the European ocean energy industry could spend €0.8 bn to €1 bn in R&D and a further €3.5 bn to €4.5 bn to deploy the projected capacities. This will only happen with continued support from the EU and national funds and high-risk public financing products, such as the European Investment Bank's InnovFin EDP<sup>15</sup>.

<sup>14</sup> Tidal range has not been included in the figure as its larger scale would not allow discrimination between the other technologies. A 240 MW tidal range barrage has been in operation since 1966 and a tidal range lagoon of 320 MW is expected to be completed in 2021.

<sup>15</sup> InnovFin EDP was set up to provide risk financing for innovative energy technology projects in the form of loans and loan guarantees to first-of-a-kind commercial scale industrial demonstration projects in the field of renewable energy



**SECTION 2  
PRIORITY AREAS FOR  
TECHNOLOGICAL PROGRESS**

## SECTION 2 PRIORITY AREAS FOR TECHNOLOGICAL PROGRESS

Some technological challenges are equal across the entire ocean energy sector, others are technology-specific. Each technology will require access to public and private finance to advance. Finance must be applied appropriately to both generic and technology-specific priorities.

### 2.1 Main technology focus areas

The following technological aspects, relating to performance and cost reduction, must be addressed to reduce sector-specific risks.

**Testing and modelling.** Validation of concepts and development of high-definition modelling through to demonstration in real conditions and deployment is of prime importance for the sector's development. This step is not linear; both demonstration and modelling on sub-systems, components and the entire device in real and controlled environments are needed at the different stages of the technology's development.

**Reliability and survivability.** Increasing the reliability of ocean energy devices by developing monitoring systems in real conditions will identify potential failure modes and subsequently improve designs. A high priority must be increasing the reliability and survivability of devices to protect investment and ensure long-term availability of power production and income.

**Installation and logistics.** There is significant scope for utilising existing infrastructure (such as harbours, vessels, power cables, grid connection) and processes (including training, health and safety) from other marine industries. However, a new generation of waterborne and sub-sea solutions is needed to match the specificities of ocean energy devices and reach the targeted costs per kWh.

**Power generation and grid.** Devices and farms must be able to deliver grid compliant electricity. A key missing technological component, fundamental to the development of ocean energy on a large scale, is a central power electronic hub to collect and efficiently transmit electricity from multiple devices to shore through an export cable.

**Standardisation of the industry leading to certification.** De-risking the industrial roll-out and accessing finance will be enabled through the availability of suitable standardisation processes, building on existing guidelines and sector knowledge.

### 2.2 Technology-specific priorities

The objective for all ocean energy technologies is to become competitive energy sources. As ocean energy devices are rolled-out on an industrial basis, the cost of producing electricity should start decreasing and tend towards €100 per MWh. To achieve this, it is necessary to tackle the specific challenges of each technology and move them along their development paths.

#### 2.2.1 Wave: Innovation to deploy large farms by 2030

Wave energy converters (WECs) have progressed significantly over the last decade, from scaled testing to full-scale prototypes. Field demonstrations have shown the importance of further R&D focussing on subsystems and components with an increasing number of innovative concepts.

A minimum of 10MW of full-scale wave energy converter prototypes should be deployed by 2020. The learnings from this phase will allow enhanced whole WEC systems through improvements of sub-systems and components. Subsequently, the most promising consolidated concepts should be demonstrated in farms for a total of a further 100MW by the mid-2020's.

- Prioritise subsystems and components. Research, development and innovation in wave energy should focus on key components and subsystems, tested both individually and as part of the whole device.
- Power take-off (PTO) systems. PTO systems require near full-scale demonstration in real sea conditions for validation.

### 2.2.2 Tidal stream: Competitive from 2030, bolstering EU worldwide leadership

Tidal stream technology is at a stage along its development path which requires full-scale demonstrations supported by the right policy and economic conditions. It is expected that the demonstration farms phase will be underway by 2020, by which time around 200MW of capacity could be deployed in Europe alone. The tidal stream sector should therefore strive to deploy ten farms of 20MW to 30MW with devices laid out in several arrays across Europe during the mid-2020s.

- Prioritise deployment. Increase reliability of devices through testing and deployment, permitting the certification of sub-systems and components.
- Focus research, development and innovation efforts on technologies and processes necessary to develop and optimise farms such as subsea power hubs, lay-out optimisation, and characterisation of the environment.

### 2.2.3 Tidal range: Ready for roll-out in Europe

The Swansea Bay Tidal Lagoon project (320MW), expected to be operational in 2019, will set the standard for future development in tidal range projects. The lagoon set-up is novel but the power generating technology is well understood as it has been used in early tidal range projects such as La Rance, France and is informed by traditional hydro-electricity projects.

With the accumulated know-how from past projects and a successful project in Swansea Bay, tidal range technology will be ready for industrial roll-out. A further full-scale project (yet to be outlined) of between 1 GW and 2 GW will start tidal range on the path to significant energy cost reductions.

Tidal range's main challenge is not the power producing technologies *per se*, but rather how the individual aspects to build and operate the project fit together and the overall economics of upfront capital expense and long-term payback of up to fifty years. There are also consenting challenges that require innovative approaches to facilitate project development.

- Support research and demonstration including environmental approaches.
- Promote enabling policy frameworks to streamline and facilitate consenting processes.

### 2.2.4 Ocean Thermal Energy Conversion (OTEC): Exporting European technology

The construction of a 14 MW OTEC project (NEMO) in Martinique, France, demonstrates the potential for the EU to develop a technology and know-how for export around the world's tropical regions. Moreover, the potential for high average availability factors could rapidly lead to significant reductions in cost of energy.

The OTEC sector should connect up to 20 MW of scaled prototypes by the early 2020s, leading to the demonstration of full-scale power plants of around 100 MW.

Subsequently, OTEC technology could be rolled-out industrially taking advantage of the export markets.

- Focus efforts on improving heat exchangers for OTEC use.
- Develop materials and manufacturing processes to significantly scale-up the power plant, notably the cooling pipes' dimensions, to allow a better yield.

### 2.2.5 Salinity gradient: First large plant by 2030, demonstrating EU state-of-the-art

Salinity gradient is in the R&D phase, with up-scaling to megawatt prototypes expected around 2020. While still research driven, the technology could grow rapidly and become increasingly commercial.

The development of a 50 MW demonstration plant by mid-2020s is a necessary first step towards subsequently deploying a full-scale (200 MW) plant. If successful, module salinity gradient storage solutions could be developed and used in combination with other renewable energy systems by 2030.

- Focus research on membranes, bio-fouling and materials.

### 2.3 Timeframe for creating a new power industry

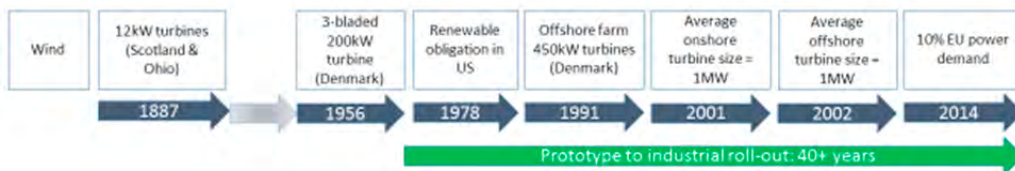
Moving a new power generating concept to an industrial reality, and feeding substantial amounts of electricity into the grid, requires decades of investment, innovation and applied learning. Ocean energy development has advanced significantly, and follows a similar development timeline to that of other energy industries.

As an example, modern wind turbines commenced deployment in the early 1970s on the back of the oil crisis. In 2014, over 40 years later, installed wind turbines in the EU can meet around 10% of EU electricity demand<sup>16</sup>. Ocean Energy Europe expects similar penetration of ocean technologies on the power market by 2050 – some 50 years after the sea tests for the first wave energy device and 40 years after sea tests for the first tidal stream device.

The average size of wind turbines in 1991 was 224kW, and it took until 2001 for turbines to reach 1 MW. Similarly, the first offshore wind turbines deployed in 1991 had a rated capacity of 450kW. Eleven years later, in 2002, the average size reached 2 MW. This occurred through a learning process based on establishing small-scale working generators which were then scaled up. Once the technology was developed models for specific uses could be developed.

To harness different resources viably, the ocean energy industry is developing concepts, including: small wave devices for calmer seas such as the Mediterranean; smaller tidal turbines for slower currents or near-shore areas; and devices that can be attached to harbour walls, dams, bridges and other existing infrastructure. A range of ocean energy devices must be developed to take into account the range of different sea conditions.

Figure 2. Development of wind turbines, from early experiments to industrial roll-out



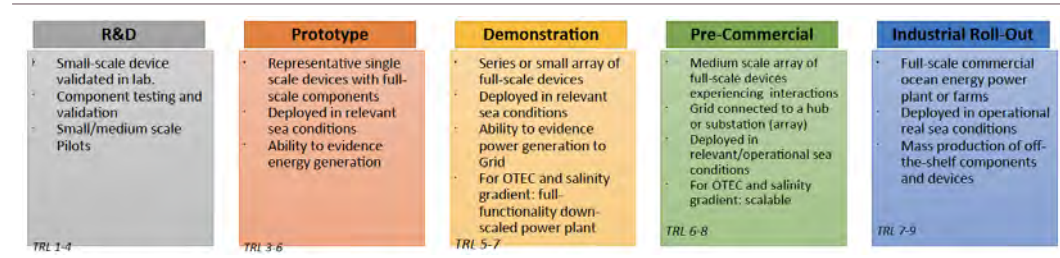
Source: Ocean Energy Europe, adapted from European Wind Energy Association, Danish Wind Industry Association, US Office of Energy Efficiency and Renewables.

## 2.4 A phased approach to technological progress

Technological and commercial maturation occurs over several phases, or Technology Reference Levels (TRL), from concept design to commercial deployment at sea.

Moving from one phase to the next requires increased deployment, leading to technological and hence economic improvements. To assess and analyse the different steps to industrial roll-out, the following phases and criteria have been identified.

Figure 3. Phases of Technology Reference Levels



Source: Ocean Energy Europe. Generated through consultation with Ocean Energy Europe and the Ocean Energy Forum; preliminary analysis at October 2015.

A timeline for the development of the five ocean energy technologies throughout these phases has been developed. It gives guidance as to where technologies currently are and when they could reach the next phase of development.

**It is essential to understand that this timeline is highly dependent on overcoming the barriers faced by ocean energy developers, the level of public support offered in the short and medium term by EU, Member States, and regional authorities.**

**Addressing the current barriers to project deployment, while providing significant short- and long-term stable and predictable investment conditions are essential. Inaction could delay industrial roll-out, or in a worst case scenario result in a loss of accumulated knowledge and jeopardise Europe's global leadership position in ocean energy.**

Figure 4. Timeline for the development phase of ocean energy technologies



Source: Generated through consultation with the Ocean Energy Forum; preliminary analysis at October 2015.

DRAFT



SECTION 3  
OVERCOMING THE CHALLENGES:  
MOVING OCEAN ENERGY  
THROUGH THE PHASES TO  
INDUSTRIAL ROLL-OUT

## SECTION 3 OVERCOMING THE CHALLENGES: MOVING OCEAN ENERGY THROUGH THE PHASES TO INDUSTRIAL ROLL-OUT

Barriers to technology development and deployment are diverse. These barriers can be specific to both technology and phases of development, and often overlap. They include:

- 1 Financial, economic, and market (including access to finance, ability to access markets, etc.).
- 2 Political & governance.
- 3 Consenting & environmental (including positive and negative impacts).
- 4 Social (such as public acceptability and resource conflict).

Approaches can be developed to address and overcome these barriers, however it is important that projects continue to be developed, consented and commissioned in parallel with the recommendations made in this report.

### 3.1 Specificities of ocean energy and cross-cutting challenges to deployment

#### 3.1.1 High CAPEX requirements call for upfront capital availability

Ocean energies, like most renewables, are CAPEX-intensive: the cost of the device, infrastructure and installation represent a very high share of the kWh cost. This contrasts with gas-fired power stations, for example, where the plant itself represents just 25% of the electricity cost, the remainder coming mostly from gas purchases. Whilst different for each ocean energy technology, total CAPEX (including costs of capital) is estimated at 60 – 80% of the final cost of energy.

This means that developers need access to high levels of funding upfront, before any electricity – and therefore revenue – is generated. Support schemes for the first arrays must, therefore, include a high proportion of upfront finance, whether debt-, grant- or equity-based.

#### 3.1.2 Uncertainties inherent to innovative projects require technology demonstration to lower risks and cost of finance

All energy projects bear investment risks – market, technological and regulatory risks – all of which have a direct impact upon project revenue. The greater the risk, the greater the cost of financing the project or insuring the risk.

Ocean energy technologies are at early developmental stages and operate in a harsh marine environment, all of which create specific additional uncertainties and risks. Risks can be linked to both installation and operation.

To improve access to finance, and decrease the cost of both capital and insurance, the understanding of risks must be captured and communicated. Formalisation of knowledge and experience from installation and operation of projects is required to make these risks measurable and predictable. The data required are currently lacking and will only be gathered progressively, as more devices are put in the water.

#### 3.1.3 Financing ocean energy in today's energy market with a limited pool of potential investors

The pool of available investors for emerging technologies has dramatically reduced due to the economic crisis, creating a need for Member State support to help technological development of emerging technologies.

Ocean energy technologies are insufficiently mature to take advantage of the financing sources and mechanisms used for e.g. wind energy deployment in the last 10 years. Original equipment manufacturers' (OEM) balance sheets are constrained by their clients' lack of demand which hampers their appetite for developing emerging technologies. Venture capitalists and business angels have entered and left the ocean energy sector due to lack of market visibility and resulting inadequate risk/return ratios.

Combined with global low energy prices and the economic downturn the investment conditions will require new and innovative financing models, and public support for new technologies and the first farms will be critical to success or failure of the sector. This follows the pattern for other renewable energy technologies such as wind and solar.

### 3.1.4 Planning and licensing frameworks are required which afford confidence to industry, regulators and stakeholders

For marine energy development to move forward in a sustainable manner, current practices in the areas of consenting and licensing, planning, and research and monitoring must be reviewed and enhanced.

Consenting and licensing procedures are an often cited barrier to the development and progress of ocean energy. From a regulator's perspective sufficient evidence on which to base their licensing decision and to ensure compliance with the relevant legislative regime(s) and the application of EU environmental Directives is required.

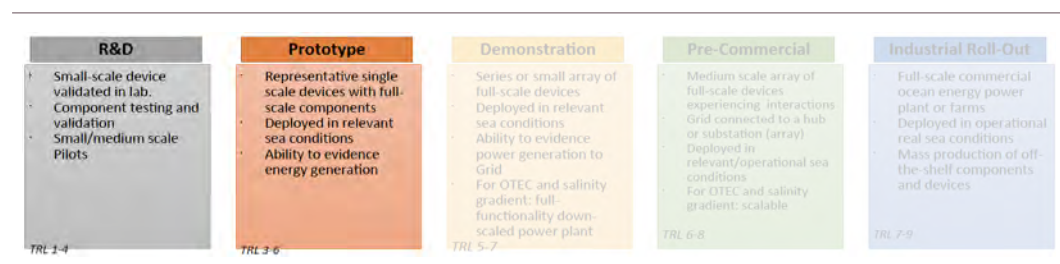
The lack of clarity and consistency in EIA and AA (Habitats Directive) obligations and application, the costs associated with these and the seemingly overly-precautionary requirements placed on small scale or single-unit deployments, are the main concerns.

These issues should be addressed in advance of technology and project development to ensure that the necessary processes and systems are in place to support developers through the consenting process.

There is a need for a pan-European sustained research and monitoring agenda in relation to environmental effects of devices, which addresses high level strategic questions, regarding, for example, population level effects, cumulative impacts and ecosystem models, in addition to specific environmental effects. This should be accompanied by a robust operational level research and monitoring programme that enables better assessment of broad scale effects of ocean energy and other marine related activities. Collaboration between industry, public bodies, academia, etc., will yield the most effective use of resources in reducing uncertainty through multi-scale investigations.

The implementation of the Maritime Spatial Planning (MSP) Directive across the EU presents an opportunity for improving planning and consenting processes for ocean energy. Improvements can be achieved through (among others) rationalisation of existing requirements, increasing transparency and certainty for developers, better consideration of cumulative impacts and co-location opportunities, and more effective inclusion of stakeholders in decision-making processes.

## 3.2 R&D and Prototypes: Financing early development



### 3.2.1 Financing full-scale prototypes with grant solutions

Not all ocean energy technologies are “first-farm-ready”. Some of the technologies, such as wave energy, require further rigorous single device testing before they can reach the next phase in their development. Exhaustive full-scale demonstration makes technological and economic sense. It is also understood that R&D will continue to advance as the device goes through its development stages.

Financing instruments for such development phases are predominantly and appropriately grant-based, e.g. the EU’s Horizon 2020 or national research programmes. Grants are and have been provided, though not always at levels enabling the EU to stay at the forefront of technological development. The estimated cost of taking an ocean energy device from drawing board to prototype ranges from €50m to €100m, depending on technology and scale. To keep the future market competitive, several devices in each technology should have the opportunity to develop through to prototype, hence requiring higher innovation investment than would otherwise be available.

Grants have the advantage of fostering collaboration between companies and providing access to project data, both of which can be requirements for the financial award, and which in turn can then benefit the entire sector, justifying the public expenditure.

#### RECOMMENDATION

- Public authorities should maintain significant levels of grant funding programmes sufficient to enable testing, demonstration and improvements of full-scale prototypes.

### 3.2.2 Standardised testing to make technology comparable

To be considered successful, a prototype must undergo tests in real sea conditions. Different testing centres in different EU countries do not always generate comparable data, creating a challenge for investors selecting technologies for demonstration phase projects.

EU-wide standardisation, building on existing work, such as the standards developed by the International Electrotechnical Commission (IEC) Technology Committee (TC) 114 Marine Energy<sup>17</sup>. The industry needs to develop and share guidelines on optimal device operation and farm layout requirements. This is an essential step towards the development of industry-wide standards, permitting the certification of ocean energy devices, that are an important support to financial institutions when judging project risks and making investment decisions. See also Section 3.4.2.

#### RECOMMENDATION

- The ocean energy sector should develop EU-wide standards for testing of full-scale prototypes.

### 3.2.3 Approach to deliver rational prototype development

To reduce the risk of significant device failures in the demonstration phase, device sub-systems and components should be tested and effectively validated prior to use on full-scale devices. To address this, “*Wave Energy Scotland*” (the ‘WES Approach’) put in place a programme for wave devices allocating funding through a phase-gate process: each stage of development is only funded once the stage before is fully tested and validated.

A similar approach could be used at EU level to stimulate advances in less mature ocean energy technologies that are not yet demonstration ready, by funding critical component testing before full-scale demonstration.

17 [http://www.iec.ch/dyn/www/?p=103:7:0:::FSP\\_ORG\\_ID,FSP\\_LANG\\_ID:1316,25](http://www.iec.ch/dyn/www/?p=103:7:0:::FSP_ORG_ID,FSP_LANG_ID:1316,25)

## KEY RECOMMENDATION 4.1

### KEY RECOMMENDATION

- Establish a Europe-wide phase-gate procedure – 2016 to 2025 – for sub-systems, components and devices whereby funding is only made available once clear performance indicators, determined by an independent multi-disciplinary panel of experts from a variety of stakeholders, have been achieved.

### 3.2.4 Licensing and consenting priorities

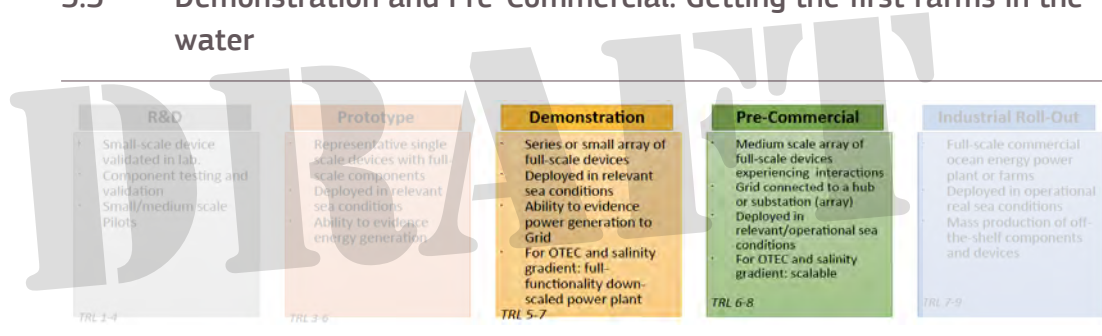
#### RISK-BASED APPROACH TO CONSENTING

To ensure that prototype deployments can proceed without unnecessary regulatory delays, a banded consenting process is required, in which the level of impact assessment is based on the environmental sensitivity of the site, technology risk profile and scale of deployment. The development of this proportionate approach would enable single device deployments which would have minimal impacts on the surrounding environment to be fast-tracked through the consenting process.

#### PRE-CONSENTED DEMONSTRATION SITES

Access to testing at sea for device developers will be facilitated by the provision of pre-consented demonstration test sites. These will allow developers faster access to testing facilities by bypassing the need for individual device consenting.

## 3.3 Demonstration and Pre-Commercial: Getting the first farms in the water



The demonstration stage is characterised by multiple grid-connected devices-deployment in real sea conditions. Usually considered “R&D Phase 2”, this is the *demonstration* phase and does not have to be commercially viable.

From this stage onwards, devices are installed as pre-commercial arrays suitable to inform future large commercial farms. These arrays optimise space usage and resource extraction, and should be connected to a hub or substation feeding electricity to the shore.

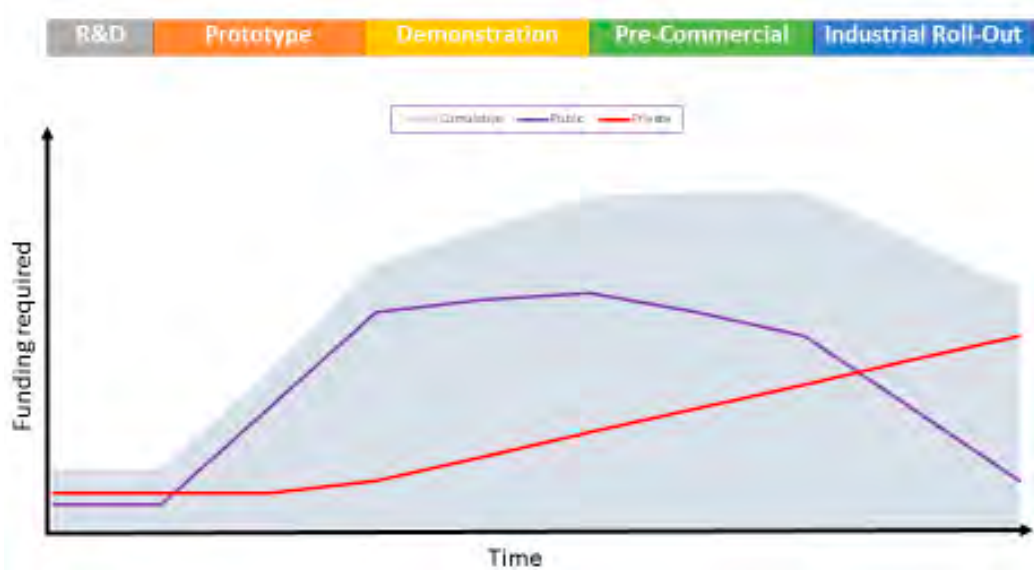
### 3.3.1 Focusing on investment support rather than pure revenue support

In the *demonstration and pre-commercial* phases, considerable uncertainty about both revenue from power production and maintenance costs means financial risk remains high and transition to a pure demand-pull dominated mechanism is premature. Upfront capital to support investments therefore, remains essential.

This upfront capital no longer needs to be grant-only. It can take the form of public equity, public debt, repayable loans or even access to low cost finance (e.g. zero or low interest loans) provided lending criteria are suitable for high-risk projects.

Revenue-based support schemes can and should commence implementation to give long-term visibility and confidence to investors and reduce the cost of capital. Short-term or short-lived support schemes do not give market players the visibility required for long-term energy investments.

Figure 5. Indicative share of private and public funding per development phase



Source: Generated through consultation with the Ocean Energy Forum; preliminary analysis at October 2015.

A combination of both private and public funding can be considered, provided it ensures both the upfront capital requirements of early stage projects and the medium-term visibility to entice investors to consider a new and promising technology and market.

#### RECOMMENDATIONS

- Investment support must remain an essential part of support schemes for each specific technology until the *industrial roll-out* phase is reached. If withdrawn too early in favour of revenue-support mechanisms, the technology might not have reached the required maturity to make use of the scheme.
- Investment support can come in the form of equity, debt, repayable grants, or capital guarantees.

#### 3.3.2 Keeping public financing schemes flexible to account for changes inherent to innovation

Innovative projects are by nature subject to planning uncertainties. Financial mechanisms put forward by both EU and governments need to keep pace with advances in the ocean energy sector and respond quickly to new developments, delays, or small changes in project parameters. Several ocean energy projects did not proceed or risked failure (such as Skerries or some other NER300-funded projects) due to the inability of support schemes to adapt to delays.

#### RECOMMENDATION

- Innovation funding processes need to be less bureaucratic, more flexible and more responsive, to match the fluid nature of innovative technology development.

### 3.3.3 Applying State aid rules to better enable ocean energy projects

EU State aid rules should allow Member States to adequately support new technologies as they emerge and move through demonstration and pre-commercial stages to reach industrial roll-out. An explicit distinction needs to be made between support for mature technologies and support for emerging technologies.

Emerging technologies such as ocean energy require *investment- or project-specific support* rather than pure *revenue support*. Even with the more restrictive *Guidelines on regional State aid for 2014-2020* it is still possible for national governments to set up adequate *revenue support* schemes to incentivise ocean energy production. However, for investment and project-specific (individual) support, EU State aid guidelines remain burdensome and restrictive.

This could be achieved e.g. by increasing the notification thresholds for individual and investment aid for emerging technologies to €30m. Eligible costs caps (percentages) should also be increased for emerging technologies, using the same logic as that applied to projects developed in European regions with low per capita GDP.

National authorities should offer guidance on combining diverse sources of funding into a successful investment support for projects.

#### RECOMMENDATION

- State aid rules should be more flexible for emerging technologies and provide increased thresholds for eligible costs and notification.

### 3.3.4 A more risk-friendly culture at public investment banks

Commercial debt will not be available in the short-term for ocean energy projects given their current risk profile. Some technologies will require more time than others to reduce risks to a bankable level. Consequently, the European Investment Bank's current low-risk investment stance is inadequate both for the ocean energy sector and for Europe's industrial development in general.

The new InnovFin scheme, with an initial envelope of €100m for all renewables, is an important step in this direction though budgets are clearly misaligned with the financial needs of the *demonstration and pre-commercial* phase: ocean energy projects in those phases are likely to cost each in the range of €40m to €100m. The European Fund for Strategic Investments (EFSI) should also become relevant for ocean energy as budgets are at more appropriate levels.

#### RECOMMENDATION

- National investment banks, the EIB and European Investment Fund should support the industry's progress to the next phase of development by unlocking risk capital.

### 3.3.5 Solutions to deliver the first demonstration farms and arrays

Technology-specific demonstration projects will be required, as learnings from a given pilot farm cannot be transferred from one ocean energy technology to another. For these early projects, risks cannot be insured and are too high for a single player, calling for public backing.

Before the ocean energy sector can reach bankability and commercial viability necessary for industrial roll-out, the first ocean energy pilot farms must reach financial close. Demonstration and *pre-commercial* farms require a specific financing solution, as high levels of uncertainty and risk make them unsuitable for commercial debt or pure revenue-based finance.

**The following solutions should be considered:**

*Solution 1 – The Meygen/Raz Blanchard approach:* A funding plan combining upfront capital support – whether grant-, equity- or debt-based – as well as ongoing revenue support matches ocean energy's risk profile and recognises the risk being undertaken throughout the process.

**KEY  
RECOMMENDATION  
4.3**

*Solution 2 – Publicly funded pilot zones:* Possibly targeted at tidal range as several technologies are reputedly first-farm ready. The cost of cabling, substation, environmental assessments and other permits is prohibitive for a single project to carry, potentially multiplying project costs by a factor of 3-5. Some examples already exist for wave energy, for example the Wave Hub test site off Cornwall, UK. Public funding (e.g. structural funds, NER300, Horizon 2020, etc.) could be orientated towards pre-consented areas for tidal deployment, including infrastructures such as a grid connection, cabling, subsea hub etc.

**KEY  
RECOMMENDATION  
4.2**

*Solution 3 – Creation of an EU insurance offering or fund to underwrite various project risks:* This would be targeted at the first ocean energy projects to cover risks such as availability, performance, unforeseen events, failures, etc. A common reserve fund available to multiple projects in the initial farm roll out, to spread the risk and reduce the cost of providing guarantees.

**KEY  
RECOMMENDATION  
4.4**

### 3.3.6 Licensing and consenting priorities

#### 3.3.6.1 Guidance on application of EU Directives

Although each Member State implements its own processes, these must all comply with EU Directives including Environmental Impact Assessment (EIA), Habitats and Birds Directive and the Marine Strategy Framework Directive. Often the manner in which they have been translated into national legislation presents hurdles, which can be difficult to surpass where there is significant uncertainty. There needs to be a comparative review of how Directives are transposed across Member States, and how national regulations are implemented (e.g. Habitats Regulations), as there must be lessons to be shared between countries. Clear guidance on the application of these Directives to ocean energy developments will enable a more consistent approach to consenting across Member States and enable existing best practice to be shared.

#### 3.3.6.2 Marine spatial planning

Enhancing knowledge of the marine environment is crucial to informing better plans and more efficient licensing. Initiatives are therefore required to help facilitate the deployment of ocean energy in the most sustainable and effective locations within the EU marine area. This will also address issues concerning ongoing facilitation of future ocean energy development such as the provision of grid infrastructure.

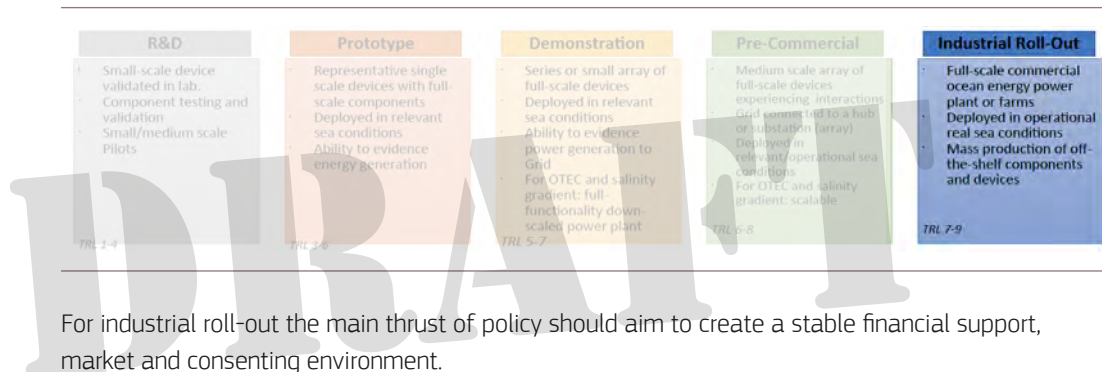
#### 3.3.6.3 Environment research agenda

The development and deployment of demonstration and pre-commercial devices and arrays will provide a key opportunity to validate predicted environmental impacts. A data gap analysis will be required to identify priority issues, enabling a strategic research agenda to be established to cover emerging gaps in knowledge. A research agenda should focus on addressing key consenting issues and risks whilst gathering information and data to help inform the planning and consenting of larger scale projects. Existing strategic research programmes such as the UK's Offshore Renewables Joint Industry Programme for Ocean Energy (ORJIP) could play a key role in the development of an EU strategic research agenda for ocean energy.

### 3.3.6.4 Environmental monitoring and data sharing

A strategic broadscale monitoring programme on highly mobile species such as birds and mammals would greatly assist decision makers in ensuring obligations under environmental Directives are met. From the developers' perspective, a common structure for project monitoring should be established which is focused on likely environmental impacts and seeks to progress projects through a risk-based approach. This will provide guidance for determining project baseline characterisation requirements and developing project environmental management plans that are proportionate to the level of risk posed by any specific proposed ocean energy project. A review of the environmental impacts associated with new and emerging technologies on an ongoing basis will ensure that the best and most up-to-date information and data regarding the potential impacts of ocean energy projects are available to decision makers, developers and stakeholders. Sharing data from monitoring programmes will both facilitate future project consenting and reduce duplication of effort. Existing platforms and programmes for data sharing could play a key role in data sharing and dissemination including the International Energy Agency (IEA) Ocean Energy Systems' Annex IV programme (along with its Tethys database) and the Crown Estate's Wave and Tidal Knowledge Network.

## 3.4 Industrial Roll-out: Reducing costs and planning deployment



### 3.4.1 Reducing financing costs while moving towards revenue-based support

#### 3.4.1.1 Ensuring stability of income in the industrial roll-out phase

Industrial roll-out enables a shift from investment support to revenue support via market-pull instruments such as feed-in tariffs, or renewable certificates. It is essential that this transition is tailored to the specific needs of the given technology as not all ocean energy technologies will reach this phase at the same time even with the same energy source strand. Attempting to shift the policy environment too soon is likely to result in a collapse of demand, slowing of deployment, even a potential halt. This would delay the growth of the technology and the learning opportunities, and may mean the collapse of even leading companies resulting in a loss of knowledge and opportunities.

When designed properly, revenue-based schemes have been shown to drive innovation, deployment and cost reduction in renewable energy technologies, such as in Denmark for onshore wind in the 1990s. Revenue-based schemes should be suitably targeted, predictable and stable. Revenue support can also be gradually and predictably reduced in time to adapt to cost reductions and avoid over-compensations, possibly linked to the total volume of technology that comes online or its estimated cost.

Regulatory uncertainty in revenue support, such as during the Electricity Market Reform (EMR) debate in the UK, greatly contributes to a reduction in confidence and increase of the cost of capital. In the worst cases such as retro-active changes to renewable support in Spain, it may lead to market slowdown and reduction of industrial development.

## RECOMMENDATIONS

- Stable, long-term revenue support schemes ensure the predictability of income, thus reducing risk and reducing the cost of accessing capital, taking account of the size and quality of the resource, with objective and defined criteria.
- Governments should strive to achieve cross-party support for policy initiatives relevant to ocean energy. This could reduce the potential for destabilising the policy environment following changes in administration and act to reduce political risk to the support schemes, hence lowering the cost of capital.

### 3.4.1.2 Reducing insurance costs

Insurance for ocean energy projects is currently expensive, with high deductibles and limited cover. The insurance sector's experience with ocean energy is very limited, particularly with regard to marine operational issues.

In the ocean energy sector, operating data and credible estimates of potential claims costs are still being developed. The number of players in the sector with relevant credible experience is limited but growing. The ocean energy sector must identify and exploit opportunities to accelerate insurers' confidence in, and knowledge of, the sector, its technology and the likely claims costs for insurance costs to be managed.

## RECOMMENDATIONS FOR THE OCEAN ENERGY SECTOR

- Set-up a working group with developers, contractors, etc. and insurers/brokers, to derive a contract structure model with risk options and strategies, codes of best practice, certification standards for marine deployment, moorings, cabling, sea fastenings, vessels, studies of weather risk etc., and use it to engage with the insurance industry.
- Develop mechanisms for co-operation between the ocean energy sector and the insurance sector with a view to enabling protected access to data.

**KEY  
RECOMMENDATION  
4.5**

### 3.4.1.3 Providing loan guarantees

At the current stage of development of the ocean energy sector, the risk profile of projects means that there is limited or no availability of commercial debt, with commercial models relying on equity and grant funding. Market analysis suggests limited availability of equity from venture capital sources or the public equity markets due to low project returns. The use of loan guarantees might enable public authorities to leverage more finance into the ocean energy sector than would otherwise be the case were it simply to provide direct grant support.

Loan guarantees can cover the risk of default as well as the cost of the scheme. Pricing this risk is critical and the responsible public sector body must have the required commercial expertise to undertake the necessary due diligence.

These instruments are more fitting for the post demonstration phase, yet work on their design needs to begin now so that they are available when needed. This will also give technology developers and funders a line of sight to future funding opportunities and so incentivise near term CAPEX funding.

## RECOMMENDATION FOR THE OCEAN ENERGY SECTOR

- Establish a working group between ocean energy industry and private and public finance institutions on loan guarantee design.

### 3.4.2 Certification and standards

Bespoke standards and certification practices are required for ocean energy to progress towards industrial roll-out. Equipment and methods developed as well as information and data gathered during the phases leading up to industrial roll-out is fundamental to moving the standardisation process forward; project developers and investors need to have guarantees on machine performance.

Building on existing work, such as the standards developed by the International Electrotechnical Commission (IEC) Technology Committee (TC) 114 Marine Energy<sup>18</sup>, the industry needs to develop and share guidelines on optimal device operation and farm lay-out requirements. This is an essential step towards the development of industry-wide standards permitting the certification of ocean energy devices, that are an important support to financial institutions when judging project risks and making investment decisions. See also Section 3.2.2.

### 3.4.3 Licensing and consenting priorities

#### 3.4.3.1 Reviewing licensing guidance

As projects grow in both size and number, more information on environmental impacts will become available. Guidance on the environmental assessment of ocean energy projects during the licensing process should be prepared and updated as required.

#### 3.4.3.2 Engagement with other marine stakeholders

With industrial roll-out, the potential for conflict with other stakeholders in relation to access to marine resources, aesthetics and visual amenity, noise, and other factors will require particular consideration. Good practice in outreach to other ocean stakeholders should be developed and shared. Strong and well informed dialogue and communication with all interested stakeholders will be important to the continued development of the sector. Marine spatial planning has a key role to play here.

#### 3.4.3.3 Promoting benefits of ocean energy

Regional support will be vital for the long-term development of ocean energy. The economic and social benefits of development should be highlighted and communicated at a local level to ensure community endorsement and support. The potential benefits of ocean energy at a Member State, regional and EU level should also be established and communicated to stakeholders.

## 3.5 Governance

### 3.5.1 Increasing co-operation between Member States

Different Member States and regions will have interests in different ocean energy technologies dependent on their natural resources and the state of their industry. There is, however, substantial potential for co-operation between authorities on both common issues and individual technologies. Developing a common understanding of the sector's technological, policy and financing needs at the different stages of development will facilitate dialogue and co-operation.

The ocean energy industry launched TP Ocean – the Technology and innovation Platform for Ocean energy – to identify challenges and research priorities and produce a detailed Strategic Research Agenda (SRA).

### RECOMMENDATION FOR THE OCEAN ENERGY SECTOR

- Publish and communicate a comprehensive Strategic Research Agenda, identifying and prioritising research and development areas to accelerate ocean energy development.

18 [http://www.iec.ch/dyn/www/f?p=103:7:0:::FSP\\_ORG\\_ID,FSP\\_LANG\\_ID:1316,25](http://www.iec.ch/dyn/www/f?p=103:7:0:::FSP_ORG_ID,FSP_LANG_ID:1316,25)

## RECOMMENDATIONS FOR NATIONAL AND EU AUTHORITIES

- Dialogue with industry to take into account the priorities identified by the industry and all the possibilities offered by EU research, infrastructure and development funds.
- Make full use of knowledge developed by the ocean energy sector and co-operative research frameworks such as the European Energy Research Alliance and EU Strategic Energy Technology (SET) Plan to concentrate efforts on priority areas and avoid replication of research and wastage of public funds.

## RECOMMENDATIONS FOR JOINT ACTION

- Leverage available Member States and EU (co-)funding and facilitated co-operation opportunities to run multi-Member State ocean energy innovation and demonstration programmes.
- Identify and promote good practice in simple approaches to consenting, in stakeholder consultation and involvement in maritime spatial planning, in the application of financial policies and disseminating the knowledge gained from publicly available R&D findings to facilitate the expansion of ocean energy.

### 3.5.2 Sharing knowledge

Knowledge and data sharing mechanisms across the industry will help to both facilitate the consenting process and leverage learnings from each project, reducing possible duplication of efforts in both research and deployment, particularly in environmental monitoring and impact assessment, supply chain, processes and health and safety. The ocean energy industry needs to commit to participate in structured knowledge and data sharing mechanisms. These can play a significant role in accelerating the cost reduction pace and achieving a more competitive cost of energy. However, data sharing mechanisms need to take full account of businesses' commercially sensitive information, to minimise any risk of seeing a reduced appetite for investment in innovation.

Not all types of data can or need to be shared at all stages of a technology's development. Examples of useful data sharing in the different development phases are shown below.

Figure 6. Examples of data sharing in development phases

R&D	Prototype	Demonstration	Pre-Commercial	Industrial Roll-Out
<ul style="list-style-type: none"> <li>• Academic papers, scientific publications, fundamental knowledge generation</li> <li>• Computational Fluid Dynamic modelling methodology</li> <li>• Resource potential</li> </ul>	<ul style="list-style-type: none"> <li>• High level results from type tests</li> <li>• Validate test: methodologies, including for grid connection</li> <li>• Resource characterisation</li> <li>• Measurement methodology, sensors</li> </ul>	<ul style="list-style-type: none"> <li>• Yield information</li> <li>• Knowledge creation on inter-array connections</li> <li>• Interaction between devices (wakes), devices &amp; resource</li> <li>• Resource modelling</li> <li>• Grid compliance methodologies</li> </ul>	<ul style="list-style-type: none"> <li>• Information needed to create standards (taking into account IP issues)</li> <li>• Health and Safety procedures</li> <li>• Aggregated statistics on power quality and generation (taking into account commercially sensitive data)</li> </ul>	<ul style="list-style-type: none"> <li>• Serial technical issues</li> <li>• Serial or unresolved Health and Safety issues</li> <li>• Power curves</li> <li>• Operation and maintenance processes</li> </ul>

Source: Generated through consultation with the Ocean Energy Forum; preliminary analysis at October 2015.

## RECOMMENDATION FOR EUROPEAN COMMISSION, OCEAN ENERGY SECTOR AND NATIONAL AUTHORITIES

- Establish a Europe-wide industry-run platform where data in standardised and anonymous form are fed in by project and device developers. Public or EU-funding for individual projects could be made conditional to fully participating in the data and knowledge platform. Clear rules to protect intellectual property rights are required to ensure full industry buy-in into the system. This action could build on initiatives such as the Wave and Tidal Knowledge Network.

### 3.5.3 Implementing strategic planning approaches

In order to facilitate ocean energy developments in the most sustainable locations within the EU marine area, a clear focus on strategic planning is required, supported by effective communications and consultation. At a local level, decision-makers and the public should be provided with information regarding the potential for social and economic, as well as environmental, benefits. At an EU level, strategic planning is required to ensure that the most effective areas for the deployment and demonstration of emerging and established technology are brought forward. This will also enable grid-related issues to be addressed, including the strategic marine grid, connections to the existing grid, grid/interconnector upgrade and alternative approaches where grid solutions prove prohibitive in the short- to medium-term.

#### RECOMMENDATIONS FOR OCEAN ENERGY SECTOR

- Identify and promote benefits of ocean energy development, providing decision makers and the public with information regarding the potential for local socio-economic and wider environmental benefits, and ensuring that relevant information is available to inform strategic planning and project consenting.
- Develop guidance on the implementation of EU environmental Directives and strategic planning to ensure robust and informed planning approaches at Member State level.
- Develop a 'Communications and Consultation Strategy' to provide outline processes for effective communication with regulators, statutory stakeholders, NGOs, communities and key representatives from other marine sectors.

### 3.5.4 Maximising economic development through ocean energy roll-out

Ensuring regional support and community endorsement is critical to the long-term aspirations of ocean energy and to maximising Blue Growth for Europe. There is a need to understand the onshore planning implications and associated skills and supply chain requirements relating to the construction, operation and maintenance requirements of ocean energy developments. This will help ensure the maximisation of potential social and economic benefits.

#### RECOMMENDATION FOR REGIONAL AUTHORITIES

- Develop regional manufacturing/industrial plans through Member State scenario mapping. This will identify the onshore planning implications and related skills and supply chain requirements relating to the associated construction, operation and maintenance and decommissioning requirements of ocean energy projects.

### 3.5.5 Enhancing approaches to environmental planning and assessment

Enhancing knowledge of the marine environment is crucial to informing better plans and more efficient licensing for all marine related activities. This should be informed by the strategic and project environmental assessment under the SEA, EIA, Natura 2000 and MSF Directives. Ongoing review of environmental impacts associated with new and emerging technologies will ensure that the best and most up-to-date information is available to decision-makers, developers and stakeholders. A key component will be the establishment of a strategic environmental research programme to address key consenting issues and emerging gaps in knowledge. The UK's Offshore Renewables Joint Industry Programme (ORJIP) for Ocean Energy has shown how industry, regulators and researchers can collaborate to identify and address the priority challenges.

A framework for strategic broadscale monitoring which is focused on likely environmental impact and seeking to progress projects through a risk-based approach will provide guidance for determining project baseline characterisation requirements and developing project environmental management plans that are proportionate to the level of risk posed by a project.

## RECOMMENDATIONS FOR OCEAN ENERGY SECTOR

- Investigate the possibility and best means of expanding the remit of ORJIP Ocean Energy to inform the development of strategic research plans for the EU and Member States.
- Explore the ORJIP model and consider how it could be expanded to cover all Member States.
- Establish a working group to develop a common framework for project monitoring and environmental management.

### 3.5.6 Developing efficient risk-based licensing processes

The development of fit-for-purpose, effective and efficient licensing systems for ocean energy projects across Member States is crucial to building momentum in the European ocean energy sector. Consenting processes and requirements should be proportionate to the potential environmental risk posed by a specific development. Providing EU-level guidance to Member States addressing common licensing issues will ensure that best practice and experience gained in consenting ocean energy projects by regulators, agencies and developers is shared throughout the EU and used to inform future decisions and processes.

**KEY  
RECOMMENDATION  
4.6**

## RECOMMENDATION FOR THE OCEAN ENERGY SECTOR

- Utilise the outputs from the Horizon 2020 RiCORE project to explore legal and regulatory approaches to developing a risk-based licensing approach.

## RECOMMENDATION FOR THE EU

- Develop a set of EU licensing guidance notes focusing on common consenting issues to inform the development of Member State-level licensing manuals.

## RECOMMENDATIONS FOR NATIONAL AUTHORITIES

- Identify and share good practice in consenting, for example, the adoption of 'one stop shop' approaches to the consenting process.
- Utilise the strategic guidance produced at EU level to inform national guidance and decision-making.



**SECTION 4  
AN ACTION PLAN FOR  
OCEAN ENERGY**

## SECTION 4 AN ACTION PLAN FOR OCEAN ENERGY

The key actions below are fitted to the phases of development identified and used throughout this Strategic Roadmap, rather than being specific to any one technology. All ocean energy technologies are expected to go through each phase, some earlier than others. These actions, therefore, will apply across the sector as each technology advances towards industrial roll-out.

### 4.1 R&D and Prototype: Create an EU-wide phase-gate technology development process for components

#### 4.1.1 Challenge

Reducing the risk of device failures in the demonstration phase is key for less mature ocean energy technologies. To this end, device sub-systems and components should be tested and effectively validated before deployment in full-scale prototypes at sea.

#### 4.1.2 Approach

A Europe-wide system should be created to validate components and sub-systems by funding development and testing based on a number of pre-defined and clear performance indicators.

An independent and diverse multi-disciplinary panel of expert stakeholders should determine the criteria and select the most suitable projects. Funding should be allocated on the basis of performance indicators being achieved.

Until and unless the performance indicators are achieved, funding for further stages of development or demonstration of the identified components and sub-systems should not be engaged. This is known as a “phase-gate” or “stage-gate” process<sup>19</sup>.

#### 4.1.3 Benefit

Such a system would promote innovation excellence in critical components that are, as yet, unproven and unvalidated. Once the components have met their performance indicators, their use in demonstration projects reduces technology risk and increases the chances of the demonstrator being successful, creating more certainty in the sector and reducing costs.

#### 4.1.4 Potential funding sources

The process could be funded by both the European Commission and Member States with industry and the broader ocean energy sector committing to actively participating in setting criteria and performance indicators as well as promoting findings and learnings.

Potential funding sources may be Member States’ research budgets and programmes such as EU Horizon 2020, EU innovation funds, ERA-Net (co)funds.

### ACTION FOR EU, MEMBER STATES AND THE OCEAN ENERGY SECTOR (INDUSTRIAL PLAYERS)

- Set-up a European scheme, to validate components and sub-systems in the less mature ocean energy technologies.
- Identify and promote potential funding sources.

**Timeline:** 2017-2025

<sup>19</sup> The process put in place by Wave Energy Scotland is an example of such a phase- or stage-gate process

## 4.2 Demonstration and Pre-Commercial: Connect the most promising resource to the grid to enable the first demonstration farms

### 4.2.1 Challenge

With typically 3–10 machines in the water for a single development at the demonstration/pre-commercial stage, the cost of the required grid-connection and cable-infrastructure is estimated at 20–40% of total project costs. This cost is prohibitive relative to the cost of the devices, and more importantly the comparatively low revenue generated by first-of-a-kind projects. Finding the additional capital to fund the grid connection is difficult and can jeopardise a project.

Furthermore, obtaining environmental and operating consenting permits is both time-consuming and costly, potentially compromising a first project's feasibility and delaying or blocking a project.

### 4.2.2 Approach

The costs of the grid connection for early projects, whether built by the project developer or not, should be covered as public or private infrastructure investment. In some EU countries, the cost of connecting renewable projects to the grid is borne by the system as a whole. The same system for transmission financing should be applied for offshore connection.

The industry needs to identify the most suitable sites for early deployment. The objective would be to enable deployment of 300MW of demonstration or pre-commercial farms with the necessary equipment to collect and process data. It would also reduce long-term costs for identifying sites. Pre-consenting areas for deployment of the ocean energy devices would further facilitate project development.

### 4.2.3 Benefit

Removing the 20-40% costs linked to cables and grid would lower the total capital cost of projects, making them easier to finance for developers. With lower capital costs per project, more projects could be built. This would also enable innovation finance to focus on the devices and their installation, while more conventional elements of the project could be financed differently, closer to market conditions.

### 4.2.4 Potential funding sources

Potential sources are EU structural funds – ideally placed for this type of spending; Member States' budgets; national revenue from the Emission Trading System; EU demonstration programmes such as ERA-Net co-fund; European Fund for Strategic Investments.

## ACTION FOR EU, MEMBER STATES AND THE OCEAN ENERGY SECTOR (INDUSTRIAL PLAYERS)

- The ocean energy sector should identify areas suitable for demonstration and pre-commercial projects able to connect at least 300 MW of ocean energy devices EU-wide. The areas should have access to power cables and have a secured onshore grid connection. All technologies having reached the appropriate phase should be targeted, including smaller tidal stream and wave devices, which make use of a different resource.
- The ocean energy sector should establish a working group with the relevant authorities to establish a plan to fund the required infrastructure in the relevant Member States and/or EU Regions

**Timeline:** 2015-2025

### 4.3 Demonstration and Pre-Commercial: Enable a packaged approach to finance for individual farms

This approach looks at financing project by project and can be used in combination with or alongside the previous measure. Both the Meygen and the Raz Blanchard projects are valid examples of this type of package, albeit under different financing conditions.

#### 4.3.1 Challenge

Ocean energy projects are very innovative and first-of-a-kind. Uncertainties in installation times or total electricity production mean that a significant level of financial risk remains, preventing access to debt from commercial banks. Similarly, this risk cannot be borne by operators alone, nor insured at a reasonable price. For this reason, demonstration and pre-commercial farms require a significant percentage of public capital, delivered upfront to sustain the production and installation of devices.

The first project financed on commercial terms – the Meygen project – called on 80% public finance to reach financial close, packaged as 20% public equity, 35% public debt, and 25% public grant. The likely next two ‘Raz Blanchard’ projects, in French Normandy, include revenue support in the form of a guaranteed electricity price of €173/MWh and an upfront repayable grant of up to €120m. Details of the package are being negotiated and final figures are unavailable at the time of writing.

#### 4.3.2 Approach

Develop, and finance, a model for financing the first farms including guidelines on packaging finance for ocean energy based on existing experience. Raising the necessary level of finance will require funds and support from all levels: EU, national and regional. This could be packaged as a public-private partnership (PPP).

A successful financing model must include investment support to secure upfront capital in a mix of grant, equity, and debt together with private capital. Grants can be repayable, pending the right repayment conditions. It can also include revenue support as an incentive for successful electricity production, as long as it is designed in a way which does not threaten the economics of the project.

#### 4.3.3 Benefit

Putting the first farms in the water should generate sufficient production data and learnings on installation and operation to reduce technology risks and improve financiers’ understanding of ocean energy. This would also lower the cost of capital and increase banks’ and other commercial financial institutions’ appetite to supply the sector with commercial debt.

#### 4.3.4 Potential funding sources

Member States’ budgets, national revenue from the Emission Trading System, EU structural funds, EU demonstration programmes such as ERA-Net co-fund, NER400, European Fund for Strategic Investments.

#### **ACTION FOR EU, MEMBER STATES AND THE OCEAN ENERGY SECTOR (INDUSTRIAL PLAYERS)**

- Develop and finance a model for financing single demonstration/pre-commercial projects.
- Establish a public-private partnership (PPP) making use of the available sources of funding.

**Timeline:** 2015-2030

#### 4.4 Demonstration and Pre-Commercial: Create an EU insurance fund to underwrite demonstration project risks

##### 4.4.1 Challenge

Lack of empirical experience and deployment data results in uncertainties about ocean energy projects' operation and production. This means that ocean energies bear a higher technological and financial risk compared to more mature energy technologies. At present there is only limited protection available from the commercial insurance market or from manufacturer warranties.

At project level, this risk is currently overwhelmingly borne by the project developers, both limiting their pool of potential equity finance and making it difficult to leverage their funds to access commercial project finance.

##### 4.4.2 Approach

An insurance fund to insure project revenues in the early years would make projects considerably more investable. A sectoral pan-EU approach, covering all demonstration and pre-commercial farms could absorb a large share of this risk element and, thereby, lower the cost of capital and ease access to finance.

A fund that would underwrite project risks should be investigated as a potentially appropriate mechanism for supporting the sector. It could cover risks such as availability, output performance, mechanical breakdown, and defect and could provide long-term decommissioning bonds. It would be subject to suitable acceptance, risk-sharing and eligibility criteria. A relatively small amount of risk underwriting capital should be able to leverage a considerably larger amount of finance into the projects.

##### 4.4.3 Benefit

A fund in the order of €50m to €70m of underwriting risk capital could be sufficient to deploy and re-deploy across multiple projects, with the ability to raise additional private sector funding and (re) insurance market support growing through time as data availability and spread of risk improves.

##### 4.4.4 Potential funding sources

National (Green) Investment Banks, European Investment Bank, Member State budgets, national revenue from the Emission Trading System, European Fund for Strategic Investments. EIB programmes such as InnovFin or EFSI

#### **ACTION FOR EU, MEMBER STATES AND THE OCEAN ENERGY SECTOR (INDUSTRIAL PLAYERS)**

- Create a capital risk underwriting fund in 2016 to support deployment of the first demonstration and pre-commercial farms, defining scope of cover to be provided, underwriting, risk-sharing and acceptance criteria.
- Finalise insurance design, including limits, self-insurance levels, premium rates and distribution mechanisms.

**Timeline:** 2016 launch and ongoing

#### 4.5 Industrial Roll-out: Collaboration to reduce costs and plan deployment

##### 4.5.1 Challenge

If any ocean energy technology is to become commercially viable, the cost of capital needs to be reduced, optimised and grid infrastructure and financing should be amended to maximise access.

#### 4.5.2 Approach

Reducing the capital burden can be achieved through access to loan guarantees, and revenue support systems designed to deliver income security, market visibility while minimising public spending and avoiding costs overruns. Reducing insurance cost will come from reduced uncertainties on device production/operation as well as capacity building in the insurance industry.

#### 4.5.3 Benefit

A collaborative approach offers potential cost savings across the sector which will assist in achieving the stage of industrial roll-out and a subsequent shift from investment support to revenue support.

#### **ACTION FOR THE OCEAN ENERGY SECTOR (INDUSTRIAL PLAYERS)**

- Create working groups with the insurance and banking communities to increase knowledge, reduce costs and ease access to commercial debt, with a specific focus on loan guarantees.
- Devise standards for ocean energy roll-out based on learnings from the first demonstration and pre-commercial farms.

**Timeline:** 2016-2018

### 4.6 De-risking environmental consenting through an integrated programme of measures

#### 4.6.1 Challenge

In order to facilitate the cost effective, timely and sustainable award of environment licences, further development of the licencing processes are required.

#### 4.6.2 Approach

Marine spatial planning can effectively de-risk the planning process through promotion of co-location and address issues associated with grid/port access and the competing objectives of different marine stakeholders ensuring ocean energy is appropriately integrated in the Blue Growth Agenda. Promotion of a best practice document will assist in developing clarity and consistency in the application of environmental Directives. Lessons learnt from a strategic research and monitoring programme will help reduce uncertainty around key environmental issues and reduce consenting risks. Establishing a rapid feedback loop of operational level research and monitoring results and an evidence database will optimise research and monitoring funds and reduce industry's cost/risks whilst ensuring the regulator's position.

#### 4.6.3 Benefit

A proportionate approach to the risks involved using the best practice guidelines will reduce the costs/timelines easing the perceived overly precautionary regulatory process. Further, this approach will include reduced industry costs, realistic timetables and an effective and robust regulatory process.

#### **ACTION FOR THE EU**

- Support the production of a strategic ocean energy plan and resource map to inform future strategic research, development and marine spatial planning.

#### **ACTION FOR THE OCEAN ENERGY SECTOR (ALL PARTIES)**

- Commission a working group to produce best practice consenting guidelines to enable a more consistent and streamlined approach in Member States.
- Develop a strategic research and monitoring programme to build on existing environmental knowledge and address gaps in understanding on potential impacts.

**Timeline:** 2015-2025



# SECTION 5 KEY RECOMMENDATIONS

## SECTION 5 KEY RECOMMENDATIONS

Table 1. Summary of Key Recommendations

SECTION		ACTION BY			BENEFITS
Development Phase	Key Recommendation	European Commission	Member States / EU Regions	Industrial Players	
<b>SECTION 4.1 TIMELINE: 2017-2025</b>					
R&D	Create an EU-wide phase-gate technology development process for components governed by sector stakeholders	Establish a fund for the process from existing allocations – e.g. EU Horizon 2020, EU Research and Innovation funds, ERA-NET (co) funds	Identify and promote funding sources that can contribute to funding technology development projects	Design criteria and performance indicators Promote findings and learning	Promotes innovation excellence for unproved and unvalidated components Sets performance indicators that need to be reached prior to further funding Reduced costs and increased certainty in sector
Prototype					
<b>SECTION 4.2 TIMELINE: 2015-2025</b>					
Demonstration	Connect the most promising resource to the grid to enable the first demonstration farms	Utilise existing funds such as European Structural and Investment Funds, European Fund for Strategic Investments (EFSI) Work with sector to establish a working group to develop a plan to fund the required infrastructure in the relevant Member States and/or EU Regions.	Identify funding sources Be involved in working group Identify areas suitable for demonstration and pre-commercial projects able to connect at least 300 MW of ocean energy devices EU-wide	Identify the most suitable areas for early deployment with technologies having reached the appropriate phase of development for each suitable area	Removes prohibitive grid costs thus lowering total capital costs of projects making them easier to finance for developers
Pre-Commercial					
<b>SECTION 4.3 TIMELINE: 2015-2030</b>					
Demonstration	Enable a packaged approach to finance for individual farms	Promote the establishment of, and contribute to, a public-private partnership (PPP) making use of the available sources of funding	Contribute to a public-private partnership (PPP) Develop and finance a model for financing single demonstration/pre-commercial projects.	Active participation in a public-private partnership (PPP) making use of the available sources of funding	Putting first farms in water should generate installation and operational experience to reduce technology risks and improve financiers' understanding of sector
Pre-Commercial					
<b>SECTION 4.4 TIMELINE: 2016 ONWARDS</b>					
Demonstration	Create an EU insurance fund to underwrite demonstration project risks	Create a capital risk underwriting fund in 2016 to support deployment of the first demonstration and pre-commercial farms	Contribute to a capital risk underwriting fund in 2016 to support deployment of the first demonstration and pre-commercial farms, defining scope of cover to be provided, underwriting, risk-sharing and acceptance criteria	Finalise insurance design, including limits, self-insurance levels, premium rates and distribution mechanisms	Fund can be deployed and re-deployed across multiple projects Increased ability to raise additional private sector funding as data and risk-spread improves
Pre-Commercial					
<b>SECTION 4.5 TIMELINE: 2016-2018</b>					
Industrial Roll-out	Collaboration to reduce costs and plan deployment			Create working groups with insurance and banking communities (increase knowledge, reduce costs and ease access to commercial debt) Devise standards for ocean energy roll-out based on learnings	Potential cost savings across sector through collaborative approach assisting transition from investment support to revenue support
<b>SECTION 4.6 TIMELINE: 2015-2025</b>					
R&D	De-risking environmental	Support the production of a strategic ocean energy plan and resource map to inform future strategic research, development and marine/maritime spatial planning	Commission a working group to produce best practice consenting guidelines Develop a strategic research and monitoring programme using existing environmental knowledge, and address gaps in understanding impacts		Marine/maritime spatial planning, so that Member States' approach to risk is consistent and proportionate (rather than overly precautionary), will reduce costs/timelines
Prototype	consenting through an integrated programme of measures				
Demonstration					
Pre-commercial					
Industrial Roll-out					



**SECTION 6**  
**STRATEGIC ROADMAP: NEXT STEPS**

## SECTION 6 STRATEGIC ROADMAP: NEXT STEPS

The period October 2015 through to 31 October 2016 will involve further work on the Strategic Roadmap evidence base and also the start of the implementation process for the Key Recommendations. The Strategic Roadmap will then be updated to demonstrate progress on these areas.

**DRAFT**



SECTION 7  
ANNEXES

## SECTION 7 ANNEXES

Evidence-base information, such as case studies, will be included in the final Strategic Roadmap.

**DRAFT**



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SECTION 8  
REFERENCES

## SECTION 8 REFERENCES

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SECTION 9  
GLOSSARY

## SECTION 9 GLOSSARY

AA	Appropriate Assessment
Availability	The percentage of time a device or farm is available to produce power.
CAPEX	Capital Expenditure
Controlled environment	Hydrodynamics facilities (like a wave, flume tank), waves, tides, salinity and any other parameters are determined in advanced and fully controlled.
EFSI	European Fund for Strategic Investments
EIA	Environmental Impact Assessment
EMR	Electricity Market Reform
ERA-NET	European Research Area Network
GDP	Gross Domestic Product
Horizon 2020	EU Research and Innovation programme
IP	Intellectual Property
kW	Kilowatts
LCoE	Levelised Cost of Electricity
Meygen project	Tidal stream farm project under construction in the Pentland Firth (Scotland)
MSFD	Marine Strategy Framework Directive
MSP	Maritime Spatial Planning
MW	Megawatts
MWh	Megawatt Hour
Natura 2000	A network of nature protection areas in the territory of the European Union, designated under the Habitats Directive and Birds Directive respectively
NER300	Funding programme for innovative low-carbon energy demonstration projects based on sale of emission certificates from the EU Emission Trading System.
NER400	Programme following the NER300 for innovative low-carbon energy demonstration projects.
NGOs	Non-Governmental Organisations
O&G	Oil and Gas
O&M	Operation and Maintenance
OEM	Original Equipment Manufacturers
OPEX	Operational Expenditure
OTEC	Ocean Thermal Energy Conversion
PPP	Public-Private Partnership
PTO	Power Take-Off
R&D	Research and development
Raz Blanchard project	Tidal stream farm project in construction off the coast of Normandy (France)
Real sea condition	Deployed at sea with no control over the environment.

Reliability	Measurable probability of devices/farms availability in a specific environment for a given time (life of the project around 25 years, or between planned O&M).
RiCORE project	Risk based Consenting for Offshore Renewables project
SEA	Strategic Environmental Assessment
SET-Plan	European Commission Strategic Energy Technology Plan
SSEA	Strategic Social and Economic Assessment
Sub-sea hub	Equipment deployed underwater connecting and conditioning electricity from several ocean energy devices
Survivability	Measurable ability of a system (sub-system, components, etc.) to be available during/ after disturbances (sea-states, corrosion, biofouling, loading, etc.).
TP Ocean	The European Technology and Innovation Platform for Ocean Energy
TRL	Technology Readiness Level
WEC	Wave Energy Converter
WES	Wave Energy Scotland
Yield	Quantity of energy produced

### TECHNOLOGY READINESS LEVELS<sup>20</sup>

TRL 1	Basic principles observed
TRL 2	Technology concept formulated
TRL 3	Experimental proof of concept
TRL 4	Technology validated in lab
TRL 5	Technology validated in relevant environment (industrially relevant environment in the case of key enabling technologies)
TRL 6	Technology demonstrated in relevant environment (industrially relevant environment in the case of key enabling technologies)
TRL 7	System prototype demonstration in operational environment
TRL 8	System complete and qualified
TRL 9	Actual system proven in operational environment (competitive manufacturing in the case of key enabling technologies; or in space)

<sup>20</sup> HORIZON 2020 – WORK PROGRAMME 2014-2015 General Annexes Page 1 of 1 Extract from Part 19 - Commission Decision EC(2014)4995 G. Technology readiness levels (TRL). Where a topic description refers to a TRL, the following definitions apply, unless otherwise specified. [http://ec.europa.eu/research/participants/data/ref/h2020/wp/2014\\_2015/annexes/h2020-wp1415-annex-g-trl\\_en.pdf](http://ec.europa.eu/research/participants/data/ref/h2020/wp/2014_2015/annexes/h2020-wp1415-annex-g-trl_en.pdf)



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