Ocean Energy
Europe

SCALING UP INVESTMENTS IN OCEAN ENERGY TECHNOLOGIES

A brief from the
IRENA Collaborative Framework on Ocean Energy and Offshore Renewables

Citation: IRENA and OEE (2023), *Scaling up investments in ocean energy technologies*, International Renewable Energy Agency, Abu Dhabi.

ISBN 978-92-9260-528-5

For further information or to provide feedback: **publications@irena.org**

This report is available at: **www.irena.org/publications**

About IRENA

The International Renewable Energy Agency (IRENA) serves as the principal platform for international co- operation; a centre of excellence; a repository of policy, technology, resource and financial knowledge; and a driver of action on the ground to advance the transformation of the global energy system. A global intergovernmental organisation established in 2011, IRENA promotes the widespread adoption and sustainable use of all forms of renewable energy, including bioenergy and geothermal, hydropower, ocean, solar and wind energy, in the pursuit of sustainable development, energy access, energy security, and low-carbon economic growth and prosperity. **www.irena.org**

About OEE

Ocean Energy Europe is the largest network of ocean energy professionals in the world. Over 120 organisations, including Europe's leading utilities, industrialists and research institutes, trust OEE to represent the interests of Europe's ocean energy sector. As a not-for-profit organisation, every euro invested in OEE is used to promote the European ocean energy industry. **www.oceanenergy-europe.eu**

Acknowledgements

This brief was authored by Jaidev Dhavle (IRENA) and Lotta Pirttimaa (OEE) under the guidance of Francisco Boshell (IRENA), Rémi Gruet (OEE) and Roland Roesch (Acting Director, IRENA Innovation and Technology Centre). It also benefited from contributions by Jeffrey Tchouambe (IRENA), Victor Kempf (OEE) and Donagh Cagney (OEE).

This brief has benefitted from, and incorporates the inputs of, the IRENA Collaborative Framework on Ocean Energy and Offshore Renewables.

IRENA is grateful for the generous support provided by the Government of Denmark and the European Commission for this publication.

Disclaimer

Cover photo: EpicStockMedia © Shutterstock

CONTENTS

FIGURES

TABLES

BOXES

ABBREVIATIONS

EIB	European Investment Bank
EU	European Union
EUR	euro
GBP	British pound
GW	gigawatt
IRENA	International Renewable Energy Agency
kW	kilowatt
LCOE	levelised cost of electricity
MW	megawatt
MWh	megawatt hour
NDC	Nationally Determined Contributions
NECP	National Energy Climate Plan
OEE	Ocean Energy Europe
OEM	original equipment manufacturer
OTEC	Ocean Thermal Energy Conversion
PPA	purchase power agreement
PTC	Production Tax Credit
PV	photovoltaic
RD&D	research, development and demonstration
R&D	research and development
R&I	research and innovation
SME	small and medium enterprises
TW	terawatt
UK	United Kingdom
US	United States
USD	United States dollar
VRE	variable renewable energy
WETO	World Energy Transitions Outlook

1 OCEAN ENERGY

A CLEAN, PREDICTABLE AND SECURE SOURCE OF ENERGY

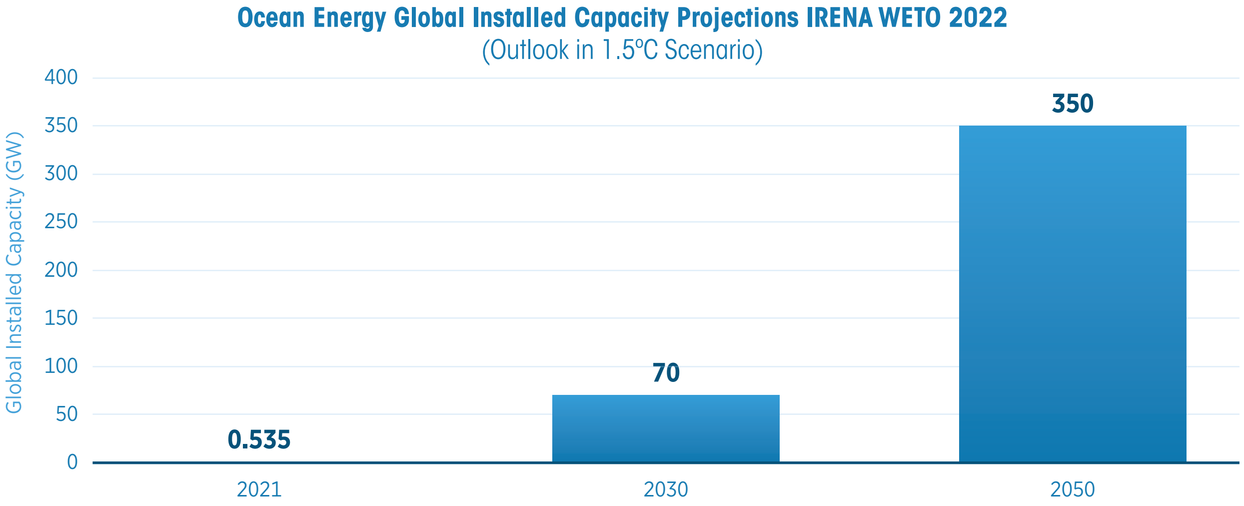
Recent global crises have made it clear that a rapid energy transition is now more relevant than ever. Current geopolitical developments have resulted in uncertainty over the security of energy supply globally. Even as countries around the world are recovering from the COVID-19 pandemic, they face yet another challenge to ensure that the basic needs of their citizens are fulfilled.

The impacts of climate change are also becoming more visible, with prolonged heatwaves, droughts, wildfires and storms harming people and ecosystems across the planet. Providing affordable energy to citizens and staying on a path to limit global temperature rise to within 1.5 degrees Celsius (°C) of pre-industrial levels requires a rapid shift away from a centralised energy system that is highly dependent on fossil fuels.

© Orbital Marine Power

Ocean energy is one of the technologies that must be scaled up for the energy system to reach full decarbonisation (IRENA, 2023). With a global market potential of 350 gigawatts (GW) by 2050 (Figure 1) (IRENA, 2022), ocean energy can provide clean, local and predictable electricity to coastal countries and island communities around the world.

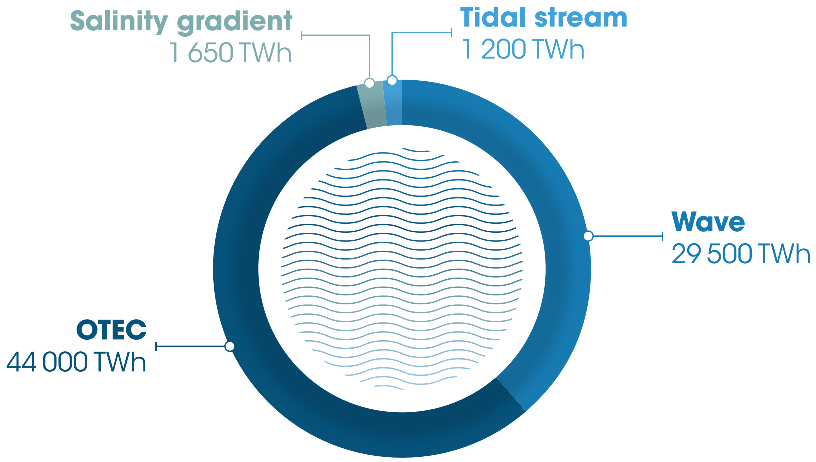
Figure 1 Global ocean energy capacity forecast, 2030 and 2050



Source: IRENA (2022).

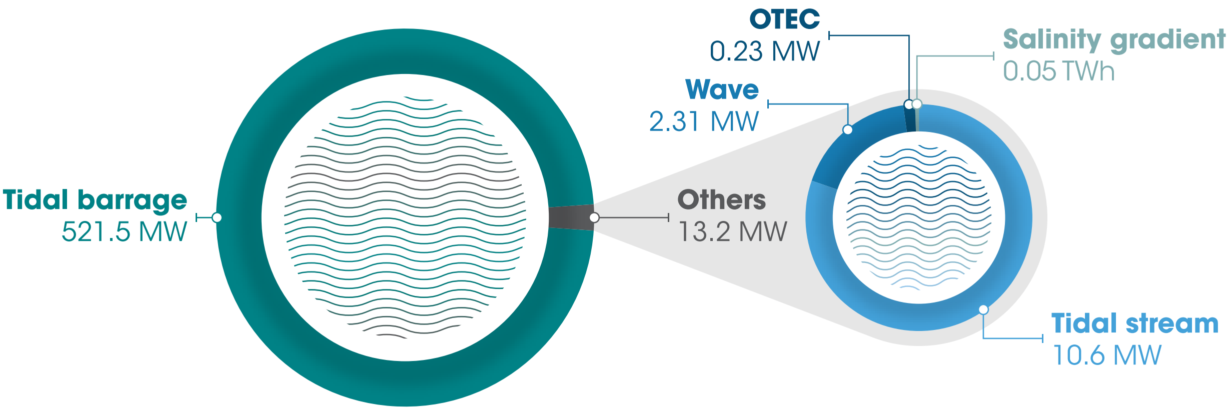
Ocean energy technologies are usually categorised according to the resource they use to generate energy. Tidal stream and wave energy converters are the most mature solutions applicable across different geographies. Additional technologies exist that are able to extract energy from temperature gradients, differences in salinity concentration and the movement of ocean currents (IRENA, 2020a). Figures 2 and 3 show global ocean energy potential and deployment, according to the International Renewable Energy Agency (IRENA).

Figure 2 Global ocean energy potential



Source: IRENA (2020a), based on Nihous, 2007; Mørk *et al.*, 2010; Skråmestø *et al.*, 2009; OES, 2017.

Figure 3 Current ocean energy deployment

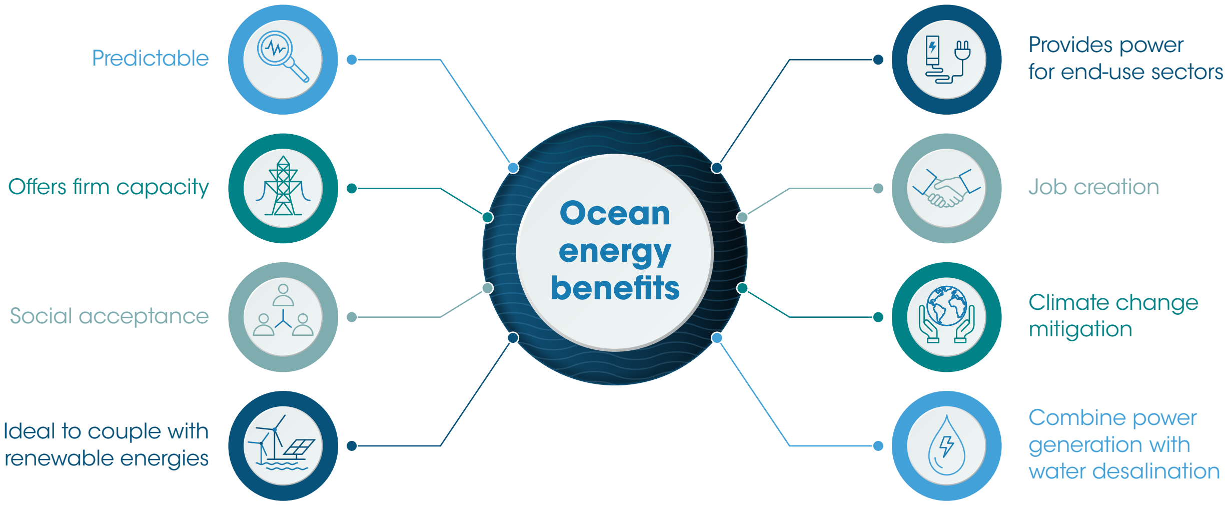


Source: IRENA (2020a).

Islands and other remote communities have a strong symbiosis and potential to integrate a "blue economy" - an ecosystem where energy harnessed from the oceans can support the decarbonisation of key marine activities such as shipping, power generation, cooling, aquaculture and water desalination (IRENA, 2020b). The need to harness this marine potential is mostly the result of a scarcity of inland space in which to deploy onshore renewables, as well as the high costs of fossil fuel imports and electricity generation.

As well as providing new project development spaces, the deployment of ocean energy technologies can facilitate new revenue streams and higher cash flows for territories, helping to reduce the levelised cost of electricity (LCOE) in these locations. The business case for ocean energy can be attributed to its contribution to climate change mitigation, the creation of new employment opportunities, and support for grid resilience (ETIP Ocean, 2019). The benefits of ocean energy technologies are summarised in Figure 4.

Figure 4 Benefits of ocean energy technologies



Source: IRENA (2020a).

New renewable energy technologies must be brought to market to balance grids powered by an increasing amount of low-cost variable renewable energy. Ocean energy can complement wind and solar power, bringing much-needed flexibility to the grid and securing the energy supply. Tidal stream technologies capture power from tidal currents and are influenced by the established cycles of the moon, sun and Earth, allowing greater predictability. Wave energy is complementary to wind energy; when the wind stops, wave energy continues to produce power (IRENA, 2021).

Ocean energy can create 680 000 direct jobs globally by 2050 (OES and IEA, 2017). Many of these jobs will be local and situated close to the corresponding resource, and may serve to support coastal communities that have been engaged historically in the shipbuilding, and oil and gas industries.

To reach appropriate volumes and facilitate cost reductions - at industrial deployment scale - ocean energy will need to develop utility-scale projects connected to main electricity grids. Some secondary markets will still be of interest - for example, for specific designs such as aquaculture, oil and gas decarbonisation, and hydrogen production. However, these alternative applications will not be enough to provide the necessary capacity to support a sustainable energy transition within a short time horizon. Co-location with other renewable energy sources, such as offshore wind or floating photovoltaic (PV) systems, can also be applied to optimise the power production profile and the use of marine space (ETIP Ocean, 2019).

To reap the benefits of ocean energy, investments must be scaled up. Similarly to how wind and solar energy were brought to market, ocean energy needs clear signals from governments to provide visibility about the future market to private investors. This requires coupling a supportive financial framework with a supportive policy framework, as described in this brief. A summary of the key proposed actions and relevant stakeholders required to achieve this objective is presented in Table 1.

Table 1 Proposed priority actions from relevant stakeholders to accelerate ocean energy deployment

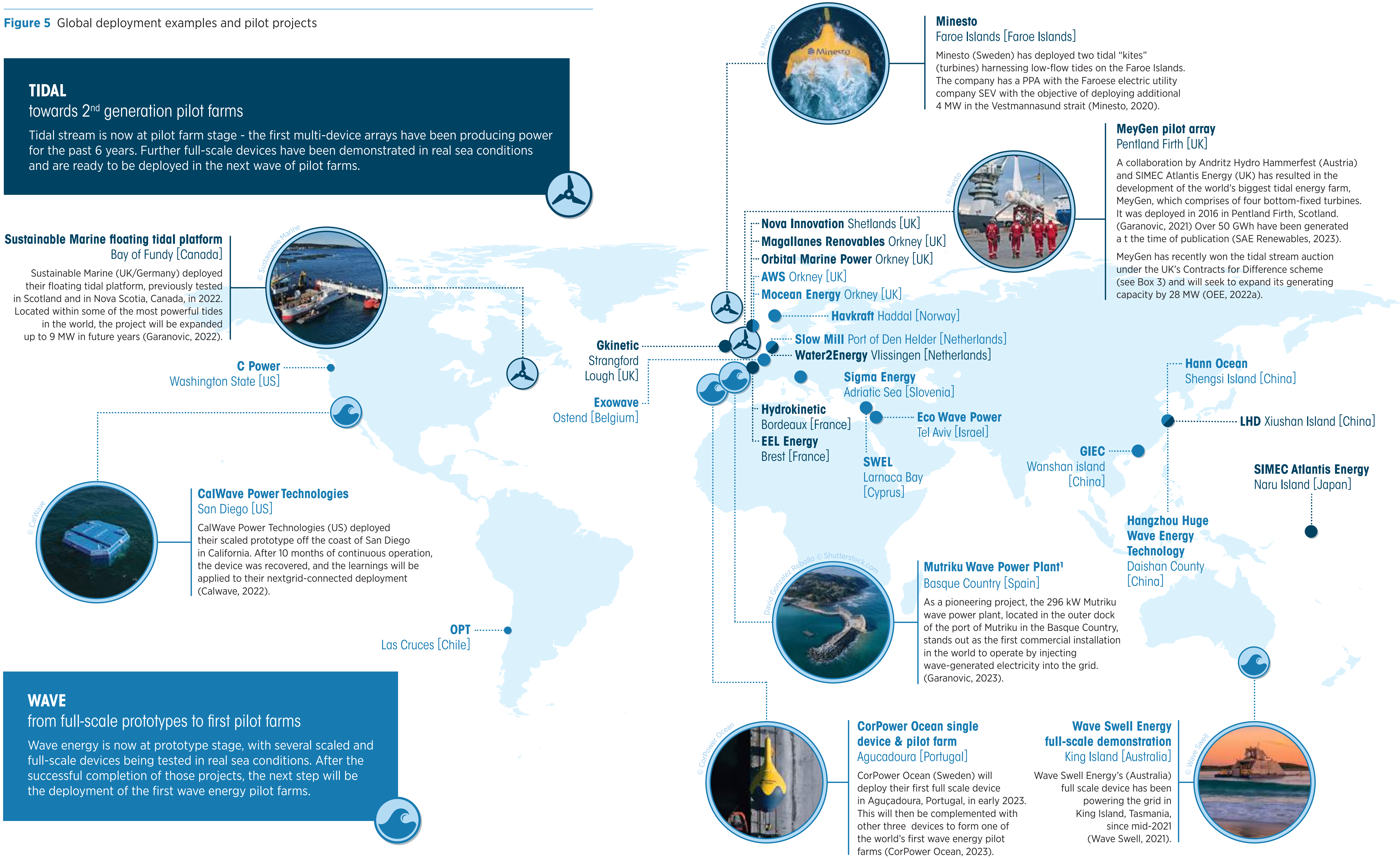
Proposed action	Stakeholder	Implications
Enhance the business case	Policy makers Industries Power system operators	Use ocean energy to power the blue economy and couple with other offshore sectors (*e.g.* ports, shipping, desalination, oil and gas, *etc.*)
	Power system operators Energy planners	Include ocean energy as a predictable energy source that can integrate VRE and energy storage.
	Policy makers	Joint tenders with other VRE installations (*e.g.* wave energy and offshore wind)
	Policy makers Local municipalities	Promote application on islands, coastal communities and micro grids
	Project developers Policy makers	Quantify and consider additional benefits, avoided costs, externalities (*e.g.* job creation, climate change mitigation or security of energy supply, *etc.*)

Proposed action	Stakeholder	Implications
Improve access to financial support	Policy makers Regulators Financial institutions	Create innovative financial revenue support schemes aimed particularly at ocean energy (*e.g.* local investments, prizes, funding based on capacity size, funding based on Technology Readiness Level)
	Policy makers	Promote blended finance which encourages private capital to invest in projects that benefit society and contribute to achieve sustainable development while also providing financial returns to investors
	Financial institutions Private investors	Invest in ocean energy technologies
	Policy makers	Improve revenue and capital support schemes across all stages of development (R&D, deployment, operation)
	Financial institutions (multilateral donors)	Increase access to finance in developing countries and SIDS
Set up and strengthen resource and site assessment	Regulators	Develop regulatory processes and frameworks for site assessment and identification
	Policy makers	Conduct effective marine spatial planning (MSP) and incorporate ocean energy on regional and national energy strategies
		Include mapped resource potential in climate and energy strategies
	Energy planners	Use advanced modelling tools
	Data owners	Improve access and exchange to baseline data, and address need for more data
	Power system operators Developers	Include assessments of local grid capacities and requirements in site assessments
	Regulators	Provide guidance and frameworks for environmental impact assessment

Source: IRENA (2020a).
Notes: VRE = variable renewable energy; R&D = research and development; SIDS = small island developing states.

This brief emphasises the need to **scale up investments in tidal stream and wave technologies**, as these ocean energy technologies are closest to reaching maturity, have a greater application potential globally and are more suitable for scalability.

Figure 5 Global deployment examples and pilot projects



TIDAL
towards 2nd generation pilot farms

Tidal stream is now at pilot farm stage - the first multi-device arrays have been producing power for the past 6 years. Further full-scale devices have been demonstrated in real sea conditions and are ready to be deployed in the next wave of pilot farms.

Sustainable Marine floating tidal platform
Bay of Fundy [Canada]

Sustainable Marine (UK/Germany) deployed their floating tidal platform, previously tested in Scotland and in Nova Scotia, Canada, in 2022. Located within some of the most powerful tides in the world, the project will be expanded up to 9 MW in future years (Garanovic, 2022).

C Power
Washington State [US]

CalWave Power Technologies
San Diego [US]

CalWave Power Technologies (US) deployed their scaled prototype off the coast of San Diego in California. After 10 months of continuous operation, the device was recovered, and the learnings will be applied to their nextgrid-connected deployment (Calwave, 2022).

OPT
Las Cruces [Chile]

WAVE
from full-scale prototypes to first pilot farms

Wave energy is now at prototype stage, with several scaled and full-scale devices being tested in real sea conditions. After the successful completion of those projects, the next step will be the deployment of the first wave energy pilot farms.

Gkinetic
Strangford
Lough [UK]

Exowave
Ostend [Belgium]

Minesto
Faroe Islands [Faroe Islands]

Minesto (Sweden) has deployed two tidal "kites" (turbines) harnessing low-flow tides on the Faroe Islands. The company has a PPA with the Faroese electric utility company SEV with the objective of deploying additional 4 MW in the Vestmannasund strait (Minesto, 2020).

MeyGen pilot array
Pentland Firth [UK]

A collaboration by Andritz Hydro Hammerfest (Austria) and SIMEC Atlantis Energy (UK) has resulted in the development of the world's biggest tidal energy farm, MeyGen, which comprises of four bottom-fixed turbines. It was deployed in 2016 in Pentland Firth, Scotland. (Garanovic, 2021) Over 50 GWh have been generated a t the time of publication (SAE Renewables, 2023).

MeyGen has recently won the tidal stream auction under the UK's Contracts for Difference scheme (see Box 3) and will seek to expand its generating capacity by 28 MW (OEE, 2022a).

Nova Innovation Shetlands [UK]
Magallanes Renovables Orkney [UK]
Orbital Marine Power Orkney [UK]
AWS Orkney [UK]
Mocean Energy Orkney [UK]

Havkraft Haddal [Norway]

Slow Mill Port of Den Helder [Netherlands]

Water2Energy Vlissingen [Netherlands]

Hydrokinetic
Bordeaux [France]

EEL Energy
Brest [France]

Sigma Energy
Adriatic Sea [Slovenia]

Eco Wave Power
Tel Aviv [Israel]

SWEL
Larnaca Bay
[Cyprus]

Hann Ocean
Shengsi Island [China]

LHD Xiushan Island [China]

GIEC
Wanshan island
[China]

SIMEC Atlantis Energy
Naru Island [Japan]

Hangzhou Huge Wave Energy Technology
Daishan County
[China]

Mutriku Wave Power Plant[1]
Basque Country [Spain]

As a pioneering project, the 296 kW Mutriku wave power plant, located in the outer dock of the port of Mutriku in the Basque Country, stands out as the first commercial installation in the world to operate by injecting wave-generated electricity into the grid. (Garanovic, 2023).

CorPower Ocean single device & pilot farm
Agucadoura [Portugal]

CorPower Ocean (Sweden) will deploy their first full scale device in Aguçadoura, Portugal, in early 2023. This will then be complemented with other three devices to form one of the world's first wave energy pilot farms (CorPower Ocean, 2023).

Wave Swell Energy full-scale demonstration
King Island [Australia]

Wave Swell Energy's (Australia) full scale device has been powering the grid in King Island, Tasmania, since mid-2021 (Wave Swell, 2021).

Notes: UK = United Kingdom; US = United States.

---

[1] *This example was provided by the Representative from Spain to IRENA's Collaborative Framework on Ocean Energy and Offshore Renewables.*

1.1 A clear path to rapid cost reduction

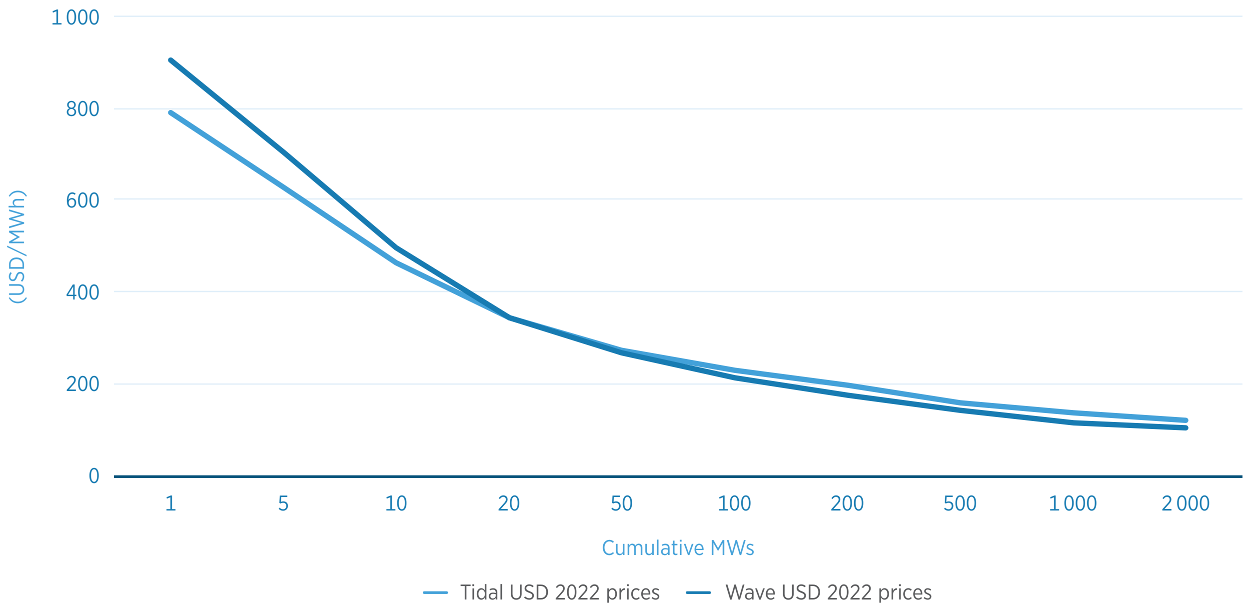
As more wave and tidal capacity is deployed, the cost of this energy will be reduced through economies of scale, the streamlining of supply chains and improvements to devices. The business models and technologies for ocean energy are similar to those for offshore wind energy and can achieve similar cost reductions. Large-scale deployment of ocean energy will deliver the most dramatic cost reductions, as has been the case for offshore wind.

Ocean energy projects are already delivering remarkable cost reductions. The European Commission's Joint Research Centre found that the LCOE (per kilowatt hour [kWh]) for tidal stream was cut by more than 40% between 2015 and 2018, showing a more rapid reduction than anticipated (Tacconi and Magagna, 2019).

The European Union's (EU) Strategic Energy Technology Plan sets out cost reduction targets for wave and tidal energy of EUR 100 per megawatt hour (MWh) [USD 118/MWh]. It is estimated that these targets will be met at around 1 GW of deployed capacity. The UK government's ORE Catapult reaches similar conclusions, forecasting costs of EUR 132/MWh [USD 170/MWh] at 730 MW installed, and EUR 89/MWh [USD 114/MWh] at 2.6 GW installed.

These projections are ambitious, and further deployments will be required to bring energy costs (as measured by LCOE) down to the levels of currently established technologies like solar PV and onshore wind. However, despite ocean energy not being the lowest-cost renewable energy option today (Figure 5), it does offer symbiotic benefits that can contribute to global efforts to deliver a transition to a sustainable energy future.

Figure 6 Ocean energy costs and deployed capacity



Source: OEE (2020).

© Tocardo

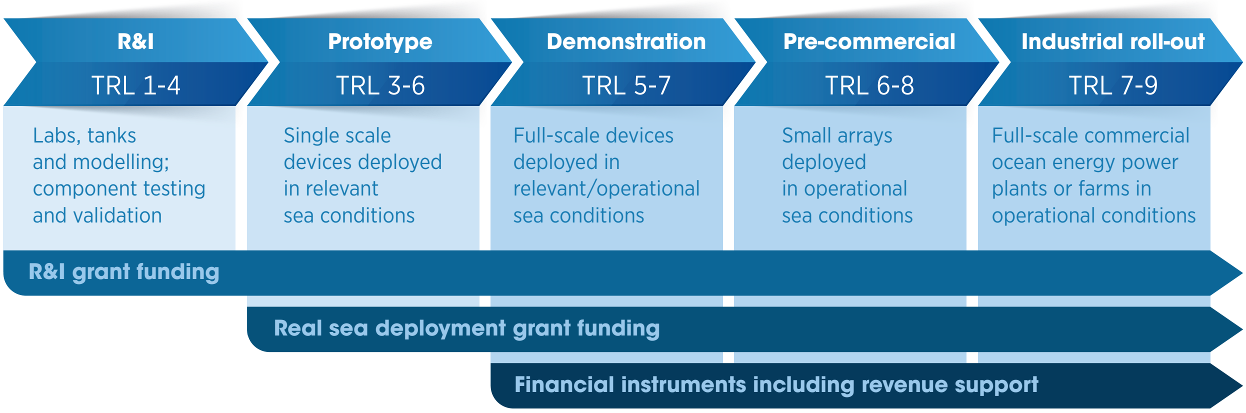
2 GUIDE TO SCALING UP INVESTMENT IN OCEAN ENERGY PROJECTS

Ocean energy technologies are still expensive and have high risk factors, which is why relying solely on market actors to deploy projects is not possible. Private investors will not engage without market visibility and clear targets set by governments. They will not shoulder the cost of development without future perspectives.

This is how onshore and offshore wind energy as well as solar PV developed into now-commercial technologies. They benefited from governmental support, such as feed-in tariffs, and had clear renewable energy targets and dedicated deployment zones. This created market visibility and attracted private investors into the sector (ETIP Ocean, 2019).

Ocean energy technologies are at different stages of development, or 'technology readiness level' (TRL) (Figure 6), and different investment instruments are needed for these stages. The more suited the financial framework, the faster the development, the cheaper the support and the greater the cost reductions, ensuring the most direct path to industrial roll-out.

Figure 7 Ocean energy investment cycle



Source: ETIP (2021).

Research and development (R&D)/research and innovation (R&I) and prototype stages: Prototype devices and components are designed and tested in laboratories and tanks before being deployed in real sea conditions to validate the technology. Each step generates valuable findings that are fed back into new R&D activities to improve performance and reduce costs.

Projects at the R&D and prototype stages do not generate revenue; their objective is to prove the technical concept. This makes it difficult to secure private investment, as investors are aware that any potential revenue will only be generated in the long term. Public funding is thus essential to support the R&D and prototype stages (ETIP Ocean, 2019).

Demonstration and pre-commercial stages: Once a full-scale prototype has been tested, the demonstration stage will validate the technology by deploying several full-scale devices over a longer period of time. Learnings will reduce technological uncertainties and help move towards standardised "off-the-shelf" components and devices. The pre-commercial stage usually entails the deployment of several units of the same device in real array conditions, serves to validate the business model for the technology and facilitates cost reductions.

At the demonstration and pre-commercial stages, projects are larger than in previous development stages, which renders public funding alone insufficient to cover the higher costs. These projects produce revenues by selling the electricity they generate over a period of 15-20 years. This is the first stage in which to attract some of the more risk-friendly investors - although only by providing them with the potential of high financial return. The most significant barriers to attracting finance are the remaining technology uncertainties, the cost of finance and the overall investment needs at this stage (ETIP Ocean, 2019).

Industrial roll-out stage: The aim at this stage is to use economies of scale to drive down costs, similar to the dramatic cost reductions seen in wind and solar PV in the past decade. This requires good market visibility to attract private investors, utilities and original equipment manufacturers (OEMs). Without a pipeline of projects justifying the initial investment, these crucial stakeholders are unlikely to engage. Clear government signals on the future market for investing are vital to unlocking the required multi-billion-dollar private investment (ETIP Ocean, 2019).

Continued R&D actions benefit all stages and are necessary to keep improving the many aspects of the technology and its deployments.

The following sections present the different investment instruments suitable for each development stage.

© Nova Innovation

2.1 R&D and prototype stages: Proving technology via grants

The main objective of the R&D and prototype stages is to validate the technology and prove it can deliver. Because R&D and prototype projects do not generate revenue, public funding is usually the main source of funds. Small- and medium-sized enterprises (SMEs) are sometimes able to raise some equity to partially fund early development. Yet ocean energy devices - unlike, for example, innovative software - require early in the development process the welding of metal and going offshore, so costs can quickly exceed that which can be financed by supportive SMEs (ETIP Ocean, 2019).

Direct grants that are able to cover up to 100% of the costs enable early-stage research as well as the development of prototypes, which are a prerequisite for pre-commercial and commercial projects. Public funding programmes can be set up at the regional, national or international levels.

To ensure the best use of public funding with the maximum impact, grant funding programmes may:

- focus on the most impactful projects - the ocean energy sector's Strategic Research & Innovation Agenda (*i.e.* prioritise the most urgent R&D topics for the sector's development);
- allocate sufficient funding for the required actions;
- avoid focusing a large portion of the budget on a single company or device;
- avoid repeating or duplicating research efforts already done in other countries; and
- contribute to progressing the sector as a whole by sharing non-confidential learnings from the development of each device.

R&D and prototype projects provide the basis for technology success by reducing technological risks at subsequent development stages. The provision of a well-documented development path can also help attract investors as the technology progresses towards commercial readiness.

Examples of grant funding programmes:

Regional

- Basque Country's Aid Programme for Investment in the Demonstration and Validation of Emerging Marine Renewable Energy Technologies

National

- Swedish Ocean Energy Fund
- France's *Investissements d'avenir*
- US Department of Energy funding for ocean energy
- Spanish Technological Development Aid Programme for investment in offshore renewable pilot projects and test platforms

Global

- European Union's R&I Programme - Horizon Europe
- US Department of Energy grant scheme for hydrokinetic energy

Classic grant funding schemes have proven their worth, although they can come with larger risks attached, especially when funding large infrastructure technologies, such as ocean energy devices (ETIP Ocean, 2019).

A recent approach to publicly funding R&D has been developed to accelerate technology development, while avoiding duplication of effort and ensuring the optimal use of public resources. The *stage-gate process* awards grants via a series of competitive, 100%-funded calls, using a pre-commercial (public) procurement model (ETIP Ocean, 2019).

The first call selects several technologies at an early stage, aiming to improve devices, components or sub-systems before overall funding requirements become too high - before devices reach full scale. Each round assesses technologies according to clear metrics and standards, and only the technologies that achieve the objectives of each stage (*i.e.* that "reach the gates") are passed onto the next stage and receive more funding to continue their development.

Examples of stage-gate programmes:

- Wave Energy Scotland's Stage Gate Process for Wave Energy
- EuropeWave

© Mocean Energy

Box 1 Examples of grant funding and stage-gate programmes*

US Department of Energy grant funding

Ocean energy has gained a renewed focus in the United States. The US House of Representatives recently passed legislation authorising the government to invest USD 687 million in the development of ocean energy solutions during 2021-2025. In 2021, the government allocated USD 112 million to the Department of Energy to support ocean energy development (ETIP Ocean, 2021). Moreover, the 2021 Bipartisan Infrastructure Bill dedicates USD 70.4 million to marine energy research, development and demonstration (RD&D), as well as USD 40 million to support the new National Marine Energy Centre.

In early 2022, the US Department of Energy announced USD 25 million to support RD&D of eight wave energy projects at the PacWave South test site off the Oregon coast. All these funding programmes stimulate national innovation and potentially attract foreign innovation by providing a strong long-term vision of political and financial support.

Spanish Technological Development Aid Programme

In December 2022, Spain's Ministry for Ecological Transition launched a first call of the Renmarinas Demos programme, for the granting of investment to pilot projects and testing platforms and infrastructure for offshore renewables. With a budget of EUR 240 million [USD 283 million], this programme aims to promote "new projects, technologies or facilities for offshore renewable infrastructures that will contribute to the development of ocean energy technologies in Spain".

The Renmarinas Demos programme promotes the following actions through four sub-programmes: the creation and adaptation and/or reinforcement of test platforms for marine renewables by research organisations (sub-programme 1); the creation or reinforcement of test platforms for marine renewables (sub-programme 2); the development of offshore renewable technology demonstrators (sub-programme 3); and joint projects of offshore renewable technology demonstrators linked to a test platform (sub-programme 4).

EuropeWave stage-gate programme

EuropeWave is a EUR 22.5 million [USD 27 million] stage-gate programme for wave energy technology, running from 2021 to 2025 through pre-commercial procurement. It is funded by Wave Energy Scotland and the Basque Energy Agency, whose grants are matched by the EU's Horizon 2020 programme. It includes an international evaluation and guidance framework for ocean energy technology (EuropeWave, 2023).

The procurement is open to all applicants, but deployment must take place in the territory of the public funders. This ensures that much of the value is retained by the participating countries.

As of early 2023, EuropeWave was at Phase 2, where five wave energy technologies among the seven technologies of Phase 1 were selected to further their concepts. This includes the design of a scale prototype device. In the third and final phase, three prototypes will be deployed at the open-water facilities of Biscay Marine Energy Platform in the Basque Country and of the European Marine Energy Centre in Scotland for a 12-month demonstration and operational testing programme (OEE, 2022b).

* *This content was formulated based on information shared by members of IRENA's Collaborative Framework on Ocean Energy and Offshore Renewables.*

2.2 Demonstration and pre-commercial stages: Attracting investors with public financial instruments

Demonstration and pre-commercial projects move beyond the single prototype to deploy several devices, forming pilot farms. The demonstration stage aims to assess whether the behaviours, production patterns and challenges observed on the first full-scale prototype are replicated across several units. At the pre-commercial stage, pilot farms get closer with each iteration to the fully commercial projects of the future, integrating additional designs, concepts, services and technological innovations (ETIP Ocean, 2019).

For example, tidal demonstration farms have several devices operating independently of one other. Pre-commercial tidal farms, on the other hand, position devices as they would in a fully commercial farm, thus maximising the use of space and resources to study the impact of different positioning designs.


© HydroQuest

Due to the larger number of devices, grant funding is still desirable yet is no longer enough to cover capital requirements, and private investment is needed to fill this gap. Due to the innovative nature of pilot farms, some technological and business uncertainties remain in manufacturing, installation and operation, resulting in higher costs of finance. Public financial instruments offering zero- or low-cost finance are therefore needed to reduce the cost of capital and attract private investors (ETIP Ocean, 2019).

Delivering demonstration and pre-commercial projects thus requires **a combination of grant funding, financial instruments and revenue support** made available to developers for continued long periods of time. Blending these will ensure that a project reaches financial close. All the aforementioned financial components must be made accessible to allow for projects to become operationalised. The high risks of demonstration projects can be mitigated by strong financial instruments, and the development of revenue support mechanisms can provide confidence to investors.

Some of the key financial elements that should be considered to improve access to new capital and to lower financial costs are **grant funding, public-supported equity and public guaranteed loans**. In addition, **insurance and guarantee funds** should be developed to reduce financial exposures and provide technical risk assurances to private investors. **Revenue support** is necessary to fund operational expenditures as well as to repay interests from debt/dividends for equity (ETIP, 2019; ETIP Ocean, 2021).

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. Reaching financial close without the entire blend of instruments is possible, yet it generally means that the chosen programmes will have to provide proportionally more funding/finance.

In financing innovative technologies, every piece of the financial package put forward by public authorities helps attract private investment. Awarded public funding or finance increases the confidence of investors, as schemes already perform an assessment of the technological and financial viability of projects. This increases the confidence in the projects among private operators, who might also be new to the technologies.

In addition to the potential leveraging of public funds (which need to be used responsibly), there is a necessity to work together with private financers in the early financial support stages for pre-demonstration and demonstration projects. Exploring avenues that allow for risk sharing (such as public-private initiatives) can be a conduit through which private investors can be brought into this stage early.

For example, the EU Innovation Fund (Box 2) provides significant grant support even before financial close, which also supports engagement and investment from private stakeholders. According to Ocean Energy Europe, since 2007 in Europe, every EUR 1.0 [USD 1.0] of public funding for ocean energy from EU and national sources has leveraged EUR 2.9 [USD 2.9] of private investments in the sector (EC, 2021).

Revenue support is also required at this stage, as projects are expected to deliver electricity and to repay investors from sales. The cost of innovative projects remains above the electricity market price, making it impossible for projects to break even without support. A larger grant could in theory offset this need but would be financially less efficient.

Box 2 Examples of public funding schemes for pre-demonstration and demonstration projects*

French *Investissements d'Avenir*: This is an innovative funding programme and a great example of blended finance. It offers two financial instruments in one: a *grant* from the French energy agency ADEME, of which two-thirds is repayable if the project generates revenue (essentially, a less-risky, zero-cost *loan*); and a *feed-in tariff* from the French state. Blending finance via a grant, repayable grant and revenue support makes for a very attractive case for private investors looking at those projects.

European InnovFIN EDP (and successor): Managed by the European Investment Bank (EIB), this facility offered commercial loans to bankable demonstration projects. Because the EIB requests visibility on future technology sales and high bankability as a prerequisite to granting loans, so far only one ocean energy project has been awarded an InnovFIN EDP loan. The successor facility to InnovFIN EDP could assume a more classic public loan approach and take on the risks associated with technology development that occur prior to first commercial sales. This would be more efficient, more effective and would support the technological risk associated with innovation, which private investors have not yet shouldered.

European Innovation Fund: This grant funding programme supports the demonstration of innovative low-carbon technologies and provides grants of up to 60% of the relevant (decarbonisation) costs of projects. Up to 40% of the grant can be given before the whole project is fully up and running, which helps projects attract private investment and close the remaining financing gap. The scheme is fairly complex in design, making it potentially difficult to access for SMEs that lack the expertise to write successful bids. Its design also targets low-innovation, large-scale projects, which puts the scheme's usefulness in question. Recognition of those shortcomings triggered recent changes and improved the innovative range and accessibility of the scheme, notably via a mid-sized call that is more suitable for ocean energy projects.

* *This content was formulated based on information shared by members of IRENA's Collaborative Framework on Ocean Energy and Offshore Renewables.*

2.3 Industrial roll-out stage: Ensuring returns for investors with revenue support

At the industrial roll-out stage, costs are reduced when more capacity is deployed, as has been witnessed in other renewable energy sectors. Given that 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. Revenue support will make these projects bankable and will enable developers to secure the necessary finance from a range of private investors. Such support is crucial for deploying the first pilot farms and commercial projects.

For the revenue support to work in practice, it needs to be earmarked for a given innovative technology, such as ocean energy. Competing with established technologies on the basis of cost will always result in the established technologies winning. Earmarking helps emerging technologies gain a foothold in the market and replicate the cost reductions that mature technologies have already achieved.

Demonstration and pre-commercial projects require higher support per MWh produced than commercial projects – but only for a limited number of projects, thus limiting the overall spending. As more capacity is deployed, subsequent cost reductions will allow for the level of revenue support to be lessened. This ensures that funds are being used as efficiently as possible, while continuing to bring ocean energy solutions to market.

Several options are available to design an effective revenue support scheme, such as sector-specific auctions, ring-fenced budgets and project-specific arrangements. All these options can be successful provided that they are well designed.

The recent move to auctions (*e.g.* for wind energy) has enabled significant cost reductions. Yet, combined with various crises in Europe, this shift has also jeopardised the survival of wind turbine manufacturers, which is much less desirable (Radowitz, 2022; WindEurope, 2022).

The large schemes put in place for wind and solar PV in the early 2000s have yielded many learnings on how to design these schemes successfully and cost-efficiently for governments. Some control over the total amount of public spending – via, for example, ring-fenced budgets or maximum capacities – is an insurance for policy makers. So too is the build-in of a reasonable cost-reduction path, allowing innovation to continue and companies to grow while keeping public spending in check.

On the other hand, schemes should ensure that a minimum revenue is made available, taking note that investors also need to observe some risk to ensure that private capital can be allocated in the most efficient manner. High visibility on support going forward is paramount to ensure high market visibility and investor interest.

For example, the US Production Tax Credit (PTC), which supports investments in clean energy technologies, requires Congress to vote periodically to ensure its validity. The PTC is a counter-example, given that it generates uncertainty until the outcome of the vote is determined. This approach has had negative impacts on the development of the US clean energy sector, especially the wind industry, which has faced periods when no tax credits were available and thus no projects were commissioned or built.

Revenue support is an excellent way of showing investors and OEMs that there will be a long-term market for ocean energy. This should be complemented with a clear signal from national governments about their longer-term intentions for the sector – such as agreement on tangible targets for technological deployment and an overall supportive policy framework. (See the next section for more details.)

Today, only a handful of countries have these kinds of schemes available for ocean energy, but the effectiveness of these measures can already be observed (Box 3).

Box 3 Examples of funding schemes for industrial roll-out projects*

Canada

Canada has allocated several grants together with feed-in tariffs of around EUR 350/MWh [USD 423/MWh] for the installation and testing of tidal stream pilot farms in Nova Scotia. Around 25 MW of renewable electricity from tidal energy is approved under the feed-in tariff, and six devices are already installed. The scheme is a “classical” and efficient feed-in tariff, ring-fenced by a total budget to avoid overruns and supported by grants to deliver demonstration and pre-commercial projects.

UK

As part of the fourth allocation round of the Contracts for Difference framework, the UK government ring-fenced GBP 20 million (USD 33.9 million) for tidal stream projects. The ringfence sets limits on how many projects can be successful and on government spending. This will finance the installation of 40 MW of capacity. Two contracts were awarded to Orbital Marine Power’s 7.2 MW Eday project in Orkney, Scotland. In Wales, Magallanes Renovables will power the 5.62 MW Morlais Magallanes project. Lastly, the MeyGen project, which has provided power to the grid since 2016, will expand its generating capacity by 28 MW (OEE, 2022a).

The Contracts for Difference scheme awards contracts based on the LCOE, and the projects bidding at the lowest price win contracts. The price that the project receives in a ringfence is the price that the last successful project receives (marginal pricing) within the ringfence. Each contract lasts for 15 years.

The scheme is designed to ensure that projects can deliver - with, for example, deadlines for projects to reach financial close (January 2024), at the agreed strike price (GBP 178.5/USD 302.5 per MWh). Eligibility also requires a lease agreement, marine licence and grid offer, thus ensuring a minimum maturity for projects.

The UK announced that the auctions are moving from bi-annual to annual. The next Contracts for Difference round is scheduled for 2023.

Power purchase agreements

Power purchase agreements (PPAs) are long-term contracts between an electricity producer and a customer, where the customer agrees to buy electricity directly from the producer. This arrangement provides financial certainty for both parties, as the price of the electricity is guaranteed for the duration of the PPA. It guarantees a certain level of revenue to the producer, lowering the cost of capital, but also provides a fixed price for consumers, shielding them from price hikes (such as the one that occurred in 2022-2023 because of the European gas crisis).

The Swedish tidal energy company Minesto has a PPA with the Faroese electric utility company SEV. The PPA covers the installation of two 100 kW tidal kites (turbines) and an additional capacity of 4 MW in the Vestmannasund strait of the Faroe Islands. In the long term, the plan is to build out tidal energy to harness the 30-70 MW of potential capacity. This is part of the Faroe Islands' goal of reaching a 100% renewable-based energy system by 2030.

** This content was formulated based on information shared by members of IRENA's Collaborative Framework on Ocean Energy and Offshore Renewables.*

© Magallanes Renovables

2.4 Creating market visibility with a supportive policy framework

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, streamlined consenting processes and the inclusion of ocean energy in wider planning processes.

National deployment targets show the path to market

National deployment targets, coupled with earmarked revenue support, are one of the best ways to give private investors and OEMs clear signals on future markets. Such targets directly publicise the size of the market, reduce the capital costs of projects by reducing perceived market risks, and increase access to finance.

The increased focus on decarbonisation efforts, as well as the current gas crisis, are added incentives for countries to plan an offshore renewables roadmap and to establish clear policies that can help in the achievement of national ocean energy targets. This includes countries' Nationally Determined Contributions (NDCs) towards reducing greenhouse gas emissions as part of the process of the United Nations Framework Convention on Climate Change, as well as pan-national or national targets such as the National Renewable Energy Action Plans (NREAPs).

At the time of writing, only three countries, all in Europe (Ireland, Portugal and Spain), have national deployment targets for ocean energy. Several countries provide support for ocean energy but do not simultaneously use targets, which is a missed opportunity.

Ireland

The Irish National Energy and Climate Plan (NECP) sets a target for ocean energy of 30 MW by 2030 and 110 MW by 2040.

Portugal

The Portuguese National Climate and Energy Plan (NECP)* includes, in its 2019/2020 version, a 70 MW deployment target for wave energy by 2030. Portuguese NECP targets have been under revision since early 2023.

Spain

The roadmap for the development of offshore wind and marine energy in Spain includes a target for 40-60 MW of marine energy by 2030.

** An integrated plan to meet the EU's climate and energy objectives, required from all EU Member States.*

Streamlined consenting processes accelerate deployments and reduce costs

Because ocean energy is an innovative technology, national and regional consenting authorities can lack experience in providing consent for ocean energy projects. Some processes were designed for large offshore oil and gas or wind energy projects that have completely different scales and environmental impacts. This lengthens a process that is already time-consuming for any renewable energy project. Thus, cutting red tape and streamlining permitting is the key demand from the wind industry today (ETC, 2023).

Tailor-made and streamlined consenting for ocean energy will accelerate development and reduce the costs of the process. A time limit of one year for the whole consent process for single devices or small pilot farms is considered the best practice in the industry, including a three-month lead time for consent applications. This would ensure that the costs and timelines related to consent are proportionate to the size of the project. Finally, appointing a single point of contact to be responsible for all the requirements and providing guidance greatly facilitates the process for developers, who are often still small companies at the early stages of development for a given technology (ETC, 2023).

Scotland

In Scotland, the Marine Scotland Licensing Operations Team is a single point of contact for the entire ocean energy consenting process. A developer can apply, within the same application, for consents for both the required offshore and onshore works. This reduces the administrative burden drastically.

The consenting process does not have a strict deadline, but Marine Scotland aims at a nine-month lead time. The time frame can vary if further consultation or a public inquiry is required. In practice, the process usually takes 1-2 years, which is already far less than in other countries (ETIP Ocean, 2021).

Wider planning processes drive ocean energy's industrial roll-out

To ensure that the wider supportive ecosystem is in place to help scale ocean energy into a large industrial sector, ocean energy should be included in wider planning processes. These could include infrastructure plans and energy networks, marine spatial planning, industrial strategies, and skilling and education strategies.

Because ocean energy technologies are new, most plans have not been drawn up with them in mind. "First come, first served, last arrived, no service" should not be the defining criteria for whether or not new sectors should be included in existing planning processes. Rather, the criteria for inclusion should focus on the overall potential of a technology, the national/local relevance, the benefits to consumers or industrial ecosystems, *etc.*

National governments should undertake cross-cutting work to ensure that key national strategies and plans explicitly account for the scale-up needs of ocean energy.

Upskilling, reskilling and information sharing

The small size of the ocean energy sector necessitates measures to strengthen capacity building and international technology co-operation among policy makers, industry, academia and users of these technologies. There is a growing need to increase the number of professionals with knowledge and skills in the development and deployment of ocean energy technology. This can be done by exchanging knowledge with the offshore renewables sector, by facilitating reskilling of the work force from the fossil fuel industry to renewables, and by working closely with academia and education authorities to align curricula with sector jobs (including a focus on education in science, technology, engineering and mathematics, or STEM).

Importantly, partnerships need to be built to share existing information and to collaborate in a more systematic manner. Front-runner countries can encourage knowledge transfer to locations where ocean energy is still in the early stages of development, and such cross-water partnerships could spur the needs for financial resources and business development analyses among emerging continental economies and islands.

3 KEY RECOMMENDATIONS

There is clear evidence that the energy crisis is growing, contributing to a widening energy poverty gap and exacerbating climate change impacts. Now, more than ever, it is important that countries accelerate their commitments to increasing the share of renewables in their energy supply and demand mix. Ocean energy is a solution with tremendous potential.

Identified recurring challenges in the deployment of ocean energy solutions include insufficient funding opportunities and a lack of market visibility. The purpose of this brief has been to provide insights through which available financing mechanisms can be scaled up to drive investments in existing and upcoming ocean energy solutions. The brief also suggests additions to existing policies that can help private investors see the opportunity more clearly and improve the business case for projects.


© Sabella

At the R&D and prototype stages, promote the development and/or replication of stage-gate programmes globally while simultaneously maintaining grant funding.

- R&D and prototype projects aim to test components or devices and do not generate revenue. For this reason, grants are critical to finance this stage - particularly the deployment of first prototypes in open waters. The addition of a 100% public funding channel, via pre-commercial procurement, represents an innovative and essential way to sustain financing for this phase. This addresses the negative externalities of technology development.

Full funding of initial prototype deployments allows core ideas to be tested and verified. This "proof of concept" then allows developers to seek some private investment for the next and more costly stage of technology development, although public support will still be needed.

- The stage-gate approach also fosters innovation by requiring technology developers to compete against each other based on standardised criteria. It thus ensures the best use of public funding and lowers the need for this funding. As the awarded projects are deployed, they support the development of local supply chains in participating countries.

At the demonstration and pre-commercial phases, leverage combined finance solutions to their highest potential.

- These pilot farms are generally project-financed, combining several sources of public and private grants, debt and equity into a package. They are expected to generate electricity and (some) revenue for private investors. Grants are no longer sufficient to ensure that projects are delivered.
- Combining different public instruments will foster a good use of public funding, as some instruments can make others cheaper. A successful financial jigsaw should include:
  - Grant funding - to reduce the total financing requirement and cost of finance.
  - Public-supported equity - to improve access to capital and lower the cost of finance.
  - Public-guaranteed loans - to improve access to capital and lower the cost of finance.
  - Insurance and guarantee fund - to cover technical risk, reduce financial exposure and allow private investors to fill the remaining financing gap at a lower cost.
  - Revenue support - to finance operational expenditure (OPEX), interests from debt and dividends for equity.
- No single public support instrument will be sufficient to deliver ocean energy demonstration and pre-commercial projects. A range of support mechanisms must be available to finance a project at the lowest cost to the public purse.

© Ocean Energy

At the industrial roll-out phase, ensure that revenue support is earmarked to attract private investors.

- Grants can cover only a portion of the overall project costs, decreasing as the technology becomes more commercial. Equity/debt providers demand higher returns for innovative projects. Wholesale electricity prices alone are not sufficient to cover those returns without a top-up. This may motivate private capital providers, given the potentials for technical leadership and a first-mover advantage in a new ocean energy market.
- The establishment of revenue support schemes specific to ocean energy projects at the national level is essential. It is highly recommended that proposed schemes enable the first demonstration and pre-commercial projects to go ahead and set a clear signal that support will be in place for a subsequent industrial roll-out. In most, if not all, cases, support can be provided to ocean energy within existing national support frameworks for renewable energy.
- Competitive auctions are a more recent type of revenue support, while feed-in tariffs or renewable certificate systems were common in the past 20 years. All can deliver well, if properly designed. For auctions specifically, it is recommended that separate “pots” be earmarked. These pots should establish a minimum amount of funding or capacity deployment solely for ocean energy. Other innovative renewable technologies can also be included in the pot, as long as they have not yet been deployed at scale.
- The development of a tax system can also be used to provide revenue support, without impacting electricity bills or public expenditure. Large companies buy electricity from producers via power purchase agreements. Without revenue support, ocean energy PPAs will be more expensive than PPAs from other energy sources. A system of tax credits allows companies to claim this extra cost back via reduced tax bills. The PPAs allow ocean energy projects to attract the necessary revenue, but this is funded through foregone tax revenues rather than a levy on electricity consumers.

Streamline and reduce timelines for licensing and consenting, and adopt an “adaptive management” approach.

- Streamlining and reducing lead times to deliver projects is a top priority for the wind industry, and it is also a significant demand in the ocean energy sector. A lead time of a maximum of one year for permitting processes is considered best practice and should be implemented by national/regional authorities, including through the provision of deadlines for processes (ETC, 2023).
- Also critical is the need to adopt an “adaptive management” approach for licensing and consenting decisions. When making decisions, authorities take on small short-term risk to gain new knowledge about environmental impacts. These learnings then inform future decisions. Authorities progressively reduce uncertainties about the impacts of ocean energy, while still controlling risk.

REFERENCES

CalWave (2022), "CalWave successfully concludes historic wave energy pilot in California with zero intervention and 99% uptime", 01 September 2022, https://calwave.energy/calwave-successfully-concludes-historic-wave-energy-pilot-in-california (accessed 27 February 2023).

CorPower Ocean (2023), "Projects", https://corpowerocean.com/projects (accessed 27 February 2023).

EC (2021), *The EU blue economy report 2021*, European Commission, Brussels, https://op.europa.eu/en/publication-detail/-/publication/0b0c5bfd-c737-11eb-a925-01aa75ed71a1 accessed 21 March 2023).

ETC (2023), *Streamlining planning and permitting to accelerate wind and solar deployment*, Energy Transitions Commission, www.energy-transitions.org/publications/planning-and-permitting (accessed 27 February 2023).

ETIP Ocean (2019), *Powering homes today, powering nations tomorrow*, Report, European Technology & Innovation Platform for Ocean Energy (ETIP), Brussels, www.oceanenergy-europe.eu/wp-content/uploads/2019/04/ETIP-Ocean-Integrated-Strategy-2019-LR.pdf (accessed 26 February 2023).

ETIP Ocean (2021), *Ocean energy and the environment: Research and strategic actions*, European Technology & Innovation Platform for Ocean Energy, Brussels, www.etipocean.eu/knowledge_hub/ocean-energy-and-the-environment-research-and-strategic-actions (accessed 4 March 2023).

Europewave (2023), x"Welcome to EuropeWave", Funding Programme Website, www.europewave.eu (accessed 27 February 2023).

Garanovic, A. (2021), "MeyGen delivers record-breaking 37GWh to UK grid as SIMEC Atlantis trims year-end losses", *Offshore Energy*, www.offshore-energy.biz/meygen-delivers-record-breaking-37gwh-to-uk-grid-as-simec-atlantis-trims-year-end-losses (accessed 26 February 2023).

Garanovic, A. (2022), "Sustainable Marine exports first floating tidal power to Nova Scotia grid", *Offshore Energy*, www.offshore-energy.biz/sustainable-marine-exports-first-floating-tidal-power-to-nova-scotia-grid (accessed 27 February 2023).

Garanovic, A. (2023), "Basque Energy Agency opens tender for Mutriku wave power plant's new turbines", *Offshore Energy*, www.offshore-energy.biz/eve-opens-tender-for-mutriku-wave-energy-plant-new-turbines/ (accessed 21 March 2023).

IRENA (2020a), *Innovation outlook: Ocean energy technologies*, International Renewable Energy Agency, Abu Dhabi, www.irena.org/publications/2020/Dec/Innovation-Outlook-Ocean-Energy-Technologies

IRENA (2020b), *Fostering a blue economy: Offshore renewable energy*, International Renewable Energy Agency, Abu Dhabi, www.irena.org/-/media/Files/IRENA/Agency/Publication/2020/Dec/IRENA_Fostering_Blue_Economy_2020.pdf?rev=57eb343cbcbc47bb8d7fa39b4cdd6a03

IRENA (2021), *Offshore renewables: An action agenda for deployment*, International Renewable Energy Agency, Abu Dhabi, www.irena.org/publications/2021/Jul/Offshore-Renewables-An-Action-Agenda-for-Deployment

IRENA (2022), *World energy transitions outlook 2022: 1.5°C pathway*, International Renewable Energy Agency, Abu Dhabi, www.irena.org/publications/2022/Mar/World-Energy-Transitions-Outlook-2022

IRENA (2023), "Ocean Energy", www.irena.org/Energy-Transition/Technology/Ocean-energy (accessed 27 February 2023).

Minesto (2020), "Faroe Islands – tidal energy to reach 100% renewable by 2030", https://minesto.com/projects/faroe-islands (accessed 27 February 2023).

OEE (2022a), "UK sets strong example with revenue support for 40 MW of tidal stream", Ocean Energy Europe, www.oceanenergy-europe.eu/cfd-ar4-tidal/ (accessed 12 March 2023).

OEE (2022b), "Five wave energy projects to continue to next phase of EuropeWave", Ocean Energy Europe, Institution Website, www.oceanenergy-europe.eu/industry-news/five-wave-energy-projects-to-continue-to-next-phase-of-europewave (accessed 3 December 2022).

OES and IEA (2017), *An international vision for ocean energy*, Report, Ocean Energy Systems and International Energy Agency, Lisbon and Paris, www.ocean-energy-systems.org/documents/24845-oes-vision-2017.pdf/ (accessed 26 February 2023).

Radowitz, B. (2022), "'We're all in trouble' | Wind turbine makers selling at a loss and in a 'self-destructive loop', bosses admit", *Recharge News*, www.rechargenews.com/wind/were-all-in-trouble-wind-turbine-makers-selling-at-a-loss-and-in-a-self-destructive-loop-bosses-admit/2-1-1197217 (accessed 4 March 2023).

SAE Renewables (2023), "MeyGen site generates the world's first 50GWh of electricity from tidal power", https://saerenewables.com/meygen-site-generates-the-worlds-first-50gwh-of-electricity-from-tidal-power (accessed 4 March 2023).

Tacconi, P. and D. Magagna (2019), "About cost-reduction of ocean energy: Lessons from Horizon 2020", *SETIS*, No. 20, pp. 11-12, https://publications.jrc.ec.europa.eu/repository/bitstream/JRC116581/setis_magazine_20_2019_ocean_energy_web.pdf.

Wave Swell (2021), "King Island project", Company Website, www.waveswell.com/king-island-project-2 (accessed 27 February 2023).

Wind Europe (2022), "Why is the European wind industry struggling?", https://windeurope.org/, https://windeurope.org/intelligence-platformproduct/why-is-the-european-wind-industry-struggling/ (accessed 4 March 2023).

IRENA

International Renewable Energy Agency

www.irena.org