FOSTERING A BLUE ECONOMY

OFFSHORE RENEWABLE ENERGY

A contribution to the
Small Island Developing
States Lighthouses
Initiative 2.0

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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

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Photographs are from Shutterstock unless otherwise indicated. Cover illustration is based on Ling Ling Federhen.

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Abbreviations

CO_2	carbon dioxide
EUR	euro
GBP	British pound
GW	gigawatt
H_2	hydrogen
IMO	International Maritime Organization
IRENA	International Renewable Energy Agency
kW	kilowatt
kWh	kilowatt-hour
LCOE	levelised cost of electricity
LHI	Lighthouses Initiative
m^3	cubic metre
MENA	Middle East and North Africa
MW	megawatt
MWh	megawatt-hour
NDC	Nationally Determined Contribution
OTEC	ocean thermal energy conversion
PV	photovoltaic
R&D	research and development
RD&D	research, development and deployment
SDG	Sustainable Development Goal
SIDS	Small Island Developing State
TWh	terawatt-hour
UK	United Kingdom
UN	United Nations
US	United States
USD	US dollar

01

INTRODUCTION

> **“Oceans, seas and marine resources are critical to sustainable development, including sustainable ocean-based economies and to the 2030 Agenda for Sustainable Development as a whole. They underpin poverty eradication and food security, are a source of employment and livelihoods and support the well-being of humans and the planet.”**
>
> *– ANTÓNIO GUTERRES,*
> *UNITED NATIONS SECRETARY-GENERAL*[1]

Oceans are a source of abundant renewable energy potential, capable of driving a “blue economy” based on sustainable use of ocean resources. Energy harnessed from the oceans, through offshore renewables, can contribute to the decarbonisation of the power sector and to other end-use applications that are relevant for a blue economy (for example, shipping, cooling and water desalination). Nascent ocean energy technologies – including wave, tidal, ocean thermal energy conversion and salinity gradient energy – can make use of this enormous potential in line with overall sustainable energy and economic development.

Along with their own intrinsic renewable energy potential, the world’s oceans provide a crucial venue for the expansion of other renewable energy sources. Offshore renewables include offshore wind (fixed and floating foundations) and floating solar photovoltaic (PV) technologies, as well as various forms of ocean energy technologies. Offshore renewables can also provide significant socio-economic opportunities to countries with coastal areas and island territories, such as job creation, improved livelihoods, local value chains and enhanced synergies among blue economy actors.

Small Island Developing States (SIDS) are positioned to become the main beneficiaries of a blue economy driven by offshore renewables, helping to address some of SIDS’ most pressing needs, including:

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[1] https://undocs.org/en/a/74/630

- **AFFORDABLE AND RELIABLE ACCESS TO ELECTRICITY:** Renewables can replace costly power generation systems dependent on imported diesel and, with offshore variants, reduce the use of scarce land for energy facilities; and

- **FRESH, POTABLE WATER SUPPLIES:** Renewable energy technologies can support sustainable local desalination.

To ensure the sustainability of renewables sourced from oceans, benefits must be maximised while addressing potential negative impacts on ocean ecosystems. How the ocean energy technologies, including tidal, are affecting the environment, including marine life, is not clear. Negative impacts could arise in the form of habitat loss, animal-turbine interactions, noise and electromagnetic fields produced by sea cables, which may impact aquatic species. However, research to address these risks is being conducted. Some studies indicate that ocean energy may actually support biodiversity through artificial reefs, fish aggregation devices and marine protected areas.

As for any infrastructure project, detailed impact assessment studies and best practices must apply. As understanding of these technologies deepens, we must continue to mitigate any potential risks while maximising the socio-economic and environmental benefits of the various technologies.

This brief from the International Renewable Energy Agency (IRENA) discusses the potential of offshore renewables to contribute to achieving the United Nations (UN) Sustainable Development Goals (SDGs), particularly in the ongoing development of islands and coastal territories. This applies particularly to SDG 7 (ensure access to affordable, reliable, sustainable and modern energy for all) and SDG 14 (conserve and sustainably use the oceans, seas and marine resources for sustainable development).

This work – initially envisaged as a contribution to the UN Ocean Conference 2020[2] – aims to support the SIDS Lighthouses Initiative and to provide input to global discussions on the potential for sustainable ocean and offshore renewable energy development.

The brief draws on insights from various IRENA analyses and studies, including: *Future of wind* (IRENA, 2019a), *Future of solar photovoltaic* (IRENA, 2019b) and *Navigating the way to a renewable future: Solutions to decarbonise shipping* (IRENA, 2019c).

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[2] The UN conference was cancelled amid the COVID-19 pandemic.

02

INNOVATION IN OFFSHORE RENEWABLES

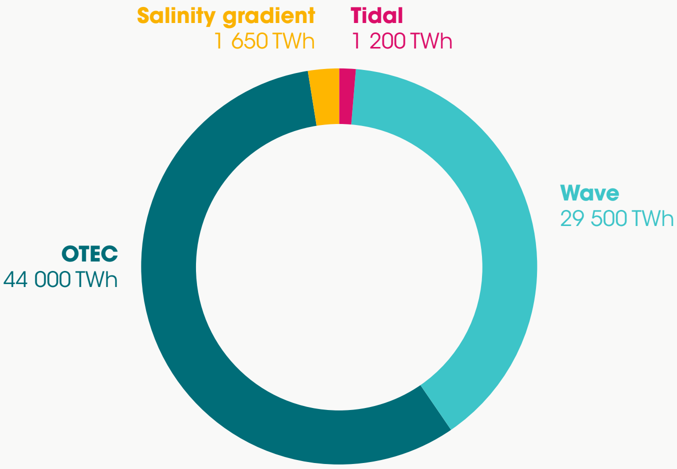
02.1

Ocean energy

The theoretical resource potential of ocean energy[3] is sufficient to meet present and projected global electricity demand well into the future. Ocean energy is highly predictable and is well suited to provide baseload power. The theoretical potential for electricity generation differs among technologies, with the aggregated potential for all ocean energy technologies combined ranging from 45 000 terawatt-hours (TWh) to well above 130 000 TWh per year (Figure 1). This means that ocean energy could cover more than twice the current global demand for electricity.[4]

Figure 1

Ocean energy resource potential (TWh)



Note: OTEC = ocean thermal energy conversion

Source: Based on Nihous, 2007; Mørk *et al.*, 2010; Skråmestø *et al.*, 2009; OES, 2017

At present, ocean energy technologies are still in developmental stages, with most technologies in the prototype phase and some just reaching commercialisation (IRENA, 2018a). The current global cumulative installed capacity across all ocean energy technologies is 535 megawatts (MW). Substantial growth in the deployment and installed capacity of ocean energy is expected in the coming years. The cumulative tidal stream and wave projects in the pipeline (excluding tidal range technology) account for nearly 3 gigawatts (GW). IRENA projects that ocean energy could reach 10 GW of installed capacity by 2030 (Figure 2).

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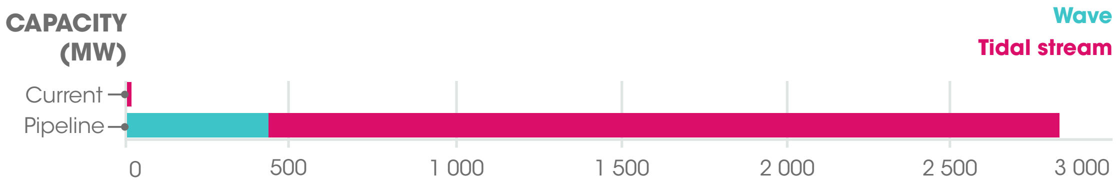
[3] Based on *Ocean energy: Technology readiness* (IRENA, 2014) and *Innovation outlook: Ocean energy technologies* (IRENA, 2020).

[4] Global electricity demand was 25 814 TWh in 2019 (Ember, 2020).

Figure 2

Active and projected tidal stream and wave capacity beyond 2020



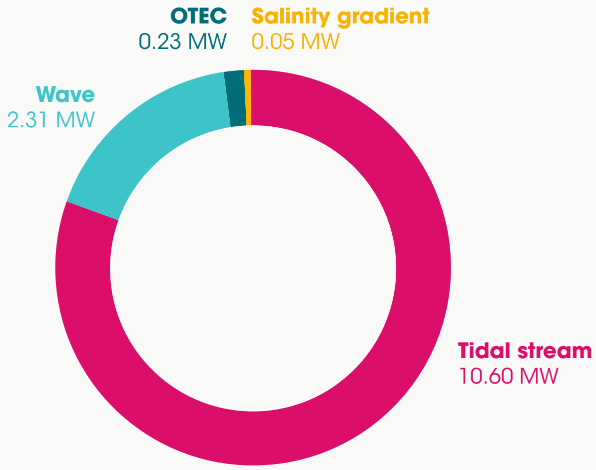
Source: IRENA ocean energy database

Ocean energy technologies are commonly categorised based on the resource utilised to generate energy. Tidal stream and wave energy converters are the most widely developed technologies across geographies apart from tidal range, which is suitable only in limited locations. Other ocean energy technologies that harness energy from the differences in temperature (for example, ocean thermal energy conversion, OTEC) or from the differences in salinity may become increasingly relevant over longer time horizons. The cumulative installed capacity in 2020 is shown in Figure 3.

Figure 3

Global active cumulative installed capacity by ocean energy technology in 2020 (MW)

(excluding tidal range technology)



Note: OTEC = ocean thermal energy conversion

Source: IRENA ocean energy database

Tidal technology

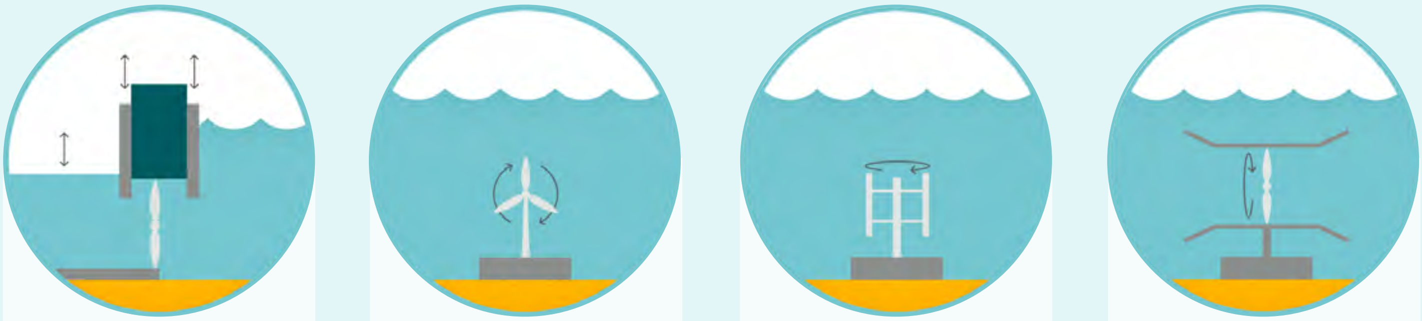
The theoretical electricity generation potential of tidal energy is the lowest of all ocean energy technologies, at around 1 200 TWh per year (OES, 2017). This is due to its location-specific nature, as only a few dozen countries can really harness this resource. Interestingly, a sub-category of tidal technology, tidal range, dominates the current cumulative global installed capacity for ocean energy technologies. Tidal range (see Figure 4) has a 98% share of global installed capacity at present, thanks to just two large installations: a 240 MW plant deployed in France in 1966, and a 254 MW plant deployed in the Republic of Korea in 2011.

Expansion beyond these plants, however, has been slow, due to significant challenges associated with deployment of the technology, including limited site availability, high capital investment and high environmental impact. For these reasons tidal range has seen limited growth, and other tidal technologies – particularly tidal current technologies, such as those with horizontal-axis turbines – are expected to come to the fore.

Whereas a few years ago single tidal turbines boasted capacities of only 100 kilowatts (kW), turbines of 1.5 MW have now been successfully deployed, and many developers are scaling them up further. Currently, projects totalling 10 MW are installed and running, with several installations representing the first phase of larger tidal current farm projects, the most advanced of which is the MeyGen project in Scotland. Another roughly 20 MW of tidal current technologies is scheduled for deployment in the next two years, and this number is expected to exceed 1 GW by 2025.

Figure 4

Examples of tidal energy technologies

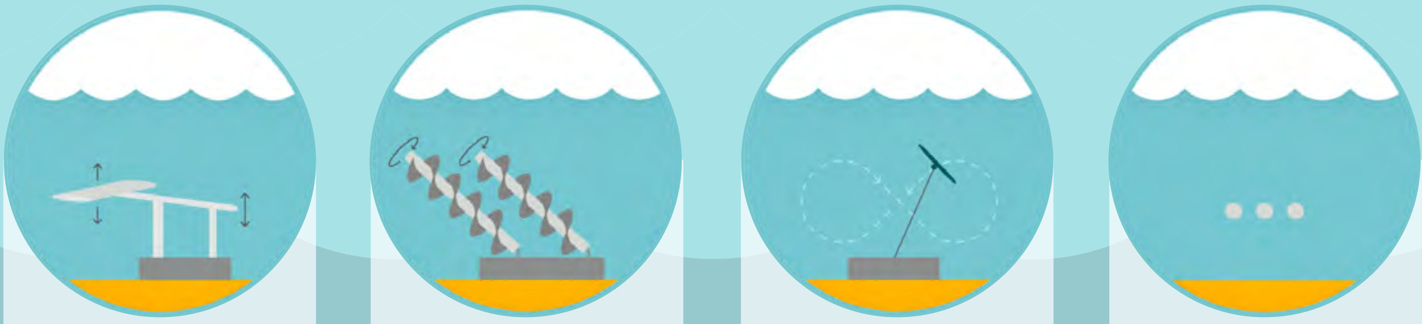


Barrage
Water that entered an enclosed tidal basin at high tide is released at low tide and generates electricity by passing through turbines.

Horizontal axis turbine
The tidal currents flow through an underwater turbine, whose blades turn 180 degrees around its horizontal axis, generating power.

Vertical axis turbine
The tidal currents flow through a vertically placed turbinewhose blades are parallel to the rotating shaft. The flow rotates the turbine around its vertical axis, generating power.

Enclosed tips (venturi)/ open-centre
The tidal stream's velocity is increased by concentrating it in a funnel or duct, in which a turbine is placed to generate energy.



Reciprocating device/ oscillating hydrofoil
The tidal flow lifts an oscillating arm with an attached hydrofoil. This up-and-down movement is converted to run a shaft or pistons to generate energy.

Archimedes screw/ spiral
A tidal stream passes through the spiral of a helical-shaped device. The device starts to turn, and the rotation is converted into energy.

Tidal kite
A kite, connected to the sea bed, moves through the tidal stream in a figure-eight shaped trajectory. The relative velocity is increased with it the electricity output.

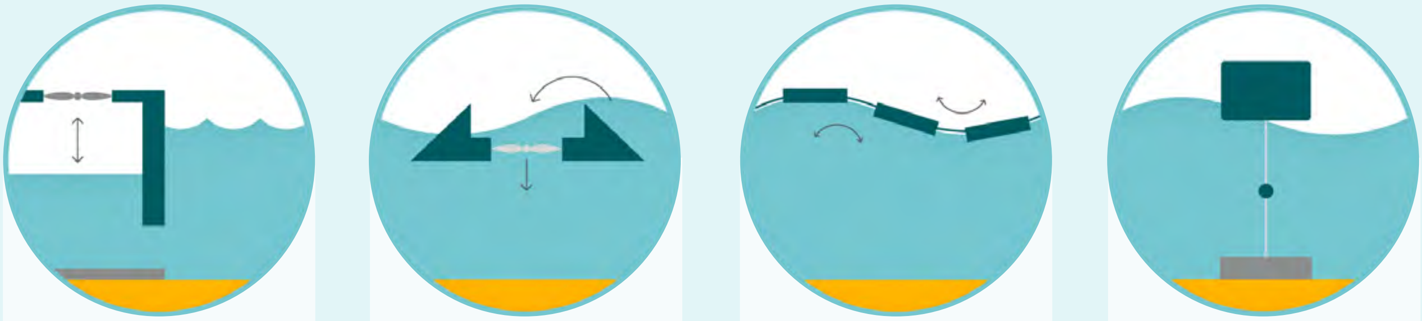
Other
Other technologies have been investigated that either fit in none of the categories or incorporate various aforementioned characteristics.

Based on IRENA, 2014; EMEC, n.d.a

Wave technology

The theoretical potential of wave energy is 29 500 TWh per year (Mørk *et al*., 2010) and can mainly be found between 30 degrees and 60 degrees latitude and in deep-water (> 40 metres) locations. Wave energy technologies have not seen a convergence towards one type of design, as has happened for other technologies such as wind energy. Many different technologies are being pursued, some of which are presented in Figure 5. In recent years, despite the absence of a clear technology convergence for wave technologies, many deployments are of the "point absorber" type. Energy is generated from the movement of a buoy caused by waves coming from all directions, relative to the base connection.

Figure 5
Examples of wave energy technologies



Oscillating Water Column (OWC)
Passing waves raise the water level within a hollow, demi-submerged structure, causing the enclosed air to compress and flow to the atmosphere, driving a turbine.

Overtopping device
Water of passing waves is captured in a reservoir and released through a shaft. A turbine is located in the shaft that generates energy when water passes.

Attenuator
The attenuator consists of multiple connected segments or a single long and flexible part that extracts energy from waves by following the parallel motion of the waves.

Point absorber
This floating or submerged buoy generates energy from the buoy's movement caused by waves in all directions relative to the base connection.

Oscillating Water Surge Converter (OWSC)
This structure uses the surge movement of the wave (back-and-forth motion) to capture energy in an oscillating arm.

Submerged Pressure Differential (SPM)
The rise and fall of passing waves cause a pressure differential in the structure to trigger pressure pumps and generate electricity.

Bulge wave
A device is placed parallel to the waves, capturing energy from its surge. Water flows through the flexible device and passes through a turbine to exit.

Rotating mass
The heaving and swaying in the waves cause a weight to rotate within this device. This rotation drives an electric generator.

Other
Certain technologies have other unique, not commonly used ways of capturing energy from the waves.

Based on EMEC, n.d.b; IRENA, 2014; WEC, 2016

The technology readiness level of wave energy is lower than that of tidal, and its deployment is currently restricted to demonstration and pilot projects. Therefore, only around 2.5 MW is installed globally. However, like tidal turbines, wave energy devices are rapidly increasing in size and power output, and around 100 MW of new instalments can be expected in the coming years.

Ocean thermal energy conversion (OTEC)

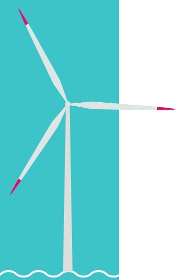
OTEC generation is based on the temperature difference between the surface and deeper layers of the ocean. At locations where this difference is around 20 degrees Celsius, energy can be produced using cycles with heat exchangers and turbines. The global technical potential of OTEC is the largest of all ocean energy sources at 44 000 TWh per year (Nihous, 2007). The technology is still in the research and development (R&D) phase, but demonstration plants rated at 100 kW have been successful in Hawaii and Japan. The Republic of Korea is currently installing a 1 MW plant in Kiribati in the Pacific Ocean. This will be the largest of its kind and is expected to demonstrate OTEC's high potential in island applications, as these locations enable using the water flows for purposes other than energy generation, such as desalination, aquaculture and cooling.

Salinity gradient

Through pressure-retarded osmosis or reverse electrodialysis, energy can be generated from the difference in salt concentration between two fluids. Riverbeds where freshwater flows into the sea are ideally suited for this because the amount of energy that can be generated is proportional to the difference in salt concentration. Due to geographical limitations, this technology has the least potential of all ocean energy technologies with only 1 650 TWh per year. As of 2020, only one such plant in the Netherlands (of 50 kW) was generating electricity, but many countries are intensively researching the technology and collecting data through small-scale testing.

Illustration by Ling Ling Federhen

Innovation paving the way towards ocean energy technology uptake

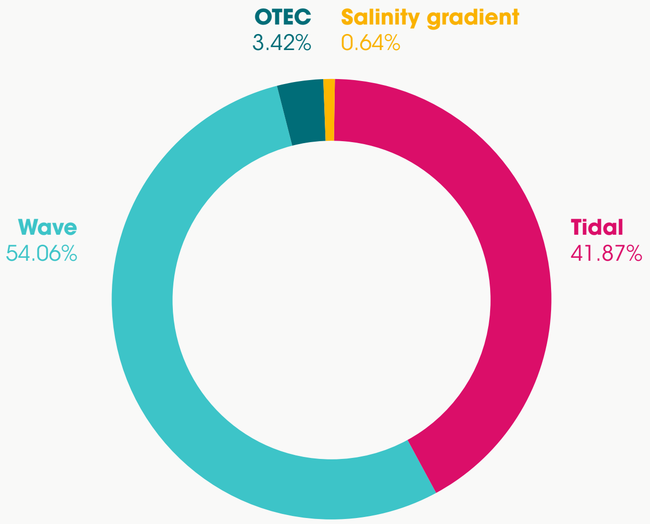


Among all types of ocean energy technology today, tidal technologies show the highest level of readiness and are the closest to approaching commercialisation. Next to tidal technologies, wave energy technologies have medium technology readiness levels, between laboratory to full-scale prototypes. In the last two decades both technologies have traversed various technology readiness levels, accompanied by an increasing invention activity trend. Tidal and wave hold the majority of filed patents worldwide in ocean energy technologies (Figure 6), with top country applicants spread across different geographies. Leaders include Australia, Canada, China, Germany, Japan, the Republic of Korea, the United Kingdom (UK) and the United States of America (US) (Figure 7).

In general, invention activity in ocean energy technologies has witnessed a surge since the early 2000s, reaching more than 24 000 filed patents by local intellectual property authorities. These technology breakthroughs were accompanied by an annual compound growth rate of 15% between 2007 and 2017. While the fastest growth was driven by wave and tidal technologies, other technologies, such as OTEC and salinity gradient, also achieved rapid progress.

Figure 6

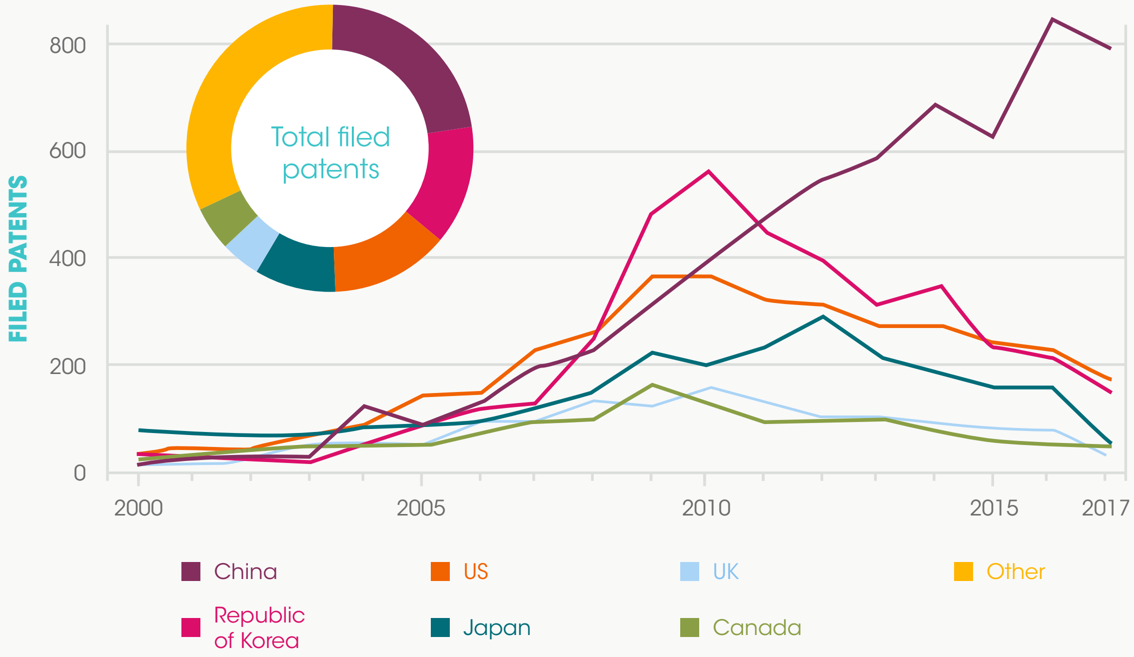
Filed patents in ocean energy technologies (cumulative, 2000-2017)



Note:
OTEC = ocean thermal energy conversion

Based on IRENA (n.d.) INSPIRE platform

Figure 7
Total filed ocean energy patents by country per year (2000-2017)



Note: Data are based on the Y02 classification for climate change mitigation technology patents of the European Patent Office. This is a country-based analysis; patents filed under regional or wider schemes are excluded. For the most recent years in the graph, total number may increase as it may take two years or more for a patent to cover the overall filing process and be included in the database.

Based on IRENA (n.d.) INSPIRE platform

02.2
Offshore wind

Offshore wind[5] technology allows countries to open new sites with high wind resources, building farms at gigawatt-scale close to densely populated coastal areas. This makes offshore wind an important addition to the portfolio of technologies used to decarbonise the energy sector. The first commercial-scale offshore wind farm was commissioned in 2002 in Denmark with an installed capacity of 160 MW.

By the end of 2019, the world's installed offshore wind capacity accounted for close to 29 GW. Around 90% of global installed offshore wind capacity is commissioned and operated in the North Sea and nearby the Atlantic Ocean.

According to IRENA's Paris-compliant scenarios, offshore wind capacity could reach 228 GW by 2030, as innovation continues and the industry evolves. By 2050, offshore wind would increase substantially, with total offshore installations nearing 1 000 GW globally (Figure 8). Asia would take the lead in the coming decades with more than 60% of global installations by 2050, followed by Europe (22%) and North America (16%).

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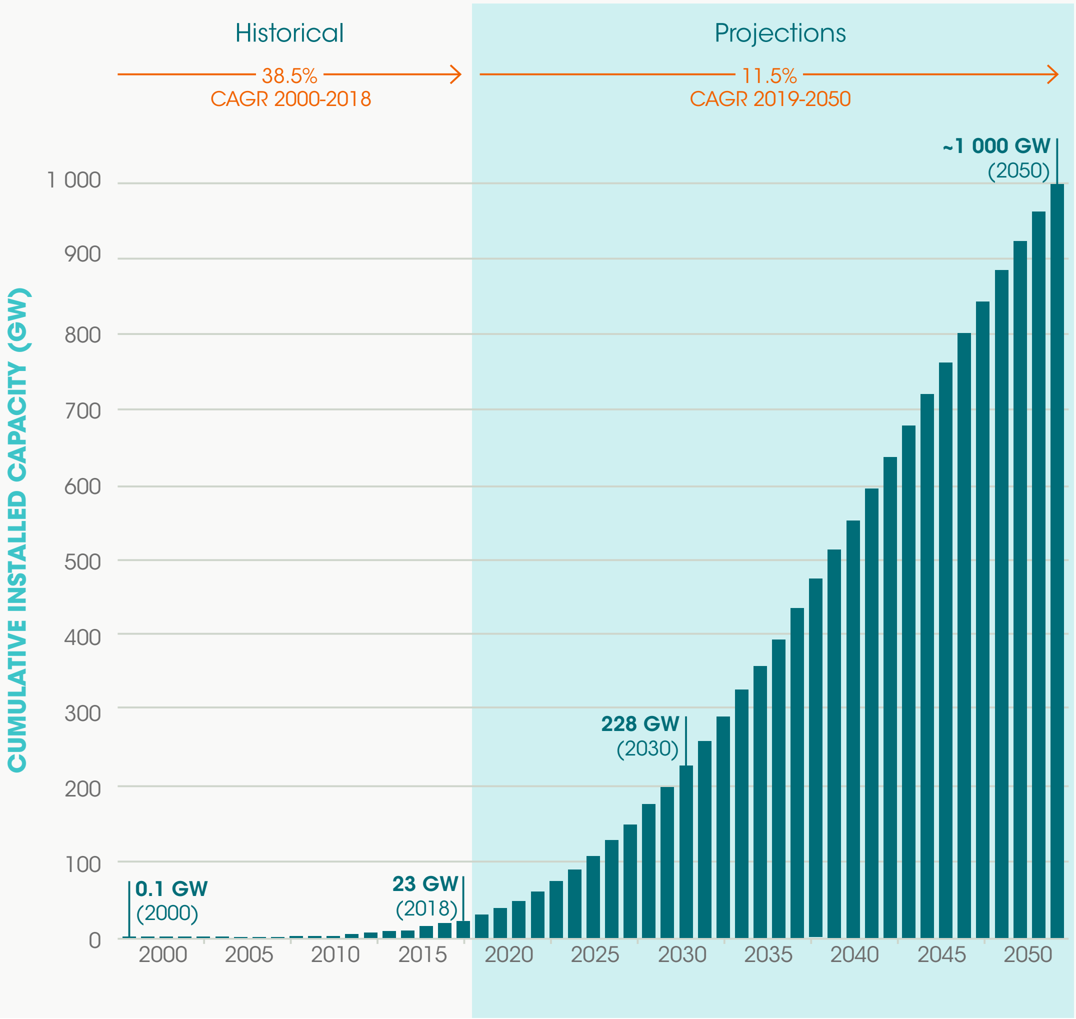
[5] Based on *Future of wind* (IRENA, 2019c).

Figure 8
Annual offshore wind capacity additions (2000-2050)



Note: CAGR = compound annual growth rate

Source: IRENA, 2019a

A main driver of this accelerated market growth and deployment is the sharp decrease in technology costs, with offshore wind currently being cost competitive with all other energy generation technologies. From 2010 to 2018, the global weighted average levelised cost of electricity (LCOE) of offshore wind decreased from USD 0.16 per kilowatt-hour (kWh) to USD 0.13/kWh. IRENA expects LCOEs to continue to fall to an average between USD 0.05/kWh and 0.09/kWh by 2030 and between USD 0.03/kWh and 0.07/kWh by 2050. In 2018, average installed costs were USD 4 353/kW and are expected to fall to between USD 1 700/kW and 3 200/kW by 2030 and between USD 1 400/kW and 2 800/kW by 2050.

R&D together with technology-driven innovation will likely lead to turbine sizes reaching between 15 MW and 20 MW in a decade or two, from around 9.5 MW today. The combination of improved wind turbine technologies, deployment of higher hub heights and longer blades with larger swept areas leads to increased capacity factors. For offshore wind farms, enhanced capacity factors are expected in the range of 36% to 58% by 2030 and 43% to 60% by 2050, compared to an average of 43% in 2018.

Developments in wind turbine technologies as well as in foundations, installation, access, operation and system integration have enabled moves into deeper waters, farther from shore, to reach sites with better wind resources. These turbines, rooted in the seabed by monopile or jacket foundations, are still restricted to waters less than 50-60 metres deep.

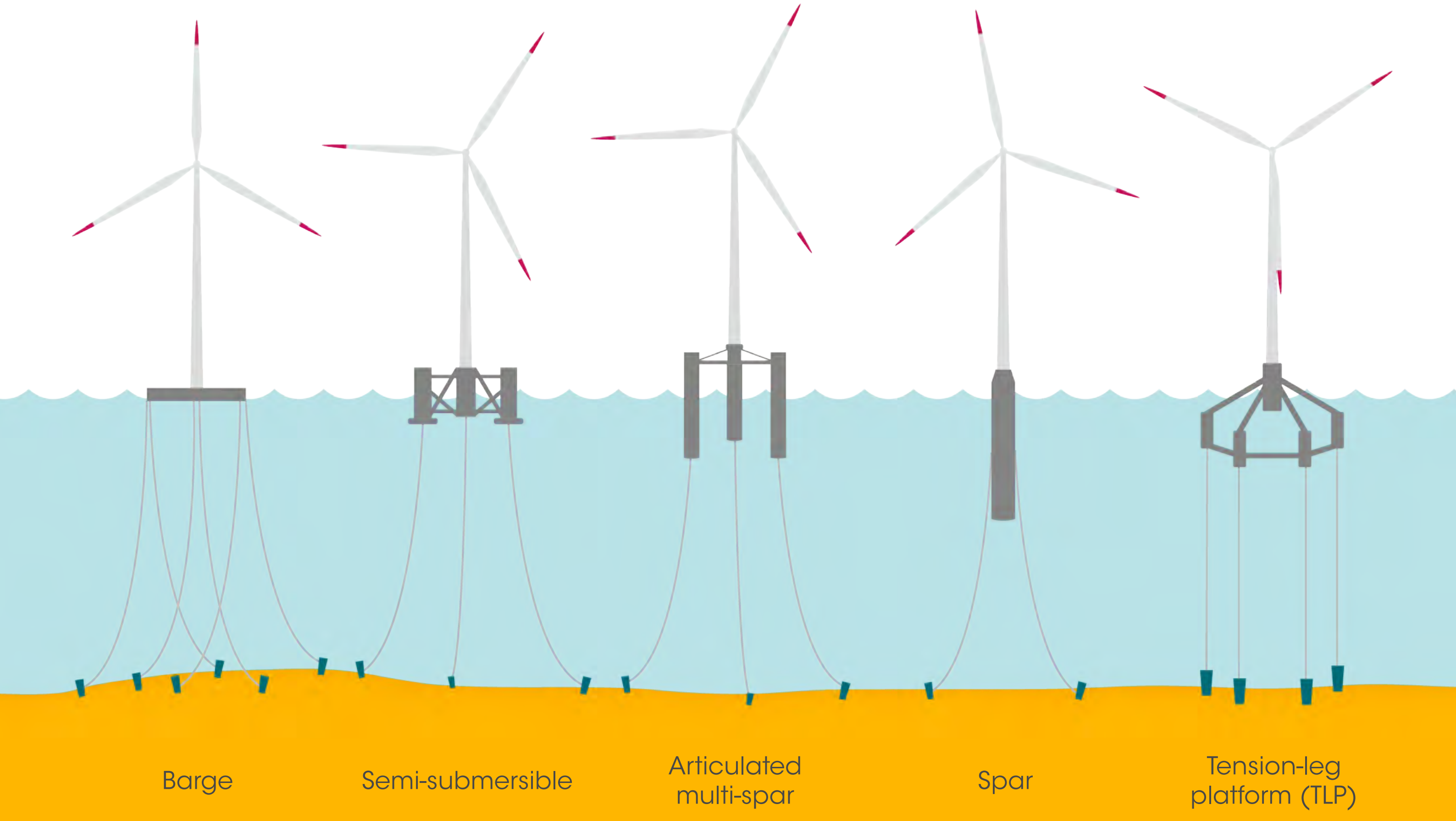
This is a major limitation, as some of the largest potential markets for offshore wind, such as Japan and the US, have few shallow-water sites. Scaling up offshore wind markets undoubtedly requires offshore wind turbines to move into deeper waters (> 50 metres) with higher wind resources. Therefore, floating foundations are potentially a game-changing technology for offshore wind generation.

Floating foundations offer the offshore wind industry two important opportunities: they allow access to sites with deeper water (below 50 metres) and as far as 80 kilometres from shore. The first full-scale prototypes for floating wind turbines have been in operation for several years, with three main designs being tested: spar buoys, spar submersible and tension-leg platforms (Figure 9).

Significant and encouraging developments in floating foundations have been seen in recent years. The Norwegian energy company Equinor is planning a floating offshore wind farm called Hywind Tampen, located 140 kilometres offshore with water depths ranging between 260 metres and 300 metres. It is an 88 MW floating wind power project designed to supply electricity for offshore oil and gas operations in the Norwegian North Sea, due to start operations in 2022.

Figure 9

Offshore wind turbine foundation technologies



Based on Mint Selection (2019)

Tampen will be the world's largest floating offshore wind farm, with 11 large wind turbines with Hywind floating foundations, with each turbine having a rotor diameter of 167 metres and 81.5 metre-long blades. It promises to explore the use of new installation methods, simplified moorings, concrete substructures and integration between natural gas and wind power generation systems.

Previously, the first offshore wind farm to deploy floating foundations began operations in October 2017 in Scotland. The Hywind wind farm in Scotland has a nominal power capacity of 30 MW, consists of five turbines of 6 MW each and uses a spar buoy design (Hirtenstein, 2017). 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 expected between 2020 and 2025.

Globally, there are 13 announced floating offshore wind projects: 9 in Europe (France, Portugal and the UK), 3 in Asia (Japan and the Republic of Korea) and 1 in the US (Power Technology, 2019). By 2030, industry experts estimate that around 5 GW to 30 GW of floating offshore capacity could be installed worldwide and that, based on the pace of development across various regions, floating wind farms could account for up to 15% of global offshore wind installed capacity, around 150 GW by 2050.

The oil and gas industries, which have operated offshore for over half a century, could leverage synergies by transferring the knowledge acquired to the offshore wind industry.

For example, several projects are being conducted in the Netherlands:

- **INTEGRATION OF WIND, GAS AND HYDROGEN (POSHYDON PROJECT):** The pilot aims to integrate three energy systems – offshore wind, offshore gas and offshore hydrogen – by producing hydrogen from seawater on a platform in the Dutch North Sea (Neptune Energy, 2020).

- **NORTH SEA ENERGY PROGRAMME:** Over 30 national and international parties collaborate in the Dutch North Sea Energy programme, which researches how an integrated approach can best utilise the North Sea's energy potential for a climate-neutral energy system (including the creation of energy hubs with offshore energy islands, roadmaps, resource mapping for offshore wind potential, etc.) (North Sea Energy, 2020).

- **ARTIFICIAL ISLAND IN THE NORTH SEA (IJVER):** A multipurpose island with 4 GW of installed capacity and 80 kilometres away from shore, it is the largest planned offshore farm in the Netherlands (Offshore Service Facilities, 2020).

The offshore wind levels needed to limit greenhouse gas emissions in line with the Paris Agreement would be difficult to reach at the current pace of technological progress. Innovation, technological breakthroughs, and policy and regulatory support can help to catalyse fast deployment (Figure 10). To achieve this aim, concrete recommendations are provided in section 5.

Figure 10

Summary of offshore wind projections and progress level

			REmap Case		
	2010	2018	2030	2050	On/Off track
TOTAL INSTALLED CAPACITY					
Offshore wind (GW)	3	23	228	1 000	Progress
Out of which, floating offshore wind (GW)	0	0.03	5 - 30	50 - 150	
LCOE					
Offshore wind (USD/kWh)	0.16 (average)	0.13 (average)	0.05 - 0.09 (average range)	0.03 - 0.07 (average range)	Progress
INSTALLATION COST					
Offshore wind (USD/kW)	4 572 (average)	4 353 (average)	1 700 - 3 200 (average range)	1 400 - 2 800 (average range)	Progress
CAPACITY FACTORS					
Offshore wind (%)	38 (average)	43 (average)	36 - 58 (average range)	43 - 60 (average range)	On track

02.3

Floating solar photovoltaic (PV)

Floating solar PV[6] is an emerging technology with the potential for rapid growth. As of the end of September 2018, the global cumulative installed capacity of floating solar PV plants totalled 1.1 GW (World Bank, 2018). Demand for floating solar PV is expanding, especially on islands (and other land-constrained territories), as the cost of the water surface is generally lower than the cost of land (GlobalData, 2018).

The world's top ten plants are located in Asia, namely in China, Japan and the Republic of Korea. In particular, the Republic of Korea has announced a 2.7 GW floating solar plant in the Yellow Sea (Radowitz, 2019). Other Asian countries, namely India, Singapore, Thailand and Viet Nam, are also actively pursuing floating solar project development.

Most activity on floating PV at present relates to freshwater artificial reservoirs. For instance, a plant in eastern China (in Panji District, Huainan City) is one of the world's largest operational floating solar plants with a capacity of 150 MW, which is expected to generate almost 78 000 megawatt-hours (MWh) in its first year. Hydropower reservoirs and other artificial bodies of water also have enormous potential for floating PV settings.

Islands are also interested in this application – such as Seychelles, which plans to build 5.8 MW of floating PV (Publicover, 2020). French developer Qair planned to start building the floating solar array on a lagoon on the East African nation's main island in late 2020, and claims that, upon completion, the installation will be the world's largest floating PV project to be built on salt water.

An offshore floating PV plant on seawater also recently began operation in the North Sea. This 8.5 kW project is expected to be scaled up in stages, up to 50 kW after one year and eventually to 100 MW, although the time frame is not known. The combined use of space with offshore wind is possible, because the solar panels can float between the wind turbines at sea, resulting in a hybrid system that can provide more stable power for the grid (Bellini, 2019).

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[6] Based on *Future of solar photovoltaic* (IRENA, 2019d).

03

INNOVATIVE RENEWABLE APPLICATIONS FOR A BLUE ECONOMY

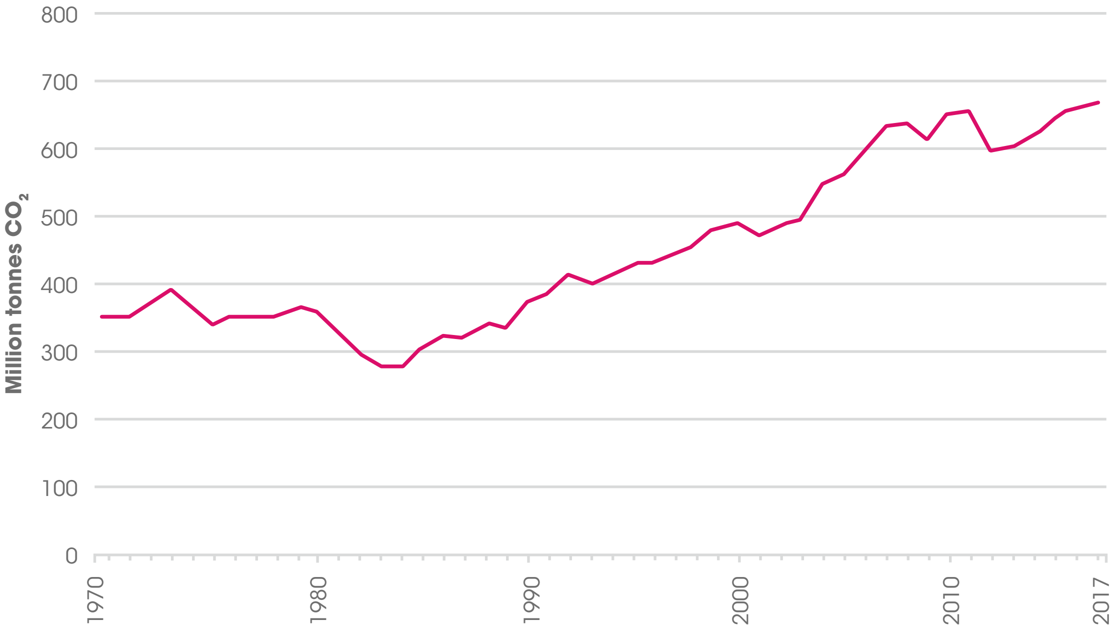
03.1

Shipping fuelled by renewables

In January 2020, the International Monetary Fund projected that global economic growth would increase from an estimated 2.9% in 2019 to 3.3% in 2020 and 3.4% in 2021 (IMF, 2020). However, the COVID-19 pandemic might lead to a revision of this projection. Within this context, in the absence of suitable mitigation policies, the International Maritime Organization (IMO) estimates that greenhouse gas emissions associated with the shipping sector could grow by 50-250% by 2050. Overall, around 80-90% of internationally traded goods, totalling 8.7 gigatonnes, are transported by ship, representing 9.3% of carbon dioxide (CO_2) emissions linked to the transport sector. The Third IMO greenhouse gas study found that, between 2007 and 2012, shipping was responsible for an average of 2.8% of annual greenhouse gases on a CO_2-equivalent basis (IMO, 2015). Figure 11 shows the historical CO_2 emissions associated with international shipping.

Figure 11

Annual CO_2 emissions associated with international shipping (1970-2017)



Source: Muntean *et al.*, 2018

Bulk and container carriers, as well as oil and chemical tankers, represent 20% of the global shipping fleet; together these vessels are responsible for 85% of the net greenhouse gas emissions associated with the shipping sector. Simultaneously, seven ports are responsible for nearly 60% of the bunker fuel sales around the world, with Singapore delivering as much as 22% of today's total bunkering. Accordingly, any shift towards the use of cleaner fuels should consider the need for infrastructure adjustment at main bunkering ports. Figures 12 and 13 show the total number of ships worldwide and the gross tonnage of ships by ship size, respectively.

Fuel price and availability will likely be the decisive factors in the choice of fuel/propulsion technology. Given its energy-intensive nature, bunker fuel costs can account for 24-41% of total shipping costs. Therefore, competitive fuel prices are a highly important factor. Low-carbon fuel options are currently not competitive, with costs ranging from double to five times those of heavy fuel oil. However, this is expected to change in the medium to long term as the adoption of clean technologies grows across sectors, technology improves, costs fall, and regulations become more favourable.

Figure 12

Share of ships worldwide, by ship size (2017)

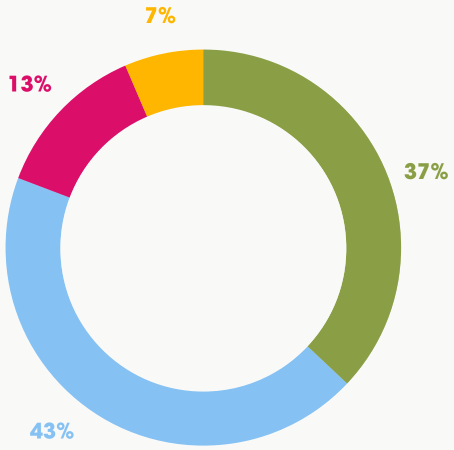
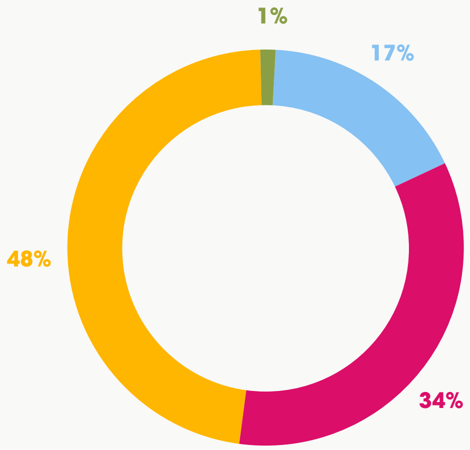


Figure 13

Gross tonnage of ships worldwide, by ship size (2017)



Source:
Equasis, 2017

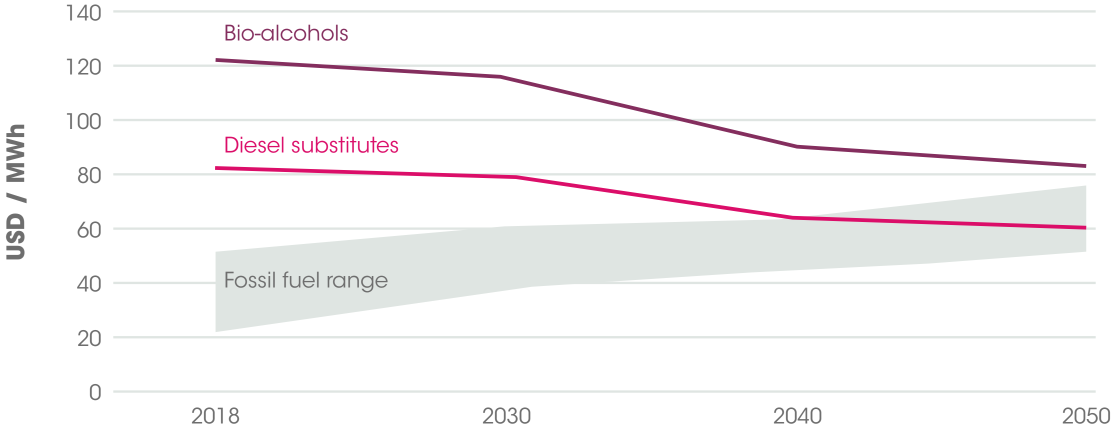
The most prominent renewable options to fuel the shipping sector are discussed in the following paragraphs.

Biofuels

From a technological perspective, biofuels are mature, require few adjustments to the existing engines of ships and port infrastructure, and can have considerable emissions reduction benefits, even as blends. Cleaned biogas holds potential as a transitional fuel that could gradually replace fossil liquefied natural gas (LNG) that is currently being introduced in the sector.

Yet three main barriers limit biofuel potential in the shipping sector: economics, availability and sustainability concerns. Advanced biofuels from residues and lignocellulosic crops can minimise sustainability issues, but these require further development. Presently, the cost of biofuels is roughly twice the price of their fossil counterparts; however, the cost of biofuels is expected to drop considerably, becoming competitive by 2040 (Figure 14).

Figure 14
Biofuel product cost projections (2018-2050)



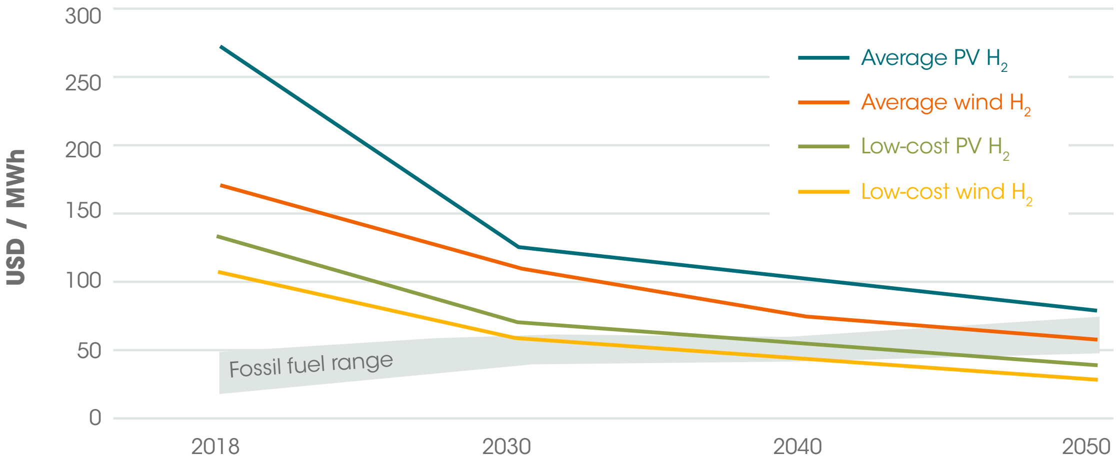
Note: Product cost includes production, transport and logistics costs.

Source: IRENA, 2019c

Hydrogen

Hydrogen is a clean energy carrier that can play an important role in the transition to zero-emission shipping. One option is the production of hydrogen from fossil fuels with CO_2 capture and storage – sometimes referred to as blue hydrogen. Some consider this a transitional solution, given the current high costs of producing hydrogen from renewable power. The better solution, however, is green hydrogen, produced through electrolysis using renewable power, as this is the only source of zero-carbon hydrogen (IRENA, 2019d). Current hydrogen costs are not competitive with those of the fossil fuels in use today. However, hydrogen costs are expected to decrease and to become competitive by 2030 (Figure 15).

Figure 15
Hydrogen product cost projections (2018-2050)



Note: Product cost includes production, transport and logistics costs.

H_2 = hydrogen

Source: IRENA, 2019d

Synthetic fuels

Other synthetic fuels being considered include methanol and ammonia. These fuels can effectively decrease and even eliminate emissions if they are produced from green hydrogen. This hydrogen is combined with CO_2 or nitrogen to yield liquid and gaseous energy commodities. IRENA's study, *Hydrogen: A renewable energy perspective* (IRENA, 2019d), shows the rapid scale-up and falling costs of green hydrogen production worldwide, driven by falling renewable power generation costs. Hydrogen can be used directly as a shipping fuel, but its storage poses challenges. Liquids derived from hydrogen (so-called e-fuels or power fuels) do not face such problems, but their production incurs additional cost and efficiency losses.

Electric propulsion

At present, for full electric propulsion to be economically viable, the weight of the battery should be comparable to that of a conventional fossil fuel system. With the current state of technology, therefore, fully electric vessels are generally unable to travel more than around 95 kilometres, with such solutions viable only for relatively small vessels. As battery technology progresses, however, the energy density and the cycle life of batteries should increase, whereas the cost of battery storage technologies, including lithium-ion, should gradually fall. IRENA's report, *Electricity storage and renewables: Costs and markets to 2030* (IRENA, 2017), shows that the expected drop in costs of stationary battery technologies by 2030 will be significant. Considering that vehicle batteries cost a fraction of what stationary batteries cost, in a shipping context the decline in battery technology costs may be even greater. Therefore, in the long term, full electrical propulsion is likely to become more attractive for larger vessels engaged in services that require longer-distance travel.

Under the existing regulatory framework – and given current carbon prices – clean fuels are not economically competitive. Thus, fuel price and availability will likely be the decisive factors in the choice of renewable fuel/propulsion technology. Other key, decisive factors will include the infrastructural adaptation costs of ships and ports, technological maturity and sustainability issues (for example, food security). The willingness and ability of shipping companies to pay a premium price for low-carbon products is another decisive factor.

As the adoption of clean technologies grows across sectors, technology improves, renewable fuel costs fall and regulation becomes more favourable, carbon-neutral options are expected to become more competitive in the medium to long term. All these developments will require a global effort, however, involving the co-operation of both private and public stakeholders.

03.2

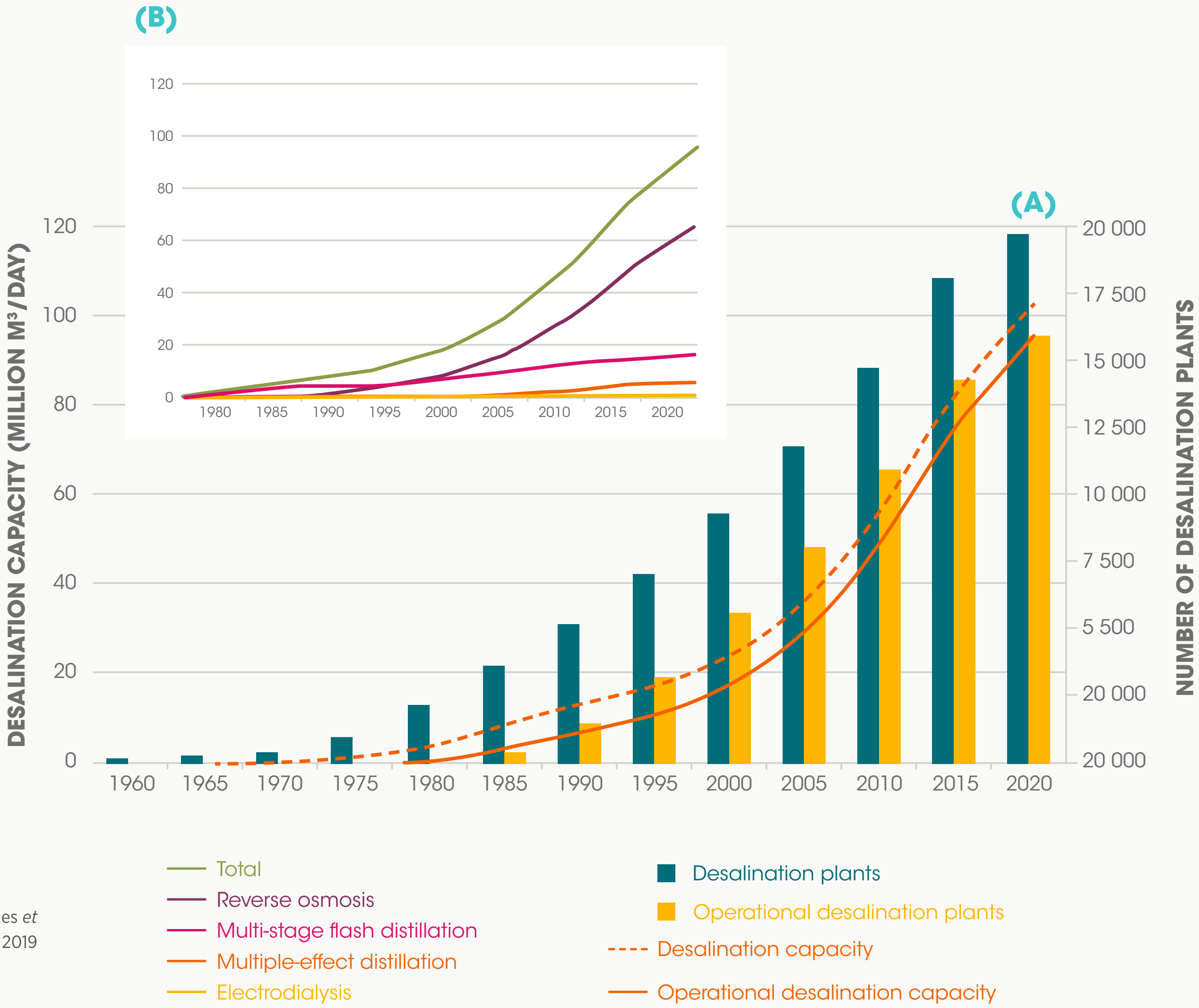
Desalination of water with renewables

Over the past ten years, the global population has grown substantially at an average annual rate of 1.14%, reaching a total of around 7.79 billion people in 2020 (UN DESA, 2019). This has resulted in increasing demand for fresh water for industrial, agricultural (irrigation), power generation and domestic (human consumption) uses, with the latter sector consuming around 60% of desalinated water (Antonyan, 2019).

As freshwater reservoirs continue to come under stress, seawater desalination is becoming the primary source of potable water for several countries, particularly in the Middle East and North Africa (MENA) region and in various SIDS. However, given the energy-intensive nature of this process, desalination is often linked to high monetary costs and accounts for significant greenhouse gas emissions. As of 2015, desalination was responsible for an estimated 76 million tonnes of annual CO_2 emissions (GCWDA, 2015). The need to decarbonise this activity is emphasised by the fact that between 2010 and 2016, global desalination capacity grew 54%. As a consequence, energy use for this purpose grew 70% over this same period (Jia *et al.*, 2019).

Figure 16

Trends in global desalination by (A) number and capacity of total and operational desalination facilities and (B) operational capacity by desalination technology (1960-2020)

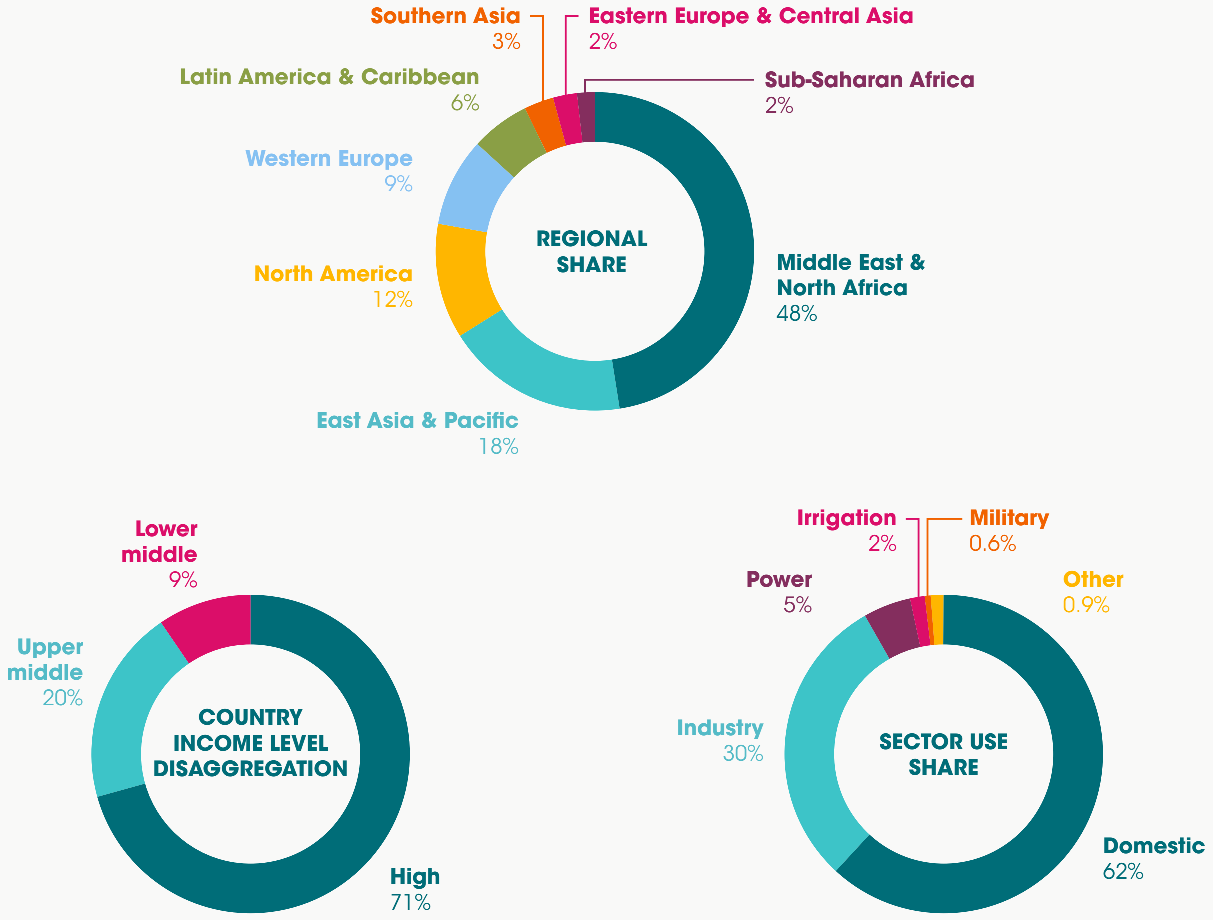


Source: Jones *et al.*, 2019

Currently nearly 20 000 water desalination facilities are spread across the world (Jones *et al.*, 2019). MENA countries – specifically Saudi Arabia and the United Arab Emirates – register the highest installed desalination capacities, at 17% and 12% respectively, followed by Spain, the US and China. Given that most desalination plants are in high-income countries, and considering that 66% of the global population faces severe water scarcity, desalination technology is not easily affordable for low- and lower middle-income countries.

Figure 17

Global share of operational desalination plants by region, country income level and sector use



Source: Jones *et al.*, 2019

While the precise emissions linked to desalination depend greatly on the energy mix of the country where the desalination plant is located, desalination currently is driven mostly by fossil fuels. The specific emissions linked to the desalination process will depend on the selected technology – either thermal desalination, which has higher energy requirements, or membrane desalination, which requires less energy. Prioritising membrane desalination (via reverse osmosis) over thermal technologies could result in a significant reduction of CO_2 emissions.

As the global need for fresh water increases rapidly, new desalination plants are being developed, and the associated increases in energy demand threaten to further drive up carbon emissions. Developing desalination infrastructure based on renewable energy is of utmost importance. The deployment of renewables in a centralised manner would result in a lower carbon footprint of desalination plants connected to the national power network. However, the direct coupling of distributed renewable systems to desalination plants would result in a higher positive impact.

Overall, the right combination of renewable energy and desalination technologies can lead to the production of fresh water in an effective, economic and environmental manner. Linking desalination with solar energy promises the highest potential to reduce carbon emissions.

Emerging options for water desalination using renewables are discussed in the following paragraphs.

Solar PV

Given that solar PV systems can be directly connected to membrane-based desalination plants, this approach appears to be one of the most promising paths towards carbon-free desalination – especially for medium and large systems – by reducing or eliminating consumption of electricity from the local grid, depending on the size of the desalination plant. For instance, in the Mediterranean Sea, the production of one cubic metre (m^3) per day of clean water has been shown to require the installation of 0.71 kW of solar PV. Considering a daily consumption of 0.20 m^3 per person and a fluctuating number of people between 100 million and 200 million, then 14.2 GW to 28.4 GW of capacity could power enough reverse osmosis plants to satisfy freshwater needs in the Mediterranean region (Ganora *et al.*, 2019).

Wind

Coastal areas with high wind potential are ideal sites for coupling wind technology with desalination, which is particularly suitable for meeting the electricity needs of reverse osmosis and electrodialysis desalination plants. Wind-powered solar water reverse osmosis desalination can be found mostly in small-scale applications, for example on the Canary Islands (wind reverse osmosis; 5-50 m^3/day) and Fuerteventura Island (diesel-wind reverse osmosis 56 m^3/day) in Spain. Further examples have been demonstrated in the UK through a wind power plant with a capacity of 12 m^3/day where wind mechanical energy could also be directly harnessed in mechanical vapour compression plants during the vapour compression phase (IRENA and IEA-ETSAP, 2012). An alternative route, given the intermittent nature of wind generation, is to capitalise on desalination as an excellent storage opportunity, particularly when wind power generation exceeds demand.

Solar thermal

Across thermal desalination methods, multi-stage flash distillation and multiple-effect distillation are the preferred technologies for the desalination of feedwater that is high in total dissolved solids. The inclusion of solar thermal is best suited for multiple-effect distillation, multi-stage flash distillation, membrane desalination and humidification-dehumidification desalination plants where, depending on whether the solar collectors are integrated in the desalination system, the process is referred to as direct or indirect. One consists of a solar collector system combined with a distillation unit.

Although the operating principle is well understood, recent research (Zheng and Hatzell, 2019; Huang *et al*., 2019) indicates that large potential exists for improving the design and overall engineering of solar desalination systems, thus increasing the system efficiency and reducing desalination costs. However, direct solar desalination, specifically concentrated solar power coupled with either membrane or thermal desalination, is a promising approach towards the development of large-scale low-carbon desalination by providing high-temperature heat and electricity, hence it can be used for membrane and thermal desalination plants.

Geothermal

The uninterrupted nature of geothermal resources represents a clear advantage over solar and wind alternatives, where geothermal wells deeper than 100 metres can already support desalination processes. For instance, high-pressure sources can be used as shaft power to drive mechanical desalination processes, while high-temperature fluids can be used to generate electricity to drive reverse osmosis or electrodialysis (Antonyan, 2019). A small-scale geothermal dual desalination system is being considered for Milos Island in Greece with a capacity of 1 920 m^3/day. This project uses a geothermal well to run an organic Rankine cycle 470 kW_e turbine as well as a multiple-effect distillation desalination unit.

The growing demand for fresh water highlights the importance of the water–energy nexus. Accordingly, sector coupling is vital for the integration of variable renewable energy and the expansion of water desalination capacity, particularly in regions with scarce freshwater resources, such as the MENA region and the Mediterranean Sea, as well as SIDS across the globe. Water desalination plants that use reverse osmosis technology, coupled with water storage, have the potential to become flexibility agents of the power system. This could result in more affordable electricity and fresh water, while increasing the profitability of renewable energy projects by reducing curtailment.

04

SOCIO-ECONOMIC BENEFITS: JOBS IN OFFSHORE WIND

Renewable energy supports a wide range of socio-economic benefits, including new opportunities for economic activity, job creation, local value creation, improved livelihoods, gender equity and other benefits.

In terms of jobs, while wind power is an established and maturing industry, ocean energy is still in the early stages of development. Consequently, deployments and jobs are still minor in ocean energy for the time being. The wind energy sector provides employment for about 1.2 million people worldwide (IRENA, 2019e), but the bulk of this presently relates to onshore installations, reflecting the fact that wind farms on land were installed for many years before the offshore segment was developed. However, the offshore wind segment is gaining traction and received USD 25.7 billion of investments in 2018, or 20% of the total for wind energy. For the first time, China led the way with offshore projects worth USD 11.4 billion. European projects attracted spending of USD 3.3 billion (Efstathiou, 2019).

Given that much offshore wind deployment is taking place in Europe, the continent has been the first to benefit from this development, with most supply chain activity in the UK and Germany, as well as in Denmark, the Netherlands and Belgium. However, China is now leading the pace on new offshore installations, a development that will lead to growing jobs and benefits domestically. Canada is also supporting the funding of its first floating tidal energy array of 9 MW, which is planned to be connected to Nova Scotia's power grid, with a total investment estimated at USD 21.7 million (Renews, 2020).

Europe aims to retain its leadership in this renewable technology area, maximising the benefits for the region. In this context, the European Commission is giving offshore renewables a prominent role within its plans to realise the European Green Deal as part of the COVID-19 recovery package. The offshore renewable energy strategy of the European Commission released on 19 November 2020 (European Commission, 2020) sets ambitious plans.

These include:

- 60 GW of offshore wind by 2030 (from 12 GW today);
- 300 GW offshore wind by 2050;
- At least 1 GW of wave and tidal energy by 2030; and
- 40 GW of wave and tidal energy by 2050.

Offshore wind projects are helping to revitalise coastal communities in the UK's Humber and East Yorkshire regions, the Isle of Wight and other areas. A GBP 310 million (USD 411 million) investment by Siemens Gamesa and ABP in turbine assembly and blade manufacturing has created around 1 000 direct and indirect jobs in Hull. The more than 300 jobs in blade manufacturing at an MHI Vestas Offshore Wind facility on the Isle of Wight are to expand to 380, plus 720 indirect and induced jobs (MHI Vestas Offshore Wind, 2018). A former oil-fired power plant has been converted into a paint and logistics facility for wind blades (Whitmarsh, 2019).

Offshore wind farms tend to require more labour inputs than onshore projects. In addition to the construction, assembly and deployment of new equipment such as platforms, they can leverage existing technical capacities and skills from the onshore wind segment (IRENA, 2018b). They can also use converted and upgraded existing infrastructure from the offshore oil and gas and shipping industries (Froese, 2018). Offshore wind development in northern Europe, for example, utilises the expertise of workboats that provide surveying, lifting and other services, and draws on the know-how of companies that build foundations for production platforms (O'Connell, 2018).

IRENA's energy transition modelling suggests that the wind industry, both onshore and offshore, may employ 3.74 million people by 2030 and more than 6 million people by 2050. Where these jobs will be created depends not only on the level of deployment in individual countries, but also on the degree to which the domestic industrial and services bases can be built and leveraged.

IRENA's "Leveraging local capacity" report series, which includes a study of the offshore wind industry entitled *Renewable energy benefits: Leveraging local capacity for offshore wind* (IRENA, 2018b), provides valuable information for policy makers on the occupational and skill structure along the value chain. For a 500 MW offshore wind farm, the human requirements from planning to decommission account for up to 2.1 million person-days. The vast majority of these are concentrated in the manufacturing and procurement segments.

05

RECOMMENDED ACTIONS TO MOVE OFFSHORE RENEWABLES FORWARD

05.1

Capacity building in renewables for a blue economy

- **BOLSTER AND ENHANCE SKILLS IN THE WORKFORCE:** There is a growing need for professionals with knowledge and skills in offshore renewables technology development and deployment. Methods to clarify future needs can include: 1) exchanging knowledge between offshore renewables (for example, in terms of materials, technology installation in waters, turbine design, port and vessel logistics, etc.), 2) facilitating the reskilling of the workforce from fossil fuel industries to renewables, and 3) working closely with academia and youth to align curricula with sector jobs.

- **EARLY EDUCATION PROGRAMMES:** Sufficient training and programmes from an early stage of education are essential to improve renewable energy knowledge and understanding. This calls for a strong focus on education in science, technology, engineering and mathematics (STEM) that can help increase technical capacity and technological learning.

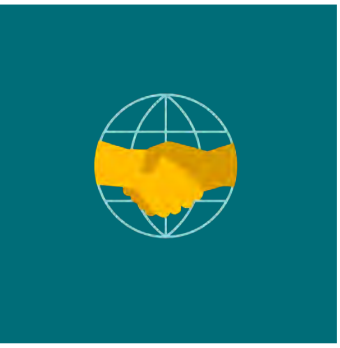
05.2

Ocean energy

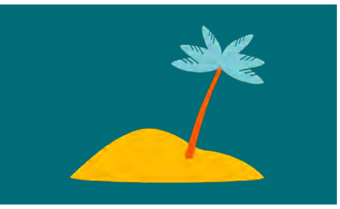
- **DE-RISK PROJECTS AND UNLOCK RESEARCH, DEVELOPMENT AND DEPLOYMENT (RD&D) FUNDING:** Ocean energy project risk assessment should create awareness on the technology reliability and raise trust among investors, who may be reluctant to provide financing in this sector. Ocean energy technologies are in major need of funds to push technologies towards the commercial stage.

Mechanisms that can help to address this include:

Fund projects based on the technology readiness level: Establish funding programmes that consider the different technology readiness level stages and remunerate projects based on stage completion (for example, components testing, successful design and efficient operational levels). Technologies close to commercialisation with a functional full-scale prototype face a lack of financial support when trying to deploy the technology in the water and generate electricity.



Emphasise stakeholder partnerships and build international co-operation: Emerging continental economies and islands may be in need of financial resources and business development analysis, both of which could be spurred by cross-water partnerships. Equally important is to strengthen international technology co-operation; policy makers, industry, academia and users of ocean energy technologies should share existing information and collaborate in a more organised manner. Front-runner countries can encourage knowledge transfer to locations where ocean energy is still at early stages of development.



Provide access to finance in SIDS: Innovative financing schemes are key to promoting ocean energy in SIDS, as risks are still perceived around the technology, hindering access to financing. Islands could be considered as new ocean energy "small" markets, which can be used as testing hubs before moving to larger markets.

- **COUPLE BLUE ECONOMY SECTORS WITH OCEAN ENERGY:** The blue economy is expected to grow, and in doing so, ocean energy is well placed as a potential solution to decarbonise sectors such as desalination, space cooling, shipping, and tourism, as well as emerging sectors such as aquaculture, green hydrogen generation, ocean observation (to power environmental equipment for monitoring) and underwater vehicle charging.

- **BOOST REGULATORY SCHEMES FOR OCEAN ENERGY:** Offshore renewables solutions must be included in the decarbonisation discussion, and countries should plan for an offshore renewables roadmap and establish clear policies that can help in the achievement of national offshore renewable targets. For a sector scale-up, different regulatory and tariff schemes that can propel ocean energy are needed. Countries should adopt different mechanisms, and their expansion and replicability in other locations could promote ocean energy deployment. Some potential solutions include providing feed-in tariffs for at least 100 MW projects or defining ocean energy tender criteria; the latter is a measure used in the Netherlands.

- **DEVELOP INNOVATIVE HYBRID RENEWABLE ENERGY SYSTEMS:** Promoting systemic approaches for ocean energy is crucial to decrease the LCOE of ocean energy technologies.

Due to their predictability, ocean energy technologies can provide baseload power and stabilise the grid and are therefore ideally suited to be developed in harmony with other renewables, offshore as well as onshore. This is particularly interesting in coastal regions and islands where a mix of energy sources is needed due to land limitations and where high shares of renewables are present. Furthermore, technologies can even be complemented to create hybrid devices (for example, wave and wind on a single floating platform).

- **BUILD MARINE SPATIAL KNOWLEDGE AND EVALUATE ITS IMPACT:** Countries must consider adequate and comprehensive marine spatial planning to enable a successful roll-out of ocean energy technologies. Governments should plan the spatial requirements for the blue economy in advance, reserving a space for R&D and commercialisation purposes of ocean energy technologies. In addition, marine spatial planning should go hand in hand with social, economic and environmental impact assessments.

05.3

Offshore wind[7]

- **ADOPT A SYSTEMIC APPROACH, DRAWING TOGETHER INNOVATIONS IN ENABLING TECHNOLOGIES, MARKET DESIGN, BUSINESS MODELS AND SYSTEM OPERATION:** The implementation of innovations to unlock flexibility across the whole power sector would result in lower costs to integrate variable renewable energy and thus support the energy transformation (IRENA, 2019f).

- **PROMOTE R&D ROADMAPS AND STRATEGIES:** Facilitate an offshore wind roadmap for national research and industry development institutions to advance offshore wind uptake in the public and private sectors.

- **PROVIDE LONG-TERM STABILITY OF POLICY INSTRUMENTS:** Policy making needs to minimise swings from strong supportive measures to aggressive curbs. Likewise, prolonged periods of policy uncertainty can greatly impact the future of the wind industry.

- **STREAMLINE THE PERMITTING PROCESS TO AVOID LONGER CONSTRUCTION PERIODS:** Streamlining the processes around applying for grid and construction permitting can reduce long lead times and construction periods. This is also linked to the need to reduce the uncertainties of regulatory and policy frameworks in countries where offshore wind is being deployed, as this could severely impact the permitting process, investor confidence and overall project risk, which feeds down to project costs.

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[7] Based on *Future of wind* (IRENA, 2019c).

- **IMPROVE EXISTING INFRASTRUCTURE ALONG WITH BUILDING A HIGH-VOLTAGE GRID, OR SUPER GRID:** This will help to transport electricity to other regions and avoid renewable energy curtailment.

- **DEPLOY SUSTAINABLE FINANCE INITIATIVES AND PROGRAMMES:** This aims to enlarge the fiscal space and to foster sector diversification to finance the energy transition process in the medium and long terms.

- **STRENGTHEN AND MAXIMISE VALUE CREATION FROM THE DEVELOPMENT OF A DOMESTIC WIND INDUSTRY:** To reinforce 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.

05.4

Floating solar PV[8]

- **PROMOTE R&D STRATEGIES AND BUILD OFFSHORE KNOWLEDGE:** Plan R&D roadmaps in harmony with the marine sector. Essential topics needed to advance the sector include further environmental assessment and impact, electrical safety, mooring and anchoring systems, and project development knowledge for offshore conditions (World Bank, 2018). Establish institutions that can help to advance the uptake of learnings from R&D in the public and private sectors.

- **PUSH INNOVATION INTO CO-LOCATION OF RENEWABLE OFFSHORE TECHNOLOGIES:** Floating PV can benefit from spatial co-location with other marine technologies. This could enhance water space use and at the same time enable a more stable power generation in the grid.

- **NURTURE TECHNOLOGY BREAKTHROUGHS:** As with any new technology, several engineering challenges need to be overcome. For instance, mooring (or anchoring) systems must be designed to withstand the dynamic forces of waves and strong winds and, due to the novelty of the technology, mooring specialists have limited experience in applying such systems to floating PV plants. As a result, floating PV installations are always moving to some extent, which increases with wind load.

- **BENCHMARK AND EXPAND "ONSHORE" PV FINANCIAL MECHANISMS:** Current successful financial practices from onshore solar PV can be used as a baseline and incorporated for floating PV technologies. In particular, the inland PV sector has built experience in feed-in tariffs, renewable energy certificates, carbon pricing and green bonds.

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[8] Based on Future of solar photovoltaic (IRENA, 2019d).

05.5
Shipping

- **SUPPLY OF ZERO EMISSION FUELS:** Upstream dynamics need to be better understood, including not only greenhouse gas life-cycle analysis of the different fuels but also the potential and production limits of clean fuels. This includes biofuels, hydrogen and ammonia. The sector needs to be sure that clean fuel supply will be constant in the long term.

- **DE-RISKING FIRST MOVERS:** Participants across the entire value chain need to be well engaged and capable of supplying a variety of clean fuels without interruptions. Simultaneously, first movers need incentives, including funding with special, attractive conditions, as well as other types of economic incentives.

- **CARBON LEVY:** For clean fuels to become viable in the near term, a carbon price of USD 250-300 per tonne would be necessary. However, the industry is only willing to pay up to USD 75 per tonne of carbon. Hence, policy makers, cargo operators and ship owners must be brought together to agree on suitable mechanisms to fund the transition towards zero carbon emissions.

- **STAKEHOLDER ENGAGEMENT:** The engagement of stakeholders needs to go beyond the shipping industry and energy-related stakeholders. Routes for engaging end-use consumers need to be identified and put in place.

- **AWARENESS OF END USERS:** Shifting to clean fuels will likely result in an increase in the final price of the transported goods, hence the final consumer needs to be made aware of which goods were transported by vessels using clean fuels.

05.6
Desalination

- **DESALINATION WITH VARIABLE RENEWABLE ENERGY RESOURCES:** Combining variable renewable technologies, such as solar and wind, with desalination processes – which require a constant energy supply – involves technical, economic and organisational challenges. This knowledge and understanding is lacking in developing countries with scarce freshwater resources (for example, on small islands). Hence, platforms are needed for developed countries to share their technical knowledge and experiences with least-developed countries and SIDS.

- **IDENTIFICATION OF NICHE MARKETS:** The identification of niche markets for renewable desalination and the establishment of proper enabling frameworks would help attract private investors.

- **MULTI-STAKEHOLDER COLLABORATION:** More collaboration and integration is needed between energy and water sector companies.
- **FUNDING MECHANISMS:** An estimated 66% of the global population faces severe water scarcity, yet more than 70% of desalination infrastructure sits in high-income countries. Mechanisms are needed urgently to enable affordable funding to low- and lower middle-income countries.

Figure 18 provides a summary of the recommended actions to move the offshore renewables sector forward.

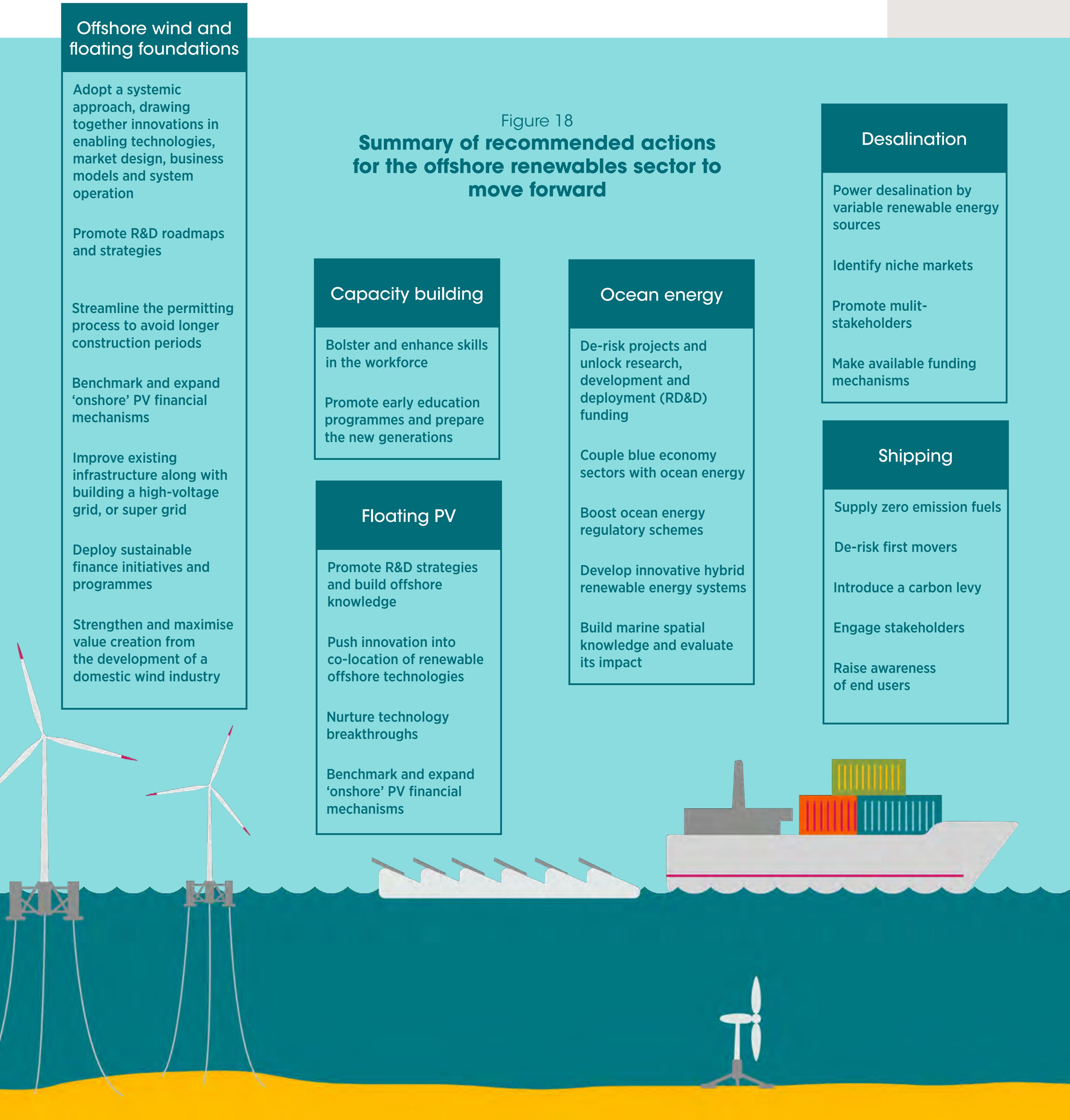

Figure 18

Summary of recommended actions for the offshore renewables sector to move forward

Offshore wind and floating foundations

- Adopt a systemic approach, drawing together innovations in enabling technologies, market design, business models and system operation
- Promote R&D roadmaps and strategies
- Streamline the permitting process to avoid longer construction periods
- Benchmark and expand 'onshore' PV financial mechanisms
- Improve existing infrastructure along with building a high-voltage grid, or super grid
- Deploy sustainable finance initiatives and programmes
- Strengthen and maximise value creation from the development of a domestic wind industry

Capacity building

- Bolster and enhance skills in the workforce
- Promote early education programmes and prepare the new generations

Floating PV

- Promote R&D strategies and build offshore knowledge
- Push innovation into co-location of renewable offshore technologies
- Nurture technology breakthroughs
- Benchmark and expand 'onshore' PV financial mechanisms

Ocean energy

- De-risk projects and unlock research, development and deployment (RD&D) funding
- Couple blue economy sectors with ocean energy
- Boost ocean energy regulatory schemes
- Develop innovative hybrid renewable energy systems
- Build marine spatial knowledge and evaluate its impact

Desalination

- Power desalination by variable renewable energy sources
- Identify niche markets
- Promote mulit-stakeholders
- Make available funding mechanisms

Shipping

- Supply zero emission fuels
- De-risk first movers
- Introduce a carbon levy
- Engage stakeholders
- Raise awareness of end users

05.7

Framework for action

As the leading global intergovernmental organisation dedicated to energy transformation, IRENA aims to help countries gain access to the latest knowledge on offshore renewables, particularly to strengthen national strategies to achieve SDG 7 and SDG 14. It also aims to support capacity building and international co-operation to foster a global blue economy.

Collaborative Framework on Ocean Energy / Offshore Renewables

In response to a call by its global membership, IRENA has created collaborative frameworks that serve as an effective platform for increased dialogue and co-ordinated action among its Members. A new Collaborative Framework on Ocean Energy / Offshore Renewables brings countries together to identify priority areas and actions and to foster international collaboration to understand the role of ocean and offshore renewables in the energy transition and ensure its widespread deployment in the future.

The collaborative framework has been endorsed by several IRENA member countries and is now operational. This platform for collaboration aims to foster advancements in areas relevant to offshore renewables including technology development, research and innovation, market incentives, regulatory frameworks and sustainability. It shows IRENA's continued commitment as a leading global platform to share knowledge and support governments in pursuit of the deployment of renewable energy.

IRENA stands ready to:

- Provide a common vision on offshore renewables potential and expected changes in the market;
- Disseminate the best offshore renewables experiences and provide policy makers with project case studies, business cases and facts on the technology;
- Facilitate international co-operation by identifying decarbonisation synergies among marine sectors;
- Give guidance on understanding the right supply chain for offshore technologies;
- Create an offshore renewables portfolio for SIDS, by understanding their energy needs and recommending technologies that can address the issues identified;
- Include financiers in the offshore renewables discussion;
- Determine offshore renewables contributions to Nationally Determined Contributions (NDCs) and support countries in drafting their NDCs;
- Assist countries in harnessing the socio-economic benefits of renewable energy, particularly in terms of new job creation and local economic value.

To facilitate ocean energy uptake, IRENA could:

- Make available to policy makers the frameworks and information on viable electricity prices for ocean energy and the creation of other market indicators that go beyond LCOE;
- Facilitate access to decision makers and underline the need for revenue support through feed-in tariffs or renewable energy certificates.

Key recent initiatives

SIDS LIGHTHOUSES INITIATIVE

Launched by IRENA in 2014, the SIDS Lighthouses Initiative supports small islands in scaling up renewable energy through partnerships between public institutions, the private sector, inter-governmental and non-governmental organisations. After the initiative's initial targets for 2020 were met ahead of schedule and even considerably exceeded, a new even more ambitious phase of the initiative was launched in 2018. The action areas for this second phase include promoting all renewable sources, including ocean energy, as well as reinforcing links between renewables and non-energy sectors – including the water sector. In this context, IRENA could play a key role in establishing a platform to share experiences and technical knowledge on water desalination to support building capacities among SIDS.

SHIPPING: GETTING TO ZERO COALITION

IRENA has joined the Getting to Zero Coalition, an alliance of more than 90 companies within the maritime, energy, infrastructure and finance sectors – supported by key governments and international organisations – that was launched at the 2019 Climate Action Summit. The Alliance is committed to getting commercially viable deep-sea zero-emission vessels into operation by 2030. With the status of knowledge partner, IRENA is supporting Workstream #1 – Fuels, Technologies & Pathways. In October 2019, IRENA participated in the Global Maritime Forum Annual Summit in Singapore where the Agency launched its report *Navigating the way to a renewable future: Solutions to decarbonise shipping* (IRENA, 2019c). This report explores the impact of maritime shipping on CO_2 emissions, characterises the shipping sector and identifies various clean energy solutions with the potential to reduce the sector's carbon footprint.

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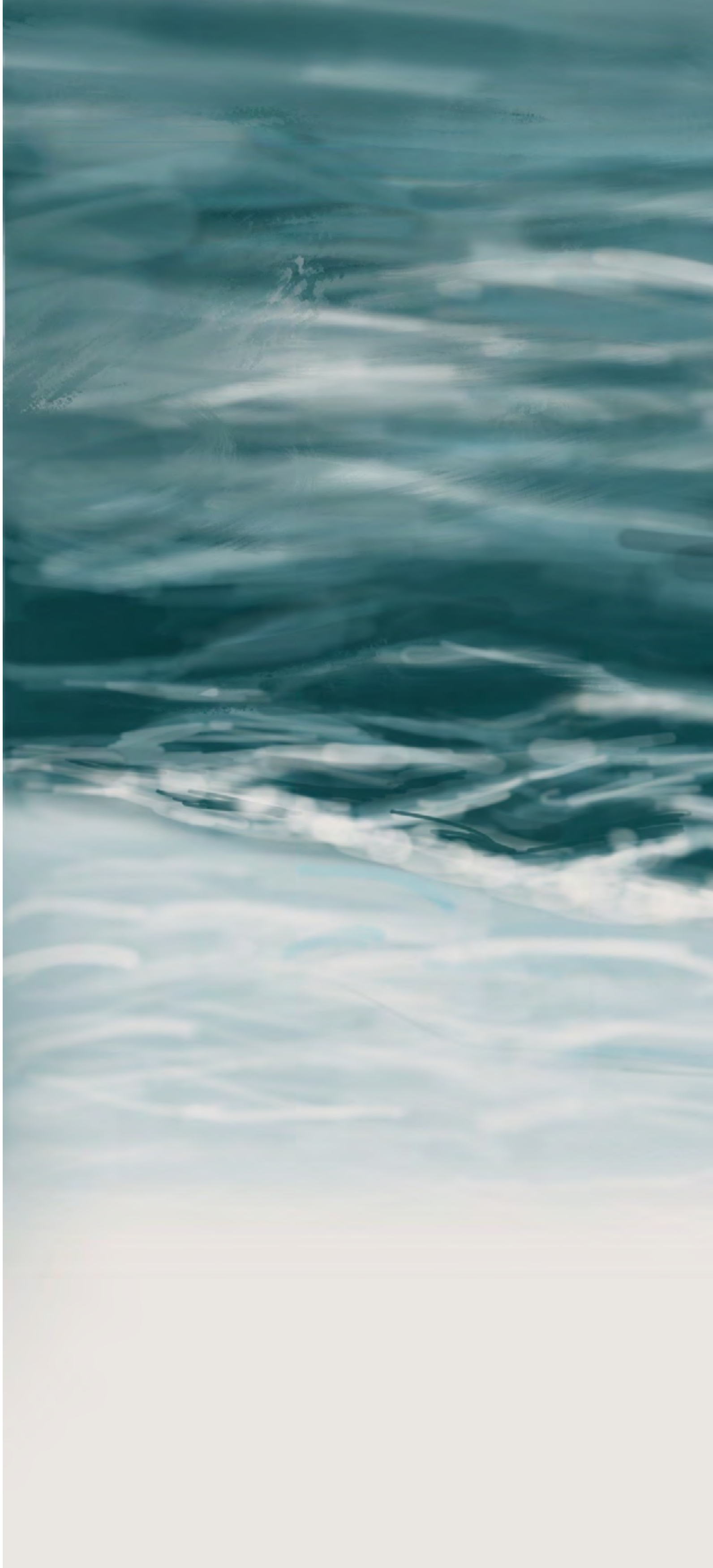

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