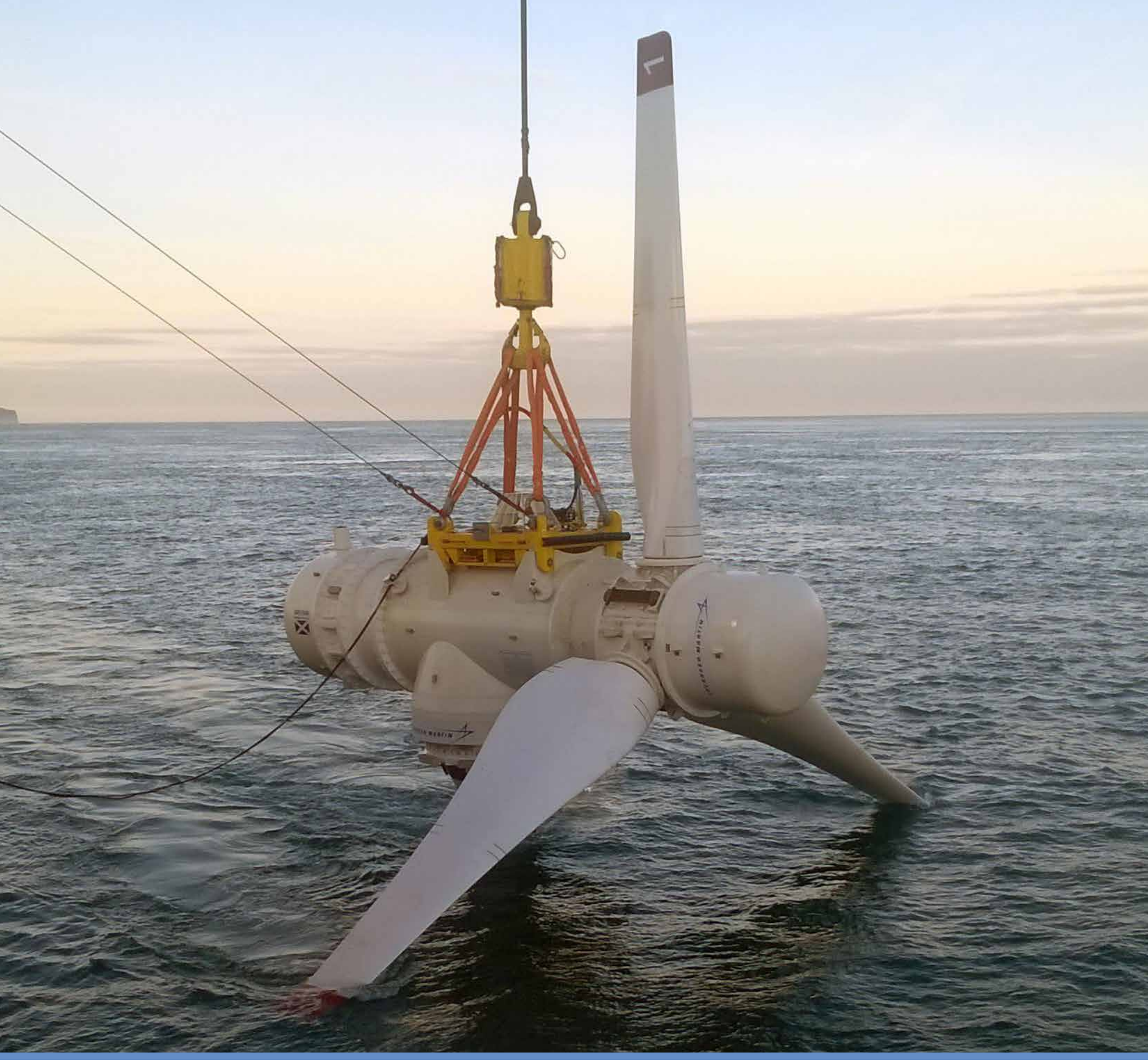

# Ocean Energy

## The largest untapped renewable resource

Global Resource Assessment

June 2026

OCEAN ENERGY EUROPE

*This publication is the most exhaustive literature review to date, gathering relevant analyses on the ocean energy resource, country by country, based on the existing literature available at the time of publication. It considers the outcomes of independent studies across the globe, published by government agencies, international organisations, as well as academic literature.*

*This report addresses a key knowledge gap by providing a consolidated view of the global ocean energy resource. Such mapping is essential to help governments assess the contribution ocean energy can make to their energy systems and design appropriate policy and funding frameworks. It provides substantiated evidence on market potential to inform investment decisions by both public and private actors.*

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**Cover photo:** Courtesy of Proteus Marine Renewables

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Photo: SKF

# Executive Summary

## OCEAN ENERGY CAN SUPPLY 13% OF GLOBAL ELECTRICITY DEMAND[1]

Ocean energy has the potential to generate 3,911 TWh of electricity per year globally (TWh/y). It is more electricity than nuclear currently produces and is close to what hydropower generates worldwide[2]. This confirms that ocean energy can become a massive source of renewable generation and help wind and solar decarbonise power systems across the world. Wave and tidal are the ideal complement to a growing share of wind and solar penetration globally, as they can produce renewable power at different times. As a result, they can help balance a variable supply of electricity with demand and displace a massive share of fossil-fuel generation.

**This global potential is based on studies from only 20 countries** that have surveyed their ocean energy resources. As a result, it represents only a fraction of the real total potential. A substantial share of the global resource remains unquantified, as many countries are yet to evaluate their potential. Global generation potential will grow as resource assessments expand and improve.

**Wave energy can generate more electricity than global nuclear power today.** Wave energy has the potential to produce 3,074 TWh/y of electricity globally compared to 2,743 TWh/y[3] for nuclear in 2023. This makes it clear that it can be an important source of electricity in many countries.

**Ocean energy can cover over 50% of electricity demand in half of surveyed countries** the United Kingdom, Ireland, Portugal, in Europe; Canada, Ecuador, and Chile in the Americas; and Indonesia, the Philippines, Australia, and New Zealand in Asia–Oceania.

**Tidal can replace 13% of global gas generation.** Tidal energy has the potential to produce 837 TWh/y of electricity globally, compared to 6,622 TWh/y[4] for gas worldwide. Tidal technologies deliver power up to 90% of the time. This significant potential can thus displace a large portion of global gas generation used to balance power markets at times of lower wind and solar output.

**The massive global potential confirms major export opportunities for countries leading in ocean energy.** Pioneering countries are set to industrialise the technology first and host the first manufacturing plants. This will enable them to scale supply chains, drive down costs, and develop the most competitive products. This competitive advantage will, in turn, drive export opportunities toward the many countries developing ocean energy – as e.g. Denmark and Germany did for offshore wind.

## OCEAN ENERGY'S POTENTIAL IS ONLY SET TO INCREASE

**Efficiency gains will increase the energy extracted from the known resource.** Testing and demonstration of wave and tidal technologies will continue to drive performance improvements. While the theoretical resource will remain unchanged, the increased technology maturity will lead to higher electricity output per device and boost the overall generation potential.

**Technological innovation will unlock new geographical resources.** New or modified devices will make it possible to generate electricity from areas not yet included in current resource assessments. For instance, low-speed tidal current technologies[5] can generate electricity from weaker flows (below 2 m/s) compared to conventional tidal systems. This will increase the number of viable deployment sites and overall generation potential.

**Much of the resource is yet to be uncovered, as many countries have not quantified their potential.** Available studies only cover 20 countries around the globe at present, and many regions have not yet assessed their full ocean energy potential. A wider geographical resource mapping – especially in South America, Africa, and Asia will clarify and increase the global generation potential.


Photo: CorPower Ocean

## OCEAN ENERGY CAN SUPPLY 21% OF EUROPE'S ELECTRICITY DEMAND

**Ocean energy can produce more electricity than gas in Europe.** Ocean energy has the potential to generate 573 TWh/y (from 188 GW) of electricity for Europe – more than hydropower (368 TWh/y[6]) or gas (559 TWh/y[7]) today. Ocean energy can produce power at different times than wind and solar. This means that this ocean energy potential can be leveraged to displace a substantial share of costly gas generation from the European grid.

**Technological progress and new studies have increased Europe's potential compared to previous estimates.** Improved testing, prototypes, and pilot farms have provided new data on electricity generation, showing we can extract more TWh from the same resource. Additionally, new studies have uncovered new resource areas. Together, those two factors significantly increased Europe's generation potential.

**The UK and France have some of the best tidal spots in the world.** They hold the largest tidal potential in Europe. This makes them prime locations to deploy the first commercial farms and industrialise the technology. 420 MW[8] of tidal capacity is set to be deployed or auctioned by 2030 in the UK and France. This will kickstart the large-scale deployment of the technology on the continent.

**The UK, Portugal, Ireland, and Spain have the best wave resource in Europe.** Wave energy can meet over 100% of electricity demand in Ireland and Portugal, and over 55% in the UK. Wave energy has the potential to fully replace all fossil fuel generation in these countries.

**Europe can leverage its technological leadership to secure a large share of the global market.** Europe leads the world in ocean energy. All ocean energy farms have been deployed in Europe, and European companies have deployed more devices than the rest of the world combined[9]. The sector is now industrialising – 16 publicly supported pre-commercial farms are set to be deployed over the next four years. Europe has the opportunity to turn long-standing technological leadership into industrial leadership during this decade and secure today a large share of the future global market.

## OCEAN ENERGY CAN MEET 36% OF ELECTRICITY DEMAND IN THE AMERICAS

**The US and Canada have the highest surveyed ocean energy potential in the Americas.** Ocean energy can provide 1,620 TWh/y per year in the United States (US) and 363 TWh/y in Canada. This is equivalent to 40% of electricity demand in the US and 64% in Canada. It represents twice as much as nuclear generation in the United States and exceeds hydropower in Canada, the country's main source of electricity.

**Wave can meet over 20% of electricity demand in Chile and Brazil.** Wave energy can generate over three times Chile's annual electricity demand and deliver 145 TWh/y in Brazil – more than biofuel and gas generation combined. Wave can help power systems manage a growing share of variable wind and solar by producing at different times. It can also reduce transmission and distribution issues by producing power close to major demand centres in both countries.

**Canada is home to the strongest tidal currents in the world.** Tidal energy has the potential to meet 13% of the electricity demand in Canada – close to what Canadian nuclear is providing today. The Bay of Fundy site in the province of Nova Scotia is widely regarded by the industry as the world's best site for tidal energy extraction. It's moving more than 160 billion tonnes of water every tidal cycle — more than all the world's rivers combined.

**The United States could soon challenge Europe's leadership.** The US Department of Energy (DOE) has invested $983M[10] in ocean energy since 2020, far outstripping all European funding. The government recently launched a $112 million call, offering up to $25M for full-scale deployment and farms. To support future deployments, the US also funded the construction of the world's largest wave energy test centre in Oregon (PacWave) set to open in 2026.

Given massive funding support and sustained political backing at both the federal and state levels, the US could quickly close the gap with Europe and challenge its global leadership in ocean energy.

## ABUNDANT WAVE AND TIDAL RESOURCES IN ASIA-OCEANIA

**Large wave resource in both continents with the best potential in Australia and Japan.** Wave energy has the potential to meet Australia's electricity demand several times over. Wave technologies can generate power when the wind drops, making it a strong complement to the country's expanding wind, solar, and battery fleet. Wave can meet 9% of electricity demand in Japan. This is equivalent to one-third of gas generation in the country. Albeit smaller, China, India, and Indonesia also possess a wave energy potential suited for large-scale generation.

**Tidal can meet 100% of electricity demand in the Philippines and over 50% in Indonesia.** Both countries are regarded by the industry as the best location for tidal deployment in Asia. The thousands of islands between the Indian and Pacific Oceans create narrow straits that accelerate water flows, creating ideal conditions for tidal stream generation. This huge tidal potential can be harnessed to replace coal, the main electricity provider in the Philippines and Indonesia, and bring clean power close to the main demand centres spread along the coastline.

**Asia is the continent with the greatest data gap, hinting at a larger actual resource in the region.** Many countries in Asia, including China, India, and South Korea, have only partially assessed their ocean energy resources. While site studies can give a clear view of generation potential in a given area, they fail to capture the overall national potential. More studies will be needed to fully assess the most likely vast potential for ocean energy in those countries.

**China is a fast-developing market for both wave and tidal, thanks to increasing policy and funding support.** The Chinese government already targeted the 'large-scale development of ocean energy' in its 14$^{th}$ 5-year plan. To achieve this, the plan provides earmarked funding for wave and tidal pilot farms. Thanks to that sustained funding, China is helping its manufacturers make up for their late start in the ocean energy race. Europe still leads the world in deployment and technological maturity. But China could leverage its industrial leadership in renewables to fast-track the scale-up of ocean energy.

## STRONG EXPECTED OCEAN ENERGY POTENTIAL IN AFRICA AND SIDS BUT NO STUDIES TO QUANTIFY IT

The best ocean energy resource is expected to lie in West and Southern Africa. Several countries, including Angola, Namibia, and South Africa, show strong wave potential, while a tidal stream resource is expected to be found in the Mozambique Channel. Small Island Developing States (SIDS) across the Caribbean, Pacific, Atlantic, and Indian Oceans all possess considerable ocean energy potential, including wave, tidal, and ocean thermal energy conversion (OTEC). Further studies are needed to map these resources and quantify their electricity generation potential.

## COUNTRY HIGHLIGHTS

### OCEAN ENERGY can cover

**70%** of electricity demand in the UK, Portugal and Ireland

**40%** of electricity demand in the US

**14%** of electricity demand in France

### WAVE ENERGY can cover

**100%** of electricity demand in Ireland, Portugal, Chile, and Australia

**50%** of electricity demand in Canada

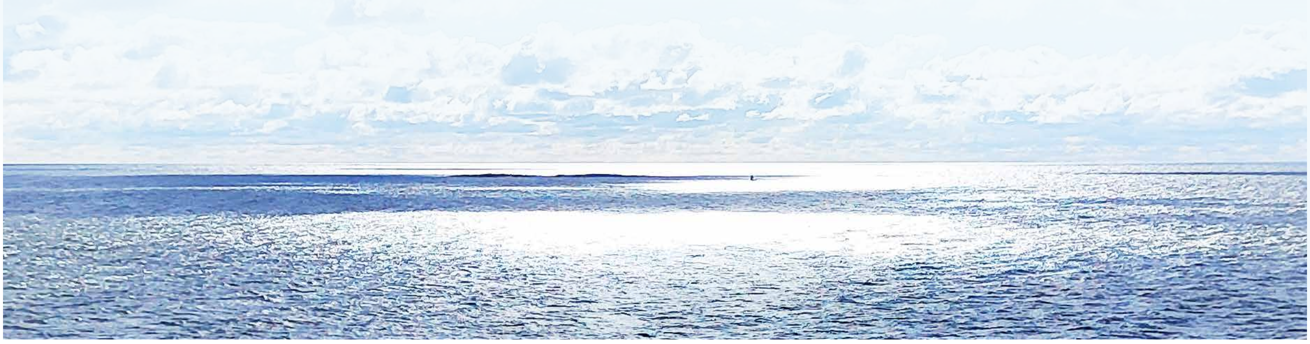
**30%** of electricity demand in Spain and Denmark

### TIDAL ENERGY can cover

**50%** of electricity demand in the Philippines and Indonesia

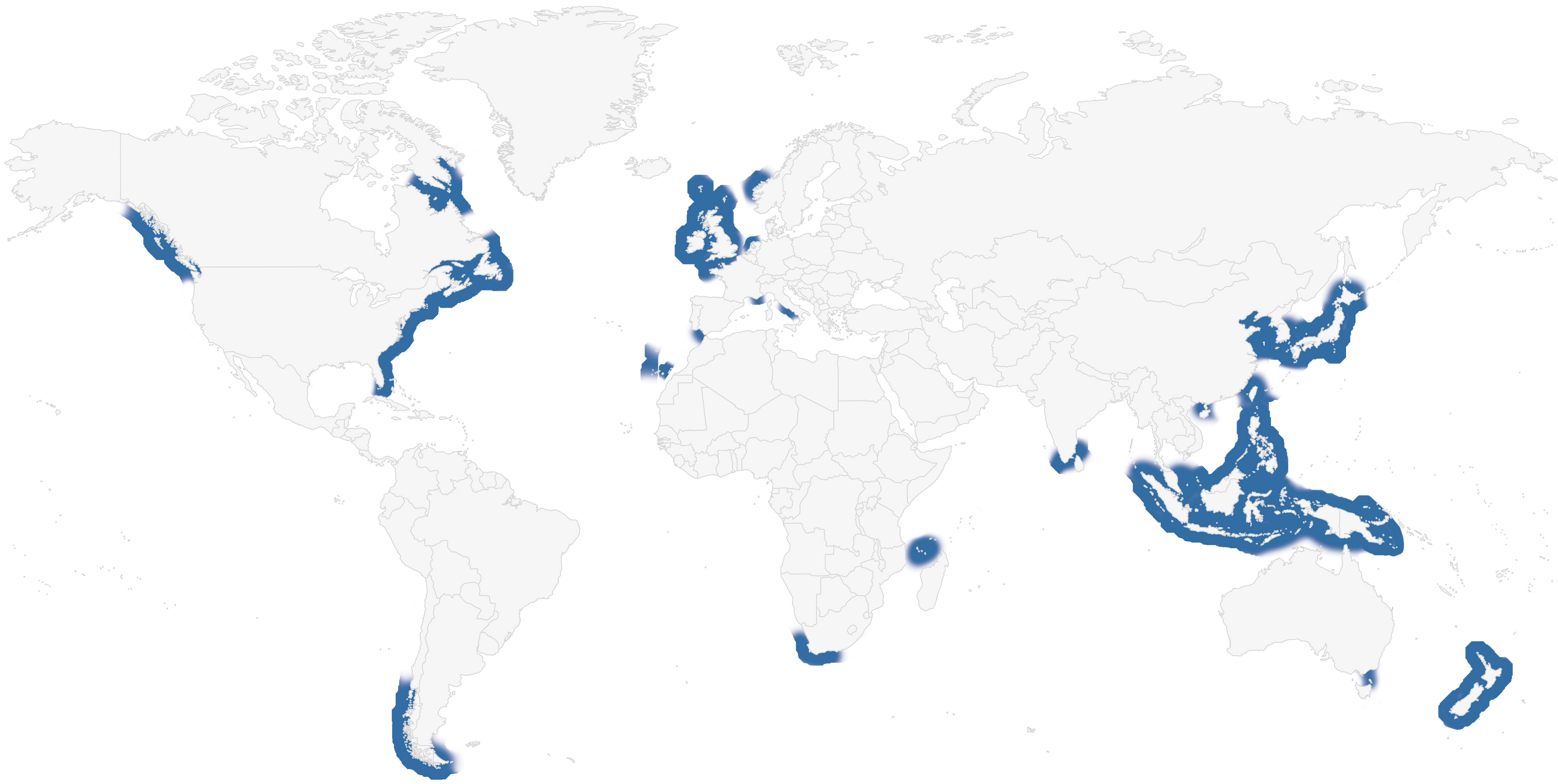
**15%** of electricity demand in the UK

**13%** of electricity demand in Canada



# Global Wave Resource

# Global Tidal Resource



# 01 A massive global potential set to increase further

## Technology improvements will increase the energy extracted from existing identified resources

All studies reviewed in this report estimate the ocean energy potential based on the state of the art of ocean energy technologies at a certain point in time. Each time developers test and demonstrate their technologies, new lessons are learned, leading to greater efficiency in capturing the same resource. This means that while the theoretical resource itself does not change, the amount of MWh extracted from it will increase as technologies improve.

Some studies referenced in this report rely on power matrices derived from technologies that are 10 to 15 years old. Consequently, they fail to account for advancements in wave and tidal energy technologies over the past decade. It is widely acknowledged that these studies underestimate the true extractable ocean energy resource. In contrast, more recent studies are far more likely to reflect the improved performance of newer technologies and provide a more accurate assessment of the resource potential. This means that future studies based on recent or future technologies will show significantly increased extraction potential from existing zones.

## Technological innovation will unlock new geographical resources

Technological developments will increase the total extractable resource. New devices designed to harness new areas with different resource characteristics will make it possible to generate electricity from sites not yet included in the resource assessment.

**Low-speed current tidal technologies** can generate power from lower currents (below 2 m/s) compared to conventional tidal systems. They can significantly expand the resource mapping by making exploitable a much larger share of the tidal resource. This substantially increases the number of sites exploitable and multiplies the installation potential[11]. Low-speed current technologies developed by European companies such as Minesto and SeaQurrent are already being deployed in European waters. This report does not yet cover low-speed current resources due to a lack of studies quantifying their potential.


Photo: Seaqurrent

## Many countries have not assessed their ocean energy resource yet

Although new studies are published regularly, many regions around the globe have not assessed their ocean energy resource or only partially done so. Several regions are entirely absent from this report due to a lack of available data or studies. Certain countries have only surveyed the theoretical potential and have yet to quantify how much of this resource is technically extractable.

A better geographical coverage from future studies will increase the total global ocean energy potential. Based on general data sources such as the Copernicus satellite system, it is evident that future studies will reveal significant ocean energy potential in South America, Africa, and missing countries in Asia and Oceania.

Those studies are yet to be conducted and therefore not included in this report:

- **Wave:** Countries with long coastlines exposed to large and consistent ocean swells are typically expected to have wave energy potential. Given their geographical positions, many countries in Central and South America, such as Peru, Ecuador, Colombia, Costa Rica, Guatemala, and Mexico, as well as Namibia, South Africa, and Madagascar in Africa, and Taiwan in Asia, likely possess significant wave energy resources. Small Island Developing States (SIDS) all have ocean energy potential that has yet to be quantified.

- **Tidal:** Regions with large tidal ranges, narrow channels, and estuaries are expected to have a strong tidal resource. Such geographical characteristics help to concentrate and amplify tidal flows, making it ideal to harness tidal streams for power generation. As a result, Taiwan, South Africa, Madagascar/ Mozambique, Mayotte, Malaysia, and Papua New Guinea are likely to have tidal potential.

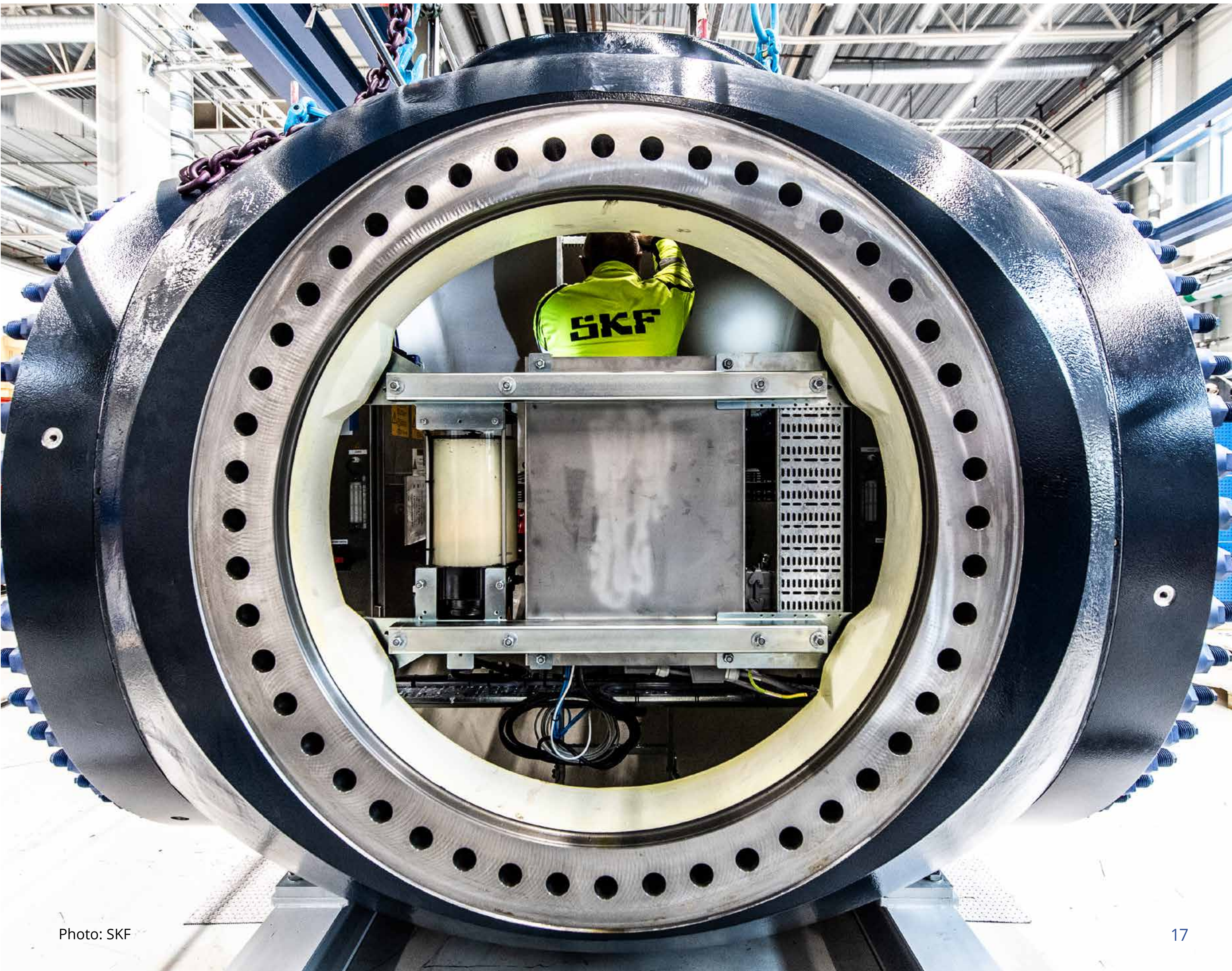
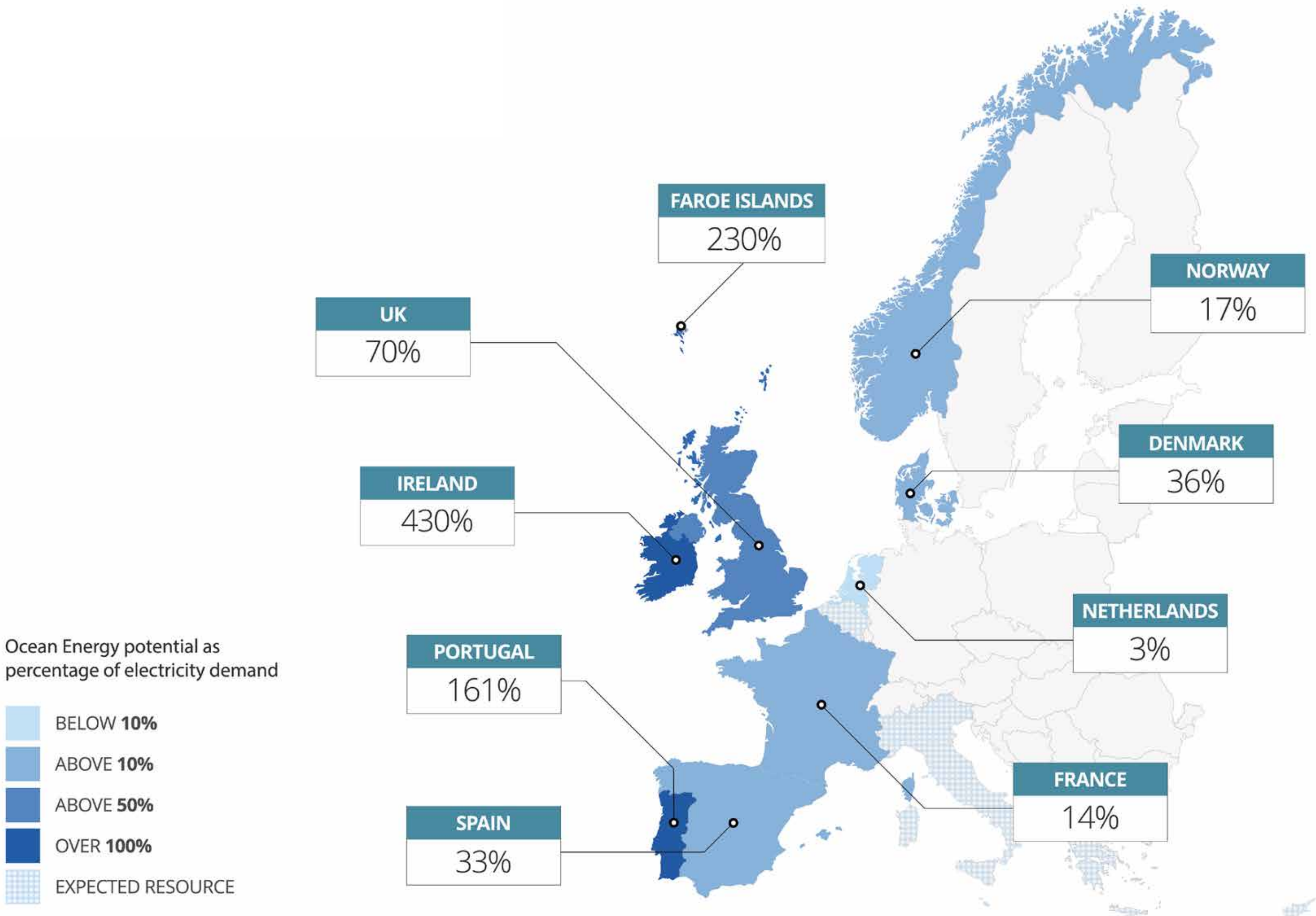



Photo: SKF

# 02 Europe: Ocean energy can provide 21% of electricity demand




Ocean energy can supply 573 TWh/y of electricity (from 188 GW) to Europe. This is equivalent to 21% of Europe's electricity demand. It is more electricity than gas[19] (559 TWh/y) delivers to the European grid today.

Ocean energy can generate electricity at different times than wind and solar, and help balance the variable supply of electricity with demand. This means Europe's significant ocean energy potential can be leveraged to displace a large share of costly gas generation in the European grid.

This potential assessment exceeds the first industry estimates from 2010, which placed ocean energy potential at 10% of Europe's electricity demand. Two factors explain this increase. First, the testing of prototypes and pilot farms over the past 15 years has led to significant technological advancements in resource extraction. These have shown that more MWh can be extracted from the same resource through improved technology performance. Second, many new studies have expanded the mapping of the ocean energy resource in Europe. This has led to the identification of new sites and increased the generation potential[20].

| Yearly potential (TWh/y) | Theoretical | Technical | Share of electricity demand[12 13 14] |
|---|---|---|---|
| Tidal stream | 653[15] | 74[16] | 3% |
| Wave energy | 2,598[17] | 499[18] | 18% |
| **TOTAL** | **3,251** | **573** | **21%** |

## Tidal

Most of the tidal potential in Europe is focused in France and the United Kingdom (UK), which have some of the strongest tidal currents on Earth. The tides pull waters from the Atlantic into the North Sea and vice-versa 4 times a day.

The UK and French coastline acts as a barrier, forcing those water masses through the narrow channels of the many British islands, and the Franco-British Channel. This creates a bottleneck effect, forcing the water flows to accelerate considerably, akin to a Venturi effect.

## Wave

Europe holds the second-largest wave energy potential of the 4 continents surveyed. The highest potential is found in the United Kingdom, Ireland, Portugal, France, Spain, and Norway. These countries share a common exposure to Atlantic waves that come crashing onto their western coastline. Those waves are very energetic, as they are created by winds travelling long distances across the open Atlantic Ocean, maximising the energy transfer from winds to waves.

Denmark, Italy, and the Netherlands also possess significant wave energy potential, with many suitable sites for deployment. Their coastlines are more sheltered from long-distance winds, resulting in lower wave energy levels compared to the Atlantic. This makes them suitable for early-stage technology testing, and for technologies exploiting less energetic waves, e.g. focused on powering offshore infrastructure and monitoring equipment. As technology progresses, interest in those markets should grow, as evidenced by wind energy's early development.

## Market

The rest of Europe doesn't share the ocean energy resource of coastal countries, but the technology's industrial potential spans across all of Europe. The ocean energy supply chain already spreads across 17 countries in Europe[21]. The manufacturing of specialised electrical components,[22] for example, is taking place in countries without significant/any ocean energy resource, such as Germany and Austria. The industrialisation of the sector will create new economic opportunities for many existing supply chains in all European countries, servicing shipbuilding, offshore wind, electrical engineering, automobile, aerospace, and more. Europe is currently home to most of the sector's industrial champions. At the time of writing, Europe has a project pipeline of 196 MW[23] of wave and tidal farms. This spans across 16 publicly supported projects that are slated for deployment over the next 4 years. The combination of funding from the EU and national governments makes these projects particularly attractive for private investors. This has led several energy majors to invest in or partner up in ocean energy projects since 2023[24].

The continent can reap the benefits of its current technological leadership by scaling up its ocean energy industry at home. Clear investment pathways can put Europe in a prime position to capture the largest share of the global ocean energy market. National revenue support and consistent funding for deployment are the main drivers to achieve this.

## United Kingdom: The ocean energy El Dorado of Europe

Ocean energy can satisfy over two-thirds of the current electricity demand in the United Kingdom[30]. This is more than natural gas, nuclear, biofuels, and waste combined are producing today[31]. The UK has both the best wave and tidal resources in Europe. Both remain accessible to European companies despite Brexit, and many EU supply chain actors are active and essential to UK projects.

| Yearly potential (TWh/y) | Theoretical | Technical | Share of electricity demand[25 26] |
|---|---|---|---|
| Tidal stream | 340[27] | 38[27] | 15% |
| Wave energy | 570[28] | 145[29] | 55% |
| **TOTAL** | **910** | **183** | **70%** |

## Wave

Wave energy alone can meet more than half of the country's electricity demand, which is as much as nuclear and natural gas combined.

The UK's massive wave resource comes from strong winds moving northwards in the Atlantic Ocean, building powerful waves over long distances, which crash against the country's western shores.

A large share of the wave energy potential is spread all along the coast of Scotland from the Inner Hebrides to the West of the Shetlands. The sites with the highest potential are found in the Northwest of Scotland, in Cape Wrath, and the Outer Hebrides, which together gather half of the potential of the UK. There is also an important wave energy resource in the West of Orkney, in the West of Shetland and the South of England, in the Sicily Isles, and from Cornwall up to the Bristol Channel.

## Tidal

Tidal energy can supply as much electricity as nuclear power currently provides in the UK[32].

The north of Scotland, where the open Atlantic Ocean meets the North Sea, is home to some of the best tidal spots in the world. Every day, vast volumes of water surge through inter-island channels and narrow headlands, creating some of the strongest currents on earth.

The Pentland Firth Strait, and the Orkney Islands in Scotland have the best potential for energy extraction. A significant potential for tidal stream deployments is also found in other areas, notably in the West of Scotland, in the Southern part of the Inner Hebrides, Wales, and off the south coast of England, towards the Isle of Wight.

## Market

The United Kingdom has been a historic centre of development for the ocean energy sector in Europe. The vast resource and the presence of world-leading research communities and supply chains have attracted numerous tidal and wave developers. Currently, the UK has about 10 MW of operational tidal stream capacity and over 1 GW of leased tidal stream energy sites[33]. The country is also home to the European Marine Energy Centre (EMEC), in Orkney, Scotland — the largest ocean energy test site in the world.

In 2022, the UK government put in place a ringfenced revenue support mechanism for tidal stream, as part of its Contracts for Difference auction system, to realise existing market opportunities. It has been renewed every year since. Thanks to this support, the government has enabled the future deployment of 140 MW[34] of tidal stream energy in its waters by 2029. Industry roll-out should therefore happen quickly if the right political and financial support continues to be provided by the UK government.

Photo: Orbital Marine Power

## France: The greatest tidal resource in the EU

Ocean energy can provide 14% of the electricity demand in France. That's as much as hydropower generation and double the output of natural gas[40]. Wave and tidal energy have the potential to become a major renewable electricity provider and ideally complement a growing share of variable wind and solar on the grid going forward.

| Yearly potential (TWh/y) | Theoretical | Technical | Share of electricity demand[35 36] |
|---|---|---|---|
| Tidal stream | | 18[37] | 4% |
| Wave energy | 400[38] | 40[39] | 10% |
| **TOTAL** | **>400** | **58** | **14%** |

## Tidal

France has the best tidal resource in the EU and some of the greatest sites in the world. The water streams coming from the Atlantic Ocean must force their way around Brittany and into the English Channel in the north of France, accelerating water flows to some of the highest speeds on the planet.

The bulk of the French tidal resource is concentrated on the country's north-west coast.

The site with the highest potential is the Alderney Race (Raz Blanchard) in Normandy, which is widely regarded by the industry as one of the best tidal sites in the world. The Fromveur Passage, off the coast of Brittany, is the second site with the highest potential for tidal generation in France.

Brittany hosts several other sites suited for tidal with slower flows, such as the Gulf of Morbihan or Paimpol Bréhat. A recent study led by the Brittany region[41], identified two new sites on the southern tip of Brittany in the Finistère: Chaussée de Sein and Raz de Sein. A potential, yet to be quantified, is also confirmed in the West of Ouessant.

## Wave

Wave energy alone has the potential to meet 10% of the electricity demand in France.

There is no recent study assessing the wave energy technical potential of France in scientific literature. The only available study on the technical potential is over 15 years old — so it does not account for the significant technological advancements in wave energy over the past decade.

Known for its surf hotspots, the French West Coast is blessed with a large wave resource all along its Atlantic coast. Powerful winds coming from the Atlantic create a strong wave climate all along the coast. According to existing literature, the spots with the highest wave energy potential are found in Brittany, Pays de la Loire, and Nouvelle-Aquitaine. Sites with high wave energy potential have been identified in Le Croisic and Capbreton.

A regional study estimates Nouvelle-Aquitaine's theoretical wave potential at 70 TWh/y[42] — roughly one-fifth of France's initial national assessment. However, the ADEME study covering the whole territory does not provide a detailed regional breakdown, making direct comparison difficult. Identified deployment hotspots are located between Biarritz and Anglet.

The figures presented above only represent the wave energy potential of the French Atlantic coast. French overseas territories and islands also present a strong potential for wave energy that has not been documented yet. The regions with the highest potential are La Réunion, French Polynesia, New Caledonia, Martinique, and Guadeloupe[43]. For these island grids, wave energy can provide a great addition to solar and wind, replacing expensive and dirty diesel generation.

## Market

France is well-positioned to become a global leader in ocean energy. The country hosts leading tidal stream and wave energy developers, large energy utilities, as well as several test centres. France also benefits from the historic know-how of its marine industry, whose skills can be easily applied in the growing ocean energy industry.

29 MW of tidal farms are slated for deployment over the next five years in France. The 17 MW project led by HydroQuest and Qair secured a €75M grant and feed-in tariff support in the summer of 2023. Meanwhile, the 'NH1' farm project led by Normandie Hydroliennes is fully permitted and set to add 12 MW in French waters. Both projects, located in the Raz Blanchard, were awarded additional support from the EU Innovation Fund in 2024, making them highly attractive to private investors.

France is well-placed to take a leading role in the development of this new global industry. Commercial calls for tidal were formally announced by French President Emmanuel Macron in 2023 and were incorporated into the national energy strategy in early 2026. A total of 250 MW of tidal capacity is set to be awarded through commercial tenders by 2030. The market visibility and scale provided by these tenders will enable manufacturers to scale up the supply chain and kickstart the industrialisation of the technology in France.


Photo: HydroQuest

## Ireland: Best wave resource in the EU, four times the electricity demand

| Yearly potential (TWh/y) | Theoretical | Technical | Share of electricity demand[44][45] |
|---|---|---|---|
| Tidal stream | 230[46] | 10[47] | 31% |
| Wave energy | 525[48] | 125[49] | 399% |
| **TOTAL** | **755** | **135** | **430%** |

### Wave

Ireland has the best wave resource in the European Union. Wave energy can cover Ireland's energy demand four times over. This is more than seven times what natural gas[50] is producing today. There is enough wave resource to cover all the electricity consumption in Ireland and export a large amount of electricity over Europe.

Ireland's considerable wave energy potential is due to its important exposure to the northern Atlantic Ocean. The western coast of the country offers the best sites in the world for the deployment of wave energy.

Most of the west coast of Ireland possesses an important wave energy potential. Over half of this potential is focused between the centre of the West Coast, in the counties of Mayo and Galway, and the south around West Kerry and Cork. Areas surrounding large cities, in the east, such as Dublin and Belfast, have lower suitability due to shipping lanes and port areas[51], and a lower exposure to Atlantic waves.

### Tidal

Tidal energy has the potential to meet a third of Ireland's electricity demand. Although it is best known for its wave energy resource, Ireland could also become a tidal stream market in Europe. Most of the tidal potential is to be found on the east coast of Ireland, complementing the wave hotspots in the west. The key areas identified for tidal stream deployment in Irish waters are around Rathlin Sound in Rathlin Island, Northern Ireland[52]. Smaller sites have also been identified in the Republic of Ireland at Wicklow Head and Mizen Head.

### Market

Ireland is home to key ocean energy players and is attracting the interest of many European developers, given its significant wave resource. The country already has dedicated research centres and testing facilities, along with a mature industrial ecosystem to grow its industry at home.

The state-owned utility ESB led the development of one of the first wave energy farm projects in Europe, planned off the coast of Clare. While the project could not proceed due to regulatory permitting bottlenecks, it clearly demonstrates strong industrial interest from major utilities. With sufficient policy and financial support, the country could become a global leader in ocean energy.

Photo: OceanEnergy

## Portugal: Wave energy can cover over 100% of the country's electricity demand

Portugal has the second-highest wave energy technical potential of the European Union. Just like Ireland and France, Portugal is one of the hot spots for wave energy in the European Union. This is thanks to the large amount of its coast exposed to the Atlantic Ocean. The coastline receives powerful waves created by strong Atlantic winds that travel over long distances.

| Yearly potential (TWh/y) | Theoretical | Technical | Share of electricity demand[53 54] |
|---|---|---|---|
| Wave energy | 184[55] | 81[56] | 161% |

## Wave

Wave energy can meet more than Portugal's current electricity demand. This means that wave energy alone could make Portugal electricity independent. The technical wave energy potential represents more than three times[57] the country's joint electricity production from hydropower and gas[58] today.

Portugal has high wave energy potential along its entire Atlantic coastline, with the highest wave energy density found from Lisbon up to the Spanish border[59]. Key hotspots are found along the coast near Viana do Castelo, Porto, Lisbon, Aveiro, Peniche, and Figueira da Foz. The literature only covers the wave energy potential on the mainland, but Portugal's islands and archipelagos — namely the Azores and Madeira — are also expected to have significant wave energy potential.

## Market

The Swedish company CorPower Ocean invested €16M in the commercial port of Viana do Castelo in Northern Portugal to build the first wave energy manufacturing plant in the world in 2020. The company deployed its first commercial-scale wave energy converter, C4, at the Aguçadoura test site in 2023. CorPower is now developing two pre-commercial wave farms with a total capacity of 15 MW at the same site. This clearly demonstrates the attractiveness of the region for wave energy developers and proves that there are significant market opportunities for wave energy in Portugal.

Portugal has the potential to become a leading player in ocean energy. Apart from its incredible wave resource, the country has engineering skills from adjacent sectors, such as wind. It boasts manufacturing facilities, industrial infrastructure, including port and grid connections ready to use for the upscaling of the ocean energy sector.

With suitable policy and financial support to achieve its 200 MW target[60] of wave energy capacity by 2030, Portugal can become one of the first markets for wave energy in Europe and beyond.

Photo: CorPower Ocean

## Spain: One of the largest wave energy resources in Europe

Spain boasts the third-best wave energy potential in the EU and some of the best sites for wave deployment in Europe.

| Yearly potential (TWh/y) | Theoretical | Technical | Share of electricity demand[61 62] |
|---|---|---|---|
| Tidal stream | 60[63 64] | 5[65] | 2% |
| Wave energy | 289[66] | 71[67] | 31% |
| **TOTAL** | **349** | **76** | **33%** |

## Wave

Wave energy can meet a third of Spain's electricity. This is more than what natural gas or nuclear power currently generates[68] in the country.

Spain's wave energy resource is concentrated along the northern coast of the country facing the Atlantic between the Portuguese and French borders. The highest potential is found in the regions of Asturias, Galicia, Cantabria, and the País Vasco. This is because their large exposure to strong and consistent Atlantic swells makes them a prime location for wave energy capture.

Spain also has an important wave energy potential in its islands, particularly around the north of the Canary Islands, where the waves are formed by ocean winds from the Atlantic over long distances.

Spain is home to the world's longest-running wave power plant in Mutriku, operational since 2011. The country's testing infrastructures, BiMEP in the Basque Country and PLOCAN in the Canary Islands, attract developers from all over the world. Several wave energy projects are slated for installation in the coming years, positioning Spain as a primary hub for deploying ocean energy technologies in Europe.

Water depth makes it difficult to deploy bottom-fixed offshore wind on a large scale in Spain. Floating wave energy devices can cope with deep waters and provide a good alternative for Spain's decarbonisation ambitions.

## Tidal

Although smaller than wave energy, the tidal energy resource could help balance an increasing supply of variable renewables on the grid, as it produces power at different times than wind and solar.

Tidal resource assessment is limited to the southern mainland. Based on existing studies, Spain's tidal stream potential is focused on the south of the peninsula, in the region of Andalusia. Most of it lies near the Strait of Gibraltar, where Atlantic waters flow into the Mediterranean. However, exploiting this potential will require coordination with maritime stakeholders, as Gibraltar hosts one of the world's busiest shipping lanes.

Beyond wave energy, Spain is also a pioneer in tidal energy. Spanish tidal developer Magallanes Renovables has been awarded 13 MW of Contracts for Difference from the UK government to deploy tidal farms in Wales and Scotland. This will make Spain one of the first European countries whose developers are deploying farms across Europe.

## Market

With its long history in shipbuilding and leadership in wind energy, Spain has the industrial skills and infrastructure to drive ocean energy's industrialisation. Spanish ports on the Atlantic coast have the capacity to be the base for the assembly, operation, and maintenance of large-scale wave energy projects. With the right political support and market visibility, Spain can to become a major market for wave energy in Europe.

Photo: Wavepiston

## Norway: Hotspot for wave energy in Scandinavia

Norway has the greatest wave resource in the Nordic region. Wave energy can provide almost a fifth of the electricity demand in Norway. This is more than what wind energy produces today.

| Yearly potential (TWh/y) | Theoretical | Technical | Share of electricity demand[69,70] |
|---|---|---|---|
| Tidal stream | 17[71] | >1[72] | 0.7% |
| Wave energy | 600[73] | 21[74] | 16% |
| **TOTAL** | **617** | **22** | **17%** |

Norway benefits from a strong wave resource generated by winds traveling along the Atlantic Ocean, the North Sea, and the Norwegian Sea, forming large waves crashing against Norway's coastline.

Initial mapping[76] indicates that the highest wave energy potential is focused along Norway's southwestern coast. However, the existing literature lacks a detailed assessment of the most suitable sites for wave energy extraction across the country.

There are no recent studies quantifying the technical potential of wave energy in Norway. The available documentation is over 15 years old. The technology has matured since the last evaluation of Norway's technical potential. This suggests that future assessments of the technical potential are likely to be higher than initial estimates.

After hydropower, wave energy could be the next industrial success of Norway. The country already benefits from a strong maritime supply chain and offshore industries, skills, and infrastructures, that are easily transferable to ocean energy.

Photo: Seaturns

## Denmark: Mainland Waves and Faroe Islands as stepping stone for low-speed tidal

Denmark has significant wave energy potential, in addition to a strong tidal resource in the Faroe Islands.

| Yearly potential (TWh/y) | Theoretical | Technical | Share of electricity demand[77 78] |
|---|---|---|---|
| Tidal stream *(Faroe Islands)* | 5.9[79] | 1[80 81] | 230%[82] *(Faroe Islands)* |
| Wave energy | 30[83] | 13[84] | 36% |
| **TOTAL** | **36** | **14** | **36%** |

## Wave

Wave energy has the potential to meet over one-third of Denmark's electricity demand. This represents 70% of what wind is producing today and is more than what coal, natural gas, and biofuels are producing[85] together today.

Wave energy can be the ideal partner to wind on the grid in Denmark, as it produces power long after the wind dies down.

Denmark's wave energy resource is less powerful than in the Atlantic because its seas are shallow and partly enclosed, so large waves have less space to build up. However, the Danish mild wave climate offers the opportunity to develop technologies designed for more sheltered areas or to test technologies developed for harsher wave conditions in the relative safety of smaller waves.

As most of the wind in Denmark is coming from the west, the highest wave energy density is found on the west coast of Denmark, in the Danish North Sea, in particular on the west coast of Jutland. This means that the wave energy resource is ideally located to complement wind power ambitions in the North Sea. Co-locating wave energy with offshore wind would generate strong synergies, smoothing power output, optimising sea-space use, and reducing shared infrastructure costs for both technologies.

## Market

Danish wave developers are progressing fast with several prototypes undergoing testing in real sea conditions and full-scale devices being demonstrated in EU waters. The country has its own wave energy test centre DanWec, suited for prototype testing, located in Hanstholm on the North Sea Coast. With the right political support, Denmark has all the means to replicate the success of offshore wind and become a central player in the global ocean energy market.

## Tidal in the Faroe Islands

No study has assessed the tidal energy potential of mainland Denmark to date. Available data focus solely on the Faroe Islands.

Tidal energy has the potential to meet several times the electricity demand of the Faroe Islands. The resource estimate above includes low-speed currents, as those are abundant around the Faroes. It is seen as conservative by technology experts, estimating the potential to be at least 1 GW, equivalent to 3.5 TWh/y.

Based on current literature, at least 13 sites are suitable for tidal energy production around the Faroe Islands.

This archipelago, located 320 kilometres northwest of Scotland, is the only land-based barrier across the Atlantic between Iceland and the UK. The straits created by the 18 islands accelerate tidal flows and present the perfect conditions for the development of tidal technology.

Additionally, despite the comparatively small size of the archipelago, peak tides in the North of the Islands happen at different times from peak tides in the South. This can greatly help balance supply and demand on the isolated grid, making the technology very appealing.

## Market

Although the market is small, the Faroe Islands could work as a stepping-stone for other island nations. Strong climate-neutrality ambitions mean that a wind-solar-tidal triumvirate could provide for the entire island. Faroese utility SEV completed a study[86] showing that adding tidal would significantly reduce total system and kWh costs on the islands while ensuring more consistent production.

Swedish company Minesto deployed a farm of three Dragon Class tidal kites at the Vestmannasund site, supported by a direct PPA from SEV. The first Dragon kite device has been supplying electricity to the grid since 2021, proving the commercial case for tidal stream in the island. Minesto aims to deploy multiple tidal farms across the islands, and supply 200 MW of predictable power to help the government achieve 100% renewable electricity by 2030.

Photo: Minesto

## Italy: Mild wave climate suited to build an export industry

No study has yet quantified Italy's wave and tidal energy potential. However, the country is included in this report because initial site assessments confirm that there is a resource to test and deploy both technologies commercially in Italian waters.

### Wave

Italy is surrounded by seas from all sides and is well connected to the Mediterranean in the South. The country's mild wave climate offers good conditions for the safe testing and development of wave energy technologies, ultimately destined for harsher wave regimes. Decarbonisation of offshore oil & gas assets is also a market being explored commercially in the last few years.

The biggest wave energy resource in Italy and of the Mediterranean, is located in the Sicily Channel[87] and on the western coast of Sardinia. This is due to the acceleration of the waves coming across smaller water channels between Sardinia and Tunisia.

Eni has deployed the new generation of its wave energy converter, the ISWEC in early 2023 off the coast of Pantelleria, proving the commercial case for offshore oil & gas decarbonisation. This installation is a first step toward the decarbonisation of the island.

### Tidal

The country's tidal resource is concentrated in the Messina Strait, between Sicily and the continent where tidal currents can reach up to 2m/s in this area[88].

### Market

Italy is an increasingly relevant development hub for ocean energy. The country's two main energy companies Eni and Enel, have been involved in ocean energy in the past and worked alongside universities and device manufacturers to develop the technology.

Italy can leverage its technological expertise, local value chain, and R&D infrastructure to build an export industry and benefit from the industrialisation of the sector in Europe. Several small-scale wave energy devices have already been tested in the Adriatic Sea and the Mediterranean Sea. With increased market visibility and funding, Italy can become a future market for ocean energy in Europe.

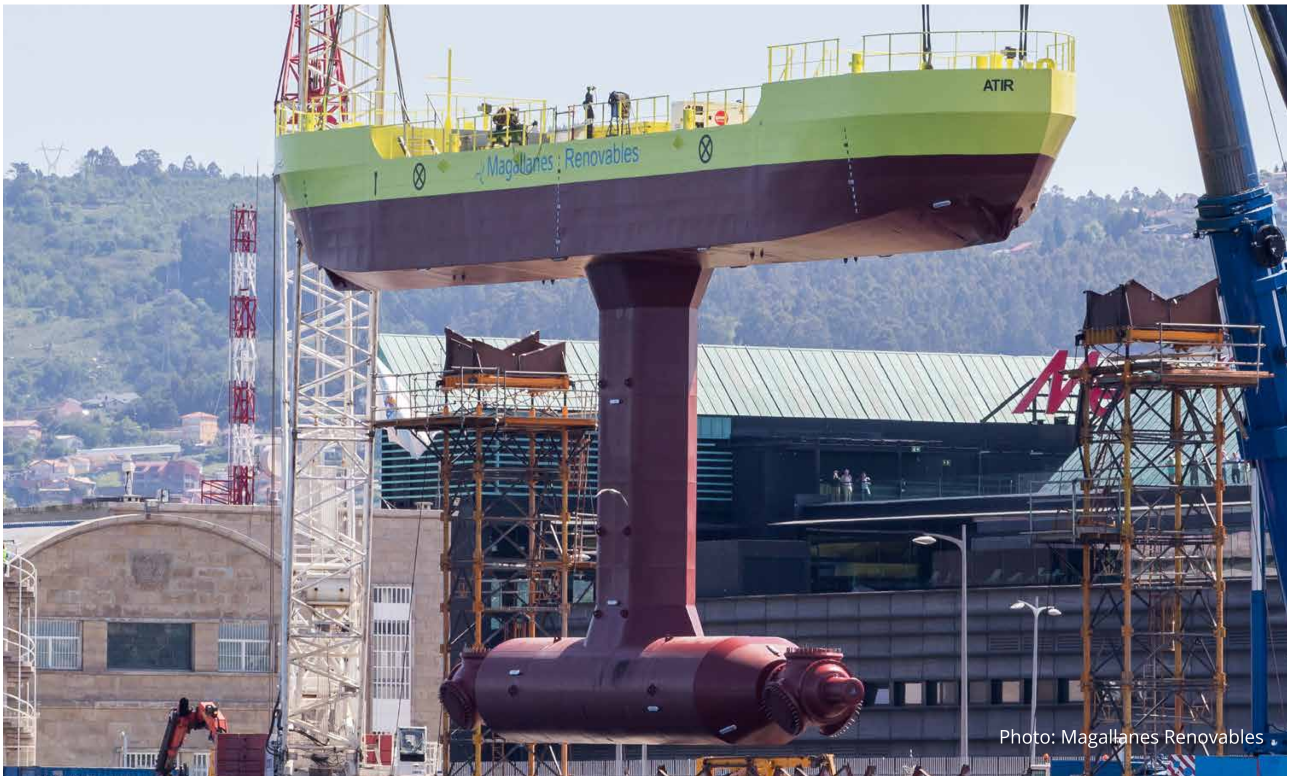



Photo: Magallanes Renovables

## The Netherlands: Co-location potential for wave and wind, good testing conditions for tidal

| Yearly potential (TWh/y) | Technical | Share of electricity demand[89 90] |
|---|---|---|
| Tidal stream | 0.25[91] | 0.3% |
| Wave energy | 2.6[92] | 2.4% |
| **TOTAL** | **2.8** | **3%** |

### Wave

Wave energy is the ideal partner for offshore wind ambitions in the Netherlands, given the need to maximise the use of the limited sea space in the country. Wave energy generates electricity at different times than wind and can therefore enable a more consistent supply of renewable electricity.

The North Sea waves are less energetic than the Atlantic coastline's waves, given the relatively sheltered coastline of the Netherlands. However, wave energy power increases toward the north, driven by stronger winds, and reaches a peak in the middle of the North Sea.

The wave energy potential is estimated to be at least 2.6 TWh/y when co-located with wind farms. The current estimate on the technical potential of wave energy assumes that only one line of wave energy devices will be deployed offshore, given the mild wave climate. However, this potential could be raised to 5.3 TWh/y[93] if a second line were deployed further from the shore. The industry estimates that at least 1.5 GW of wave energy can be deployed in Dutch waters — which would provide 3.9 TWh/y of clean electricity to the country.

### Tidal

The potential for tidal stream in the Netherlands is located around the storm surge barriers and dams. The country is home to some of the world's longest storm surge barriers, designed to protect the Netherlands from flooding. Such infrastructure offers a good location for installing tidal stream devices as they present "natural" gaps in the barrier, which see water flowing in both directions between the North Sea and the other side of the barrier.

The most suitable locations for tidal stream technologies are the Oosterscheldekering, the drainage shafts of the Afsluitdijk, the Westerschelde, and the Waddenzee.

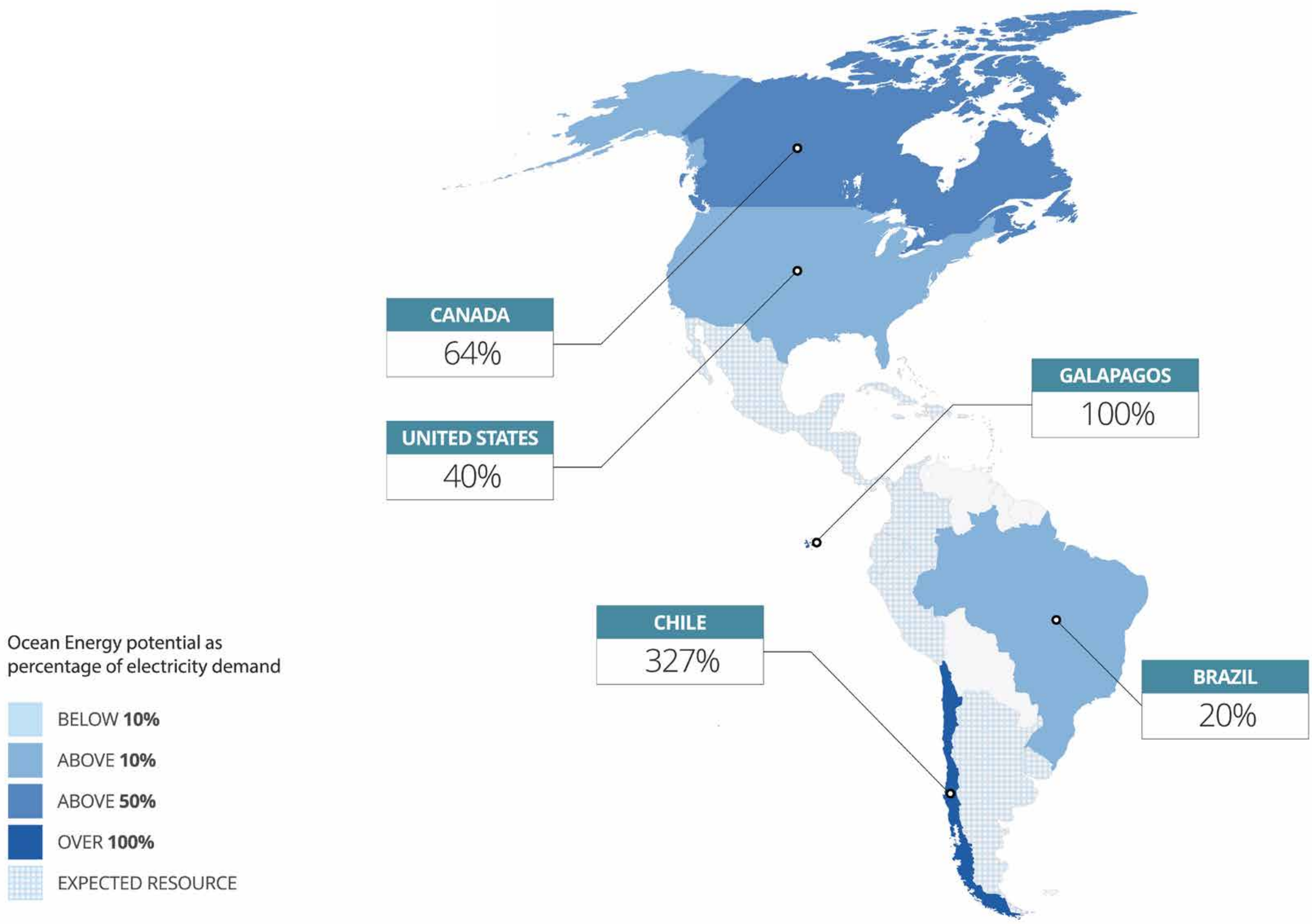
The Oosterschelde storm surge barrier in Eastern Scheldt, in the Southwest of the Netherlands, has been equipped with Tocardo's tidal pilot farm for 8 years. It was among the first tidal farms deployed in the world. This clearly demonstrates the commercial case for the development of tidal energy in offshore infrastructures in the Netherlands.

A recent study[94] funded by the Waddenfonds in the Wadden Islands reveals a new exploitable resource of 60-181 MW of wave energy and 49 MW of tidal energy, using low-flow speed technology. SeaQurrent installed its first low-speed current prototype around the island in 2024.

The offshore supply chain, skills, and port infrastructures developed with the growth of the offshore wind and oil & gas sectors are easily transferable to the ocean energy sector. With increased political support, the Netherlands could leverage its pioneering position to become a key market for ocean energy in Europe.

Photo: Tocardo

# 03 The Americas: Ocean energy can supply 36% of electricity demand




Ocean energy has the potential to meet more than a third of the total electricity demand in the Americas. This is based only on data from surveyed countries in North and South America, where studies are available. Adding the resources of countries in South and Central America that have not yet investigated their ocean energy potential will only further increase the ocean energy potential on the continent.

Available data suggest that the United States (US) has the greatest ocean energy potential in the Americas. This is, of course, due to the country's large size and extensive coastline, but could be challenged by new studies looking at the potential of South American countries.

| Yearly potential (TWh/y) | Theoretical | Technical | Share of electricity demand[95 96] |
|---|---|---|---|
| Tidal stream | 592[97] | 303[98] | 4.4% |
| Wave energy | 4,212[99] | 2,176[100] | 32% |
| **TOTAL** | **4,804** | **2,479** | **36%** |

## Wave

The Americas have the highest wave energy potential of all continents surveyed in this report. Wave energy is the most abundant ocean energy resource on the continent. It has the potential to provide more than a third of the electricity consumption in the United States and between half and 100% of the electricity demand in other countries surveyed.

Key hotspots for wave energy deployment in the Americas include Alaska and Hawaii in the United States; Nova Scotia and Labrador in Canada; the Brazilian states of Bahia and Rio de Janeiro; and much of Chile's coastline.

The continent is surrounded by the world's two largest oceans on the planet, the Pacific Ocean on the West Coast, and the Atlantic Ocean on the East Coast. The potential of wave energy is significant on both shores of the Americas. The Pacific Ocean offers considerable space for winds to form powerful waves that end up crashing all along America's coastline.

On the East side, the Atlantic Ocean provides a wave energy potential spread all over the coastline with stronger potential focused in the North, where bigger waves are formed, particularly in the US and Canadian coasts.

Most of the existing literature covers North America because there is currently little to no data available for Central and South America. However, given their great exposure to the Pacific Ocean, countries such as Colombia, Peru, and Mexico are set to become significant wave energy markets once their potential is documented.

## Tidal

Tidal stream also has an important potential in the Americas, albeit slightly overshadowed by the size of the wave resource, explaining why it has seen less focus so far.

The spots with the highest tidal stream potential in the Americas are found in Canada and in the US. This is because large volumes of seawater are funnelled through narrow channels and bays in the continent's north. In Canada, the best sites include the Bay of Fundy in Nova Scotia, the Hudson Bay, and the coast of Labrador province, in the north of the country. In the US, the Gulf of Alaska holds the most significant tidal resource.

Several European companies, like Nova Innovation or Orbital Marine Power are already developing projects in the US and Canada to harness the tremendous power of tidal streams on the continent.

More studies are required to assess the potential of tidal energy along the entire coastline of the Americas. Although less important than in North America, South America is likely to have at least some tidal stream resource, given the narrow channels created by the archipelagos and spread along the southern coastline.

## Market

North America is becoming a very significant ocean energy market. Both Canada and the United States have acknowledged the potential of ocean energy and recently started to encourage the emergence of a homegrown sector. The US government invested $983M[101] in ocean energy since 2020 to support deployments and infrastructure development. The industry is moving forward with American companies such as CalWave, ORPC, Verdant Power, Panthalassa and OPT developing and testing their own technology on the continent.

South America is currently focusing on delivering fast and cheap electricity to its populations, focusing on wind and solar tenders. Many South American markets are still in the early stages of development and have limited financial resources. As a result, it is difficult for them to assemble the support packages needed to attract investment in local ocean energy manufacturing. Yet with strong deployments of variable wind and solar, some are already looking to predictable new technologies to balance grids. Enel Green Power Chile already deployed a full-scale wave energy converter in Chilean waters in 2021. This demonstrates clear market opportunities for wave energy in South America.

## United States: Wave energy can provide more than a third of US power needs

Wave and tidal technical resources in the 50 US states can supply 1,620 TWh/year[102]. This is equivalent to 40% of the electricity generated by those states[103]. This is more than what nuclear and coal are generating today[104] in the country.

| Yearly potential (TWh/y) | Theoretical | Technical | Share of electricity demand[105 106] |
|---|---|---|---|
| Tidal stream | 445[107] | 220[108] | 5% |
| Wave energy | 2,640[109] | 1,400[110] | 35% |
| **TOTAL** | **3,085** | **1,620** | **40%** |

## Wave

The United States has the largest wave energy resource in the world, according to existing literature. Wave energy alone has the potential to supply up to one-third of the United States' electricity demand[111].

Most of the wave resource is distributed between Alaska, the West Coast, and Hawaii. And, more than half of it, is focused on Alaska. The curvature of the Gulf of Alaska creates an acceleration corridor for strong currents and large waves coming from the Pacific Ocean that end their journey on the coastline.

Outside of Alaska and Hawaii, the largest part of the US wave resource is found on the West Coast, which has five times more potential than the East Coast. Ocean waves are formed over very long distances in the Pacific and accumulate a high load of energy before crashing onto the first land masses on their way, the US coastlines.

Wave energy can play an important role in decarbonising Pacific states with significant resources, such as California, Washington, and Oregon. The State of California alone gathers more than half of the wave energy resource of the West Coast, with a potential of 140 TWh/y. This represents more than 60% of the State's electricity demand[112] in 2023.

Wave energy could also make a significant contribution to the decarbonisation of the Hawaiian archipelago, accounting for 17% (250 TWh/y) of the US' wave energy technical potential.

## Tidal

Albeit being smaller than the wave energy potential, the tidal potential is very important in the US. 90% of the tidal stream resource is focused on the Gulf of the State of Alaska, with more than half of this resource concentrated in the two top sites of Cook Inlet and Chatham Straight. This is because Cook Inlet's coastline tapers inward through a pinch created by the East and West Forelands, where the flow of water accelerates and delivers a high load of tidal stream energy.

The rest of the tidal energy potential is spread along the East Coast and the North of the West Coast. The best location on the West Coast is Puget Sound in the State of Washington. On the East Coast, the spot with the highest potential is found in the Western Passage in the State of Maine.

## Market

There is a growing momentum for ocean energy in the US, with important financial support being delivered at the federal level and the introduction of dedicated bills to boost the development of ocean energy in several US states, e.g., in New Jersey and California.

The US Department of Energy (DOE) increased its annual budget for ocean energy for the fifth consecutive year in 2024, bringing total investments over the last 7 years to $983M[113]. The government also funded the construction of the world's biggest wave energy test centre in Oregon (PacWave). The facility, expected to open by 2026, will be able to accommodate 20 wave energy converters to help American developers progress through the phases of R&D and demonstration.

Companies like CalWave, ORPC, Verdant Power, Panthalassa, and Eco Wave Power are already testing full-scale devices in US waters to harness tremendous domestic market opportunities. With ongoing policy support and political appetite both at the federal and state levels, the US could quickly catch up with Europe and become the new global leader in ocean energy.

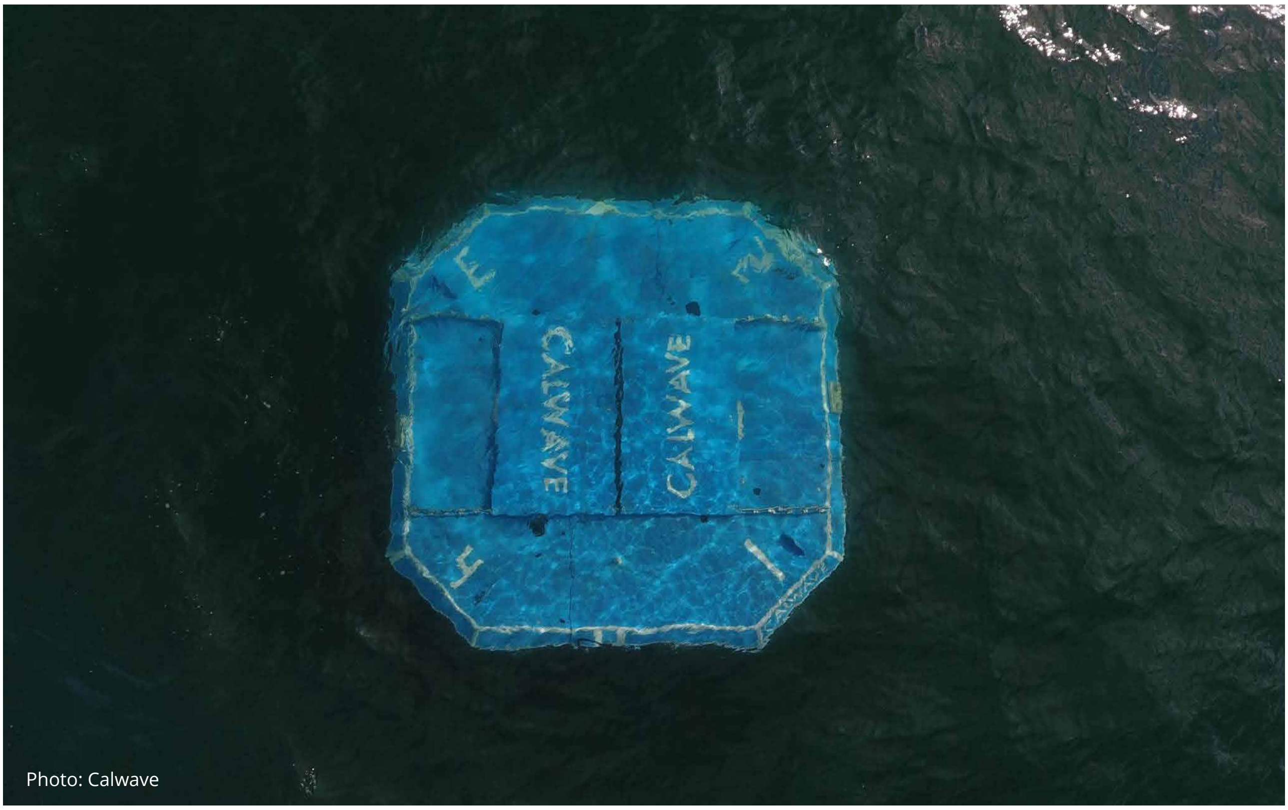


Photo: Calwave

## Canada: Strongest tidal current in the world

Ocean energy has the potential to supply over half of Canada's electricity demand. This is equivalent to what hydropower, the dominant supplier, is providing today. It's nearly twice what nuclear, natural gas, and coal combined produce today[120].

| Yearly potential (TWh/y) | Theoretical | Technical | Share of electricity demand[114 115] |
|---|---|---|---|
| Tidal stream | 147[116] | 73[117] | 13% |
| Wave energy | 546[118] | 290[119] | 51% |
| **TOTAL** | **693** | **363** | **64%** |

## Tidal

Canada boasts some of the best tidal sites in the world. The country is widely regarded by the industry as the prime location for tidal deployments, due to very high current speeds. The hot spots for tidal energy are located in the North of the country (Hudson and Labrador) and on the Eastern coast in the Bay of Fundy (between Nova Scotia and New Brunswick). The British Columbia coastline is also relevant for tidal energy extraction, with many small to medium-sized hot spots identified.

The Bay of Fundy is Canada's most energy-intensive site for tidal stream, with flows reaching 5m/s. According to Nova Scotia's government: "the Bay (....) flows 160 billion tonnes of water in and out of its passage twice a day. That amount of force is more than the combined flow of all the rivers in the world"[121].

The Minas Passage, located in the eastern part of the Bay of Fundy, is considered the world's best site for tidal energy extraction[122]. The passage works like a natural funnel between the Bay and the Minas Basin, pushing water through a narrow space and making the tidal currents faster.

## Wave

Canada's wave energy resource has the potential to supply half of the country's electricity needs. With a 71,000 km coastline bordering two oceans, Canada has access to one of the world's largest wave energy resources.

The greatest part of the wave energy potential in Canada is found on the Atlantic coast. The best sites to harness the power of wave energy on the Atlantic coast are focused on Nova Scotia and Labrador.

The wave energy potential on the Pacific Coast is also significant. This is because large waves are formed in the Pacific Ocean and crash at high intensity onto the west coast of British Columbia at the end of their journey. Dozens of sites with high potential are identified by the Canadian government between the Vancouver Islands and the Queen Charlotte Islands[123].

## Market

Canada has all the means to become one of the major ocean energy markets going forward. The combination of abundant raw wave and tidal resources provides Canada with a natural advantage to establish itself as a global leader in ocean energy.

Several Canadian provinces have already identified ocean energy as a key resource to decarbonise their energy systems and are now supporting the development of the sector. The government of Nova Scotia has put in place policies and funding programmes to boost the development of ocean energy. This includes revenue support for tidal stream demonstration projects in the Bay of Fundy. Furthermore, the Canadian government supported the development of a dedicated facility for tidal stream technology demonstration — the Fundy Ocean Research Centre for Energy (FORCE). The centre located in the Minas Passage, provides common offshore and onshore infrastructure, environmental monitoring, and four berths connected to Nova Scotia's power grid to attract tidal developers from around the world.

Photo: ORPC

## Chile: Huge wave energy potential waiting to be tapped

Wave energy has the potential to meet more than three times the electricity demand in Chile. This is 12 times more electricity than coal and natural gas combined supply to the grid[129] currently.

| Yearly potential (TWh/y) | Theoretical | Technical | Share of electricity demand[124 125] |
|---|---|---|---|
| Tidal stream | | 10.5[126] | 13% |
| Wave energy | 491[127] | 260[128] | 314% |
| **TOTAL** | **491** | **370** | **327%** |

### Wave

Chile has one of the greatest known wave energy technical potentials in the Americas. It is the renewable energy with the largest potential for energy extraction in the country[130].

Chile's vast wave energy potential stems from its 6,000 km coastline, consistently exposed to powerful Pacific swells. With most of the country's energy demand concentrated near the coast, wave energy offers a perfect solution to deliver renewable power directly to key demand centres.

Chile boasts a significant wave energy potential all along its coastlines, with many sites suited for deployment from Puerto Ventanas, in the North, to Puerto Montt, in the South[131 132].

### Tidal

Albeit considerably smaller than its tremendous wave resource, Chile also has a tidal resource. The sites with the highest potential to harness tidal energy are located in the south of the country, in the Chacao channels, which connect the Pacific Ocean to the Gulf of Ancud, and in the Magellan Strait. The tidal peak flows are estimated to be between 3.5 and 5 m/s[133], making both regions suitable for tidal stream deployments.

### Market

The Ministry of Energy has partnered with European industrials (Naval Energies and Enel Green Power) to create the Marine Energy Research and Innovation Centre (MERIC). The objective of the centre is to boost the development of ocean energy in Chile and turn the country into a global player. This collaboration has already borne fruit with the deployment of a wave energy converter (WEC) in the Chilean waters, despite the technology being at an early stage.

This success demonstrates market opportunities for wave energy in the country. More is set to follow as the technology goes down the cost curve.

## Brazil: Significant wave potential to complement hydropower

| Yearly potential (TWh/y) | Theoretical | Technical | Share of electricity demand[134 135] |
|---|---|---|---|
| Wave energy | 273[136] | 145[137] | 20% |

### Wave

Wave energy can supply 20% of Brazil's electricity demand. This is more than what biofuels, natural gas, and nuclear power are currently generating[138] together in the country.

Brazil has an extensive coastline of over 7,000 km exposed to strong currents and waves coming from the Atlantic Ocean. With nearly 80% of Brazil's population living near the coast, wave energy offers a strong opportunity to produce renewable power close to demand centres and reduce the need for long-distance transmission.

The regions with the highest wave energy potential are located between the State of Rio and the State of Bahia, offering powerful waves throughout the year. This is mainly due to the "preponderance of south winds combined with the orientation of the shoreline that induces strong swells near the coast"[139].

### Market

Wave energy can provide a sustainable solution to diversify the renewable generation mix and ideally complement hydropower and wind on the grid. Adding wave energy to the grid would help shield the country from power shortages during droughts, as it heavily depends on hydropower, which represents more than 60% of generation. Wave energy is also an ideal complement to growing variable solar and wind energy on the grid, as it can produce power when the sun is not shining and the wind is not blowing.

## Ecuador (Galapagos Islands): An opportunity to reduce dependence on costly diesel generation

| Yearly potential (TWh/y) | Theoretical | Technical | Share of electricity demand[140 141] |
|---|---|---|---|
| Wave energy | 262[142] | 81[143] | >100% |

### Wave

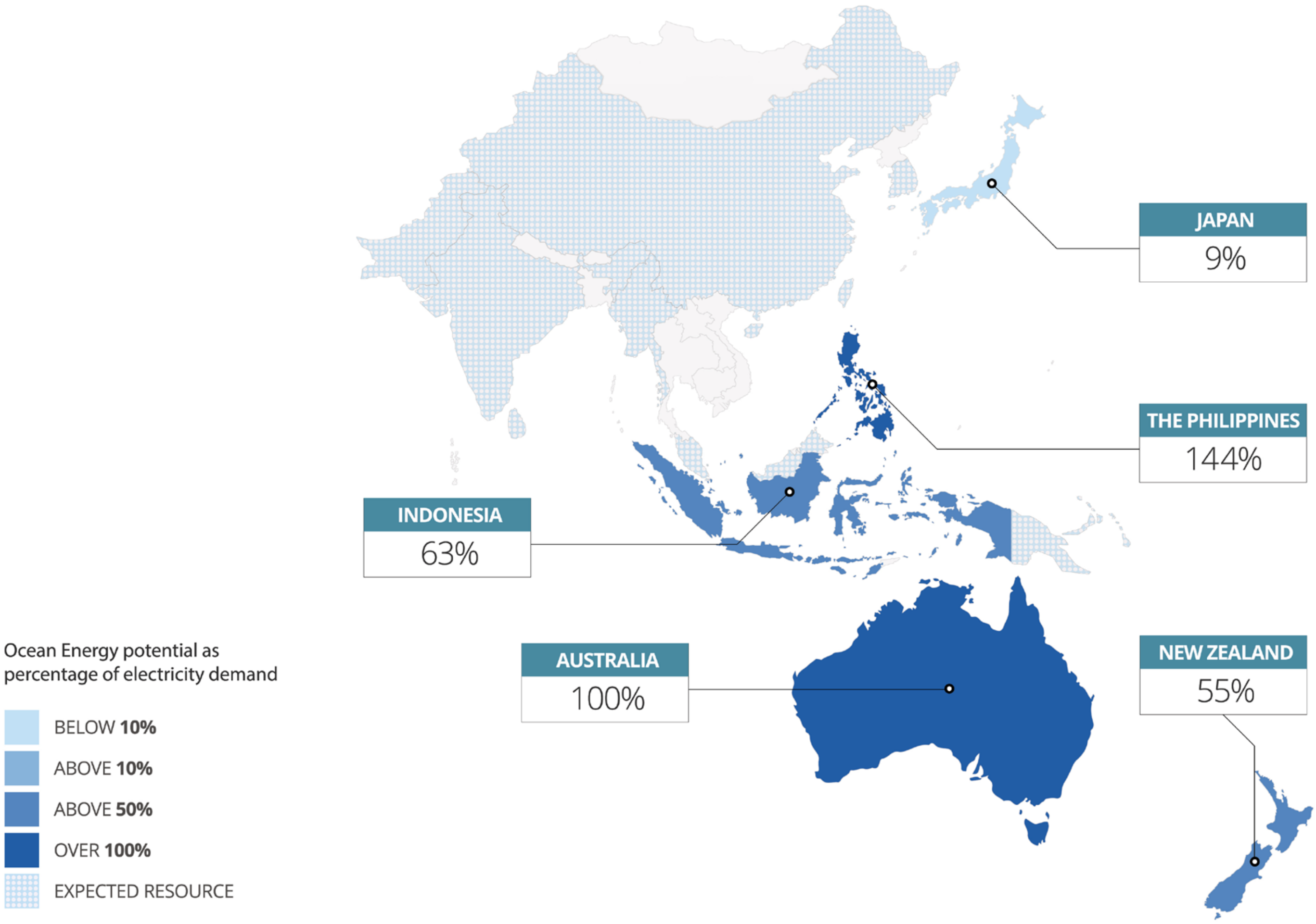
Wave energy has the potential to fully supply the electricity demand of the Galápagos Islands. This report focuses on the Galápagos Islands due to the lack of available data on wave energy potential along mainland Ecuador's coast.

The electricity demand in the Galápagos Islands is relatively small compared to its enormous wave energy potential. One wave energy farm would be sufficient to supply all the Galápagos' electricity needs year-round.

The Galapagos has a significant wave energy potential due to its exposure to the Pacific Ocean. The region is exposed to powerful southeast winds on the western and southern coasts, leading to the generation of consistent swells when blowing at the surface of the ocean.

The archipelago is currently relying heavily on imported fossil fuels to meet its electricity needs. Wave energy presents a more affordable alternative to the costly imported diesel or fuels used for generation. In addition to providing substantial savings for the local government, wave energy could significantly contribute to achieving the Galápagos government's goal of achieving carbon neutrality by 2040.

# 04 Asia & Oceania: Abundant wave and tidal resources




Asia and Oceania both possess abundant wave and tidal energy resources. Existing literature seems to indicate that the tidal potential is higher than the wave potential. However, given the size and geography of the region – large ocean areas and strong wave climates – this seems unlikely. It is probably due to the greater number of studies available to quantify the tidal potential, given that it is the most advanced technology. This might well change in the future as wave technology progresses, and more countries identify the potential to develop their wave resource.

| Yearly potential (TWh/y) | Theoretical | Technical |
|---|---|---|
| Tidal stream | 2,010[144] | 460[145] |
| Wave energy | 3,968[146] | 399[147] |
| **TOTAL** | **5,978** | **859** |

## Tidal

Asia is the continent with the highest tidal technical potential among the studied continents. The scattered land masses and thousands of islands between the Indian Ocean and the North Pacific Ocean offer narrow channels that accelerate water flow, creating favourable conditions for harnessing tidal stream energy.

Asia's tidal potential is highest in Indonesia and the Philippines, both of which possess some of the largest tidal resources globally. The industry widely regards both countries as the best spots for tidal deployment in Asia. According to current literature, Indonesia and the Philippines together make up 90% of the surveyed tidal potential in Asia and Oceania. However, countries like Japan and India also hold significant potential for large-scale tidal energy deployment, as shown by Japan's recent deployments (2 Proteus turbines) and future projects. South Korea is also expected to have a strong tidal resource, but no robust studies have yet quantified it.

## Wave

Asia and Oceania both have a vast wave energy resource. Both continents are bordered by two major oceans: the Pacific and the Indian Ocean, while Oceania also enjoys substantial exposure to the Southern Ocean. As a result, they are exposed to powerful and persistent wind patterns. This leads to the formation of consistent waves that travel long distances without interruption by landmasses, before crashing onto both continents' coastlines.

A large share of the wave energy potential across Asia and Oceania is in Australia, thanks to its ideal geographical conditions. The country possesses the world's largest theoretical wave energy potential, representing two-thirds of the total among countries surveyed in Asia and Oceania. However, this report assumes that only a portion of this vast theoretical potential can be technically harnessed,[148] given Australia's comparatively small population and limited interconnections.

Beyond Australia, several other countries, including Japan, China, Indonesia, India, and New Zealand also have substantial wave energy potential. Key hotspots are the East China Sea, Japan's northern and Pacific coasts, and the west- and south-facing shores of New Zealand.

Based on existing literature, eight countries already show important ocean energy potential in Asia and Oceania. Several other coastal countries are missing from this report because they have yet to investigate their potential.

## Market

Ocean energy is gaining momentum in Asia, with new projects launching each year. European developers started partnering with local authorities, leading to export projects in Japan, Indonesia, and the Philippines. In China, years of substantial government funding have accelerated the deployment of ocean energy. Asia's abundant resources, combined with rapid technological progress, mean that the continent could become a major market for ocean energy going forward.

## China: Fertile waters for both wave and tidal stream

There is a lack of studies mapping the ocean energy resource across the whole of China. The existing literature is either too old or targeted at specific sites in the country. Additional studies are needed to understand precisely the overall potential of both wave and tidal energy in China. Given technological improvements in extracting the resource, future studies are likely to reveal a greater potential than initial estimates.

China's ocean energy resource is expected to be substantial, given the size of its coastline and the many islands and archipelagos scattered across its waters. The country's government has, in fact taken a keen interest in the technologies and funded many prototypes aimed at extracting both resources. The hotspots are already well-known by industry players who are targeting them for development.

| Yearly potential (TWh/y) | Theoretical | Technical | Share of electricity demand[149 150] |
|---|---|---|---|
| Tidal stream | 122[151] | 28[152] | 0.3% |
| Wave energy | 114[153] | 12[154] | 0.12% |
| **TOTAL** | **236** | **40** | **0.4%** |

### Tidal

Most of China's tidal stream resource is found in the East China Sea, the Yellow Sea, and the South China Sea. Liaoning province, Shandong province, Zhejiang province, and Fujian province are all rich in tidal stream energy resources. More than half of China's surveyed tidal stream potential is located in Zhejiang Province, around the Zhoushan Archipelago. The Archipelago contains many narrow passages between islands, forcing the water through tight spaces and accelerating current speeds.

China is home to a small tidal pilot array comprised of at least two devices, with an operational capacity of 2.5 MW at the time of writing. Supported by the Chinese government[155] through a combination of grant and revenue support, the LHD demonstration project, deployed in 2018, is China's flagship tidal stream project. Continuous support in this project over the last decade demonstrates the government's ambition to scale up quickly this new industry at home. Future expansions are already considered.

### Wave

Most of China's wave energy potential lies in the East China Sea, with half concentrated in the provinces of Shandong, Zhejiang, Fujian, and Guangdong. This is due to steady Pacific winds along the southeast coast, which generate long, powerful waves across large distances.

A partnership between the Guangzhou Institute for Energy Conversion (GIEC) and China Merchants Heavy Industry Company has led to the deployment of two 500 kW wave energy converters in Wanshan, Guangdong province. This shows the interest of the government and the industry in scaling up wave energy in the country.

### Market

As of 2015, the Chinese government partnered with the UK's test centre, EMEC, to establish China's first wave and tidal energy testing facilities. Since then, several full-scale wave and tidal energy devices have been deployed in Chinese waters. This demonstrates sustained commitment from both developers and public authorities to rapidly advance ocean energy at home.

Ocean energy could be China's next industrial success in renewables, after onshore wind, solar, and now offshore wind. The country is positioning itself as one of the key players in ocean energy, thanks to continuous political and financial support to scale up ocean energy. The Chinese government targeted the "large-scale development of ocean energy" as part of its 14th 5-year plan. To achieve this and take ocean energy to the next level, the plan provides for the deployment of fleets of wave and tidal pilot farms.

## Indonesia: The best tidal resource in Asia

Indonesia has the best tidal technical potential in Asia and Oceania. It is widely considered by the industry to be the number one location in the region when it comes to tidal potential.

| Yearly potential (TWh/y) | Theoretical | Technical | Share of electricity demand[156 157] |
|---|---|---|---|
| Tidal stream | 1,008[158] | 252[159] | 58% |
| Wave energy | 421[160] | 21[161] | 5% |
| **TOTAL** | **1,429** | **273** | **63%** |

## Tidal

Tidal energy has the potential to supply over half of Indonesia's electricity demand. This is equivalent to more than 80% of the country's current coal-fired generation[162].

Geographically located between the Indian Ocean and the Pacific Ocean, the country forms a natural barrier between Australia and the Indochina peninsula. Waters trying to flow from one ocean into the other must go through narrow pathways between Indonesia's 17,500 islands — the world's largest archipelago. Those create many bottlenecks for water flows to accelerate, thus providing ideal conditions to harness tidal power.

Existing surveys show that 70% of Indonesia's tidal energy potential is concentrated in two regions: the Riau Islands in the northwest and West Nusa Tenggara in the southeast[163]. Several other sites also exhibit an important tidal potential, including West Java, West Papua, East Nusa, and Bali.

European developers such as Nova Innovation, HydroWing, and Proteus Marine Renewables have already teamed up with local authorities and industries to carry out feasibility studies to deliver multi-MW projects. HydroWing recently signed a partnership with the state-owned national power company, Perusahaan Listrik Negara's (PNL), to develop a 10 MW tidal farm in East Nusa Tenggara.

## Wave

Fewer studies are available to properly determine hot spots for wave energy deployment across Indonesia. So far, only the Eastern and Western Nusa Tenggara provinces are identified as having an exploitable wave energy potential. Data for other provinces is unavailable.

However, Indonesia is expected to harbour several other locations suited for wave energy. The country is gifted with more than 50,000 km of coastline exposed to strong swells coming from the Indian Ocean and the Philippine Sea.

## Market

The growing interest of several European developers in the region demonstrates important market opportunities for tidal energy in the country.

Indonesia could benefit from the fast development of the sector in Europe to grow an ocean energy market at home and boost the decarbonisation of its economy.

Photo: Nova Innovation

## The Philippines: Tidal stream can meet all electricity demand

The Philippines has the second-highest tidal energy technical potential in Asia and Oceania. It's regarded by the industry as one of the top locations for tidal deployment globally. Just like Indonesia, the archipelagic nature of the Philippines and its geographical location between the Indian Ocean/South China Sea and the West Philippine Sea make it ideal for developing tidal stream.

| Yearly potential (TWh/y) | Theoretical | Technical | Share of electricity demand[164 165] |
|---|---|---|---|
| Tidal stream | 700[166] | 160[167] | 144% |

### Tidal

Tidal stream has the potential to supply much more than the current electricity demand in the Philippines. This is about twice the amount currently produced by coal and gas[168], which still supply 80% of the country's electricity.

Most of the tidal energy potential is focused in the Visayas Archipelago. Several other sites with tidal energy potential have been identified by the Philippine Department of Energy, namely, Bohol Strait, Basiao Channel, Surigao Strait, Gaboc Channel, Hinatuan Passage, San Bernardino Strait, Basilan Strait, and San Juanico Strait.

UK tidal developer HydroWing has been awarded a contract by the San Bernardino Ocean Power Corporation to build the first tidal power plant in the country on the Island of Capul. This demonstrates the commercial case for tidal in the Philippines and could be a stepping stone for larger deployments.

### Wave

To date, much less work has been done on developing wave energy, therefore, there is no information available on the potential of wave energy in the Philippines.

### Market

Ocean energy can help remote Philippine islands, isolated from the national grid, achieve significant savings by replacing expensive imported diesel fuel used to power their generators. Developing an ocean energy industry could also boost job creation and economic growth in coastal communities. As ocean energy progresses toward industrialisation, the Philippines has the potential to become a significant market for tidal energy in Asia.

## Japan: A significant resource for both wave and tidal energy

Ocean energy has the potential to meet circa 10% of the current electricity demand in Japan. Japan is rich in both tidal and wave energy, with wave being the dominant resource.

| Yearly potential (TWh/y) | Theoretical | Technical | Share of electricity demand[169 170] |
|---|---|---|---|
| Tidal stream | 77[171] | 6[172] | 0.6% |
| Wave energy | 580[173] | 87[174] | 8.6% |
| **TOTAL** | **657** | **93** | **9%** |

### Wave

Wave energy alone has the potential to supply 9% of Japan's electricity production[175]. The bulk of Japan's wave energy resource is located along the Northern part of its Pacific coast, along the shores of Honshu and Hokkaido, and around Okinawa. This is due to their exposure to persistent winds traveling long distances across the Pacific, which generate high-energy wave conditions along Japan's northeastern coastline.

### Tidal

Although smaller than its wave energy potential, Japan also benefits from a tidal energy resource. According to Japan's agency, the New Energy and Industrial Technology Development Organisation (NEDO), Japan's tidal potential is concentrated in the southern part of the country. This is largely due to a powerful, wind-driven ocean current flowing southward, combined with Japan's complex coastal topography, where narrow straits and channels further accelerate water flow.

European tidal developer Proteus Marine Renewables partnered with local player Kyuden Mirai Energy and has already completed two deployments in Japanese waters. A 500 kW turbine was installed in the Naru Strait (Goto Islands) in 2021, followed recently by a larger 1.1 MW unit at the same site. This demonstrates the commercial case for tidal stream in Japan.

### Market

Beyond Japan's significant ocean energy resource, its competitive shipyards and ports offer good development perspectives for the ocean energy sector. Following the Fukushima incident, ocean energy can offer a significant contribution to Japan's pledge to diversify its energy mix.

The country's limited land space, coupled with its rapidly descending continental shelf, presents major obstacles to the deployment of both wind and solar PV technologies. However, this is an opportunity for tidal and wave technologies, which can free up space on land by being deployed offshore.

With the right policy support, ongoing collaboration between European tidal developers and Japanese firms could rapidly accelerate the development of the ocean energy market in Japan.

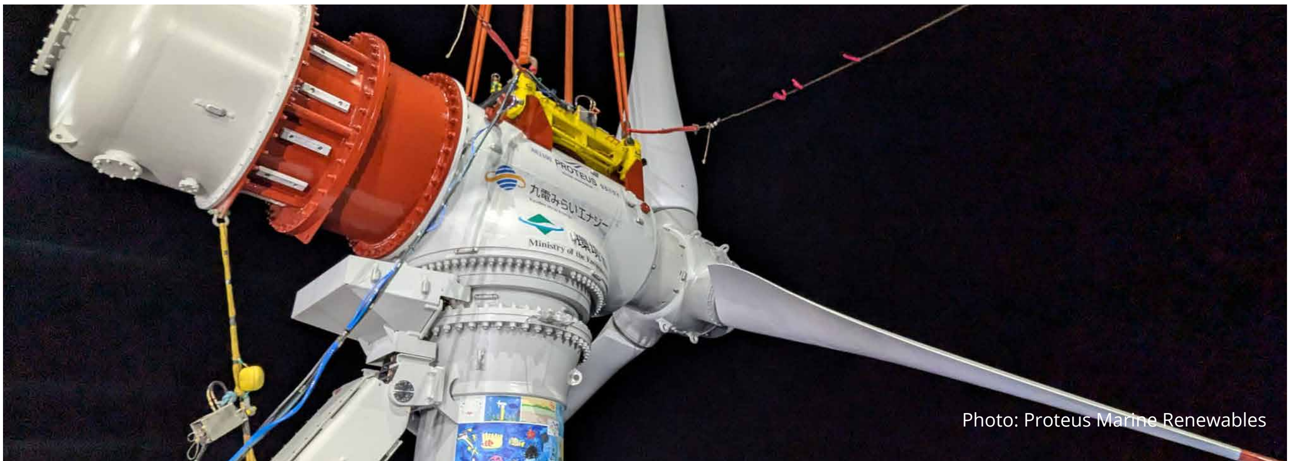


Photo: Proteus Marine Renewables

## South Korea: An important tidal potential yet to be quantified

There is a lack of literature on the theoretical and technical potential of tidal energy in South Korea. The only available study was excluded from this report due to methodological flaws leading to a significant overestimation of the resource. Despite this, South Korea's coastal geography indicates substantial tidal energy potential. However, no robust or peer-reviewed assessment currently exists to quantify it.

### Tidal

According to initial site studies, most of the tidal potential is focused on the Southwestern Sea of Korea. Korea has around 3400 islands, which form narrow channels. These channels accelerate tidal currents, making the country an ideal place to develop tidal stream.

The West and South Coasts of South Korea have many exploitable areas[176] for tidal stream energy extraction, such as Uldolmok, Jang-Juk Strait, Geocha, Jangjuk, Maenggol, and Heonggan channels, with a current velocity ranging from 2 to 6.5 m/s[177].

A tidal stream project supported by the Korean Institute of Ocean Science and Technology (KIOST) has been in operation since 2021 at the Uldolmok Tidal Power Station. This shows interest from the government and the industry, as well as market opportunities for tidal energy in South Korea.

### Tidal Range

Although not many countries are considering tidal range[178] nowadays, Korea boasts the largest plant in the world, the well-known 254 MW tidal range project at Sihwa Lake. France is the only other country to have developed tidal range, with its 240 MW "La Rance" plant in the Brittany region. It is to be noted that this report focused exclusively on tidal stream, not tidal range[179]. Thus, any reference to "tidal" above or elsewhere in the report refers to tidal stream energy and excludes tidal range potential.

### Wave

There is yet no study that quantifies the wave potential in Korea, but initial assessments of the resource reveal several sites with exploitable wave energy potential in the Southwestern islands[180] of the Korean peninsula. Most of the expected resource is located along the country's west coast in the Yellow Sea and in the south around Jeju Island.

Korea hosts the Korean Research Institute of Ships & Ocean Engineering's Wave Energy Test Site (KRISO-WETS), which is a testing platform for wave energy technologies. Located on the Jeju Island and open since September 2020, the site contains 5 berths and has a grid connection capacity of 5 MW. KRISO-WETS hosts the demonstration of the 500 kW Yongsoo Oscillating Water Column, deployed shortly after its opening.

### Market

South Korea's energy system still relies on imports for 98% of its needs. Ocean energy offers a good opportunity to boost energy security in the country by making use of an indigenous renewable energy source. The Ministries of Oceans and Fisheries target 1.5 GW of ocean energy in Korean waters by 2030. The plan calls for the installation of up to 220 MW of wave energy, 300 MW of hybrid systems, and 700 MW of tidal current energy by 2030[181].

South Korea has the potential to become an important ocean energy market in Asia. With the KRISO wave test site in Jeju and strong expected tidal resources, the country could attract leading global developers by backing its deployment ambitions with targeted funding support.

## India: A future market for both wave and tidal

There are no recent studies mapping the potential of wave and tidal in India. The latest study dates back to 2014 and does not account for technological progress in resource extraction. Given the long Indian coast on both shores exposed to the ocean, it is highly likely that future studies will reveal a higher potential.

| Yearly potential (TWh/y) | Theoretical | Technical | Share of electricity demand[182 183] |
|---|---|---|---|
| Tidal stream | 43[184] | 10[185] | 0.50% |
| Wave energy | 123[186] | 13[187] | 0.65% |
| **TOTAL** | **166** | **23** | **>1%** |

### Wave

India's wave energy resource is spread along both its western and eastern coasts. Half of the wave energy potential in India is located in the regions of Maharashtra and Tamil Nadu. Other sites with high energy density are identified in Andhra Pradesh, Karnataka, and Kerala.

According to the Indian Renewable Energy Development Agency (IREDA), "the presence of higher power along the west coast is due to the strong waves during the south-west monsoon. Maximum wave power can be obtained at the southern tip of the Indian peninsula (Kanyakumari, Nagercoil district, Koodankulam) due to the effect of refraction and the presence of strong winds prevailing in the region."[188]

### Tidal

Albeit smaller than its wave resource, India also has a tidal stream resource with its 7,500 km of coastline, including many estuaries and gulfs. Most of the tidal resource is focused on the state of Gujarat on the northwestern coast. Spots with the highest potential are identified in the Gulf of Kutch and Khambhat in western India, with current speeds of 3 m/s.[189]

### Market

The Indian government is showing a growing interest in the ocean energy sector. Tidal, wave energy, and OTEC have recently been included in the renewable energy purchase obligation scheme. The country's fast-growing electricity demand and its long coastline open to the Indian Ocean make ocean energy a strategic resource for the decarbonisation of its energy mix.

Photo: Operations at EMEC

## Australia: The highest wave energy theoretical potential around the globe

| Yearly potential (TWh/y) | Theoretical | Technical | Share of electricity demand[190 191] |
|---|---|---|---|
| Tidal stream | 8[192] | 2[193] | 0.8% |
| Wave energy | 2,730[194] | 245[195 196] | > 100% |
| **TOTAL** | **2,738** | **247** | **> 100%** |

### Wave

Australia has the highest theoretical wave energy potential on the globe and the best technical potential in Asia and Oceania, as per existing literature.

Wave energy has the potential to power the entire country's consumption many times over. Yet, despite its vast theoretical wave resource, Australia remains a relatively small market due to its population size and lack of significant interconnections. As a result, the available technical resource exploitable is unlikely to justify deployments beyond meeting domestic electricity demand[197].

Most of the energy potential is located on the Western and Southern coasts of the country, particularly around Tasmania and Victoria. These regions are directly exposed to powerful swells from the Indian and Southern Oceans, which travel long distances uninterrupted by land and crash onto Australia's southern coast. Locations with high wave energy potential include Cape de Couedic, Cape Sorell, and Cape Naturalist[198].

Further studies are still needed to identify specific deployment sites and quantify the amount of wave energy exploitable in each wave energy hotspot.

### Tidal

Australia's tidal potential is much smaller than its wave resource. The top two tidal sites are King Sound in the northwest and Banks Strait in the southeast near Melbourne, both with currents regularly reaching 2.6 m/s.

### Market

To date, Australian developers are looking at markets presenting more imminent opportunities, such as Europe. But, with a 25,760 km coastline open to three oceans and national champions like Wave Swell and Carnegie deploying full-scale technologies, Australia is well-positioned to play a part in the industrialisation of the ocean energy sector. The government has, in the past, provided market incentives such as tax rebates to help fund the start of the sector. However, the lack of consistency of the schemes and their complex nature made it difficult to develop projects in the long term.

Photo: WaveSwell

## New Zealand: Large wave potential to complement hydropower on the grid

Ocean energy can provide more than half of the current electricity demand in New Zealand[203]. This is close to what the main electricity provider (hydropower)[204] today in the country.

| Yearly potential (TWh/y) | Theoretical | Technical | Share of electricity demand[199] |
|---|---|---|---|
| Tidal stream | 52[200] | 2[201] | 4% |
| Wave energy | | 21[202] | 51% |
| **TOTAL** | **>52** | **23** | **55%** |

## Wave

Wave energy alone can provide half of the country's current demand for electricity. Most of the west and south-facing coasts from North to South have a wave energy potential. This is because they are exposed to persistent Southern Ocean winds that travel long distances and generate powerful swells.

The location with the highest resource in the South Island is the Southland coast from Fiordland to the west of Stewart Island[205]. "Only the Catlins region in the South Otago has an equivalent resource to the West Coast"[206]. In the North Island, the coastline from Wairarapa to East Cape is the region with the most important wave energy resource.

## Tidal

New Zealand's tidal resource is smaller than its wave energy resource , but still significant compared to its population and electricity demand,[207] meaning that tidal could also play an important role in the decarbonisation of the country.

The site with the highest tidal stream potential in New Zealand is the Cook Strait, located between the North and South Islands. It accounts for the overwhelming majority of the country's tidal energy resource and hosts the fastest tidal currents. Foveaux Strait and the northern and southern coasts of Stewart Island also exhibit current speeds above 2 m/s, making them suitable for tidal energy generation.

## Market

Ocean energy can make an important contribution to New Zealand's goal to increase its share of renewable energy while maintaining energy security, by being an additional provider of flexibility on the grid. 82% of electricity is generated from renewable sources in New Zealand, with over half from hydropower. Ocean energy can help to cope with wind and solar variability at times of lower-than-expected output of hydropower during dry periods.

# 05 Other ocean energy technologies

## Tidal Range

Tidal range and tidal stream are distinct technologies. Tidal range involves the use of barrages to trap water at high tide and release it at low tide through turbines built into the structure. In contrast, tidal stream relies on stand-alone underwater turbines that harness the kinetic energy of fast-moving currents to generate electricity.

This report does not include tidal range in its resource assessment. While the technology is commercially viable, as of the publication date, there are no tidal range projects under advanced development in Europe. This is largely due to two key factors. First, the number of suitable locations for tidal range deployment in Europe is limited. Second, these projects, like any new technology, lack some form of public revenue support system to be financially viable. Several projects also faced challenges in obtaining permits due to environmental concerns, though that can be mitigated if the siting is chosen carefully, as was the case for the Swansea project.

In the UK, the Swansea Bay Tidal Lagoon, which was initially planned for completion by 2020, remains stalled due to financial uncertainties. Having secured support from environmental NGOs such as Birdlife International, the project failed to gain support from the UK government for a Contracts for Difference (CfD). The requested CfD strike price was very similar to that of Hinkley Point's nuclear project. Yet the Government chose EDF's project, and it is very possible that its sheer size and subsidy needs prevented funding for anything else. Other potential tidal range projects are also located primarily in the UK, but these remain in the early planning stages. Some companies are looking at sites in Northern France as well.

Europe's most notable tidal range project is the La Rance Tidal Power Plant, located in the La Rance Estuary in Brittany, France. Commissioned in 1966, it was the world's first large-scale tidal power plant and remains the only commercial tidal range installation in Europe. The plant has a capacity of 240 MW, powered by 24 turbines, and has been in continuous operation for decades.

## Salinity gradient

Salinity gradient power is the energy created from the difference in salt concentration between two fluids, commonly fresh and salt water, e.g., when a river flows into the sea. One pilot in the Netherlands has demonstrated the feasibility of generating electricity from this difference in concentration.

Several studies document the potential of the technology. The Fraunhofer Institute has been commissioned by the European Commission to assess this material and produce a study on salinity gradient's potential in the EU. The study was carried out with

Photo: REDStack


Photo: ENGIE

input from Ocean Energy Europe members and was published in June 2024. To avoid duplication of work, the key conclusions from the report are reproduced below. More information can be found on the website of the European Commission.

The total technical potential of EU Member States is estimated to be 6.6 GW[208], corresponding to 50.8 TWh/y[209] .The study estimates that osmotic energy (salinity gradient) can produce 1.7% of the EU electricity production in 2021.

The potential varies considerably between countries. 'France shows the greatest technical potential with 19.2 TWh/y, followed by Italy with 6.6 TWh/y, Romania and the Netherlands with 5.7 TWh/y and 5.4 TWh/y'[210].

Salinity gradient's potential in Europe is lower than that of wave and tidal. However, the technology can be a useful complement to produce renewable baseload power and complement variable renewables on the grid going forward.

## OTEC / SWAC

The resource for Ocean Thermal Energy Conversion (OTEC) is considerable. The IEA-OES estimates the global theoretical potential of OTEC at 44,000 TWh/y. The technology essentially uses seawater going through a heat pump system to generate heating/cooling (SWAC) or electricity (OTEC).

Despite clear potential around the entire equator belt between the tropics, no complete full-scale offshore OTEC project has been successfully deployed at the time of writing. This is due to both the high initial cost of the technology, as well as some technological challenges that remain unsolved. The cold-water pipe needed to pump cold water up from around 1000m depth, particularly, and the size of the heat exchanger means that an offshore version of OTEC is likely only realistic in the future, after a land-based version has been proven.

Land-based OTEC is more likely to be deployed, as it could benefit from pipes running on the seabed to the desired depth, thus avoiding the challenges of the cold-water pipe. Financial support would still be needed to deploy any unit at scale.

SWAC is currently the most successful way to use temperature differences in the ocean. A successful 20MW pilot has been deployed by ENGIE in Marseille, France, where the technology is cooling an entire building block and could pave the way for more projects around the world. Some others already exist in Asia, though little information is known about them, as they are generally integrated into brand-new developments.

SWAC is close to the commercial stage and should be promoted further as a cooling solution for new and existing builds, wherever the conditions are right.

# 06 Annexes

## Summary tables

### Tidal Stream

| Yearly potential (TWh/y) | Theoretical | Technical | Practical |
|---|---|---|---|
| **EUROPE** | **653** | **74** | |
| France | | 18 | |
| Spain | 60 | 5[211] | |
| United Kingdom | 340 | 39 | 34[212] |
| Ireland | 230 | | |
| The Netherlands | | 0.25 | |
| Denmark | 6 | 1 | 1[213] |
| Norway | 17 | 1 | 1[214] |

| Yearly potential (TWh/y) | Theoretical | Technical |
|---|---|---|
| **AMERICAS** | **592** | **303** |
| Canada | 147 | 73[215] |
| USA | 445 | 220 |
| Chile | | 10.5 |
| **ASIA AND OCEANIA** | **2,010** | **460** |
| China | 122 | 28[216] |
| Indonesia | 1,008 | 252 |
| The Philippines | 700 | 160[217] |
| India | 43 | 10 |
| Japan | 77 | 6 |
| Australia | 8 | 2[219] |
| New Zealand | 52 | 2 |
| **GLOBAL TOTAL** | **3,255** | **837** |

## Wave Energy

| Yearly potential (TWh/y) | Theoretical | Technical | Practical |
|---|---|---|---|
| **EUROPE** | **2,598** | **499** | |
| France | 400 | 40 | |
| United Kingdom | 570 | 145 | 107[220] |
| Portugal | 184 | 81[221] | 57[222] |
| Ireland | 525 | 125 | 90[223] |
| Spain | 289 | 71 | 46[224] |
| The Netherlands | | 2.6 | |
| Norway | 600 | 21 | |
| Denmark | 30 | 13 | |

| Yearly potential (TWh/y) | Theoretical | Technical |
|---|---|---|
| **AMERICAS** | **4,212** | **2,176** |
| Canada | 546 | 290[225] |
| USA | 2,640 | 1,400 |
| Chile | 491 | 260[226] |
| Brazil | 273 | 145[227] |
| Ecuador (Galapagos) | 262 | 81[228] |
| **ASIA AND OCEANIA** | **3,968** | **399** |
| China | 114 | 12[229] |
| Indonesia | 421 | 21 |
| India | 123 | 13[230] |
| Japan | 580 | 87 |
| Australia | 2,730 | 245[231] |
| New Zealand | | 21 |
| **GLOBAL TOTAL** | **10,778** | **3,074** |

## Summary table of potential in installed capacity

| Installed capacity (GW)[232] | Tidal Technical | Wave Technical | Total / continent |
|---|---|---|---|
| Europe | 21 | 167 | 188 |
| Americas | 87 | 731 | 818 |
| Asia and Oceania | 131 | 134 | 265 |
| **TOTAL GLOBALLY** | **239** | **1,032** | **1,271** |

# Definitions and methodology

## Definition of the different potentials outlined in the report

### Theoretical potential[233]

The theoretical potential refers to the total amount of energy physically available for an ocean energy resource in a given area, assuming perfect capture and conversion efficiency, and without considering any technological, environmental, spatial, or economic constraints.

These figures are presented in the report to outline the upper limit of energy that can be extracted. However, we consider that it is not precise enough to be considered for political decision-making.

### Technical potential

The technical potential is a subset of the theoretical potential. It adds engineering and technological criteria to the theoretical potential, such as device capacity, capacity factors, depth restrictions etc… It is a "proportion of the theoretical resource that can be captured using existing technology"[234]. This figure is set to increase as the technology develops and improves.

### Practical potential

The practical potential is a subset of the technical potential. It considers climatic, natural, engineering, and technological constraints, together with economic and legal constraints – such as environmental restrictions, marine spatial planning, etc. This potential can thus increase or decrease depending on the evolution of legislation at the national level. As a result, it can underestimate the real usable potential.

Criteria to determine the practical potential can vary widely across studies, making comparisons difficult. In addition, data on practical potential remains scarce outside Europe. This report focuses exclusively on technical potential.

### Which potential to use?

The theoretical potential is useful to assess the existence of a resource and for potentially more impartial comparisons between countries, excluding economic or technological considerations that might vary. Yet it is not a valid picture of the ocean energy potential that a country can realistically exploit. It is thus not viable for industrial or political decision-making.

Technical potential measures how much of a resource can be harnessed with state-of-the-art technology at a given time. It can increase as the technology improves and with new resource mapping, but it remains the most stable benchmark to assess the technology's long-term potential. By contrast, practical potential varies widely depending on political and economic choices, which can shift rapidly over time.

The technical potential is also the most documented metric, making it the most robust basis for comparison and consistent assessment across countries.

Consequently to all the above, this report chooses to focus on the technical potential.

## Definition of the different ocean energy technologies mentioned in the report

### Tidal Stream

Tidal currents are caused by the gravitational forces of the sun and the moon, and are particularly concentrated in narrow bodies of water, such as around islands or inlets. Tidal turbines can be fixed to the seabed or floating and anchored to the seafloor.

Most existing tidal stream technologies are designed to harness high-speed currents[235]. However, technologies able to capture energy from low-speed flows, such as Minesto and SeaQurrent, are already deployed Europe. This study includes exclusively high-speed current sites, as insufficient data is available to comprehensively assess the potential of low-speed current areas.

### Wave energy

The movement of waves is caused by the wind as it blows across the surface of the sea. As a result, wave energy devices can generate power when there is wind and long after the wind dies down. The energy created depends on the speed, height, and frequency of the wave. Several concepts coexist, aimed at harvesting different resources.

### Tidal range

Tidal range technology, despite also using tides to produce electricity, is a completely separate technology from tidal stream devices. Instead of harnessing the flow of tidal currents, tidal range installations produce energy from the difference in sea levels between high and low tides. Tidal range operates on the same principle as hydropower, requiring a dam or barrier to hold a large body of water.

This report focuses exclusively on tidal stream potential. Thus, any reference to tidal throughout the report refers to tidal stream energy and excludes tidal range potential.

## Ocean Thermal Energy Conversion (OTEC)

OTEC exploits the difference between deep cold and warm surface water to produce a steady power supply via heat exchange technologies. OTEC generally targets a 20°C or more temperature differential, though lower differentials are possible.

## Sea Water Air Conditioning (SWAC)

SWAC installations are located close to shore and pump water from the nearby sea or ocean. Depending on the water depth and the season, the pumped seawater is used to cool or heat a closed freshwater loop via a series of heat exchangers. A single system can provide heating or cooling to an urban area several kilometres wide.

# Methodological exception to estimate the technical and practical potential where data is lacking

All countries covered in this report have assessed their theoretical potential. However, several with significant wave and tidal resources have not yet published scientific estimates of their technical potential. To avoid foregoing the entire wave and tidal resource in countries where there is no literature yet, a conversion ratio was applied to estimate the technical potential, based on available data on the theoretical potential.

For example, no robust data on wave and tidal technical potential exists for Canada, Chile, the Galapagos, or Brazil. However, several studies have assessed their theoretical potential. To estimate their technical potential, a conversion ratio was applied based on the most comprehensive study in the Americas assessing the US technical potential[236]. This ratio was applied to the wave theoretical potential of Canada, Chile, and Galapagos. This yielded an estimate of their respective technical potential.

A ratio was also used to estimate the technical potential (from practical potential) for wave energy in European countries lacking data. This ratio was derived from countries where both technical and practical potential have been documented.

All figures calculated using a ratio are marked with footnotes throughout the report. The reference countries and derived ratios are outlined in the table below.

All ratios were calculated using data from countries within the same continent. Applying a ratio based on comparable wave and tidal climates is the most robust alternative for estimating technical and practical potential. Regions with similar oceanographic characteristics are far more likely to exhibit comparable conversion ratios from theoretical to technical potential.

| Reference countries | Ratios wave | Ratios tidal |
|---|---|---|
| *From theoretical to technical potential* | | |
| United Kingdom, Ireland | | 9% |
| United States | 53% | 49% |
| Indonesia, Japan | 11% | |
| Indonesia, Japan, New Zealand | | 23% |
| *From practical to technical potential* | | |
| United Kingdom, Ireland, Spain | 141% | |

# Capacity factors to convert production (TWh/y) to installed capacity (GW)

Most studies referenced in this report provide their findings in terms of energy generation. When a potential is expressed as installed capacity, a capacity factor is applied to convert it into production figures. It is important to note that capacity factors for both wave and tidal energy are spatially variable, meaning they can differ significantly between sites and regions.

To ensure consistency throughout this report, a standard capacity factor for wave and tidal energy has been selected, based on available literature and industry feedback. The capacity factors used are 40% for tidal stream, based on operational tidal farms in the water and industry consultations. For wave energy, a capacity factor of 34% is used based on an estimate of the European Commission Joint Research Centre (JRC)[237]. In both cases, this is likely to be conservative compared to what the technology can achieve in the future.

# 07 Endnotes

1. IEA, 2025, Global Energy Review, Total Electricity Generation in 2023
2. Ibid
3. Ibid
4. Ibid
5. Low-speed current resources are not included in this report due to limited studies quantifying their potential
6. Eurostat, Electricity and heat statistics, 2023; IEA, UK, Countries & Regions 2023
7. Ibid
8. 250 commercial tidal calls in France, UK tidal CfDs, Innovation Fund-supported project in France
9. Ocean Energy Europe, 2024 Stats & Trends, p.23
10. U.S DOE, 2026, Water Power Technologies Office Budget Over Time
11. The industry estimates that such technology could multiply the potential several times over by unlocking new sites across many regions of the globe
12. Eurostat Workbook, generation, electricity available for final consumption in the EU in 2023, 2413 TWh
13. IEA, 2023, Monthly Electricity Statistics: Final Electricity Consumption, United Kingdom, 262 TWh
14. Share of electricity demand means the percentage of the electricity demand that can be covered based on the technical potential as the upper bound and the practical potential as the lower bound
15. Sum of theoretical potentials of the UK, Ireland, Denmark, Spain, and Norway
16. Sum of the technical potentials of France, Spain, the UK, Ireland, Norway, the Netherlands, and the Faroe Islands.
17. Sum of the theoretical potentials of the UK, Ireland, France, Portugal, Spain, Norway, and Denmark.
18. Sum of the technical potentials of France, the UK, Ireland, Norway, Denmark, Spain, the Netherlands and Portugal
19. Eurostat, Electricity and heat statistics, 2023, 458 TWh of Gas in 2023, IEA, UK, Countries & Regions 2023, 101 TWh
20. See section 1 on technology improvement and new studies unlocking new resources
21. Ocean Energy Europe, 2030, Ocean Energy Vision, 2020, p.16
22. Sub-systems such as power take-offs, drivetrains, seals, bearings, gearboxes, control system blades
23. Ocean Energy Europe, Stats & Trends report, 2023, UK CfD AR6, AR7 results, and Innovation Fund 2023/24 call awards
24. Ocean Energy Europe, Stats & Trends report, 2024, p.22
25. IEA, 2023, Monthly Electricity Statistics: Final Electricity Consumption, United Kingdom
26. Share of electricity demand means the percentage of the annual electricity demand that can be covered based on the technical potential
27. Carbon Trust, 2011, Carbon Trust Foreword to UK Tidal Current Resource and Economics Study
28. Schlütter et al., 2015, Resource Mapping of Wave Energy Production in Europe
29. Ibid
30. IEA, 2023, Monthly Electricity Statistics: Final Electricity Consumption, United Kingdom
31. IEA, electricity generation by source in the UK, 2023
32. Ibid
33. ORE Catapult, 2018, Tidal Stream and Wave Energy Cost Reduction and Industrial Benefit
34. Sum of tidal stream Contract for Difference: from Allocation rounds 4 to 7
35. IEA, 2023, Monthly Electricity Statistics: Final Electricity Consumption, France
36. Share of electricity demand means the percentage of the annual electricity demand that can be covered based on the technical potential
37. France Energies Marines, Tecnalia et al for Directorate-General for Energy, 2023, Study on Offshore Energy Potential in the Atlantic Ocean
38. ADEME, 2010, Feuille de route sur les énergies renouvelables marines, p14
39. Ibid
40. IEA, 2023, Countries & Regions, France

41. Bretagne Ocean Power, 2023, Etude de dérisquage des zones de potentiel hydrolien en Bretagne
42. Etude ARTELIA, 2012, GIP littoral aquitain, étude sur le potentiel des énergies marines
43. ADEME, 2010, Feuille de route sur les énergies renouvelables marines, p14
44. IEA, 2023, Countries & regions, Ireland
45. Share of electricity demand means the percentage of the annual electricity demand that can be covered based on the technical potential
46. SEAI, 2005, Tidal & Current Energy Resources in Ireland
47. Department of Communication, Energy and Natural Resources, Offshore Renewable Energy Development Plan I, 2014, Ireland's tidal energy resource, technical potential of 3 GW converted into generation
48. Department of Communication, Energy and Natural Resources, Offshore Renewable Energy Development Plan I, 2014, Ireland's wave energy resource
49. Schlütter et al. 2015, Resource Mapping of Wave Energy Production in Europe
50. IEA, 2023, Countries & Regions, Ireland
51. EVOLVE, January 2023, review of practical deployment locations for European ocean energy projects
52. Ibid
53. IEA, 2023, Monthly Electricity Statistics: Final Electricity Consumption, Portugal
54. Share of electricity demand means the percentage of the annual electricity demand that can be covered based on the technical potential
55. WaveC, 2004, Potential and Strategy for the Development of Wave Energy in Portugal
56. Figure calculated using a ratio, see the methodology section for more information
57. IEA, 2023, Countries & Regions, Portugal
58. Ibid
59. Projecto Offshore Plan, 2017, Planeamento das Energias Renováveis Offshore em Portugal, Wave Atlas, Wave energy resource
60. National Energy & Climate Plans, 2023, estimated trajectories per renewable energy technology
61. IEA, 2023, Monthly Electricity Statistics: Final Electricity Consumption, Spain
62. Share of electricity demand means the percentage of the annual electricity demand that can be covered based on the technical potential
63. Departamento de Energías Renovables, Agencia Andaluza de la Energía, 2009, Estudio Sobre El Potencial Bruto De Energías Marinas En El Litoral Andaluz (Fase I). This study only covers the region of Andalusia.
64. The resource is shared between Spain and Morocco
65. Figure calculated using a ratio, see the methodology section for more information
66. IDAE, 2010, Evaluacion del potential de la energia de las olas
67. Ibid, applying coefficient from p.120 to Tabla 6.6. Energía media anual bruta por fachadas y profundidades(TWh/año) – sin aplicar un factor de reducción de conflictos
68. IEA, 2023, Countries & regions, Spain
69. IEA, 2023, Monthly Electricity Statistics: Final Electricity Consumption, Norway
70. Share of electricity demand means the percentage of the annual electricity demand that can be covered based on the technical potential
71. Grabbe, 2009, A review of the tidal current energy resource in Norway
72. Enova 2007, "Potensialstudie av havenergi i Norge" in Holmberg ans al, 2011, Wave Power Surveillance study of the development, Elforsk rapport.
73. Ibid
74. Ibid. Wave power potential is estimated to be between 12-30 TWh, with an average = 21.
75. IEA, 2023, Countries & regions, Norway
76. Ibid
77. IEA, 2023, Countries & regions, Denmark
78. Share of electricity demand means the percentage of the annual electricity demand that can be covered based on the technical potential
79. Knud Simonsen, 2020, Analysis of the energy potential of tidal streams on the Faroe Shelf
80. Figure calculated using a ratio, see the methodology section for more information
81. Estimate including low-speed currents
82. SEV, 2022, a record year, 434 GWh of electricity generated
83. Energistyrelsen, Elkraftsystem and Eltra, 2005 "Bøljekraftstrategi – Strategi for forskning og udveckling"
84. Schlütter et al. Resource Mapping of Wave Energy production In Europe, 2015
85. IEA, 2023, Countries & Regions, Denmark

86. Helma Maria Trondheim, et al., 2023, 100% Sustainable Electricity in the Faroe Islands
87. Sannino et al. 2013, Wave energy resource assessment in the Mediterranean
88. T. J. Hammons (2011). Energy Potential of the Oceans in Europe and North America: Tidal, Wave, Currents, OTEC and Offshore Wind, Electricity Infrastructures in the Global Marketplace
89. IEA, 2023, Monthly Electricity Statistics: Final Electricity Consumption, The Netherlands
90. Share of electricity demand means the percentage of the annual electricity demand that can be covered based on the technical potential
91. DNV - Marine-energy-in-the-Dutch-North-Sea, Potential benefits to the Dutch energy system, 2021
92. Ibid
93. Ibid
94. TNO, 2024, Het potentieel van energie uit water in en rondom het Waddengebied
95. IEA, 2023, Total Electricity Production, Central & South America, North America: 6881 TWh
96. Share of electricity demand means the percentage of the annual electricity demand that can be covered based on the technical potential
97. Sum of the theoretical potentials of Canada, the US
98. Sum of the technical potentials of Canada, the US and Chile. No data is available for other regions. This figure is therefore rather conservative.
99. Sum of the theoretical potentials of Canada, Chile, Brazil, Galapagos, and the US
100. Sum of the technical potentials of Canada, Chile, Brazil, Galapagos, and the US
101. U.S DOE, 2026, Water Power Technologies Office Budget Over Time
102. National Renewable Energy Laboratory for the US Department of Energy Office, 2021, Marine Energy in the US: An overview of Opportunities
103. Ibid
104. IEA, 2023, Countries & Regions, United States
105. IEA, 2023, Monthly Electricity Statistics: Final Electricity Consumption, United States
106. Share of electricity demand means the percentage of the annual electricity demand that can be covered based on the technical potential
107. Moreno A., 2017, Ocean Energy Europe 2017 Conference and Exhibition
108. National Renewable Energy Laboratory for the US Department of Energy Office, 2021, Marine Energy in the US: An overview of Opportunities
109. Jacobson, 2011, Mapping and Assessment of the United States Ocean Wave Energy Resource, Electric Power Research Institute
110. National Renewable Energy Laboratory for the US Department of Energy Office, 2021, Marine Energy in the US: An overview of Opportunities
111. Based on electricity production levels of the 50 US States in 2019 and based on the electricity demand reported in the IEA, 2023, Monthly Electricity Statistics for the United States of 4023 TWh in 2023
112. California Energy Commission, 2023, Total System Electric Generation
113. U.S DOE, 2026, Water Power Technologies Office Budget Over Time
114. IEA, 2023, Monthly Electricity Statistics: Final Electricity Consumption, Canada
115. Share of electricity demand means the percentage of the annual electricity demand that can be covered based on the technical potential
116. A. Cornett, 2006, Inventory of Canadian Marine Renewable Energy Resources, p.84, 42 240 MW using a capacity factor of 0,4.
117. Figure calculated using a ratio, see the methodology section for more information
118. Government of Canada, What is Marine Renewable Energy, Wave energy resource, 37GW + 146.5GW using a capacity factor of 0,34
119. Figure calculated using a ratio, see the methodology section for more information
120. IEA, 2023, Countries & Regions, Canada
121. Nova Scotia Department of Energy, The power of the highest tides in the world
122. Karsten, tidal energy institute, 2012, Tidal Energy Resource Assessment Map for Nova Scotia
123. Marine Energy Technology Group, 2019, Commercial Potential of Marine Renewables in British Columbia
124. IEA, 2023, Monthly Electricity Statistics: Final Electricity Consumption, Chile
125. Share of electricity demand means the percentage of the annual electricity demand that can be covered based on the technical potential
126. Agence de l'environnement et de la maîtrise de l'énergie, CVA, Etude stratégique de la filière hydrolien marin, juin 2018, 2-4 GW in South Chile
127. Garrad Hassan, 2009, Preliminary site selection, Chilean marine energy resources, theoretical potential of 164.9 GW converted into generation

128. Figure calculated using a ratio, see the methodology section for more information
129. IEA, 2023, Countries & regions, Chile
130. Asociacion de Energia del Mar, Chile´s Marine Energy Strategy – a Roadmap for Development and Funding Needs, January 2014
131. Garrad Hassan, 2009, Preliminary site selection, Chilean marine energy resources
132. Hacuna & al., 2008, Evaluation of the potential of wave energy in Chile
133. Garrad Hassan, 2009, Preliminary site selection, Chilean marine energy resources
134. IEA, 2023, Countries & regions, Brazil
135. Share of electricity demand means the percentage of the annual electricity demand that can be covered based on the technical potential
136. Ocean Engineering Department, Federal University of Rio de Janeiro, Energies, 2019, Ocean Renewable Energy Potential, Technology, and Deployments: A Case Study of Brazil. Theoretical potential of 91.8 GW converted into generation
137. Figure calculated using a ratio, see the methodology section for more information
138. IEA, 2023, Countries & regions, Brazil
139. Ocean Engineering Department, Federal University of Rio de Janeiro, Energies, 2019, Ocean Renewable Energy Potential, Technology, and Deployments: A Case Study of Brazil.
140. IEA, 2023, Total electricity production, Countries & regions, Ecuador
141. Share of electricity demand means the percentage of the annual electricity demand that can be covered based on the technical potential
142. Energy strategy reviews, 2014, The potential of wave energy converters in the Galapagos islands
143. Figure calculated using a ratio, see the methodology section for more information
144. Sum of the theoretical potentials of China, Indonesia, Japan, India, the Philippines, Australia, and New Zealand
145. Sum of the technical potentials of China, Indonesia, the Philippines, India, Japan, Australia, and New Zealand
146. Sum of the theoretical potentials of China, Indonesia, India, Japan, and Australia
147. Sum of technical potentials of China, Indonesia, India, Japan, and Australia, and New Zealand
148. The report takes 100% of Australia's electricity demand as the maximum technical potential that can be harnessed, despite much larger real potential. This is due to limited electricity export possibilities. This avoids introducing bias in data that would see Australia dwarfing other countries' resources and make data analysis difficult or pointless.
149. IEA, 2023, Monthly Electricity Statistics: Final Electricity Consumption, China
150. Share of electricity demand means the percentage of the annual electricity demand that can be covered based on the technical potential
151. Zhang Y.-L., Lin Z. & Liu Q.-L., 2014, Marine renewable energy in China: Current status and perspectives, Water Science and Engineering, p293, theoretical capacity including average-time power converted into generation
152. Figure calculated using a ratio, see the methodology section for more information
153. Ibid, average power converted to generation
154. Figure calculated using a ratio, see the methodology section for more information
155. Under China's Special Fund Program for Marine Renewable Energy, set in 2010 to support the development of domestic ocean energy projects
156. IEA, 2023, Countries & regions, Indonesia, electricity production + imports: 434 TWh
157. Share of electricity demand means the percentage of the annual electricity demand that can be covered based on the technical potential
158. World maritime university, ocean energy overview: feasibility study of ocean energy implementation in Indonesia, 2018, Table 3, tidal current, theoretical potential of 287.8 GW converted into generation
159. Ibid, Table 3, tidal current, technical potential of 71.9 GW converted into generation
160. Ibid, Table 3 wave energy, theoretical potential of GW 141.4 converted into generation.
161. Ibid, Table 3 wave energy, technical potential of 7.9 GW converted into generation
162. IEA, 2023, Countries & regions, Indonesia, Electricity generation
163. Ibid
164. IEA, 2022, Countries & regions, total electricity production in the Philippines
165. Share of electricity demand means the percentage of the annual electricity demand that can be covered based on the technical potential
166. Quirapas et al, Renewable and Sustainable Energy Reviews, 2015, Ocean renewable energy in South east Asia: A review, theoretical potential of 200 GW converted into generation
167. Figure calculated using a ratio, see the methodology section for more information
168. IEA, 2023, Countries & regions, The Philippines
169. IEA, 2023, Countries & regions, Japan, total electricity production

170. Share of electricity demand means the percentage of the annual electricity demand that can be covered based on the technical potential
171. Hennequin, 2016, Hydro, Tidal and Wave Energy in Japan Business, Research and Technological Opportunities for European Companies, EU-Japan Centre for industrial Cooperation, theoretical potential of 22 GW converted into generation
172. Ibid
173. Ibid, theoretical potential of 195 GW converted into generation
174. Ibid
175. IEA, Country & regions, Japan, electricity generation
176. Hwang and Jo, Energies 2019, Tidal Current Energy Resource Distribution in Korea
177. Ibid
178. Tidal range is more akin to hydropower and very different from tidal stream. See the definitions section for more details.
179. See definitions and methodology section for a definition of tidal range and tidal stream
180. Kim et al., 2011, Offshore and nearshore wave energy assessment around the Korean Peninsula, Energy 36
181. Ko et al., 2019, Current Policy and Technology for Tidal Current Energy in Korea
182. IEA, 2023, Countries & regions, Indonesia, electricity production + import + imports: 1980TWh
183. Share of electricity demand means the percentage of the annual electricity demand that can be covered based on the technical potential
184. AFD and IREDA, 2014, Study on Tidal & Waves Energy in India: Survey on the Potential & Proposition of a Roadmap, sum of tidal stream potentials in Khambhat and Kutch regions. Theoretical potential of 12.4 GW converted into generation.
185. Figure calculated using a ratio, see the methodology section for more information
186. Ibid, theoretical potential of 41 GW converted into generation
187. Figure calculated using a ratio, see the methodology section for more information
188. AFD and IREDA, 2014, Study on Tidal & Waves Energy in India: Survey on the Potential & Proposition of a Roadmap
189. Ibid
190. IEA, 2023, Monthly Electricity Statistics: Final Electricity Consumption, Australia
191. Share of electricity demand means the percentage of the annual electricity demand that can be covered based on the technical potential
192. Commonwealth Scientific and Industrial Research Organisation, 2012, Ocean renewable energy: 2015-2050 An analysis of ocean energy in Australia
193. Figure calculated using a ratio, see the methodology section for more information
194. Wave Atlas Commonwealth Scientific and Industrial Research Organisation, 2018, The Australian Wave Energy Atlas - Project Overview and Final Report to ARENA
195. Figure calculated using a ratio, see the methodology section for more information
196. Wave energy can only provide as much electricity as there is demand. In 2023, Australia's electricity demand is 245 TWh (IEA, 2023, Monthly Electricity Statistics: Final Electricity Consumption, Australia).
197. Ibid
198. Commonwealth Scientific and Industrial Research Organisation, 2012, Ocean renewable energy: 2015-2050 An analysis of ocean energy in Australia
199. IEA, 2023, Monthly Electricity Statistics: Final Electricity Consumption, New Zealand
200. Vennell, 2012, Estimating the power potential of tidal currents and the impact of power extraction on flow speeds, theoretical potential of 15 GW converted into generation
201. Power projects limited, 2008, Development of Marine Energy in New Zealand Prepared for Electricity Commission Energy Efficiency and Conservation Authority & Greater Wellington Regional Council, Table 4.1 Summary Estimates of Wave and Tidal Reserves
202. Ibid
203. IEA, 2023, Countries and regions, New Zealand, electricity generation
204. Ibid
205. D. Johnson, P. McComb, B. Beamsley and R. Zyngfogel,2008, MetOcean Solution Ltd
206. Ibid
207. Ibid
208. Fraunhofer, 2024, EnTEC – Final Report - The potential of osmotic energy in the EU
209. With an operating time of 8,000 hours per year.
210. Fraunhofer, 2024, EnTEC – Final Report - The potential of osmotic energy in the EU
211. Figure calculated using a ratio, see the methodology section for more information
212. Corporate Value Associates, 2018, Synthèse de l'Etude stratégique de la filière hydrolien marin, p 24
213. Knud Simonsen, 2020, Analysis of the energy potential of tidal streams on the Faroe Shelf

**214.** Grabbe, 2009, A review of the tidal current energy resource in Norway

**215.** Figure calculated using a ratio, see the methodology section for more information

**216.** Ibid

**217.** Ibid

**218.** Ibid

**219.** Ibid

**220.** EVOLVE, January 2023 , review of practical deployment locations for European ocean energy projects

**221.** Ibid

**222.** Ibid

**223.** Ibid

**224.** IDAE, 2010, Evaluacion del potential de la energia de las olas. Tabla 6.8. Energía media anual neta por fachada y profundidad en TWh/año.

**225.** Figure calculated using a ratio based on the theoretical potential, see the methodology section for more information

**226.** Ibid

**227.** Ibid

**228.** Ibid

**229.** Ibid

**230.** Ibid

**231.** Ibid

**232.** Based on the generation figures available in the Summary Table. See the methodology section below for capacity factors applied.

**233.** Definitions of theoretical potential vary across reports and are often imprecisely stated. This report consolidates the key variables used in defining theoretical potential across all reports analysed in this literature review.

**234.** National Renewable Energy Laboratory for the US Department of Energy Office, 2021, Marine Energy in the US: An overview of Opportunities

**235.** High-speed current technologies are technologies are expected to generate power starting from tidal currents of at least 2 m/s.

**236.** National Renewable Energy Laboratory for the US Department of Energy Office, 2021, Marine Energy in the US: An overview of Opportunities

**237.** Joint Research Center, 2016, Ocean Energy Status Report, Appendix B.3, p.56.

## About Ocean Energy Europe

Ocean Energy Europe (OEE) is the voice of the ocean energy industry.

Over 120 organisations, including Europe's leading utilities, industrialists and research institutes, trust OEE to represent the interests of the sector, making it the largest network of ocean energy professionals in the world.

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