SET-Plan

Ocean Energy - Implementation Plan

Revised October 2021

(Original version 5th March 2018 as agreed by the Ocean Energy TWG)

Prepared by Implementation Working Group Ocean Energy

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EXECUTIVE SUMMARY

The Set Plan Temporary Working Group (TWG) was formed in 2017 with the task of developing this implementation plan. The Group recognised the significant opportunity for ocean energy technologies to provide sufficient renewable energy supply to meet the demands of the future. The original plan however focused on the challenges for wave and tidal. The ambition of the plan was to outline a structured approach that will enable both of these technologies to follow a development path - with the ultimate destination of a commercially viable wave and tidal industry. The indicative timescale and ambition developed in the Declaration of Intent was for this to happen for tidal by 2025 and for wave by 2030. Given the length of time that the industry has been in development, the IWG recognised that this was not a long time and significant work and supports were required if these timelines were to be met. It is not just about development of technologies but the development of a new industrial sector with large scale manufacturing and deployment supply chains developed that would enable the economies of scale required to meet the commercialisation target.

Co-ordination between MS, partnering non-EU countries and EC to date has been in the development of research and roadmaps which setting out the aspiration of Wave and Tidal Sector. The principle of the original plan, and this revised version, is to turn those aspirations into operational actions.

This plan outlines three high level actions

1. Co-ordination between Member States (MS), partnering non-EU countries and Regions to share and track critical information annually that will demonstrate the clear development of the ocean energy technologies.
2. Collaboration between MS, Regions and the European Commission to ensure the effective use and appropriate blending, if possible, of funds to drive large scale deployment.
3. The need for annual monitoring of progress with a progress review carried out at the end of each phase to determine Go/No Go to the next phase:
    a. Phase 1 (2018 -2020) **COMPLETE** – A feasibility **DISCOVERY** phase to develop:
        i. a collective monitoring approach by MS and partnering non-EU countries in 2018 and an agree oversight management process for projects and funding which outlines achievable interim commercialisation targets;
        ii. the likely levels of funding required for phase 2 and 3.
    b. Phase 2 (2020-2025) **ONGOING** – Collaborative **DEVELOPMENT** Phase with operational arrays demonstrating the ability to meet the technical and financial metrics.
    c. Phase 3 (2026-2030) – Commercialisation Scale **DEPLOYMENT** Phase to build the sectors supports with large scale deployments that will drive costs to a commercial level. After 2030 the ambition is that the sector **DELIVERY** will be at scale via a commercial market with a functioning supply chain.

Note: The phase timescales are indicative and are proposed for planning purposes and it is understood that tidal and wave will each progress at a different pace from each other. See indicative phase timelines and activities on page 21.

Funding levels proposed in this plan: It should be noted that through this plan, the Implementation Working Group (IWG) only provided an estimate of the funding required for the Technical and Environmental/Socio-economic phases mentioned above. The current estimate is for funding levels totalling 1. BN EUR between 2021 and 2025. The breakdowns are outlined in the Action Fiches in Appendix 7.

- EUR 335 million coming from the industry (private funds - 33% of the total);
- EUR 400 million coming from national/regional programmes - (40% of the total);
- EUR 271 million coming from EU funds (27% of the total – mainly from Horizon Europe and the ETS Innovation Fund)"

It will be a key part of the annual oversight process to refine these estimates and to determine how to maximise the benefit of the funding streams provided across the member States, partnering non-EU countries and regions and the EC and to determine opportunities for blending or pooling funding sources. While it is understood from previous analysis that a significant level of investment is required for the sector, it is estimated that an investment of circa 1BN EUR in the SET Plan [wave and tidal industries] would result in a net benefit to Europe due to the creation of a new industry, which would profit from activity both within Europe and internationally[1].

[1] The benefits of such an investment can be measured in terms of Gross Value Added (GVA) and job creation. As an example recent UK study undertaken by the University of Edinburgh and the Offshore Renewable Energy Catapult forecasted that, provided the wave and tidal industries could reach cost parity with offshore wind industry by 2030, an investment of circa £1bn in the wave and tidal industries at that time could return a GVA to the UK of approximately £5bn. Further to this, the same study presented how such an investment in 2030 would be the first stepping stone in a path to achieving greater returns on investment further down the line; by 2040, a potential investment of £5bn could result in a GVA of around £30bn and by 2040 and investments of £15bn by 2050 could result in a GVA of circa £140bn. It is expected that these returns on investment, seen in a member state, could be replicated at a European level.

BASIS FOR THE IMPLEMENTATION PLAN

Initially the Implementation Plan was written by the 'Temporary Working Group for Ocean Energy' (TWG) in 2018. Now chaired by Gianmaria Sannino (Italian National Agency for New Technologies, Energy and Sustainable Economic Development), the Implementation Working Group (IWG) comprises of 12 EU Member States, Norway and the UK with representative from the relevant Government Agencies, Regional representatives, industry sectors representatives, research associations and the education sector.[2]

The actions listed within the Implementation Plan are primarily based upon 2 key sources:

(1) THE EU STRATEGY ON OFFSHORE RENEWABLE ENERGY

The EU 'Offshore Strategy' was released in November 2020 by the European Commission. It sets out the EU's potential and ambitions in the field of offshore wind and ocean energy. The Strategy recognises that initial deployments are needed to kickstart wave and tidal's cost reduction trajectories. It commits the European Commission to coordinate funding with national and regional authorities to fund the deployment of 100MW of ocean energy by 2025 and around 1 GW by 2030

(2) ETIP OCEAN's 'STRATEGIC RESEARCH & INNOVATION AGENDA'

The European Technology and Innovation Platform for Ocean Energy (ETIP Ocean) is funded by the European Commission to define research and innovation priorities for the ocean energy sector and promote solutions to the industry, European and national policy makers.

This network produced an updated Strategic Research an Innovation Agenda for Ocean Energy in June 2020. It identified essential priority areas to be addressed to improve ocean energy technology and decrease its risk profile, and formed the basis for the Strategic Roadmap.[3]

INTRODUCTION

The clean energy transition represents an important opportunity for Europe. We have the potential to create entirely new industries creating significant employment. However, to achieve this, Europe must lead this transition, and not simply adapt to it.[4]

This can only be achieved via close cooperation between the European Union, Member States, regions, partnering non-EU countries, industry and researchers. In this context invited stakeholders and SET Plan countries[5] reached an agreement on common objectives specifically for the ocean energy sector. These are:

- to bring ocean energy to commercial deployment,
- to drive down the levelised cost of energy (LCOE),
- to maintain and grow Europe's leading position in ocean energy and
- to strengthen the European industrial technology base, thereby creating economic growth and jobs in Europe and allowing Europe to compete on a global stage.

[2] See Annex 6 for more information on the Ocean Energy Temporary Working Group

[3] See Annex 6 for more information on both sources

[4] 'Clean Energy for All Europeans – unlocking Europe's growth potential', European Commission press release, Nov 2016

[5] For more information on the SET Plan and the wider policy framework, see Annex 5.

The deployment and cost reduction targets are complementary and self-reinforcing. Greater deployments will drive down costs, and lower costs will drive further deployments. However, deployments must come first to kick off this virtuous cycle.

Deployment driven 'learning by doing' is one of the two pillars of dramatic cost reduction. 'Learning by innovation' - via RD&I projects is the other pillar. These pillars are also complementary. New components, techniques and materials developed in the lab can be integrated into commercial deployments. And experiences from these deployments must be brought back to the lab to ensure a continuous process of cost reduction and technology improvement.

Ultimately a combination of both step changes in technology performance combined with mass production will deliver the required cost reduction and performance improvements of both wave and tidal technology. Overall, this group recognises that the combination of both step changes in innovation and significant volumes of ocean energy generation devices must be deployed to achieve these targets.

In order to achieve the development and deployment requirements outlined above there are also different forms of financial supports required during the different phases. In the initial phase, there is a need for the "Technology Push" through mechanisms such as grants to stimulate the technology development to pre or early commercial stage. In parallel appropriate levels of "Market Pull" must be available, which incentivises wider scale deployment, supply chain development and ultimately the LCOE reduction required for fully commercial operations and the ability to compete with other forms of renewable energy generation.

The actions of this Implementation Plan are structured into these two pillars – there are a set of 'Technology Push Actions' and a set of 'Market Pull Actions'. These actions are separate but strongly complement each other. Both sets of actions should happen in parallel, with differing emphasis upon each pillar depending on the different stages of wave and tidal technologies.

OCEAN ENERGY

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

European Policy has very successfully taken the first generation of renewable energy technologies, such as solar and wind, to commercially competitive levels. The EU will, however, need other technologies to further diversify its low-carbon generation capacity, if it is to meet its objective of reducing greenhouse gas emissions to 80–95 % below 1990 levels by 2050. By 2050 power generated by the ocean energy sector could avoid the equivalent of 276m tonnes of CO2 emissions annually.

Ocean energy comprises five distinct technologies: wave energy, tidal stream energy, tidal range energy, ocean energy thermal conversion (OTEC) and salinity gradient power generation. The variations in ocean resource and location will require different technological concepts and solutions. In order to speed up the time to market of ocean energy technologies it is important to prioritise and concentrate efforts for a limited number of technologies. Priority will be given to tidal stream and wave energy which have a high market potential for Europe and sufficient scale on a European level either as isolated arrays or hybridised with other offshore renewables. It should be noted that OTEC and other technologies can form part of future considerations if a roadmap and actions are agreed for these technologies.

Ocean Energy offers a unique chance to create a new industrial sector, created in Europe, generating jobs in its regions throughout the local supply chains. Spurred by ambitious renewable energy policies, the European ocean energy sector is a world leader today, home to the most advanced technology in the field. Continued investment and support are now needed to reap the benefits of Europe's first mover position. Europe's technological advantage, and the need to stay close to the resource to reduce costs, ensures that manufacturing remains European. The complexity of the supply-chain which may encompass engineering services, metal & mechanical work, power electronics, electricity cables, mooring systems, naval industry, will require an involvement of practically all Member States and partnering non-EU countries each providing their own specialised resources.

Ocean energy can be an EU industrial success story. With favourable support over the coming decade, Europe will obtain leadership in a global market, worth a potential €653bn between 2010 and 2050, and an annual market of up to €53bn, significantly benefiting the European economy.

The successful development of a competitive European ocean energy industry would also place the European industry in a prime position to seize export opportunities in the global market.

The work of the SET Plan Ocean Energy Implementation Working Group has taken into account the set of key actions identified within the Offshore Strategy, as this is considered to be the Declaration of Intent agreed by the EU Commission, Regions, Member States, Stakeholders and the Ocean Energy Industry. These actions are the focus of this implementation plan.

1.1. THE VISION OF THE OCEAN ENERGY IMPLEMENTATION PLAN

Given the wide range of actors involved in the ocean energy sector, including governments at regional, national and European levels, coordination and a common vision will be essential if the agreed targets for tidal stream and wave energy are to be met.

The various high-level actions of the Implementation Plan are listed at the end of the document. These contain cross-cutting actions that impact the overall ocean energy sector. There are also several actions, which relate specifically to tidal stream and wave. While not precluding wider action on other aspects of these technologies, the primary focus of actions over the coming years should be on the following areas:

Tidal stream: Demonstration projects in operational environments, based on arrays of devices with TRL levels of 7-9, to bring tidal stream technology to the point of industrial roll-out. This includes continued support for development of tidal stream technology with TRL levels up to 6, to ensure that knowledge and experience from the demonstration projects can be channelled back into technology improvements.

Wave: A systematic and structured focus on support for technology development up to TRL level 6. This should be part of a wider initiative to create stage gate metrics for wave device components and sub-systems, which will support the competitive procurement of reliable wave devices up to a TRL level of 8. This will also require a support mechanism for wave array early demonstration projects in real environments – such support is currently missing in Europe.

1.2. ANALYSIS OF EXISTING ACTIONS AT MEMBER STATES AND REGIONAL LEVEL

Cooperation and coordinated actions can only be undertaken if there is a solid understanding of the different activities that are currently taking place across Europe.

The Implementation Working Group therefore agreed to carry out a high-level mapping exercise of activities that are currently ongoing in the Member States. This would serve as an indication of the level of support available and the focus of the Member States activities. In line with the agreed Implementation Plan, the OceanSET project has been providing support during the Discovery Phase of the SET Plan IP, building a strong foundation for the development of the subsequent Development, Deployment, and Delivery phases. Focusing on wave and tidal technologies, the key purpose of the Discovery Phase was to obtain a solid understanding of the current activities across Europe, with the overall objective of determining how the sector will evolve for the subsequent Phases of the SET Plan Implementation Plan.

The development of a collaborative information sharing process across the Member States, partnering non-EU countries, and regions is at the core of the OceanSET project. This is accomplished through the annual process, comprising four key stages: mapping, analysis, monitoring and review.

The main actions comprising this process are as follows:

- To gather information on the ocean energy sector across Europe
- To compile and analyse the data collected from stakeholders and to conduct a gap analysis;
- To assess the progress of the ocean energy sector by tracking projects and key metrics and to consider other factors (identification of best practices, state of-the-art);
- To provide recommendations on the next steps required to progress the implementation of the SET Plan and suggest approaches to stimulate industry and research progress in priority areas

Member States and partnering non-EU countries participating in the Implementation Working Group partook in a survey which gathered information on the state of their own ocean energy sector. The data collected is used to inform the European Commission of the supports required to

develop the sector. The survey has been focusing on four areas, aligned with the requirements of the Implementation Plan:

- General information
- Technical information
- Financial information
- Environmental information

The survey contains two sections, a Member States survey capturing high-level information from Member States and the partnering non-EU countries on their ocean energy sector, and a Developers survey gathering detailed information from developers who have devices with a TRL 7 or above. The tables of results from the Member States surveys for 2018 and 2019 are below. Individual results of the Developers survey are confidential due to the commercially sensitive nature of the data supplied from developers. However, aggregated and anonymised results are published in the OceanSET Annual Report and provide an insight into the technical, financial and environmental aspects of ocean energy projects active in Europe.

2019	UK (Scotland)	UK (Cornwall, England)	UK (Wales)	Germany	Italy	Spain	Portugal	Sweden	Ireland	Netherlands	France	Denmark
Does your Member State have current policies which support the development and deployment of ocean energy technology?	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	Yes	Yes
Is there an assigned Ministry/Department owner at Government Level?	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	Yes	Yes
Public funding actually spent on OE (wave, tidal) in your country in 2019? (€m) Exclude private funding.	9.9	Unavailable	13.4	Unavailable	2.54	0.4	Unavailable	4.7	3.8	1	Unknown	9
Are there test site facilities in your country for ocean energy (prototypes)?	Yes	Yes	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Please indicate up to which TRL these test sites facilitate	8	8	9	4	5	9	9	8	9	9	7	7
How long does the consenting process take when deployment is outside of a test site?	2	3			3	3	1	1	5	1	5	0
Does your marine planning strategy accommodate the harnessing of ocean renewable energies by wave and tidal stream technologies?	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	Yes

Table 1: 2019 mapping of Ocean Energy activities in MS and Regions.

ANALYSIS OF OCEAN ENERGY PROJECTS IN THE CONTEXT OF THE SET-PLAN OCEAN ENERGY IWG

Prepared with the help of Davide Magagna

PLEASE NOTE DATA REGARDING NATIONAL PROJECTS MAY NOT BE COMPLETE DUE TO AVAILABILITY OF NATIONAL PROJECTS INFORMATION.

A review of policy mechanisms supporting the development of ocean energy technologies is undertaken to understand the level of support received by the sector and identify any gaps that may need to be addressed for the design of specific collaborative actions at the European level. The analysis considers EU funds made available through different Research and Development (R&D) Framework programmes (FP6, FP7, Horizon 2020), national and regional programmes collected by the JRC and expected 2019 contributions for the period between 2007, the year in which the SET-Plan started and 2019. Projects expected to begin 2019, such as NER300 are accounted in the analysis. It shall be noted that the main difference between the previous assessment and the current one is affected by the following factors:

- New ERDF and Interreg projects that have been awarded in 2019 contributing to further demonstration projects
- Variation in funds provided at National level and collected through IEA
- Termination of Horizon 2020 projects that the European Commission has awarded, but that could not proceed as initially expected.

European, ERDF and National programmes have contributed to funding ocean energy projects for EUR 1.726 billion for a total worth of the projects equal to EUR 2.16 billion. However, it shall be noted that the termination of some Innovation Action (IA) projects has a strong effect on the funds made available and used by the consortium. The total project costs leveraged by EU-awarded Horizon 2020 projects has fallen from EUR 328 million to EUR 108 million, with the EU contribution being reduced from EUR 163 to 90 million. This is a significant blow to the sector's ambition but also highlights the difficulties that project developers are having. A breakdown of the funds and project cost is provided in Table 2, whilst Figure 1 presents the breakdown of funds given to wave and tidal energy technologies

	Funding Contribution	Total Project Costs
ERDF	€253,190,108	€358,746 847
EU	€373,753,790	€631,532,515
Ocean-ERANET	€13,469,842	€18,629,654
National	€504,799,333	€504,799,333
Regional	€578,814,003	€648,114,003
Total	**€1,726,870,711**	**€2,161,822,352**

Table 2: Breakdown of funds for ocean energy through European, ERDF and national programmes 2017-2019. Source: JRC analysis

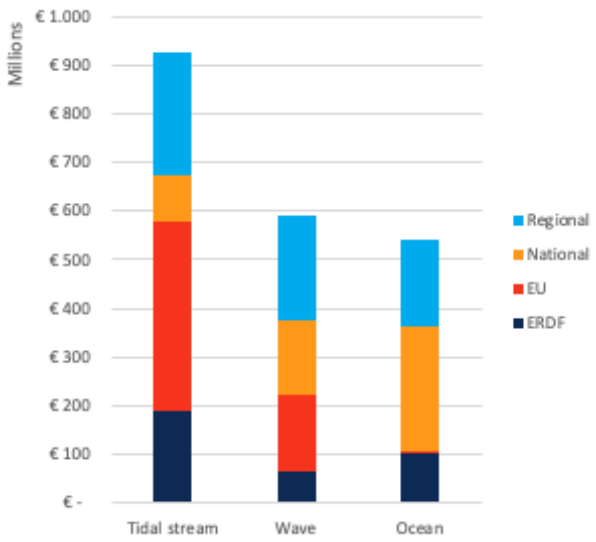

Figure 1: Breakdown of funding for wave and tidal energy technology for the period 2007-2019. Projects or programmes on ocean energy in general are not taken into account.

It emerges that EUR 592 million of funds have gone to wave energy R&D and EUR 925 million to tidal energy. About EUR 540 million were directed to other research areas such as resource modelling, array modelling, and not to one specific technology.

A significant shift in the funding of Research, development and deployment (RD&D) projects for wave and tidal energy has taken place since 2014. Up to 2013, the total costs of RD&D projects was comparable for the two technologies (about 280 million), as were the public funds associated with it (about EUR 210 million). Since 2014 tidal energy project funding amounts to EUR 640 million (of which EUR 330 million of public funds) against the EUR 316 million for wave energy projects (of which EUR 297 million of public funds). This difference is partly related to the award of some tidal energy demonstrator projects at higher TRL, which were also required to leverage private finance.

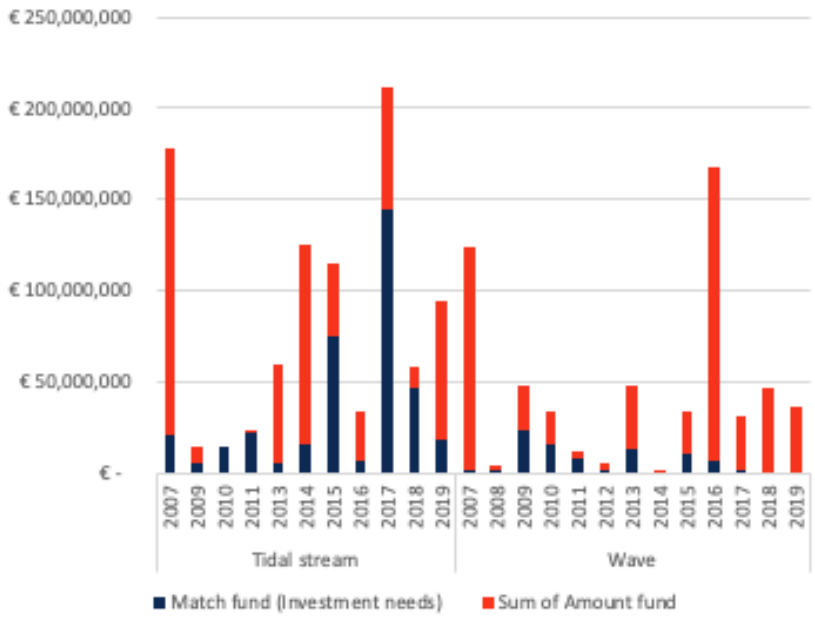

Figure 2: Yearly breakdown of funds dedicated to wave and tidal energy. It shall be noted that funds allocated to projects such as NER300 (still to be delivered) and to H2020 that have been terminated are still accounted in this figure.

The European Commission supports different activities addressing the development of ocean energy technologies. In particular, since 2014, the year when the Horizon 2020 (H2020) Framework Programme was launched, the EC has supported 47 projects (last update Feb 2020) addressing different technologies at various stages of the development. With the H2020 Framework Programme, the EC has funded EUR 156 million of ocean energy projects, a significant increase from the EUR 60 million directed to ocean energy during the 7th Framework Programme (Figure 3).

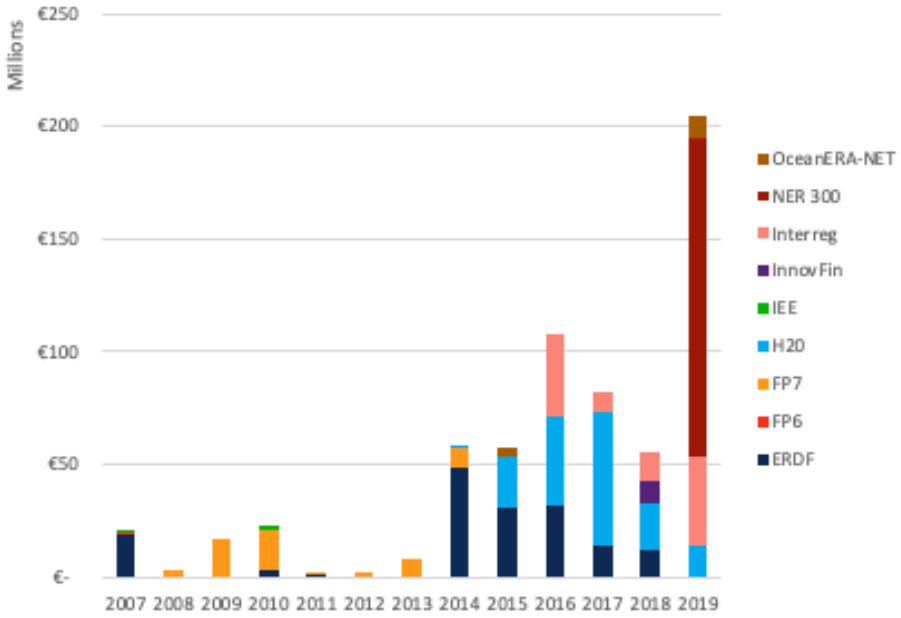

Figure 3: Breakdown of EU support for ocean energy in the different framework programmes since 2007

In total under the Horizon 2020 Framework Programme the EU has supported projects for a total cost of EUR 383 million, funding directly 52% of the funds EUR 199 million, when projects funded under the Life programme are taken into consideration. RD&D projects support by the EU fall mostly under the IA, RIA (Research Innovation Actions) and also under Climate actions.

Ocean-ERA-NET cofund is a network of 8 European RTD agencies located in 6 different MS (France, Ireland, Portugal Spain, Sweden, United Kingdom), receiving support from the H2020 programme for the coordination of research projects. The Ocean-ERA-NET cofund follows up the Ocean-ERA-NET project which consisted of European RTD agencies from 8 different MS (Belgium and Netherlands took part in the first Ocean-ERA-NET). Under the first Ocean-ERA-NET call for projects 13 R&D projects were granted for a total of EUR 11 million. A second OceanERA-NET confund call was launched in 2019, the funding approved for the joint call was of EUR 6.8 million.

Interreg projects aim at fostering transnational cooperation among neighbouring countries, encouraging collaboration to improve economic, social and territorial development of European regions. Since 2016, 16 Interreg projects have supported exclusively or partly ocean energy development for a total of EUR 132 million.

One particular area of research that is addressed by the EU programme is the provision of infrastructure. Horizon 2020 supports the Marinet 2 and Marinerg-I projects, whilst Foresea is supported by the Interreg framework. The Foresea project offers project developers access to leading test centres in Europe to support wave and tidal energy technology deployment at higher TRL. Marinet 2 and Marinerg-I are two projects that provide access to research and infrastructures across Europe. Marinet 2 brings together 39 partners across Europe, offering access to test facilities ranging from small-scale wave tanks to test-centres (EMEC and Bimep), whilst offering training for early researchers and young professionals on thematic such as wave energy modelling, resource assessment and environmental modelling. The Marinerg-I project brings together 14 EU research and test centres and works on implementing best-practices, guidelines, and standers to de-risk investments in ocean energy. The long term aims it to develop and integrated European Research Infrastructure designed to facilitate the growth and development of offshore renewable energies.
There are no significant changes from 2018 in these areas. The Marinerg-I project was concluded at the end of 2019. It has developed a business plan to support ocean energy development research infrastructure and monitoring of projects. Marinet 2 is still ongoing and delivering the expected results.

The mix of contribution available in Europe from EU, national and regional funding could provide a significant boost to the development of wave and tidal energy technologies in achieving the targets set in the SET-Plan DOI. It is suggested that, in line with the recommendation from the Offshore Strategy, support for ocean energy is provided for wave and tidal energy technology with a focus on deployment of 100MW by 2025 and 1GW by 2030.

THE LINKS BETWEEN THE MARKET UP-TAKE AND FINANCIAL ACTIONS AND TECHNICAL ACTIONS

It is recognised that in order to meet the technical actions outlined in the plan there is a requirement for significant financial support in order to enable these actions.

This link is particularly strong for higher TRL technical actions such as real-sea deployments. These activities are significantly more expensive and typically require the involvement of private capital. Market instruments such as Feed-in Tariffs must be made accessible for these activities. Often such policies are in the remit of energy officials, rather than research & innovation officials. This requires cross-government work to ensure that renewable market policies are aligned with research & innovation policies.

Lower TRL activities can usually be facilitated by classic RD&I funding, although care must be taken to ensure that it can be blended with other funding sources such as regional funds.

While there is no one solution that meets all needs there are a number of solutions that Member States can consider and some are already in place. Some of the forms of funding mechanisms are listed below:

- Local capital grants - i.e. innovation funding from states, local funding from regions.
- Public Procurement of Innovation.
- Revenue support schemes from Member States and partnering non-EU countries.
- European funding (Horizon Europe, InterReg, Innovation Fund, European Innovation Council, Infrastructure programmes).
- EIB Loan funding.

While some or all of these have been used as a wide range of support mechanisms at regional, national and European-level, the main focus to date has been in the form of grants or financial instruments. It is recognised by the IWG that it is time to encourage the use of other financial instruments.

Tidal technology in particular has now reached the point where a range of different devices have reached high TRL levels, with demonstrated performance in real operational conditions – in some cases as part of wider arrays.

Continued investment support will be required to reduce capital costs and lower total projects costs. Yet large scale deployment requires revenue support to attract investors.

Dramatic reductions in LCOE will only be realised through deployment to ramp up 'learning by doing' and through mass production, delivering economies of scale and scope.

Currently tidal stream is competing on the market against other technologies which already managed to attain lower LCOEs via large scale deployment. These technologies have all been received significant & targeted revenue support. Only equivalent support will ensure industrial roll out of ocean energy and give the sector a chance to reach ambitious 2030 targets.

The aim of this plan is to support collaboration of MS, Regions and EC to ensure that the financial and technical actions work in tandem and allow for the co-ordinated development of the sectors.

THE ACTIONS TO BE MONITORED UNDER THIS IMPLEMENTATION PLAN

The IWG recognises the need to monitor the following key operational actions at Member State level that will ensure the progress of the ocean energy sector in line with the aspirations of the EU Offshore Renewable Energy Strategy. The actions that emerged are based on the local mapping analysis feedback and supported by the project review carried out by the IWG. The actions are accompanied by a detailed activity fiche with resources, targets, and ownership. The Members of the IWG and Stakeholders will collate the results of activities related to these actions each year to monitor and report on progress at EU, MS, partnering non-EU countries, and Regional levels.

The high-level actions are grouped as follows:

Technical Actions	
Design and Validation of Ocean Energy Devices	1.1 - Demonstration of ocean energy devices to increase experience in real sea conditions
	1.2 - Demonstration of ocean energy pilot farms
	1.3 - Improvement and demonstration of PTO and control systems
	1.4 - Application of innovative materials from other sectors
	1.5 - Development of novel wave energy devices
	1.6 - Improvement of tidal blades and rotor
Foundations, Connections and Mooring	1.7 - Advanced mooring and connection systems for floating ocean energy devices
	1.8 - Improvement and demonstration of foundations and connection systems for bottom-fixed ocean energy devices
Logistics and Marine Operations	1.9 - Optimisation of maritime logistics and operations
	1.10 - Instrumentation for condition monitoring and predictive maintenance
Integration in the Energy System	1.11 - Developing and demonstrating near-commercial application of ocean energy in niche markets and hybrid systems.
	1.12 - Quantifying and demonstrating grid-scale benefits of ocean energy
Data Collection & Analysis and Modelling Tools	1.13 - Marine observation and modelling to optimise design and operation of ocean energy device
	1.14 - Open-data repository for ocean energy operation and performance
Cross-Cutting Challenges	1.15 - Standardisation and certification

Environmental, Policy and Socioeconomic Actions	
2.1 - De-risking of Environmental Consenting through an integrated programme of measures	▪ Promoting open data sharing on environment, consenting procedures and policy among MS. ▪ Promoting the development of environmental standards and certification ▪ Encouraging a circular economy approach in the design of ocean energy technologies* ▪ Promoting simplified consenting procedures (including cross-border deployments)
2.2 - Promoting Ocean Energy in Marine Spatial Planning	
2.3 - Promoting political support and public backing for ocean energy	
Market Uptake and Financial Actions	
3.1 - Dedicated revenue support for the first wave & tidal demonstration farms, to allow developers to attract the necessary private investment to action these deployments.	
3.2 - Create of an Investment Support Fund for ocean energy farms.	
3.3 - Encourage the creation of an EU Insurance and Warranty Fund to underwrite various project risks, as envisaged in the OceanSET dedicated report.	
3.4 - Funding from EU, national, regional and private sector to support demonstration and innovation projects under the Technical and Environmental, Policy and Socioeconomic Actions	
3.5 - Support the development of novel mechanisms to close funding gaps (such as a Public Procurement of Innovative Solutions)	

*A circular economy approach will be an integral part of all technical actions – in particular all actions concerned with the Design & Validation of Ocean Energy Devices

NOTE: It is important to state that both the Technical and Market Up-Take and Financial actions are inter-dependant on each other and must be considered in parallel. The Market Up-Take and Financial actions are really the key enablers for the technical actions.

More details about each action are provided in the Action Fiches (Annex 6).

A full review of the funding required for the Technical and Environmental & Socio-economic actions was carried out. The total figure estimate as required to enable the plan to 2025 is just over €1bn. Note that this does not include numbers for Financial & Market Uptake Actions based on the fact that this investment funding would be provided in addition to the €1bn investment by Industry, MS, partnering non-EU countries and EC.

THE MONITORING PLAN

The Monitoring Plan methodology was agreed by the IWG and has been implemented via the OceanSET project since March 2019.

The monitoring activities over the three years have comprised:

- Carrying out the resource and support mapping annually
- Requesting each Member State (MS) and partnering non-EU country complete a register of funded projects and ensure that funding recipients complete a report that captures LCOE progress. The format of reporting and details required was developed by the working group and agreed by all Stakeholders.
- Requesting each Member State, partnering non-EU country and region report separately on their activity under each action as part of the annual review.
- The monitoring plan attempted and continues to attempt to ensure maximum transparency across Industry, MS, Regions and European Commission to outline what funding is going towards the sector development

The European Commission has launched a call for a Coordination and Support Action to continue coordination of activities after the current OceanSET project ends in March 2022. If successful, a new consortium would continue to execute the Implementation Plan actions via an 'OceanSET 2' project. This is likely to commence in Q3 2022.

INDICATIVE TIMELINES

The chart below sets out an indicative timeline and phases of development for the sectors and this will be reviewed as part of the monitoring plan to determine progress and pace.

Indicative Timeline	2021-2025 Discovery	2026-2030 Deployment	2030+ Delivery
Proposed activities under the Implementation Plan			
Monitoring Activities = Technology push = Market pull = Both	• Ongoing monitoring with a view towards enabling large scale deployment of tidal and the convergence of wave technologies towards and tracking of LCOE development • Incentivise infrastructure and supply chain development	• Ongoing monitoring with a view towards enabling large scale deployment of tidal and the convergence of wave technologies towards and tracking of LCOE development • Incentive large scale infrastructure and further supply chain development	• Incentivise market development to drive significant LCOE reductions
Tidal	Technology Development	Large Scale Arrays	Commercial Development
Wave	Technology Development	Large Scale Arrays	Commercial Development

ANNEX 1: STAKEHOLDERS AND COUNTRIES INVOLVED IN THE PROCESS

Under the SET Plan an Implementation Plan (IP) for Ocean Energy was elaborated by a temporary working group comprising representatives from the European Commission (EC), Member States (MS) and other stakeholders and was adopted on 21 March 2018. For the execution of the IP, the temporary working group has evolved to assume the role of an Implementation Working Group (IWG).

COMPOSITION OF THE IMPLEMENTATION WORKING GROUP

EC Coordinating Officer (CO): Matthijs SOEDE (DG RTD G3) matthijs.soede@ec.europa.eu **Head of Unit responsible**: Hélène Chraye (DG RTD G3) **EC Associated Officer (AO):** Dermot BUTTLE (DG RTD G1)	
National Representatives (Countries)	
Ireland	SEAI (Sustainable Energy Authority of Ireland)
Spain	CDTI (Centre for the Development of Industrial Technology)
UK	BEIS (Department for Business, Energy and Industrial Strategy)
Denmark	Danish Energy Agency
Finland	Ministry of Economic Affairs and Employment
Portugal	DGEG (Direção Geral de Energia e Geologia)
France	ADEME (Agency for Ecological Transition)
Italy	ENEA (Agenzia nazionale per le nuove tecnologie, l'energia e lo sviluppo economico sostenibile)
Sweden	SWEA (Swedish Energy Agency)
Belgium	FPS Economy General Directorate Energy
Netherlands	Ministry of Economic Affairs and Climate Policy
Germany	TBC
Cyprus	TBC
Stakeholders	
Ocean Energy Europe	Donagh Cagney
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EC Participants	

EC SET PLAN	SET Plan Secretariat
EC-MARE	Xavier Guillou
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ANNEX 2: OUTPUTS FROM STRATEGIC ROADMAP

Table 3. Summary of Actions

SECTION		ACTION BY			BENEFITS
Phase of Development	**Actions**	**European Commission**	**Member States / EU Regions**	**Industrial Players**	
ACTION PLAN 1 SECTION 4.1	**TIMELINE: 2018-2025**				
R&D Prototype	A European phase-gate technology development process for systems and devices	Establish the Fund for the process from existing allocations – e.g. EU Horizon 2020, EU Research and Innovation funds, ERA-NET (co) funds	Identify and promote funding sources that can contribute to the Fund	Design criteria and performance indicators. Promote findings and learnings. Participating companies to contribute to the Fund	Enables countries with different ocean resources to have comparable measures and performance indicators that will allow learnings and results to be shared at a European level, ensuring better value for public funding and acceleration of technology development.
ACTION PLAN 2 SECTION 4.2	**TIMELINE: 2018-2025**				
Demonstration Pre-Commercial	Create an Investment Support Fund for ocean energy farms, financing single demonstration/ pre-commercial projects, providing different types of finance and access to finance to developers	Promote the establishment of, and contribute to a public-private partnership (PPP) through best use of existing sources of funding	Contribute to a PPP	Further discussion by key industry stakeholders and financial institutions on design options and development of the finance model. Actively participate in PPP.	Enables several demonstration/pre-commercial farms beyond the MeyGen and Raz Blanchard projects to be built and ensures that learnings and results shared at a European level.
ACTION PLAN 3 SECTION 4.3	**TIMELINE 2016-2018 PREPARATION & DESIGN; 2018 - LAUNCH**				
Demonstration Pre-Commercial	Create an EU Insurance and Guarantee Fund to underwrite project risks, focusing on the gaps in existing guarantee/ insurance cover	Create Fund and contribute through best use of existing sources of funding	Contribution to Fund; defining scope of cover to be provided, underwriting, risk-sharing and acceptance criteria	Further discussion by key industry stakeholders and financial institutions on design options and development of the finance model. Contribution through insurance premiums.	Insuring technological/ operational risks will reduce financial risks which increases the ability to leverage additional private finance. Allows development of suitable commercial insurance products and the use of data and knowledge from first projects to inform future projects.
ACTION PLAN 4 SECTION 4.4	**TIMELINE: 2017-2018**				
R&D Prototype Demonstration Pre-Commercial Industrial Roll-out	De-risking environmental consenting through an integrated programme of measures (five projects) to overcome development challenges: Planning, consenting, research, socio-economics and demonstration strategy	Commission Directorate Generals to fund the projects	Input to development of tender specifications to ensure best project outputs		Facilitates sustainable developments, addressing key consenting issues, both currently and in the future as the industry develops and the first arrays are built out.

ANNEX 3: FINANCING/FUNDING SOURCES

Funding controlled by Member States

Most Countries have Research and Innovation programmes, usually limited to TRL level 7.

Higher TRL financial support provided by Member States and partnering non-EU countries need to comply with the EU's State aid rules. Relevant documents are two Commission Communications: 1. Framework for State aid for research and development and innovation[6], which limits aid intensity for applied research undertaken by large enterprises to 60% (or 70% in case of cross-border cooperation or cooperation with an SME or a research organisation); 2. Guidelines on State aid for environmental protection and energy 2014-2020[7] which in the case of CCS, energy infrastructure, district heating infrastructure and aid in the form of tradable permits allows for a higher aid intensity (up to 100%).

Important Projects of Common European Interest (IPCEI) are transnational projects of strategic significance for the EU. In 2014 the European Commission adopted specific State aid guidelines for IPCEIs[8] allowing Member States and partnering non-EU countries to provide financial support to such projects undertaken by industry beyond what is usually possible for R&D and innovation projects. For example, public funding may also support the first industrial deployment of the results of an R&D project and may cover a higher percentage of the funding gap. An example is the IPCEI on High Performance Computing (HPC) and Big Data Enabled Applications launched in January 2016 by Luxembourg, France, Italy and Spain[9].

Within European Structural and Investment Funds (ESIF), the relevant fund is the European Regional Development Fund (ERDF). However, the ERDF Regulation stipulates prohibits supporting investments to achieve greenhouse gas reductions from activities covered by the ETS. R&I activities can nevertheless be supported if they are included in the Smart Specialisation Strategy of the respective Member States, partnering non-EU countries or region[10]. This is a bottom-up process, hence the initiative would need to come from the Member State and partnering non-EU countries.

Funding by European Investment Bank (EIB)

The European Fund for Strategic Investment[11] (EFSI) ("Juncker Plan") can be relevant in case projects expect to have a business case / achieve a Return on Investment (possible with

[6] http://eur-lex.europa.eu/legal-content/EN/TXT/?uri=celex:52014XC0627(01)

[7] http://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A52014XC0628%2801%29

[8] http://eur-lex.europa.eu/legal-content/EN/TXT/?uri=uriserv:OJ.C_.2014.188.01.0004.01.ENG

[9] https://ec.europa.eu/commission/commissioners/2014-2019/oettinger/blog/luxembourg-launches-supercomputing-project_en

[10] http://s3platform.jrc.ec.europa.eu/

[11] http://www.eib.org/efsi/; https://ec.europa.eu/commission/priorities/jobs-growth-and-investment/investment-plan_en

complementary funding by grants) and the main hurdle is the reluctance of banks to provide loans to inherently risky innovation projects. A key objective of EFSI is to leverage additional private funding, hence EFSI may be most appropriate for R&I activities rather close to the market and with confirmed revenue support

InnovFin-EDP[12] (Energy Demo Projects) enables the EIB to finance innovative first-of-a-kind demonstration projects in the fields of renewable energy, sustainable hydrogen and fuel cells. In projects focusing on hydrogen production/distribution, the hydrogen should come primarily from renewable sources. The projects may include first-of-a-kind power, heat and/or fuel production plants and first-of-a-kind manufacturing plants. The EIB provides loans of between EUR 7.5m and EUR 75m. InnovFin-EDP has been designed to address the financing bottleneck identified in the EU's Strategic Energy Technology (SET) Plan. EIB loans are subject to a project's bankability prospects, meaning that they will only be for projects very close to the market and with confirmed revenue support.

European Commission programmes

Currently available EU grants are limited to Horizon 2020 and the Research Fund for Coal and Steel (RFCS[13]), which, however, are not aimed at TRL higher than level 7.

The Innovation Fund (IF) was proposed by the Commission as part of a reformed Emission Trading System (ETS). The type of instrument (grant, loan, guarantee) is not yet decided, it might depend and evolve with the maturity of the project. Current planning is to adopt a Delegated Regulation setting the Fund's detailed rules in the first half of 2018 with the Fund being operational in 2020. Before 2021 (and conditional to the new ETS Directive being adopted) available funding are the proceeds from 50 million ETS allowances from the Market Stability Reserve and the leftovers from NER300 (up to EUR 1 billion). For the period from 2021 to 2030, proceeds from an additional 400 million (Commission proposal) or 600 million (European Parliament amendment) ETS allowances would be available. The value of one allowance is the price of ton of CO2, when the allowance is auctioned (today the ton of CO2 is valued at around 5 EUR, but it is expected to be higher with the implementation of the proposed ETS reform).

The Commission proposal for a new ETS Directive defines the scope of the Innovation Fund rather broadly: demonstration projects in the areas CCS, innovative renewable energy technologies and low-carbon technologies and processes in industrial sectors covered by the ETS. The Innovation Fund could cover a maximum of 60% of the costs of projects.

[12] http://www.eib.org/attachments/thematic/innovfin_energy_demo_projects_en.pdf

[13] Could be interesting for R&I projects in the steel industry requiring co-funding of not more than around EUR 3 million (http://ec.europa.eu/research/industrial_technologies/rfcs_en.html)

ANNEX 4: OCEAN ENERGY

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

- Wave energy converters derive energy from the movement of waves and can be located flexibly – on the shoreline, the nearshore or offshore at depths of over 100m – to harness the available energy most efficiently. A range of full-scale prototypes have been deployed; however, further technology development, testing and demonstration are required prior to commercialisation and industrial rollout.
- Tidal stream turbines harness the flow of the currents to produce electricity. Tidal turbines can be fixed directly to and mounted on the seabed, or tethered/moored to the seabed and buoyant, floating on surface or in mid water. A number of device designs are at a late TRL stage, and are feeding electricity into the grid in real operational environments – both individually and as arrays.
- Tidal range uses the difference in sea level between high and low tides to create power. Tidal range technology uses the same principles as conventional hydropower, and requires a barrier to impound a large body of water, driving turbines generating electricity. Tidal range is the more established ocean energy technology, with several projects generating power around the world. FINAL NOVEMBER 2016 16 | OCEAN ENERGY FORUM
- Ocean Thermal Energy Conversion (OTEC) exploits the temperature difference between deep cold ocean water and warm surface waters to produce electricity via heat-exchangers. OTEC is suited to oceans where high temperature differences will yield the most electricity. A number of demonstration plants are being developed in EU overseas territories opening up export opportunities.
- Salinity gradient power generation utilises the difference in salt content between freshwater and saltwater, found in areas such as deltas or fjords, to provide a steady flow of electricity via Reverse Electro Dialysis (RED) or osmosis. Deployment potential is significant around Europe, however, further technology development is required to bring salinity gradient to maturity.

ANNEX 5: WIDER POLICY CONTEXT

The **Energy Union Strategy**[14], launched in early 2015 and being one of the 10 big priorities of the European Commission (EC), includes research, innovation and competitiveness at the same level of importance with its 4 other dimensions, for accelerating the decarbonisation of the European energy system cost-effectively. The Strategic Energy Technology (SET) Plan has been recognised as one of the major tools to deliver this goal by contributing to the cost reduction and improve of performance of low carbon energy technologies through impactful synergetic innovation actions.

As part of the deliverables of the Energy Union strategy, the European Commission adopted a Communication for an **Integrated Strategic Energy Technology Plan**[15]. The Communication identifies ten priority actions to accelerate the energy system transformation through coordinated or joint investments between European countries, private stakeholders (including research and industry) and the European Commission. These actions have been defined building on the proposals of the Integrated Roadmap (that was developed with stakeholders and Member States) and in line with the new political priorities defined in the Energy Union strategy.

The first round of the public consultation process was dedicated to the 1st Energy Union Research, Innovation and Competitiveness common priority, for "being the world leader in developing the next generation of renewable energy technologies including environment-friendly production and use of biomass and biofuels, together with energy storage". It focused on Actions 1 and 2 of the SET Plan Communication (C(2015)6317):

- Action 1: "to sustain technological leadership by developing highly performant renewable technologies and their integration in the EU's energy system"; and
- Action 2: "to reduce the cost of key technologies"

Out of the ten priorities, these actions are the most relevant action for the Ocean Energy Implementation Working Group.

To initiate this consultation, and on the basis of the SET Plan Integrated Roadmap, the European Commission developed Issues Papers that addressed the R&I challenges for concentrated solar power/solar thermal electricity (CSP/STE), offshore wind, photovoltaic, ocean and deep geothermal sectors/technologies. For the first three Issues Papers - on CSP/STE, offshore wind and photovoltaic - the European Commission initiated the public consultation in October 2015 by sending these Issues Papers to relevant research and industrial stakeholders and SET Plan countries requesting them to take position on the proposed targets/priorities in accordance with the guidelines set out in the document entitled "the SET Plan actions – Implementation process and expected outcomes".

Relevant stakeholders and SET Plan countries were invited to provide their comments for this public consultation round in the form of "input papers" by 20th November 2015. During a dedicated SET Plan Steering Group meeting on 9th December 2015, invited stakeholders and

[14] Energy Union Package, COM (2015)80 final.

[15] C(2015) 6317 final

SET Plan countries discussed the Issues Papers and reached an agreement on common targets that took the form of a Declaration of Intent (DoI). At the Steering Group meeting of 20th January 2016, the DoIs for CSP/STE, Offshore Wind and Photovoltaic were endorsed.

Following the same process, for ocean energy and deep geothermal energy, stakeholders and SET Plan countries were invited to provide comments in the form of "input papers" by 17th June 2016. They were requested to take position on the proposed targets/priorities again in accordance with the guidelines set out in the document in the box underneath. During a dedicated Steering Group meeting on 12thJuly 2016, stakeholders and SET Plan countries held discussions on the Issues Papers and reached an agreement on common targets. Following a period of review, the Declarations of Intent (DoIs) for both deep geothermal and ocean energy were presented and endorsed at the Steering Group meeting of 14th September 2016.

The high-level targets for the ocean energy sector are

- to bring ocean energy to commercial deployment,
- to drive down the levelised cost of energy (LCoE),
- to maintain and grow Europe's leading position in ocean energy and
- to strengthen the European industrial technology base, thereby creating economic growth and jobs in Europe and allowing Europe to compete on a global stage.

Ocean energy technologies need to demonstrate their reliability and capacity to survive in aggressive sea conditions ensuring, device availability to reduce risk for project developers and investors. They need to demonstrate their market potential and, with sufficient capacity deployment, become cost-competitive in comparison with other energy technologies.

ANNEX 6: ACTIONS FICHES

Strategic Energy Technology Plan - Technology Development Actions

SECTION 1 - TECHNICAL ACTIONS

TECHNICAL ACTIONS: DESIGN & VALIDATION OF OCEAN ENERGY DEVICES

Action 1.1 Demonstration of ocean energy devices to increase experience in real sea conditions

Demonstration of ocean energy devices to increase experience in real sea conditions	
Targets: 100MW deployed by 2025 & a reduction of LCOE for wave energy and tidal energy to 15 cEUR/kWh by 2030 and 2025 respectively	**Monitoring mechanism**: Annual progress reports

Scope: Demonstration of ocean energy devices in real sea conditions for long periods of time provides invaluable learnings. It is the only way to properly validate the technology and an essential step to commercialisation. Risk can be mitigated by a comprehensive dry testing of subsystems. Onshore testing should be carried out before any at-sea deployment of complete devices. Several successful programmes have assisted in this process, such as MaRINET, FORESEA and Blue-GIFT. Complemented by onshore testing, more real sea experience is required to demonstrate performance, reliability, availability, maintainability and survivability. Common issues could be then identified and addressed through further R&I actions.

Around 10 large projects and around 10 medium size projects are required under this topic.

Key actions include:

- Testing at onshore and offshore facilities in Europe.
- Demonstration of scalability.
- Optimisation of key PTO components.
- Real sea, long-term deployment of full-scale devices.
- Definition of performance, reliability, availability, maintainability and survivability KPIs.
- Facilitation of knowledge transfer and cross-sector collaboration.
- Pre-normative research to provide guidelines and technical specifications to assist in the certification process.

TRL: Advanced research /Industrial research & demonstration → TRL 5-9

Total budget required: 150M EUR

Expected impact	**Timeline**
• Demonstrate improved performance, reliability, availability, maintainability and survivability. • Contribute to LCOE reduction approaching SET Plan targets (actions should clearly state estimated LCOE at project start and end) • Reduce risk and uncertainties. • Reinforce the industrial supply chain. • Improve manufacturing readiness levels. • Knowledge and data exchange, respecting the protection of company IP. • Better knowledge of environmental impacts.	01/2022 – 12/2025

• Attract private investors to the sector and reduce the cost of this investment to projects	

Action 1.2 Demonstration of ocean energy pilot farms

Demonstration of ocean energy pilot farms	
Targets: 100MW deployed by 2025 & a reduction of LCOE for wave energy and tidal energy to 15 cEUR/kWh by 2030 and 2025 respectively	**Monitoring mechanism**: Annual progress reports

Scope: Deployment of ocean energy pilot farms in full operational conditions for long periods of time is essential to advance this sector. It is the only way to achieve high TRLs while reducing costs, reducing risks and attracting investors for future commercial projects. Pilot farms, even with a small number of devices, require higher investments with uncertain returns, due to the inherent uncertainties of technology development and deployment.

To focus on the technologies with the greatest chances of success, ocean energy devices should have been satisfactorily demonstrated at full scale before this action. The innovation component should mainly lie on the pilot farm subsystems and activities that enable a cost-effective pilot farm. Where established, stage-gate processes can help ensure that this approach is followed. Projects funded under this Priority Topic should not include the development of single devices, which is within the scope of the previous Priority Topic. At the same time, projects funded under this Priority Topic should show clear progress beyond the state of the art 7 pilot farm projects are required under this topic.

Key actions include:

- Support for demonstration of full-scale wave and tidal devices in small pilot farms at open sea.
- Demonstration of interactions between devices.
- Optimisation of shared electrical components, e.g. power cables, subsea hubs and substations.
- Demonstration of other potential shared equipment such as foundations and mooring lines.
- Optimisation of installation procedures and means, e.g. vessels, remote operated vehicles and equipment.
- Demonstration of improved manufacturing and assembly techniques.
- Optimisation of operation and maintenance techniques, including data analytics and other digital techniques.
- Definition of performance, reliability, availability, maintainability and survivability KPIs at array scale.
- Facilitation of knowledge transfer and cross-sector collaboration.
- Monitoring campaigns to better understand environmental impacts.
- Socio-economic impact assessments.
- Power quality and energy system integration studies.
- Integration of storage technologies or combination with other uses such as hydrogen production, desalination or other offshore renewable sources.
- Pre-normative research to provide guidelines and technical specifications to assist in the certification process at array scale

TRL: Advanced research /Industrial research & demonstration → TRL 7-9

Total budget required: 350M EUR

Expected impact	**Timeline**
• Contribute to LCOE reduction approaching SET Plan targets (actions should clearly state estimated LCOE at project start and end, and in following deployment stages). • Demonstrate improved performance, reliability, availability, maintainability and survivability for the whole pilot farm. • Improve operation and maintenance strategies • Better definition of risk and uncertainties for future deployment stages. • Reinforce the industrial supply chain and identify supply gaps. • Achieve high manufacturing readiness levels for all the components and equipment at array scale with the capability in place to begin full rate production. • Knowledge and data exchange within the sector but also collaborating with other sectors, respecting the protection of company IP. • Better knowledge of environmental impacts at array scale. • Understand socioeconomic benefits of deploying ocean energy projects.	01/2022 – 12/2025

• Estimate potential benefits to the global energy system due to the integration of wave or tidal resources. • Understand dismantling and recycling operations introducing eco-design requirements from the first stages of development with a circular economy approach. • Attract private investors to the sector and reduce the cost of this investment to projects	

Action 1.3 Improvement and demonstration of PTO and control systems

Improvement and demonstration of PTO and control systems	
Targets: 100MW deployed by 2025 & a reduction of LCOE for wave energy and tidal energy to 15 cEUR/kWh by 2030 and 2025 respectively	**Monitoring mechanism**: Annual progress reports

Scope: PTO and control systems (including gearboxes, electric generators and power electronics) are key subsystems of wave energy converters. PTO and control systems can be improved to increase the efficiency of the whole converter, to increase reliability and to avoid extreme events that might compromise device survivability. Control systems dynamically adapt to and mitigate the forces of the continually changing ocean conditions. This can prevent damage during extreme events, contribute to increased performance and the viability of the technology. The manufacturing and testing of prototypes are relatively costly, and it is imperative that data from the demonstration are available to avoid repeating early engineering mistakes. Verification in realistic environments at small scale for longer periods could make best use of scarce resources. Onshore testing and controlled lab testing can provide significant information. Development and demonstration of PTO technology should be combined with control strategies as their requirements are inherently coupled

Around 10 medium size projects focused on high TRLs and around 5 small projects focused on medium TRLs are required under this topic.

Key actions include:

- Demonstrate the reliability, robustness and performance of PTO and control systems.
- Optimisation and simplification through standardisation, modularity and scalability of key PTO components.
- Validation of 'wave-to-wire' models12 to facilitate global optimisation of ocean energy devices.
- Improvement of control strategies to reduce the impact of the stochastic nature of the input (e.g. reduce extreme loading, increase production).
- Uncertainty assessment of loads and strengths on critical components to derive lifetime, safety factors and reliability.
- Demonstrate delivery of grid-compliant power including short-term energy storage solutions to smooth power output when needed.
- Improve understanding of the limitations in scaling-up PTO components.
- Cooperation between technology developers and key vendors to develop interoperability between systems (e.g. standardisation and unification of SCADA system requirements).
- Pre-normative research to provide guidelines and technical specifications to assist in the certification process

TRL: Advanced research /Industrial research & demonstration → TRL 4-8	
Total budget required: 60M EUR	
Expected impact	**Timeline**
• Improve performance, reliability and survivability. • Convergence (standardisation) and simplification of designs to allow a reduction in maintenance costs. • Reduce fatigue on components, unexpected failures, unplanned maintenance and thus increase availability. • Improve manufacturing readiness levels. • Better knowledge of environmental impacts. • Contribute to LCOE reduction approaching SET Plan targets (actions should clearly state estimated LCOE at project start and end). • Knowledge and data exchange, respecting the protection of company IP. • Reinforce the EU supply chain.	01/2022 – 12/2025

Action 1.4 Application of innovative materials from other sectors

Application of innovative materials from other sectors	
Targets: 100MW deployed by 2025 & a reduction of LCOE for wave energy and tidal energy to 15 cEUR/kWh by 2030 and 2025 respectively	**Monitoring mechanism**: Annual progress reports

Scope: Components and systems used in ocean energy devices need to be resistant to corrosion and the heavy loads they are subject to. Significant experience has been accumulated by other offshore industries which use many materials and coatings in the ocean. Materials such as reinforced concrete, polymers, composites, and concrete-steel/composite-steel hybrids systems have demonstrated some advantages in other offshore sectors, such as reduced costs. Demonstrating the potential benefits of these new materials in ocean energy converters, moorings and foundations whilst ensuring structural integrity and durability is required. Increased access to test facilities may also be needed.

A few medium size projects and around 5 small projects are required under this topic.

Key actions include:

- Transfer of innovative materials, anti-fouling coatings, and manufacturing processes that are generally applicable to multiple ocean energy devices and processes.
- Characterisation and experimental testing of innovative materials properties.
- Demonstration of materials that ensure long durability in sea water (ideally up to the project lifetime).
- Demonstration in relevant and operational environments to understand survivability and reduce risks.

TRL: Advanced research /Industrial research & demonstration → TRL 5-7

Total budget required: 25M EUR

Expected impact	**Timeline**
• Improve survivability, reliability and affordability by reducing biofouling and corrosion and extending lifetimes. • Reduce CAPEX and OPEX. • Contribute to LCOE reduction approaching SET Plan targets (actions should clearly state estimated LCOE at project start and end)	01/2022 – 12/2025

Action 1.5 Development of novel wave energy devices

Development of novel wave energy devices	
Targets: 100MW deployed by 2025 & a reduction of LCOE for wave energy and tidal energy to 15 cEUR/kWh by 2030 and 2025 respectively	**Monitoring mechanism**: Annual progress reports

Scope: There is a continuous flow of new ideas and concepts to harness wave energy, coexisting with several more developed technologies. This topic aims to support radical improvements in key device functions – such as energy capture or energy transformation – which could provide a step change in the overall wave energy technology performance. Identification of novel concepts should use internationally agreed evaluation criteria via structured product verification approaches that build on prior knowledge and experience (e.g. a stage-gate approach). Several international initiatives are currently defining a methodology to assess wave energy technologies at various stages of development (e.g. H2020 DTOceanPlus tools and IEAOES Task 12 evaluation framework). This will provide a framework within which novel device research can be sustainably funded.

Around 10 small projects and around 5 medium size projects are required under this topic

Key actions include:

- Numerical modelling and simulation of novel wave energy concepts and subsystems demonstrating a step change from current benchmarks.
- Experimental validation of novel concepts at laboratory (scaled prototype) against global metrics.
- Demonstration of technology in relevant environment.
- Verification following standards for stage progression through scale testing.

TRL: Advanced research /Industrial research & demonstration → TRL 3-6

Total budget required: 45M EUR

Expected impact	**Timeline**
• Breakthrough innovations, including key enabling technologies and whole concepts, with very high potential for cost reduction. • Encourage convergence to successful technologies by streamlining the whole sector's knowledge and experience. • Contribute to LCOE reduction beyond SET Plan targets (actions should clearly state estimated LCOE at project start and end). • Concentrate funding on the most promising concepts	01/2022 – 12/2025

Action 1.6 Improvement of tidal blades and rotor

Improvement of tidal blades and rotor	
Targets: 100MW deployed by 2025 & a reduction of LCOE for wave energy and tidal energy to 15 cEUR/kWh by 2030 and 2025 respectively	**Monitoring mechanism**: Annual progress reports

Scope: There are different blade solutions under development in terms of shape and material. Certain tidal turbine blades are made of composite material to ensure the correct strength and lowest possible weight. Blade edges can erode rapidly, facilitating water ingress, accelerating fatigue and the risk of failure. Failure in a blade can create long downtimes, which reduces annual energy production and increases operating costs. Improving the seaworthiness of blades will reduce the likelihood of this type of failure. There is also a need for further technology investigation and demonstration of improved reliability and efficiency of tidal turbine blades and rotor, including pitch and yaw control.

Around 5 medium size projects and a few large projects are required under this topic.

Key actions include:

- Structural tests to verify performance of materials in tidal blades over their expected lifetime.
- Better modelling of the turbulences and their impact on the blades.
- Characterisation of novel materials.
- Improved manufacturing processes to produce tidal blades.
- Long-lasting coatings or antifouling materials to reduce operation and maintenance costs.
- Cooperation between technology developers and key vendors for the development of control techniques of tidal turbine blades and rotor.
- Demonstration of blades and control systems in real sea conditions

TRL: Advanced research /Industrial research & demonstration → TRL 4-6

Total budget required: 55M EUR

Expected impact	**Timeline**
• Improve performance and reliability. • Reduce fatigue due to cyclical loading. • Contribute to LCOE reduction approaching SET Plan targets (actions should clearly state estimated LCOE at project start and end)	01/2022 – 12/2025

TECHNICAL ACTIONS: FOUNDATIONS, CONNECCTIONS & MOORINGS

Action 1.7 Advanced mooring and connection systems for floating ocean energy devices

Advanced mooring and connection systems for floating ocean energy devices	
Targets: 100MW deployed by 2025 & a reduction of LCOE for wave energy and tidal energy to 15 cEUR/kWh by 2030 and 2025 respectively	**Monitoring mechanism**: Annual progress reports

Scope: Floating systems offer the potential to harvest wave or tidal power in deeper areas. However, large current and wave responses of these devices result in loads on mooring and connections systems that are more challenging than for existing floating structures. Tailored solutions for this challenge must be developed, optimised and tested at sea.

Around 10 medium size projects and a few large projects are required under this topic.

Key actions include:

- Advance the design of tailored mooring and connection of electrical or other power transmission systems for floating wave and tidal requirements.
- Reduce the cost of cabling by applying innovations from other sectors or developing novel applications tailored to ocean energy.
- Develop or apply advanced simulation of the mooring system and its installation to reduce uncertainties and margins in the design.
- Advance combined mooring and electrical connectors or hydraulic power transmission to reduce component cost and number of connection operations, included in systems for sharing an anchor between devices in arrays.
- Develop novel systems for safe and quick connection/disconnection that do not require large vessels and diving teams.
- Reduce maintenance requirements of station-keeping systems.
- Reduce station-keeping interference with power performance requirements.
- Develop new materials with improved fatigue, damping, stiffness, bio-fouling management or other cost-reducing characteristics (This should be coordinated with 5.1.3 Application of innovative materials from other sectors).

TRL: Advanced research /Industrial research & demonstration → TRL 3-6	
Total budget required: 50M EUR	
Expected impact	**Timeline**
• Reduce CAPEX and OPEX. • Contribute to LCOE reduction according to SET Plan targets (actions should clearly state estimated LCOE at project start and end)	01/2022 – 12/2025

Action 1.8 Improvement and demonstration of foundations and connection systems for bottom-fixed ocean energy devices

Improvement and demonstration of foundations and connection systems for bottom-fixed ocean energy devices	
Targets: 100MW deployed by 2025 & a reduction of LCOE for wave energy and tidal energy to 15 cEUR/kWh by 2030 and 2025 respectively	**Monitoring mechanism**: Annual progress reports

Scope: The engineering of bottom-fixed foundations for ocean energy devices presents its own set of challenges. These include developing and reducing costs of bespoke electrical connection and cabling, designing foundations optimised for the installation and operating conditions of ocean energy arrays, and improving installation operations and maintenance. For tidal energy, the central challenge that governs design typically is high currents and their loads and effects on the foundation and cabling. For wave energy, design is typically governed by the largest wave expected during the device's deployment.

Around 5 medium size projects for the higher TRLs and around 5 small projects for the lower TRLs are required under this topic.

Key actions include:

- Reduce the cost of electrical connection of device. These could be improvements to existing methods or novel solutions, such as low-cost, high reliability, low maintenance connectors. At-sea power conversion or other approaches can be considered if potential for cost reduction is demonstrated.
- Reduce cost of, or need for, secondary steel structure for electric cables or other form of power transmission to shore.
- Overall cost reduction should be considered, i.e. not only manufacturing but also installation, maintenance and other costs associated with a particular solution.
- Tidal only: design robust and optimised foundations that can be installed cost-effectively in the conditions of tidal farms, which may include hard seabed, strong currents, short operating windows for installation in slack tide. These may be novel solutions or improvements to existing foundations types such as monopiles, jackets or gravity-base.
- Improve installation of wave and tidal devices, including novel designs, procedures and tools. New dedicated tools could address the conditions of tidal or waves sites that pose challenges not currently addressed by offshore industries.
- Design, develop or validate foundation and connection systems designs that optimise installation in wave or tidal site conditions.
- Demonstrate high cost-reduction potential by improving foundations or power transmission to shore.

TRL: Advanced research /Industrial research & demonstration → TRL 4-6	
Total budget required: 35M EUR	
Expected impact	**Timeline**
• Reduce CAPEX and OPEX. • Contribute to LCOE reduction according to SET Plan targets (actions should clearly state estimated LCOE at project start and end)	01/2022 – 12/2025

TECHNICAL ACTIONS: LOGISTICS & MARINE OPERATIONS

Action 1.9 Optimisation of maritime logistics and operations

Optimisation of maritime logistics and operations	
Targets: 100MW deployed by 2025 & a reduction of LCOE for wave energy and tidal energy to 15 cEUR/kWh by 2030 and 2025 respectively	**Monitoring mechanism**: Annual progress reports

Scope: Vessel logistics and costs for ocean energy installation and operation is an area with potential for dramatic and early cost reductions. For example, unclear safety requirements increase downtime of vessels and equipment for operations, greatly impacting costs. Selectively adapting good practices form other sectors, developing bespoke operations and tools, and documenting and sharing experience will be crucial to rapidly reducing these costs. It is thus essential that actions within this Priority Topic be well coordinated with those in the Challenge Area for demonstration of devices, to ensure focus on solving real and specific problems encountered during open-sea deployments. The emphasis should be on "learning by doing".

Around five medium size projects and a few of large projects are required under this topic.

Key actions include:

- Reduce the cost of electrical connection of device. These could be improvements to existing methods or novel solutions, such as low-cost, high reliability, low maintenance connectors. At-sea power conversion or other approaches can be considered if potential for cost reduction is demonstrated.
- Reduce cost of, or need for, secondary steel structure for electric cables or other form of power transmission to shore.
- Overall cost reduction should be considered, i.e. not only manufacturing but also installation, maintenance and other costs associated with a particular solution.
- Tidal only: design robust and optimised foundations that can be installed cost-effectively in the conditions of tidal farms, which may include hard seabed, strong currents, short operating windows for installation in slack tide. These may be novel solutions or improvements to existing foundations types such as monopiles, jackets or gravity-base.
- Improve installation of wave and tidal devices, including novel designs, procedures and tools. New dedicated tools could address the conditions of tidal or waves sites that pose challenges not currently addressed by offshore industries.
- Design, develop or validate foundation and connection systems designs that optimise installation in wave or tidal site conditions.
- Demonstrate high cost-reduction potential by improving foundations or power transmission to shore.

TRL: Advanced research /Industrial research & demonstration → TRL 4-6

Total budget required: 55M EUR

Expected impact	**Timeline**
• Demonstrate reduction in cost of marine operations and maintenance. • Improve know-how and data available to industry and future projects for marine operations necessary to ocean energy, reducing risks, uncertainty and costs.	01/2022 – 12/2025

Action 1.10 Instrumentation for condition monitoring and predictive maintenance

Instrumentation for condition monitoring and predictive maintenance	
Targets: 100MW deployed by 2025 & a reduction of LCOE for wave energy and tidal energy to 15 cEUR/kWh by 2030 and 2025 respectively	**Monitoring mechanism**: Annual progress reports

Scope: The combination of smaller and cheaper sensor technology with telecommunication (Internet of Things) has opened new opportunities for significant cost reduction in the operation and maintenance of energy assets, particularly offshore. For ocean energy, these technologies also offer the possibility to fast-track industry learning to reduce maintenance requirements and operating costs.

A few medium size projects and around 5 small projects are required under this topic.

Key actions include:

Apply recent advances in condition and structural health monitoring from other sectors to ocean energy – particularly those currently developed for offshore wind.

- Apply latest sensor technology to existing ocean energy deployments.
- Document and share experience on sensors performance and reliability, and methods for adapting them to the harsh ocean energy environment.
- Improve transmission or storage of data collected from sensors, such as underwater data transmission.
- Develop common guidelines to facilitate transfer of device-specific sensor and monitoring systems across technologies.
- Identify novel solutions for ocean energy monitoring and develop, test and deploy bespoke instrumentation.
- Improve conditions-based and predictive maintenance with analysis of data streams, application of big data methods and machine learning, including artificial intelligence, or digital twin models training with existing operating data.
- Take advantage of ongoing, separately-funded ocean energy deployments at sea and fund additional activities.
- Monitoring/analytical equipment and activity is funded in exchange for open access to the generated data. Budget allocation discussed here concerns additional costs related to introducing specific sensors and the analysis of their data.
- In addition to the above, any action to develop or apply instrumentation, or analyse their data, that has demonstrably high potential to reduce costs for ocean energy should be considered

TRL: Advanced research /Industrial research & demonstration → TRL 4-6

Total budget required: 25M EUR

Expected impact	**Timeline**
• Reduce OPEX by optimising O&M. • Increase energy production by improving availability and improved survivability by early detection of failure risk. • Contribute to LCOE reduction according to SET Plan targets (actions should explain how this cost reduction is achieved).	01/2022 – 12/2025

TECHNICAL ACTIONS: INTEGRATION IN THE ENERGY SYSTEM

Action 1.11 Developing and demonstrating near-commercial application of ocean energy in niche markets and hybrid systems.

Developing and demonstrating near-commercial application of ocean energy in niche markets and hybrid centrals	
Targets: 100MW deployed by 2025 & a reduction of LCOE for wave energy and tidal energy to 15 cEUR/kWh by 2030 and 2025 respectively	**Monitoring mechanism**: Annual progress reports

Scope: Ocean energy is closer to cost-competitiveness in specific niche markets. Public support can remove the remaining obstacles to industry-led growth in those markets and allow scale and competition in the private sector to deliver further cost reductions in the nearer term. Actions in this Priority Topic should aim to deliver sufficient deployment for a sufficient time to de-risk the technical pathway to the individual niche markets. Co-use of the maritime space is expected to be a need as the energy transition progresses. Actions in this topic also explore the potential for hybrid projects, namely involving wave-wind technologies.

Around 10 medium size projects and a few large projects are required under this topic, preferably supporting at least one of tidal, wave and OTEC systems

Key actions include:

- Identify the best niche applications for first near-commercial deployment of ocean energy. These could include microgrids and islands or isolated applications such as aquaculture or desalination. A key criterion to evaluate niche markets is the overall value proposition of ocean energy relative to alternatives available to this particular market. Advance tailored solutions for these initial niche applications.
- Deploy and demonstrate in the niche market(s), where ocean energy is closest to competitive with alternatives. Selected technologies should have demonstrated technology and manufacturing readiness as well as near-cost competitiveness for this application.
- Identify best spots and incentivise deployment and demonstration to mainstream hybrid centrals.

TRL: Advanced research /Industrial research & demonstration → TRL 7-9

Total budget required: 100M EUR

Expected impact	**Timeline**
• De-risk commercial development of ocean energy in special applications. • Availability of open-access information and data to developers interested in the niche market. • Steppingstone to market-driven deployment expanding from the initial niche market out. • Contribute to LCOE reduction before SET Plan targets are achieved (actions should clearly state estimated LCOE at project start and end).	01/2022 – 12/2025

Action 1.12 Quantifying and demonstrating grid-scale benefits of ocean energy

Quantifying and demonstrating grid-scale benefits of ocean energy	
Targets: 100MW deployed by 2025 & a reduction of LCOE for wave energy and tidal energy to 15 cEUR/kWh by 2030 and 2025 respectively	**Monitoring mechanism**: Annual progress reports

Scope: The correlation of ocean energy intermittency with that of solar and wind power will reduce the need for storage, transmission and demand-response. Other benefits such as grid resilience to security threats may also be significant. Providing reliable estimations of these benefits would help better inform policy and investment decisions.

A few small projects are required under this topic.

Key actions include:

- Identify technical issues and solutions with the introduction of wave or tidal-generated power on the European grid in the foreseeable range of deployment scenarios. This could include a cost benefit analysis with consideration for power quality, predictability, intermittency, market price fluctuations, and costs of curtailment and under-production.
- Quantify the benefits in terms of reduced requirements for transmission infrastructure, demand-response and storage, due to variability that is out-of-phase and correlated to solar and wind power. Provide estimates of cost of energy that account for this benefit of ocean energy. Previous and ongoing projects combining multiple renewable energy sources as well as storage assets should be included for an up-to-date approach to this issue, including virtual power plant applications where appropriate. Quantifying benefits in terms of grid resilience in general and to security threats in particular should be considered.
- Engage with utilities and regulators to include their perspective and their evaluation of challenges, solutions and benefits.
- In addition to the above, any action should be considered that can demonstrate a high potential to better inform policymakers and grid managers on the costs and benefits of significant penetration of ocean energy in the European energy mix.

TRL: Advanced research /Industrial research & demonstration → TRL 7-9	
Total budget required: 6M EUR	
Expected impact	**Timeline**
• All remaining issues on pathway to grid-scale integration clearly identified. • Reliable estimates of cost of energy that account for ocean power's lesser requirements for storage, transmission and • demand-response, for the range of deployment scenario that can be reasonably expected.	01/2022 – 12/2025

TECHNICAL ACTIONS: DATA COLLECTION,

ANALYSIS & MODELLING TOOLS

Action 1.13 Marine observation and modelling to optimise design and operation of ocean energy devices

Marine observation, modelling and forecasting to optimise design and operation of ocean energy devices	
Targets: 100MW deployed by 2025 & a reduction of LCOE for wave energy and tidal energy to 15 cEUR/kWh by 2030 and 2025 respectively	**Monitoring mechanism**: Annual progress reports

Scope: Meteorological and marine observation, modelling and forecasting for ocean energy are largely similar to those of existing coastal and offshore activities, but certain promising applications require specific research, innovation and new methodologies.

A few medium size projects and around 5 small projects are required under this topic.

Key actions include:

- Forecast near-field and real-time waves or currents for real-time and predictive control of devices, including wave-to-wave where appropriate. This will increase production, optimise operation and improve prediction of loads for blades, prime movers or PTO.
- Estimate impact on power production of device-induced changes in the wave and current fields. These changes include wake and wave shadows or turbulence, and wave-current interaction.
- Observe, model and forecast intra-site and small-scale variability in waves/currents. This could include mean regime studies for yield prediction or fatigue design, and extreme regime (storms) for safer and optimised design.
- Develop applications of cheaper and easily deployed wave and current instruments and novel developments such as X-band radars that are used to measure waves and currents.
- Improve communication or storage of the data collected.
- In addition to the above possibilities, any action should be considered that can demonstrate high-cost reduction potential by way of improved characterisation of the ocean environment.

TRL: Advanced research /Industrial research & demonstration → TRL 6-9	
Total budget required: 25M EUR	
Expected impact	**Timeline**
• Deliver marine and meteorological data that improve performance, reliability, availability and survivability through better designs and more efficient operations. • Contribute to LCOE reduction according to SET Plan targets (actions should explain how this cost reduction is achieved).	01/2022 – 12/2025

Action 1.14 Open-data repository for ocean energy operation and performance

Open-data repository for ocean energy	
Targets: 100MW deployed by 2025 & a reduction of LCOE for wave energy and tidal energy to 15 cEUR/kWh by 2030 and 2025 respectively	**Monitoring mechanism**: Annual progress reports

Scope: It is difficult and time-consuming to find, access and process the data necessary to design and improve ocean energy devices and operation. This adds costs, slows down design improvements and constitutes an important barrier for new entrants. New technologies allowing better collection, analysis and processing of large datasets are an important opportunity for ocean energy. Activities should be coordinated and should avoid redundancy with existing repositories such as the WTKN (Wave and Tidal Knowledge Network) or WES knowledge library.

A few medium size projects and around 5 small projects are required under this topic.

Key actions include:

- Develop tools to facilitate identification, access and reuse of data produced by ocean energy projects; promote open-source access of such tools and support online access and query service. These may include digital twin platforms and unified SCADA for data handling.
- Apply recent advances in automation and data collection, pre-processing, protocols, storage and communication.
- Coordinate existing data repositories and databases, provide support as appropriate, and create new repositories and databases, where relevant.
- Classify data based on needs of various types of users, e.g. high-level processed data for policymakers and the general public, down to raw-level data for particular R&I needs. This data should be categorised by application and/or by sensor technology or project.
- Take advantage of existing formats commonly used in similar fields when possible, while minimising overhead on data providers. If needed, generate new tailored templates for ocean energy data collection, sharing and use.

TRL: Advanced research /Industrial research & demonstration → High TRL

Total budget required: 10M EUR

Expected impact	**Timeline**
• Accelerate R&I on ocean energy and public access to information of interest. • Contribute to LCOE reduction according to SET Plan targets (actions should explain how this cost reduction is achieved).	01/2022 – 12/2025

TECHNICAL ACTIONS: CROSS-CUTTING CHALLENGES

Action 1.15 Standardisation and certification

Standardisation and certification	
Targets: 100MW deployed by 2025 & a reduction of LCOE for wave energy and tidal energy to 15 cEUR/kWh by 2030 and 2025 respectively	**Monitoring mechanism**: Annual progress reports

Scope: The applicable guidelines, standards and procedures for ocean energy technologies are relatively limited. Guidelines and technical specifications have been mainly developed for power performance assessment of wave and tidal energy. There is a lack of consensus on testing requirements and other evaluation criteria beyond power performance. Experience and results from previous publicly funded projects should contribute to advancing towards more widely accepted standards and associated certification procedures. This in turn will facilitate coherent development and assessment of technologies and avoid unnecessary costs and risks.

Around 5 small projects are required under this topic.

Key actions include:

- Gather best practices from laboratory testing of sub-systems to final system validation in the relevant marine environment.
- Assess guidelines, specifications and standards in real-case, open-sea projects, and apply experience gained in other industries.
- Develop internationally recognised standards that are proportionate to the level of development of new technology areas, practical and widely used, in collaboration with international bodies working on this field such as IEC-TC114, IECRE, DNVGL, BV.
- Involve investors and utilities, insurance providers and regulators in the definition of standards, e.g. in steering committees or equivalent, in order to ensure that the certification process reduces the cost of capital and insurance.

TRL: Non – TRL, 'Coordination & Support Action'

Total budget required: 10M EUR

Expected impact	**Timeline**
• Improve technical specifications, guidance and standards as appropriate to the sector's technological development. • More widespread application of those specifications, guidance and standards. • Reduce costs of insurance and capital for projects.	01/2022 – 12/2025

SECTION 2 – ENVIRONMENTAL, POLICY AND SOCIOECONOMIC ACTIONS

Action 2.1 De-risking of environmental consenting through an integrated programme of measures.

Title: De-risking of environmental consenting through an integrated programme of measures.	
Targets: Accelerating the deployment of ocean energy installations generating the least impact on the environment.	**Monitoring mechanism**: Monitored through the MS and partnering non-EU countries implementation of the Marine Strategy Directive and local planning permitting procedures in MS.

Description: De-risking of environmental consenting is crucial to accelerate the deployment of ocean energy technologies. As with every new technology development, there can be risks associated with the deployment of ocean energy devices. Any actions that have never been undertaken before can cause unforeseen impacts. There is not enough data today to be certain which – if any – of these hypothetical impacts pose a real risk. This can, in some cases, lead to hampering consenting of ocean energy projects. Some of the main challenges are:

- long and burdensome consenting processes,
- requirements for extensive monitoring data, and
- the absence of dedicated legislation for ocean energy.

Good communication and better sharing of information and experience among consenting authorities, developers, researchers and other stakeholders would facilitate the consenting processes. To help consenting authorities make informed decisions, environmental research results should be clearly and effectively disseminated to them

This action should consider the following sub-actions:

- Promoting open data sharing on environment, consenting procedures and policy among MS
- Promoting the development of environmental standards and certification
- Encouraging a circular economy approach in the design of ocean energy technologies
- Promoting simplified consenting procedures (including cross-border deployments)

TRL: 1-9	
Total budget required: 7.2 M EUR	
Expected impact	**Timeline:**
Completing the whole consenting process in one year and introduce a 3-month limit for every consenting decision from the date of submission.	2025

Action 2.2 Promoting Ocean Energy in Marine Spatial Planning

Title: Promoting Ocean Energy in Marine Spatial Planning.	
Targets: Accelerating the deployment of ocean energy installations in agreement with other users of the sea.	**Monitoring mechanism**: Monitored through the MS implementation of the Maritime Spatial Planning Directive and local planning permitting procedures in MS.

Description: Maritime Spatial Planning (MSP) is the tool to manage the use of our seas and oceans coherently and to ensure that human activities take place in an efficient, safe and sustainable way.

Many activities take place in Europe's seas. At any given time, fishing, aquaculture, shipping, renewable energy, nature conservation and other uses compete for maritime space. The main objectives of MSP are:

- reducing conflicts and creating synergies between different activities
- encouraging investment through predictability, transparency and legal certainty
- increasing cross-border cooperation between EU countries to develop renewable energy, allocate shipping lanes, lay pipelines and submarine cables etc
- protecting the environment by assigning protected areas, calculating impacts on ecosystems and identifying opportunities for multiple uses of space

All coastal EU countries have to submit their MSP to the European Commission during 2021 and review them at least every ten years.

Regarding renewable energy, till the date, many plans have been designed considering currently mature technologies given their great potential for renewable generation in the coming years. Less mature technologies have been left behind and this causes concern since those technologies at different maturity level could compete in locations and future implementation could be compromised.

Policy makers responsible for MSP designing should consider ocean energy targets in the EU Strategy on offshore renewable energy and analyse how their MS could contribute to achieve them among others by including them in their MSP.

TRL: 6 - 9

Total budget required: 3 M EUR

Expected impact	**Timeline:**
All coastal EU countries with significant ocean energy resource to identify deployment areas in their MSP	2021 and in every MSP revision

Action 2.3 Promoting political support and public backing for ocean energy

Title: Promoting political support and public backing for ocean energy.	
Targets: Accelerating the deployment of ocean energy installations and value chain development through political and community engagement	**Monitoring mechanism**: Annual progress reports focusing social indicators such as number of jobs created per year, number and turnout of OE companies per year, number of start-ups, OE technology degree of acceptance by citizens
Description: Ocean energy deployments benefit from the identification of socio-economic positive potential for communities, regions and Member States hosting development, and the EU, to maintain political support and public backing. This action proposes to develop assessments of the socio-economic components associated to ocean energy (at pilot and array scales) by reviewing the supply and value chain structure, industry plans, social acceptance, education needs, to establish the best routes to favour developers, communities and the EU, in particular in EU islands with significant endogenous resource.	
TRL: 6-9	
Total budget required: 3 M EURO	
Expected impact Increase social acceptance of ocean energies among professional users of the sea and citizens. Identify uncertainties with regards to environmental monitoring and licensing/consenting process. Identify uncertainties in regulations in different regions/MS. Develop a specific ocean energy framework for EU islands.	**Timeline:** 01/2022 – 12/2025

SECTION 3 – FINANICAL & MARKET UPTAKE ACTIONS

Action 3.1 Dedicated revenue support for the first wave & tidal demonstration farms

Description of each R&I Activity (repeat as many times as the number of R&I Activities)	
Title: Dedicated revenue support for the first wave & tidal demonstration farms	
Targets: 100MW of deployment by 2025 and r*eduction of LCOE for wave energy and tidal energy to 15 cEUR/kWh by 2030 and 2025 respectively*	**Monitoring mechanism**: Annual progress reports

Scope: Providing a mechanism to secure private investment for higher TRL demonstration and pre-commercial projects, and to support the deployment of these wave and tidal devices for their full operational lifetimes.

Description & Actions: Dedicated revenue support allows large-scale deployment of new technologies and the consequential dramatic drop in the cost of energy. Dedicated revenue support has been an undisputed critical policy instrument to bring to market mature renewables such as wind (onshore and offshore) and solar PV.

Revenue support is needed because newer technologies have not had the opportunity to drop their costs, and so they cannot compete in the market against technologies which have already deployed 100s of GWs of capacity.

Dedicated revenue support also provides signals to investors, OEMs and utilities that they should support new technologies – as the dedicated support is a strong indicator that there will be a large market that is worth investing in.

Ideally dedicated revenue support for ocean energy would involve a clear calendar of auctions for the coming decade. However, this is likely to be more feasible once the technology has been further established and national governments see the strong economic benefits associated with the creation of an ocean energy industry.

In the meantime, revenue support must still be available for individual ocean energy demonstration and pre-commercial projects. There are several means to deliver this:

- Via dedicated 'pots' within existing wider Feed-in Tariff mechanisms – e.g. auctions with ringfenced budgets dedicated to wave or tidal projects.
- Actions for 'innovative renewables' that allow emerging renewables (with similar energy costs) to compete against each other – see for example the German Bundesnetzagentur's 'innovation auction' of 250MW in Summer 2021.
- Allocation of revenue support to individual projects without auctions – as allowed for in the updated State Aid Guidelines for energy
- Allowing ocean energy projects to compete against other more established technologies, while ensuring that ocean energy projects can benefit from investment support such as the EU ETS Innovation Fund to be competitive in these auctions.

TRL: Advanced research /Industrial research & demonstration - TRL 1-8	
Total budget required: circa €225/MWh - depending on technology and project	
Expected impact	**Timeline**
Several pre-commercial/demonstration wave & tidal arrays which de-risk the technology, reduce costs substantially and secure investor confidence in the sector	01/2021 – 12/2026

Action 3.2 Creation of an investment fund for ocean energy farms

Description of each R&I Activity (repeat as many times as the number of R&I Activities)	
Title: Creation of an investment support fund for ocean energy farms: EU and National Authorities should create a fund providing flexible capital, and enabling further private capital to be leveraged	
Targets: Facilitating access to investment finance for ocean energy technology development.	**Monitoring mechanism**: Half year reporting to monitoring group presenting progress in setting up the facility

Description: Ocean energy projects are inherently innovative and, in the current state of development, often first-of-a-kind. Uncertainties in installation times, maintenance patterns or average electricity production imply a significant level of technical and, thus, financial risk, preventing project developers from accessing debt from commercial banks and private equity.

For the industry to go forward public support is required to take on some of those risks that operators alone cannot carry nor insure, and stimulate participation of private financiers.

Furthermore, different projects will have different financing needs as developers don't have the same access to own or private investment and national/EU support. A Fund with the flexibility to either provide directly, or help source elsewhere, different types of finance (debt, equity, grant, etc) will be able to cater for the needs of more projects and, thus, be more successful at pushing the industry towards commercialisation. It will also ensure the best possible use for public finance by avoiding pure grant funding where a repayable instrument can be used.

This action will have two stages:

1. Feasibility study on the creation of a Common Investment Support Fund.
2. Creation of a Common Investment Support Fund.

If the feasibility study doesn't have a positive outcome, other ways of support to ocean energy technology developers in finding financial support for their projects should be explored.

TRL: Industrial research & demonstration / Innovation & market uptake. Starting at TRL 7 to TRL9

Total budget required: 200-300M EUR of private/public investment funding (this is to be outside of contributions from EU, MS and partnering non-EU countries which are in actions 1.1 to 1.6 which totals almost 800M EUR)

Expected impact	**Timeline**
Analysis to determine finance requirements for each sector	January 2022
Fund for financing single demonstration/pre-commercial projects. • *Access to private and public resources* • *Blending of grants, equity, debt* • *Due diligence from recognised body*	*Funds to start in 2023*

Action 3.3 Creation of an EU insurance and Warranty fund to underwrite various project risks.

Description of each R&I Activity (repeat as many times as the number of R&I Activities)	
Title: Creation of an EU Insurance and Warranty Fund to underwrite various project risks: This would be targeted at the first ocean energy projects to cover technology risks such as availability, performance, failures, etc. A common reserve fund available to multiple projects in the initial farm or plant roll-out, to spread the risk and reduce the cost of providing guarantees.	
Targets: Facilitating access to finance for ocean energy technology development.	**Monitoring mechanism**: Half year reporting to monitoring group presenting progress in setting up the facility.

Description: Because of their innovative nature, ocean energies bear a higher technological and, thus, financial risk than more mature energy technologies. As with all early stage technologies, it is difficult to predict electricity production accurately enough to guarantee financial returns. Equally, assessing how often operations at sea, which have significant impacts on costs, are required, can only be achieved by installing more ocean energy devices and farms and gathering data from the projects. At current stages of deployment, such data is lacking, resulting in a paradoxical situation where reducing risks will only come from taking risks.

At project level, this risk is currently overwhelmingly borne by the project developers, both limiting their pool of potential equity finance and making it difficult to leverage their funds to access commercial project finance.
Project developers could attempt to cover risks, either by asking the device manufacturer to shoulder some himself, which he might do to a certain extent, or by insuring them on the market. Yet solutions for innovative technologies are only offered as technology matures as insurers equally require an idea of the risks to estimate insurance premiums. Currently no insurance product exists for ocean energy covering risks adequately, at a reasonable price.

The OceanSET project undertook a feasibility study to assess how an Insurance & Warranty Fund should be established. The report provides detailed technical consideration as to how the Fund should be established and operated.

This action will have two stages:

1. Support to operationalise the Fund (creation of Risk Panel, establishing of risk criteria, drafting of default coverage terms, etc) and coordination of eligible projects.
2. Negotiation with public financial institution to secure guarantee to underpin the EU Insurance and Warranty Fund.

TRL: Industrial research & demonstration / Innovation & market uptake. TRL 8 to 9

Total budget required: 50-70M EUR of public or private insurance funds – Outside of the 800M EUR from MS, partnering non-EU countries, Regions and EU in actions 1.1 - 1.6.

Expected impact	**Timeline**
Launch of the fund	2024

Action 3.4 Funding from EU, national, regional & private sector to support demonstration and innovation projects under the Technical, and Environmental, Policy & Socioeconomic Actions

Description of each R&I Activity (repeat as many times as the number of R&I Activities)	
Funding from EU, national, regional & private sector to support demonstration and innovation projects under the Technical, and Environmental, Policy & Socioeconomic Actions	
Targets: 100MW deployed by 2025 & a reduction of LCOE for wave energy and tidal energy to 15 cEUR/kWh by 2030 and 2025 respectively	**Monitoring mechanism**: Annual progress reports

Scope: Actions 1.1 to 1.15 and Actions 3.1 to 3.6 of the Implementation Plan require funding to be implemented.

Description:

This funding must come from a combination of public and private sources. The public funding will be further divided amongst European, national and regional level funders.

The below table is taken from the ETIP Ocean 'Strategic Research & Innovation Agenda' and sets out a proposed division of funding.

	2021	2022	2023	2024	2025	TOTAL	%
EU	45	50	54	58	64	271	27%
Member States	70	75	80	85	90	400	40%
Private	57	62	66	72	78	335	33%
TOTAL	172	187	200	215	232	**1,006**	

Private investment cannot be directly channelled by the SET Plan IWG. However, implementation of the Actions – and in particular the 'Market Uptake' actions will create the necessary incentives for private investors to commit to the sector.

The below table further breaks down the necessary funding by TRL stage.

	R&I (TRL 1-4)	Prototype (TRL 3-6)	Demonstration (TRL 5-7)	Pre-commercial (TRL 6-8)	Industrial Roll-Out (TRL 7-9)	TOTAL
Million €	111	194	220	206	275	**1,006**
%	11%	19%	22%	21%	27%	**100%**

TRL: Non – TRL, 'Coordination & Support Action'	
Total budget required: 1006M EUR	
Expected impact	**Timeline**
• Implementation of the Technical and Environmental, Policy & Socioeconomic Actions	01/2022 – 12/2025

Action 3.5 Support the development of novel mechanisms to close funding gaps (such as a Public Procurement of Innovative Solutions)

Description of each R&I Activity (repeat as many times as the number of R&I Activities)	
Support the development of a Public Procurement of Innovation Solution Support the development of novel mechanisms to close funding gaps (such as a Public Procurement of Innovative Solutions)	
Targets: Deployment of 100MW by 2025 and reduction of LCOE for wave energy and tidal energy to 15 cEUR/kWh by 2030 and 2025 respectively	**Monitoring mechanism**: Annual progress reports

Scope: Identifying and implementing novel funding mechanisms to fill specific funding gap where private investment is not available.

Description: The unique challenges of crossing the 'commercial valley of death' has meant that there are specific innovation activities where necessary private investment is not available.

This is a problem for two specific innovation activities:

- Developing and demonstrating utility-scale wave energy convertors
- Deploying small demonstration wave and tidal farms, which must operate for their full technical lifetime (typically circa 15 years)

The high risks and costs, and the long period before potential payback mean that private investment has not been available for these activities. Existing funding instruments require a % of co-funding from private investors, and so they are not suitable for these activities.

Novel funding instruments are needed, which can close the 'funding gap' for these activities.

Of particular interest is the 'Public Procurement of Innovation' (PPI) approach. This allows 100% funding of innovative actions. It is combined with a phase gate approach to ensure a competitive dynamic and a focus on pre-defined performance metrics.

The sector has already adapted a similar 'Pre-Commercial Procurement' approach for low TRL-level wave devices, in the EuropeWave project.

A PPI action focused the development and demonstration of a higher-level utility scale wave energy convertor would be the logical follow-on action from the EuropeWave project.

TRL: Advanced research /Industrial research & demonstration → TRL 6-8

Total budget required: 40M EUR

Expected impact	**Timeline**
High-TRL wave device technology at a utility scale and meeting a range of performance and survivability criteria, which is ready for demonstration at array scale.	01/2024 – 12/2025