Powering Homes Today, Powering Nations Tomorrow

Policy Solutions to Deliver Ocean Energy Industrial Roll-Out

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ETIPOCEAN

European Technology & Innovation Platform for Ocean Energy

An Integrated Strategy for the ocean energy sector

LEAD AUTHORS

Donagh Cagney, Remi Gruet, Ocean Energy Europe

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JQ&ROS Visual Communications

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EXECUTIVE SUMMARY

Europe needs Ocean Energy

Europe has a rich source of clean, predictable ocean energy, which today remains largely untapped. The ocean energy industry estimates that 100GW of wave and tidal energy capacity can be deployed in Europe by 2050, meeting 10% of Europe's current electricity needs.

Ocean energy produces electricity at different times from wind and solar. It is an essential solution to help a variable wind and solar production match with a variable power demand every hour of the day. This will become increasingly valuable as Europe reaches 80%-100% renewable electricity.

Ocean energy is a new industry, that can deliver 400,000 EU jobs by 2050, billions of euros in exports, and industrial activity – specifically in coastal regions, where this is most needed.

5 innovative technologies, ranging from R&D to pre-commercial stage

Tidal stream – In recent years, tidal stream supplied record volumes of predictable power. New projects are being deployed in Europe and across the globe, with economic impacts already visible across the supply chain.

Wave energy – Several promising prototypes have been deployed or will reach European waters in 2019. They target different wave climates and markets, and are stimulating the first wave energy industrial clusters. Step-by-step approaches are producing fewer but more effective technologies.

OTEC & SWAC – Ocean Thermal Energy Conversion (OTEC) projects now focus onshore, to reduce costs and benefit from economies of scale. Sea Water Air Conditioning (SWAC) is more advanced and is already servicing commercial districts and data centres in Europe.

Salinity Gradient – Small scale prototypes aim to prove the technology and reduce costs to enable scaling-up.

Tidal range – A proven technology, tidal range is commercial with revenue support. The infrastructure works needed can provide additional benefits, such as tourism or costal protection. Industrial roll-out will be triggered by the right policy conditions.

Challenges to financing innovation across 5 stages of development

R&D AND PROTOTYPES: FINANCING PROJECTS THAT DO NOT MAKE A RETURN

The objective of R&D and prototype deployments is to generate learnings and allow further innovation. Such projects do not generate returns, so a high percentage of grant funding is thus required - often up to 100%.

Grant funding through Horizon 2020 or national programmes has been rather successful in bringing innovations from design to full-scale sea-worthy prototypes. Rationalisation is still possible to optimise public expenditure, reward innovative success, and avoid duplication of R&D activities. Such a 'stage-gate' solution is currently running in Scotland. Action 1 presents which benefits a European approach could bring.

DEMONSTRATION AND PRE-COMMERCIAL FARMS: REMOVING TECHNOLOGY RISK, LOWERING COSTS OF CAPITAL AND PROVIDING MARKET VISIBILITY

The objective of demonstration and pre-commercial farms is to standardise technology and validate the business model. Technological or business uncertainties remain at those stages, in manufacturing, installation and operation. Those uncertainties constrain access to finance, except for more risk-savvy institutions or programmes, who require much higher returns than for commercial technologies.

To attract investors, those projects must be able to repay interests on loans and dividends on equity. The price of electricity is not sufficient to generate those returns, as all innovative technologies require economies of scale to reduce costs. A 'top up' on power sales is thus needed to allow the project to secure further investments.

Beyond financial institutions, OEM and utilities also require future market visibility to justify riskier investments into a new industry. Energy policies such as renewable energy targets, decarbonisation strategies and tendering processes, are essential to provide them with the necessary market visibility.

INDUSTRIAL ROLL-OUT – REDUCING COSTS THROUGH VOLUME

At industrial roll-out, the objective is to use volumes to drive down costs. Economies of scale will allow ocean energy to achieve the same dramatic cost reductions as wind and solar, given the similarity in business models. This can only be achieved with good market visibility, which justifies investments into production facilities and incremental R&D.

As for Demonstration and Pre-commercial projects, revenue support beyond electricity market prices is required to harness investor finance. Utilities and independent financiers will not engage if they cannot make a minimum return on projects. OEMs will not engage if they do not see a pipeline of orders that justifies the initial investment and ramp-up of production.

Revenue support, earmarked for ocean energy, will make projects financeable, and will demonstrate to OEMs that there is market for their products, as presented in Action 3.

ACROSS ALL STAGES: LICENSING AND CONSENTING MANDATORY STEPS FOR ANY PROJECT

Deploying devices in the ocean enables to develop the technology and learn about potential impacts, while respecting local environments and communities.

Licensing and consenting authorities must strike the right balance between protecting against potential risks and allowing ocean energy deployments to happen so they can generate learnings. Initial studies show no significant impacts on the environment from ocean energy, though monitoring must continue as more devices are put in the water.

Action 4 highlights how better data collection, sharing best practices and a more structured 'adaptive management' approach to decision-making will strengthen ocean energy licensing and consenting.

An Integrated Strategy: actions required to develop technology from early research to industrial roll-out

Part V of this document lays down 4 actions required to get the sector to commercial roll-out. They will create the right policy framework for each of the 5 development phases that devices must pass through to reach commercialisation.

ACTION 1 – R&D AND PROTOTYPE: FINALISE A EUROPE-WIDE STAGE GATE PROGRAMME WHILE MAINTAINING CLASSIC GRANT FUNDING

The establishment of a European stage-gate programme will further improve an already well functioning funding structure for those stages. This action is informed by discussions with national governments, the European Commission and academia, and follows the positive results achieved by an existing national scheme: Wave Energy Scotland.

In a stage-gate programme, grants are awarded via a series of competitive calls, covering up to 100% of costs. Calls target improvements in devices, components and sub-systems, and are assessed according to clear metrics and standards. The programme works like a funnel for the most successful innovations: manufacturers compete, with each call awarding more funding to fewer applicants until only the best devices, components or sub-systems remain in the programme.

A pan-European programme would be more cost-efficient, and avoid duplication of R&D.

ACTION 2 – DEMONSTRATION AND PRE-COMMERCIAL FARMS: A BLEND OF GRANT & FINANCIAL INSTRUMENTS TO HELP PROJECTS REACH FINANCIAL CLOSE

A blend of financial instruments is needed to finance demonstration and pre-commercial farms, as no private party will invest without return and visibility on future markets. Such instruments should include:

- Grant funding – to reduce the total financing requirement and cost of finance
- Public-supported equity – to improve access to capital, and lower cost of finance. Public equity can price risk more appropriately – and thus facilitate project financing. The EU Investment Platform scheme is an example.
- Public-guaranteed loans – to improve access to capital, and lower cost of finance. Loans can be guaranteed by public bodies – such as the EU Innovfin EDP scheme – to enable lower rates than with commercial lenders.
- Insurance & Guarantee Fund – to cover technical risk, reduce financial exposure and allow private investors to fill the remaining financing gap at lower cost.
- Revenue support – to finance OPEX, interests from debt and dividends for equity

Those instruments can ideally be used in combination, as each reduces total finance needs, whether upfront or annual. This ensures best use of available public funding. Reaching financial close without the entire blend of programmes is possible, yet it means the other available programmes will have to provide proportionally more.

ACTION 3 – FROM DEMONSTRATION TO INDUSTRIAL ROLL-OUT: REVENUE SUPPORT AS ONLY WAY TO FULLY FINANCE PROJECTS

National-level revenue support earmarked for ocean energy will allow projects to deploy. Manufacturing of large numbers of devices will reduce the cost per kWh – as has happened with wind and solar.

Several options are available to design effective revenue support mechanisms: competitive auctions in reserved 'pots', Feed-In-Tariffs, tax credits for private Power Purchase Agreements, etc. Support should slowly move from low volumes at higher €/kWh, to larger volumes at lower €/kWh. Capacity limits can be set to control total budgets. Further clauses can ensure support levels that avoid overcompensation.

ACTION 4 – A SET OF INITIATIVES TO GENERATE DATA AND BEST PRACTICE FOR LICENSING AND CONSENTING

Better data and best practices will empower licensing and consenting authorities to allow ocean energy deployments while still protecting local environments.

Programmes to monitor the environmental impacts of projects across Europe will produce comparable and consistent data for authorities. The sharing of best practice will allow authorities to learn from their peers and to develop similar processes across Europe. An 'Adaptive Management' approach can empower authorities to protect local environments while still gathering data on deployments to make better decisions in the future.

Action 2 proposes a blending of solutions to those challenges.

PART I

Europe needs Ocean Energy

EUROPE NEEDS OCEAN ENERGY BY 2050

10% of Europe's energy needs by 2050

OCEAN ENERGY RESOURCE ESTIMATES

100GW
Capacity

10% of Europe's power consumption

Europe has a rich source of clean, predictable ocean energy, a valuable resource, which as of today remains untapped. The ocean energy industry estimates that 100GW of capacity can be deployed in Europe by 2050. This target is consistent with recent studies on the practical deployment potential of ocean energy in Europe. Globally, the market for ocean energy could see 337GW of installed capacity by 2050[i].

337GW
Installed Capacity
Wave and Tidal Energy

100GW of ocean energy could meet around 10% of Europe's power consumption.[ii] This is as much as standard hydro-electric dams are producing today. And it will be needed, as Europe's energy transition further accelerates.

Predictable energy to complement other renewables

RENEWABLES PENETRATION: 80%-100%

Driven by the moon
100% predictable
Years in advance

Europe in 2050 must become very different from today to reach net zero carbon emissions.[iii] Much more of the economy will be electrified. Wind and solar energies will form the backbone of the electricity system. Renewable penetration will reach up to 80%-100% of supply.[iv]

To balance this variability, more flexible electricity sources will be needed. Tidal stream and wave energy produce at different times from wind or solar, making them an ideal complement to those technologies.

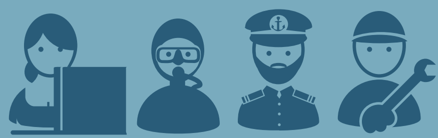
Driven by the moon, the energy that tidal stream and tidal range can harness is 100% predictable, years in advance. Waves can also be predicted with high accuracy as they are created by the wind and persist long after the wind is gone. OTEC and salinity gradient can deliver non-stop power, and can be ramped up or down as needed.

Ocean energy's production profile means that it becomes most valuable as Europe completes its energy transition, and more variable renewables are connected to electricity systems.

Jobs & economic development in coastal areas

OCEAN ENERGY CAN DELIVER...

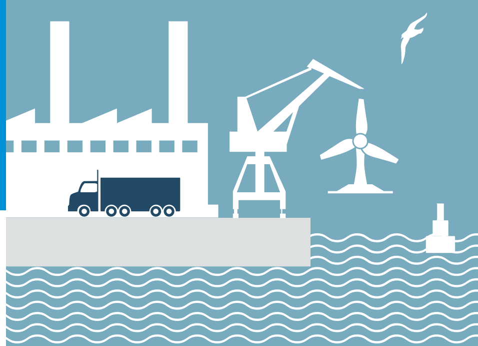
400,000 jobs
by 2050



Ocean energy can deliver skilled 400,000 jobs by 2050[v].

These jobs will cluster along Europe's coastline, close to where the first ocean energy farms are deployed.

GROWTH **OPPORTUNITIES**



This means economic activity for Europe's coastal regions. It means the revitalisation of the infrastructure and supply chains that serviced historical sectors such as shipbuilding, fishing and oil & gas. And it means growth and opportunities for Europe's coastal communities.

European export leadership

EUROPEAN PATENTS

66% Tidal | 44% Wave

Europe is already a global leader in ocean energy technology. The latest info shows that Europe has 66% of global tidal energy patents, and 44% for wave energy.[vi] Most projects around the globe use European technology[1].

Europe can now translate this into export success, and dominance of a market worth €53bn annually.[vii]

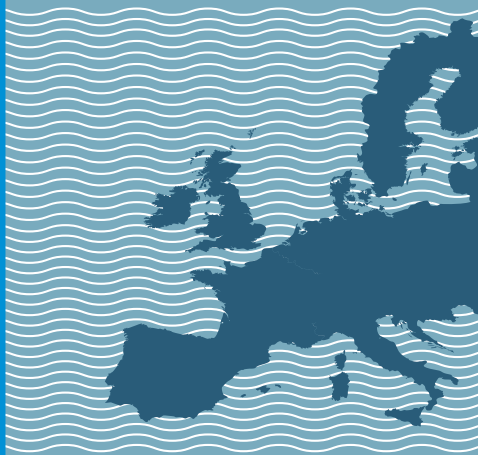
EUROPE CAN DOMINATE A MARKET OF

€53BN

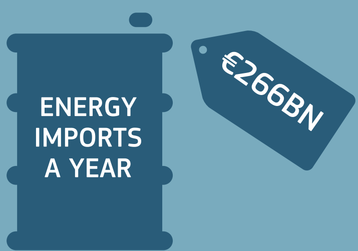
ANNUALLY

In doing so, Europe will be building on successes already achieved within the wind sector. By 2015 European wind turbine manufacturers had supplied 49% of cumulative global wind capacity.[viii] The EU now consistently exports €7bn-€8bn of wind energy goods and services each year.[ix]

Security of supply and avoided imports bill for fossil fuels



EUROPEAN CAN SAVE

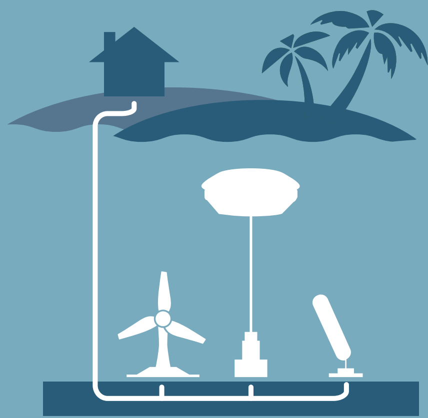


Europe cannot afford to indefinitely rely on geopolitical competitors, autocratic regimes and unstable regions for its energy needs.

The continent has been blessed with some of the greatest ocean energy resources in the world. Harnessing this energy sources will play an important role in building an energy-independent Europe. It will slash the €266bn that Europe spends each year on energy imports.[x]

Benefit for EU islands

HAVE LITTLE TO NO VISUAL IMPACT



Tidal currents and waves are usually strong around and between islands, making them a prime location to extract the most electricity via ocean devices. The high cost of electricity from diesel generation on islands – 300-600€/MWh – makes ocean energy already appealing today, in some cases, even competitive. Producing at different times from wind and solar, they are an ideal complement to balance small or independent grid systems.

Ocean energy technologies have little to no visual impact, preserving the landscape and touristic value of the environment. Installed offshore, they leave land use best used for other economic activities – e.g. tourism. In many cases installation makes use of the local economy and skills – the more industrialised the island, the more local content!

[1] For example European developers hold all the berths in Canada's Bay of Fundy test site. Developers such as Wello, Sabella and Tocardo have projects in Indonesia. European wave developers are installing devices in Hawaii.

PART II

State of the technology

1.

TIDAL STREAM

Delivering GWh of power on demand while seeking market visibility

Europe has achieved a technological breakthrough in tidal stream during the past 2 years: predictable power is being generated, and the technology's nascent economic impact is becoming clear. An export market is also developing.

Major progress on electricity and data generation from pilot projects

2017-2018 have been breakthrough years for tidal stream. European homes and businesses are being powered by tidal energy. It is not only the world's first tidal arrays which are delivering on their potential - individual demonstration projects have equally achieved major successes.

◁ Installed in 2017, **Orbital Marine Energy's** device generated more than 3GWh hours during its year-long deployment in the North Sea.[xi]

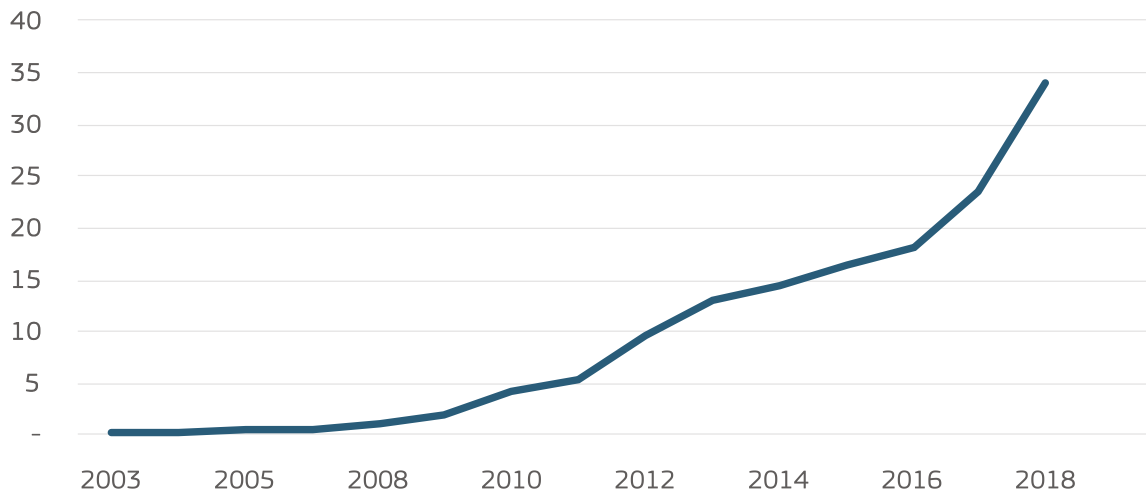
In October 2018 **Sabella** redeployed its turbine off Ushant Island in Brittany France. On average the turbine provides 15% of the island's energy needs and this can increase to 50% when required.[xii] ▷

◁ Since late 2015, **Tocardo's** 5 turbines have been powering 1000 Dutch homes from tidal flows through the Eastern Scheldt storm barrier.

◁ **Nova Innovation** is doubling the size of the world's first tidal array. The array has delivering baseload power to the grid. The first turbine was installed in March 2016.

MeyGen is the world's largest tidal farm, powered by 4 turbines developed by Andritz Hydro Hammerfest and SIMEC Atlantis Energy installed end 2016. Over 12.5GWh have been generated at time of publication.[xiii] ▷

Tidal stream's recent record of power production shows just how far the technology has come. More power has been generated by tidal stream since the start of 2017 than in the previous 13 years combined.



Source: Ofgem Renewables and CHP Register, public releases from developers, information supplied to OEE by developers

Fig. 1 - Cumulative GWh produced by tidal stream in Europe, 2003 - 2018 [xiv]

Power production from those projects has been consistently confirming the predictability of tidal stream. Predictability makes it easier and cheaper to balance Europe's electricity grid, and will become increasingly important as even more power from variable renewables such as wind and solar comes online.

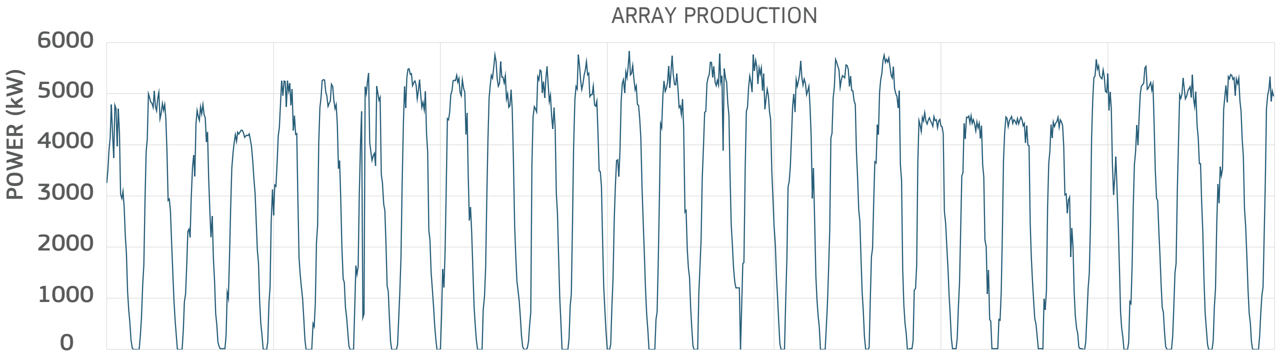


Fig. 2 - Power generation at the MeyGen tidal farm reflects the flows of the tides. As the tide gathers pace, more power is generated. Power production peaks when water is flowing at its fastest. During the short periods of high and low tide, there is no water movement, and so no power is generated.[xv] Power production varies because there is a natural rhythm of more powerful 'spring tides' and less powerful 'neap tides'.

Tidal's predictability and guaranteed short cycle times make it the perfect partner for energy storage. The time period between tides is very short, so only a small volume of storage cans enables a device or array to deliver baseload load power on a continuous basis or when it is most needed. Nova Innovation is already providing this grid service to make tidal array includes an integrate battery pack.[xvi] Sabella has integrated a battery with its turbine at Ushant Island, which smooths the power fluctuations that waves can create.

Now that the first range of tidal stream turbines has been tested and proven, the industry is developing the next phase of projects.

These will be essential to test new machines, to de-risk the technology, and to further reduce energy costs.

Many of these projects were originally planned for Europe. But project developers are increasingly being attracted abroad, by more favourable market opportunities.

MARKET DEVELOPMENT IN EUROPE….

HydroQuest plans to deploy its 1MW device at EDF’s Paimpol-Bréhat site in 2019. The grid-connected site will allow HydroQuest to test their turbine for an initial 12-month period.

Sabella plans to deploy two additional 0.5MW turbines at their Ushant Island site. These are part of a wider project to power the island via a combination of tidal, wind, solar and storage.

SIMEC Atlantis Energy plans to install two extra turbines of up to 2MW each at the MeyGen site in 2019, and are working towards another expansion. The MeyGen project is permitted for up to 398MW, to be built in stages.

Orbital Marine Power is developing what will be the first floating tidal stream turbine to go into commercial production. This improved 2MW device will be deployed and grid-connected in early 2020.

....AND BEYOND EUROPE

DP Energy have a 9MW site in the Bay of Fundy, Canada, which boasts some of the world's strongest tides. The site is grid connected and the project is supported by a grant and revenue support at €350/MWh.[xvii]

Minesto is developing a pre-consented site off Keelung City in north Taiwan. This will be a base for further installations in Taiwan and across Asia. Minesto has been active in Taiwan for several years, and established a local subsidiary in 2017.

Several developers are in talks to supply turbines for a '**tidal bridge**' of up to 25MW. The bridge will link two islands within Indonesia, and turbines installed underneath will harness the tidal forces.

Beyond power produced and projects deployed, tidal stream has seen a convergence in the technology. The more successful tidal turbines have all been horizontal-axis, with two or three blades, similar to underwater wind turbines.

This is a crucial step in the path to full commercial roll-out. As a consistent design for tidal turbines emerges, common performance standards will be agreed, 'off-the-shelf' components can be used, and competitive supply chains emerge. This will increase the rate of cost reduction for tidal energy.

An already visible economic impact, even at this early stage

Beyond consistent power production, the first farms have also demonstrated the industry's important contribution to local economies.

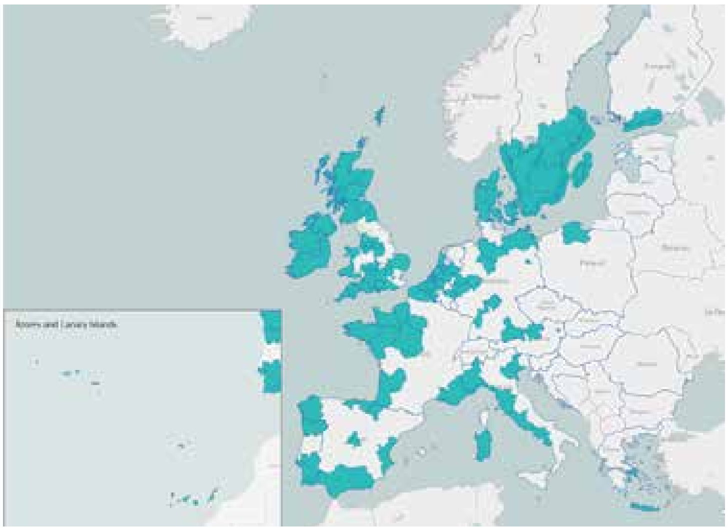
- 25% of project expenditure during construction of Nova Innovation's tidal array went directly to local companies in the Shetland Islands. Over 80% of its supply chain content expenditure was in Scotland. 60% of Nova's supply chain expenditure went to companies in the Highlands and Islands region of Scotland.[xix]

- The Port of Nigg in Scotland has become the base for the assembly and maintenance of the MeyGen tidal turbines.

Such activity has contributed over €130m in Gross Value Added to the economy of north-west Scotland by 2017, supporting almost 2000 full time equivalent worker years.[xx]

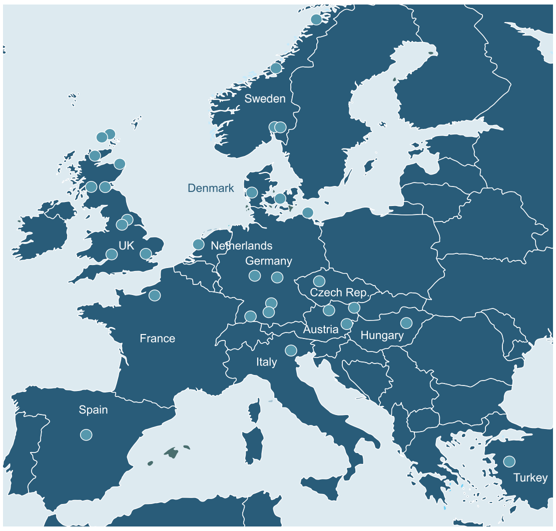
Nigg Port is a clear example of a wider trend – the repurposing of infrastructure and human skills from legacy industries such as oil and gas, ship building and fisheries, to service ocean energy needs.

The economic impact of tidal energy has not just been limited to coastal regions. Businesses across Europe are benefiting from the emergence of a new tidal stream industry:



Source: Ocean Energy Supply Chain in Europe. Joint Research Centre

Fig. 3 -The European Commission's Joint Research Centre has mapped wave and tidal's supply chain along the continent's coastal regions



Source: Andritz Hydro

Fig. 4 -Turbine manufacturer Andritz Hydro manufactures in Austria and south Germany, and has identified at least 14 supplier countries.

2.

WAVE ENERGY

A step-by-step approach to prototype development

Wave technologies progress at more sustainable pace than before. This step-by-step approach has produced several promising prototypes, which cater for different wave climates and market opportunities.

Several concepts catering for different wave environments and markets

A variety of promising wave devices have been designed, tested and deployed over the past 2 years, to suit a variety of geographical conditions and business models.

◁ Following successful half-scale testing during 2018, **CorPower Ocean** is now focusing on the deployment of a full-scale version. Reduced costs and complexity are at the core of the device's design. While average energy generation is maximised, the device 'detunes' during very large waves, to increase survivability and reduce capital costs.

Wello's first 'Penguin' device has survived 2 years in the North Sea, weathering waves of almost 20 metres. A second Penguin has been extensively re-designed, to exploit learnings from the deployment of the first device. It will be deployed in spring 2019. ▷

◁ Building on testing of successively larger versions, **AW-Energy** will deploy its first commercial WaveRoller in Portugal in 2019. The device sits on the seabed and harnesses near-shore waves. The seabed limits the size of waves which ensures lower extremes and more consistent power production. On-board storage allows smooth power to the grid, and can provide frequency services to electricity system operators.

A grid-connected wave energy convertor has been deployed off the north coast of Spain for the last 2 consecutive winters. The Marok-A-5 device has been recently upgraded with an advanced turbine – which has been first tested in the Mutriku Plant (see below). The deployment is being supported by the **Basque Energy Agency**, and is part of the EU 'OPERA Project'

The Mutriku Plant has generated over 1.8 GWh since its commissioning in 2011[xxi]. The facility was incorporated into the design of a new breakwater to protect the harbour, thereby reducing investment and future operating costs. In addition to producing electricity for the grid, the plant offers testing opportunities for turbines and control strategies.

Belgian developer **Laminaria** will deploy a full scale prototype in the Orkney Islands in 2019. This follows an extensive programme of testing, from initial tank tests to sea trials with a ¼ scale device off the Belgian coast in 2014-2015.

A SOLUTION FOR SPECIFIC NEEDS AND NICHE MARKETS

Developers of smaller scale wave devices have also taken important strides forward. Smaller devices target offshore operations, such as aquaculture or oil & gas platforms, where power is harder to source.

The technology within these devices can subsequently be scaled-up to deliver utility-scale volumes of power. Focusing on niche markets allows the technology to be established and improved at a lower level of risk and cost.

Resen Waves is a good example, having completed the commercial sale of a first device. It provides electric power and data communication to autonomous sensors on the sea bed. It is now possible to have online access to under water sensors all year round, without having to replace batteries.

Fred Olsen is another example, has just completed a deployment of their device, which is designed to remotely power offshore equipment.

Albatern has developed a wave energy array product to power fish farms in the rapidly-growing aquaculture market and other off-grid markets where diesel generation is currently used.

First wave supply chains beginning to emerge

Although not as advanced as tidal stream, the first signs of wave energy industrial clusters are also emerging.

For now this economic eco-system is largely build upon companies which are already active in related domains, such as maritime operations, electricity systems, engineering and early-stage research. But there are also a range of organisations, who are increasingly or exclusively focusing on wave energy as a source of profits and future business. For example, Orkney-based Green Marine operates a fleet of vessels focused on installing, servicing and decommissioning ocean energy projects. The Basque Country's Energy Agency has mapped the region's wave energy supply - see below.

Source: The Basque Energy Agency

Fig. 5 - The Energy Agency of the Basque Country has mapped the region's wave energy supply chain, and categorised each player according to the critical component, system or service it provides.

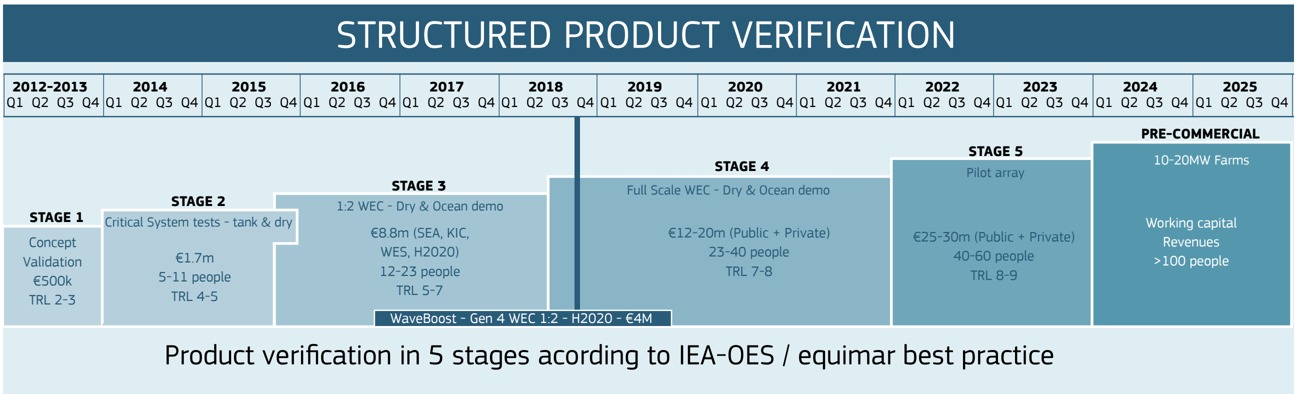
Learning from the past: growing slower to progress faster

Wave technology development processes have undergone a revolution in recent years. Following Aquamarine and Pelamis bankruptcies, the focus has moved away from quickly building large-scale prototypes.

Instead, a more step-by-step approach is taken to developing the latest generation of wave energy convertors. Typically, this includes up to six phases, where the successful completion of one phase conditions funding for the next:

1. Design, modelling and control
2. Very small-scale separate testing of device, components and sub-systems in small tanks
3. Small-scale testing in larger tanks
4. Small-scale testing in sheltered sea conditions
5. Medium-scale testing in sheltered sea conditions
6. Full-scale testing in exposed sea conditions

This gradual approach allows developers to continually validate and improve their modelling and technology, including key components. Once validated, learnings from each step are incorporated into the next, thereby reducing risk and costs.



Source: Corpower

Fig. 6 - CorPower Ocean's step-by-step approach to Research, development and innovation underpinned the creation of their C3 wave device.

This means that less full-scale wave prototype demonstration projects hit the water, yet that those who do are more likely to be successful. And as projects are more successful, the sector as a whole progresses more rapidly.

3.

OTEC & SWAC

Developing onshore to exploit synergies and lower costs

OTEC generates power by exploiting the difference in temperatures between warm seawater at the surface and cooler water at deeper levels. The technology can generate 24/7 non-stop power, and is a key technology for EU islands and export markets around the equator and in tropical latitudes.

Developers and utilities are also using the core technology to deliver an integrated range of different solutions, beyond just power production. Existing applications such as Sea Water Air Conditioning (SWAC) and desalination help the technology build a business case and break into commercial markets.

Bringing OTEC back onshore to deliver cost savings at scale

More challenging offshore technically and financially, ocean thermal energy conversion (OTEC) has shifted back onshore in the past 2 years. Attempts at floating offshore installations have been delayed for now, until onshore installations are running.

The move will allow developers to make use of the significant economies of scale of larger OTEC installations, while lowering technical risks. Larger OTEC plants deliver cheaper power, as output can be scaled up without a corresponding increase in costs. Similarly, technical challenges such as the pipe pumping cold water to the surface are much simplified onshore.

Efforts have been focused on scaling up to a 10MW plant, as a first-step towards delivering a commercial offshore product. As an example, **Naval Energies** has an onshore OTEC prototype in La Réunion.

Harnessing synergies to establish the business case

Pumping deep seawater is at the core of OTEC – and it can be used for more than just power production. Dutch company **Bluerise** is developing projects across the Caribbean and the Indian Ocean that combine power production with district cooling. As well as decarbonising both power and heating/cooling systems, combining both revenue streams helps to make projects bankable and will pave the way towards larger scale offshore OTEC power production.

OTEC is also well suited to the production of fresh drinkable water from the sea. Deep seawater's purity is ideal for drinking purposes, and is already being brought onshore by OTEC activity. The combination of power generation and desalination process allows for more competitive costs than one process in isolation.

Desalination is a rapidly growing market – the UN estimates that half of the world's population will be living in water-stressed areas by 2030.[xxii]

SWAC – an already commercial technology

Sea Water Air Conditioning (SWAC) projects which provide heating and cooling for buildings and districts are already being delivered commercially – including in Europe. Running since 2016, **Engie**'s 'Thassalia' project will service 500,000m² of building space in Marseille by 2020.[xxiii] Seawater is pumped to heat exchangers and pumps. The heated or cooled water is then piped to individual buildings in the city's revitalised 'Euroméditerranée' port area.

Monaco has been using seawater heat pumps as far back as 1963. Today 75 sea water heat pumps produce 20% of the Principality's energy consumption.[xxiv] As in Marseille, the seawater provides heating in winter and cooling in summer.

Applications are not just limited to district heating/cooling, nor to warmer regions. Google has been cooling one of its data centres with seawater in the Bay of Finland since 2011.[xxv]

In summer 2018, a Microsoft data centre was installed on the seabed off the Orkney Islands. Sea temperatures will reduce the cooling energy needs by up to 95%. The centre will be immersed for one year, but has been designed to operate for five years without direct intervention.[xxvi]

4.

SALINITY GRADIENT

Research at scale

Seawater typically has 200 times more salt than fresh river water. When the two mix, the resulting chemical pressure can generate non-stop renewable power. Research for this high-potential technology is at an early stage, but successes have already been achieved.

Small-scale demonstrations point to important market potential

It has been estimated that where large rivers enter the world's oceans, there is a realistic annual potential of 5,177 TWh of salinity gradient power.[xxiv] That's more than 22 times Spain's annual power consumption today.

Salinity gradient demonstration activity is focused in the Netherlands. A new technique, known as 'Reversed Electro Dialysis' has been successful implemented at a pilot in Afsluitdijk. This has paved the way for a scaled-up 1MW pilot plant.

Fujifilm are involved in the establishment of the pilot plant. It makes use of two types of membranes, which allows the pass through of charged ions. Electricity is generated by arranging these two types of membranes in a 'stack'.

In 2018 a process was identified to produce hydrogen, using leaked voltage from the salinity gradient process. This boosts the business case for the technology. It is estimated that the river Rhine alone can be used to generate 1,750 MW of power and produce 1.6bn m^3 of hydrogen each year.[xxviii]

Membrane research as a path to cost reduction

A 2 MW plant would require at least 2,000,000m^2 of membrane, which will need regular maintenance and occasional replacement. The membranes are the most critical cost component, accounting for 50%-80% of capital costs of a salinity gradient project. Membranes suitable for salinity gradient power are currently 2-3 times more expensive than standard commercially-available membranes.[xxix]

5.

TIDAL RANGE

Proven technology, commercial with revenue support

Tidal range has been producing predictable power in Europe since the 1960s. It uses 'low-head' hydro-electric turbines, the likes of those used in hydro-electric dams. It is thus proven technology, and can be integrated into pre-existing or custom-built infrastructure, potentially providing other services.

There is an estimated 1000 GW of technically harvestable tidal range energy resource in the world.[xxx] Europe is one of the regions where this potential is strongest. In the UK, tidal range has the potential to supply up to 12% of the country's power needs.[xxxi] 2 regions in the Normandy and Picardy regions of France have up to 15GW of available capacity.[xxxii]

Individual tidal range installations can deliver significant volumes of power. The proposed Cardiff Tidal Lagoon project could power 1.5m homes annually.[xxxiii]

Providing both electric power and infrastructure services

The sites provide wider public services in addition to power generation. The La Rance facility is also a bridge, allowing up to 60,000 vehicles to skip a 30km journey each day.[xxxiv] The South Korean installation improves the water quality within a pre-existing reservoir.

Proven technology, commercially available with public support

The first major tidal range plant (240MW), at the La Rance estuary in France, has been generating power since 1966. A 254MW plant was opened at Sihwa in South Korea in 2011.

Energy production costs at these two sites are competitive, varying between €0.02-0.04/kWh. These low costs are due to the depreciated capital expenditure at La Rance, and the re-purposing of an existing seawall at Sihwa.[xxxv]

Current projects are close to other renewable energy technology prices. Yet their custom-built infrastructure and added environmental measures mean the first few projects will require public financial support. Revenue support, such as a Feed-In-Tariff, Contract for Difference, or a Certificate/Quota systems, for a small number of projects would be enough to bring the technology to commercial roll-out. For example, the Swansea Bay Tidal Lagoon project is seeking support at similar / kWh levels than the Hinkley Point nuclear power plant.

PART III

Key innovations to progress Ocean Energy through 5 phases of development

Different ocean energy technologies and devices are at different phases of development. The right support framework needs to be in place at each phase, for ocean energy to improve performance, reduce costs, and reach commercialisation.

The Ocean Energy Forum Roadmap clearly defined those phases and their differentiations to simplify the useful Technology Readiness Level (TRL) scale and account for the fact that project can benefit from similar finance structure throughout several TRLs.

This document will follow the same methodology and use the Roadmap's phases as per figure 7 below.

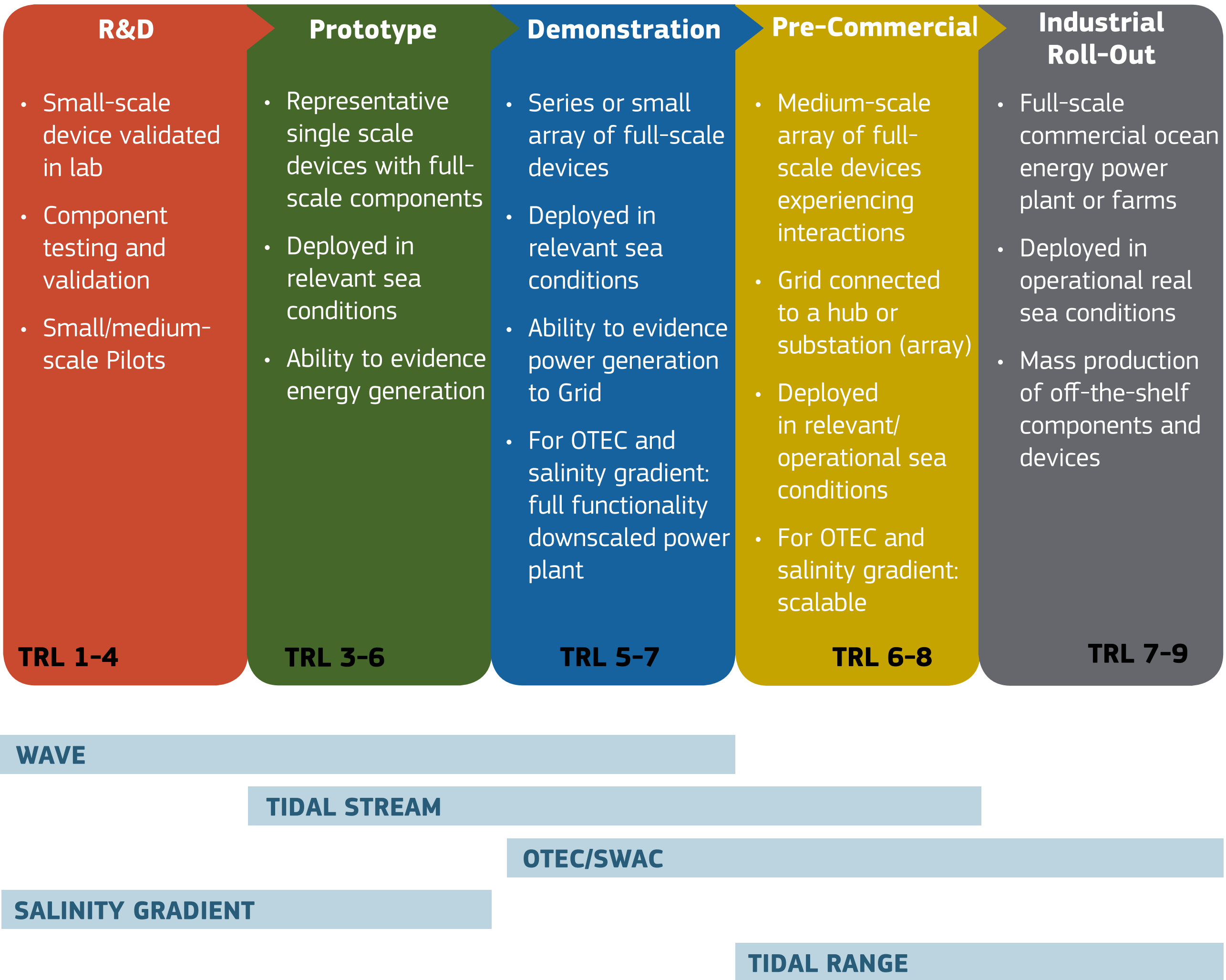


Fig. 7 - Where ocean energy technologies are in the 5 stages of development

The next double-page identifies the key innovations that the ocean energy sector must take to reach industrial roll-out, and indicates at which stage of development these actions are likely to take place. Innovation actions are taken from the Strategic Research Agenda for Ocean Energy.

Allocating those innovations to a specific stage is mostly indicative – individual innovation actions may take place at a different stage than the one presented, depending on the project in question. However the wider trend is valid – as technology progresses innovation actions are more likely to be:

- At a larger scale
- More costly and complex
- Increasingly focused on supply chain and operation/maintenance actions

The next page also shows how basic R&D requirements are informed by later-stage developments. Learnings from prototype, demonstration, pre-commercial and even industrial roll-out are all fed back into new R&D activities. The main target for this continuous R&D are cost reductions and performance improvements. This is a virtuous cycle of innovation.

Part III and IV of this document first consider the challenges linked to financing the respective phases and propose an Integrated Strategy – 4 Actions required to bring the sector to commercial readiness.

	R&D	Prototype
Technology	• Develop device design & numerical modelling methodologies • Develop and iteratively redevelop of higher performance/lower cost devices, components & sub-system: - Power take-off systems – e.g. direct drive turbines, bi-radial wave turbines - Moorings, foundations, anchors & cable connections - Control systems that monitor conditions and respond dynamically to mitigate adverse impacts - Novel materials for blades, moorings, power take offs & hull - Protections against corrosion and biofouling • Improve device reliability/ survivability • Develop successively larger devices to improve power to cost ratios	• Validate design & recalibrate numerical models • Prove concept at smaller-scale/in test conditions • Undertaken accelerated lifespan testing of materials and components • Validate interactions of device, components, sub-systems, anchoring, moorings and foundations. • Improve device reliability/ survivability
Environmental & Social		• Generate first data on environmental impacts to inform consenting & licencing regimes
Economic viability		• Use first results to prove concept and attract initial investors

Demonstration	Pre-Commercial	Industrial Roll-Out
• Implement lessons from prototype stage • Prove concept at full-scale • Achieve & demonstrate device survivability, reliability, availability & power yield • Deploy foundations, anchoring & mooring systems for extended periods of time in real ocean conditions • Validate performance of device, components and sub-systems for extended periods of time in real ocean conditions • Validate cable connection and grid compatibility • Establish operations & maintenance procedures for single devices • Improve device reliability/ survivability	• Implement lessons from demonstration stage • Further improve device survivability, reliability, availability and power yield • Improve array layouts and device design based on array interactions • Further reduce uncertainty, risk and cost of foundations, anchoring systems • Establish manufacturing & assembly lines for standardized devices & components • Establish and improve operations & maintenance procedures for arrays – including predictive and preventive O&M processes • Deploy quick release and wet-mate connectors, and hubs for subsea power connections	• Address any serial technical issues • Use additional learnings to incrementally improve design & performance of OE devices • Optimise operations & maintenance procedures for arrays • Establish fleet of vessels tailored to ocean energy needs, that can maintain position in rough seas
• Generate data on environmental impacts to inform consenting & licencing regimes • Provide examples to inform national Marine Spatial Plans • Develop of standard procedures for monitoring of environmental impact of projects	• Increase standardisation of licensing and environmental consenting of OE projects • Increasingly limit environmental restrictions to address known risks • Map social & economic impact on local/regional/national communities	• Address remaining unresolved health, safety & environmental issues • Establish standardised procedures for zoning and environmental consenting of OE projects • Set up specialised training programmes to meet industry needs

• Produce data on performance, reliability, survivability & costs to showcase risk reductions to investors
• Begin standardisation of device, components and sub-systems
• Competitive outsourcing of some components & sub-systems
	• Source from supply chain bespoke vessels capable of maintaining position in rough sea conditions
	• Prove performance & limited risk to allow
	  • Equity investment at lower Return on Investment
	  • Availability of commercial debt for projects
	• Dramatically reduced insurance premiums
		• Further reduce risk and cost of capital by fully standardising devices, components, sub-systems & procedures for manufacture, assembly, installation
		• Establish dedicated assembly lines/manufacture facilities allow major cost reduction via economies of scale
		• Harness new supply chain to competitively source 'off-the-shelf' components & sub-systems

PART IV

Challenges in financing innovation, from early stage to commercialisation

Ocean energy technologies are at different phases of development. The right financial framework needs to be in place at each phase, for ocean energy to improve performance, reduce costs, and reach commercialisation. The Ocean Energy Forum Roadmap defined five clear phases as presented in PART III and those are the definitions used in this document:

R&D and prototypes:
Financing projects that do not make a return

Phases: **R&D** | **Prototype** | Demonstration | Pre-Commercial | Industrial Roll-Out

As per the Ocean Energy Forum definition, these stages culminate in putting a single full-scale prototype in real sea conditions. Both **wave energy** and **salinity gradient** devices are currently going through the 'Research & Development' and 'Prototype' stages. Many **tidal stream** devices are already at Demonstration stage, though some prototypes are still completing their test runs.

The technological R&D priorities for each ocean energy technology are already well understood and have been mapped out at a European level in ocean energy Strategic Research Agenda reports[2].

OBJECTIVE: TESTING TO GENERATE LEARNINGS RATHER THAN REVENUE

Each step along the way to a full-scale prototype in real conditions serves a learning purpose. That last step validates the technology. Many of those projects are not grid connected and merely monitor electricity generation – no revenues are generated.

Learnings at these stages of development are extremely valuable. R&D and prototype work, if undertaken well, sets a technology up for success. The risks at subsequent stages of development are reduced, and a structured and documented earlier approach can attract investors as the technology reaches commercial readiness.

Projects at these phases are only meant to stay in the water for a given length of time. Once they have supplied the required learnings, they are decommissioned. Access to consented ocean sites often require projects to locate in test centres. Services, operation & maintenance activities at these sites also have a cost that funding will cover for a limited time without a steady revenue stream.

Private investors are typically very reluctant to support R&D and prototype activities. They know that there is a high risk that any individual technology will not ever make a return. They also know that any returns will only be made in the long-term. Where private investment is available, it is often the developer's own capital. Grants of up to 100% funding are required to close the gap.

CHALLENGE: FUNDING INNOVATION WHILE MAKING 'BEST USE OF PUBLIC MONEY'

Grants have clear advantages for funding authorities - they are flexible, easy to manage, and can be awarded competitively. They also reduce the private financing need for innovations and don't put future financial pressure on companies the way a loan would.

When funding technology projects, decision-makers' primary goal is to stimulate innovation and drive forward technical progress. Decision-makers also have to balance this objective with other important considerations:

- Funding cannot create an unfair advantage, by allocating large portions of a total budget to a single company. This can push other potentially more successful ideas out of the innovation ring.
- Funding shouldn't focus upon one sole device or company. Putting 'all eggs in one basket' risks losing all if the individual device fails.
- Duplication is best avoided – e.g. funding the same research twice in different countries.

There are structured funding mechanisms which balance these needs while also driving innovation. See the below case study on Wave Energy Scotland. This stage-gate approach is well suited to wave energy, and makes best use of public money.

[2] For example, TP Ocean's Strategic Research Agenda for Ocean Energy – sege: https://www.oceanenergy-europe.eu/wp-content/uploads/2017/03/TPOcean-Strategic_Research_Agenda_Nov2016.pdf

AVAILABLE TODAY: CLASSICAL GRANTS AND A NATIONAL STAGE-GATE PROCESS

Grants are available to early-stage research, development and first prototype deployment from a wide range of EU and national sources.

EU sources of grant funding include **Horizon 2020, EU structural funds, the SME Instrument, the LIFE Programme and the Ocean Energy ERA-NET Co-fund**. National and regional funding agencies also offer grants, such as Ireland's **Ocean Energy Prototype Development Fund** and the Basque Country's **Aid Programme for Investment in the Demonstration and Validation of Emerging Marine Renewable Energy Technologies. MaRINET2** helps developers to access research infrastructure, including various labs, tanks and open sea test sites. Interreg programmes such as **FORESEA** and its successor **OceanDEMO** will help cover the costs of deploying in test centres.

European entities such as **InnoEnergy** and national entities such as **BPI France** have taken equity in ocean energy companies to complement the funding needs of some higher TRL projects.

Horizon 2020 has been the single most important programme for the ocean energy industry in the past 5 years, awarding over €180M in projects grants. Funding has been well targeted to meet ocean energy's most important technological challenges, as presented by ETIP Ocean and the sector[3].

The Wave Energy Scotland stage-gate process is also a first of its kind – see box for more information.

USING 'STAGE-GATE' PROCESSES TO OPTIMISE PUBLIC SPENDING FOR INNOVATION

A stage-gate process for wave energy, **Wave Energy Scotland (WES)**, has been set up in 2016 by the Scottish Government. It targets early stage R&D and prototype deployment and provides 100% funding via a pre-commercial procurement process.

The 'stage-gate' concept is based on:

Competitive bidding: an initial competitive call selecting a wide number of technologies at early stage followed by funding rounds targeting increasing TRLs, for a decreasing number of awardees

'Gated' funding: funding for the next round can only be awarded if the objectives of the previous rounds or 'stages' have been successfully completed – passing the 'Gate'

The stage-gate process remains competitive, flexible, ensures best use of a finite public budget, and rewards technological success. It avoids picking winners, duplication of efforts and concentration of funding.

At time of writing WES has funded 86 contracts, invested £38.6m and been involved with 177 separate organisations across 13 different countries [xxxvi].

[3] E.g. the priorities in the Strategic Research Agenda for Ocean Energy

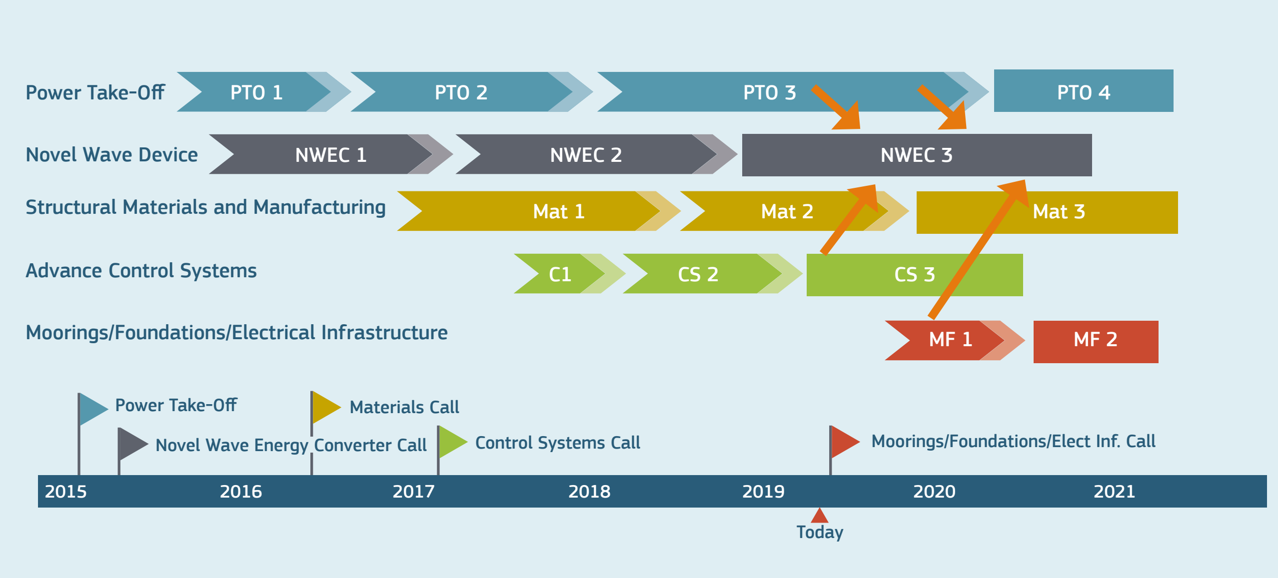


Fig. 8 - WES proposes 5 programmes focused on different elements of wave devices.

CALL FOR ACTION: DIRECT GRANTS TO WAVE VIA A EUROPEAN STAGE-GATE PROGRAMME

Because of the absence of revenue, early-stage research and prototype development will always need significant public support - sometimes up to 100% funding. Technology developers invest their own capital during this phase. Yet the time horizon to revenue generation is generally too far away to attract further private investors.

A combination of straight grants and a structured approach, such as a stage-gate is particularly relevant. This approach is well suited to wave energy: the wide range of potential ways to harness the energy of waves means that a structured stage-gate approach provides a valuable direction – a 'funnel' – for research.

Given the WES experience, an EU-wide stage gate programme for pre-commercial procurement would accelerate technology demonstration, while minimising EU-wide spending and avoiding duplication of efforts. The Ocean Energy Forum Roadmap was already recommending such a programme and the European Commission's DG Research, Innovation and Development has produced a stage-gated call for 2019-2020.

See Integrated Strategy Action 1 in Part IV for more information on the initiative to setup such a programme.

Demonstration and Pre-Commercial farms:
Removing technology risk, lowering costs of capital and providing market visibility

Phases: R&D | Prototype | **Demonstration** | **Pre-Commercial** | Industrial Roll-Out

Tidal stream has reached the stage of demonstration and pre-commercial arrays. In the coming years, **wave energy** devices will also advance from prototype to demonstration stage. A number of larger **OTEC** demonstration projects are being planned, though some are still at prototype stage.

Dubbed "the Valley of Death", these phases are often the most difficult to finance due to technology uncertainties, cost of finance and total investment needs of projects. Unlike in previous phases, ocean energy demonstration and pre-commercial projects do have to generate revenues. Grant funding for these projects never covers all project costs. Financial instruments and private investment must fill the gap. This will only happen if expected project revenues are sufficient to repay this capital and its cost.

OBJECTIVE: ACHIEVING STANDARDISED TECHNOLOGY AND VALIDATING THE BUSINESS MODEL

After testing a single prototype, moving to the demonstration phase – a tidal farm or larger plants for OTEC – aims to validate the technology over several units or at increased size, and over longer periods of time. Learnings from several machines identify potential weak points, further improvements in installation and operation and the device's responsiveness to real ocean conditions. These learnings enable manufacturers to remove technological uncertainties and reach off-the-shelf components and devices.

The pre-commercial phase specifically should be a smaller version of future commercial project. It aims to validate the business model for that technology. It identifies the main cost components and cost reduction pathways – automation, bulk-manufacturing, streamlining of installation/operation... It proves the business case.

Both phases are crucial to deliver a new commercial product, and the benefits that go along with a new home market.

CHALLENGE: REMAINING TECHNOLOGY RISK MEANS HIGH COST OF CAPITAL AND LOW ACCESS TO CAPITAL

Given the scale of demonstration and pre-commercial projects, grants never cover 100% of project costs. This gap must be filled by private investors, who are very sensitive to the degree of risk they incur in the project.

All energy investments carry some form of risks – market, technological and regulatory – all of which have a direct impact on project costs. The greater the risk, the greater the cost of financing and insuring the project.

Technological/business uncertainties remain at Demonstration/Pre-commercial stages, in manufacturing, installation and operation. Those uncertainties translate into financial risks requiring guarantees or insurance coverage. They increase the cost of finance for projects and decrease the willingness of lenders to provide finance. Banks generally will not extend credit. Private investors are often unwilling to finance the project.

Where private investors do agree to enter a project, they demand high returns, to compensate them for the high risk they face. This dramatically increases financial costs, and can easily render a project economically unviable.

If private investors are willing to take equity, they demand returns that increase project costs prohibitively.

The MeyGen project offers a good example of the financing challenges faced by ocean energy projects. The first phase of MeyGen involved the installation of 4 turbines. The project required €57.5m (£51m) of investment in different forms, and circa 80% of this had to be met by public sources.

Public source	£m	% of Project Cost [xxxvii]
Grants	13.3	26%
Repayable debt	17.5	35%
Equity	9.7	20%
Total public investment	**40.5**	**80%**

Insurance could be used to mitigate technology risk, yet commercial insurance products covering early development risks do not exist. If they did, insurance premiums would likely be prohibitive. Similarly, manufacturer guarantees cannot cover all the risk before the device has reached off-the-shelf status and uncertainties are removed.

To improve access to finance, and decrease the cost of both capital and insurance, these uncertainties must be exposed and addressed. The data required will only be gathered progressively, as more devices are put in the water. Learnings from projects installation and operation will make these risks measurable and predictable – enabling insurance or guarantees to cover them.

CHALLENGE: CLOSING THE FUNDING GAP - APPROPRIATE REVENUES TO SECURE PRIVATE INVESTMENT

Contrary to the R&D/Prototype phases, demonstration and pre-commercial projects are generally 'project-financed': they include various public and private sources and a mix of grant, loan, debt and equity. For these reasons, projects must be able to repay loan interest and service equity. Project revenue must be enough to convince private investors to close the funding gap. This requires revenue support – i.e. a 'top-up' payment in addition to electricity sales.

Beyond financial institutions, OEM and utilities also require future market visibility to justify investments into a new industry. Renewable targets and medium-term revenue support both give a necessary market visibility to convince those large actors to invest early on into riskier projects than their immediate bottom line recommends.

The challenges of revenue support and market support in these phases are very similar to those outlined for revenue support in the industrial roll-out phase further down. Please refer to it for more details.

AVAILABLE TODAY: EU-LEVEL FINANCIAL INSTRUMENTS THAT REQUIRE A RETURN FROM PROJECTS

Several instruments have been developed in the recent past to finance the demonstration/pre-commercial phase for energy projects. However, these instruments require projects to deliver a return on any equity or loans. Only ocean energy projects with earmarked revenue support can deliver this today. Also, their design often offers few solutions to cover the risks inherent to those phases. In practice, this means that these instruments are often available but inaccessible to an innovative sector such as ocean energy. The most visible/ambitious of those instruments include:

- The European Commission's **InnovFIN EDP** facility offers commercial loans to bankable demonstration projects and to businesses with firm prospects of selling their technology to future customers. The facility is managed by the European Investment Bank and backed by a European Commission guarantee, allowing the bank to take on riskier projects.

- The EU **NER300 scheme** for innovatived energy demonstration projects concluded with mixed results as its design did not enable many projects to make use of the funding. A next version, the Innovation Fund, will offer blended grants and equity/loans from the end of 2020[xxxviii].

- **Horizon 2020**, while in theory more targeted at earlier research, used several calls to grant-fund demonstration projects. In 2019, it even put forward a blending call providing grants to projects benefiting from an InnovFin loan, a very progressive move.

- Regional governments have participated in projects. For example the **Brittany Region** in France has supported Sabella's tidal turbine deployment. **Wales** has supported Marine Power Systems in the development of their WaveSub device. **Normandy Region** partnered with SIMEC Atlantis in a joint venture for Raz Blanchard projects.

- Some national financial instruments also exist. For example, the new Scottish Government **Energy Investment Fund** ('EIF') continues the work of the closed Renewable Energy Investment Fund (REIF). REIF offered flexible finance - grants, equity and guarantees - on commercial terms to ocean energy demonstration projects and was key to funding the MeyGen Project.

Those instruments have contributed or attempted to contribute to a first wave of ocean energy projects. Learnings from those attempts must be used to make them evolve. Some additional instruments, such as a dedicated insurance fund, remain needed.

CALL FOR ACTION: FIT-FOR-PURPOSE, LOW-COST FINANCING INSTRUMENTS AND REVENUE SUPPORT

A blend of grant funding, financial instruments and revenue support is essential to deliver demonstration projects and pre-commercial pilot farms. Secured upfront capital will cover the higher risks of demonstration projects, while revenue support will ensure institutional investors invest into a new sector earlier than they otherwise would.

The two actions from the OEF Roadmap remain very much relevant: an Investment Platform and an Insurance and Guarantee Fund. Yet neither will be enough on its own if revenue support is not provided at national level.

See Integrated Strategy Action 2 in Part IV for more information.

Industrial Roll-out:
Reducing costs through volume

Phases: R&D › Prototype › Demonstration › Pre-Commercial › **Industrial Roll-Out**

Tidal range technology is mature and is ready for industrial roll-out now. **Tidal stream** will be the next ocean technology to reach industrial roll-out after the completion of the first few pre-commercial projects. The right framework will need to be already in place to facilitate this transition.

OBJECTIVE: DRIVING DOWN COSTS VIA VOLUMES AND MARKET CERTAINTY

The more a renewable energy technology is deployed, the lower its costs will be. This rule has been repeatedly demonstrated – most recently with solar, offshore wind and batteries. Bloomberg NEF found the cost of solar PV dropped by 72% between 2009 and 2017[xxxix].

Deployment of just 1000 MWs of tidal stream farms will allow a cost reduction to just over 10c/kWh[xl] – in line with the target that European countries have set within the SET Plan. This is a small investment: just 0.1% of installed EU electricity generation.[xli]

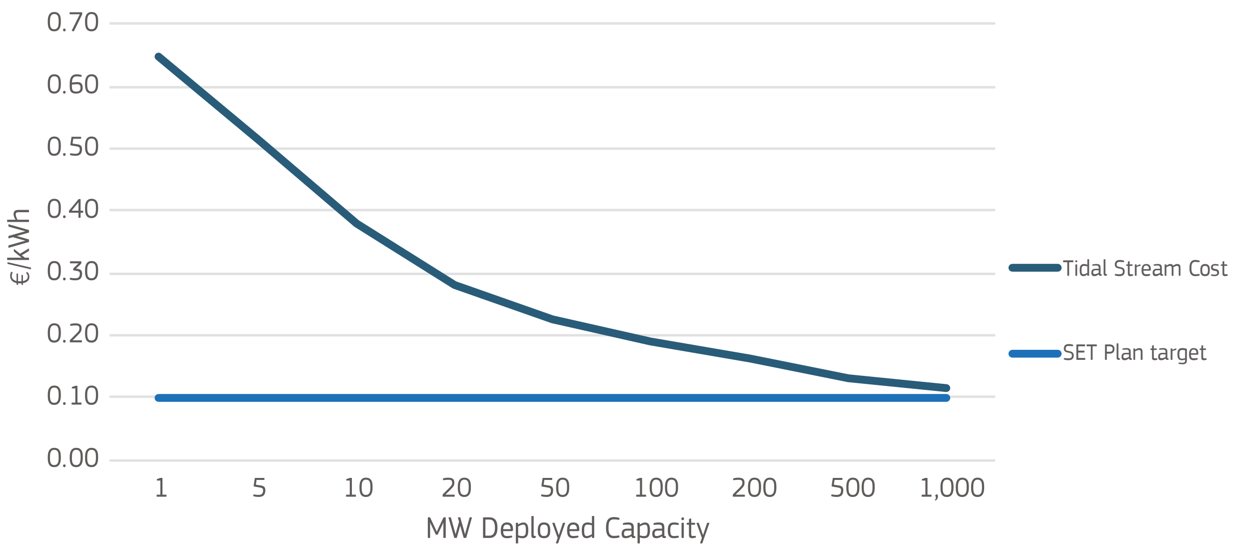


Fig. 9 - ORE Catapult projections of tidal stream costs & deployed capacity

CHALLENGE: ESTABLISHING A BUSINESS CASE FOR PROJECTS WHEN POWER PRICES DO NOT REPAY INVESTMENTS

Revenue support which pays a 'top-up' on power from ocean energy allows these projects to cover their costs and establish a business case. By making projects bankable, revenue support enables developers to secure the necessary finance from investors. As ocean energy costs reduce, so too will the amount of required revenue support.

To ensure that revenue support is available in practice, it needs to be earmarked exclusively for ocean energy projects. If ocean energy is required to compete for revenue support on the basis of cost, then already-established technologies will always win.

Earmarking allows emerging technologies to establish a foot in the market, and to use this to achieve the same cost reductions that their counterparts have already realised.

CHALLENGE: UNLEASHING INVESTOR AND OEM FINANCE

Investors and Original Equipment Manufacturers (OEMs) need confidence that there will be a market for their product. The investments they make into product development and new production facilities will generate sufficient returns only when larger numbers of devices are being produced for multiple ocean energy projects.

National governments can incentivise investors and OEMs to ramp up manufacturing activity and install capacity. This multi-billion euro private investment will be unlocked by clear government signals that there is a future market worth investing in.

Clarity can be provided by setting national targets for ocean energy deployments. Budgets can be allocated to earmarked revenue support over several years. Governments can also conclude 'sectoral deals'. For example the UK government recently agreed with the offshore wind sector that up to £557 million in revenue support would increase capacity up to 30GW by 2030 [xlii].

AVAILABLE TODAY: LOW NATIONAL SUPPORT, LIMITED MARKET VISIBILITY

At the time of writing, no country provides ring-fenced revenue support for ocean energy only in Europe.

Many countries provide revenue support for renewables, but ocean energy must compete directly against more established technologies. In some countries levels of revenue support do not match the higher costs of ocean energy.

For example:

- In the UK, tidal and wave projects are technically eligible for revenue support, but must compete directly against offshore wind, which already has more than 18GW of installed capacity in Europe [xliii].
- In France, revenue support is focused on two specific tidal stream demonstration projects;
- The Netherlands offers a feed-in tariff at a level which does not correspond to the costs of today's ocean energy projects [xliv].

Market visibility for ocean energy could also be further improved. The EU SET Plan has targets for reductions in the cost of energy. These targets require further technology development and deployment of significant volumes of ocean energy. But these capacity deployments are not yet reflected in the National Energy and Climate Plans of any participating national governments [xlv].

CALL FOR ACTION: EARMARKED REVENUE SUPPORT AT NATIONAL LEVEL

Europe risks losing out on ocean energy industrial roll-out. Developers will focus their attention where ever revenue support and market visibility are present. The Nova Scotia regional government in Canada has made clear its commitment to tidal energy. It offers revenue support of circa €350/MWh[xlvi] at several tidal sites. European technology developers are now involved in all of these sites.

National governments must put in place earmarked revenue support for ocean energy, in combination with clear signals on future markets.

See Integrated Strategy Action 3 in Part IV for more information.

Across all stages:
Licensing and consenting, mandatory steps for any project

Phases: R&D → Prototype → Demonstration → Pre-Commercial → Industrial Roll-Out

All ocean energy technologies that are being deployed in the ocean go through consenting and licensing procedures. These procedures determine if and how devices can be deployed in the ocean.

OBJECTIVE: DEPLOYING OCEAN ENERGY WHILE RESPECTING LOCAL ENVIRONMENTS AND COMMUNITIES

Even once the technology is ready and finance secured, ocean energy projects must obtain licensing and consenting prior to deployment. These regulatory requirements are important to safeguard local environments and to respect the needs of any nearby communities. But they can impose additional risk and costs. In some cases delays and additional costs undermined feasibility to the point that the project was cancelled.

CHALLENGE: EVIDENCE-BASED DECISIONS REQUIRE MORE EXTENSIVE DATA AND KNOWLEDGE

In other sectors environmental impact assessments are based upon knowledge and data from past experiences. This allows regulators to put in place rules that protect against established risks, while otherwise allowing activities to go ahead.

But this knowledge base is still being built up for ocean energy. To date there have been relatively few ocean energy deployments, and environmental monitoring of these projects has focused on different impacts. There is still no comprehensive body of evidence that regulators can use as a basis for consenting and licensing decisions.

A stronger evidence base can be provided via coordinated research projects that monitor priority environmental impacts of projects across Europe using consistent methodologies.

Knowledge exchange and the joint development of common approaches can help regulators across Europe apply a consistent approach to ocean energy licensing and consenting. This would also help national regulators incorporate ocean energy into forthcoming national Marine Spatial Plans.

CHALLENGE: DECISION-MAKERS HAVE TO BALANCE RISK AND REWARD

Regulators must find the right balance between the safeguarding of local environment against unknown risks, and imposing restrictions which stop the deployment of ocean energy. This is not an easy balance to find, given the lack of available data.

Consenting and licensing authorities have limited experience, and often lack standard protocols to follow, or agreed metrics to measure against. There are not yet established 'best practices' between authorities.

The 'precautionary principle' is important, but if it is applied in an overly rigid manner, the development of ocean energy projects will be held back. Alternative decision-making processes, such as an 'Adaptive Management' approach can help find the best balance of risk and reward. Developers can start build-out of a given demonstration project and, depending on monitoring results, continue their work and increase activities incrementally.

'Adaptive Management' strikes a balance between guarding against short-term risk and allowing authorities to gather more information on a potential risk. This incremental approach allows authorities to gradually increase their knowledge of a potential environmental impact, without unduly exposing a local environment to unnecessary risk.

AVAILABLE TODAY: A MIX OF POSITIVE INITIATIVES ACROSS EUROPE

The situation differs across Europe, depending the approach and resources of different licensing authorities.

European projects such as **RiCORE**[4] and **MUSES**[5] have delivered valuable insights and promoted the building of capacity within European authorities.

The **EU Marine Spatial Planning Directive** is creating a common framework for managing human activities on the sea. This offers an important occasion for national authorities to integrate ocean energy when implementing the Directive. National Plans need to be established by 2021.

The European Commission has just funded a programme of environmental monitoring of wave and tidal devices, via the **European Maritime and Fisheries Fund**.

The Scottish government has assigned responsibility to one entity, for the integrated management of Scotland's seas. **Marine Scotland** has been provided with sufficient capacity and authority. It has a special branch focused on planning and policy for marine offshore energy. It works closely with colleagues responsible for Licensing and Operations, and Science, as well as developers and interested stakeholders.

CALL FOR ACTION: CONTINUE CURRENT INITIATIVES AND INCREASE DATA COLLECTION

A range of different initiatives will ensure that progress continues to be made in this area:

- Efforts to collect and share environmental impact data must continue, with adequate funding.
- An 'Adaptive Management' approach should be adopted by authorities.
- Best practices need to be shared between authorities, and continually updated.
- When completed, national Marine Spatial Planning rules will need to firmly integrate the needs of ocean energy projects.

See Integrated Strategy Action 3 in Part IV for more information.

[4] Risk Based Consenting for Offshore Renewables - http://ricore-project.eu/

[5] Multi-Use in European Seas - https://muses-project.eu/

ACTIONS REQUIRED BY THE OCEAN ENERGY FORUM STRATEGIC ROADMAP

The Ocean Energy Forum set out an ambitious yet realisable Roadmap to bring ocean energy to commercial roll-out. The Roadmap identified four key recommendations for industry and policy makers, which are essential to realise the sector's full potential. Two years on, several of these actions have shown progress.

EARLY STAGE & PROTOTYPE: USING STAGE GATE FUNDING TO DE-RISK TECHNOLOGY DEVELOPMENT

Work has begun on a European stage gate funding structure for wave energy. A Horizon2020 call invites national funding authorities to propose a Pre-Commercial Procurement Programme, with up to €20m contribution from the European Commission.

DEMONSTRATION & PRE-COMMERCIAL ARRAYS: INVESTMENT FUND LACKING REVENUE SUPPORT

The European Commission is leading work on setting up a European 'Blue Economy' Investment Platform. It will be focused on maritime-based industries, including ocean energy, though will most likely require projects to be bankable, and thus have access to revenue support on top of electricity sales.

DEMONSTRATION & PRE-COMMERCIAL ARRAYS: INSURANCE AND GUARANTEE FUND STILL NOT IN PLACE

Much more work remains to be done here. While there are EU-level financial instruments available, these are not designed to address the specific challenges. Insurance costs for these projects remain prohibitive.

DE-RISKING ENVIRONMENTAL CONSENTING: FUNDING OF DATA COLLECTION

Work on this action continues. The European Commission has awarded contracts to two international consortia, who will gather, analyse and share data on the environmental impacts from 7 wave energy device deployments.

PART V

An Integrated Strategy: actions required to develop technology from early research to industrial roll-out

Both the EU and the ocean energy sector wish to see Europe powered by 100GW of ocean energy by 2050[xlix]. National governments, the European Commission and the sector have agreed a target of 10 €cents/kilowatt hour for tidal stream and wave, by 2030 and 2035 respectively[l]. An accompanying 'Implementation Plan' has been agreed, to facilitate cooperation between the sector and European, national and regional funding authorities[li].

These costs targets can only be realised if large volumes of tidal stream and wave capacity are deployed before 2030 and 2035. To realise those large volumes, ocean energy is looking at four updated actions.

Action 1- R&D and Prototype: Finalise an EU-wide stage-gate programme while keeping grant funding

Phases: **R&D** | **Prototype** | Demonstration | Pre-Commercial | Industrial Roll-Out

Objective & rationale – R&D and prototype projects aim to test components or devices and do not generate revenue. For this reason, grants are the only way to finance them. To foster best use of public money it is important to avoid a few pitfalls:

- creating unfair advantages for one recipient over others
- putting all ones' eggs in the same basket or company
- repeating or duplicating research efforts across several countries

Proposed Action – A truly European stage-gate approach, channelling 100% public funding via pre-commercial procurement, is an essential step to deliver an ocean energy sector. Wave Energy Scotland[6] has demonstrated the value of this approach.

Following a previous recommendation in the Ocean Energy Forum Strategic Roadmap, an initiative to 'Europeanise' this approach has started. Horizon 2020 is putting forward a call with that purpose. National and regional funding agencies now need to work with the European Commission to establish and fund an ambitious pan-European stage-gate framework.

This will enable authorities to make best use of funding at their disposal. It will focus European, national and regional research in one direction, aided by shared standards and measurements techniques. Developers will compete against each other in a wide playing field to develop the best solutions. 100% funding will allow them to deliver these solutions.

This will turbo-charge the emergence of European wave energy global champions.

Ocean energy developers are operating across the globe. To ensure that any ocean energy standards and metrics are applicable in new markets, it is important that any stage-gate process link up with international work on standards.

Main actors – Member States and European Commission – Setup the EU-wide phase-gate.

[6] See Part III.1 R&D & Prototypes – Box on the WES stage-gate instrument

Action 2 - Demonstration and Pre-commercial farms:
A blend of grant & financial instruments for projects to reach financial close

Phases: R&D | Prototype | **Demonstration** | **Pre-Commercial** | Industrial Roll-Out

Objective & Rationale – The Demonstration and Pre-commercial phases aim to deliver off-the-shelf technology and validate business models. Yet they face several barriers to financing:

- Technological uncertainties, which translate into a financial risk for investors
- High cost of capital (interest rates/dividends) and low access to capital (investment)
- The need for revenue support to offset costs of innovation and break-even budgets

Since the 'European Energy Programme for Recovery' in 2009, and the NER300 later, the EU has been searching and testing instruments to finance the 'Valley of Death' of innovation. Until recently with mitigated success.

Proposed Action – A blend of grant and financial instruments to secure investments.

Existing sources of publicly-backed debt and equity such as InnovFIN EDP or EIF must be maintained and reinforced, while complementary instruments should be developed. Blending those different solutions into a single project will ensure it reaches financial close. Blending will also foster a good use of public funding, as some instruments can make others cheaper: typically, an insurance and guarantee fund will reduce the cost of capital and thus the total investment needs of the whole project.

A successful blended financial jigsaw must include grants as a base component, combined with a portfolio of instruments covering debt and equity. Several pieces of that jigsaw already exist at EU or national level and some of the most relevant are highlighted below.

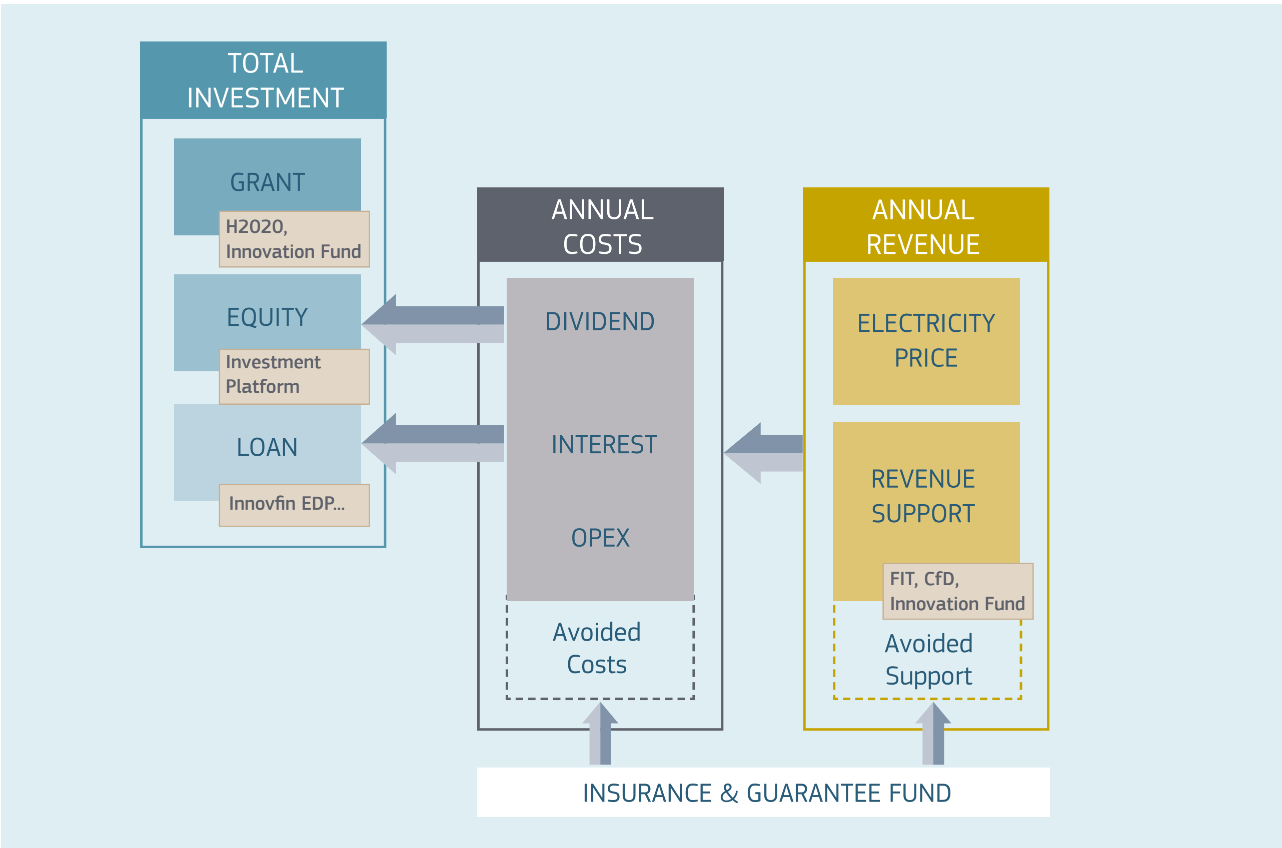


Fig. 10 - Example of a blended project financing package for Ocean Energy

'EU Innovation Fund': Stakeholder consultations were carried out on how to efficiently design this upcoming instrument in 2018-2019. They concluded that grants remained essential for all and any industrial sector going through the Valley of Death. Given other instruments offer debt or equity, the Innovation fund should aim to offer a blend of grant and revenue support.

'EU Investment Platforms': An Investment Fund focused at least in part on ocean energy is also required, as recommended by the Ocean Energy Forum's Strategic Roadmap. It can channel investments and spread the risk across a number of projects. The focus on ocean energy will allow strong due diligence to be undertaken in a cost-effective manner. The Fund could operate as a stand-alone entity or as part of a wider 'Blue Economy Investment Platform'. National instruments such as the Scottish REIF have been precursors in that respect.

'InnovFin EDP': This new instrument, enables the European Investment bank's to provide debt to riskier innovative projects than is normally usual. The enabling factor is a 100% guarantee through the EU budget, preventing project failure to impact the banks triple A rating. It financed the AW-Energy wave project in Portugal. The instrument has evolved positively since its start in 2017. Yet further flexibility in its rulebook could help it become truer to its purpose of financing riskier projects. Bankable projects can be financed by commercial banks and the EIB should have the means to take the risks commercial banks avoid.

'Insurance and Guarantee Fund': Risk-coverage is the currently missing part of the financial jigsaw. As detailed in the Strategic Roadmap, this Fund would dramatically reduce the cost of individual projects, by covering risk at attainable premium rates. The reduced project risk would significantly improve access to and costs of equity and debt, further reducing overall project costs. Risk would be mutualised amongst several projects, allowing the Fund to cover multiple demonstration projects. The premium would generate revenue and slowly replenish the Fund to insure further projects.

These four initiatives are an example of what a successful finance package could look like, providing grant, debt and equity while reducing financial and overall project costs. Other instruments can be used in combination or in place of the above, where available at EU or national/regional level.

The last piece of the jigsaw must be revenue support: projects cannot attract debt or equity if they are not making a return. Wholesale electricity prices alone are not sufficient to cover the higher costs of innovative projects without a top-up – see Action 3 below.

No single public support instrument will be sufficient to deliver ocean energy demonstration/pre-commercial projects. A range of different support mechanisms must be available, blended to finance a project a lowest cost to the public purse. All pieces of the financing jigsaw must be in place for projects to be delivered.

Main Actor – European Commission and national governments – to complete work on existing financing programmes and propose an insurance and guarantee fund;

Ocean energy sector – to further define exact requirements of an insurance and guarantee fund.

Action 3 - From Demonstration to Industrial roll-out:
Revenue support as only way to fully finance projects

Phases: R&D | Prototype | **Demonstration** | **Pre-Commercial** | **Industrial Roll-Out**

Objective and rationale – Ocean energy projects in the demonstration, pre-commercial and industrial roll-out stages require earmarked revenue support to attract the necessary private investment. Grants can only cover a portion of overall project costs, decreasing as technology becomes more commercial. Equity/debt providers demand higher returns for innovative projects. Wholesale electricity prices alone are not sufficient to cover those returns without a top-up.

Proposed Action – Establish revenue support schemes at national level specifically for ocean energy projects.

The schemes should enable the first demonstration and pre-commercial projects to go ahead, and set a clear signal that support will be in place for a subsequent industrial roll-out. In most if not all cases, support can be provided to ocean energy within existing national support frameworks for renewable energy.

For competitive auctions, separate 'pots' can be earmarked. These pots establish a minimum amount of funding or capacity deployment just for ocean energy. Other innovative new renewable technology can also be included in the pot, as long as it has not yet been deployed at scale. For example, bottom-mounted offshore wind should not be included, but floating offshore wind might be eligible under certain circumstances. Competition is still maintained within these pots, but earmarking ensures that innovative new technologies can actually win tenders and subsequently deliver projects. With 23MW of installed capacity, ocean energy cannot be expected to compete with bottom-mounted offshore wind which in 2019 had installed 1000 times as much capacity - 23GW globally.

Alternatively, a tax system can be used to provide revenue support, without impacting electricity bills or public expenditure. Large companies buy electricity from producers via 'Power Purchase Agreements' (PPAs). Without upfront revenue support, ocean energy PPAs will be more expensive than PPAs from other energy sources. A system of tax credits allows companies to claim this extra cost back via reduced tax bills. The PPAs allows ocean energy projects to attract the necessary revenue, but without imposing a levy on electricity consumers.

In any framework, levels of revenue support can be progressively reduced, as more ocean energy projects are deployed and energy costs decrease. This allows the continued roll-out of ocean energy, while still ensuring that funds are being used as efficiently as possible.

Support per MWh produced must be higher for demonstration and pre-commercial projects than for projects at the industrial roll-out phase. Yet these high levels of support will only be required for a limited number of projects, thus requiring a small total budget. Upper capacity thresholds can be used to avoid runaway public spending. As capacity increases, costs will go down, thus keeping the total budget within acceptable limits.

Revenue support should also be complemented with a clear signal from national governments, about their longer-term intentions for the sector. This will increase investor and OEM engagement, which will reduce the capital costs of projects and strengthen industrial roll-out.

Main Actors – National governments – to establish revenue support schemes for ocean energy.

Action 4 - A set of initiatives to generate data and best practice for licensing and consenting

Phases:	R&D	Prototype	Demonstration	Pre-Commercial	Industrial Roll-Out

The consenting and licensing of ocean energy projects is hindered by a lack of data on the environmental impact of these deployments. Authorities must find the right balance between safeguarding local environments and allowing more learnings. Several initiatives should be continued and expanded to address this challenge.

Task 1 – **Launch further calls to fund the cross-border collection and sharing of environmental impact data**. Calls should allow the monitoring of multiple ocean energy projects, using the same methodologies to measure the same environmental impacts.

Main actors – European Commission and national regional funding authorities – for example via Co-Funds and Interreg programmes – to fund monitoring projects.

Licensing and consenting authorities – to participate in monitoring projects and incorporate new data into their decision making.

Technology & project developers, researchers and supply chain actors – to participate in monitoring projects.

Task 2 – **Adopt an 'Adaptive Management' approach for licensing and consenting decisions**. When making decisions, authorities take on small short-term risk, to gain new knowledge on environmental impacts. These learnings then inform future decisions. Authorities progressively reduce uncertainty about the impact of ocean energy, while still controlling risk. Licensing and consenting authorities can incorporate adaptive management via training or existing guidelines – e.g. the US Department of the Interior's 2009 technical guidelines for adaptive management.

Main actors – Licensing and consenting authorities – to incorporate adaptive management techniques in their organisations

EU, national and regional funding agencies – to fund trainings and knowledge-exchange on Adaptive Management techniques.

Task 3 – **Develop and continually update 'best practices'** on ocean energy licensing, consenting and marine spatial planning. The current vacuum is a valuable opportunity for authorities to work together to create a harmonised approach to ocean energy licensing/consenting across Europe.

Main actors – Licensing and consenting authorities – to incorporate adaptive management techniques in their organisations

EU, national and regional funding agencies – to fund trainings and knowledge-exchange on Adaptive Management techniques.

Technology & project developers, researchers and supply chain actors – to participate in and implement monitoring projects and share knowledge and experience.

SOURCES

i. IEA OES

ii. 'Ocean Energy Strategic Roadmap', Ocean Energy Forum, November 2016 - https://webgate.ec.europa.eu/maritimeforum/sites/maritimeforum/files/OceanEnergyForum_Roadmap_Online_Version_08Nov2016.pdf

iii. 'The Commission calls for a climate neutral Europe by 2050', European Commission press release, 28/11/18 - http://europa.eu/rapid/press-release_IP-18-6543_en.htm

iv. Bloomberg New Energy Finance – 2018 Report

v. Ocean Energy Europe 2016 – based on equivalent from offshore wind employment figures

vi. https://www.oceanenergy-europe.eu/ocean-energy/ Retrieved 05/03/19 @ 17:07

vii. 'Marine Renewables Green Growth Paper' Carbon Trust, 2011 - https://www.carbontrust.com/media/597981/marine-green-growth-carbon-trust.pdf

viii. 'Wind Energy – backbone of the EU global leadership in renewables', Wind Europe, September 2016 - https://windeurope.org/wp-content/uploads/files/policy/position-papers/WindEurope-Global-leadership-in-wind.pdf

ix. 'Local impact, global leadership – the impact of wind energy on jobs and the EU economy' Wind Europe, November 2017 - https://windeurope.org/wp-content/uploads/files/about-wind/reports/WindEurope-Local-impact-global-leadership.pdf

x. 'A policy framework for climate and energy in the period from 2020 to 2030' European Commission Communication, 2014 - https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=COM:2019:1:FIN&from=EN_ ?)

xi. 'Scotrenewables Tidal Clocks Record Level of Power Generation' Orbital Marine Power press release, 18/09/18 - https://orbitalmarine.com/news?start=8

xii. Sabella

xiii. @simecatlantis tweet – 04/03/19

xiv. OEE – Data compile from Ofgem Renewables and CHP Register, public releases from developers, confidential information supplied to OEE by developers.

xv. MeyGen project

xvi. 'A World-First for Nova Innovation: the 'Holy Grail' of Baseload Tidal Power' 'Nova Innovation 02/11/18 - https://www.novainnovation.com/news/a-world-first-for-nova-innovation-the-holy-grail-of-baseload-tidal-power

xvii. https://energy.novascotia.ca/renewables/programs-and-projects/tidal-fit, retrieved 05/03/19 @16:11. $1 CAD = €0.66

xviii. 'Tidal scheme goes live in Shetland', The Scotsman, 09/03/16 - https://www.scotsman.com/news/tidal-scheme-goes-live-in-shetland-1-4057039

xix. In first 18 months of project https://ore.catapult.org.uk/stories/nova-innovation-case-study/ Retrieved 05/03/19 @16:13.

xx. Source: BiMEP

xxi. Biscay Marine Energy Platform, S.A

xxii. United Nations note on water scarcity - http://www.un.org/waterforlifedecade/scarcity.shtml. Retrieved 28/02/19 at 14:58

xxii. https://www.engie.com/en/journalists/press-releases/thassalia-marine-geothermal/ Retrieved 15/03/19 @ 09:18

xxiv. Ocean Energy Systems Country Profile - https://report2016.ocean-energy-systems.org/country-reports/monaco/technology-demonstration/. Retrieved 28/02/19 at 15:49

xxv. https://www.google.com/about/datacenters/inside/locations/hamina/ - Retrieved on 05/03/19 @ 16:19

xxvi. 'Ocean Energy and the Regions - A Partnership for Growth', FORESEA project, October 2018 - http://www.nweurope.eu/media/4477/ocean-energy-and-the-regions.pdf

xxvii. 'Salinity Gradient Energy - Technology Brief', IRENA, June 2014 - http://www.irena.org/documentdownloads/publications/salinity_energy_v4_web.pdf

xxviii. 'Blue Energy for H2!' Redstack press release, 29/11/18 - https://www.redstack.nl/en/news/94/blue-energy-for-h2

xxix. 'Salinity Gradient Energy - Technology Brief', IRENA, June 2014 - http://www.irena.org/documentdownloads/publications/salinity_energy_v4_web.pdf

xxx. 'Tidal Energy - Technology Brief', IRENA, June 2014 - https://www.irena.org/documentdownloads/publications/tidal_energy_v4_web.pdf

xxxi. 'Wave and tidal energy: part of the UK's energy mix', UK Dept for Business, energy & Industrial Strategy, January 2013 - https://www.gov.uk/guidance/wave-and-tidal-energy-part-of-the-uks-energy-mix

xxxii. http://www.tidallagoonpower.com/projects/international/france/progress-to-date/ - retrieved on 15/03/19 @ 08:57

xxxiii. http://www.tidallagoonpower.com/ - retrieved on 05/03/19 @ 16:34

xxxiv. 'La Rance Tidal Power Plant - 40-year operation feedback – Lessons learnt', EDF + BHA presentation, October 2019 - https://tethys.pnnl.gov/sites/default/files/publications/La_Rance_Tidal_Power_Plant_40_year_operation_feedback.pdf

xxxv. 'Tidal Energy - Technology Brief', IRENA, June 2014 - https://www.irena.org/documentdownloads/publications/tidal_energy_v4_web.pdf

xxxvi. https://www.waveenergyscotland.co.uk/ Retrieved 05/03/19 @ 16:43

xxxvii. '£51 Million Meygen Financial Close Completed' SIMEC Atlantis press release, 18/09/14 - https://simecatlantis.com/2014/09/18/51-million-meygen-financial-close-completed/

xxxviii. European Commission Innovation Fund delegated regulation - see https://ec.europa.eu/clima/sites/clima/files/innovation-fund/c_2019_1492_en.pdf

xxxix. 'Global Trends in Renewable Energy Investment 2018', Bloomberg New Energy Finance 2018

xl. 'Tidal Stream and Wave Energy Cost Reduction and Industrial Benefits' ORE Catapult, May 2018. 2012 GBP converted to 2018 EUR https://s3-eu-west-1.amazonaws.com/media.newore.catapult/app/uploads/2018/11/19142426/Tidal-Stream-and-Wave-Energy-Cost-Reduction-and-Industrial-Benefit.pdf

xli. In 2016 there was 990,918 MW of installed electricity capacity – see 'EU Energy in Figures - Statistical Handbook' - https://publications.europa.eu/en/publication-detail/-/publication/99fc30eb-c06d-11e8-9893-01aa75ed71a1/language-en/format-PDF/source-79929745

xlii. 'Offshore wind Sector Deal', UK Department for Business, Energy and Industrial Strategy, March 2019 - https://www.gov.uk/government/publications/offshore-wind-sector-deal/offshore-wind-sector-deal

xliii. 'Wind energy in Europe in 2018 – Trends and statistics', February 2019, Wind Europe - https://windeurope.org/wp-content/uploads/files/about-wind/statistics/WindEurope-Annual-Statistics-2018.pdf

xliv. 'SDE+ voorjaar 2019', The Netherlands Enterprise Agency, February 2019 - https://english.rvo.nl/sites/default/files/2019/02/Brochure%20SDE%20voorjaar%202019.PDF

xlv. For all NECPs, see: https://ec.europa.eu/energy/en/topics/energy-strategy-and-energy-union/governance-energy-union/national-energy-climate-plans

xlvi. https://energy.novascotia.ca/renewables/programs-and-projects/tidal-fit, retrieved 05/03/19 @16:11. $1 CAD = €0.66

xlvii. https://ec.europa.eu/maritimeaffairs/policy/maritime_spatial_planning_en - Retrieved on 05/03/19 @ 17:03

xlviii. 'Marine Renewables and Offshore Wind - Marine Offshore Renewable Energy Branch – Stakeholder Brief', Scottish Government - see https://www2.gov.scot/Resource/0054/00540133.docx

xlix. 'Ocean energy development in Europe: Current status and future perspectives', Magagna D & Uihlein A, International Journal of Marine Energy, June 2016. https://ec.europa.eu/jrc/en/publication/ocean-energy-development-europe-current-status-and-future-perspectives

l. 'SET Plan – Declaration of Intent on Strategic Targets in the context of an Initiative for Global Leadership in Ocean Energy' European Commission, September 2016 - https://setis.ec.europa.eu/system/files/integrated_set-plan/declaration_of_intent_ocean_0.pdf

li. 'SET-Plan Ocean Energy - Implementation Plan, Final', SET Plan Steering Committee, March 2018 - https://setis.ec.europa.eu/system/files/set_plan_ocean_implementation_plan.pdf

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The European Technology and Innovation Platform for Ocean Energy (ETIP Ocean) is a recognised advisory body to the European Commission, and is part of the EU's main Research and Innovation policy the Strategic Energy Technology Plan (SET Plan). ETIP Ocean defines research and innovation priorities for the ocean energy sector and promote solutions to the industry, European and national policy makers. ETIP Ocean also informs and supports the SET Plan's 'Ocean Energy Implementation Plan'.

From 2016-2018 ETIP Ocean has been managed by Ocean Energy Europe (OEE) in partnership with the University of Edinburgh, which represents the European Energy Research Alliance (EERA).

ETIP Ocean's mandate was renewed by the European Commission for 2019-2021. For this phase OEE and the University of Edinburgh have been joined by Tecnalia and WavEC.

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