Strategic Research and Innovation Agenda for Ocean Energy

October 2024

Co-funded by the European Union

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European Technology & Innovation Platform for Ocean Energy

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Co-funded by UK Research and Innovation (UKRI) under the UK government's Horizon Europe funding guarantee [10045928].

ETIP Ocean is supported by the SEETIP Ocean project.

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ACKNOWLEDGEMENTS:

Valuable information and feedback were received from members of the ocean energy sector, and in particular the ETIP Ocean Technology Working Group.

PHOTOGRAPHIC CONTENT:

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GRAPHIC DESIGN: JQ&ROS Visual Communications (jqrosvisual.eu)

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European Technology & Innovation Platform for Ocean Energy

Strategic Research and Innovation Agenda for Ocean Energy

This Strategic Research and Innovation Agenda (SRIA) for ocean energy outlines the priority research, development and innovation challenges that must be focused upon in the years ahead. The SRIA gives guidance to all funders of innovation – industry, EU, national and regional – by presenting concrete research and innovation actions that will allow ocean energy to meet its SET Plan targets.

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Foreword

Rosalinde van der Vlies

Director – Clean Planet, Directorate-General for Research and Innovation, European Commission

Innovation is at the heart of the EU's energy transition, driving us towards a sustainable and resilient future. To reach the EU's climate goals by 2050, new low-carbon technologies must be brought to market by the next decade. The International Energy Agency indicated that one-third of the energy mix in 2050 will depend on technologies which are not yet in the market. Ocean energy is one of the technologies to scale up. Harnessing the power of our seas provides an indigenous renewable source of energy, reinforcing the EU's energy security, competitiveness and resilience.

The EU is a long-standing supporter of ocean energy. Horizon Europe and its predecessors have allocated almost €450 million for the development of ocean energy technologies. Europe is currently the technological leader in ocean energy, it installed the first and largest tidal pilot farms in the world and the highest number of full-scale wave energy devices. Pilot farms deployed today were first developed with EU funding – and are now generating clean electricity and powering European homes.

The Strategic Research and Innovation Agenda for Ocean Energy reflects the progress made in the past years, and presents what needs to happen to ensure that the EU remains the global leader in the sector. Addressing these R&I priorities will drive the development of ocean energy technology, accelerate the progress towards industrial roll-out and help deliver on the targets of the EU Offshore Renewable Energy Strategy and the Renewable Energy Directive.

Achieving the ambitious goals set out in this agenda requires a collective effort. Collaboration between the European Commission, Member States, national and regional governments, industry stakeholders, and research communities is essential to scaling up ocean energy. Together, we can drive forward the innovations needed to harness the full potential of ocean energy.

The recently published communication 'Delivering on the EU offshore renewable energy ambitions', and the revamped Strategic Energy Technology Plan are sealing our long-standing commitment in setting policies to fight against climate change but also shows our ambition to increase our competitiveness as outlined in the new Political Guidelines for the next European Commission 2024-2025.

I am confident that this Strategic Research and Innovation Agenda for Ocean Energy will guide our efforts and ensure that we continue to lead in this new global sector. Collaboration will be crucial to turn these aspirations into reality, advancing towards a clean and sustainable energy future.

Executive summary

Ocean energy can help deliver a competitive, resilient and zero-emissions Europe

A secure and sustainable electricity system must be emission-free, affordable and home-grown. Europe is already well advanced towards that objective, with renewables accounting for nearly half of the EU's electricity consumption today. But other technologies are needed in the mix to balance production from variable sources.

Ocean energy is a European industry with an abundant renewable resource right on our doorstep. Ocean energy can deliver 100 GW of capacity in Europe by 2050, providing 10% of Europe's current electricity consumption.

Because ocean energy is highly predictable and produces at different times, it will play an important role in complementing wind and solar – able to replace gas on the grid and reinforcing the security of energy supply.

European companies are global leaders in ocean energy. Bringing the sector to market in Europe will consolidate this lead and help build a new strategic zero emission export industry.

Ocean energy can be the new European success story that helps build a competitive, resilient and zero emissions Europe.

167 MW pipeline of publicly supported projects in Europe

Ocean energy is currently at demonstration and pre-commercial stage depending on the technology considered:

- Tidal stream is moving from pilot farms to pre-commercial farms.
- Wave energy is moving from prototypes to pilot farms.
- OTEC and salinity gradient are at R&I phase, while tidal range and SWAC can be rolled out in suitable locations.

The next five years will be crucial for the sector's progress towards industrialisation. A project pipeline of 167 MW in Europe is publicly supported via EU programmes or national schemes, making those projects very attractive for private investors.

In fact, several private companies are already investing in those projects or have partnered up to help technology developers deliver, e.g. Equinor, TotalEnergies, ENGIE, or Qair[1].

Photo: Proteus Marine Renewables

1 For a more detailed list please see Chapter 2.5.

Key R&I actions to accelerate the path from research to deployment

This Strategic Research & Innovation Agenda (SRIA) identifies the main 'Challenge Areas', each of which contains a number of research and innovation priorities – 'Priority Topics' – that the ocean energy sector should work on and what EU, national and regional R&I funding should focus upon during the period of 2025-2030 to deliver the greatest progress in the ocean energy sector.

The SRIA aims at addressing five overarching goals by 2030:

- Make ocean energy competitive;
- Reinforce the industrial capacity;
- Fill in the knowledge gaps;
- Increase social and environmental acceptance;
- Improve market confidence and attract investors.

Design & validation of ocean energy farms

Ocean energy devices must be deployed and operated at sea for significant periods to optimise design and performance, and to validate business models for investors. Scaled and full-scale single devices and pilot farms are crucial to improving reliability, energy yield, availability, operating cost as well as lifetime costs of devices. They also generate the information that private investors require to consider finance, which is necessary to bring the sector to commercialisation.

Next generation of technologies and subsystems

New ideas and concepts for capturing ocean energy are constantly emerging and evolving, and they coexist with the incremental development of more mature alternatives. These less mature or yet to be invented concepts may deliver disruptive improvements in performance or cost of ocean energy devices.

Analysis and modelling tools

Developers and investors require robust analysis and modelling tools to predict array performance, optimise farm design, and plan and manage construction and operation. The accuracy and affordability of these tools has a direct impact on the innovation and development process of ocean energy. Business cases are critically dependent on model predictions of energy yield (revenue) and of device and system reliability.

Integration of enabling technologies

Harnessing the vast renewable energy potential of the oceans relies on the effective transfer of technological advances from other sectors. The uptake of new enabling technologies by the ocean energy sector can accelerate its path to competitiveness. These can include new materials for devices and components, smaller and lower-cost sensors and data transmission solutions, as well as new computational methods such as artificial intelligence.

Ocean energy market development

Identifying the most promising initial markets for ocean energy will facilitate the path to commercialisation. Off-grid locations may present early commercial opportunities for some ocean energy technologies, Co-location with other offshore activities could reduce costs e.g. by sharing some electricity export infrastructure. Accurate assessments of the benefits of ocean energy relative to other renewables, such as better predictability and non-synchronicity with solar or wind power, would help better inform policy and investment decisions.

Unlocking private investment with public funding

Public funding from the EU, countries and regions, provided at the appropriate development stages, can draw in substantial amounts of private investments. Public funding acts as a market signal to investors, confirming that those technologies are part of the EU's long-term energy future. It also provides a 'seal of validation' for projects, confirming that those are deemed worthy of investments. In addition, public funding reduces the total amount of private capital to be sourced. Finally, it makes the overall project cheaper by reducing financing costs. Those 4 impacts of public funding greatly help projects to find investors and reach financial close.

Overall, delivering SRIA activities is expected to require almost 200 projects with a total budget around €1.4 billion. The contribution from private funding is estimated at around 40% of the total, and there needs to be active engagement with the private sector, including established energy companies, to realise these investment opportunities.

Table 1. Challenge Areas and Priority Topics for ocean energy research, development and innovation.

DESIGN AND VALIDATION OF OCEAN ENERGY FARMS

Demonstration of pilot farms
Demonstration of single devices
Design and validation of other ocean energy technologies

NEXT GENERATION OF TECHNOLOGIES AND SUBSYSTEMS

Disruptive wave energy devices
Innovative PTO and control systems
Advanced moorings, foundations and power connections

ANALYSIS AND MODELLING TOOLS

Advanced simulation of ocean energy subsystems and devices
Analysis and planning tools for ocean energy farm deployment
Modelling and simulation of farm construction and operation

INTEGRATION OF ENABLING TECHNOLOGIES

Innovative materials and manufacturing processes
Application of latest instrumentation and sensor technology
Use of artificial intelligence and big data

OCEAN ENERGY MARKET DEVELOPMENT

Application of ocean energy in off-grid markets
Demonstrating grid-scale benefits of ocean energy
Co-location of multiple technologies

COORDINATION AND SECTOR SUPPORT ACTIONS

Coordinating sector efforts
Accessing and upgrading testing facilities
Support to ocean energy sector development

1 Ocean energy for a competitive Europe

Photo: CorPower Ocean

Delivering a sustainable, secure, and home-grown energy transition is Europe's main challenge and a major opportunity now and for the coming decades.

Addressing this challenge requires fundamental changes in the energy system, already well advanced with commercial renewables making up 44% of EU electricity consumption in 2023, and a radical shift in the way we think about energy. But reaching a zero-emission system, will also require the development and scale-up of innovative energy solutions.

Therein lies also the opportunity: to create a healthier and cleaner environment; to generate high-skilled, sustainable jobs; and to become a global powerhouse in zero emission technologies.

Ocean energy can play a significant role in unlocking this opportunity. It is a home-grown industry with an abundant renewable resource right on our doorstep. And it can help push the penetration of renewable energies further into the electricity mix.

Ocean energy can be the European success story that helps build a competitive, resilient and zero emissions Europe.

1.1 Ocean energy can help deliver on the EU's political priorities

The European Commission recognises the potential of ocean energy and has put forward deployment targets for the technology. The EU Strategy on Offshore Renewable Energy[2] aims at reaching 100 MW of ocean energy in the energy mix by 2027 and 1 GW by early 2030's.

These short-term targets pave the way to the industrial roll-out of ocean energy. By 2050, ocean energy can deliver 100 GW of secure, predictable and renewable power capacity in Europe – all along the Atlantic coast from Portugal to Norway, along the Baltic Sea and the periphery of the Mediterranean – the equivalent of 10% of Europe's current electricity consumption.

By scaling up ocean energy now, Europe can reap the benefits of this new clean technology industry from the very near term as well as to 2050 and beyond. Helping to achieve the EU's political priorities and objectives of the European Green Deal, ocean energy will help balance Europe's grid, enhance its competitiveness and deliver long-term energy security.

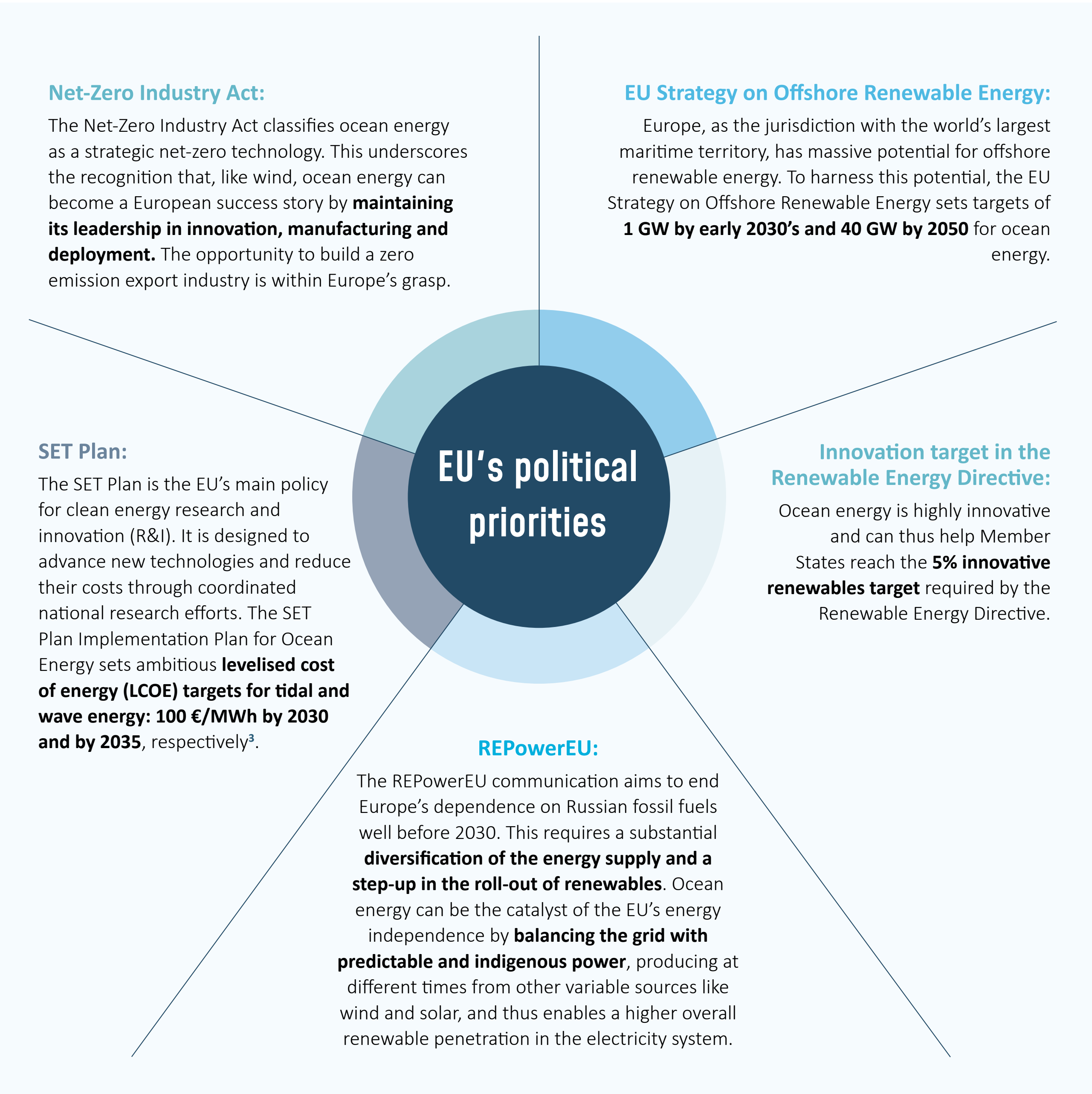


Figure 1.1. Ocean energy can help deliver on the EU's political priorities.

2 EU strategy on offshore renewable energy – Delivering on the EU offshore renewable energy ambitions (COM/2023/668 final).

3 SET Plan Ocean Energy Implementation Plan, IWG Ocean Energy, 2021.

Europe
World leader in **tidal stream** and **wave energy**

Ocean energy will enhance Europe's competitiveness

European companies are global leaders in ocean energy. The **world's first and largest tidal pilot farms are located in Europe**, and new projects will break existing records again; for example, the world's largest tidal pilot farm, with 17.5 MW, will be deployed in France in 2026. **Europe is also home to the most advanced wave devices**, with 13.3 MW of capacity tested since 2010. Europe has installed the majority of the global capacity, with 74% for tidal and 50% for wave since 2010[4].

Europe has a chance to consolidate this lead and dominate a new global high-value market. This will **enhance European competitiveness and build a new strategic zero-emission export industry**. The value chain is already forming; research, development, component suppliers and OEMs are spread across Europe, while device assembly typically occurs on coastal regions near deployment sites. Countries that support the ocean energy sector will have the chance to replicate the benefits from Europe's offshore wind success – in a new home-grown industry with low delocalisation risks.

Ocean energy global market
€53bn / year
by 2050

Ocean energy can become a massive export market

The global ocean energy market is estimated to be worth **€53bn per annum by 2050**, and Europe already has the lead in technology development, manufacturing, and deployment. Europe has installed more wave and tidal energy than the rest of the world combined[8], and European ocean energy companies are already forming international partnerships to export their technology to new markets. However, other countries such as the US and China are catching up, so it is imperative that development in Europe is accelerated.

Ocean energy can create
500,000 jobs
by 2050

Ocean energy creates jobs across Europe

Ocean energy can create **500 000 jobs**[5] **in Europe and a gross value-added of €140bn by 2050**[6], all along the supply chain and across European territories. These are local manufacturing, assembly, and service jobs, revitalising coastal communities historically tethered to legacy industries such as shipbuilding and fossil fuels. These jobs are also created in the upstream supply chain, especially in countries with an existing specialised manufacturing industry, including Austria, Germany, Sweden and Czech Republic.

Ocean ener
competitive
energy s

4 Ocean energy stats & trends 2023, Ocean Energy Europe, 2024.

5 A study into the potential social value offered to Europe from the development and deployment of wave and tidal energy to 2050, ETIP Ocean, 2022.

6 A study into the potential economic value offered to Europe from the development and deployment of wave and tidal energy to 2050, ETIP Ocean, 2021.

Ocean energy strengthens the EU's energy security

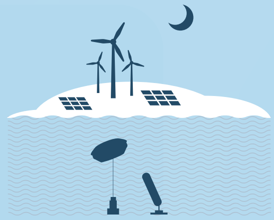
As the EU aims to end its dependence on Russian fossil fuels, diversification of the energy supply with domestic energy sources is imperative and the only way to ensure security of supply as well as price stability.

Ocean energy is **flexible, predictable and will play an important role in complementing variable renewables** – replacing gas in the grid and reinforcing the security of energy supply in Europe's renewables-based electricity grid.

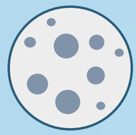
Regulated by the constant cycles of the moon, sun and earth, **tidal stream is 100% predictable**. The future output of tidal power is known for any moment in time. Moreover, the time between tide changes is so short that even a small amount of storage can be used to enable non-stop, flexible tidal power – this is already happening today.

Wave energy's production pattern is different to wind and solar, and thus able to smooth out grid output. Wave energy works particularly well with wind – the waves are built up by the wind, so when the wind dies down, wave energy can step in to maintain power production. When combined, correlated wind and wave produce an overall power output that is both smoother and more reliable. Wave energy is also typically available when solar resource is at its minimum, both daily (little irradiation at night) and seasonally (less solar resource but great wave resource in winter).

Several recent studies quantify the **benefits of ocean energy to European grids**; all point to the lower system costs of having a diversified system with a wide range of renewables including ocean energy.[7]



Wave energy: complements variable renewables



Driven by the moon
Tidal stream is 100% predictable years in advance

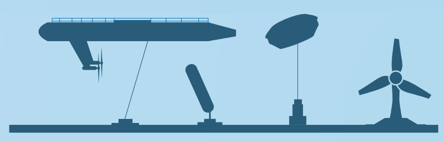
Operates in harmony with the environment

Pioneering environmental sustainability

Ocean energy has minimal visual impacts, preserving the aesthetic and touristic value of the environment. Installed offshore, it does not compete for land. Ocean energy's social acceptability is one of the highest among energies and enhanced by its environmental sustainability. To date, there have been **no recorded collisions with marine mammals**, while the sector develops and employs high-tech environmental monitoring tools. In some cases, the **artificial reef effect of offshore installations even creates new habitats** for marine animals.

Ocean energy is ready to deliver

Ocean energy is on the brink of industrialisation. In order to maintain the European leadership and deliver all the benefits ocean energy has to offer, **the European sector and policymakers must act without delay**. The right support system will unleash the oceans' potential in order to achieve a 100% decarbonised Europe.



7 Please see the Annex for a list of recent studies.

8 Ocean energy stats & trends 2023, Ocean Energy Europe, 2024.

1.3 Road to industrialisation

Highly innovative, and still pre-commercial, ocean energy technologies are currently expensive and carry technological risks. This makes it challenging for private investors to commit financially without clear governmental support – in terms of targets and funding. Private investment in ocean energy projects requires similar policies to what spurred the development of onshore and offshore wind or solar PV, which all benefitted from long-term government support, deployment targets and dedicated zones.

That said, bringing ocean energies to commercialisation will likely require much less public support than previous renewable energies, as much of the technology is derived from existing products or supply chains. Drive trains for example are very similar to those used in wind turbines, and manufactured by the same OEMs, such as SKF. Ocean energy also benefits from all the learning of other offshore energy or sea users, reducing the cost of offshore operations, vessel rentals, monitoring activities, etc.

As the deployment of wave and tidal energy capacity increases, costs will decrease significantly. Ocean energy's business model is similar to that of offshore wind energy – steel, cement, electronics, offshore operations are some of the key cost components. Which means that similar cost reductions can be achieved.

Large-scale deployment will bring about cost reductions from technology improvements and optimisation, as well as, crucially, reduced financing cost. High cost of finance, from banks or equity investors, remains a main cost component of early innovative technologies – one that disappears with proven, mass-deployed products, allowing for aggressive cost reductions from the early phases of industrialisation.

The European Union's SET Plan established cost reduction targets in 2018, of 100 €/MWh for tidal by 2030 and for wave by 2035. These targets are projected to be achievable at around 1 GW of deployed capacity[9]. Achieving these cost reductions requires a range of different financial instruments tailored for the various phases of technological development from R&I all the way to the industrial roll-out phase. As with any sector, continuing R&I, including early-phase research is essential to maintain innovation and progress.

1 RESEARCH, DEVELOPMENT AND PROTOTYPE PHASES

At these phases, devices and components are designed, tested, and deployed to validate technology. These projects do not generate revenue, focusing instead on proving technical concepts, which makes securing private investment difficult.

Public funding is essential to support these phases. Direct grants that cover up to 100% of the costs enable early-phase research as well as the development of prototypes, which are a prerequisite for pre-commercial and commercial projects.

2 DEMONSTRATION AND PRE-COMMERCIAL PHASES

Full-scale prototypes are tested over extended periods to reduce technological uncertainties and move towards standardised components. This phase involves deploying multiple devices to validate the business model and facilitate cost reductions. While these projects generate revenue by selling electricity, public funding alone is insufficient, and attracting private investors requires offering potentially high returns.

Financial instruments, such as grants, publicly guaranteed debt, insurance & guarantee funds and revenue support, reduce the capital costs, attract private investors and help make a business case. To ensure the best use of available public funding, these instruments should be used in combination, as each reduces the total finance needs in different ways.

3 INDUSTRIAL ROLL-OUT PHASE

At this phase, economies of scale are leveraged to reduce costs, similar to the cost reductions achieved in wind and solar PV. As the price of electricity for ocean energy does not yet cover the costs and returns for equity/debt providers, ocean energy projects need a "top-up" to provide a business case.

Earmarked revenue support will make these projects bankable and will enable developers to secure the necessary finance from a range of private investors, utilities, and original equipment manufacturers. Such support is crucial for deploying the first pilot farms and commercial projects.

Once the financial framework is set up, a supportive policy and regulatory framework will maximise its effectiveness. This policy framework can also help leverage further private investments by providing more visibility on the future market. An ideal supporting framework would consist of national deployment targets for ocean energy, streamlined permitting processes and the inclusion of ocean energy in wider planning processes.

CONTINUOUS R&I EFFORTS ARE ESSENTIAL AT ALL PHASES

To improve technology and deployment efficiency. Initially, prototype devices and components are designed and tested in laboratories and tanks. This preliminary testing enables deployment in real sea conditions, providing invaluable insights that validate the technology. These insights from advanced phases are continuously integrated into new R&I activities, creating a "virtuous cycle" of incremental innovation.

9 Smart, G.; Noonan. Tidal Stream and wave Energy Cost Reduction and Industrial Benefit: Summary Analysis, ORE Catapult, May 2018.

1.4 Overarching goals to achieve with this SRIA

Ocean energy can provide numerous socio-economic benefits and contribute to the EU's political priorities. Research and Innovation (R&I) contributes to overcome the remaining obstacles to the development and scale-up of ocean energy innovative solutions. However, an effective R&I strategy needs to prioritise the ongoing efforts and also increase the collaborations among private and public stakeholders.

This SRIA updates previous R&I priorities seeking to address five overarching goals by 2030:

- Make ocean energy competitive;
- Reinforce the industrial capacity;
- Fill in the knowledge gaps;
- Increase social and environmental acceptance;
- Improve market confidence and attract investors.

Key Performance Indicators (KPI) should be used to track progress on all these aspects based on international recognised metrics. Examples of KPIs to quantify progress are presented in the following tables for each goal. Further examples of KPIs can be found in the IEA-OES Framework for Ocean Energy Technology[10].

Projects to address these R&I priorities should set SMART objectives, i.e. ones that are specific, measurable, attainable, realistic and timely. There is a diverse range of ocean energy technologies which are constantly innovating and developing, plus there may be different paths to achieve the overarching goals. It is therefore not possible to set particular targets in this document for the whole ocean energy sector over the 6-year period covered by this SRIA. Each funding call should instead establish the right level of ambition.

MAKE OCEAN ENERGY COMPETITIVE (COMPETITIVENESS)

Unleashing Europe's ocean energy potential involves further technological advancements and cost reduction efforts on various domains:

- **Power performance of ocean energy devices:** Improvements in the hydrodynamic capture, the power conversion efficiency and the performance of the associated control (controllability).
- **Operative performance of ocean energy deployments:** Continuous progress in the efficiency of installation processes (installability) and demonstrating reliability and maintainability of ocean energy technologies.
- **Affordability of ocean energy farms:** Cost reductions in the upfront investment, annual operational expenditure and incidentally final energy production costs.

Table 1.1. Examples of KPIs to quantify progress on making ocean energy competitive

Domain	Examples of KPIs to quantify progress
Power performance	• Power capture • Capture length (wave energy), Power coefficient (tidal stream) or equivalent • Power conversion efficiency • Annual Energy Production (AEP)
Operative performance	• Mean Time to Install (MTTI) • Mean Time to Failure (MTTF) • Mean Time to Repair (MTTR) • Availability Factor (AF)
Affordability	• Capital expenditure (CAPEX) • Operational expenditure (OPEX) • Levelised Cost of Energy (LCOE)

10 J. Hodges et al., 'An International Evaluation and Guidance Framework for Ocean Energy Technology', IEA-OES, Oct. 2023. Available: https://www.ocean-energy-systems.org/publications/oes-documents/market-policy-/document/an-international-evaluation-and-guidance-framework-for-ocean-energy-technology/

REINFORCE THE INDUSTRIAL CAPACITY (INDUSTRY)

Ocean energy offers a unique opportunity to build a new industrial sector, created in Europe, generating jobs and economic value in its regions throughout the local supply chains. Reinforcing the industrial capacity with large scale manufacturing and deployment, effective supply chains will enable the economies of scale required to meet the commercialisation target.

- **Manufacturability of ocean energy devices:** Incorporation of advanced manufacturing technologies, lean manufacturing practices and continuous improvement methodologies to obtain faster, cheaper and minimum waste processes, compatible with the supply chain's capability, readiness and maturity.
- **Local content:** Capacity-building initiatives to increase the participation of local industries in the supply chain and quantification of the future socio-economic benefits of ocean energy commercialisation.
- **Technology Push Policies:** Policies that encourage the development and adoption of ocean energy technologies. They can involve funding for R&I, training, tax incentives for innovation or regulations that can help industries to stay competitive by continually innovating and improving their products and processes.

Table 1.2. Examples of KPIs to quantify progress on reinforcing the industrial capacity.

Domain	Examples of KPIs to quantify progress
Manufacturability	• Manufacturing Readiness Level (MRL) • Lead time • Supplier quality
Local Content	• Economic development: Gross Value Added (GVA) and exports • Workforce development: № of jobs • Spillover effects
Technology Push Policies	• R&I policies • Training schemes

Photo: SKF

FILL IN THE KNOWLEDGE GAPS (KNOWLEDGE)

Over the years the research community has developed a broad understanding and knowledge of ocean energy processes. However, there is still untapped knowledge and issues stakeholders are not aware of that can create significant risks and unconscious bias. These are sometimes referred to as 'known unknowns'. Addressing the knowledge gaps will deliver important cost reductions.

- **Strategies to mitigate technical risks:** Gaining experience in critical failure modes and survivability of ocean energy devices.
- **Knowledge exchange:** Sharing information and experiences between different stakeholders in the ocean energy sector can accelerate innovation and learning. Fostering clearer communication among industry players, governments, and investors can help align expectations and facilitate the allocation of funding to technologies.
- **Standardisation:** Establishing common protocols and guidelines for the design, testing, and operation of ocean energy devices ensures that all devices are evaluated on the same criteria, making it easier to compare and contrast different technologies.

Table 1.3. Examples of KPIs to quantify progress on filling the knowledge gaps.

Domain	Examples of KPIs to quantify progress
Technical Risk Mitigation	• Critical Failure Modes • Survivability (Likelihood of exceeding an acceptable level of damage in extreme conditions)
Knowledge Exchange	• Findability • Accessibility • Interoperability • Reusability
Standardisation	• New technical specifications • Compliance with standards (certification)

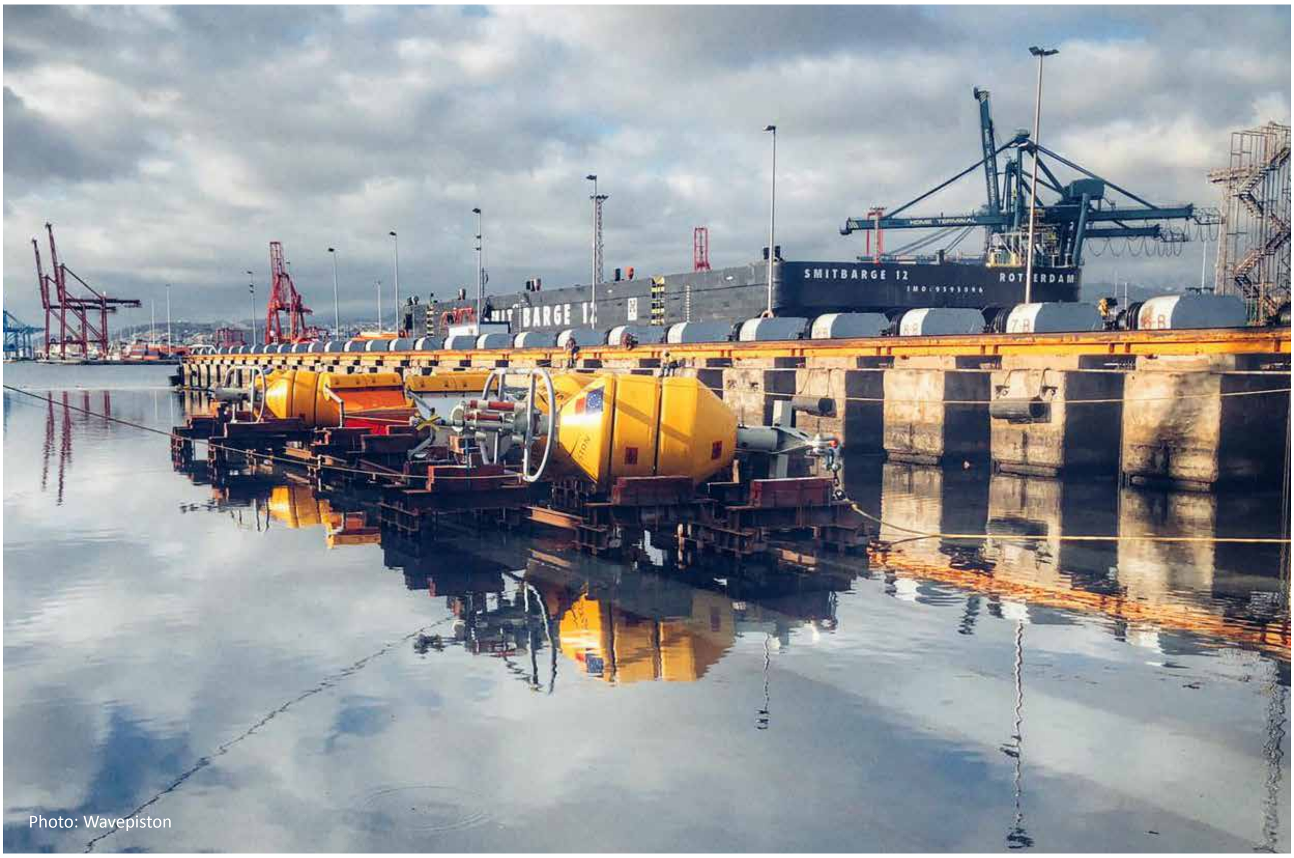


Photo: Wavepiston

INCREASE SOCIAL AND ENVIRONMENTAL ACCEPTANCE (ACCEPTANCE)

Ocean energy acceptability depends on bringing induced benefits for the society, making effective use of natural resources, reducing risks and harms to the operating environment and complying with relevant regulations. Further efforts are needed in the following domains:

- **Life Cycle Analysis:** Evaluation of the sustainability, circularity and other socio-economic considerations of an ocean energy technology.
- **Environmental Impact:** Understanding and mitigating the potential environmental effects of ocean energy technologies & projects.
- **Social Impact:** Fostering positive attitudes towards ocean energy, increasing energy security, providing development opportunities, culture preservation, and demonstrating the return on public funding.

Table 1.4. Examples of KPIs to quantify progress on increasing social & environmental acceptance.

Domain	Examples of KPIs to quantify progress
Life Cycle Analysis	• LCA can include a wide range of impact categories, including: • Global Warming Potential (GWP, kg CO_2eq) • Marine Eutrophication (kg N-eq) • Embodied Energy (MJ) • Cumulative Energy Demand (CED) • Energy Return on Investment (EROI) • Material circularity
Environmental Impact	• Footprint • Pollution • Noise • Energy modification • Electromagnetic fields • Effects on biodiversity
Social Impact	• Technology acceptance • Energy security • Development opportunities • Culture preservation • Cumulative energy produced over project cost

IMPROVE MARKET CONFIDENCE AND ATTRACT INVESTORS (INVESTORS)

Building market confidence is a gradual process that requires multiple efforts and collaboration. Evidence should be provided on the technology maturity, economic viability, market potential, regulatory compliance, as well as demonstration through pilot projects of operational data and additional benefits.

- **Bankability:** Ability of a technology, project of entity to generate enough cash flow to attract financing and investment.
- **Credible technology projections:** Estimating how the cost-efficiency would improve as the cumulative production increases, the planned projects and the potential demand for a specific market.
- **Added benefits:** Ocean energy can contribute to cope with variability and uncertainty in both generation and demand, while maintaining a satisfactory level of reliability at a reasonable cost, over different time horizons.

Table 1.5. Examples of KPIs to quantify progress on improving market confidence.

Domain	Examples of KPIs to quantify progress
Bankability	• Return on Investment (ROI) • Debt Service Coverage Ratio (DSCR) • Feed-In-Tariff (FIT) • Project Risk Allocation
Credible Technology and Market Projections	• Estimated learning rate • Installation pipeline • Target market size
Added Benefits	• Predictability • Out-of-Sync • Dispatchability • Energy security

Photo: AW-Energy

2 Progress in the sector

Photo: Nova Innovation

Ocean energy harnesses energy from the movement of waves and tides, as well as from salinity and temperature differences in the seawater. The different ocean energy technologies are:

- Wave energy — the motion of wind generated waves;
- Tidal stream — free flowing currents;
- Tidal range — impounding the rising and falling tide;
- Ocean Thermal Energy Conversion (OTEC) — capturing temperature differences including Sea-Water Air Conditioning (SWAC) for heating and cooling;
- Salinity gradient — between fresh and salty water.

Ocean energy is currently at demonstration and pre-commercial stage depending on the technology considered. The next five years will be crucial for the sector's progress towards industrialisation. A project pipeline of 167 MW in Europe is publicly supported via EU programmes or national schemes[11], making those projects very attractive for private investors.

11 Ocean energy stats & trends 2023, Ocean Energy Europe, 2024.
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'ONDEP project secures €19M EU funding to deploy WaveRoller Array in Portugal', Ocean Energy Europe, 2024. Available at: https://www.oceanenergy-europe.eu/industry-news/ondep-project-secures-e19m-eu-funding-to-deploy-waveroller-array-in-portugal/.

Tidal stream: Pre-commercial farms in the making

The first multi-device tidal pilot farms have been producing power since 2016, and the most advanced tidal energy companies are preparing to deploy the next tranche of pre-commercial farms. Over the next five years, capacity expansions will be concentrated in leading tidal markets, with projects planned in the UK and France.

In the UK, 121 MW will be added to the grid in Scotland and Wales, supported by the government's Contracts for Difference (CfD) Allocation Rounds AR4, AR5 and AR6, which provide long-term revenue certainty and attract private investments. EU grant funding will also facilitate the addition of 14 MW of new tidal farms in the UK waters through the SEASTAR and EURO-TIDES projects.

In France, a financial package from the government, including a 65 M€ grant plus a feed-in-tariff (level yet to be finalised at the time of writing), will establish the country's first pre-commercial farm with the 17.5 MW FloWatt project in Normandy.

The current development pipeline in Europe could increase to 700 MW by 2028, provided that existing market mechanisms are maintained, and new announcements lead to ambitious actions, especially the support for commercial tidal farms pledged by French President Macron.

Wave energy: Testing and demonstration in real conditions

Several scaled and full-scale wave devices are undergoing testing and demonstration in real sea conditions, after which the next step will be the deployment of the first wave energy pilot farms. These advancements are the result of significant R&I investments over the past decade. This trend is expected to continue, with additional deployments planned in the coming years. Projects will be spread across Europe, showing the technology's versatility and market potential.

While most wave energy deployments have so far consisted of full-scale prototypes, the wave energy sector in Europe is already preparing for the pilot farm stage. This is demonstrated by the launch of the first Horizon Europe calls for European wave pilot farms at the end of 2023, along with support for two wave projects from the Innovation Fund: Saoirse (CorPower Ocean) and SEAWORTHY (Floating Power Plant).

The rest of this section gives some examples on how ocean energy has progressed so far in the five overarching goals defined by the SRIA.

2.1 Competitiveness – Make ocean energy competitive

Ocean energy technologies are not cost competitive yet in comparison to other renewables, but they are making progress year by year. Tidal energy in Europe reached 93 GWh of cumulative electricity production from existing demonstration projects and pilot farms in 2023. These projects and pilot farms are contributing with continued hours of operation which help to improve key factors affecting competitiveness, increasing technology reliability and providing data for optimising maintenance tasks.

CASE STUDY: PROGRESS OF THE MEYGEN PROJECT

One example of this progress is the MeyGen project. Its first phase comprises four 1.5MW turbines installed on gravity foundations and demonstrates that the development of tidal arrays is both commercially viable and technically feasible. The MeyGen site has been operational since 2017, and features SIMEC Atlantis' longest-deployed turbine in continual operation since December 2018, with an average availability of 95% and the invaluable lessons and experience drawn from the construction, installation, operation and maintenance of this phase will be fed into subsequent phases.[12]

The next 2 phases have been already awarded Contracts for Difference (CfD):

- MeyGen Phase 2 in Allocation Round 4 for 28MW with a target commissioning date of 2027. The project will be transformational for the tidal energy industry, delivering the world's first commercial scale tidal array and securing MeyGen as the home of tidal energy.
- MeyGen Phase 3 was successful in AR5 and secured CfD totalling 22MW at a significantly higher strike price than AR4, with a target commissioning date of 2028.

MeyGen future phases would seek to expand the consents and build out a total capacity of 398 MW.

12 Lessons Learnt from MeyGen Phase 1A Final Summary Report. MeyGen Lessons Learnt Full Report_0.pdf (bv.com).

2.2 Industry – Reinforce the industrial capacity

43.8 MW of ocean energy devices have been demonstrated in Europe since 2010. Despite the fact that only 12.75 MW is currently in the water, the decommissioned projects have led to considerable advancements in technological readiness and to develop an industry around ocean energy.

In wave energy, Southern Europe confirms its status as a hotspot for deployments with 4 installations in 2023. This is a consequence of both the excellent resource and the growing policy support, especially along the Atlantic coastline, in some cases deploying national technology, in other cases attracting foreign technology developers, but always developing a local industry. This is the case of the Swedish company CorPower Ocean (CorPower) in Portugal.

CASE STUDY: LOCAL IMPACTS OF THE HIWAVE-5 PROJECT

CorPower successfully installed its first commercial scale wave energy converter in northern Portugal in 2023 as part of its HiWave-5 collaborative project with Portuguese electricity company EDP, SimplyBlue Group and ENEL Green Power, whose aim is to deliver certified and warrantied wave energy devices to the market. This demonstration will be extended within the EU-SCORES project with three further units to complete a 1.2MW wave energy array.

The CorPower C4 device was launched in the port of Viana do Castelo, before being towed to the Aguçadoura site located 4km offshore. After connecting to a pre-installed anchor on the seabed, the device was connected to the Portuguese national grid through a subsea export cable. The system is now undergoing a commissioning programme, with functions and operational modes being gradually verified. Operations and Maintenance methods for offshore service access, device retrieval and tow-back to the on-land service base in Viana do Castelo are also in the test plans. Most of these works are done by local suppliers developing an industry that will be prepared for future deployments of wave energy. Just as an example, CorPower named the Portuguese company Costa & Rego as its 'supplier of the year' in recognition of the role it played in the development of its first commercial-scale wave energy converter. Costa & Rego, established in 1982, delivers metal structure and industrial support equipment for a number of industries.

CorPower is also investing €16 million into a new Research & Development, Manufacturing and Service Centre in Viana do Castelo. The centre will be used for the HiWave-5 pilot project and to supply commercial wave energy farms in the future. This investment plans around 15 engineering jobs for the next three years.

Europe currently has a lead in the ocean energy sector, and so is able to capture significant benefits from developing ocean energy. These include significant GVA and jobs from manufacturing, operation and maintenance, often in remote coastal communities with significant local content, thus facilitating a more just transition.

Photo: Corpower Ocean

Photographer: Marco Mendes

2.3 Knowledge – Fill in the knowledge gaps

Rolling out a new ocean energy industry relies on having access to knowledge in a wide range of fields. These range from basic science, to engineering and design tools, aspects relating to installation, operation and maintenance, tools for policy, economics and financial plus wide-ranging environmental aspects. In some cases, this knowledge can be accessible from other sectors and in other cases it must be specifically generated for ocean energy. In any case, knowledge needs to be shared among different stakeholders and for this, international collaboration is essential since knowledge has no borders.

Collaborative projects funded by the EU typically bring together multiple stakeholders, including industry players, researchers, and supply chain companies. These consortia ensure that project results are shared broadly, benefitting the entire sector. Knowledge dissemination often happens through events like industry conferences, where project outcomes are showcased. For example, several EU-funded projects will be hosting side events at the OEE2024 conference, facilitating collaboration and knowledge exchange across the industry.

Test centres also play a critical role in knowledge sharing. They gain experience from various testing and demonstration projects and apply these lessons to subsequent projects. The European Marine Energy Centre (EMEC), with over 20 years of experience testing ocean energy devices from around the world, exemplifies this approach, continuously improving through the knowledge gained from each project.

Supply chain players from other industries bring valuable expertise to the ocean energy sector by applying their experience to new technologies. For example, SKF, a long-standing supplier of drive trains for the wind energy sector, now works with nearly all tidal energy developers, leveraging their prior knowledge to contribute to the advancement of ocean energy solutions.

CASE STUDY: IEA-OES SHARES KNOWLEDGE INTERNATIONALLY

Ocean Energy Systems (OES), a Technology Collaboration Programme linked to the International Energy Agency (IEA), plays a key role in generating and sharing knowledge internationally. The IEA-OES Work Programme consists of research, development, demonstration, analysis and information exchange related to several key aspects to accelerate ocean energy development and deployment.

Since its creation in 2001, IEA-OES has worked on guidelines for testing and evaluation, grid integration, assessment of environmental effects and monitoring efforts, exchange and assessment of information and experience, cost assessment, jobs creation, wave and tidal modelling, alternative markets or status of OTEC. It has also implemented two databases: one about consenting processes and an interactive web-based GIS mapping application with detailed global information related to ocean energy (facilities, resource, relevant infrastructures and general geographical information).

Photo: EMEC

Photographer: Mike Brookes Roper

2.4 Acceptance – Increase social and environmental acceptance

To ensure ocean energy development is embraced by the public and supports sustainable growth, it must include a social aspect. The sector will make decisions impacting communities, and these decisions should be based on scientific evidence and past experience rather than personal perceptions. Current environmental monitoring points to very low impacts of ocean energy on the environment, whether for mammals or fish, and across the potential pressures considered. Similarly, acceptance among local communities is so far very high, possibly because of the high local economic content of projects, offering opportunities for people and infrastructures. However, more information is always needed and verifiable data is not always available to support all decisions. Therefore, the sector must balance taking some risks with learning from evidence to stay on course and gain more experience.

As the previous section mentioned, the IEA-OES has collaborated on a database[13] of environmental effects of ocean energy and offshore wind. This facilitates the exchange of information and data. It also serves as a commons for marine and wind energy practitioners, enhancing the connectedness of the renewable energy community as a whole.

CASE STUDY: SAFEWAVE PROJECT FACILITATES PERMITTING

In Europe, the SafeWave project[14] is making a notable contribution to social and environmental acceptance of wave energy. The project aims to overcome some of the non-technological barriers that could hinder the future development of ocean energy:

- Environmental risk and uncertainty about the potential environmental impacts of wave energy developments;
- The need for a Maritime Spatial Planning (MSP) approach to overcome the potential competition and conflicts between ocean energy and other marine users;
- Complex and long permitting processes;
- Potential opposition among host communities of future deployments.

One of the main outputs of SafeWave is an update of MARENDATA[15], a data platform designed to provide instant access to marine renewable energy industry-specific information related to resource and impact assessment. MARENDATA, a data provider of European Marine Observation and Data Network (EMODnet), integrates data sets from various sites, providing scientifically robust data on the potential environmental effects of marine energy devices to support consenting and licensing processes. The platform is suitable for both technical and non-technical audiences, making it easy for stakeholders to access detailed information on a particular marine energy project or test site, as well as view data on one or multiple environmental parameters at different test centres. Contributions to this type of data bases from new deployments will reinforce the knowledge on social and environmental progress and then facilitate permitting processes.

SafeWave also develops an education and public participation strategy to work in collaboration with coastal communities in France, Ireland, Portugal and Spain, to co-develop and demonstrate a wave energy education and public participation framework. This framework includes among others a systematic literature review to understand opposition to marine renewable energy and a critical review of education and public participation strategies.

Photographer: Colin Keldie

Photo: Mocean Energy

13 Tethys, Environmental Effects of Wind and Marine Renewable Energy https://tethys.pnnl.gov/.
14 https://www.safewave-project.eu/ er.
15 https://marendata.eu.

2.5 Investment – Improve market confidence and attract investors

Policy signals including deployment targets to improve market visibility, combined with revenue support are essential measures to attract investors. The pipeline of projects developed based on public support such as the UK CfD mechanism is a clear example.

However, the progress to a full commercial ocean energy sector requires early investors ready to assume some risks, albeit under some predictable conditions. Early investors are usually looking for reliable technology and a predictable market. Public investment programmes such as EuropeWave can help to give confidence to future investors by providing real experience and data on global performance, efficiency, reliability, etc. based on international standards and metrics.

Off-grid applications such as Wavepiston project to produce electricity and desalinate seawater in the Canary Islands or the Mocean Energy device to provide subsea power and remote communications off the coast of Orkney are aiming at maturing the technology and attracting other energy sector stakeholders, while providing market insights and learning by doing.

With a medium-long term view, investors need to see a predictable market with a pipeline of projects based on public support such as the UK CfD mechanism or specific designed auctions for ocean energy.

Several promising collaborations between technology developers and industrial investors are already happening in Europe. The below list includes examples of these collaborations and is not exhaustive.

Investor	Technology	Description
TotalEnergies	CorPower Ocean™	TOTAL ENERGIES joined CORPOWER OCEAN's Pilot Access program. • The Pilot Access Program will provide TotalEnergies deep insights into CorPower Ocean's wave technology and its operation through the HiWave-5 pilot at the Aguçadoura site in northern Portugal including comprehensive access to data, results, and operations from the extended test programme, • TotalEnergies will also be able to provide valuable insights to test plans, drawing upon extensive expertise in offshore installation, maintenance and operations.
	mocean energy & verlume	TOTAL ENERGIES joined the Renewables for Subsea Power Project led by Scottish companies MOCEAN ENERGY and VERLUME. • Joining RSP offers TotalEnergies access to all data and results from the extended test program, taking place at a site 5 km east of the Orkney mainland. TotalEnergies will also be able to offer input to test plans and will be provided with a feasibility assessment of the use of RSP technology at a location of their choice.
Shell	ORPC	SHELL purchased two ORPC Modular devices for deployment at a Shell Facility on the Lower Mississippi River in 2024.
	WAVEPISTON	SHELL signed a partnership with WAVEPISTON to identify wave energy opportunities.

Investor	Technology	Description
equinor	HAVKRAFT	EQUINOR signed a partnership with HAVKRAFT to conduct a feasibility study to use wave energy for decarbonisation of offshore operations. • The study exploring the integration of wave power as a sustainable energy source for mobile offshore drilling units (MODUs). • Equinor has engaged Havkraft to conduct a study that will investigate the feasibility of integrating wave power solutions on MODUs, with the goal of significantly reducing operational CO_2 emissions and promoting sustainable development within the industry.
ESB Energy for generations Simply Blue Energy	CorPower Ocean™	State-owned Irish utility ESB and leading Irish renewable developer SIMPLY BLUE created a joint venture to deliver a 5 MW wave energy pre-commercial farm off the coast of County Clare in Ireland.
engie	ORBITAL MARINE POWER sweetch energy	ENGIE Research & Innovation's branch Laborelec joined ORBITAL MARINE POWER's EURO-TIDES tidal farm project. ENGIE is also a shareholder of Compagnie Nationale du Rhône that has created a joint venture with the salinity gradient company Sweetch.
Qair	HydroQuest	French utility QAIR continues its collaboration with tidal developer HYDROQUEST to deliver the FloWatt project off the coast of Normandy.
sev	Minesto	Faroe Islands utility SEV extended its partnerships with Swedish tidal company MINESTO • PPA between Minesto and SEV is now updated and renewed for two more years after approval from the Energy Agency in the Faroe Islands (Orka). • The PPA covers the capacity of the three tidal power plants in Vestmanna and is an extension of the first off-taker relationship in the world where energy from Minesto's unique tidal energy dragons is supplied.
Ørsted	WAVEPISTON	WAVEPISTON has recently signed a project partnership with Ørsted for the investigation of co-location of offshore wind and wave energy in Danish waters.

Photo: HydroQuest

3 Methodology

Photo: Minesto

To update the SRIA a comprehensive review of ocean energy research and innovation (R&I) projects was conducted in 2023, led by The University of Edinburgh[16]. This was a collaboration between the Supergen ORE Hub, SEETIP Ocean[17], and the European Energy Research Alliance (EERA). The review covered those projects funded by the Commission, Member States, and other national and regional bodies, with a grant of >€100k. It included only those active in or after 2022, thus excluding projects that were largely completed prior to publication of the previous SRIA in mid-2020. The funded projects identified were compared with the recommendations of the 2020 SRIA.

The gap analysis highlights a reasonable progress regarding funding (74%) compared to the 2020 SRIA recommendation. However, the projects funded have been smaller than was proposed in the SRIA. Furthermore, just over a quarter of the projects identified did not align well with the priority topics in the six challenge areas of the SRIA, suggesting the previous scope was too narrow. A summary of the results by previous Challenge Area is given in Figure 4.1, but the report has significantly more detail[16].

16 P. W. Wong and H. Jeffrey, 'Research and Innovation for Wave and Tidal Stream in the UK and EU A 2023 Summary', Supergen ORE, Aug. 2023. Available: https://www.policyandinnovationedinburgh.org/policymakers-toolkit.html.

17 Support to SET Plan Implementation Working Group and European Technology and Innovation Platform for Ocean Energy, Horizon Europe Grant agreement № 101075412.

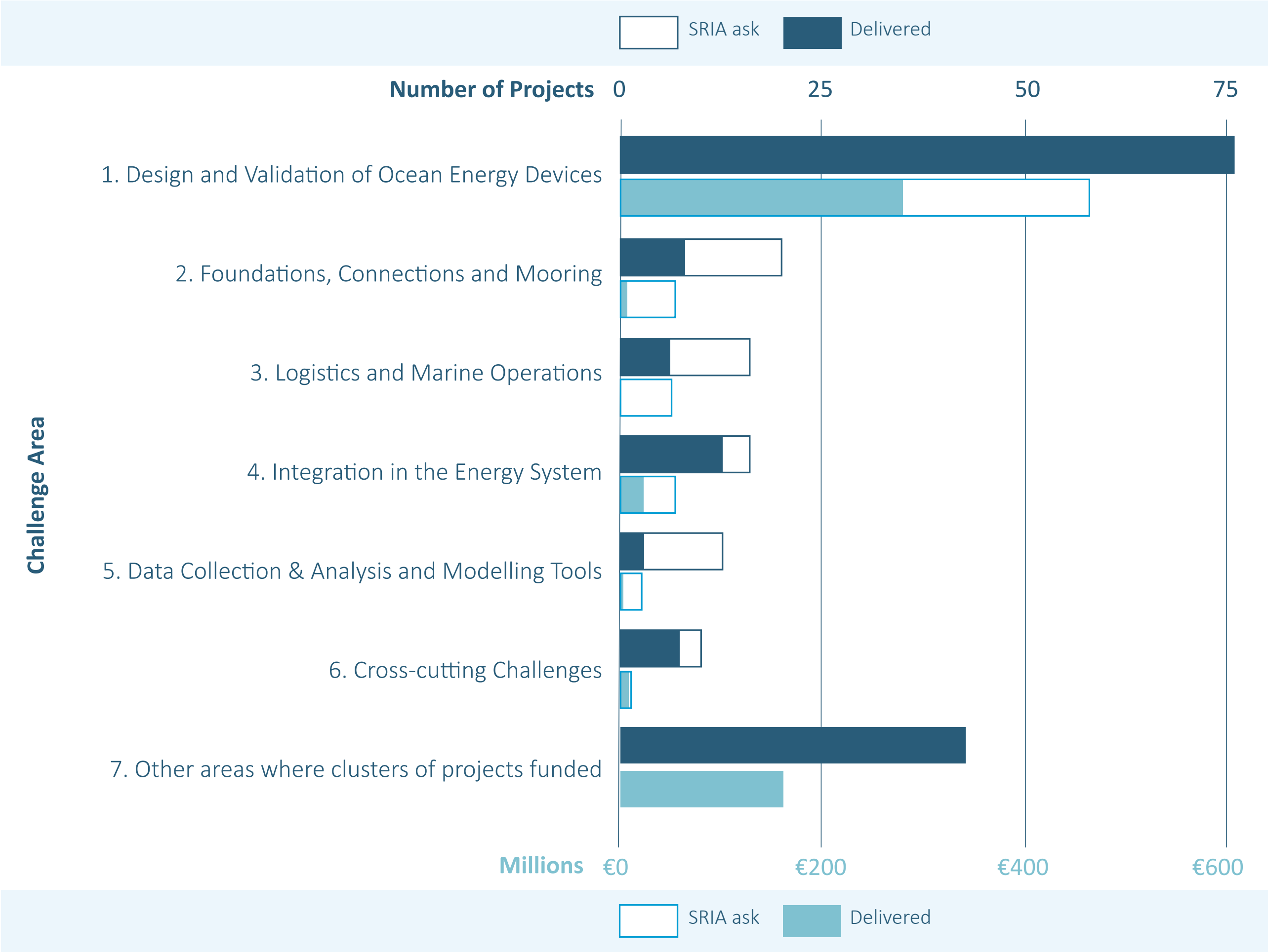

Figure 4.1. Number of projects funded (top bars) and total public funding committed (bottom bars), by SRIA Challenge Area.

Building on this result, a wide range of potential priority R&I topics were discussed with ocean energy sector stakeholders and representatives through an ETIP Ocean Technology Working Group (TWG). An introductory meeting, followed by a series of three online workshops each with themed breakout groups, were held with the TWG. An in-person workshop was held alongside the Ocean Energy Europe annual conference (OEE2023) to validate the discussions with the TWG and collate additional feedback from conference attendees. A questionnaire was then sent to the TWG, and participants at the OEE workshop were also invited to contribute.

The output from this consultation was used to inform the update of the SRIA with regrouped and refocused main Challenge Areas and corresponding Priority Topics to address the 2030 targets for the sector. Overall, the feedback from ocean energy stakeholders has confirmed that both the topics in the 2020 SRIA and the additional topics identified in the review of R&I projects are all still a priority for the sector. None of the discussions with the TWG suggested these topics have been fully addressed or completed; all still require future funding to facilitate further development within the sector, such as reduced cost and improved performance.

After having regrouped the Challenge Areas and corresponding Priority Topics, a further round of consultations was held in 2024 through online meetings and another questionnaire both with the ETIP Ocean TWG and with European, national and regional representatives of public funders through the Implementation Working Group on Ocean Energy. All the feedback from the R&I objectives and their practical implementation was collated and presented in a final validation meeting with ETIP Ocean representatives.

Photo: CalWave

4 Description of Challenges

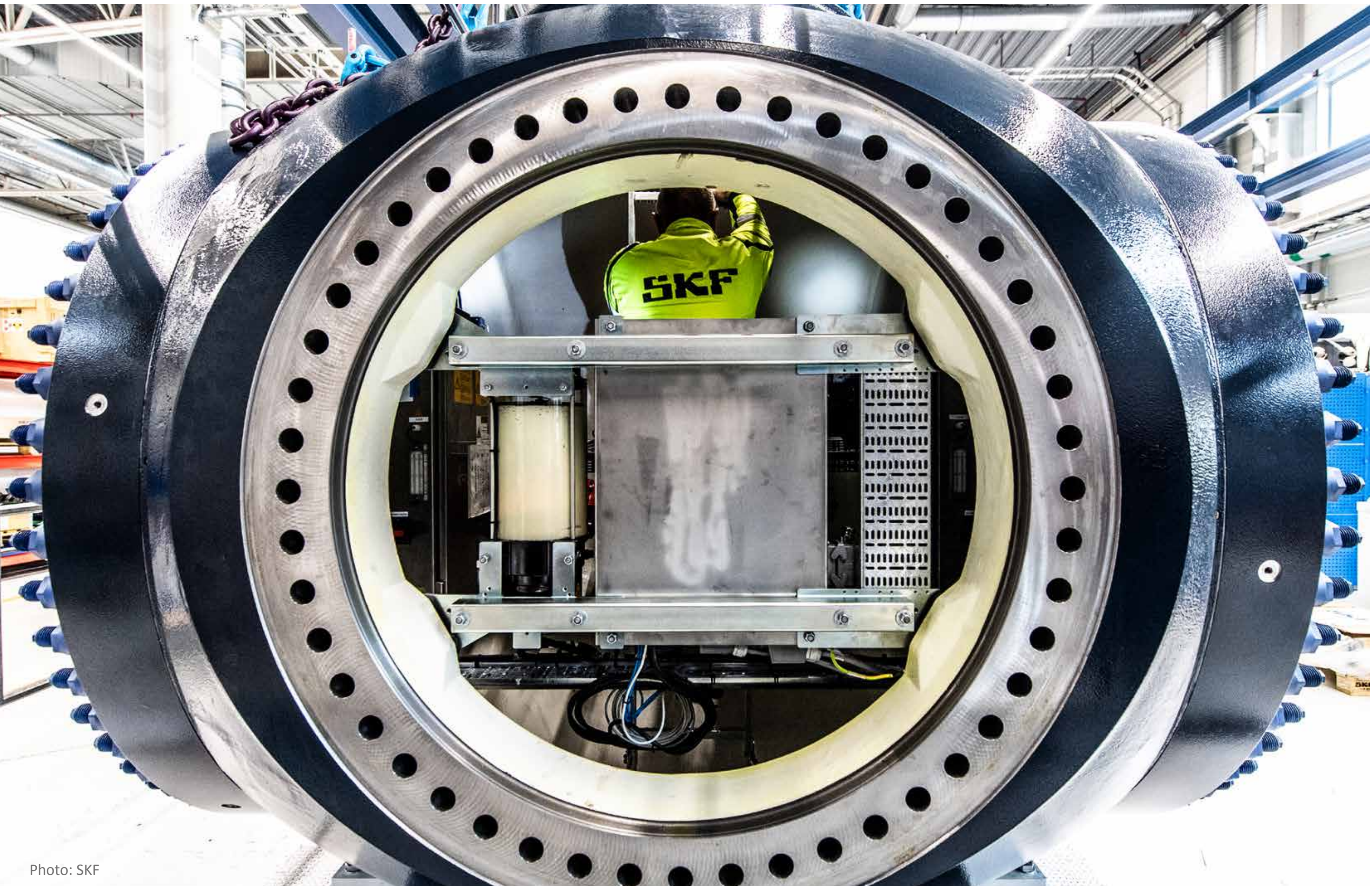

Photo: SKF

The Challenge Areas represent the set of R&I fields that the ocean energy sector has identified as requiring investment in the period 2025 to 2030. As described in the previous section, the Challenge Areas have been identified taking into account sector progress and findings from an extensive consultation with ETIP Ocean's Technology Working Group.

The ocean energy professionals agreed on grouping the sector's priorities in six Challenge Areas structured in three main layers, as shown in Figure 4.1.

On top lies the design and validation of ocean energy farms, which is considered most crucial by the ocean energy industry and research professionals. The Challenge Area focuses on the demonstration of pilot farms and single devices, which includes site-specific issues such as logistics, mooring and foundations, data collection or environmental monitoring.

The mid layer comprises four Challenge Areas, building blocks that aim to foster increasing levels of technology cost-efficiency and maturity, exchanging results with the overlying Challenge Area:

- Next generation of technologies and subsystems,
- Analysis and modelling tools,
- Integration of enabling technologies, and
- Ocean energy market development.

At the bottom, a cross-cutting challenge area collects results from the design and validation of ocean energy farms and feeds back the learnings. It comprises different types of support actions ranging from sharing data and experience to standardisation, upgrading facilities, coordinating sector efforts or capacity building.

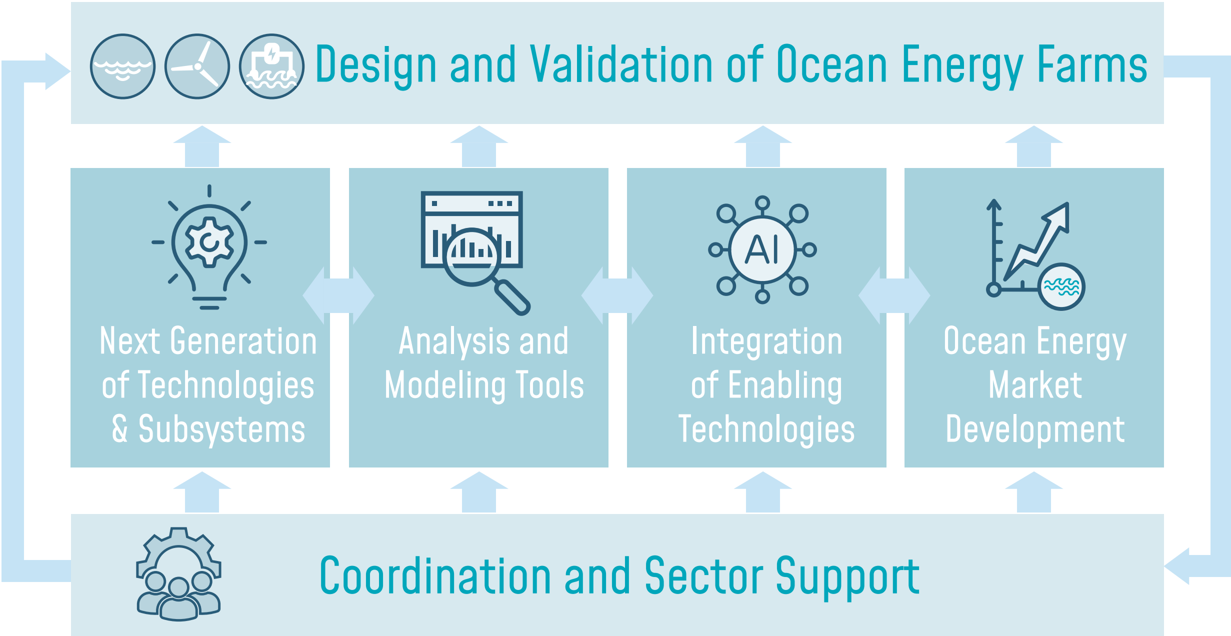

Figure 3.1. Illustration of New Challenge Areas.

There are common principles that apply to multiple Challenge Areas and Priority Topics, such as:

- **Increase** the participation of local industries in the supply chain.
- **Assess** the sustainability and circularity of ocean energy technologies.
- **Understand and mitigate** any potential environmental effects.
- **Quantify** the future socio-economic benefits of ocean energy commercialisation.
- **Foster** clear communication among industry players, governments and investors.
- **Share** information, experiences and data between different stakeholders.
- **Disseminate** both promising and disappointing outcomes.
- **Respect** the protection of company IP.
- **Use** recognised international assessment frameworks.
- **Establish** common protocols and guidelines.
- **Provide** credible pathways for future technology development.
- **Contribute** to increasing energy security.

In addition to these principles, funded projects should demonstrate a wider impact on the European political priorities.

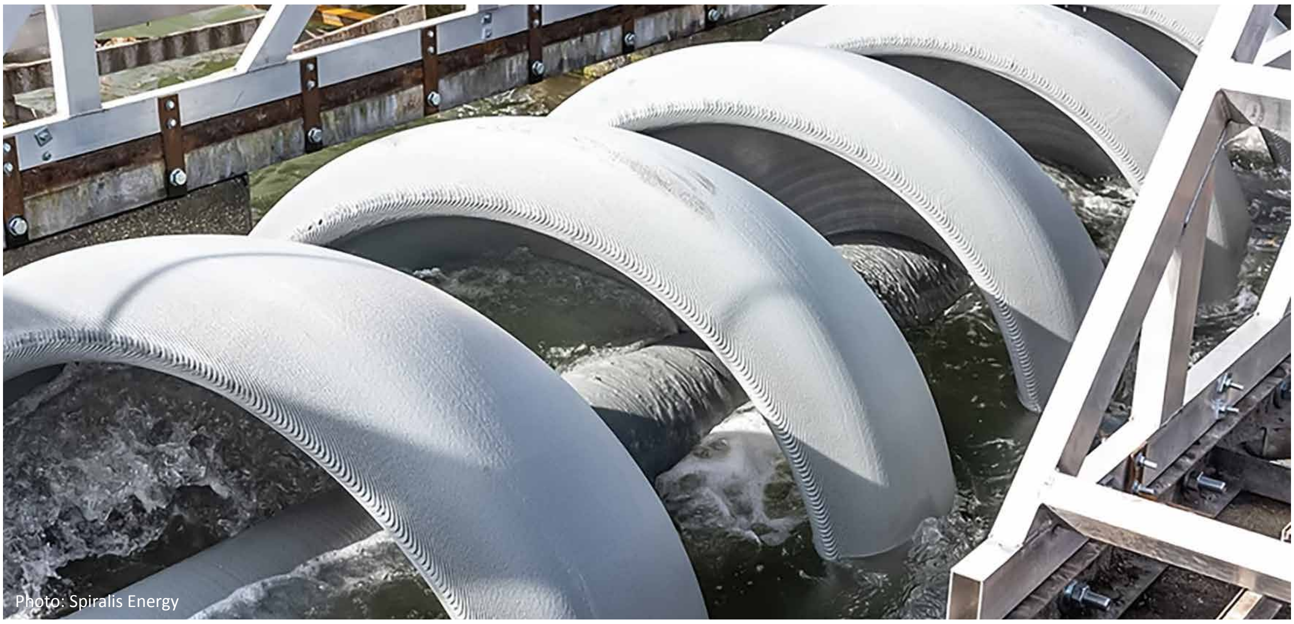
Photo: Spiralis Energy

Table 4.1 summarises the 6 Challenge Areas and 18 Priority Topics of the SRIA. The following subsections describe the specific scope and Actions of each Priority Topic and Challenge Area. The topics are not ordered, all are considered a priority for the ocean energy sector over the next five years.

Table 4.1. List of Challenge Areas and Priority Topics of the SRIA.

Challenge Areas	Priority Topics
I Design and validation of ocean energy farms	**I.1** Demonstration of pilot farms
	I.2 Demonstration of single devices
	I.3 Design and validation of other ocean energy technologies
II Next generation of technologies and subsystems	**II.1** Disruptive wave energy devices
	II.2 Innovative PTO and control systems
	II.3 Advanced moorings, foundations and power connections
III Ocean energy analysis and modelling tools	**III.1** Advanced simulation of ocean energy subsystems and devices
	III.2 Analysis and planning tools for ocean energy farm deployment
	III.3 Modelling and simulation of farm construction and operation
IV Integration of enabling technologies	**IV.1** Innovative materials and manufacturing processes
	IV.2 Application of latest instrumentation and sensor technology
	IV.3 Use of artificial intelligence and big data
V Ocean energy market development	**V.1** Application of ocean energy in off-grid markets
	V.2 Demonstrating grid-scale benefits of ocean energy
	V.3 Co-location of multiple technologies
VI Coordination and sector support actions	**VI.1** Coordinating sector efforts
	VI.2 Accessing and upgrading testing facilities
	VI.3 Support to ocean energy sector development

4.1 Design and validation of ocean energy farms

Ocean energy devices must be deployed and operated at sea for significant periods to optimise design and performance, and to validate business models for investors. This includes the demonstration of single devices and of pilot farms, scaled and full-scale, as shown in Table 4.2.

This Challenge Area is a crucial area to focus on for projects and funding. Despite increased levels of activity in the period between 2020-2024, the sector agrees that the Challenge Area has only been partially addressed and more R&I is needed. Success in this Challenge Area will be crucial in delivering ocean energy farms that begin to crystallise the huge potential of the sector, at a scale that impacts Europe's energy independence and sustainability.

While the primary focus of this challenge is the demonstration of wave and tidal stream technologies, the challenge supports design optimisation of other ocean energy technology, such as ocean thermal energy conversion, seawater air conditioning and salinity gradient power.

Projects address R&I needs of generating devices as well as site-specific issues such as logistics, mooring and foundations, data collection or environmental monitoring. Funders may choose to split calls by technology (wave, tidal, other) since they are at different stages of maturity.

Table 4.2 provides an overview of the Priority Topics, applicability, TRL and budget that needs to be deployed within the 6-year period covered by the SRIA to successfully address them.

Table 4.2. Priority Topics on Design and Validation of Ocean Energy Devices.

Priority Topics	APPLICABILITY	TRL	BUDGET REQUIRED (M€)
Demonstration of pilot farms	Wave / Tidal	6-9	600
Demonstration of single devices	Wave / Tidal / Other	6-8	162
Design optimisation of other technologies	Other	4-8	26

4.1.1 Demonstration of pilot farms

CONTEXT

Several wave and tidal devices have now been successfully demonstrated in real open-sea conditions, including some devices operating near-continuously over several years. The next step to meet 2030 targets is pilot/pre-commercial demonstration. This will require overcoming new challenges, particularly operating devices at acceptable cost over the break-even time for investment. Projects at this stage are expected to raise private funds, but public support is still needed as initial cost of energy will not be competitive.

MAIN IMPACTS

Competitiveness | Industry | Acceptance | Investment

APPLICABILITY

Wave | Tidal Stream

SCOPE OF ACTIONS

Public support should be conditional to significant private participation. The objective of public support here is to de-risk all aspects of the project, and thus reduce costs, as some costs (e.g. debt interest) are not related to the individual device design and its operation. Those represent major uncertainties, largely out of the field of expertise of ocean energy device developers, but that greatly impact the cost of capital. The device design to be used in the pilot farm is expected to have been satisfactorily demonstrated before entering this action, though changes to incorporate the learnings from prior projects should be allowed. Pilot farms must be connected to the electricity grid. Demonstrations should incentivise continuous power production while respecting the existing environmental regulatory framework.

- Fabrication, deployment and operation of multiple units (IEA-OES Stage 5 activities).
- The innovation component should mainly lie on the farm systems (e.g. shared mooring, foundations and electrical connection) and supporting industrial activities (e.g. industrial design, manufacturing processes, installation methods, operation and maintenance).
- Includes a go/no-go decision ahead of entering the fabrication phase. The qualification process should include extensive technical and financial viability assessment, certification and project risk allocation, since these are typical requirements to raise private capital.
- Support should incentivise operation in real conditions for a period of at least five years.
- Public support should be conditional on sharing of data and experience of the pilot farm and its monitoring.
- Explore synergies of projects with marine biodiversity and other socio-environmental benefits.

EXPECTED OUTCOMES

- Improved power and operative performance of the ocean energy farm, including cumulative energy production and total system availability.
- Increased understanding, predictability and outcomes of operations and maintenance operations for ocean energy farms.
- Increased affordability of ocean energy farms.
- Data from the deployed project suited to validation and improvement of modelling tools that enable farm operation and future farm planning (see Challenge III).
- Demonstrated global socio-economic impacts and local benefits of large-scale ocean energy deployment.
- Evidence and credible KPIs to support techno-economic models, business cases and to lower perceived risk to acceptable levels for private investors.

IMPLEMENTATION

TRL	6-9	NO. OF PROJECTS	10
TYPE OF ACTION	DEMONSTRATION	SIZE OF PROJECTS[18]	LARGE & VERY LARGE

18 Please refer to the Definitions for indicative project sizes.

4.1.2 Demonstration of single devices

CONTEXT

Successful demonstration at-sea is the major milestone after which a device is sufficiently de-risked to access pilot farm or pre-commercial opportunities. Particularly for wave devices, experience has shown that at-sea deployment is a key enabler of learning, where unforeseen challenges, costs, and new solutions are revealed, including to improve performance and cut costs. Consequently, at-sea testing is now required to validate business models for investors. However, at-sea testing is often the "valley of death" of innovations in the ocean energy sector: too risky for most investors, and too expensive for developers to finance on their own. As in other sectors, SMEs and micro-companies are often the fastest movers and best innovators; but unlike in many other sectors, product demonstration is far too expensive for these SMEs. Public support is therefore vital to help ocean energy innovators cross the valley of death.

MAIN IMPACTS

Industry · Knowledge · Acceptance · Investment

APPLICABILITY

Wave · Tidal Stream · Other Ocean

SCOPE OF ACTIONS

To qualify for support, projects should have high potential for improved power performance, reliability, availability, maintainability, and survivability compared to previous iterations of the same device. Extensive prior lab and tank testing of all critical components and subsystems is required to qualify. The deployment site should have been assessed following international standards. Demonstration must be undertaken at a reasonably large scale suitable to test performance in realistic open-sea conditions.

- Detailed design, fabrication, deployment and operation of new large-scale prototypes (IEA-OES Framework Stage 3 activities) and first-of-a-kind full-scale prototypes (Stage 4 activities).
- At-sea demonstration of single generating devices will include site-specific components and systems, as well as data collecting instruments and offshore operations.
- Development and application of standardised, independent costs and performance assessment based on internationally recognised evaluation procedures and metrics (overlaps with Priority Topic VI.1).
- Includes a go/no-go decision ahead of entering the fabrication phase, i.e. a third-party review of technical and financial viability of projects.
- Support should require operation for several years of deployment, to validate the technology over a duration approaching the break-even time of commercial deployments.
- Public support should be conditional on sharing of data and experience such as metocean, power and operative performance, actual costs, or social and environmental assessments.

EXPECTED OUTCOMES

- Validated performance, operation and maintenance characteristics of the device.
- Demonstrated maturity of the technologies and manufacturing processes including production cost, quality and yield targets.
- Increased findability, accessibility, interoperability and reusability of the demonstration datasets, respecting the protection of company IP.
- Demonstrated sustainability, circularity and other socio-economic considerations of ocean energy deployment.
- Improved knowledge of positive and negative socio-environmental impacts.
- Evidence and credible KPIs to support techno-economic models, business cases and to lower perceived risk to acceptable levels for private investors.

IMPLEMENTATION

TRL	6-8	NO. OF PROJECTS	16
TYPE OF ACTION	DEMONSTRATION	SIZE OF PROJECTS	SMALL, MEDIUM & LARGE

4.1.3 Design and validation of other ocean energy technologies

CONTEXT

Other ocean energy technologies include Ocean Thermal Energy Conversion (OTEC), salinity gradient, Sea-Water Air Conditioning (SWAC), and tidal range. OTEC in particular has high generation potential baseload capacity and predictability. However, in Europe, its potential is limited to outermost regions and islands in tropical areas. SWAC is deployed in southern Europe and its expansion could significantly reduce the expected rise in electricity demand for cooling. These technologies are at varying degrees of development: OTEC and salinity gradient are at the R&I stage, whereas SWAC and tidal range can be rolled out in suitable locations.

MAIN IMPACTS

Knowledge
Acceptance

APPLICABILITY

Other Ocean

SCOPE OF ACTIONS

OTEC and Salinity Gradient require more basic research and manufacturing experience to reduce cost, whereas support for SWAC and Tidal Range should focus on capitalising on existing know-how and upscaling.

<table>
<tr><td rowspan="2">OTEC</td><td>Closed-cycle
Development of existing solutions and promising innovations, and the business case for applications in remote locations, particularly those in hydric stress for freshwater production.</td><td rowspan="3">Assess potential biodiversity or fisheries co-benefits from the upwelling of nutrient-rich cold water.
Assess opportunities for synergies with EU objectives and programmes for remote tropical islands and regions case for investors, and raise coastal settlements’ awareness of its benefits.</td></tr>
<tr><td>Open-cycle
Basic research, as well as novel engineering, manufacturing and deployment solutions for cold water pipes and heat exchangers.</td></tr>
<tr><td>SWAC</td><td>Pilot projects to expand scope of application and SMEs participation and know-how.
Independent assessment of existing and new projects costs and performance to provide a convincing business case for investors, and raise coastal settlements’ awareness of its benefits.</td></tr>
<tr><td>Salinity Gradient</td><td colspan="2">Basic research on membranes performance and non-membrane emerging technologies (e.g. hydrophobic nanoporous powder).
Improvement of manufacturing readiness and performance of membranes.</td></tr>
<tr><td>Tidal Range</td><td colspan="2">Better understanding of the environmental impact on sensitive inter-tidal zones.</td></tr>
</table>

EXPECTED OUTCOMES

- Improved knowledge in the critical failure modes and survivability.
- Increased findability, accessibility, interoperability and reusability of the demonstration datasets, respecting the protection of company IP.
- Contribution to establishing common protocols and guidelines for the design, offshore testing and operation of ocean energy devices.
- Credible cost and performance projections.
- Improved knowledge of positive and negative socio-environmental impacts.

IMPLEMENTATION

TRL	4-8	NO. OF PROJECTS	9
TYPE OF ACTION	APPLIED RESEARCH & DEMONSTRATION	SIZE OF PROJECTS	VERY SMALL, SMALL & MEDIUM

4.2 Next generation of technologies and subsystems

New ideas and concepts for capturing ocean energy are constantly emerging and evolving, and they coexist with the incremental development of more mature alternatives. Thanks to the high level of activity in the period between 2020-2024, projects have brought technologies from concept to prototype. The most promising ones can pass to the next stages of development with the demonstration and validation in the ocean environment (Challenge Area I). However, as with all sectors, there are still opportunities for innovation with long-standing impact on the SRIA goals.

Hence, the topics of this Challenge Area focus on significant improvements in device concepts and critical subsystems (see Table 4.3) that will propel future ocean energy competitiveness and fill in the knowledge gaps. The aim is to develop technologies, subsystems and components that demonstrate high potential for significant reduction in cost, risk and maintenance; and where possible can be used by a wide range of developers.

Table 4.3 provides an overview of the Priority Topics, applicability, TRL and budget that needs to be deployed within the 6-year period covered by the SRIA to successfully address them.

Table 4.3. Priority Topics on Next Generation of Technologies and Subsystems.

Priority Topics	APPLICABILITY	TRL	BUDGET REQUIRED (M€)
Disruptive wave energy devices	Wave	1-5	54
Innovative PTO and control systems	Wave / Tidal	4-8	45
Advanced moorings, foundations and power connections	Wave / Tidal / Other	4-8	73

Photo: BiMEP

4.2.1 Disruptive wave energy devices

CONTEXT

Unlike wind power where the three-blade horizontal axis turbine emerged as a clear winner, in wave power there is still a diversity of concepts being explored and assessed. The sector is still at a stage where some of the less mature or yet to be invented concepts may deliver disruptive improvements in performance or cost. Public support is required to foster new technologies where researchers and engineers have the opportunity invent new solutions that offer the potential for a step-change improvement in LCOE.

MAIN IMPACTS

Competitiveness

Knowledge

Acceptance

APPLICABILITY

Wave

SCOPE OF ACTIONS

In the context of this Priority Topic, public support should not focus on concepts that have previously been tested, for example large-scale devices (rigid and high cost) that concentrate load onto small areas and conventional electromagnetic generators. Instead, the focus should be on new low TRL concepts, which are completely different to the technologies that exist today, be highly survivable, environmental acceptable and exhibit the potential for significant reductions in LCOE.

- A range of small grants to incentivise the exploration of multiple radical innovations.
- Development of enabling technologies (e.g. materials and modular generators) required to unlock disruptive wave concepts (link to Challenge Area I.IV).
- Concept development (IEA-OES Stage 1 activities) and design optimisation (IEA-OES Stage 2 activities) of breakthrough wave energy technologies.
- Develop novel solutions to improve manufacturability, installation and maintenance, as well as to complement non-technical challenges such as consenting, environmental impact, critical raw material use, and circularity.
- Develop novel solutions that complement non-technical challenges such as consenting, environmental impact, critical raw material use, and circularity.
- Projects should implement a rigorous development plan in accordance with international procedures for wave energy technology development.

EXPECTED OUTCOMES

- Demonstrated readiness, suitability and robustness of underlying technologies.
- Improved knowledge in the critical failure modes and survivability of ocean energy devices.
- Increased findability, accessibility, interoperability and reusability of the research datasets, respecting the protection of company IP.
- Contribution to establishing common protocols and guidelines for the design, testing and operation of ocean energy devices.
- Improved knowledge of positive and negative socio-environmental impacts.
- Credible cost and performance projections for disruptive wave devices.

IMPLEMENTATION

TRL	1-5	NO. OF PROJECTS	20
TYPE OF ACTION	BASIC RESEARCH & APPLIED RESEARCH	SIZE OF PROJECTS	VERY SMALL, SMALL & MEDIUM

4.2.2 Innovative PTO and control systems

CONTEXT

A Power Take-Off system (PTO) is used to convert the kinetic energy captured by the device to electricity. PTOs are a significant expenditure for most concepts, usually requiring highly customised or entirely new components and parts. In wave energy, for example, PTOs must effectively and efficiently deal with low speed-high torque (and at times reversing) motions, in direct contrast to wind energy generators and other more mature generator technology optimised for higher speed, lower torque and single direction dynamics. PTOs must optimise interaction of the mechanical drivetrain, electric generator, and control software, a complex multi-physics process. Further, control systems are used to maximise energy conversion, which essentially means maximising PTO force over the device motion, and thereby profoundly modifying device hydrodynamic response. Progress in PTO performance, cost, reliability and controllability will significantly enhance the business case for ocean energy. This will require significant upstream R&I for which public support remains vital.

MAIN IMPACTS

Competitiveness, Industry, Knowledge, Investment

APPLICABILITY

Wave, Tidal Stream

SCOPE OF ACTIONS

PTOs for turbine-type tidal stream devices need innovations that improve reliability, reduce maintenance, and improve control strategies. For other tidal stream devices and most wave devices, the potential for a step-change in performance with new PTO concepts should also be explored as well as incremental innovations over existing system. The complexity of multi-physics non-linear interactions mean that test rigs, including hardware in the loop or hydrodynamics in the loop, are indispensable to calibrate numerical models and control strategies.

- Develop device-specific PTO or control innovations for those devices that have demonstrated high potential.
- Develop PTO innovations for components or control strategies that can be used by several devices or device types where possible.
- For earlier-stage research on PTO and control systems support tests using hardware-in-the-loop or hydrodynamics-in-the-loop test rigs with existing facilities, where possible using existing facilities (linked to topic VI.2 if new facilities needed).
- For later-stage, also support testing of near-full-scale PTOs for long periods in realistic conditions to assess their reliability.
- Support efforts for standardisation, modularity, inter-operability, and scalability (overlap with Priority Topic VI.1).
- Assess opportunities to improve circularity and reduce use of critical raw materials.

EXPECTED OUTCOMES

- Improved power and operative performance of the PTO, including its conversion efficiency and availability.
- Demonstrated maturity of the manufacturing processes including production cost, quality and yield targets.
- Improved knowledge in the critical failure modes and survivability of ocean energy devices.
- Increased findability, accessibility, interoperability and reusability of the datasets, respecting the protection of company IP.
- Contribution to establishing common protocols and guidelines for the design, testing and operation of ocean energy devices.
- Credible cost and performance projections.

IMPLEMENTATION

TRL	4-8	NO. OF PROJECTS	9
TYPE OF ACTION	APPLIED RESEARCH & DEMONSTRATION	SIZE OF PROJECTS	VERY SMALL, SMALL & MEDIUM

4.2.3 Advanced moorings, foundations and power connections

CONTEXT

Moorings, foundations, and power connections used by ocean energy devices represent a significant part of their cost. Compared to those of offshore oil and gas or wind, ocean energy devices require significantly smaller moorings or foundations, but many more of them per unit of power, as well as smaller vessels and new installation procedures. Dynamic electrical cables and pipelines are typically subjected – on a daily basis – to extreme drag forces for floating tidal devices, and to extreme fatigue cycles for floating wave devices. Protecting cables for bottom-fixed tidal devices may require new solutions as trenching is expensive in rocky seabed. Rapid mechanical or electrical connection would enable new maintenance strategies that lower cost of energy. Subsea or floating hubs to facilitate connection of multiple devices to one export cable will be required as arrays of ocean energy devices are deployed. Electrical connections particularly offer opportunities to develop standard solutions that work for multiple devices or technologies.

MAIN IMPACTS

Competitiveness | Industry | Knowledge | Investment

APPLICABILITY

Wave | Tidal Stream | Other Ocean

SCOPE OF ACTIONS

Public support should focus on solutions that may be shared by many devices or on device-specific solutions that are likely to be required where the device has shown high potential in standardised assessment procedures. Solutions are needed for floating and bottom-fixed devices, plus those mounted on other support structures.

- Design and testing of innovative shoreline support structures, bottom-fixed foundations, anchoring systems, mooring configurations, or power connection topologies adapted to ocean energy.
- Develop new solutions lowering the cost of connection and disconnection of mooring and power lines.
- Develop integrated station keeping and power connection solutions.
- Design of electrical cables and connection systems adapted to ocean energy requirements:
  - For floating devices: validated for many more fatigue cycles and switchgear tolerating high inertial loads;
  - For bottom-fixed devices: alternatives to trenching for protection and dynamic cables designed for extreme drag.
- Design and installation of improved bottom-fixed foundations and coastal defence-integrated support structures for ocean energy devices. Improvement may be on cost, performance, or sustainability.
- Standardisation, modularity and inter-operability of these products (overlap with Priority Topic VI.1).

EXPECTED OUTCOMES

- Increased reliability and affordability of ocean energy technology.
- Demonstrated maturity of the manufacturing processes including production cost, quality and yield targets.
- Improved knowledge in the critical failure modes and survivability of ocean energy devices.
- Increased findability, accessibility, interoperability and reusability of the datasets, respecting the protection of company IP.
- Contribution to establishing common protocols and guidelines for the design, testing and operation of ocean energy devices.

IMPLEMENTATION

TRL	4-8	NO. OF PROJECTS	12
TYPE OF ACTION	APPLIED RESEARCH & DEMONSTRATION	SIZE OF PROJECTS	VERY SMALL, SMALL, MEDIUM & LARGE

4.3 Ocean energy analysis and modelling tools

The accuracy and affordability of analysis and modelling tools has a direct impact on the innovation and development process of ocean energy. Business cases are critically dependent on model predictions of energy yield (revenue) and of device and system reliability. Device developers thus rely on validated models to assess performance, optimise design, and evaluate new solutions in the early stages. Developers and investors require robust tools to predict array performance, optimise farm design, and plan and manage construction and operation.

There has only been a moderate level of activity in this Challenge Area in the period between 2020-2024, therefore the sector agrees it has only been partially addressed and more R&I is needed.

The Priority Topics of this Challenge Area focus on software tools (see Table 4.4) provides an overview of the Priority Topics, applicability, TRL and budget that needs to be deployed within the 6-year period covered by the SRIA to successfully address them.

Table 4.4 that may build on, or complement, existing analysis and modelling tools used in ocean energy and other related sectors. These can be open-source or proprietary tools. Whenever possible, tools should help developers assess progress based on KPIs. To that purpose, the IEA-OES evaluation framework can be a useful starting point for early-stage developers, helping to guide their technology development.

Table 4.4 provides an overview of the Priority Topics, applicability, TRL and budget that needs to be deployed within the 6-year period covered by the SRIA to successfully address them.

Table 4.4. Priority Topics on Ocean Energy Analysis and Modelling Tools.

Priority Topics	APPLICABILITY	TRL	BUDGET REQUIRED (M€)
Advanced simulation of ocean energy subsystems and devices	Wave / Tidal / Other	1-5	29
Analysis and planning tools for ocean energy farm deployment	Wave / Tidal	4-8	33
Modelling and simulation of farm construction/operation	Wave / Tidal	4-8	27

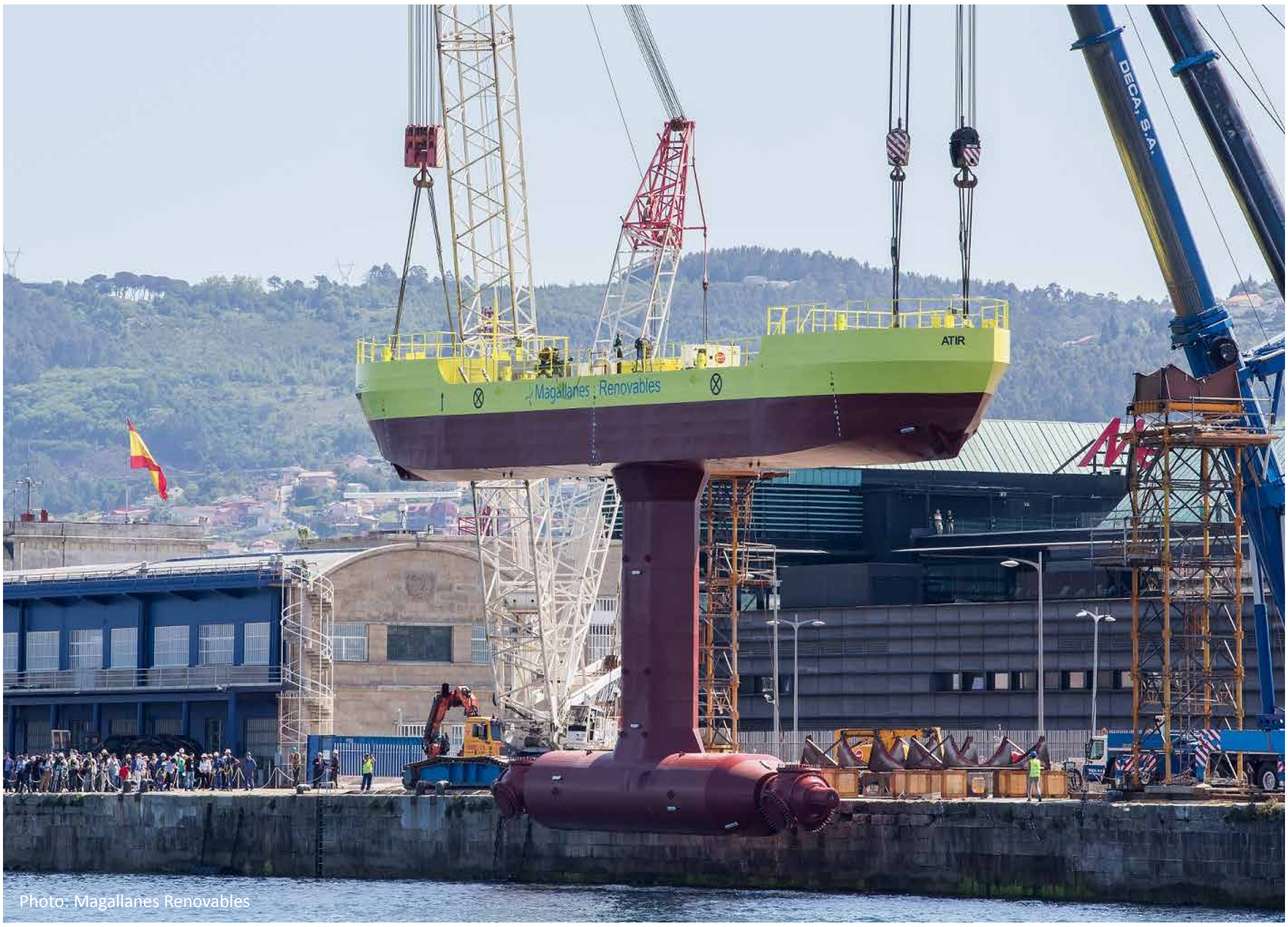

Photo: Magallanes Renovables

4.3.1 Advanced simulation of ocean energy subsystems and devices

CONTEXT

Accurate and computationally affordable numerical models of ocean energy devices and subsystems are critical to every aspect of innovation, development and investment. This is particularly true of this sector because at-sea testing and even tank-testing is a large investment for developers. These models combine multiple bodies and multiple physics in highly non-linear interaction, and usually need to be calibrated with physical models, ideally at-sea but often initially in lab tanks and with test rigs including hardware in the loop or hydrodynamics in the loop. Progress in numerical modelling of ocean energy devices would benefit the entire sector, but necessitates basic research upstream of the scope of privately-led initiatives.

MAIN IMPACTS

Competitiveness, Knowledge, Investment

APPLICABILITY

Wave, Tidal Stream, Other Ocean

SCOPE OF ACTIONS

Support should be coordinated to ensure delivery of tools that are a) thoroughly validated, b) professionally documented and supported, c) persist beyond the life of a short-term grant. Focus on innovations for more accurate or more computationally efficient numerical modelling of ocean energy devices and subsystems (e.g. drivetrain, mooring and dynamic cables). Means to calibrate them cost-effectively with physical modelling such as tank testing and hardware in the loop should also be supported. Assimilation of available data-streams from at-sea operations would be highly valuable. Public support should be focussed on open-source software, which could include open-source modules interoperable with established industry software.

- Fundamental research to improve accuracy and computational efficiency (this could include overlapping activities with Priority Topic IV.3).
- Better representation of material and component degradation in models, such as testing at sea for corrosion, or fatigue test for cables and mooring (overlap with Priority Topic II.3).
- Calibration and validation of novel models based on standardised tests in the lab, and with open-sea demonstration projects data where possible (overlap with Challenge Area I and Priority Topic VI.1).
- Inter-comparison, benchmarking and assessment of numerical models.
- Inter-operability and integration of tools of different spatial and temporal resolutions, and of open-source software with established industry software, including industry standard software from other sectors if widely used in ocean energy.

EXPECTED OUTCOMES

- Improved power performance of the ocean energy devices.
- Improved knowledge in the critical failure modes and survivability of ocean energy devices.
- Increased findability, accessibility, interoperability and reusability of the demonstration datasets, respecting the protection of company IP.
- Contribution to establishing common protocols and guidelines for the design, testing and operation of ocean energy devices.

IMPLEMENTATION

TRL	1-5	NO. OF PROJECTS	9
TYPE OF ACTION	BASIC RESEARCH & APPLIED RESEARCH	SIZE OF PROJECTS	VERY SMALL, SMALL, MEDIUM

4.3.2 Analysis and planning tools for ocean energy farm deployment

CONTEXT

Ocean energy farms require accurate planning tools based on high-resolution models of devices and their interaction, coupling, and marine logistics. Revenue predictions that underpin investment cases rely solely on validated models. Cost of capital for such projects may depend critically on the credibility of the simulation of the details of array physics. Theoretical models must be validated and improved with real data from first pilot farms (see Challenge Area I) as soon as these are available, with state-of-the-art sensors, data transmission, and data analysis (see Challenge Area IV). This is a particularly pressing need for tidal stream projects.

MAIN IMPACTS

Competitiveness
Industry
Knowledge
Investment

APPLICABILITY

Wave
Tidal Stream

SCOPE OF ACTIONS

Support should be coordinated to ensure delivery of tools that are a) thoroughly validated, b) professionally documented and supported, c) persist beyond the life of a short-term grant. The highest priority is to improve accuracy of predictions of energy yield (and hence revenue) and of reliability and hence de-risk the technologies for site conditions relevant to the deployment of 100's of MW of the technology. A further priority is the integration and coupling of existing models for hydrodynamics, array environment, marine logistics, cabling, or other aspects crucial to array planning and economics, that are currently developed independently. This Priority Topic may use marine logistics models developed in Priority Topic III.3 and instrumentation addressed in Priority Topic IV.2.

- Adaptation of existing models of hydrodynamics, devices, array environment, and other modules necessary for array analysis and planning tools.
- Integration of data streams from at-sea deployments to continuously improve the accuracy of array analysis and planning tools.
- Deployment of instruments that address data needs specific to improving array tools, in pilot farms or devices (coordinate with Challenge Area I and Priority Topic IV.2).
- Basic science and research on array physics, both theoretical and observational, particularly interactions and wake effects between arrays making use of data streams from first arrays (see Priority Topic I.2) to improve accuracy and reliability of predictions for site conditions relevant to the deployment of 100's of MW of the technology.
- Development and improvement of "industry standard" models of farm physics with the required credibility for investors. This could be based on models from other sectors if appropriate. Public support should focus on open-source modules, but this could include support to integration or inter-operability with proprietary software.
- Advances in numerical modelling of arrays, such as those that improve the trade-off between computational costs and accuracy, or between resolution and spatial coverage (both essential for investment and to deliver substantial contributions to SET Plan targets).
- High performance computing time as required for project or research needs.
- Coupling or interface of array models with marine spatial planning, fishery and biodiversity management, and co-benefit solutions such as artificial reefs, harbour or nearshore agitation, sediment transport and beach profile management. Studies should focus on actionable results for managing the coastal environment, after engaging with decision-makers to assess their needs.

EXPECTED OUTCOMES

- Credible yield (revenue), performance and reliability projections for ocean energy farms to defined levels of confidence.
- Improved operative performance of the ocean energy farm, including total system availability.
- Increased affordability of ocean energy farms.
- Demonstrated maturity of the manufacturing processes including production cost, quality and yield targets.
- Improved knowledge in the critical design condition and survivability of ocean energy devices.
- Increase the findability, accessibility, interoperability and reusability of datasets, respecting the protection of company IP.
- Contribution to establishing common protocols and guidelines for the design, testing and operation of ocean energy devices.

IMPLEMENTATION

TRL	4-8	NO. OF PROJECTS	9
TYPE OF ACTION	APPLIED RESEARCH & DEMONSTRATION	SIZE OF PROJECTS	VERY SMALL, SMALL & MEDIUM

Photo: Groupe Legendre - Ifremer

4.3.3 Modelling and simulation of farm construction and operation

CONTEXT

Vessel operations for the construction and maintenance of offshore renewable energy farms represent a major expenditure, between a quarter and a third of the cost of energy. This is likely to also be the case for the first offshore ocean energy farms. As weather-risk is a major cost-driver for any offshore operation, the interface of planning tools with quality operational marine meteorology is an important aspect of this development. Public support is essential to deliver these tools in time for planned ocean energy farm projects.

MAIN IMPACTS

Competitiveness | Industry | Knowledge

APPLICABILITY

Wave | Tidal Stream

SCOPE OF ACTIONS

Support should be coordinated to ensure delivery of tools that are a) thoroughly validated, b) professionally documented and supported, c) persist beyond the life of a short-term grant. Actions should include a strong focus on optimising procedures and on delivering tools that facilitate their planning, including vessel and accessibility simulators. For floating devices in particular, optimal procedures may be device-specific so tools should provide a greater degree of modularity and flexibility. Public support should be focussed on open-source tools, but this can include interfaces with, and modules for, established industry software.

- Adaptation of marine operations planning tools from other sectors such as offshore wind.
- Support the continuous update of models with data streams and experience from constructions and operations in pilot arrays (links with Priority Topic I.2: farm demonstrators).
- Models should ensure compliance with Health, Safety and Environmental (HSE) standards in force.
- Engage with operational marine meteorology to deliver products adapted to the special requirements for tidal arrays (e.g., high resolution current modelling), and wave devices (e.g., risk of sudden resonant response endangering crew transfer even in mild seas).

EXPECTED OUTCOMES

- Improved operative performance of the ocean energy farm, particularly total system availability.
- Increased affordability of ocean energy farms.
- Demonstrated maturity of the manufacturing processes, particularly installation cost, quality and yield targets.
- Improved knowledge in the critical failure modes and survivability of ocean energy devices.
- Increased findability, accessibility, interoperability and reusability of datasets, respecting the protection of company IP.
- Contribution to establishing common protocols and guidelines for the design, testing and operation of ocean energy devices.

IMPLEMENTATION

TRL	4-8	NO. OF PROJECTS	10
TYPE OF ACTION	APPLIED RESEARCH & DEMONSTRATION	SIZE OF PROJECTS	VERY SMALL, SMALL & MEDIUM

4.4 Integration of enabling technologies in ocean energy systems

Harnessing the vast renewable energy potential of the oceans relies on the effective transfer of technological advances from other sectors. The uptake of new enabling technologies by the ocean energy sector can accelerate its path to competitiveness.

New materials for devices and components, and new manufacturing and assembly processes can decrease fabrication costs and increase durability. Smaller and lower-cost sensors and data transmission solutions have enabled the better monitoring of structural behaviour and of component operating conditions in other sectors, and thereby accelerated design iteration and improvement. New computational methods such as artificial intelligence are rapidly increasing their application to research and engineering, enabling heretofore too complex or computationally expensive analysis.

The Priority Topics in this Challenge Area aim to accelerate the effective application of such enabling technologies in the ocean energy sector by delivering new and useable solutions to identified problems, as summarised in Table 4.5 provides an overview of the Priority Topics, applicability, TRL and budget that needs to be deployed within the 6-year period covered by the SRIA to successfully address them.

Table 4.5. The level of activity in this Challenge Area has been diverse in the period between 2020-2024, from moderate for innovative materials to low or non-existent for sensing and use of monitoring or data analysis techniques. As a consequence, SRIA objectives have been partially addressed however further R&I should be incentivised.

Table 4.5 provides an overview of the Priority Topics, applicability, TRL and budget that needs to be deployed within the 6-year period covered by the SRIA to successfully address them.

Table 4.5. Priority Topics on Integration of Enabling Technologies in Ocean Energy Systems.

Priority Topics	APPLICABILITY	TRL	BUDGET REQUIRED (M€)
Innovative materials and manufacturing processes	Wave / Tidal / Other	4-8	39
Application of latest instrumentation and sensor technology	Wave / Tidal / Other	4-8	42
Use of artificial intelligence and big data	Wave / Tidal / Other	4-8	21

Photo: Crestwing

4.4.1 Innovative materials and manufacturing processes

CONTEXT

Naval grade steel is the material of choice for most offshore projects, but reinforced concrete, polymers, composites, and concrete-steel hybrid systems have demonstrated higher performance in certain offshore applications. New developments such as steel with better corrosion resistance, or self-healing concrete, may also be of value to ocean energy. New welding methods for steel could significantly reduce costs and enhance structural performance in offshore wind. Applying new materials or manufacturing methods to offshore structures is usually a long and high-risk endeavour, unlikely to be led by private initiative. Public support is needed for their application to ocean energy.

MAIN IMPACTS

Competitiveness | Industry | Knowledge

APPLICABILITY

Wave | Tidal Stream | Other Ocean

SCOPE OF ACTIONS

Support should be restricted to projects that aim to deliver realistic solutions to precisely defined problems that are identified by the ocean energy sector, and where the enabling technology is clearly advantageous over existing solutions. The scope includes the application of existing materials and manufacturing methods to ocean energy. The development of novel materials specifically for ocean energy may be appropriate when sector-wide disruptive potential is demonstrated, and the material is not being developed in other applications. For those materials where laboratory assessment confirms high potential, at-sea demonstration should be supported.

- Identification and adaptation of new materials, manufacturing and assembly methods, particularly from offshore wind, with applicability to multiple devices and processes in ocean energy.
- In addition to cost and performance, the assessment should include environmental impact and sustainability, local content, and reduced dependence on imported critical raw materials.
- Evaluation of new materials in lab tests, e.g. fatigue performance of mooring materials.
- Evaluation of samples of new materials in open-sea conditions, such as corrosion or anti-fouling performance.
- Demonstration of long-term material behaviour in realistic ocean conditions – and results dissemination of both promising and disappointing outcomes.

EXPECTED OUTCOMES

- Increased affordability of ocean energy farms.
- Demonstrated maturity of the manufacturing processes including production cost, quality and yield targets.
- Improved knowledge in the critical failure modes and survivability of ocean energy devices.
- Increased findability, accessibility, interoperability and reusability of datasets, respecting the protection of company IP.
- Contribution to establishing common protocols and guidelines for the design, testing and operation of ocean energy devices.

IMPLEMENTATION

TRL	4-8	NO. OF PROJECTS	11
TYPE OF ACTION	APPLIED RESEARCH & DEMONSTRATION	SIZE OF PROJECTS	VERY SMALL, SMALL & MEDIUM

4.4.2 Application of latest instrumentation and sensor technology

CONTEXT

Advancing the performance and survivability of ocean energy technologies relies on various sensing and monitoring technologies, data collection methods and instrument design. Reduction in costs of instrumentation and their connectivity provides opportunities to better characterise load, response, and power performance. This could greatly expand research results from open-sea testing, reduce maintenance costs, and optimise design of ocean energy devices and arrays. Such applications are best tested at-sea, but teams leading open-sea deployment are typically under such pressure that they must focus their resources exclusively on the delivery of a safe structure on time and on budget. Public support can thus make a critical difference in accelerating the uptake of promising sensor technology in ocean energy.

MAIN IMPACTS

Competitiveness · Industry · Knowledge · Acceptance · Investment

APPLICABILITY

Wave · Tidal Stream · Other Ocean

SCOPE OF ACTIONS

The focus should be on at-sea demonstration of existing instrumentation with convincing use-cases for the resulting data streams within the project timeframe. Projects should be evaluated on demonstrated progress enabled by the new data streams, and funding mechanisms incentivise such outcomes. Instruments can be monitoring device and array behaviour, or the surrounding environment (e.g., metocean, biodiversity). Priority should be given to sensors with potential for sector-wide benefits over applications that are device-specific or site-specific, and to projects that agree to the widest dissemination of results.

- Incorporation of new sensors into devices being designed for at-sea tests (coordinate with Priority Topic I.1 and I.2), that deliver data demanded by the project developer to underpin their future contribution to SET plan targets, or to development of modelling tools (Priority topic IV.1-3) or the sector.
- Retrofitting of currently operating devices with new sensors.
- Demonstration of new sensors or capabilities on offshore test platforms.
- Adaptation of sensors and their support structures to ocean energy applications: harsh conditions, remote operation, low maintenance requirements, fatigue cycles for load cells, etc.
- Development to customised or novel instrumentation may be appropriate where a particular gap in existing offerings is identified for the ocean energy sector, such as required accuracy, reliability or data transmission and storage.
- Interface of data streams to neural network training and digital twins (links with Priority Topic IV.3).
- On-line dissemination of sensor data (coordinate with Priority Topic VI.1).

EXPECTED OUTCOMES

- Improved operative performance of the ocean energy farm, including total system availability.
- Demonstrated global socio-economic impacts and local benefits.
- Improved knowledge in the critical failure modes and survivability of ocean energy devices.
- Increased findability, accessibility, interoperability and reusability of datasets, respecting the protection of company IP.
- Contribution to establishing common protocols and guidelines for the design, testing and operation of ocean energy devices.

IMPLEMENTATION

TRL	4-8	NO. OF PROJECTS	12
TYPE OF ACTION	APPLIED RESEARCH & DEMONSTRATION	SIZE OF PROJECTS	VERY SMALL, SMALL, MEDIUM

4.4.3 Use of artificial intelligence and big data

CONTEXT

Numerical modelling plays a central role in the design and early-stage assessment of innovations for ocean energy devices and arrays. Some of the challenges in their applications include new geometries requiring calibration of numerical models with costly physical model tests, especially for wave devices; trading off accuracy and computational cost; representing the non-linear interaction of hydrodynamics, platform and drivetrain mechanics, and electromagnetic forces; and the computational cost of fatigue life calculations, whose accuracy directly impact maintenance costs. For some of these challenges, recent advances in computational physics, such as artificial intelligence applications, may deliver higher performance than purely physics-based modelling. Much of this research is fundamental in nature, so privately-led initiatives must be complemented with public-supported research.

MAIN IMPACTS

Competitiveness
Knowledge

APPLICABILITY

Wave
Tidal Stream
Other Ocean

SCOPE OF ACTIONS

Support should be restricted to projects that propose solutions with convincing use-cases to clearly identified problems, where the new method is clearly advantageous over existing approaches, and the solutions will be applied within the project timeframe. Developments with broad potential applicability should have priority. Support should prioritise projects with access to open-sea or physical model test data. Projects should address the major challenges of the sheer amount of data generated in future ocean energy farms, including data storage, processing, transmission and integration.

- Artificial intelligence research that (1) train neural networks with existing datasets of open-sea tests of wave and tidal devices or arrays, and (2) deliver valuable alternatives to existing numerical modelling tools.
- Artificial intelligence applications that train neural networks with physical modelling data (wave tank, test rigs, etc.). These could be fundamental research of broad applicability (e.g., turbulence modelling), or more device-specific if the device developer has a clear interest in the proposed alternative to existing numerical models.
- Comparison of AI-based applications performance with conventional analysis, such as physics-based or statistical methods.
- Sector-wide sharing of results, including negative research findings, on the application of artificial intelligence.

EXPECTED OUTCOMES

- Improved operative performance of the ocean energy farm, including total system availability.
- Improved knowledge in the critical failure modes and survivability of ocean energy devices.
- Increased findability, accessibility, interoperability and reusability of datasets, respecting the protection of company IP.
- Contribution to establishing common protocols and guidelines for the design, testing and operation of ocean energy devices.

IMPLEMENTATION

TRL	4-8	NO. OF PROJECTS	12
TYPE OF ACTION	APPLIED RESEARCH & DEMONSTRATION	SIZE OF PROJECTS	VERY SMALL, SMALL, MEDIUM

4.5 Ocean energy market development

The development of an effective ocean energy market requires a combination of technological advancements, collaboration, a supportive policy framework and adequate funding. Several ocean energy technologies are now at a stage where commercial deployment opportunities are emerging in certain markets tailored to the specific characteristics of the EU's five sea basins. Developers can use the first pilot experiences, which have demonstrated performance and durability over several years of operation, to validate their value proposition relative to conventional alternatives and accelerate the path to technology cost reduction.

The level of activity in this Challenge Area has been low in the period between 2020-2024. The sector agrees that this challenge has only been partially addressed and more R&I is needed.

The Priority Topics in this Challenge Area (see Table 4.6) provides an overview of the Priority Topics, applicability, TRL and budget that needs to be deployed within the 6-year period covered by the SRIA to successfully address them.

Table 4.6 will identify the most promising initial markets for ocean energy, and support first commercial projects therein. The benefits of ocean energy relative to other renewables, such as better predictability and non-synchronicity with solar or wind power, will be assessed and the business case assessed for grid-scale deployments. Synergies with other activities in the coastal zone and marine space will be identified and promoted. Aspects such as system integration, which is necessary to stabilise the energy system, or combination with battery storage, hydrogen production, etc. are also within the scope.

Table 4.6 provides an overview of the Priority Topics, applicability, TRL and budget that needs to be deployed within the 6-year period covered by the SRIA to successfully address them.

Table 4.6. Priority Topics on Ocean Energy Market Development.

Priority Topics	APPLICABILITY	TRL	BUDGET REQUIRED (M€)
Application of ocean energy in off-grid markets	Wave / Tidal / Other	5-8	69
Demonstrating grid-scale benefits of ocean energy	Wave / Other	6-9	45
Co-location of multiple technologies	Wave / Tidal / Other	4-8	51


Photo: Floating Power Plant

4.5.1 Application of ocean energy in off-grid markets

CONTEXT

Electricity is far more costly in off-grid locations and those may present early commercial opportunities for ocean energy. Off-grid applications include isolated power systems in islands and remote settlements, desalination, aquaculture, metocean or navigation buoys, marine datacentres and other offshore platforms. Isolated coastal settlements in high latitudes with long winter nights, and where wind power is impractical or too intermittent by itself, may be particularly suited for ocean energy. Certain off-grid markets may not be remote: for example, powering shoreline or nearshore facilities where the cost of cabling, or paperwork involved, for a grid connection, may make small ocean energy devices an attractive alternative.

MAIN IMPACTS

Competitiveness | Industry | Acceptance | Investment

APPLICABILITY

Wave | Tidal Stream | Other Ocean

SCOPE OF ACTIONS

Support should focus on pre-commercial projects with significant private participation. Final disbursement decision should be conditional on an independent assessment of technical and financial viability, including of claimed other funds. Projects are expected to use devices that have demonstrated performance over several years of deployment; but support to less mature technology developed for specific applications, such as powering offshore buoys or other platforms, are also within the scope of this topic. Pre-commercial projects overlap with activities in Priority Topic I.2 and should follow the same approach where possible.

- Deployment of off-grid applications, e.g. powering of buoys and other shoreline or offshore platforms, where development costs are small enough for many SMEs to assume a greater share of the risk.
- Projects integrating ocean energy with battery storage, other renewables or other power sources, for specific off-grid applications (may overlap with previous action), with a focus on projects able to demonstrate commercial or near-commercial solutions (plug-and-use types).
- Pre-commercial projects in off-grid applications, as per activities described in Priority Topic I.2.
- Desktop studies that analyse a wide range of off-grid applications for ocean energy and assess the cost ocean energy must target to be a competitive solution.
- Local initiatives and local SME participation in projects.
- Standardisation, inter-operability and data-sharing for off-grid applications of ocean energy.

EXPECTED OUTCOMES

- Increased affordability of ocean energy farms.
- Demonstrated global socio-economic impacts and local benefits of large-scale ocean energy deployment.
- Evidence, based on credible KPIs, supporting that the business case is structured so as to represent an acceptable risk to private investors.

IMPLEMENTATION

TRL	5-8	NO. OF PROJECTS	7
TYPE OF ACTION	DEMONSTRATION	SIZE OF PROJECTS	VERY SMALL, SMALL, MEDIUM & LARGE

4.5.2 Demonstrating grid-scale benefits of ocean energy

CONTEXT

Solar and wind power are now the cheapest form of energy, with an increasing share of markets, but further penetration is limited not by their cost but by the need to scale up transmission, storage, and demand response to ensure grid stability. The excellent predictability of tidal energy, and wave energy being out of phase with other renewables, makes these sources of renewable energy more attractive. Accurate assessments of these benefits would help better inform policy and investment decisions, and it may also help initial deployments of ocean energy.

MAIN IMPACTS

Competitiveness · Industry · Acceptance · Investment

APPLICABILITY

Wave · Tidal Stream · Other Ocean

SCOPE OF ACTIONS

A priority is to analyse production data from first arrays, and to quantify local-scale benefits in terms of increased renewable penetration, reduced storage or transmission build-out needs. Quantifying grid-scale stabilisation benefits of ocean energy is highly dependent on assumptions for ocean energy cost and scale or timing of deployment, but assessment for a range of realistic scenarios would be valuable for the sector. To be policy-actionable, these studies should include comparison with existing and upcoming technologies for grid stability management, inclusive of costs and other societal benefits.

- Analysis of production data from first ocean energy deployments, and assess their potential to reduce grid stability costs, or other renewables penetration, at the local scale. This requires transparently assessed performance data and is another reason to demand them as a pre-condition to public support in deployments (see Priority Topic I.1).
- Analysis of scenarios integrating ocean energy deployment with transmission infrastructure build-up as planned at Member State and European level.
- Analysis comparing grid-scale benefits of ocean energy deployments with other alternatives. In addition to costs, the comparison should include other European energy priorities such as sustainability, security of supply, job creation, landscapes and biodiversity.
- Engagement with utilities, regulators, environmental actors, defence specialists, and other stakeholders of relevance.
- Public support should require, or at least incentivise, sharing of technical data and experience.

EXPECTED OUTCOMES

- Increased affordability of ocean energy farms.
- Demonstrated global socio-economic impacts and local benefits of large-scale ocean energy deployment.
- Evidence, based on credible KPIs, supporting that the business case is structured so as to represent an acceptable risk to private investors.
- Quantified grid system benefits.

IMPLEMENTATION

TRL	6-9	NO. OF PROJECTS	8
TYPE OF ACTION	APPLIED RESEARCH & DEMONSTRATION	SIZE OF PROJECTS	VERY SMALL, SMALL & LARGE

4.5.3 Co-location of multiple technologies

CONTEXT

One important advantage of offshore renewables, and ocean energy in particular, is that their use of land space is minimal. Ocean energy seascape impact is also expected to be limited compared to ever higher offshore wind turbines. Nonetheless, efficient use of the coastal marine space is essential for the rapid and consensual deployment of ocean energy. Synergies with other offshore activities must therefore be explored. Opportunities exists for most types of ocean energy, perhaps except for tidal energy. For example, ocean energy can share some electricity export infrastructure with offshore wind. An array of wave devices up-wave of an offshore wind farm may reduce wave height therein, increasing weather windows for maintenance operations. Other offshore platforms such as agriculture farms can benefit from an electricity source. Actions in this priority topic will accelerate the exploitation of such opportunities and thereby reduce marine space needed and costs for ocean energy.

MAIN IMPACTS

Competitiveness Acceptance Investment

APPLICABILITY

Wave Other Ocean

SCOPE OF ACTIONS

Sharing of marine space, of electricity export infrastructure; and of ports, docks and vessels; as well as other parts of the supply chain for offshore wind; should be considered. In a first phase, priority should be given to exploiting such synergies not requiring extensive new technological developments. Hybrid devices, floating platforms combining multiple technologies and other opportunities requiring longer development should be considered in a later phase. Scope may overlap with that of Priority Topic V.1.

- Quantification of the potential savings from sharing infrastructure, vessel, and nearby suppliers with offshore energy and other marine activities.
- Assessment of the benefits to marine operations from nearby ocean energy farms, such as reduced wave activity in ports and wind farms.
- Assessment of the benefit in terms of supply chain diversification so as to move away from bottlenecks experienced by ever increasing offshore wind demands (e.g. parts, ports and vessels), exacerbated by increasing wind turbine size.
- Assessment of synergies with technologies for biodiversity (e.g. artificial reefs), beach profile management (e.g. nourishment), and generally integrating ocean energy with coastal area management.

EXPECTED OUTCOMES

- Increased affordability of ocean energy farms.
- Demonstrated global socio-economic impacts and local benefits of large-scale ocean energy deployment.
- Evidence and credible KPIs supporting that the business case is structured so as to represent an acceptable risk to private investors.
- Quantified power system benefits.

IMPLEMENTATION

TRL	4-8	NO. OF PROJECTS	9
TYPE OF ACTION	APPLIED RESEARCH & DEMONSTRATION	SIZE OF PROJECTS	VERY SMALL, SMALL & LARGE

4.6 Coordination and sector support actions

Ocean energy requires important upfront investment, as did other energy sources in the past, and effective use of available funds requires coordination. Privately-led initiatives do not yet have sufficient resources on their own, for example, for open-sea testing. In turn, for the sector to best benefit from the limited number of at-sea campaigns that can be supported, some of the results from these tests should be shared sector-wide, while ensuring a developer's privately-led innovations benefit themselves first. Other sector-wide needs that require coordination and support include advancing standards, upgrading testing facilities and developing the supply chain or professional training. The Priority Topics in this Challenge Area will address these and other coordination tasks to accelerate the technical development and commercial deployment of ocean energy (see Table 4.7).

The level of activity in this Challenge Area has been low to moderate in the period between 2020-2024. 70% of the €70m public investment was for accessing and upgrading testing facilities and development of project infrastructure. The sector agrees that this has only been partially addressed and more R&I is needed.

Table 4.7 provides an overview of the Priority Topics, applicability, TRL and budget that needs to be deployed within the 6-year period covered by the SRIA to successfully address them.

Table 4.7. Priority Topics on Coordination and Sector Support Actions.

Priority Topics	APPLICABILITY	TRL	BUDGET REQUIRED (M€)
Coordinating sector efforts	Wave / Tidal / Other	N/A	8
Accessing and upgrading testing facilities	Wave / Tidal / Other	6-8	66
Support to ocean energy sector development	Wave / Tidal / Other	N/A	16

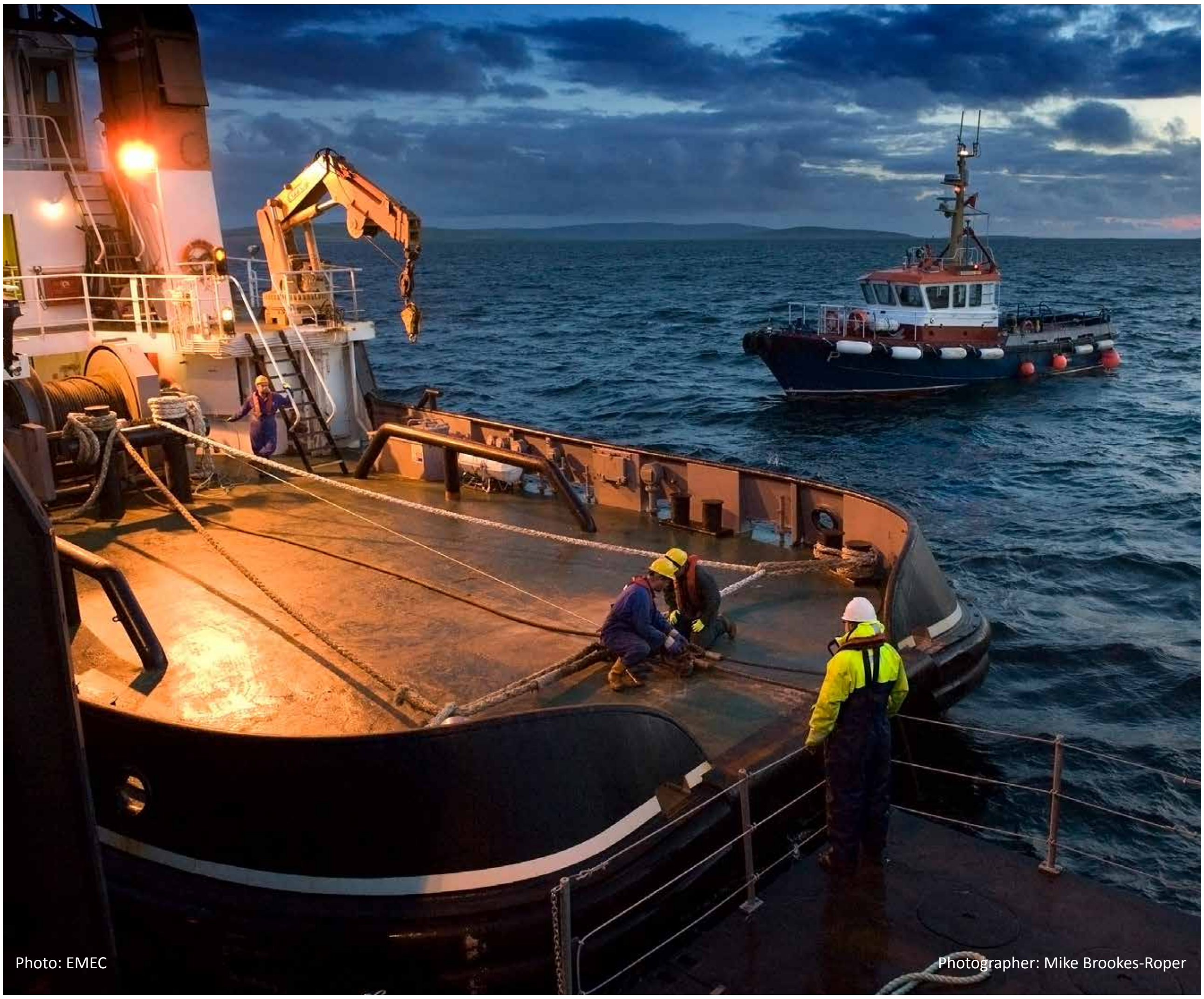

Photo: EMEC

Photographer: Mike Brookes-Roper

4.6.1 Coordinating sector efforts

CONTEXT

Activities in this Priority Topic will foster sector coordination, knowledge sharing and advance technical specifications and standards. Coordination is required for effective allocation of public and private capital in the sector and accelerate its development. “Bottom-up” information flow is necessary to exploit investments in at-sea deployments: vessel-deck and factory-floor know-how must inform engineering, which must guide research, which must give reliable numbers that policymakers must be capable to account for. The shorter these loops, the faster the sector can grow. As in other sectors, and particularly in the marine realm, up-to-date technical specifications, standards and certification are essential to reduce risk and increase investor confidence.

MAIN IMPACTS

Industry Acceptance

APPLICABILITY

Wave Tidal Stream Other Ocean

SCOPE OF ACTIONS

Support should focus on increasing the coordination and knowledge sharing among ocean energy stakeholders (public and private), other users of the sea and the society as a whole.

- Quantify and demonstrate the benefits that the ocean energy sector can deliver in employment and European manufacturing capacity, as well as the synergies with coastal landscape, biodiversity, tourism and fisheries.
- Engage with stakeholders including local communities and their representatives, potential suppliers, and energy and grid operators: an honest assessment of opportunities that ocean energy can deliver must be provided by the sector; and, in turn, projects must account for local communities’ preferences.
- Assess sector progress, identify and update research and innovation priorities.
- Accelerate the uptake of private sector experience and evolving priorities into public-funded research, education and training.
- Demand open-data streams from public-funded projects, disseminate good practices, caveats, and environmental impact data from early deployments.
- Open-data repository for ocean energy, using existing platforms such as EMODNET, to reduce redundancy, increase data access, and ensure previous deployment data is used to improve new projects.
- Identify most pressing needs for, and support development of, technical specifications, standards and certification procedures.
- Report good practices and causes of delays in consenting procedures and identify opportunities for streamlining and accelerating them.
- Communication to local communities and the general public, including on-site visits to existing deployments.

EXPECTED OUTCOMES

- Encouraging the development and adoption of ocean energy technologies.
- Increased participation of local industries in the ocean energy supply chain.
- Demonstrated global socio-economic impacts and local benefits of large-scale ocean energy deployment.

IMPLEMENTATION

TRL	N/A	NO. OF PROJECTS	6
TYPE OF ACTION	COORDINATION AND SUPPORT	SIZE OF PROJECTS	VERY SMALL & SMALL

4.6.2 Accessing and upgrading testing facilities

CONTEXT

Innovation in the ocean energy sector requires extensive testing of components and devices. Material properties must be qualified for sea operation in the lab. Device components such as drivetrain, cables, connectors, moorings, or anchors must first be tested onshore. Tank testing is required to validate (and calibrate) numerical models of devices. At-sea testing is the final and often most expensive step. As in other industries, small SMEs and micro-companies are often the fastest movers and most efficient innovators; but unlike in many other industries, for ocean energy devices, testing is often far too expensive for such SMEs. Public support to SMEs' access to test facilities is therefore vital for the sector to keep innovating. Maintaining and upgrading test facilities is also required. Many are large and need a pool of potential users at the European level to operate cost-effectively, so European-level coordination and support is particularly valuable for this Priority Topic.

MAIN IMPACTS

Industry | Knowledge | Acceptance

APPLICABILITY

Wave | Tidal Stream | Other Ocean

SCOPE OF ACTIONS

This topic focuses on the maintenance, upgrading, expansion or accreditation of both onshore labs, test rigs as well as at-sea testing facilities. Support for use of onshore test facilities is included in the actions below, as well certain uses of offshore test platforms. Support to at-sea demonstration of devices is in the scope of actions in Challenge Areas I and II.

- Access to onshore test facilities. Support schemes should facilitate the participation of SMEs and micro-companies (this Action could facilitate the Priority Topics and Actions in Challenge Area II).
- Access to offshore test facilities. Support schemes should facilitate the participation of SMEs and micro-companies.
- Use of hardware in the loop or hydrodynamics in the loop as cost-effective early-stage model calibration, before proceeding to multi-directional tank testing.
- Development and certification of software simulation environments; towards digital twins for device, component and farm design.
- Development of procedures and technical specifications that reduce lead time to testing.
- Design of more efficient test campaigns, including at-sea tests, and deploy instrumentation to expand data harvesting from tests (overlap with Priority Topic IV.2).
- Collaboration between testing facilities, such as sharing experience on consenting, construction and offshore maintenance logistics.
- Standardisation of testing and assessment procedures for ocean energy, including accreditation of testing facilities.

EXPECTED OUTCOMES

- Increased participation of local industries in the ocean energy supply chain.
- Improved knowledge in the critical failure modes and survivability of ocean energy devices.
- Increased findability, accessibility, interoperability and reusability of the datasets, respecting the protection of company IP.
- Contribution to establishing common protocols and guidelines for the design, testing and operation of ocean energy devices.

IMPLEMENTATION

TRL	6-8	NO. OF PROJECTS	8
TYPE OF ACTION	DEMONSTRATION	SIZE OF PROJECTS	SMALL, MEDIUM & LARGE

4.6.3 Support to ocean energy sector development

CONTEXT

In addition to technical developments, the growth of the ocean energy sector also needs non-technical business support. This includes support to improve the industrial capability and skills of SMEs and value chains. Moreover, non-technical support is needed to de-risk future deployments such as environmental surveys or project consenting.

MAIN IMPACTS

Competitiveness Industry Acceptance

APPLICABILITY

Wave Tidal Stream Other Ocean

SCOPE OF ACTIONS

Actions proposed herein focus on sector-wide coordination.

- Support existing test sites, coastal communities or marine structure owners interested in hosting pre-commercial projects to adapt their structure to host projects.
- Preparation and de-risking of sites for future commercial deployments, including support for environmental surveys, consenting and grid connections.
- Facilitate the contact of SMEs with potential investors.
- Skills building, training and retention of talent and experience in the sector, from factory floor to engineering, research and education, and project management and financing.
- Analyse and publish critical success factors in building regional ecosystems around supply chains in ocean energy, including a review of best practices from offshore wind.

EXPECTED OUTCOMES

- Increased affordability of ocean energy farms.
- Improved maturity of the manufacturing processes including production cost, quality and yield targets.
- Increased participation of local industries in the ocean energy supply chain.
- Demonstrated global socio-economic impacts and local benefits of large-scale ocean energy deployment.

IMPLEMENTATION

TRL	N/A	NO. OF PROJECTS	7
TYPE OF ACTION	COORDINATION AND SUPPORT; DEMONSTRATION	SIZE OF PROJECTS	VERY SMALL, SMALL & MEDIUM

5 Implementation plan

Photo: Orbital Marine Power

Public funding from the EU, countries and regions, provided at the appropriate development stages, can draw in substantial amounts of private investments. Public funding acts as a market signal to investors, confirming that those technologies are part of the EU's long-term energy future. It also provides a 'seal of validation' for projects, confirming that those are deemed worthy of investments. In addition, public funding reduces the total amount of private capital to be sourced. Finally, it makes the overall project cheaper by reducing financing costs. Those 4 impacts of public funding greatly help projects to find investors and reach financial close.

Table 5.1 shows the estimated financing requirements for each Challenge Area and Priority Topic that needs to be deployed within the 6-year period covered by the SRIA to successfully address them. 'Funding' represents the amount of public funds, whereas 'Budget' includes both public and private funding required to address the Priority Topic.

Table 5.1. Public & private budget needed to address all Priority Topics within each Challenge Area.

Challenge Areas	Priority Topics	No. of projects	Funding (million €)	Budget (million €)
Design and validation of ocean energy farms	Demonstration of pilot farms	10	300	600
	Demonstration of single devices	16	108	162
	Design and validation of other ocean energy technologies	9	18	26
Next generation of technologies and subsystems	Disruptive wave energy devices	20	37	54
	Innovative PTO and control systems	9	30	45
	Advanced moorings, foundations and power connections	12	49	73
Analysis and modelling tools	Advanced simulation of ocean energy subsystems and devices	9	20	29
	Analysis and planning tools for ocean energy farm deployment	9	23	33
	Modelling and simulation of farm construction and operation	10	19	27
Integration of enabling technologies	Innovative materials and manufacturing processes	11	27	39
	Application of latest instrumentation and sensor technology	12	29	42
	Use of artificial intelligence and big data	12	15	21
Ocean energy market development	Application of ocean energy in off-grid markets	12	47	69
	Demonstrating grid-scale benefits of ocean energy	11	31	45
	Co-location of multiple technologies	9	35	51
Coordination and sector support actions	Coordinating sector efforts	6	6	8
	Accessing and upgrading testing facilities	8	44	66
	Support to ocean energy sector development	7	11	16
TOTAL		**192**	**845**	**1,407**

Overall, delivering the SRIA activities is expected to require almost 200 projects requiring a total budget around €1.4 billion. The contribution from private funding is estimated at around 40% of the total, and there needs to be active engagement with the private sector, including established energy sector companies to realise these investment opportunities.

The share of public funding coming from countries and regions needs to increase from the previous 2020 SRIA. EU funding is expected to contribute 41% of the total budget, with the national/regional share of public funding around 19%.

Table 5.2. Main funders per Challenge Area.

Challenge Areas	EU	Countries	Private
Design and validation of ocean energy farms	48%	6%	46%
Next generation of technologies and subsystems	31%	36%	33%
Analysis and modelling tools	25%	43%	32%
Integration of enabling technologies	26%	43%	32%
Ocean energy market development	42%	26%	32%
Coordination and sector support actions	34%	34%	32%
TOTAL	**41%**	**19%**	**40%**

Typically, a combination of various project sizes will be needed to fully address the Priority Topics as shown in Table 5.3.

Table 5.3. Public & private budget needed for the different size of projects.

	Size of projects				
Type of Funding	Very small	Small	Medium	Large	Very Large
Public Funding (€m)	<1	1-3	3-8	8-20	20-40
Private Funding (€m)	0-0.2	0.2-1.5	1.5-4	4-10	10-40
Total Budget (€m)	<1.2	1.2-4.5	4.5-12	12-30	30-80
TOTAL	**70**	**50**	**42**	**20**	**10**

Table 5.4 shows the implementation plan identifying the projects needed to deliver the 2030 targets per Challenge Area. It is divided in 3 periods spanning from 2025 to 2030. Each period roughly covers two implementation years, i.e. Early = 2025/26, Mid= 2027/28 and Late = 2029/30.

Table 5.4. Indicative deployment of projects per SRIA period and Challenge Area.

Challenge Areas	Early	Mid	Late	Trend in the nº of projects
Design and validation of ocean energy farms	18	9	9	
Next generation of technologies and subsystems	21	10	10	
Analysis and modelling tools	11	10	7	
Integration of enabling technologies	9	18	9	
Ocean energy market development	8	10	14	
Coordination and sector support actions	7	7	7	
Total	**73**	**63**	**56**	

Likewise, an analogous representation of the suggested implementation plan is shown, this time in terms of the budget that should be mobilised.

Table 5.5. Indicative allocation of budget (€m) per SRIA period and Challenge Area.

Challenge Areas	Early	Mid	Late	Trend in the budget allocated
Design and validation of ocean energy farms	394	197	197	
Next generation of technologies and subsystems	86	43	43	
Analysis and modelling tools	36	31	22	
Integration of enabling technologies	26	51	26	
Ocean energy market development	41	50	74	
Coordination and sector support actions	30	30	30	
Total	**613**	**402**	**392**	

The implementation plan follows similar trends both in terms of number of projects and budget required. Priority Topics within Design and validation of ocean energy farms, Next generation of technologies and subsystems as well as Analysis and modelling tools should be kicked off earlier. Results then will inform Priority Topics within Integration of enabling technologies and ocean energy market development, which should peak in the mid and late period respectively. Lastly, funding of Priority Topics within Coordination and sector support actions should have a fairly constant intensity throughout the duration of the SRIA.

Acronyms

CAPEX: Capital Expenditure

CfD: Contracts for Difference

EC: European Commission

EERA: European Energy Research Alliance

ETIP Ocean: European Technology and Innovation Platform for Ocean Energy

EU: European Union

GVA: Gross Value Added

HE: Horizon 2020, Horizon Europe: the EU Framework Programmes for R&I

HSE: Health, Safety and Environmental

IEA-OES: International Energy Agency – Ocean Energy Systems

IP: Intellectual Property

KPI: Key Performance Indicator

LCOE: Levelised Cost of Energy

OEM: Original Equipment Manufacturer

OPEX: Operational Expenditure

OTEC: Ocean Thermal Energy Conversion

PTO: Power Take Off

R&I: Research and Innovation

SET Plan: Strategic Energy Technology Plan

SME: Small and Medium Enterprise

SRIA: Strategic Research and Innovation Agenda

SWAC: Sea-Water Air Conditioning

TRL: Technology Readiness Level

TWG: Technology Working Group (within ETIP Ocean)

Definitions

This section intends to clarify the meaning of some terms specifically used in the context of the SRIA to help its reading. It does not include terms that the authors consider well-known by the ocean energy sector and without a specific meaning for the SRIA.

ACTION

Set of activities leading to a measurable impact on the priority topic of interest. Depending on the level of ambition, one or several Actions could be grouped to make up a Project.

BUDGET REQUIRED

Estimated mix of public and private funding to address the challenges of a specific priority topic. It should not be considered as a spending ceiling but as the best estimation from the authors at the moment of preparing this SRIA. This funding should be spread out over several Projects of different sizes and technology readiness levels. Indicative project sizes used in this agenda are as follows:

- Very large projects > €20m;
- Large projects between €8m and €20m;
- Medium projects between €3m and €8m;
- Small projects between €1m and €3m;
- Very small projects: < €1m.

CHALLENGE AREA

The R&I field identified requiring investment during this SRIA period.

EXPECTED IMPACT

The expected effects of Projects over the medium term. This may include the uptake, diffusion, deployment, and/or use of the Project's results by direct target groups. Outcomes generally occur during or shortly after the end of the project. A research Project should never be an aim in itself, but it should always try to achieve something of interest for the ocean energy sector. The expected outcome should be one of the most important metrics to evaluate R&I Projects.

FUNDING INSTRUMENTS

The public support mechanism for R&I projects at EU, National and Regional level. These funding instruments are usually combined with in-house and/or private funding.

GO/NO-GO DECISION

A project milestone to demonstrate readiness before entering the manufacturing and deployment phase. Requiring verification by external reviewers, it typically involves:

- Delivering the detailed engineering plans, a techno-economic assessment (including KPIs based on internationally recognised metrics) and a complete implementation plan.
- Presenting a clear and convincing pathway to obtaining necessary permits for the demonstration and achieving certification by an independent certification body.
- Demonstrating how the project will get a financial close.

PRIORITY TOPIC

A relevant topic within a Challenge Area according to the opportunity for the sector in Europe and the urgency to be overcome.

PROJECT

One or several Actions with measurable objectives beyond the State-of-the-art, producing specific private and public results and with well-defined expected outcomes. It will usually require a mix of public and private funding.

SCOPE

Short description of the extent of a Priority Topic to clarify what is included within it.

STATE-OF-THE-ART

Starting point for all R&I projects derived from this SRIA. Funded projects should clearly demonstrate progress beyond this starting point.

STAGES

Defined period of the development process, aligned with phases of funding and decision points. Division of the technology development process into Stages provides clarity on the expected activities which must be successfully completed by the end of a funded Project. Stages are based on the IEA-OES Framework for Ocean Energy Technology, the IEC Technical Specification 62600-103:2018 and are related to Technology Readiness Level (see below).

- Stage 0 (Concept creation) means TRL 1;
- Stage 1 (Concept development) means TRLs between 2 and 3;
- Stage 2 (Design optimisation) means TRL 4;
- Stage 3 (Scaled demonstration) means TRLs between 5 and 6;
- Stage 4 (Commercial-scale single device demonstration) means TRLs between 7 and 8;
- Stage 5 (Commercial-scale array demonstration) means TRL 9.

STAGE GATE METRICS

The specific parameter(s) used to evaluate how well a technology satisfies a key area to measure the success of the technology, in order to demonstrate progress and achieved performance.

TECHNOLOGY READINESS LEVEL

This term referring to technology maturity is usually well-known in R&D projects, but the authors want to clarify the following concepts:

- **Low TRL** means TRLs between 1 and 3
- **Medium TRL** means TRLs between 4 and 5
- **High TRL** means TRLs between 6 and 8
- **Very High TRL** means TRL 9
- **Entry TRL:** The TRL that has been achieved prior to the start of the project;
- **Final TRL:** TRL achieved at the end of a project

Annex

LIST OF RECENT STUDIES ABOUT GRID BENEFITS OF OCEAN ENERGY

P. Diesing et al. "Offshore versus onshore: The underestimated impact of onshore wind and solar photovoltaics for the energy transition of the British Isles."*IET Renewable Power Generation* 17.13 (2023): 3240-3266.

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ETIP Ocean brings ocean energy experts together to share knowledge and define priorities to boost the sector's development.

ETIP Ocean maximises knowledge-exchange across the ocean energy sector through webinars and workshops. It puts forward recommendations for policymakers and industry in high-quality publications. Together with the SET Plan Implementation Working Group for Ocean Energy, ETIP Ocean launched the Forum for Sectoral Dialogue for Ocean Energy bringing public and private leaders in ocean energy together.

ETIP Ocean is a recognised advisory body to the European Commission, as part of the SET Plan – the EU's main research and innovation policy instrument.