IRENA
International Renewable Energy Agency

Offshore innovation widens renewable energy options

Opportunities, challenges and the vital role of international co-operation to spur the global energy transformation

Brief to G7 policy makers

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About IRENA

The International Renewable Energy Agency (IRENA) is an intergovernmental organisation that supports countries in their transition to a sustainable energy future, and serves as the principal platform for international co-operation, a centre of excellence, and a repository of policy, technology, resource and financial knowledge on renewable energy. IRENA promotes the widespread adoption and sustainable use of all forms of renewable energy, including bioenergy, 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

Overview

Recent data and research findings confirm the rapid capacity growth, ongoing cost and performance improvements, increasing technological sophistication and continued need for international standardisation for new renewables, such as offshore wind power and nascent ocean energy technologies. This brief by the International Renewable Energy Agency (IRENA) provides background and recommendations to policy makers in the G7 on how to step up progress, particularly to broaden the world's future energy options and meet international climate goals.

Offshore wind market status and outlook

- Offshore wind energy has recently seen rapid technology cost reductions and substantial uptake in different markets.
- Today 90% of global installed offshore wind capacity is in the North Sea and nearby Atlantic Ocean, but capacity is growing elsewhere.
- The offshore wind market grew by around 4 gigawatts (GW) in 2017, accounting for around 10% of total wind capacity additions that year. The total investment value for this 4 GW was around USD 20 billion.
- Denmark, Germany and the United Kingdom (UK) were pioneers in the sector and are now established leaders, with China recently emerging as a key player.
- However, the globalisation of offshore wind must be encouraged to achieve the more than 520 GW of total installed capacity by 2050 outlined in IRENA's 2050 transformation roadmap (REmap), up from around 20 GW in mid-2018.
- Power generation from the more than 520 GW would account for nearly 4% of global electricity generation in IRENA's REmap case in 2050.
- Development is needed of a harmonised and documented global standardisation framework that enables countries to access the cost-effective potential of offshore wind.

Offshore wind cost and performance outlook

- From 2020 to 2022 the cost of electricity from newly commissioned offshore wind power projects will range from USD 0.06/kilowatt-hour (kWh) to USD 0.10/kWh based on current trends and the prices awarded in auctions in 2016-2018, a significant decline compared to USD 0.14/kWh in 2017.
- Advances in offshore wind turbine technology, wind farm development, and operations and maintenance are helping to drive down the cost of electricity from offshore wind.

- Increasing developer experience (which reduces project development costs), increasing industry maturity (lower cost of capital) and economies of scale across the value chain are also helping to lower costs.

- The representative installed cost between 2011 and 2016 for an offshore wind farm in European waters was around USD 4 500/kW but declined in 2017 and is anticipated to stay below USD 4 000/kW.

- The increase in turbine size helps to increase wind farm output. These larger turbines with larger swept areas yield higher capacity factors for the same resource quality.

- The capacity factors for offshore wind farms are high, with the average of new projects to have 50% capacity factors by 2022 as turbine size grows and the technology improves. Further gains are possible, as 12 megawatt (MW) pilots are in development that are significantly larger than today's largest 9.5 MW turbine.

- Offshore wind power also offers a solution to space and acceptance issues in some markets.

- This makes offshore wind power a particularly attractive proposition given its ability to scale and the fact that the decreasing cost of electricity for new offshore wind projects means that new projects can often now compete directly with fossil fuel-fired electricity without financial support.

Emerging offshore renewable technology

- New technology developments such as floating foundations will increase the economic potential of offshore wind technology by opening up larger areas to development than are currently feasible with fixed-bottom foundations.

- Floating wind farms are a new development, with a first 30 MW demonstration project, "Hywind", now operating successfully in the UK. Hywind's developers are targeting an electricity cost of USD 0.05 to 0.07/kWh by 2030.

- This unleashes the potential of deep-water offshore wind power, relevant for countries with limited continental platform areas, such as Japan.

- Other forms of ocean energy are beginning to emerge – such as tidal barrage, tidal current, wave energy and thermal gradient – but they are yet to be deployed commercially at scale.

- In 2017 cumulative ocean energy capacity (excluding offshore wind and tidal barrage) doubled worldwide from less than 12 MW in 2016 to over 25 MW in 2017, led by tidal current and wave energy.

- Wave energy has significant potential, but so far a robust and economic technology is missing.

- Apart from electricity generation, other options such as seawater cooling are already successfully deployed around the world.

Recommendations

- G7 countries can play a leading role in facilitating investments in secure and sustainable energy, including strengthening efforts in energy R&D for offshore wind and marine renewable energy technologies.

- Joint efforts are needed to develop technically and economically viable technology solutions for ocean technologies still in the development stage.

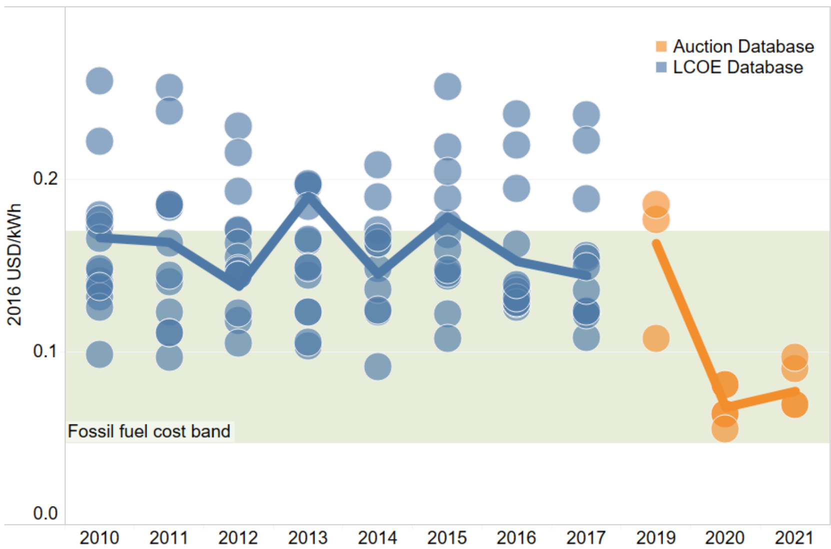
- The G7 can call on IRENA's knowledge and network to help accelerate the energy transition globally. With the group's 2018 president, Canada, now a State in Accession to IRENA, all G7 countries are formally engaged with the intergovernmental agency. IRENA stands ready to deepen its support to the G7 as needed.

1. Rise of a competitive giant

Advances in offshore wind turbine technology, wind farm development, and operations and maintenance are helping to drive down the cost of electricity from offshore wind farms. Other factors contributing to this improvement in competitiveness include increasing developer experience (which reduces project development costs and risks), increasing industry maturity (lower cost of capital) and economies of scale across the value chain.

From 2010 to 2016 the global weighted average levelised cost of electricity (LCOE) of offshore wind power decreased from USD 0.17/kWh to USD 0.14/kWh (Figure 1). Meanwhile the LCOE for projects that were successful in auctions in 2016-2018 (for projects to be commissioned in 2020-2022) in Europe and North America ranged from around USD 0.06/kWh to USD 0.10/kWh (IRENA, 2018a). These auction results have heralded a step change in competitiveness for projects that will be commissioned in the coming years. Offshore wind is now an attractive proposition to provide clean, low-cost electricity that can compete head-to-head with fossil fuels without financial support.

Figure 1: Global levelised cost of electricity from offshore wind farms by year of commissioning, 2010-2021



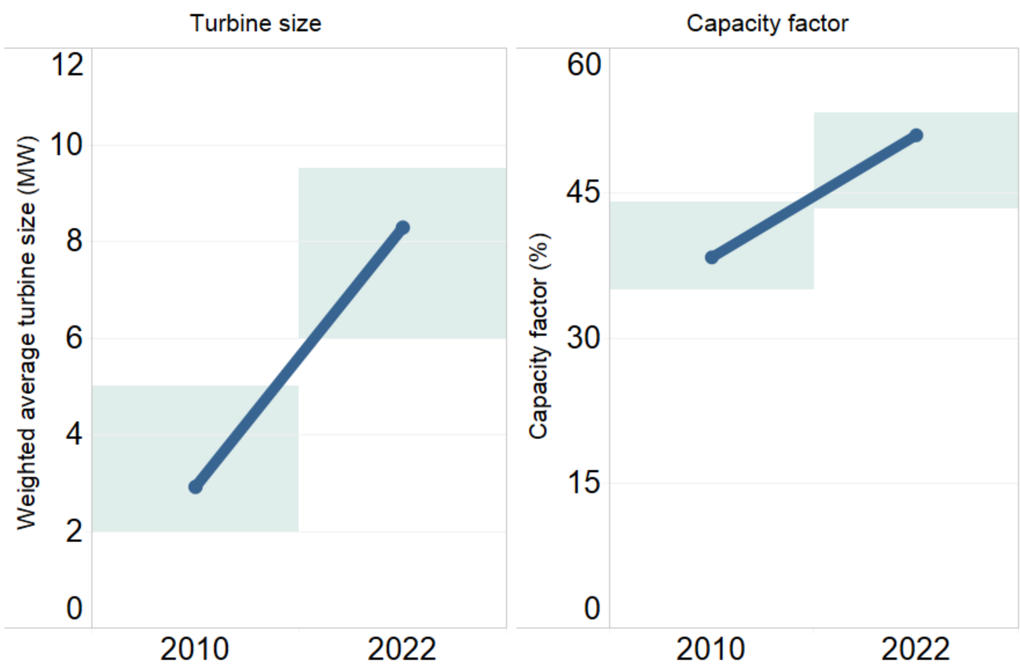
Source: IRENA, 2018a.

The cost reductions seen for offshore wind farms have been driven by technology improvements that have raised capacity factors[1], as well as by declines in total installed costs, operations and maintenance costs, and the cost of capital as project risk has declined.

Improvement in wind turbine technology is helping to drive down costs. Between 2010 and 2022 the weighted average turbine size for newly commissioned offshore wind farms could increase from 2.9 MW to 8.3 MW (Figure 2), an increase of 184%. The growth in turbine size helps to increase wind farm output. These larger turbines with greater swept areas yield higher capacity factors for the same resource quality. As a result, the global weighted average capacity factor of new offshore wind farms could increase by a third between 2010 and 2022, to 51%.

Offshore wind turbines deployed at present typically have a rated capacity of about 6 MW, with rotor diameters of around 150 metres, but wind farms with today's largest commercially available 9.5 MW capacity and 164-metre diameter blades will be installed from 2019 onwards. These technology improvements are set to continue beyond 2022, as GE announced in 2018 that it is developing the 12 MW Haliade-X turbine for offshore applications, with 107-metre-long blades resulting in blade diameters of over 200 metres. The industry is also working on concepts for even larger turbines.

Figure 2: Average offshore wind farm turbine size and capacity factors, 2010-2022



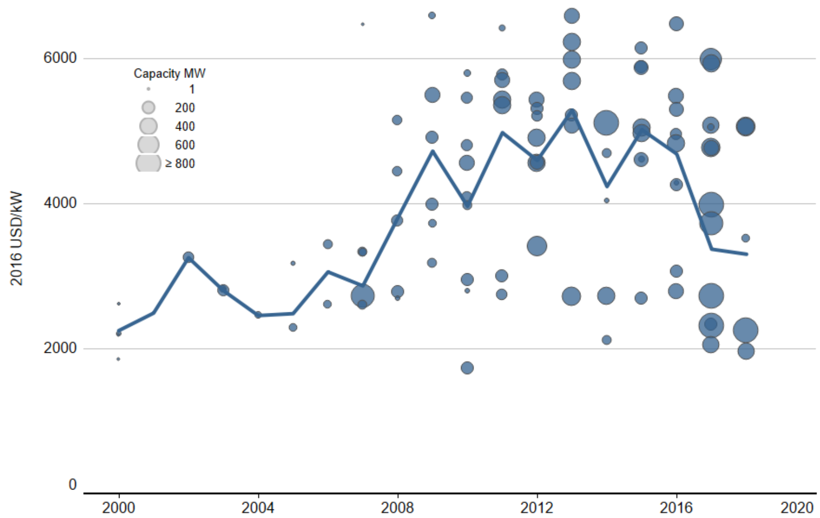
Based on: IRENA Renewable Cost Database; MAKE Consulting, 2018; and Global Data, 2018.
Note: Data in this chart are for the year the offshore wind farm is commissioned. The lines represent the global weighted average of projects in that year, while the band represents the range for all projects.

[1] The capacity factor is the number of equivalent hours in a year that the generation asset is operating at full capacity, divided by the total number of hours in the year.

The main cost components of offshore wind farms are the turbines (including towers), the foundations and the grid connection to shore. The turbine represents the largest cost component, accounting for around 45% of the total installed cost (IRENA, 2018a). In 2016 the average installed cost for a European offshore wind farm was USD 4 697/kW (Figure 3). Between 2002 and 2015 offshore wind farm projects were increasingly sited farther from the coast and in deeper waters in order to access higher wind speeds (IRENA, 2018a). This led to increasing installed costs up to around 2012/2013 (IRENA, 2018a) as more expensive foundations were required and installation costs were also higher.

However, since around 2013 installed costs for commissioned projects have started to fall as the industry has matured, as larger turbines are installed and as project developers have become more experienced. Larger turbines help to amortise installation and foundation costs, while larger projects also have proportionately lower project development costs. At the same time developer experience has streamlined and optimised wind farm project development and design, reducing costs and lead times. Greater economies of scale in supply chains, as well as competition, have reduced costs across the board.

Figure 3: Total installed costs and capacity of offshore wind farms worldwide, 2000-2018



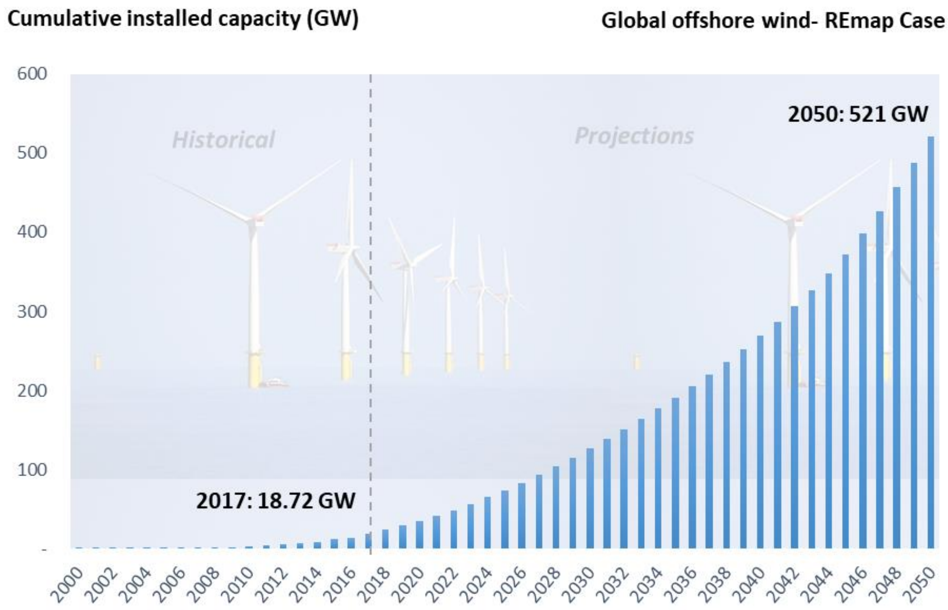
Source: IRENA Renewable Cost Database.
Note: The line represents the weighted average of all projects in that year.

2. Surging capacity as costs fall and experience grows

The offshore wind market grew by around 4 GW in 2017 and accounted for around 10% of total wind capacity additions in that year (IRENA, 2018b), while total installed offshore wind capacity reached around 20 GW in mid-2018. Offshore wind technology allows countries to exploit the generally high wind resources offshore, while developing gigawatt-scale programmes close to densely populated coastal areas. This makes offshore wind an important addition to the portfolio of technologies available to decarbonise the energy sector of many countries. This potential could see offshore wind grow from around 20 GW today to more than 520 GW by 2050 – accounting for nearly 4% of global electricity generation.

If the world is to meet the goals of the Paris Climate Agreement, then the pace of offshore wind power installations will need to grow significantly. IRENA's analysis of the pathway for transformation of the global energy system sees total installed offshore wind capacity rising to 521 GW by 2050[2], or nearly 10% of the total global installed wind capacity in 2050 of 5 444 GW (IRENA, 2018c). In addition to increases in new offshore wind power installations, in the future developments also will be needed to replace existing wind turbines. This will begin in earnest in the early 2030s as the earliest projects reach the end of their economic lives and will further accelerate from 2040. As a result, the total yearly capacity addition would reach around 33 GW in 2050, representing a more than eight-fold increase from the 4 GW of capacity addition in 2017.

Figure 4: Historical and projected total installed capacity of offshore wind, 2000-2050



Source: IRENA, 2018b, 2018c.

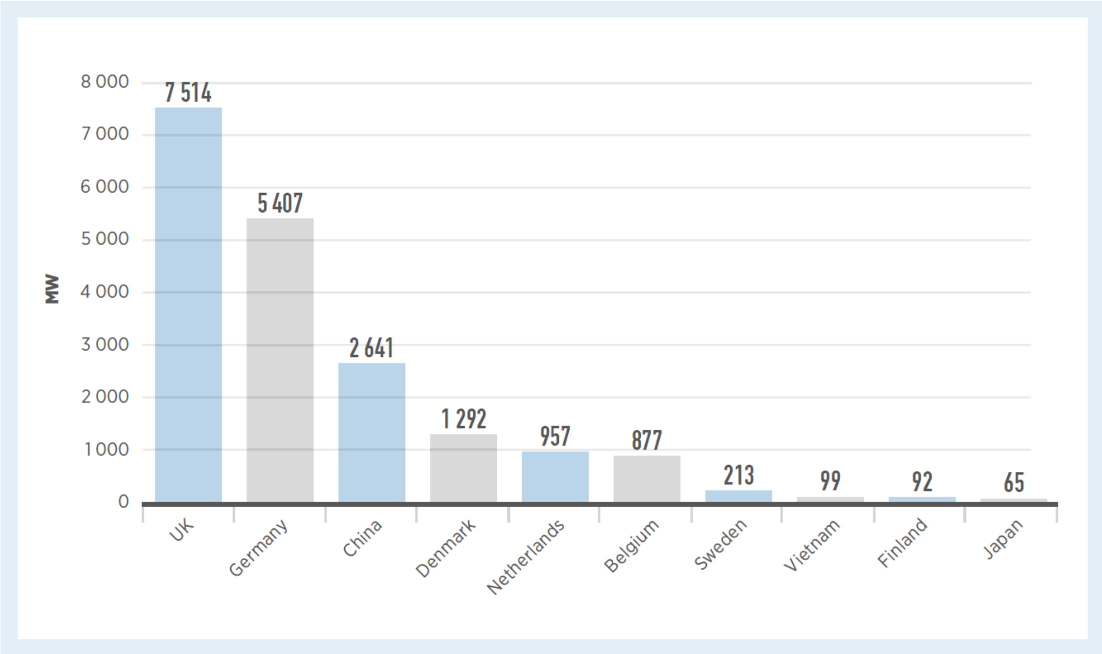
Today 90% of global installed offshore wind capacity is located in the North Sea and nearby Atlantic Ocean (IRENA, 2018b). In early September 2018 the world's largest operational offshore wind farm officially opened. Located in the Irish Sea, the Walney Extension Offshore Wind Farm has a total capacity of 659 MW and is capable of powering nearly 600 000 homes in the UK. The UK had the largest installed offshore wind capacity worldwide as of the end of 2017, at around 7.5 GW, compared with 5.4 GW in German waters, 2.6 GW in Chinese waters and 1.3 GW in Danish waters (IRENA, 2018b). However, the expansion of offshore wind markets is moving beyond these front runners. Countries such as Australia, Canada, China, India, Japan, the Republic of Korea, Turkey and the United States have ambitious plans to develop their offshore wind markets over the next few years.

In the United States, for example, the state of Massachusetts has energy legislation that calls for 1 600 MW of new offshore wind energy by 2027. As a result, the 800 MW Vineyard Wind project off the coast of southern Massachusetts is scheduled to start construction in 2019. Similarly, India's Ministry of New and Renewable Energy has announced ambitious plans for 5 GW of offshore wind by 2022 and 30 GW by 2030 (MNRE, 2018).

[2] A revised analysis taking into account the latest technology and policy developments in 2018, as well as recent country targets, will be presented in IRENA's upcoming global energy transformation publication in 2019.

With this growth the importance and benefits of harmonising international standards that adapt to different local conditions is becoming increasingly important. Because turbine manufacturers and other industry stakeholders operate transnationally, the industry is a major promoter of these harmonisation efforts that not only make offshore wind farm development easier in new markets, but also provide significant benefits to local jurisdictions by lowering costs and ensuring that standards are based on proven systems.

Figure 5: Installed capacity of offshore wind by country in 2017



Source: IRENA, 2018b.

3. Leveraging local industrial capacity for offshore wind projects

Offshore wind projects create ample opportunities for local value creation. Income and jobs can be maximised by leveraging existing economic activities and building upon domestic supply chains. To avoid skills gaps, however, education and training must be attuned to the emerging needs of the offshore wind industry. This is crucial, as training and skill building form an important part of efforts to generate capable local supply chains.

The development of a typical 500 MW offshore wind farm requires around 2.1 million person-days of work.[3] Manufacturing takes up 59% of the labour requirements of such a project, followed by operations and maintenance (24%) and installation and grid connection (11%). Factory workers account for more than half of the labour needed in manufacturing.

Maximising local value creation depends on successfully leveraging existing expertise as well as capacities in other industries that can provide expertise, raw materials and intermediate products. In particular, steel, copper, lead and fibreglass are heavily used for the development of an offshore wind project.

[3] For example, the construction phase of the Triton Knoll project in the UK is expected to support around 3 000 jobs and to sustain 170 jobs during its 25-year economic life according to project developers.

Countries that do not have sufficient capacity to manufacture all the equipment locally can derive jobs and other benefits in segments of the value chain that are easier to localise or that are, by necessity, local (*e.g.*, operations and maintenance jobs and, to a lesser extent, installation and grid connection).

To strengthen the industrial capability of domestic firms, policy measures and interventions are needed that contribute to increased competitiveness. These measures could include industrial upgrading programmes, supplier development programmes, promotion of joint ventures, development of industrial clusters and investment promotion schemes (IRENA, 2018d).

Offshore wind development benefits from synergies with offshore oil and gas, specifically in terms of skills and occupational groups. Successful job migration between sectors, however, depends on dedicated retraining policies. Specific policy measures, such as upgrading and supplier development programmes, support for joint ventures, or industrial promotion schemes, may be needed to strengthen the industrial capacity of domestic firms.

4. The emergence of ocean energy technologies

Offshore wind is not the only marine energy technology that could be exploited. New designs and improvements are emerging for power generation technologies such as tidal barrage, tidal current, wave energy and thermal gradient. The oceans can provide more than just electricity, however, and other technologies such as seawater cooling already have been successfully economically deployed around the world.

In 2017 cumulative ocean energy capacity (excluding offshore wind) doubled worldwide from less than 12 MW in 2016 to over 25 MW in 2017. Tidal current deployments have increased to over 17 MW, due largely to new projects including the MeyGen/Inner Sound Phase 1A in the UK and the Paimpol-Bréhat in France. Wave energy deployments also have doubled to 8 MW in 2017 (OES, 2018a). Among ocean energy technologies, wave and tidal energy converters are the technologies of greatest medium-term potential that, like so many other innovations in the past, could become cost-competitive much faster than expected.

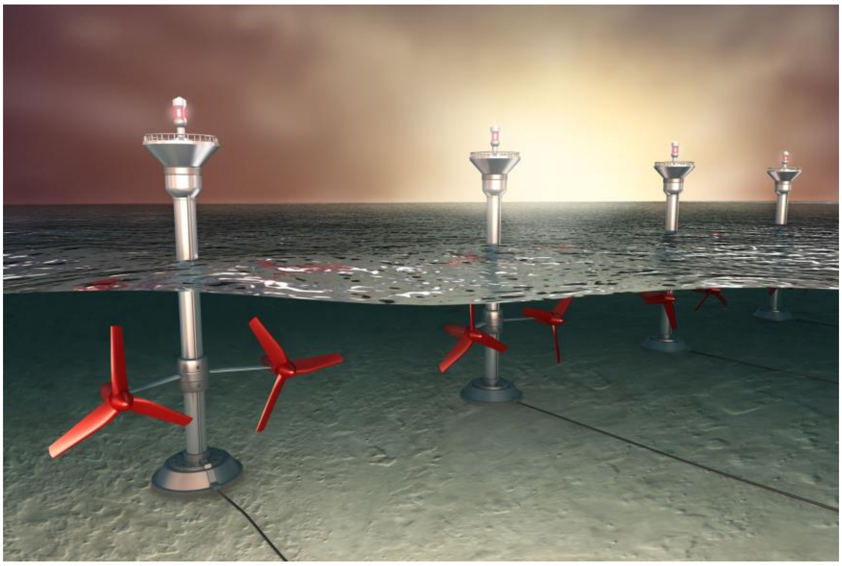
In Japan, Wave Energy Technology conducted demonstration trials on its scalable, floating wave energy prototype off Kobe city in Japan. The demonstration of the wave energy technology is part of the development of a commercial-scale unit of up to 1.2 MW (OES, 2018a)[4]. In Italy, the first full-scale prototype of a 2.5 MW oscillating water column (OWC) power generating unit that is integrated in a breakwater was under construction as of the end of 2017 in the port of Civitavecchia in Rome and was developed by the Università Mediterranea di Reggio Calabria.

For tidal energy technologies a distinction must be made between tidal range (barrage) and tidal current technologies. Tidal barrage technologies are similar to conventional hydropower that has a reservoir, but in a marine environment. However, the costs and difficulty of widespread development of these technologies mean that there is an increasing technology focus on tidal current, or "in-stream" technologies that are more modular and that could potentially be more easily and rapidly deployed in a wider range of locations. These projects are small today, but a significant increase in the installed capacity of tidal current technologies could occur, based on the range of projects currently planned.

Nova Scotia in Canada is a good example, as this province has an important tidal energy potential due to its large tidal range, and the Bay of Fundy has the highest tidal range in the world. In addition to

[4] As of end-2017.

existing facilities such as the 20 MW Annapolis Royal Generating Station, the government of Nova Scotia has the goal of generating a total of 300 MW of power from in-stream tidal energy projects within the next five years.



Tidal currents carry massive renewable energy potential
(Image: Shutterstock)

Ocean thermal energy conversion (OTEC) produces electricity based on abrupt temperature changes, such as between cold, deep ocean water and warm, tropical surface water. OTEC is still at the demonstration stage, with less than 1 MW installed globally as of the end of 2017 (OES, 2018a). Demonstration plants include a 15 kW OTEC plant in La Réunion, France (Indian Ocean); a 100 kW plant in Okinawa, Japan; a 30 kW plant in Saga, Japan; and a 105 kW plant in Hawaii, United States (Pacific) – all of which are operational – along with a 10.7 MW plant in Martinique, France (Caribbean), that is currently under construction (OES, 2018b).

International initiatives are emerging to support the development and deployment of ocean energy technologies. For example, the Ocean Energy Systems (OES)[5] initiative, which includes all G7 counties as members, has a goal of advancing research, development and demonstration of conversion technologies to harness energy from all forms of ocean renewable resources – such as tides, waves, currents, temperature gradient (OTEC and submarine geothermal energy) and salinity gradient for electricity generation, as well as for other uses, such as desalination – through international co-operation and information exchange. Building upon these initiatives and expanding international collaboration will be crucial to accelerate the entrance of these technologies into a commercial stage.

[5] The OES is also known as the "Technology Collaboration Program on Ocean Energy Systems" and is an intergovernmental collaboration among countries operating under a framework established by the International Energy Agency in Paris.

5. Innovation, standardisation and co-operation to accelerate growth

Continuous technology innovation and standards that provide quality assurance will be integral to the scaling up of ocean energy technologies. The development and harmonisation of standards for offshore wind will be crucial to facilitating its more widespread deployment. Lessons learned from the offshore oil and gas sectors offer opportunities to reduce effort to develop these standards, but they cannot be applied one-to-one to develop offshore wind standards. It is also important that quality infrastructure is put in place to operationalise these standards.

Continuous innovation in offshore and ocean technologies is an important part of the success of these technologies to date, but many more innovations are emerging that either are ready for commercialisation today or could be ready in the near future. For example, innovations in the development of wind farms – such as optimisation of the site layout for better use of wind resources, minimisation of aerodynamic wake effects and optimum use of varying seabed conditions – will enable much more informed and holistic layouts of offshore wind farms that reduce costs and improve performance. Innovation opportunities also exist and are being harnessed rapidly in operations, maintenance and service (OMS).

Technology innovation: Floating offshore wind

Developments in wind turbine technologies as well as in foundations, installation, access, operation and system integration have permitted moves into deeper waters, farther from shore, to reach sites with better wind resources. Today, turbines are being routinely installed in water depths of up to 40 metres and as far as 80 kilometres from shore. These turbines, rooted in the seabed by monopile or jacket foundations, are still restricted to waters less than 50 metres deep. This is a major limitation, as some of the largest potential markets for offshore wind, such as Japan and the United States, have few shallow-water sites.

Floating wind farms therefore are one of the most exciting developments in ocean energy technologies. Floating foundations offer the offshore wind industry two important opportunities: 1) they allow access to sites with water deeper than 50 metres, and 2) floating foundations ease turbine set-up, even for mid-depth conditions (30-50 metres) and may in time offer a lower-cost alternative to fixed foundations (IRENA, 2016). The first full-scale prototypes for floating wind turbines have been in operation for several years with three main designs being tested (Figure 6): spar buoys, spar-submersible and tension-leg platforms.

These are just entering the market as commercial projects, with a first 30 MW demonstration project operating successfully in the UK since 2017. The Hywind Scotland Wind Farm has a nominal power capacity of 30 MW, consists of five turbines of 6 MW each and uses a spar buoys design (Equinor, n.d.). After three months of operation, the Hywind farm claimed to have achieved a remarkable average capacity factor of 65% (Equinor, 2018). Based on progress seen in the market, three to five additional foundation designs are expected to be demonstrated at full scale by 2020, and the commercialisation of floating offshore wind could be anticipated between 2020 and 2025.

The ability of floating offshore wind turbines to unlock areas of deep water close to shore and large population centres, notably in Japan and the United States, could potentially greatly expand offshore wind deployment. Floating foundations therefore are potentially a “game-changing” technology for offshore wind power.

Figure 6: Examples of floating foundation designs

Illustration by Joshua Bauer, National Renewable Energy Laboratory, US Department of Energy.

Standards: Facilitating offshore wind uptake in new markets

Given that the first offshore wind markets emerged in Europe – a region with large areas with relatively shallow waters (particularly in Denmark and Germany) – the focus was on fixed structures, and floating offshore wind turbines have emerged only recently. The standards for floating offshore wind are only now being developed for new markets such as Japan and the United States. An added complication is that the natural and climatic conditions in Europe do not reflect the extreme conditions that can be found in other parts of the world, leading to the need to adjust standards to address, for example, typhoons, cyclones, earthquakes and icing. In the case of China, the offshore wind industry started by applying components and equipment used in other industries. As such, the industrial supply chain for offshore wind power is now focusing on technology development of specialised installation equipment (*e.g*., vessels) and methods tailored for national conditions.

At the International Electrotechnical Commission, the sub-committee TC 88/PT 61400-3-2 is working on standards for the "Design requirements for floating offshore wind turbines". The aim of the work is to minimise the technical risks for this technology, facilitating its scale-up. The sub-committee is at present led by the United States and the Republic of Korea. It includes experts from European countries, such as Denmark, France, Germany, the Kingdom of the Netherlands, Norway, Spain and the UK, as well as from other countries with a potential market for this technology, such as China, Japan and South Africa (IRENA, 2018e).

Standardisation in marine technologies will be crucial to spur widespread deployment of these technologies in the future. Countries require a blueprint, drawing on the experience of leading actors, to explore their full offshore wind potential. Development is needed of a harmonised and documented global standardisation framework that enables countries to access the cost-effective potential of offshore wind.

Offshore wind has the potential to be inclusive, cost-effective and game-changing. In this context IRENA provides a global platform that allows for the cross-pollination of ideas and best practice worldwide. The time is now for governments to put in place detailed offshore standardisation and quality control strategies to capitalise on what promises to be an exciting future for wind power and other marine technologies as their costs continue to fall.

6. Recommendations to G7 policy makers

Offshore energy technologies can play an important role in providing clean, affordable and secure energy from domestic resources. Offshore energy technologies can therefore help governments meet their economic, environmental, development and social goals in an increasingly cost-effective manner. However, the right regulatory, policy and institutional framework settings are essential to unlocking this economic potential and the creation of domestic supply chains, value added and jobs. This section identifies key recommendations to ensure that these benefits are realised.

Central and local governments, as well as other stakeholders, should ensure that the potential of low-cost offshore wind power is facilitated, not hindered.

The offshore wind industry is increasingly mature and delivers commercially proven solutions. However, the development of new markets needs to be facilitated by ensuring that:

- Clear regulatory and legal frameworks for the development and exploitation of offshore wind farms have been developed in conjunction with other offshore stakeholders.
- Supporting infrastructure in terms of grid connections, offshore substations, etc. is planned, and energy synergies with development zones are exploited to reduce costs from the sharing of assets where appropriate.
- Technical specification accounts for weather conditions in the future markets for ocean technologies; *e.g.*, very low temperatures or exposure to hurricanes. Internationally harmonised industry standards and quality control would help the globalisation of such technologies.
- Long-term goals and competitive procurement programmes exist for offshore wind. These can provide the certainty to industry to invest in the necessary onshore infrastructure and supply chains to ensure competitive project costs.

There are different models for how to achieve these goals, and countries should share experiences in terms of best practice to learn from one another.

Continued public support and public-private partnerships are needed for innovative offshore energy technologies and systems.

The enhancement of R&D of innovative technologies is crucial for the future, recognising that economic growth and protecting the environment can and should be achieved simultaneously. Continued investment in low-carbon technologies remains critical for ensuring future energy security and mitigating risks to sustainable growth of the global economy. G7 countries should play a leading role in facilitating investments in secure and sustainable energy, including strengthening efforts in energy R&D for offshore wind and marine renewable energy technologies.

Mission Innovation (MI) is a key tool to support clean growth and the global transition to a low-carbon economy. G7 countries could consider a joint initiative to further develop offshore renewable energy solutions. Offshore renewable energy including offshore wind and other marine technologies provides a unique opportunity to accelerate the deployment of renewable energy.

Offshore wind is a key pillar for renewables deployment in Germany, France and the UK. Significant potentials exist in all other G7 countries. This includes oceanic and inland sea applications (*e.g*., in the case of Canada). Offshore wind poses particular challenges, and a dedicated supply chain is needed. Innovation is focused on larger turbines and floating devices, as well as on clustering and processing of offshore wind electricity (*e.g*., potentially in the future for the production of hydrogen).

R&D support is required for emerging marine energy technologies at an early stage of development.

Many innovative marine technologies, such as tidal in-stream and wave energy, are at an early stage of development, and different concepts are at various stages of progress towards commercialisation. Joint efforts are needed to develop technically and economically viable solutions as well as to support a range of pathways to potential commercialisation.

IRENA can help the G7 make energy use more sustainable.

The G7 can call on IRENA's knowledge and network to help accelerate the energy transition globally. With the group's 2018 president, Canada, becoming a State in Accession to IRENA on 18 September 2018, all G7 countries are now formally engaged with the intergovernmental agency. IRENA stands ready to deepen its support to the G7 as needed.

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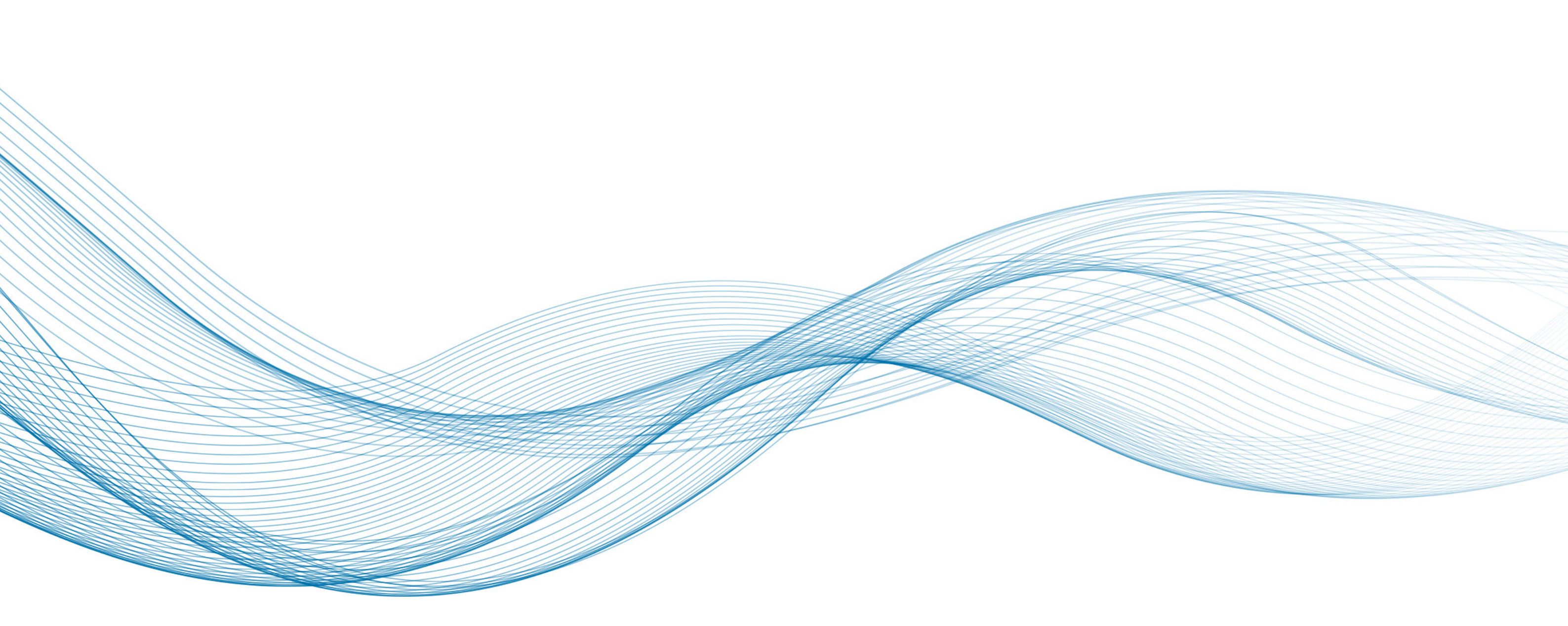

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