OceanSET

Support to the realisation of the Ocean Energy Implementation Plan for the SET-Plan

Deliverable D3.2

Financial Requirements for the SET Plan

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EXECUTIVE SUMMARY

The OceanSET project was developed to support the delivery of the Ocean Energy Implementation Plan (IP) of the European Strategic Energy Technology Plan (SET Plan). Achieving the technology development actions identified in the IP will require significant financial support.

OceanSET's WP3 is assessing the financial requirements for each of the eleven technology development actions, identifying where gaps exist in the funding requirements, and the resources and financing approaches that can bridge the gaps. This report is the first step in that process, establishing a clear understanding of the scale and nature of each technology development action, and the financial requirements of each action.

The recent publication of the Strategic Research and Innovation Agenda has refreshed the understanding of the priorities for ocean energy sector and has updated financial requirements estimates, particularly for the IP's Technical Actions. Both the SRIA's assessment and analyses undertaken within this OceanSET task indicate that the initial IP budget estimates underestimate the financial requirements for the Actions 1.1 to 1.4.

The IP's estimated budgets for the Financial and Environmental Actions are found to adequate, generally. A limited assessment of the Financial Actions 2.1 and 2.2 is presented here as both are the subject of ongoing feasibility studies to be reported in later deliverables.

Clarity is provided on the objectives of some Actions although it is noted that further clarity is required in others.

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ABBREVIATIONS AND ACRONYMS

DGEG	Direção Geral de Energia e Geologia (Directorate General for Energy and Geology, Portugal)
EC	European Commission
EU	European Union
EVE	Ente Vasco de la Energía (Basque Energy Board)
FEM	France Energies Marines
IP	Ocean Energy Implementation Plan
IWG	Implementation Working Group
MS	Member States
OEE	Ocean Energy Europe
PLOCAN	Oceanic Platform of the Canary Islands
R&D	Research and development
R&D&I	Research and development and innovation
SEAI	Sustainable Energy Authority of Ireland
SET Plan	Strategic Energy Technology Plan
WES	Wave Energy Scotland

1. INTRODUCTION

1.1 Background to OceanSET

The European Strategic Energy Technology Plan (SET Plan) Ocean Energy Implementation Plan (IP)[1], prepared by a temporary working group comprising representatives from the European Commission (EC), Member States (MS) and other stakeholders, was adopted by the SET Plan Steering Committee 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). The OceanSET project will assist the IWG to continue their work to deliver on the targets set in the IP.

Support for the Ocean Energy (OE) sector to date has focused on the development of research and roadmaps which have set out the aspirations of wave and tidal sector. The principle of the IP is to transform those aspirations into operational technology development actions. Eleven actions have been identified, both cross-cutting (i.e. relating to all OE technology), and, technology specific (i.e. relating to either wave or tidal), in three groupings:

- Technical Actions – six actions to ensure support at all technology readiness levels (TRLs) to ensure development of tidal arrays and to drive convergence in wave technologies;
- Finance Actions – three actions to ensure investment and insurance support funds are available to support the development of the sector;
- Environment Actions – two actions to share knowledge on safety and environmental matters.

The actions presented in the IP are primarily based upon the Ocean Energy Strategic Roadmap [2], which has been agreed by the EC, MS, Regions, stakeholders and the wider ocean energy sector. The ambition of the IP is to pursue a structured approach that will enable wave and tidal technologies to follow a credible development path, with an ultimate destination of a commercially viable product and industry. The target timescale presented in the IP is 2030 for tidal technologies and 2035 for wave technologies.

OceanSET will focus on assessing the progress of the ocean energy sector and will monitor National and European Union (EU) funded projects in delivering successful supporting actions. Relevant data will be collected annually and will be used to inform MS and the EC on the progress of the sector. It will also be used to review what works and what doesn't and to assess how to maximise the benefit of the funding streams provided across the Regions, MS and the EC.

The OceanSET partners include representatives from Ireland (SEAI), UK (WES, University of Edinburgh), France (FEM), Portugal (DGEG), Spain (EVE, PLOCAN), Italy (ENEA) and the industry representative body Ocean Energy Europe (OEE). The Sustainable Energy Authority of Ireland (SEAI) is the lead partner for the project.

[1] SET Plan Ocean Energy Implementation Plan, Initiative for Global Leadership in Ocean Energy. https://setis.ec.europa.eu/actions-towards-implementing-integrated-set-plan/implementation-plans.

[2] Ocean Energy Strategic Roadmap, Building Ocean Energy for Europe. Ocean Energy Forum (2016). https://webgate.ec.europa.eu/maritimeforum/en/node/3962

1.2 Background to Work Package WP3

The eleven technology development actions identified in the IP are presented with a high-level description of the target, scope, anticipated activities, and expected outcomes of each action, together with a timeline and an outline budget estimate. It is recognised that delivering the technology development actions will require significant financial support.

The aim of OceanSET's WP3 is to provide greater clarity on the activities required to achieve the expected outcomes and to improve the budget estimates for each of the eleven technology development actions (Task 3.1), identifying where gaps exist between the available funding mechanisms and the funding requirements (Task 3.2), and the resources and financing approaches that can bridge the gaps (Task 3.3 & 3.4).

1.3 Scope of report

Task 3.1 set out to establish a clear understanding of the scale and nature of each technology development action in the IP, and the financial requirements of each action.

Section 2 considers each action (or grouping of actions where this is warranted) in turn, presenting an interpretation of the activities anticipated in the IP and reviewing previous budget estimates for the actions against a current estimate.

2. FINANCIAL REQUIREMENTS

The IP identified eleven technology development actions and provided an outline budget estimate for each action, together with an indicative breakdown of the contribution from industry, Members States and Regions, and the EU over the period 2018 to 2030 (Table 1). The IP recognised that the outline budget estimate would need to be validated and agreed over the life of the IP.

TABLE 1: SUMMARY OF THE IP TECHNOLOGY DEVELOPMENT ACTIONS

ACTION		ACTION TITLE	EXPECTED INVESTMENT (€M)	PROPOSED INVESTMENT SPLIT (€M)		
				INDUSTRY	MS & REGIONS	EU
Technical	1.1	Tidal energy – technology device development and knowledge building (up to TRL6).	€145.0	€40.0	€52.5	€52.5
	1.2	Tidal energy – system demonstrations (device and array) and knowledge building in operational environment (TRL 7-9).	€395.0	€152.0	€121.5	€121.5
	1.3	Wave energy – technology device development, including system demonstration and knowledge building (up to TRL6).	€222.5	€65.0	€77.5	€80.0
	1.4	Wave energy – system demonstration (device and array) at large scale (device) and early demonstration array scale, leading onto large scale deployment (TRL 7-9).	€335.0	€122.5	€105.5	€107.0
	1.5	Installation, logistics and testing infrastructure as well as supply chain development for the wave and tidal sectors.	€100.0	€30.0	€35.0	€35.0
	1.6	Development of stage gate metrics (technical standards and guidelines) for wave technology evaluation.	€6.5	€-	€2.6	€3.9
Finance	2.1	Creation of an investment support fund for ocean energy farms.	€-	€-	€-	€-
	2.2	Creation of an EU Insurance and Guarantee Fund to underwrite various project risks.	€-	€-	€-	€-
	2.3	Wave Energy Europe Pre Commercial Procurement (PCP) action for development of wave energy technology.	€24.0	€-	€18.0	€6.0
Environment	3.1	Development of certification and standards to support offshore renewable technology development	€8.0	€-	€5.0	€3.0
	3.2	De-risking environmental consenting through an integrated programme of measures	€6.5	€-	€3.9	€2.6
		Total Budget	€1,242.5	€409.5	€421.5	€411.5

An indicative timeline was presented, broken down into phases: three phases of *Discovery*, collaborative *Development*, and commercialisation-scale *Deployment*, leading to a fourth and final phase of *Delivery* at scale via a commercial market with a functioning supply chain (Figure 1).

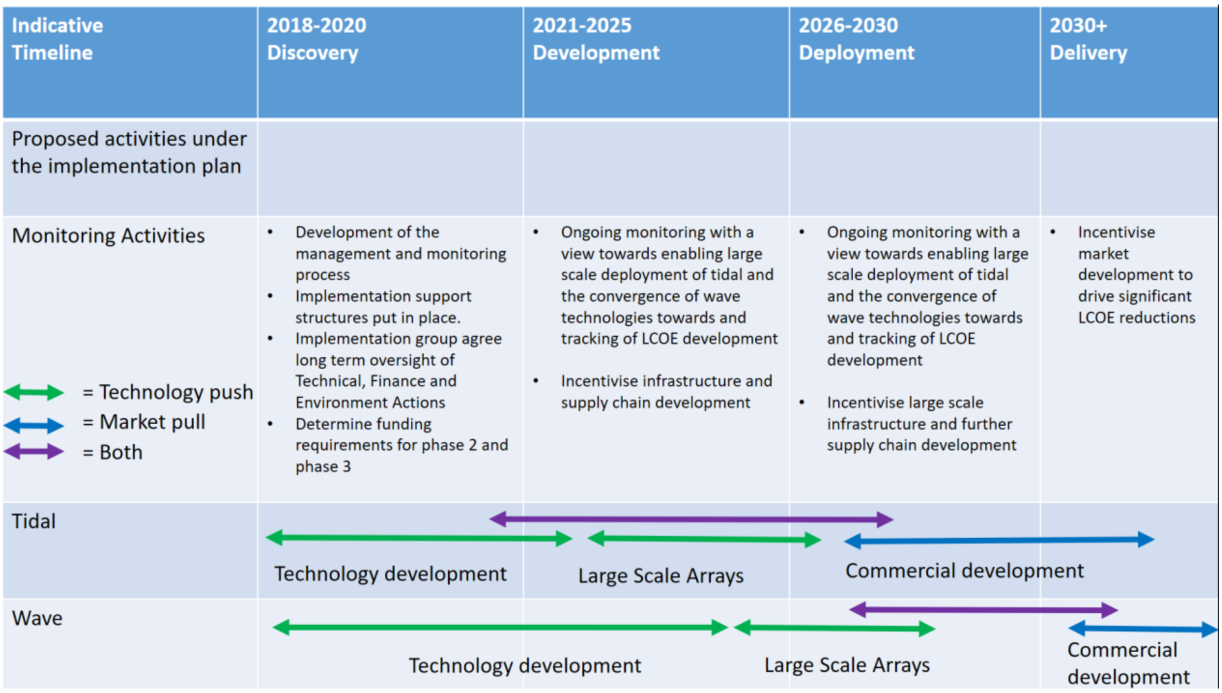

Figure 1: Indicative timeline and phases of development for the tidal and wave sectors.

This acknowledged that technology development in the wave sector (and therefore progression to large-scale arrays and commercial development) would lag the tidal sector by approximately 5 years.

The IP recognised that the outline budget estimate (Table 1) would need to be validated, and, that the indicative timeline for the phases (Figure 1) would have to be reviewed as part of a monitoring process. OceanSET is supporting the IWG during the *Discovery* phase to develop the monitoring processes and to review and validate the IP's outline budget estimate and indicative timeline.

In May 2020, ETIP Ocean published a new Strategic Research & Innovation Agenda [3] (SRIA) identifying the research and innovation priorities for ocean energy sector over the next 4 to 5 years together with estimates of the scale of activity required in each priority topic during a period that corresponds to the Development phase of the IP (2021-2025).

For wave and tidal technology, the SRIA identifies seventeen "Priority Topics" in six "Challenge Areas" (Table 2). The target TRL is indicated for each priority topic using the categorisation: low (TRL 1 to 3); medium (TRL 4 to 6); or, high (TRL 7 to 9). A priority topic's target TRL is expressed typically as a range (e.g. low to medium; medium to high).

[3] https://www.etipocean.eu/resources/strategic-research-and-innovation-agenda-for-ocean-energy/

The SRIA presents the scale of activity anticipated as being necessary to progress each priority topic in terms of the quantity of small, medium and large projects [4]. A total budget for delivering all priority topics is developed assuming budgets of: 50M€ for an array project; 10M€ for a large project; 5M€ for a medium project; and, 2M€ for a small project.

TABLE 2: STRATEGIC RESEARCHAND INNOVATION AGENDA CHALLENGE AREAS AND PRIORITY TOPICS.

Challenge Area	Priority Topic	Wave	Tidal	TRL	Number and size of actions	Budget (M€)
Design and Validation of Ocean Energy Devices	Demonstration of ocean energy devices to increase experience in real sea conditions	✓	✓	Medium to High	~10 large, 10 medium	150
	Demonstration of ocean energy technology at array scale	✓	✓	High	7 array scale projects	350
	Improvement and demonstration of PTO and control systems	✓	✗	Medium to High	~10 medium, 5 small	60
	Application of innovative materials from other sectors	✓	✓	Medium to High	A few medium, ~5 small	25
	Development of novel wave energy devices	✓	✗	Low to Medium	~10 small, 5 medium	45
	Improvement of tidal blades and rotor	✗	✓	Medium to High	~5 medium, a few large	55
	Development of other ocean energy technologies	✗	✗	Low to Medium	A few medium	15
Foundations, Connections and Mooring	Advanced mooring and connection systems for floating ocean energy devices	✓	✓	Medium	~10 medium	50
	Improvement and demonstration of foundations and connection systems for bottom-fixed ocean energy devices	✓	✓	Medium to High	~5 medium, ~5 small	35
Logistics and Marine Operations	Optimisation of maritime logistics and operations	✓	✓	Medium to High	~5 medium, a few large	55
	Instrumentation for condition monitoring and predictive maintenance	✓	✓	Medium to High	A few medium ~5 small	25
Integration in the Energy System	Developing and demonstrating near-commercial application of ocean energy in niche markets	✓	✓	High	Several medium a few large	80
	Quantifying and demonstrating grid-scale benefits of ocean energy	✓	✓	High	A few small	6
Data Collection & Analysis and Modelling Tools	Marine observation modelling and forecasting to optimise design and operation of ocean energy devices	✓	✓	Medium to High	A few medium ~5 small	25
	Open-data repository for ocean energy	✓	✓	High	~5 small	10
Cross-cutting Challenges	Improvement of the environmental and socioeconomic impacts of ocean energy	✓	✓	Medium to High	~5 small	10
	Standardisation and certification	✓	✓	High	~5 small	10
					Total	1,006

[4] Projects are distinguished by their cost: large projects over 8M€; medium projects between 2M€ and 8M€; small projects less than 2M€.

2.1 IP Actions 1.1 [tidal] & 1.3 [wave]

The focus of technical actions 1.1 and 1.3 is technology development up to TRL 6 [technology demonstrated in relevant environment] in the tidal and wave sector respectively. As a similar range of activities is expected in both actions, the financial requirements are considered together.

2.1.1 Interpretation of Actions 1.1 & 1.3

The implementation plan identifies the need addressed by these actions to be the development of reliable, robust and efficient technology that ensures long-term cost reduction. Intra- and inter-sectoral knowledge transfer (including cross-border state/ academia/ industry collaboration) is to be encouraged.

Two general themes are anticipated:

- Novel system and sub-system concepts (TRL 1-3): Identify and develop promising low TRL system/ sub-system technologies & components.
- Intermediate technologies (TRL 4-6): Development of technology maturity.

The expectation is that Member States will deliver an annual pipeline of projects developing innovative technologies to improve the reliability and effectiveness of current tidal turbine technologies. Suggested topics were:

- Tidal
  - Investigation of alternative materials to improve cost, performance, survivability.
  - Innovative material & manufacturing processes for main structure & critical components (blades, moorings/foundations, electrical etc.).
  - Development of novel or improved power take-offs (PTOs).
- Wave
  - Identify novel/innovative PTO designs.
  - Improve current PTO designs.
  - Develop innovative wave energy converters (WECs).

2.1.2 Financial Requirement Assessment for Actions 1.1 & 1.3

An attempt is made here to identify which of the SRIA’s priority topics, and the anticipated project activity, is pertinent to IP Action 1.1 and 1.3 (i.e. those targeting technical activities in the low to medium TRL categories):

- Priority topics targeting the high TRL category exclusively are excluded. These topics are associated more closely to IP Actions 1.2 and 1.4.
- Certain priority topics are better associated with other IP actions
  - 'Improvement of the environmental and socioeconomic impacts' in the cross-cutting challenge area is associated with IP Action 3.2.
  - 'Optimisation of maritime logistics and operations' in the Logistic and marine operations challenge area is associated with IP Action 1.5.

On this basis, nine of the seventeen priority topics are considered be relevant to IP Action 1.1 and 1.3 (Table 3). Where the TRL range of these topics is expressed as 'low, 'medium', or, 'low to medium', the project activity, and associated budget estimate, is relevant in its entirety. Where the TRL range is expressed as 'medium to high', only activity associated with the smaller scale of project is assumed to be relevant to the medium TRL category (i.e. the category pertinent to IP Action 1.1 and 1.3).

By this analysis, an estimated budget of 220M€ is necessary to progress the priority topics associated with IP Action 1.1 and 1.3 during the Development phase of the IP (2021-2025).

While the SRIA indicates which technology a priority topic is applicable to (wave, tidal, or both) it doesn't attempt to present separate budgets for wave and for tidal technology. However, by assuming an equitable split of activity where a priority topic is indicated as being relevant to both technologies yields an estimated budget of 95M€ for tidal technology (IP Action 1.1) and 125M€ for wave technology (IP Action 1.3).

These SRIA budget estimates are larger than the budget estimates for the same period presented in Annex 8 of the IP, 85M€ for IP Action 1.1 (tidal) and 87.5M€ for IP Action 1.3 (wave), a total of 172.5M€.

TABLE 3: CHALLENGE AREAS AND PRIORITY TOPICS OF THE SRIA RELEVANT TO ACTION 1.1. AND 1.3.

Challenge Area	Priority Topic	Wave	Tidal	TRL	Number and size of actions	Relevant actions	Budget [M€]
Design and Validation of Ocean Energy Devices	Demonstration of ocean energy devices to increase experience in real sea conditions	✓	✓	Medium to High	~10 large, 10 medium	10 medium	50
	Improvement and demonstration of PTO and control systems	✓	×	Medium to High	~10 medium, 5 small	5 small	10
	Application of innovative materials from other sectors	✓	✓	Medium to High	A few medium, ~5 small	5 small	10
	Development of novel wave energy devices	✓	×	Low to Medium	~10 small, 5 medium	~10 small, 5 medium	45
	Improvement of tidal blades and rotor	×	✓	Medium to High	~5 medium, a few large	5 medium	25
Foundations, Connections and Mooring	Advanced mooring and connection systems for floating ocean energy devices	✓	✓	Medium	~10 medium	10 medium	50
	Improvement and demonstration of foundations and connection systems for bottom-fixed ocean energy devices	✓	✓	Medium to High	~5 medium, ~5 small	5 small	10
	Instrumentation for condition monitoring and predictive maintenance	✓	✓	Medium to High	A few medium ~5 small	5 small	10
Data Collection & Analysis and Modelling Tools	Marine observation modelling and forecasting to optimise design and operation of ocean energy devices	✓	✓	Medium to High	A few medium ~5 small	5 small	10
						Total	220

2.2 IP Actions 1.2 [tidal] & 1.4 [wave]

The focus of technical actions 1.2 [tidal] and 1.4 [wave] is technology demonstration in operational environments and the encouragement of intra- and inter-sectoral knowledge transfer (including cross-border state/ academia/ industry collaboration). As a similar range of activities is expected in both actions, the financial requirements are considered together.

2.2.1 Interpretation of Actions 1.2 & 1.4

The need addressed by this action is support for deployment of single device and early array projects to demonstrate readiness for commercialisation.

Action 1.2 [tidal] builds on flagship demonstration projects [5] and is intended to support early array demonstrations and the development and testing of next-generation technologies at full-scale. The outline budget estimate of 395.0M€ (Table 1) appears to be developed on an expectation of

- Three single next-generation device full-scale demonstrations;
- Four array demonstrations each rated at 10MW.

Action 1.4 [wave] seeks to support early demonstration arrays to address challenges such as interconnection, mooring, and resource-device interactions, to increase reliability and performance and reduce cost and risk. The action also seeks to support the development of novel materials and manufacturing processes for main structure, moorings/foundations, and electrical sub-systems. The outline budget estimate of 335.0M€ (Table 1) appears to be developed on an expectation of

- Four array demonstrations.

The IP does not indicate an anticipated rated capacity of the wave array demonstrations; however, it is reasonable to assume it will be less than that of the tidal arrays, given the ratings of current wave technology. Early wave array demonstrations can be expected to have a rated capacity of no more than 5MW. Furthermore, Action 1.4 does not appear to support, explicitly, single device deployments; a necessary step on the path to array demonstrations. If four array deployments are to be achieved, at least four successful single full-scale device deployments must be anticipated. While it may be argued that some have occurred previously, it is proposed that an objective of three single full-scale device deployments is included explicitly in the action description.

[5] Examples include, Simec Atlantis' MeyGen Phase 1A and 1B (also known as Project Stroma), Orbital Marine Power's FloTec, Nova Innovation's Shetland Array, Sabella's deployment at Ouessant and HydroQuest's deployment Paimpol-Bréhat.

2.2.2 Financial Requirement Assessment for Actions 1.2 & 1.4

Two SRIA priority topics are considered relevant to IP Actions 1.2 and 1.4 (Table 4). A similar approach to that used in section 2.1 is used to identify project activity which is pertinent to IP Action 1.2 and 1.4, namely that which is targeting the high TRL category.

TABLE 4: CHALLENGE AREAS AND PRIORITY TOPICS OF THE SRIA RELEVANT TO ACTION 1.2. AND 1.4.

Challenge Area	Priority Topic	Wave	Tidal	TRL	Number and size of actions	Relevant actions	Budget [M€]
Design and Validation of Ocean Energy Devices	Demonstration of ocean energy devices to increase experience in real sea conditions	✓	✓	Medium to High	~10 large, 10 medium	10 large	100
	Demonstration of ocean energy technology at array scale	✓	✓	High	7 array scale projects	7 array-scale projects	350
						Total	450

By this analysis, the SRIA estimates a budget of 450M€ is necessary to progress the demonstration of ocean energy technology during the Development phase of the IP (2021-2025). Separate estimates for tidal and wave technology are not offered. Neither is the rated capacity of the array projects indicated, in contrast to the IP which indicates a capacity of 10MW for a tidal array.

The SRIA budget estimate is larger than that presented in Annex 8 of the IP for the same period, namely 150M€ for IP Action 1.2 (tidal) and 125M€ for IP Action 1.4 (wave), a total of 275M€. However, it is not wholly inconsistent with the total IP budget if it is either assumed the IP actions are concentrated in the Development phase, or, the SRIA actions extend outwith the Development phase.

The high-level descriptions of the actions in both the IP and the SRIA represent a significant challenge to determining the financial requirements as the scope of the projects is not well defined. For example,

- Are the deployments at a pre-existing test site or at a new previously undeveloped site?
- What duration of deployment is considered?
- Are design and manufacturing costs considered as part of the demonstration project?

A ‘*bottom up*’ structured analysis was attempted initially. Key cost drivers were defined for four categories of demonstration projects – single device (wave); single device (tidal); array (wave); and array (tidal) – and evidence sought to support the assignment of values to each cost driver. However, it became apparent that this approach would not deliver a result of sufficient quality. Assigned values were often subjective, as a result of a lack of supporting evidence, or based on a very narrow evidence base. Furthermore, some cost drivers were clearly dependent on the innovation objectives and needs of individual projects which makes generalisation problematic. It was considered inappropriate for the OceanSET project to prejudge these aspects.

As an alternative, a ‘*top down*’ approach was adopted that examined the costs associated with historic and current demonstration projects to allow the development of a budget estimate for IP Actions 1.2 and 1.4 without pre-determining the specific nature or scope of individual demonstration projects.

Publicly available data was obtained from several sources [6]:

- European-funded ocean energy demonstration projects – primarily via the CORDIS website;
- Direct funding actions undertaken by OceanSET partners, notably EVE and WES.

The data collected quantifies the overall cost of the project (not just the funding that was provided to the project). An assessment of the project scopes revealed a range of funded activities which limited the ability to draw a definitive conclusion the full cost of the demonstration. For example, some tidal array project data related to capital expenditure only and did not cover other lifetime costs of the project or cost of capital. Similarly, many wave energy demonstration projects were concerned with power take-off development only.

2.2.2.1 Tidal

Reported costs of four single tidal device deployment projects were in the range 8.6 to 20.0M€/MW with a median value of 10.8M€/MW [7]. The analysis identified seven tidal array projects with reported costs in the range 4.2 to 18.0M€/MW and a median value of 8.3M€/MW which matches the low end of the range for single tidal device deployment projects.

Applying these cost estimates to the stated aim of IP Action 1.2, namely three single device demonstrations (each assumed to have a rated capacity of 1MW) and four 10MW array demonstrations, suggests a budget cost estimate of between 195M€ and 780M€ with a median of some 365M€ would be required. The median estimate is not inconsistent with the IP budget estimate for Action 1.2 over all three phases of the IP.

2.2.2.2 Wave

Reported costs of six single wave device deployment projects (excluding PTO only projects) were in the range 8.5 to 19.2M€/MW with a median value of 13.9M€/MW [8]. The analysis identified just one wave array project with reported costs of 8.2M€/MW [9] which again matches the low end of the range for single wave device deployment projects and is very similar to the reported costs for a tidal array project.

With these cost estimates, the aim of IP Action 1.4 as interpreted in section 2.2.1, namely three single full-scale device demonstrations (each assumed to have a rated capacity of 0.5MW) and four 5MW array demonstrations, will require a budget estimated at between 175M€ and 200M€.

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[6] The OceanSET partners decided that it would not be appropriate to launch an additional survey for this subtask to avoid confusion, 'survey fatigue' and undermine the collection of data via the main OceanSET annual survey.

[7] A fifth project reported a cost of 76.2M€/MW but this rejected as an outlier in this analysis.

[8] A seventh project reported a cost of 53.3M€/MW but this rejected as an outlier in this analysis.

[9] The Clean Energy from Ocean Waves (CEFOW) project. https://cordis.europa.eu/project/id/655594

2.3 IP Action 1.5

2.3.1 Interpretation of Action 1.5

Action 1.5 is intended to address the need for suitable on- and off-shore testing facilities, appropriate infrastructure in the regions where OE is likely to be exploited, and dedicated installation and O&M supply chains for OE.

- Infrastructure
  - Support for building a strong accessible network of European on- and off-shore test facilities able to satisfy developers' needs at all development stages (all TRLs).
  - Policy measures (both technical & non-technical) to improve electrical grid and port infrastructure to facilitate OE projects.
- Installation and logistics
  - Support for developing best practice procedures for installation and O&M, making use of inter-sector knowledge and experience (e.g. offshore wind).
  - Dedicated supply chain development.
  - Design tools for generic array and inter-array issues.

2.3.2 Review of Current Status

A review of work already commissioned which explores infrastructure development within Europe in support of the Ocean Energy sector. Information has been identified on the following.

2.3.2.1 Testing infrastructure

Significant work has been conducted at a Member State level over the last decade or more to provide testing infrastructure necessary to support the sector. The H2020 funded MARINERG-i project [10] has identified over 38 different test facilities and infrastructures throughout the Europe which cater for the ocean energy sector, ranging from dry lab and test rigs to test tanks to open ocean facilities.

The intention of the MARINERG-i project is to bring relevant European test infrastructure together as an integrated European Research Infrastructure for the offshore renewable energy (ORE) sector. The benefit of testing infrastructure working collectively, both to industry and the individual research facilities, has been demonstrated in other projects: FP7 Marinet; H2020 Marinet II; Interreg NWE ForeSEA and Interreg NWE OceanDEMO. An application to the European Strategy Forum on Research Infrastructures (ESFRI) [11] will allow these facilities to continue to work together to provide better research support for the ocean sector.

The proposed MARINERG-i distributed research infrastructure proposes to deliver a set of core services, which can be summarized as:

[10] http://www.marinerg-i.eu/

[11] European Strategy Forum on Research Infrastructures. https://ec.europa.eu/info/research-and-innovation/strategy/european-research-infrastructures/esfri_en

1. Access to ORE research and testing facilities
2. Establishing of best practises and common standards for testing
3. Data, knowledge and tools archiving and access
4. Data sharing, knowledge transfer and collaboration
5. Operational and strategic planning of infrastructures, research and technology development
6. Access to internationally leading ORE researchers
7. Support ORE innovation
8. Upskilling and training of staff and researchers

Overall, the picture that emerges is that the immediate need of sector is satisfied by the present infrastructure and that the focus for the next 3 to 5 years should be on standardising and improving testing procedures and methodologies.

However, a need for improvement in dry testing facilities is noted and a gap analysis is planned to ascertain if there is a requirement for further test facilities to support the sector.

The development and operation of open-water testing facilities has been slower than anticipated. Sites which service a range of technologies (e.g. both wave and tidal) and offer a range of environmental conditions for mid TRL testing remain reasonably well utilised. However, several sites which were initially envisaged for TRL 7+ wave technologies are shutting down (e.g. Wavehub in Cornwall), have stopped licensing applications (e.g. Westwave in Ireland) or are looking to diversify the range of technologies supported (e.g. AMETS in Ireland is now focussing on floating wind).

2.3.2.2 Port development

The Ocean Energy sector's requirement for port infrastructure is similar to that of the offshore wind sector. Several studies into the requirements of the offshore wind sector in Europe have been commissioned.

A WindEurope Ports Platform [12] study to assess the importance of the role of ports in realising LCOE reduction for offshore wind found that without proactive investment of ports and vessel owners, and the involvement of ports and vessel operators in developing and realising the future vision, a significant LCOE reduction opportunity could be missed. In a scenario that envisaged the installation of 7GW annual until 2030, investment in ports was estimated to be responsible for 5.3% of the total LCOE reduction (equivalent to a project CAPEX reduction of €185,000/MW for a new wind farm). Investments of €0.5 to 1 billion to upgrade and adapt facilities and machinery, and develop new infrastructure, represents between 10 and 20% of the equivalent CAPEX saving.

The European Maritime and Fisheries Fund (EMFF) Nessie project identified examples of hard infrastructure hotspots in the North Sea basin supporting the development of wave, tidal and offshore wind energy supply chain [13]. A main recommendation was that "clear ambitions and stable, predictable

[12] https://windeurope.org/policy/topics/offshore-wind-ports/

[13] Non-technical Challenges in developing Offshore Renewable Energy Projects, June 2018. http://www.nessieproject.com/

policy making are essential for all ports to maintain their vital role in the development of cost driven and price effective offshore wind energy."

It seems that the development of ports will remain in the more commercially active and resource benign locations. Regardless this should not pose a significant challenge for the ORE industry in the coming years as projects will generally be small scale and can be planned out of traditional heavier industry ports and transported to the resource intensive locations. The need will be to consider investment for more cost-efficient transport shipping methods and development of O&M ports in more remote locations.

2.3.2.3 Grid development

To date, grid development in response to the deployment of ORE (primarily wind) has been driven on a national basis. Each country has its own regulatory regime, renewable energy development plans, support mechanism, timing and process for tendering and auctioning power capacity, maritime spatial planning, grid development plans, and technical and environmental standards and assessment methods.

The current European grid infrastructure (both onshore and offshore) is considered by the wind sector to be a significant limiting factor for its expansion. Work is therefore needed at a European level.

The master plan for European grid development is the European Network of Transmission System Operators' (ENTSO-E) biennial Ten-Year Network Development Plan (TYNDP) [14]. It aims to coordinate electricity system planning across 43 transmission system operators (TSOs). The most recent TYNDP, published in 2018, foresees up to €114bn (€10.4bn/year) of investments for grid infrastructure to 2030. Out of this, €27bn is for 21 individual projects that would develop into a "Northern Seas Grid Infrastructure". ENTSO-E believes that offshore grids will be developed using a range of all available AC and DC technologies and will comprise a combination of all currently proposed designs: radial connections, hubs, hybrid projects and meshed grids. The realisation of a European offshore grid will require investment from both private and public sources. The task is so big that it cannot be left to National Governments alone and cannot be done with a piecemeal approach.

The ocean energy sector will largely leverage off these upgrades. However, the benefits of bringing ocean energy on to the system early should be recognised given that it could be used to balance the generation system. Tidal stream's energy production is entirely predictable as it is driven by the movements of the moon. In addition, wave energy produces electricity for hours after the wind drops, making it the perfect partner for offshore wind.

Transmission and distribution system operators do not currently take account of the potential for wave and tidal deployments in their plans. As a result, future installations might be constrained by grid availability. To ensure the swift deployment of the ocean energy sector, such plans should reflect the Commission's projections for ocean energy realistically.

[14] https://tyndp.entsoe.eu/

2.3.2.4 Supply Chain development

Europe is home to the most advanced companies in both tidal and wave energy. European technology developers currently hold 66% of global tidal energy patents, and 44% for wave energy. Most projects currently planned or built around the globe use European devices. Tidal and wave energy devices are being deployed from Norway to Portugal, as well as in the Mediterranean.

Coastal regions will be host to assembly, installation and maintenance activities. Yet ocean energy offers significant economic opportunities beyond deployment sites. Northern and Central European countries are already manufacturing components and will do so increasingly as supply chains specialise, as seen for offshore wind. Some have developed leading full-scale devices and are already exporting their technologies.

Several current EU projects are focusing on the development of the supply chain and cross-sectoral networking for the OE sector. For instance, the Ocean Power Innovation Network [15] (OPIN) is a 3-year initiative delivering support to encourage both cross-sectoral and cross-regional collaboration for the ocean energy sector. The network currently has 377 members from 27 countries and continues to grow. A study commissioned by OPIN [16] identified key areas for the development of the ocean energy supply chain in Interreg Northwest Europe region. Challenges common to three offshore technologies (tidal stream, wave and floating wind) were identified: cabling, mooring systems, manufacturing and installation logistics, and operational strategies.

These challenge areas have also been identified as requiring research prioritisation in the recently published ETIP Strategic Research Agenda (SRIA) and investment requirements for these areas have been noted.

2.3.3 Financial Requirement Assessment for Action 1.5

The implementation plan provides an indicative investment requirement for this action of €100M with a profiled investment over the three phases of the implementation plan of €10M in the Discovery phase (2018-2020), €40M in the Development phase (2021-2025) and €50M in the Deployment phase (2026-2030). The indicative contributions from industry, Member States and the EU to the total investment are noted as €30M, €35M, and €35M respectively. The implementation plan does not provide any detail of how the contribution split might vary over the three phases or whether the activities anticipated in the action, as developed in the preceding section, would see varying contribution splits.

While this budget might seem low given that the output of this action is considerable capital investment in infrastructure, it is important to note that the bulk of investment in areas such as port and grid development will be delivered for other more immediate needs and will be financed by parallel activities.

[15] https://www.nweurope.eu/projects/project-search/opin-ocean-power-innovation-network

[16] https://www.nweurope.eu/media/8935/bvga-21187-summary-report-for-value-chain-study-r2-final.pdf

The SRIA identifies a single priority topic that relates to IP Action 1.5 (Table 5) although the focus is limited to just one aspect of IP Action 1.5, concentrating on the potential for cost reduction in maritime logistics and operations supply chain. The SRIA budget for this priority topic is larger than that presented in the IP for the Development phase.

TABLE 5: CHALLENGE AREAS AND PRIORITY TOPICS OF THE SRIA RELEVANT TO ACTION 1.5.

Challenge Area	Priority Topic	Wave	Tidal	TRL	Number and size of actions	Relevant actions	Budget [M€]
Logistics and Marine Operations	Optimisation of maritime logistics and operations	✓	✓	Medium to High	~5 medium, a few large	~5 medium, a few large	55
						Total	55

2.3.3.1 Testing infrastructure

The assessment of the MARINERG-i project is that existing testing infrastructure is generally sufficient and appropriate for the ocean energy sector's immediate requirement, although improvements in dry testing facilities are noted as desirable. The ability of the present offshore test sites to satisfy the future requirements of the sector should be subjected to a thorough gap analysis. Sites such as EMEC; AMETS and BiMEP may be able to provide testing opportunities in the short term for wave technology, i.e. during the Development phase of the IP (2021-2025). However, whether these sites can accommodate the longer-term, grid connected, pre-commercial array deployments envisaged during the Deployment phase (2026-2030) is not certain and needs consideration. Cost estimates for establishing a new site is estimated to be between 20M€ and 30M€, based on the costs associated with establishing the BiMEP and AMETS site.

2.4 IP Action 1.6

2.4.1 Interpretation of Action 1.6

The aim of Action 1.6 is the EU-wide adoption of a system of metrics for evaluating technology performance, and other key parameters, in stage-gated technology development processes such as is envisaged in Actions 1.1 to 1.5. A system of stage gate metrics provides an objective and comparable approach to assess and select technologies in funding programmes.

2.4.2 Financial Requirement Assessment for Action 1.6

The definition of stage gate metrics for wave energy is being delivered through a co-ordinated international effort which will deliver EU-wide, and indeed global, consensus on technology evaluation through two connected routes:

- IEA-OES Task 12 – an international activity conducted under the auspices of the International Energy Agency Ocean Energy Systems group to deliver an internationally agreed technology evaluation framework for ocean energy;

- DTOceanPlus – a Horizon 2020 funded project which will deliver an open-source suite of software design tools which will accelerate the development and deployment of the ocean energy sector. One part of the suite of tools is the Stage Gate design tool which will define a set of stages, metrics and engineering activities for subsystems, devices and arrays. Within this defined process, the DTOceanPlus Deployment and Assessment design tools will deliver design and development support with technical evaluation of the specified metrics.

Both activities cover wave and tidal stream energy and are building on experience of Wave Energy Scotland, the US Department of Energy and a series of Ocean ERA-NET, EERA and SEAI supported workshops.

With the publication of the IEA-OES Task 12 report, a consistent and rigorous framework for measuring success and guiding the supporting engineering activity in critical target areas of ocean energy technology development is available. The success, or otherwise, of IP Action 1.6 will depend on the degree to which this framework is adopted by funding bodies and technology development agencies. Promoting the framework and encouraging the uptake of tools which implement it, such as those developed within DTOceanPlus, will be essential to this success.

The financial requirement for this activity is not expected to be significant and the IP estimates should be sufficient. Incorporating the framework into the development and evaluation of the Commission's future wave energy technology development calls would be a significant contribution.

2.5 IP Action 2.1

2.5.1 Interpretation of Action 2.1

Action 2.1 seeks the creation of a Common Investment Support Fund to provide flexible capital for OE projects at TRL 7 or greater. OE projects, particularly innovative first-of-a-kind projects, have significant technical (and thus financial) risks that prevent access to commercial debt finance or private equity. Public support is required to take on some of the risks that developers alone cannot carry or insure against. A Common Investment Support Fund is expected to enable the leveraging of private capital.

Flexibility in the type of finance provided to projects (debt, equity, grant, etc.) is essential to cater for the needs of a wide range of projects, recognising the varying financing needs of different projects.

Financing costs associated with innovative ocean energy farms can make up as much as 50% of total project costs. Targeted EU instruments can reduce those financing costs by providing grants, guaranteed loans, or low-cost debt. This public finance also re-assures investors, making it easier for projects to reach financial close.

2.5.2 Financial Requirement Assessment for Action 2.1

The European Commission published a Market Study in 2018 [17] which considered the proposed structure of an investment support fund as outlined in the Ocean Energy Strategic Roadmap [18] and by the IWG. As part of this study the characteristics of such a fund were outlined following industry surveys and review of international best practises:

1. The fund should help leverage additional private capital and reduce the finance costs.
2. The fund should aim at making itself obsolete for a given technology: funding projects until a technology has been de-risked enough to be able to source commercial debt/private equity without it.
3. The fund should provide finance flexibly (grant, debt or equity) to suit the diverse profiles of projects while requesting a strong due diligence.
4. Support to wave and tidal technology should be differentiated to reflect the different level of development of the two sectors.
5. Revenue support mechanisms (e.g. feed-in tariffs) should also be set in place to help attract private investors to projects. However, a more harmonised approach should be considered by Member States in developing these support mechanisms for this sector.

It was noted that learnings from publicly funded projects need to be made more openly available to the funding authorities and the industry broadly while preserving IP as necessary.

While an estimated budget for the investment fund was between 200M€ and 300M€ over a five- to ten-year period, a figure repeated in the IP, it would ideally be left to the market to determine the value of the fund.

Pros and cons of three options were considered:

- Option 1: Put the capital into an existing instrument (InnovFin Energy Demo Projects);
- Option 2: Set up a new fund managed by the European Investment Bank;
- Option 3: Set up a new fund managed by the EU Commission.

The report did not recommend any one option. It did, however, note that the fund would need to be developed in conjunction with '*strong and stable public support to the sector as a whole.'*

The development of a Common Investment Support Fund was anticipated in two stages: feasibility; and, creation. The feasibility study should scope and define an appropriate mechanism for creating the fund, while considering the mechanisms already in place such as InnovFin EDP, Innovation Fund, Investment Platform, and, BlueInvest. Allowing these funds to combine under e.g. EU Invest would greatly improve their efficiency and accessibility for the industry.

[17] Market Study on Ocean Energy, 2018. https://op.europa.eu/en/publication-detail/-/publication/e38ea9ce-74ff-11e8-9483-01aa75ed71a1

[18] Ocean Energy Strategic Roadmap, Building Ocean Energy for Europe. Ocean Energy Forum (2016). https://webgate.ec.europa.eu/maritimeforum/en/node/3962

It is recommended that the OceanSET partners commission such a feasibility study in the second half of the project, to outline an appropriate mechanism and explore options to streamline aspects of public funding schemes.

Given the indications in section 2.2 of the cost requirements for the industry to deploy both single devices (€220M) and arrays (€450M) over the next five to ten years and given that capital costs will form part of this cost, the indicative range of 200M€ to 300M€ remains valid.

It should be noted that, unlike other IP Actions, the resources allocated to a Common Investment Support Fund would be repaid with an associated return. The outturn cost of the action – if any – is therefore the difference in the return required by the fund, compared to market rates.

2.6 IP Action 2.2

2.6.1 Interpretation of Action 2.2

Action 2.2 seeks the creation of an EU Insurance and Guarantee Fund to underwrite various technology related project risks, e.g., availability, performance, O&M costs. The fund would support the initial OE farm projects by providing a common reserve fund.

Project developers overwhelming bear the risks currently. No insurance products exist that cover such project risks adequately at a reasonable price which limits projects ability to raise equity finance or commercial project finance.

A fund that insurers project revenues during its early years would make projects considerably more investable. A sectoral pan-EU approach, covering all demonstration and pre-commercial farms could absorb a large share of this risk element and, thereby, lower the cost of capital for ocean energy developers and ease access to finance.

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

The development of an EU Insurance and Guarantee Fund is anticipated in two stages: feasibility; and, creation.

2.6.2 Financial Requirement Assessment for Action 2.2

In 2016, the Ocean Energy Forum Roadmap [18] indicated that a budget of €50-70M would be required for such an Insurance fund. The EU Commission later produced a Market Study Report in 2018 [17] which assessed the proposed structure. The report recommended that a re-insurance fund should be considered as the most appropriate mechanism. The authors argued that this would be the best way to prevent public moneys from distorting the market while allowing commercial insurers the opportunity to '*acquire the necessary data and expertise to enable them to correctly assess and price risks.'*

However, it was noted that a re-insurance fund, as opposed to an insurance fund, has the disadvantage of introducing a slightly more complicated procedure, as project developers would not apply for the fund themselves, but would have to do so via their insurer. In addition, unlike the Common Investment Support Fund outlined in section 2.5, there are no existing instruments that could be used and neither the EIB nor the Commission are specialised in providing insurance or re-insurance to the ocean energy sector.

What is clear is that further work is required to develop such a mechanism. The OceanSET project has just issued a tender for the development of a feasibility study on this. It is anticipated that this will give a more updated estimate of cost for the financial requirement.

The outcome of the tender will be a report of sufficient detail and scope that it can be used by public decision-makers to establish an Insurance and Guarantee Fund in the short-to-medium term.

The Report will address the following key themes:

- Understanding and assessing the "Technology risk" associated with wave and tidal devices;
- Defining which risks should be in and out of scope of the Fund;
- The role of testing and due diligence processes in limiting the technology risk;
- The optimal size of the Fund, considering the pipeline of ocean energy projects as collated by the OceanSET project;
- The optimal role for public authorities in the establishment of the Fund;
- The role of performance warranties;
- How to design the Fund to harness existing expertise from the commercial insurance sector, and to create a path for standard commercial insurance products to become available and ultimately replace the Fund;
- Assessment of criteria and design options for all aspects of the Fund.

It is anticipated that this report will be completed by Q2 2021 and costings and proposed timelines for such a fund will be updated then.

2.7 IP Action 2.3

2.7.1 Interpretation of Action 2.3

Action 2.3 seeks to establish an EU-wide innovation programme to develop innovative solutions to the technical challenges faced by the wave energy sector. The competitive procurement programme is expected to use the EU pre-commercial procurement (PCP) model to develop key sub-systems, systems and devices. The focus for the innovation programme is expected to be determined by the technology challenges identified in Action 1.3.

The financial requirement of a PCP-based innovation programme can be considered in two parts:

- The financing of the PCP R&D contracts;
- The financing of the programme and contract management.

As noted in the IP, financial provision for the PCP R&D contracts is made in the provision for Action 1.3. The financial requirement for Action 2.3 is therefore assumed to be concerned with the second part.

2.7.2 Financial Requirement Assessment for Action 2.3

Establishing a dedicated team to establish and operate a PCP-based innovation programme will require an annual operating budget to cover staff costs (e.g. a programme manager, project contract managers, project engineers, communications staff, administrative support staff), office and business costs, provision for legal and procurement advice, provision for external expert advice, advisory group support, and travel.

Using Wave Energy Scotland's experience of operating a multi-stream innovation programme, an appropriate operating budget is estimated to be between 1M€ and 1.5M€ per annum depending on the complexity of the innovation programme pursued:

- A lean programme that pursues a restricted number of technology challenges concurrently, can be delivered with a smaller team and would be at the lower end of the range;
- A multi-stream innovation programme that pursues multiple technology challenges concurrently, would be at the upper end of the range, with an increased requirement for project contract managers, project engineers and external experts.

The financial requirement to support a dedicated team to establish and operate a PCP-based wave energy innovation programme throughout the Development and Deployment phases of the IP (2021-2030) is estimated to be between 10M€ and 15M€ depending on the scale of ambition for the programme. This is lower than the 24M€ indicated in the IP, although this assumes the IP estimated budget was intended solely to provide for the programme and contract management activity.

2.8 IP Action 3.1

2.8.1 Interpretation of Action 3.1

Action 3.1 seeks the establishment of standards and certification processes specifically for the ocean energy sector to streamline design and development and lead to more efficient certification of ocean energy technologies. The expectation is this action will build on existing work (e.g. TC114) to develop guidelines governing the design of equipment, test methodologies, and data processing during the Development phase leading to commercial roll-out, and, on the requirements for optimal device operation and farm lay-out. The action is expected to deliver relevant environmental standards for OE and common safety standards for deployment and operation.

The terminology used by various organisations and sectors to describe a set of rules or guidelines which should be followed during the various stages of technology and project development varies: International Standards; Technical Specifications; Recommended Practice; Guidelines. Some are a legal requirement where others are not. Publishers include IEC, ISO, DNV, Lloyds, API, IEEE and other similar organisations, and include regional or national authorities for planning and consenting purposes. Within the text below, no distinction is made between these and all are described as a 'Standard'.

Achieving the SET Plan targets for ocean energy requires technology developers to have knowledge of, and implement, the relevant Standards at the early stages of development to be prepared for the future requirements of device qualification/ certification. In doing so, ocean energy technology will be better placed to satisfy the demands of relevant stakeholders, including insurance and finance.

Activities in this action are expected to be coordinated through appropriate authorities and committees, supported by user experience from relevant technology developers.

2.8.2 Review of Current Status

Bespoke Standards for the ocean energy sector are emerging and their suitability for the sector is under investigation. The US Department of Energy included specific requirements for the use of the IEC-62600 series of technical specifications in some of their ocean energy programmes in 2019 [19], ring-fencing a dedicated budget for developers to work with the National Labs to implement the technical specifications. Elsewhere, the Commission has funded studies through Horizon 2020 (OPERA [20]) and Interreg 2 Seas (MET-Certified [21]). The focus of OPERA was the reduction of costs for wave energy technology, while the focus of MET-Certified was the testing and certification of tidal technologies.

These projects have concentrated predominantly on assessing the technical specifications of the IEC, neglecting a wider body of Standards which may be applicable throughout the entire technology and project development lifespan. This Action must consider this wider aspect.

A detailed assessment of Standards available at all stages of the development process, from early R&D through to site assessment and consenting, needs to be undertaken to determine where there are gaps. Such studies should identify where Standards are being required but are not appropriate for ocean energy technology, are desirable but are not available, or, where current Standards are silent (i.e. where users are left to their own interpretation). This has the aim of ensuring that developers can focus on compliance with Standards which are applicable and appropriate. Where available Standards are found to be unsuitable or not available, effort should be focussed on addressing these failings with subject matter experts assisting with updating text or drafting new text or new Standards where necessary.

Barriers to the adoption and use of Standards at early stages of technology development which have been identified previously include: the financial commitment to access Standards; the time commitment to become proficient in applying them; the perception of stifling innovation; and perceived difficulty with engaging in the Standard development process.

[19] DE-FOA-0002080: Water Power Technologies Office 2019 Research Funding Opportunity. Up to $400,000 available to work with the National Labs (NREL and/or Sandia)

[20] Open Sea Operating Experience to Reduce Wave Energy Cost. http://opera-h2020.eu/

[21] Marine Energy Technology Certified. http://met-certified.eu/

2.8.3 Financial Requirement Assessment for Action 3.1

In summary, anticipated activities in this Action should include:

- Assessment of the Standards requirements during full project lifetime including R&D, design, planning and operation. Indication of decommissioning requirements.
- Identification of non ocean energy specific Standards used in the sector.
- Determining the additional cost to technology developers, and benefits gained, of implementing Standards at various stages of project development.
- Engaging with relevant stakeholders across the entire technology development process, including research organisations, technology developers, marine operations contractors, equipment suppliers, certification agencies and national planning authorities.
- Review results from previous projects specifying implementation of Standards, e.g. MET-Certified and OPERA.
- Establish guides to assist developers with the journey towards certification, identifying supporting knowledge databases or software required to assist the achievement of certification.

The outputs of this Action are designed to ensure appropriate and relevant Standards are identified for the various stages of technology development:

- Detailed list and flowchart simplifying the identification of Standards required at each step of research, development, design and operation of OE technologies.
- Gap analysis, identifying Standards which are to be updated, or initiated.
- A complete set of Standards appropriate and applicable to Ocean Energy technologies, having been tested in real technology and project development scenarios.

In establishing a programme to address the issues identified above sufficient funding provision is required to:

- Liaise with IECRE and other relevant organisations to identify outstanding areas of Standards development.
- Provide sufficient resource for 'first drafts' of new documents required to fill the gaps.
- Liaise with certification agencies to perform test case technology qualification, or other process as appropriate, involving technology developers.
- Supply complete sets of relevant Standards to technology developers involved in the programme.

The initial estimate of the financial requirement for this activity is up to 8M€ over the Development phase of the IP.

2.9 IP Action 3.2

2.9.1 Interpretation of Action 3.2

Action 3.2 aims to assist developers and authorities in the licensing and consenting process for OE projects by developing guidance documents to facilitate procedures to test and operate ocean energy farms in line with current environmental legislation and encouraging a common attitude towards licensing and consenting.

Action 3.2 is based on Action Plan 4 of the Ocean Energy Strategic Roadmap [22] which is described as "*de-risking environmental consenting through an integrated programme of measures to overcome development challenges*" [see Table 3 in Annex 2 of the IP]. Five areas ("*projects*") are indicated, the same areas as stated in the IP, namely:

- **Planning review** – Guidance on the application of spatial planning and assessment to ensure compliance with Directives/Regulations when selecting sites.
- **Consenting** – Review of consenting and licensing processes to produce a best practice guide.
- **Environmental demonstration strategy** – Developed through intensive monitoring of the first demonstration deployments. Cost of monitoring expected to be socialised to minimise burden on first movers. Monitoring information published and available to regulators, developers, stakeholders, etc.
- **Research best practice** – Approaches for site specific planning and monitoring: pre-application [site characterisation, public consultation]; application [techniques for presenting impact assessments and mitigation measures]; post-consent & monitoring [publication of data and analysis].
- **Socio-economics** – Assessment of benefits and impacts of ocean energy developments (jobs, turnover, GDP share). Produce best practice guide by reviewing supply and value chain methods, industry plans, scenario mapping techniques, master planning techniques, tariff and lease award processes.

The roadmap appears to anticipate funding for these "*projects*" coming from the Commission's Directorate Generals with MS/Regions providing input to tender specifications to ensure best project outputs.

2.9.2 Review of Current Status

Planning review – The Commission's Marine Strategy Framework Directive (MSFD) (adopted on 17 June 2008) is concerned with the management of those human activities which have an impact on the marine environment. It enshrines an approach that integrates the concepts of environmental protection and sustainable use in a legislative framework that requires MSs to implement, and update every 6 years, a marine strategy. Progress towards implementation and fulfilment of reporting obligations under the MSFD appears to be good [23]. However, it is not clear how the various MS marine strategies accommodate the harnessing of ocean renewable energy by wave and tidal stream technology. The ETIP Ocean project [24] produces an annual paper on environmental impact issues – including Marine Spatial Planning.

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[22] Ocean Energy Strategic Roadmap, Building Ocean Energy for Europe. Ocean Energy Forum (2016). https://webgate.ec.europa.eu/maritimeforum/en/node/3962

[23] https://ec.europa.eu/environment/marine/eu-coast-and-marine-policy/implementation/scoreboard_en.htm

[24] https://www.etipocean.eu/

Consenting – Historic [25] and current [26] projects continue to review aspects of the consenting and licensing processes for ocean energy technology. Furthermore, the IEA-OES has a permanent task on the consenting processes for ocean energy in OES Member Countries [27] with three key objectives:

- To review and update annually the state of the consenting processes in OES member countries;
- To determine progress in implementing recommendations made in previous annual reviews;
- To develop a policy brief for regulators and decision-makers on the key needs of the ocean energy sector.

Environmental demonstration strategy – Efforts to assess the environmental impacts of ocean energy technology are underway. An example is the SEA Wave project [28] which undertook to monitor the environmental impacts associated with a proposed wave array project [29]. A data sharing platform, MARENDATA [30], has been revived to disseminate data collected by SEA Wave and similar projects (e.g. WESE). A long running IEA-OES task, Task 4, has been engaged in bringing together information on monitoring methods and environmental effects of ocean energy development to expand baseline knowledge and disseminate such to those in industry; national, state, and regional governments; and the public.

2.9.3 Financial Requirement Assessment for Action 3.2

Several of the "*projects*" in Action 3.2 appear to be progressing through standing activities by bodies such as the IEA-OES and ETIP Ocean, and through individual 'one-off' projects. However, some of the "*projects*" don't appear to have progressed (e.g. socio economics). This is not attributed to the IP estimated budget which still appears to be a reasonable provision for the activity.

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25 RICORE https://ec.europa.eu/inea/en/horizon-2020/projects/h2020-energy/wind-energy/ricore; SOWFIA https://ec.europa.eu/energy/intelligent/projects/en/projects/sowfia

26 DTOcean Plus, https://www.dtoceanplus.eu ; WESE http://wese-project.eu/.

27 https://www.ocean-energy-systems.org/oes-projects/consenting-processes-for-ocean-energy-on-oes-member-countries/

28 SEAwave, http://www.emec.org.uk/projects/ocean-energy-projects/environmental-monitoring/sea-wave-strategic-environmental-assessment-of-wave-energy-technologies/

29 CEFOW, https://ec.europa.eu/inea/en/horizon-2020/projects/h2020-energy/ocean/cefow

30 http://marendata.eu

3. CONCLUSIONS

The estimation of budget costs for the IP Actions is hampered, generally, by the limited detail regarding the activities anticipated in the Actions, resulting in broad generalisations being applied to obtain budget estimates. This applies to the Technical Actions in particular.

Assessment of the Technical Actions has taken consideration of the Strategic Research & Innovation Agenda (SRIA) published in May 2020 and setting out the research and innovation priorities for ocean energy sector over the next 4 to 5 years, that is during the Development phase of the IP (2021-2025).

An analysis of the SRIA suggests the IP's budget estimates for the early TRL activities anticipated in Actions 1.1 [tidal] and 1.3 [wave] should be revised upwards. An estimated budget of 220M€ is considered necessary to progress those SRIA priority topics associated with Action 1.1 [tidal - 95M€] and Action 1.3 [wave - 125M€] during the Development phase. This contrasts with IP budget of 172.5M€ for the same period, 85M€ for Action 1.1 (tidal) and 87.5M€ for Action 1.3 (wave).

The SRIA's budget estimates for the higher TRL demonstration activities anticipated in the IP Actions 1.2 [tidal] and 1.4 [wave] are higher than the IP estimates for the Development phase although are not wholly inconsistent with the total budget estimate for the actions over all phases of the IP. A separate analysis of the costs associated with demonstration deployment projects has produced a likely range for the estimated budget for each action

- Action 1.2 [tidal] - between 195M€ and 780M€, with a median of some 365M€, to deliver three single device demonstrations and four 10MW array demonstrations;
- Action 1.4 [wave] - between 175M€ and 200M€ to deliver three single device demonstrations and four 5MW array demonstrations.

Establishing financial requirements for IP Action 1.5 has proved to be inconclusive. Evidence from the MARINERG-i project suggests that present physical testing infrastructure satisfies the immediate requirements of the sector but a gap analysis to assess future requirements is recommended. The development of other infrastructure (port facilities and electrical networks) are expected to be driven by more mature technologies in the ocean energy sector, particularly offshore fixed and floating wind. However, wave and tidal technologies should benefit directly from this activity given the similar requirements. The development of a supply chain capable of supporting the ocean energy sector is being progressed by several current projects. Again cross-sectoral collaboration with more mature technologies will benefit nascent wave and tidal technologies and such synergies should be the focus of future effort.

The publication of the IEA-OES's Task 12 framework is noted as providing the basis for delivering the objective of the final technical action, Action 1.6 [Development of stage gate metrics for wave technology evaluation]. The success, or otherwise, of the action will depend on the degree to which the framework is adopted by funding bodies and technology development agencies. This will require promotion of the framework and of tools which implement it. Incorporating the framework into the development and evaluation of the Commission’s future wave energy technology development calls would be a significant contribution. The financial requirement is not expected to be significant and the IP estimates are considered to be sufficient.

The ambition for the three Finance Actions are relatively clear, the creation of: a Common Investment Support Fund (Action 2.1); an Insurance and Guarantee Fund (Action 2.2); and, an EU-wide innovation programme based on PCP principals (Action 2.3).

The insurance fund is the subject of a feasibility study undertaken elsewhere in the OceanSET project. Comment on the financial requirement is not made at this time as the study has yet to report.

Previous estimates for value of the investment fund, namely between 200M€ and 300M€, remain reasonable following the analysis of demonstration deployment project costs reported here. However, the appropriate form of the fund is not clear and a proposal to commission a feasibility study to recommend efficient and effective structures for investment fund in the second half of the OceanSET project is under consideration.

The purpose of the funding requirement for the proposed innovation programme has been clarified: to provide the operating budget for a dedicated team to establish and operate a PCP-based wave energy innovation programme. The estimate of between 10M€ and 15M€ budget to support the team over the Development and Deployment phases of the IP (2021-2030), depending on the scale of ambition for the programme, is lower than the 24M€ indicated in the IP.

The relatively modest IP budget estimates for the two Environmental Actions appear to be adequate. Activities addressing the several aspects covered by the two Actions are apparent, receiving financial support through a variety of EU funding programmes. However, the two Actions would benefit from expressing the objectives and the anticipated activities with greater clarity to allow a more focussed response.

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