OCEAN ENERGY SYSTEMS

An International Vision for Ocean Energy

INDUSTRIAL GOAL

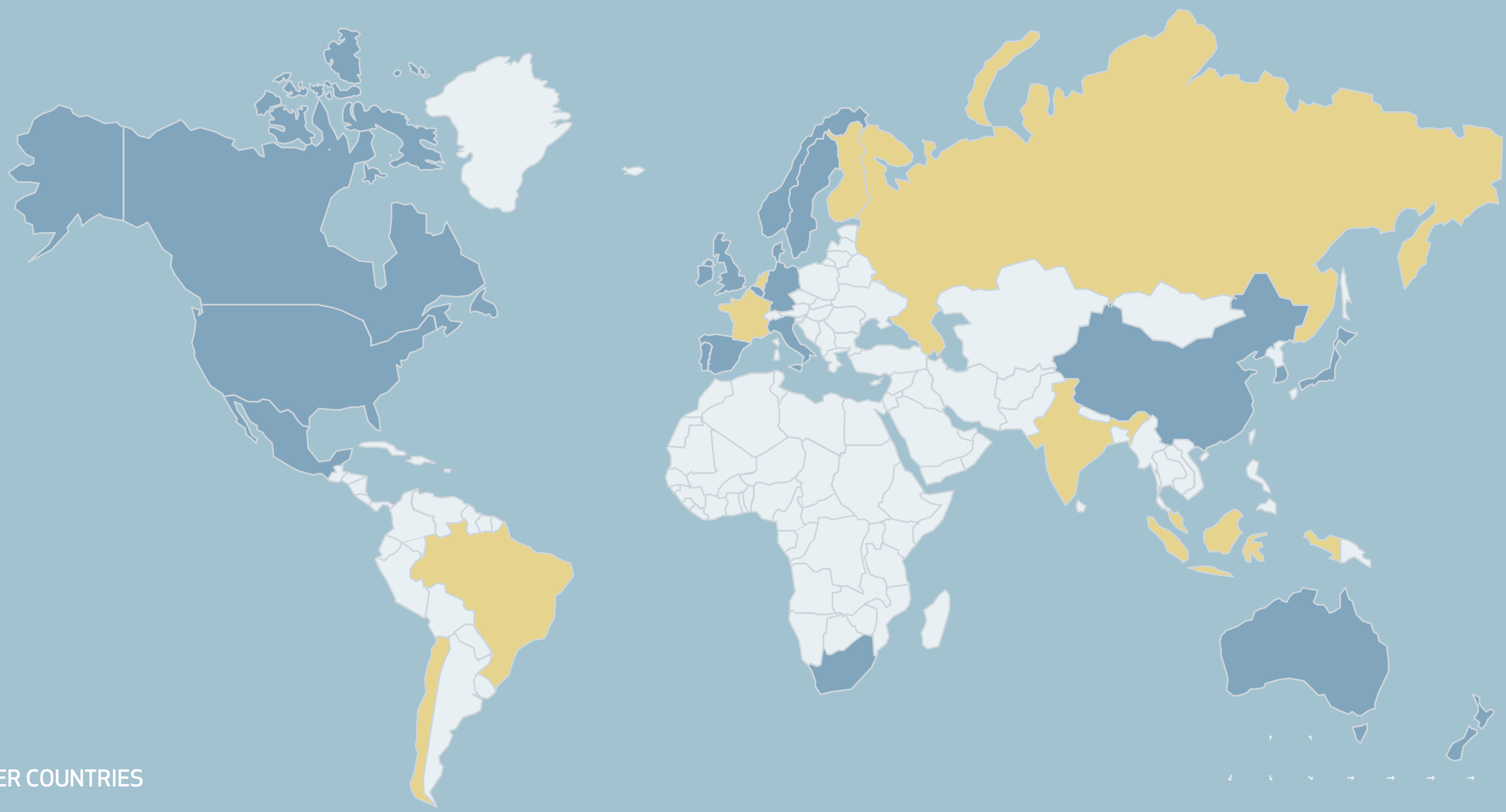
By 2050 ocean energy will have grown to 337 GW of installed wave and tidal energy capacity.

SOCIETAL GOAL

By 2050 ocean energy will have created 1.2 million direct jobs and saved nearly 1.0 billion tonnes of CO_2 emissions.

OES Membership

(as at 1 September 2012)



MEMBER COUNTRIES

OBSERVER COUNTRIES & COUNTRIES CURRENTLY INVITED TO JOIN OES

iea Energy Technology Network

The Ocean Energy Systems Implementing Agreement (OES) is the **Authoritative International Voice for Ocean Energy.** We collaborate internationally to accelerate the viability, uptake and acceptance of ocean energy systems in an environmentally acceptable way.

Who is OES?

AN AUTHORITATIVE INTERNATIONAL VOICE

The Ocean Energy Systems Implementing Agreement (OES) is an intergovernmental collaboration between countries, which operates under a framework established by the International Energy Agency in Paris. OES was founded by three countries in 2001 and has grown to its present 19 country governments.

National governments appoint a Contracting Party to represent it on the Executive Committee (ExCo). The Contracting Party can be a government ministry or agency, a research institute or university, an industry association or even a private company. Membership is by invitation and payment of an annual subscription fee.

The representatives meet every 6 months to review the work of the ExCo. Project work is undertaken through Annexes (to the OES contract), which are project teams formed from the government representatives to address specific issues of interest to the parties, and Activities (shorter term projects). Membership of the annexes is usually voluntary and participation is by cost-sharing and task-sharing.

The strength of OES is that it is an intergovernmental and multi-national organization, which lends it an ***Authoritative International Voice***. The diverse backgrounds of its ExCo ensure that all points of view can be represented at meetings – from central governments to marine energy project developers. Working collaboratively, the ExCo and Annex teams can achieve more through pooled capital, resources and efforts. There is a natural transfer of current experience and knowledge on ocean energy issues, whether it is R & D topics, policy initiatives or device developments.

Why Ocean Energy?

Utilization of ocean energy resources will contribute to the world's future sustainable energy supply. Ocean energy will supply electricity, drinking water and other products at competitive prices, creating jobs and reducing dependence on fossil fuels. It will reduce the world energy sector's carbon emissions, whilst minimizing impacts on marine environments.

THE OES VISION FOR INTERNATIONAL DEPLOYMENT OF OCEAN ENERGY

Worldwide, there is the potential to develop 337 GW of wave and tidal energy by 2050 and possibly as much again from Ocean Thermal Energy Conversion. Developments will be in locations with high resource availability. The cumulative rate of growth to 337 GW of installed wave and tidal energy between 2030 and 2050 is comparable with the growth of offshore wind over the last 20 years. Although modelling stopped in 2050, we would expect marine energy to continue to grow in successive years.

Deployment of ocean energy can provide significant benefits in terms of jobs and investments. By 2050, the ocean energy deployment described in this Vision could create 1.2 million direct jobs.

The global carbon savings achieved through the deployment of ocean energy could also be substantial. By 2050 this level of ocean energy deployment could save nearly 1 billion tonnes of CO_2.

OES GLOBAL OCEAN ENERGY DEPLOYMENT VISION [1]	2050
Installed Capacity (GW) [2]	337
Direct Jobs [3]	1.2 MILLION
Investment in 2050 year (US$) [4]	61.8 BILLION
Carbon Savings (tonnes of CO_2) [5]	1.0 BILLION

[1] IEA, 2012. Energy Technology Perspectives: Pathways to a Clean Energy Future. IEA, Paris, June 2012.

[2] Source: ETP 2012 2° scenario with high renewable variant.

[3] Source: REN21, 2012: Renewables 2012; Global Status Report. Paris, REN21 Secretariat.

[4] Source: As for 3 above.

[5] Source: Carbon savings calculated from deployment figures in ETP 2012 and global power sector carbon intensity projection out to 2050 from the IEA's ETP 2010.

World Energy Supply and Demand[6]

Global primary energy consumption in 2008 was 143,851 TWh.

Total renewable power generation capacity increased from 1,300 GW in 2010 by 8% to 1,360 GW in 2011, of which 29% (390 GW) came from non-hydro renewables. Not surprisingly, wind (40%) and solar PV (30%) exceeded new hydro installations (25%).

The share from fossil fuels (oil, coal and natural gas) will drop from 81.1% to 75% in 2035, whilst renewables share will grow from 12.8% to 18% by 2035. Demand for each fuel source is steadily increasing and, for the past decade, coal has been the fastest-growing global energy source, meeting 47% of new electricity demand.

Primary energy demand is forecast by 33% between 2010 and 2035 with 90% of that growth coming from non-OECD countries due to faster rates of growth of economic activity, industrial production, population and urbanisation. In 2000 Chinese energy use was only half that of the United States but, in 2009, China had overtook the US to become the world's largest energy user. By 2035 China will consume nearly 70% more energy than the US, although per capita energy use will still be half that of the US.

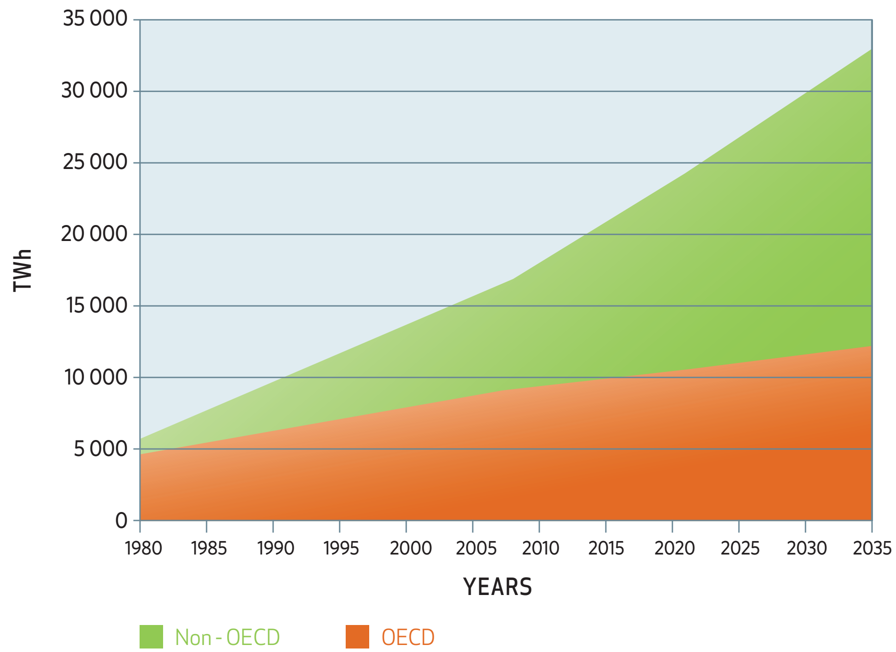
Due to global recognition of anthropological effects on climate change, an increasing amount of attention is being paid to energy production from renewable energy sources and low-carbon technologies. Other motivations for this shift include increasing oil prices, energy security, industrial competitiveness, local economic development and other environmental impacts such as urban air pollution. The renewable energy market has seen 30-40% growth rates in recent years, due to market-creating policies and cost reductions. For the first time, in 2010, more money was invested in renewable energy than in conventional generation. Subsidies for renewables is forecast to grow from $66 billion in 2010 to $250 billion by 2035, compared with $409 billion of subsidies for fossil fuels in 2010.

World electricity consumption has been projected to grow by 2.5% per annum between 2008 and 2035 from 16,819 TWh to 32,922 TWh (Figure a), assuming that current national energy policies remain unchanged.

In 2008, over 3,700 TWh of power was produced globally using renewable sources of energy. This is expected to triple to 9,000 TWh by 2035, assuming current policies remain unchanged. However, introduction of policies, which would reduce CO_2 emissions and improve end-use energy efficiency, could lead to further increases, 11,000 – 14,500 TWh (Figure b). Renewable energy accounted for nearly half of the estimated 208 GW of new electrical generation capacity installed in 2011 and the share of non-hydro renewables rose from 10% in 2004 to 37% in 2011. Wind energy has enjoyed rapid growth for the last fifteen years with installed capacity, increasing from 17 GW in 2000 to 238 GW in 2011.

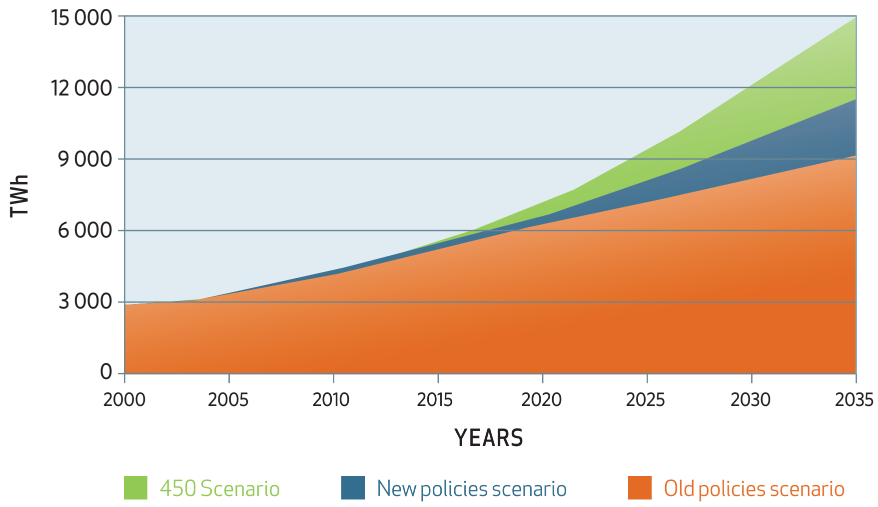
During 2011 the installed capacity of ocean energy more than doubled due to the commissioning of the Sihwa Lake Tidal Power Plant, near Seoul, South Korea, in August 2011. Whilst the rate of growth of ocean energy is otherwise relatively slow at present, modelling undertaken for this report indicates that ocean energy may experience similar rates of rapid growth between 2030 and 2050 as offshore wind has achieved in the last 20 years.

Figure a WORLD ELECTRICITY DEMAND 1980 - 2035



Source: IEA's World Energy Outlook 2010, table 7.1, IEA, Paris

Figure b **WORLD ELECTRICITY GENERATION FROM RENEWABLES**



Source: IEA's World Energy Outlook 2010, figure 10.2, IEA, Paris

[6] This section has been compiled from the following documents:
IEA, 2010. World Energy Outlook 2010. IEA, Paris, November 2010.
IEA, 2011: World Energy Outlook 2011. IEA, Paris, November 2011.
REN21, 2012: Renewables 2012; Global Status Report. Paris, REN21 Secretariat.
IEA, 2012: Energy Technology Perspectives 2012. IEA, Paris, June 2012.

Ocean Energy Resources

The oceans contain 97% of the earth's water and 71% of the earth's surface is covered by seawater. Approximately 3 billion people live within 200 km of the coast and migration is likely to cause this number to double by 2025. Therefore, marine energy resources offer ready potential for delivery of power, drinking water and other products to coastal markets.

Ocean energy resources are contained in:

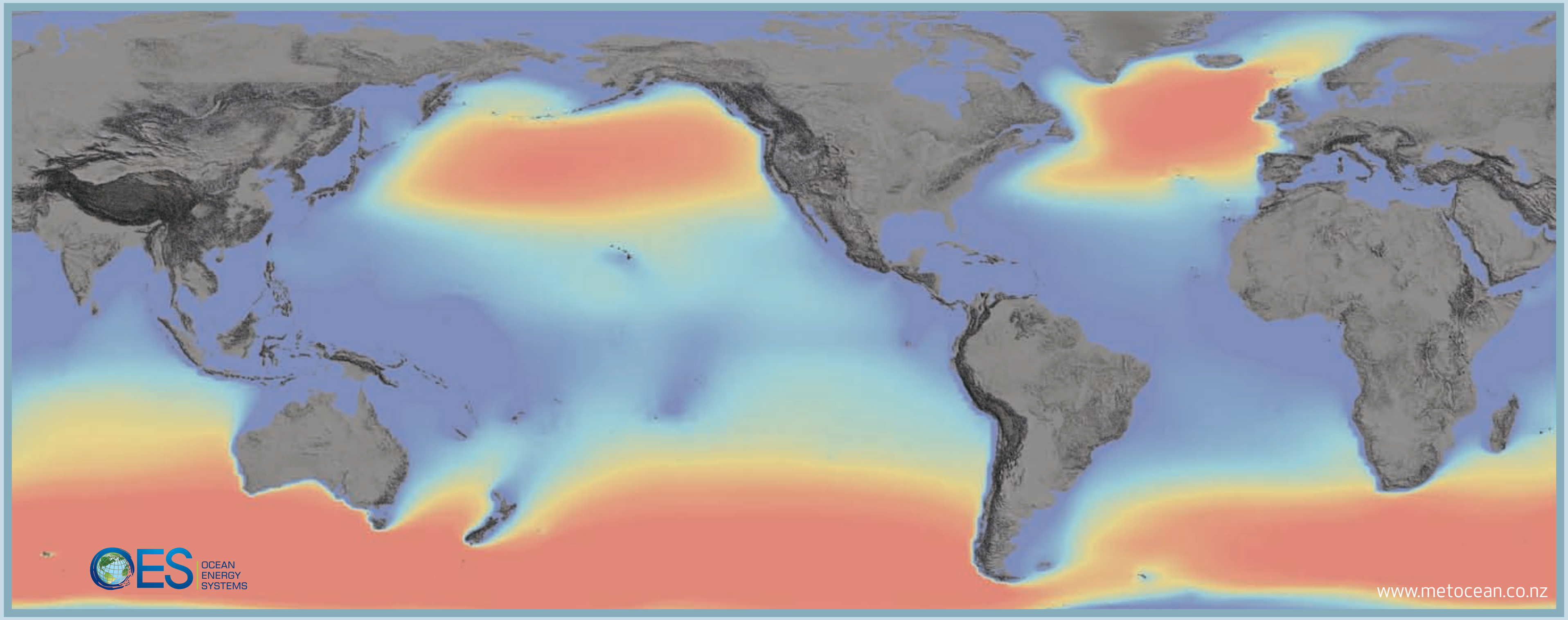
1. Ocean waves & swells	4. Ocean currents
2. Tidal range (rise & fall)	5. Ocean thermal energy
3. Tidal currents	6. Salinity gradients

These ocean resources are vast but not evenly distributed (see the following maps). Wave energy tends to be greatest at higher latitudes, whilst ocean thermal energy is distributed about the equator. Salinity gradients and tidal range are more patchily distributed. The key point is that some form of ocean energy is available at every coast and often more than one form could supply local power needs. These different forms of ocean energy can be harnessed to produce electricity, drinking water, heat, hydrogen or bio-fuels.

Tidal Currents and Ocean Currents

The movement of ocean water volumes, caused by the changing tides, creates tidal current energy. Kinetic energy can be harnessed, usually nearshore and particularly where there are constrictions, such as straits, islands and passes. Tidal current energy results from local regular diurnal (24 hours) or semi-diurnal (12+ hours) flows caused by the tidal cycle. Tides cause kinetic movements, which can be accelerated near coasts, where there is constraining topography, such as straits between islands.

Open ocean surface currents are driven by latitudinal distributions of winds (clockwise in the northern hemisphere and anti-clockwise in the southern hemisphere). They tend to operate at shallow depths (<800 m) and are slower but more continuous flows than tidal currents.

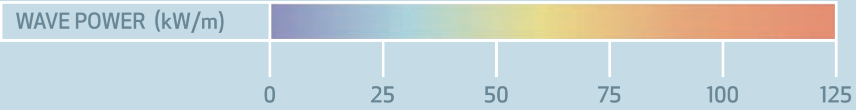


Wave Power

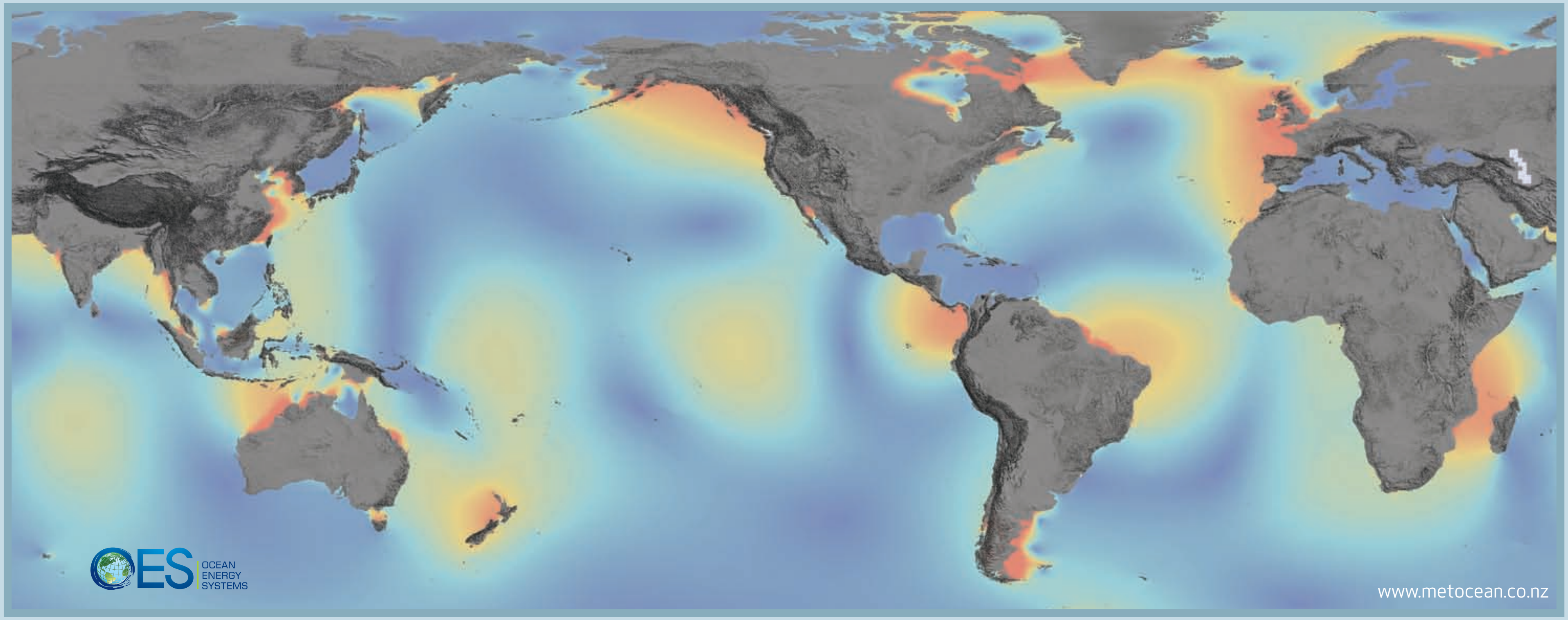
Waves are created by the action of wind passing over the surface of the ocean. Wave heights and thus energy are greatest at higher latitudes (greater than 40° from the equator), where the trade winds blow across large stretches of open ocean and transfer power to the sea swells. West-facing coasts of continents tend to have better wave energy resources.

The map has been shaded to enhance the wave power flux between 15 - 75 KW/m, which is the likely operational range of wave energy converters.

The worldwide theoretical potential of wave power has been calculated as 29,500 TWh / year [7].



[7] Mork, G., Barstow, S., Pontes, M.T. and Kabuth, A., 2010. Assessing the global wave energy potential. In: Proceedings of OMAE2010 (ASME), 29th International Conference on Ocean, Offshore Mechanics and Arctic Engineering, Shanghai, China, 6 – 10 June 2010.



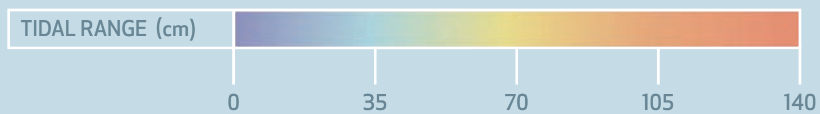
Tidal Range

Tidal range energy is potential energy derived by height changes in sea level, caused by the gravitational attraction of the moon, the sun and other astronomical bodies on oceanic water bodies. The effects of these tides are complex and most major oceans and seas have internal tidal systems.

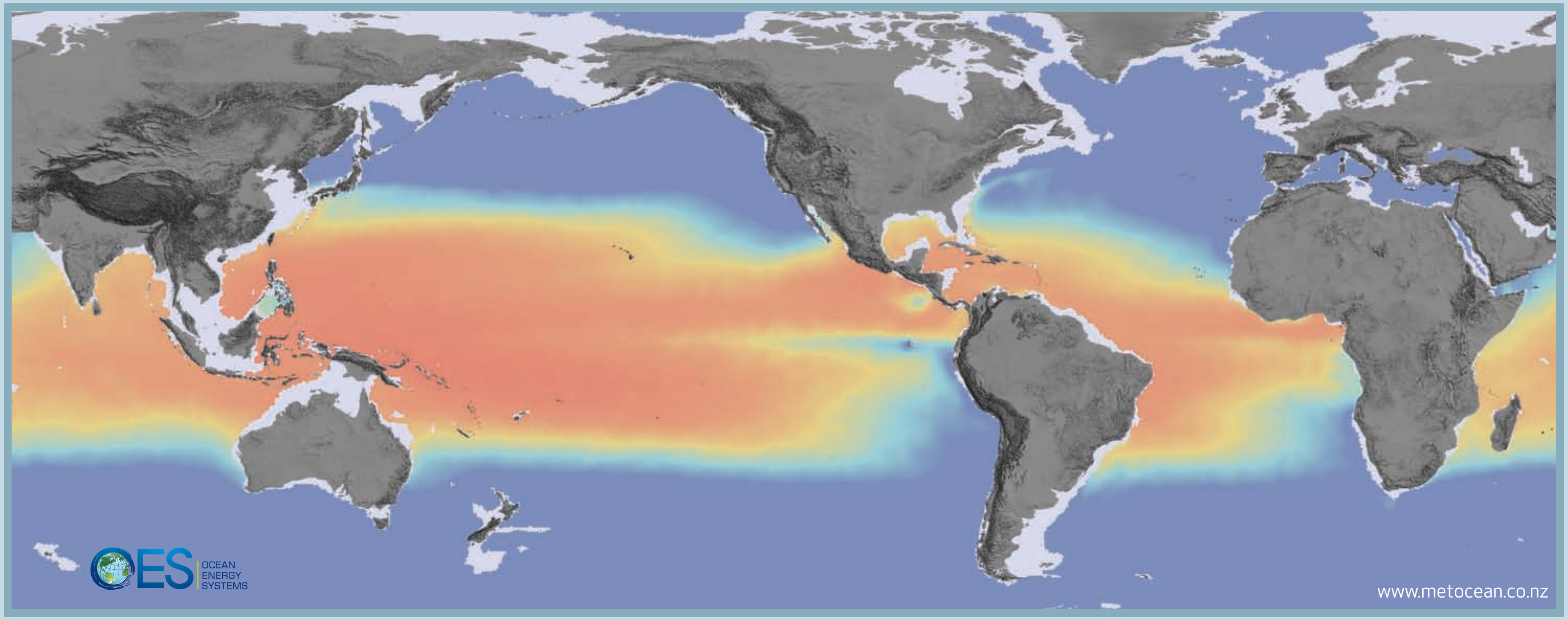
The rise and fall of the tide (range) offers the opportunity to trap a high tide, delay its fall behind a barrage or fence, and then exhaust the potential energy before the next tidal cycle.

The map shows the global pattern of the M2 tidal constituent, the principal lunar semidiurnal component. Note that the range is usually significantly amplified nearshore, so that tidal ranges may reach as much as 17 m in the Bay of Fundy (eastern Canada).

The worldwide theoretical power of tidal power (including tidal currents) has been estimated at around 1,200 TWh / year [8].



[8] World Energy Council, 2010.

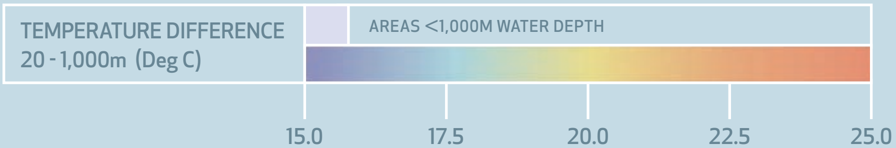


Ocean Thermal Energy

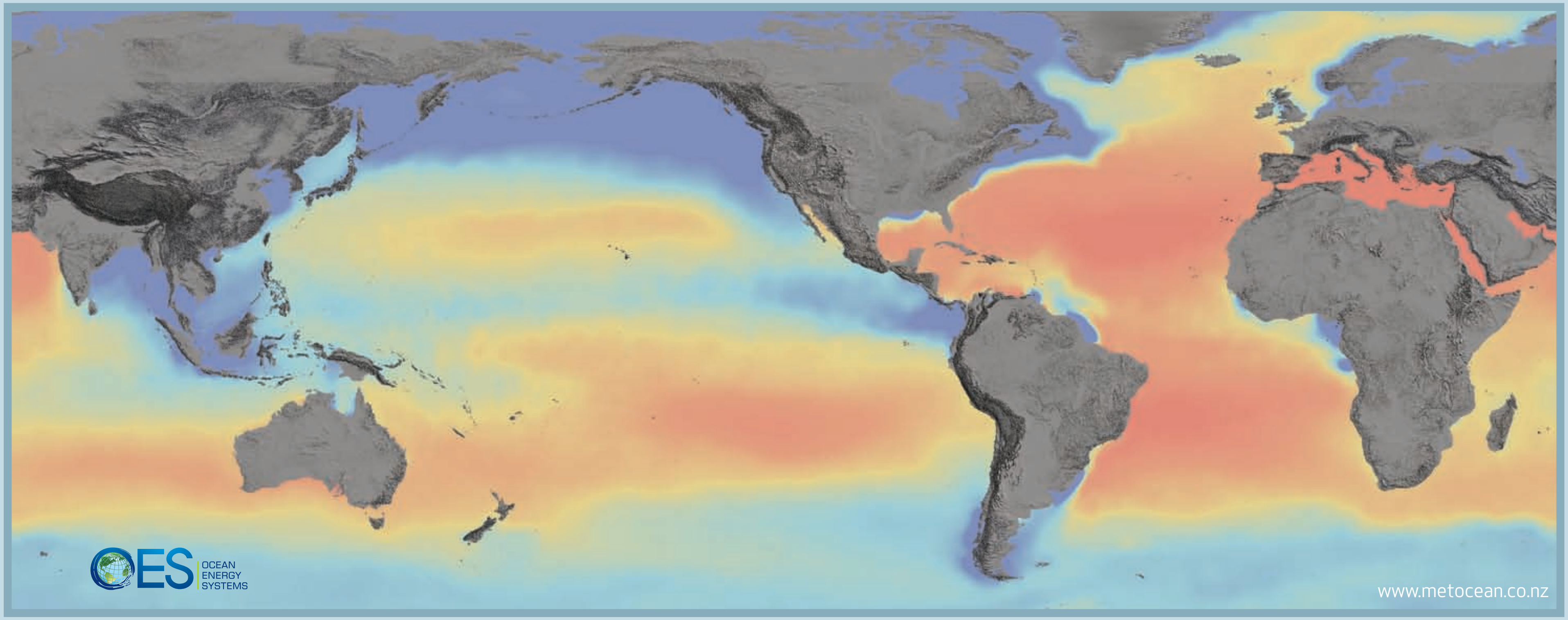
Ocean thermal energy arises from the temperature difference between near-tropical surface seawater, which may be more than 20° C hotter than the temperatures of deep ocean water, which tends to be relatively constant at about 4° C. Bringing large quantities of this cold seawater to the surface enables a heat exchange process with the warmer surface waters, from which energy can be extracted.

The map shows the temperature difference between waters at 20m and 1,000m depths.

The worldwide theoretical potential of ocean thermal power conversion has been conservatively estimated at 44,000 TWh / year [9].



[9] Nihous, G.C., 2007. A preliminary assessment of ocean thermal energy conversion resources. Journal of Energy Resources Technology, 129, page 10 – 17 (March, 2007).

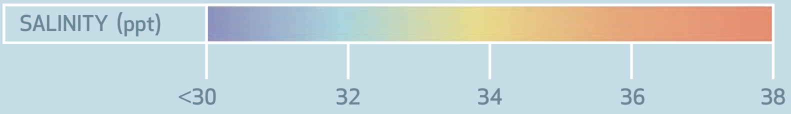


Salinity Gradient Power

Seawater is approximately 200 times more saline than fresh river water, derived from rain, snowmelt and groundwater, which is delivered to the coast by major rivers. Global salinity differences arise from submarine and surface current movements. The relatively high salinity of seawater establishes a chemical pressure potential with fresh river water, which can be used to generate electricity. Salinity gradient power thus has its greatest potential at the mouths of major rivers, where large volumes of fresh water flow out to sea.

Fresh water has salinity values of less than 0.5 ppt (parts per thousand), whereas seawater has salinities of 30-50 ppt. The map shows sea surface salinity rather than the gradient between seawater and fresh river water. Major rivers, such as the Amazon and the Congo produce much less saline waters at their river mouths.

The worldwide theoretical potential for osmotic power has been estimated at 1,650 TWh / year [10].



[10] Scramesto, O.S., Skillhagen S.-E. and Nielsen, W.K., 2009. Power production based upon osmotic pressure. In: Waterpower XVI, Spokane, WA, USA; 27 – 30 July 2009.

Ocean Energy Technologies

Wave Energy

Wave power captures kinetic and potential energy from ocean waves to generate electricity. Wave energy converters (WECs) are intended to be modular and deployed in arrays. At present there is little design consensus for wave energy devices with no industry standard device concept. Due to the diverse nature of the wave resource it appears unlikely that there will be one single device concept that is used, rather a small number of device types that exploit different regions of this vast resource.

DEVICE TYPE	ATTENUATOR	OVERTOPPING	OSCILLATING WATER COLUMN (OWC)	POINT ABSORBER	OSCILLATING WAVE SURGE CONVERTER (OWSC)
DESCRIPTION	Attenuator devices are generally long floating structures aligned in parallel with wave direction, which then absorbs the waves. Its motion can be selectively damped to produce energy.	Overtopping devices are a wave surge/focusing system, and contains a ramp over which waves travel into a raised storage reservoir.	In an OWC, a column of water moves up and down with the wave motion, acting as a piston, compressing and decompressing the air. This air is ducted through an air turbine.	A point absorber is a floating structure absorbing energy from all directions of wave action due to its small size compared to the wavelength.	An OWSC extracts energy from the surge motion in the waves. They are generally seabed-mounted devices located in nearshore sites.
DIAGRAM					

Figure c: Classification of wave energy converters

Tidal Currents

Tidal current power captures the kinetic energy of the moving water of the tide. Several different tidal current energy converter device technology concepts have been proposed and developed in recent years (Figure d). The main differences between concepts relate to the method of securing the turbine in position, the number of blades and how the pitch of the blades is controlled. Tidal current devices are generally modular and intended for deployment in 'arrays' for commercial use in order to obtain a significant combined energy output (similar to the onshore wind approach).

DEVICE TYPE	HORIZONTAL AXIS TURBINES	VERTICAL AXIS TURBINES	OSCILLATING HYDROFOIL
DESCRIPTION	These devices have two or three blades mounted horizontally to form a rotor; the kinetic motion of the water current creates lift on the blades causing the rotor to turn driving an electrical generator.	These devices generally have two or three blades mounted along a vertical shaft to form a rotor; the kinetic motion of the water current creates lift on the blades causing the rotor to turn driving an electrical generator.	This device operates like an aeroplane wing but in fluid; control systems alter their angle relative to the water current, creating lift and drag forces that create device oscillation; this physical motion from this oscillation feeds into a power conversion system.
DIAGRAM			

Figure d: Classification of tidal current devices

Tidal Range (Tidal Rise and Fall)

Tidal energy can also be captured based on the potential energy of the difference in the height of water at high and low tides. Technologies such as tidal barrages are used to convert this energy into electricity. The 240 MW tidal barrage at La Rance in northern France has been in operation since 1967. The new 254 MW tidal barrage at Sihwa Lake near Seoul in the Republic of Korea began operations in August 2011 (Figure e).

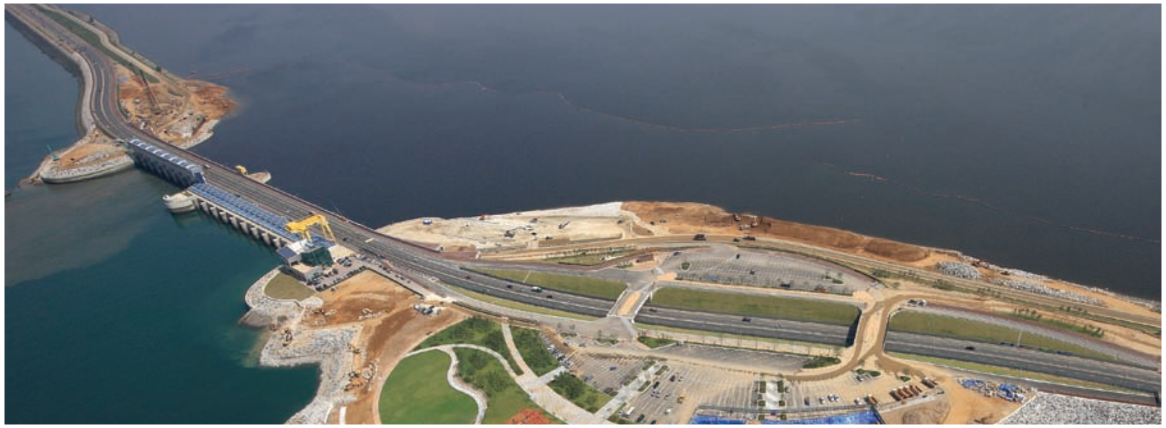


Figure e: Sihwa Lake Tidal Power Station, Korea

Ocean Currents

Ocean currents are the constant flows of water around the oceans. These currents always flow in one direction and are driven by wind, water temperature, water salinity and density amongst other factors. They are part of the thermo-haline convection system, which moves water around the world (Figure f). Ocean current energy technologies are being developed to capture the kinetic energy carried in this constant flow of water. The primary design concepts for ocean current energy are based on water turbines, deployed in arrays.

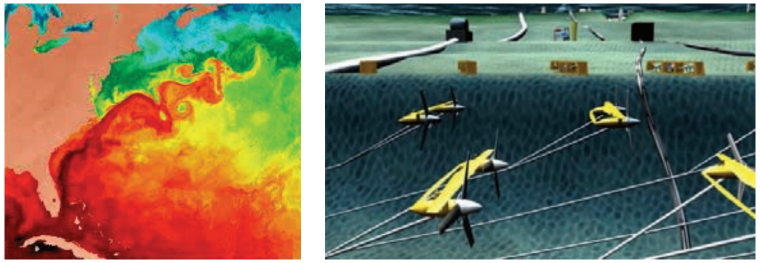


Figure f: Gulf Stream ocean current and energy converters (FAU)

Ocean Thermal Energy Conversion (OTEC)

OTEC is a technology to draw thermal energy from the deep ocean and convert it to electricity or commodities. This technology requires a temperature difference of 20° C between the warm surface water and cold deep water and, as such, is only possible in certain areas of the world; the tropics are the key area for this technology. The key uses for OTEC are to generate electricity, desalinate water, provide heating and cooling and support mariculture (Figure g).

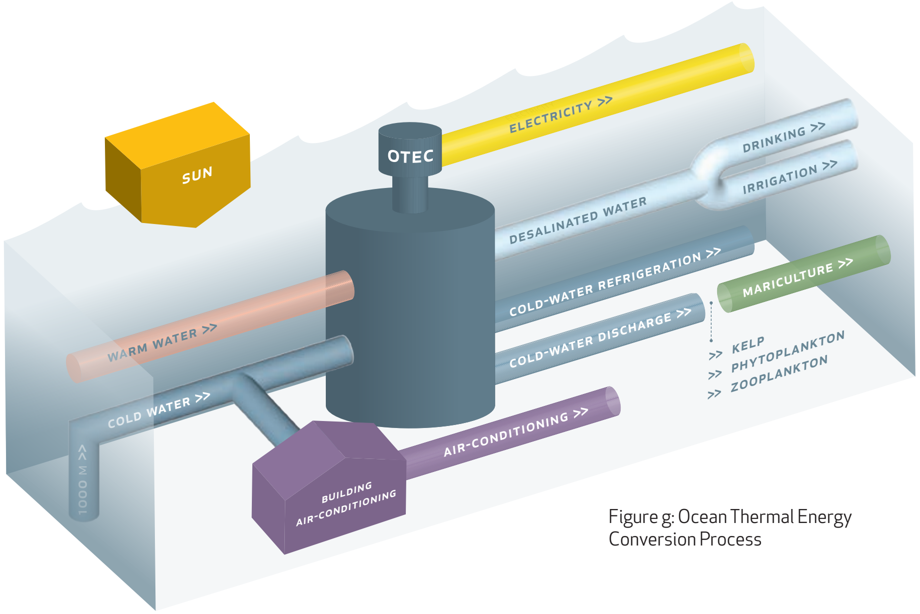


Figure g: Ocean Thermal Energy Conversion Process

Salinity Gradient Power

Salinity gradient power is energy from the chemical pressure difference; based on the difference in salt concentration between fresh water and salt water. As such, this can be exploited at the mouth of rivers where fresh water meets the saline water. There are two technologies being developed to convert this energy into electricity: pressure-retarded osmosis (PRO; Figure h) and reverse electrodialysis (RED).

Figure h: Statkraft Osmotic Power Station (Tofte, Oslo Fjord, Norway)

Learning and Cost Reduction in Ocean Energy Technologies

The learning rate of a technology is an expression of its cost reduction potential, usually expressed as the decrease in technology cost with each doubling of cumulative installed capacity. Technology cost reduction can be achieved through improved technical performance and the reduced production costs, which come with increasing installed capacity.

Multiple types of learning will occur for ocean energy technologies:

> **LEARNING BY ADAPTATION** *from applying lessons learnt from other technologies or industries to ocean energy.*

> **LEARNING BY DOING** *from experience of deploying technologies, and*

> **LEARNING BY INNOVATION** *from research and development,*

Cost reductions for ocean energy technologies will not be straightforward linear reductions over time: step-change reductions will occur due to scaling up in size, economies of scale and introduction of new innovative technologies are also likely.

As an example, the most up-to-date analysis of the effects of learning has been published by the Carbon Trust with the pertinent results graphically displayed in Figures i and j; these clearly show the beneficial effects of combining learning by doing with learning by research and learning by adaptation[1].

LEARNING BY DOING

The effects of learning by doing, that is, simply moving to a scaled-up manufacturing process will be insufficient to reduce the unit cost of electricity from wave and tidal energy technologies (and other ocean energy technologies) to be competitive with other forms of renewable power generation (red lines in Figures i and j).

LEARNING BY RESEARCH AND ACCELERATED INNOVATION

The Carbon Trust performed additional analysis on the effect, which technology innovation and learning by research could have on the unit costs of electricity generated from wave and tidal energy technologies. Additional cost reduction achieved by learning by research and accelerated innovation (blue lines in Figures i and j). By 2020, costs for electricity from wave energy are forecast to have declined to18p/kWh and, from tidal energy, to 16p/kWh. By 2025 cost reductions has reached the level of today's offshore wind (~15p/kWh) for both technologies.

This analysis clearly demonstrates the requirement for a balance of both technology push and market pull mechanisms to promote efficient and effective cost reductions.

[1] The cost reductions are indicative only and are based on a Carbon Trust assessment of the potential for deployment given the state of the present technology development and the UK Government's present energy plans and policies. The roll out scenarios have been developed from the Carbon Trust's analysis of the IEA Global Blue Map scenario and ESME and CCC model runs.

Figure i **WAVE:** POTENTIAL IMPACT OF INNOVATION ON LEVELISED COSTS OF ENERGY (MEDIUM GLOBAL DEPLOYMENT)

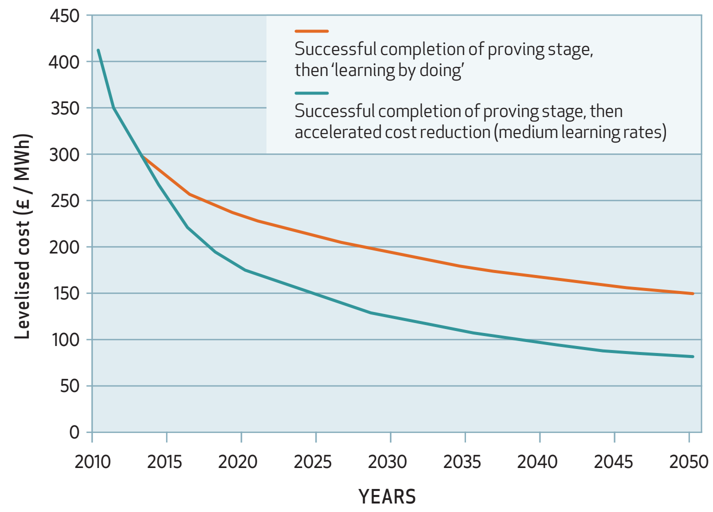
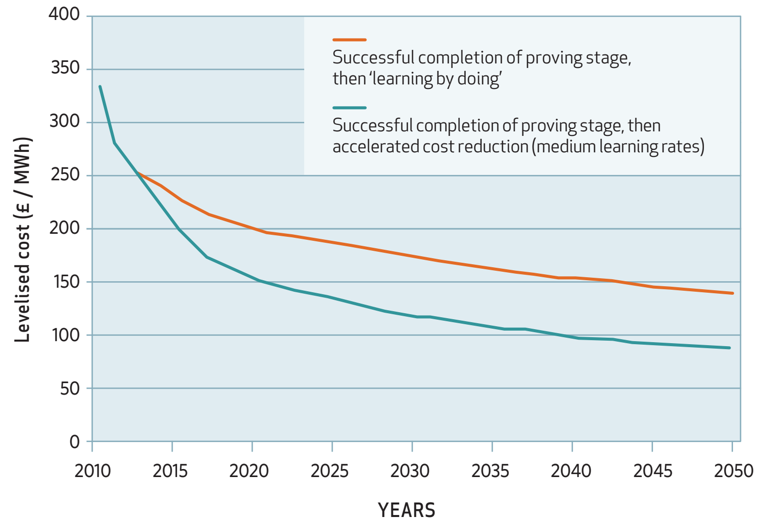


Figure j **TIDAL:** POTENTIAL IMPACT OF INNOVATION ON LEVELISED COSTS OF ENERGY (MEDIUM GLOBAL DEVELOPMENT)



Synergies with other Sectors and Benefits

BENEFITS OF OCEAN ENERGY

The resurgence of interest in marine energy arises from social and political changes requiring emissions reductions and replacement of fossil fuel generation with renewable energy generation. Governments around the world are setting renewable energy targets, both statutory and aspirational, whilst putting in place mechanisms and policies to secure greenhouse gas emissions.

Some forms of ocean energy, such as OTEC, salinity gradients and even waves may be constant enough for baseload electricity generation, whilst most forms of ocean energy are reasonably forecastable and reliable, such that both diversity and security of supply can be enhanced. Some forms of ocean energy will yield alternative products, including drinking water, heating, cooling and biofuels.

New industries may be created or transferred from declining industries, which will lead to creation of new jobs and/or promote investment in new skills and capabilities.

SYNERGIES WITH OTHER SECTORS

Future development of the ocean energy sector will be linked with developments in other sectors, such as offshore wind energy, exploiting positive synergies in technology developments (e.g., components), infrastructure, supply chain and policies.

There will be significant opportunities for co-location of technologies; for example, ocean energy and offshore wind energy, utilizing common platforms or wave/wave or wind/tidal hybrid systems. Mutual learning processes, shared infrastructure and innovations from a shared supply chain will be of great benefit to the future expansion of both the ocean energy sector and related sectors (Figure k).

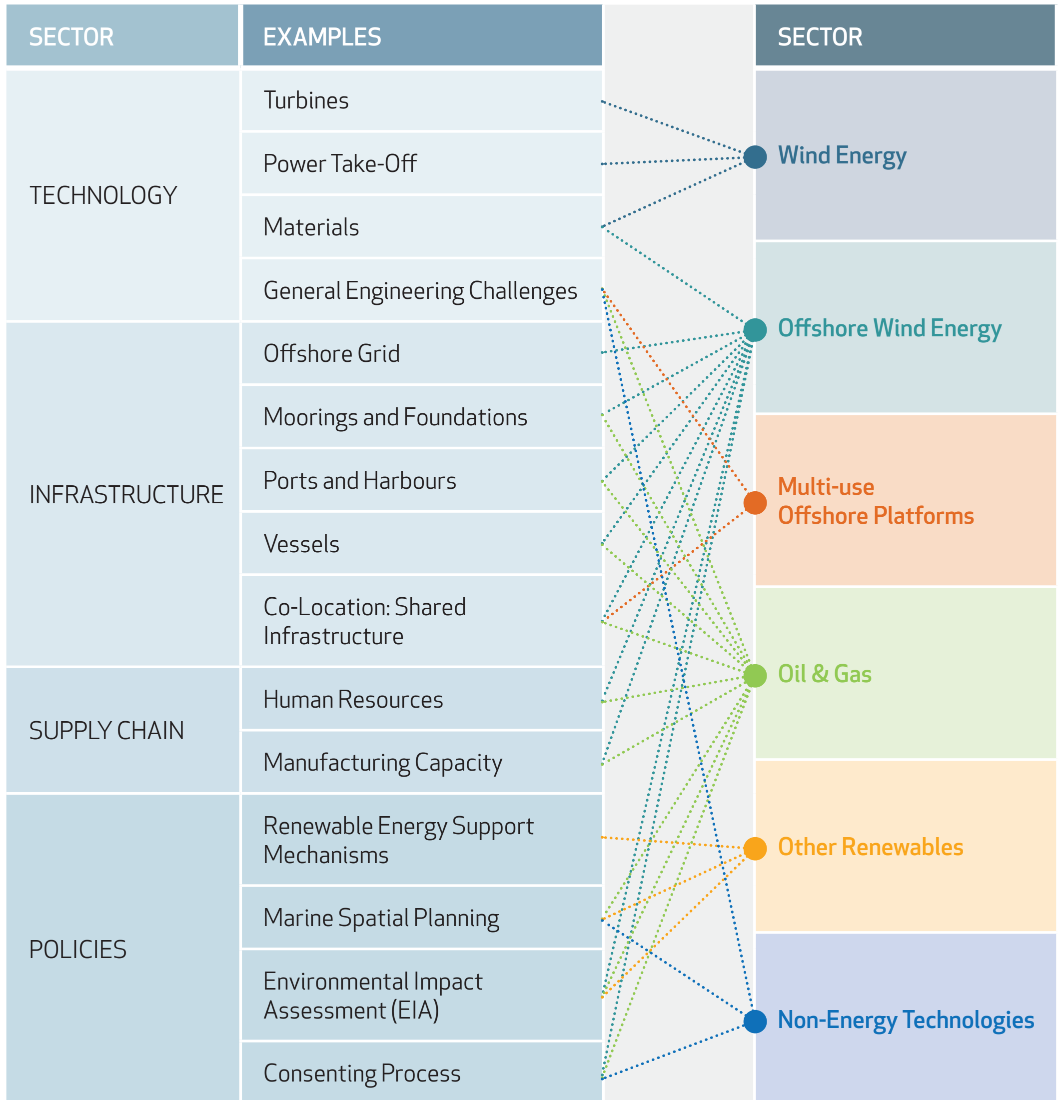


Figure k: Ocean energy synergies with other sectors

Markets for Ocean Energy

There are three key markets for ocean energy technologies: grid-connected electricity, off-grid power for remote communities and other uses, including desalination. These potential markets vary in size and also in terms of which ocean energy technologies are best suited to the market needs.

Figure l: Grid-connected electricity for utility-scale applications.

GRID-CONNECTED ELECTRICITY

The dominant market for ocean energy technologies will be electricity generation, both in terms of providing market pull for technology development and also in terms of the size of the market opportunity. Grid-connected electricity generation is the key market for which utility-scale ocean energy technologies are being developed (Figure l). Increasing demand for low-carbon renewable electricity is supporting the growth of the ocean energy sector. In some countries, legal obligations to meet renewable energy targets and carbon reduction targets provide additional incentives to develop electricity production from ocean energy. With many countries expecting to move towards highly electrified energy systems in the future, this market will continue to grow and will provide a significant opportunity for ocean energy technologies.

Figure m: Off-grid communities will utilize small-scale, stand-alone applications.

OFF-GRID POWER FOR REMOTE COMMUNITIES

Ocean energy technologies will provide locally produced, secure, competitively priced and low-carbon electricity supply for off-grid communities in remote coastal and island locations (Figure m). These remote off-grid areas are traditionally dependent on expensive imported fossil fuels, particularly diesel generators. Therefore, ocean energy could be an attractive alternative on both economic and environmental grounds. This niche market of remote off-grid communities is where ocean energy technology is likely to first reach grid parity (due to the high cost of alternative diesel generation). For example, remote communities could develop wave and in-river resources to produce electricity on-site.

This market also includes the potential for dedicated power production for remotely located demand applications, such as data centres. Data centres require high levels of both electricity supply and cooling capacity; both of which ocean energy technologies could supply.

Figure n: Drinking water may be an important product of ocean energy.

OCEAN ENERGY FOR OTHER USES – COOLING, HEATING AND DESALINATION FOR DRINKING WATER

Ocean energy technologies can be developed for a range of other uses, including seawater air conditioning, heating and desalination for drinking water (Figure n). Some wave power devices and Ocean Thermal Energy Conversion (OTEC) technologies will produce drinking water and heating/cooling. In communities where both clean energy and fresh drinking water are scarce commodities, an ocean energy and desalination plant could be a critical technology and important market opportunity. The expected growth in the desalination market between 2008 and 2016 is estimated to be worth US$64 billion .

Policies for Ocean Energy

National governments use many policy instruments to ensure and enable investment in new technologies, including marine energy technologies. These policies are intended to:

1. Accelerate the maturation of ocean energy technologies to commercial readiness
2. Make them cost-effective with regard to other renewable energy technologies.

The selection of appropriate policies by national governments depends upon the maturity of the ocean energy sector, their national supply/demand balance, energy system resilience and willingness to invest in new technologies. Figure o shows the range of policy instruments adopted by national governments in the OES countries to promote and accelerate ocean energy in their national waters.

Most countries in which marine energy technologies are currently being developed have renewable energy or renewable electricity generation targets, although a few have specific policies to promote ocean energy uptake. Similarly these countries use 'technology-push' mechanisms through capital grants or financial incentives to create early-stage opportunities. Fewer countries use market, industry or supply chain initiatives specifically for ocean energy developments.

Most of the more advanced countries are developing marine energy testing centres, of which the European Marine Energy Centre (EMEC) is the most well known. There is a growing network of wave and tidal energy testing centres, pilot zones and offshore hubs.

Lastly, specific space/resource allocation regimes have been developed for ocean energy and competitive permitting is likely to become more common. Competition for space from other users of marine space and resources is likely to grow quickly and forward planning processes, such as marine spatial planning, may benefit uptake of ocean energy.

POLICIES	DESCRIPTION
CAPACITY OR GENERATION TARGETS	
Legislated Targets	National targets for total energy or electricity production
Aspirational Targets And Forecasts	Non-legislated targets or forecasts for deployment of ocean energy technologies
CAPITAL GRANTS AND FINANCIAL INCENTIVES	
R&D Programs/Capital Grants	Grants to encourage innovative research into ocean energy technologies
Prototype Deployment Capital Grants	Grants to encourage deployment of prototype devices
Project Deployment Capital Grants	Grants for deployment of projects (usually matching funds)
Prizes	Prizes for achieving production targets from prototype devices
MARKET INCENTIVES	
Feed-In Tariffs	Guaranteed price (in $/kWh or equivalent) for ocean energy-generated electricity
Tradable Certificates and Renewables Obligations	Legislated requirements for electricity generators to invest in ocean energy-generated electricity
Tendering Processes	Tendering for capped supply from ocean energy-generated power
INDUSTRY AND SUPPLY CHAIN DEVELOPMENT	
Industry & Regional Development Grants	Cluster developments
Industry Association Support	Government financial support for establishment of industry associations
RESEARCH AND TESTING FACILITIES AND INFRASTRUCTURE	
National Marine Energy Centres	R & D and deployment centres
Marine Energy Testing Centres	Testing centres for prototype and pre-commercial device trials
Offshore Hubs & Pilot Zones	Consented sites with connection infrastructure for devices
RESOURCE ALLOCATION AND INDUSTRY STANDARDS	
Standards/Protocols	Development of international standards for wave, tidal and ocean currents
Permitting Regimes	Crown Estate competitive tender for Pentland Firth licences
Space/Resource Allocation Regimes	Department of Interior permitting regime in United States Outer Continental Shelf

Figure o: Policy options for ocean energy

Challenges for Uptake of Ocean Energy

Development of an international ocean energy industry presents significant opportunities for new participants and for existing suppliers in related supply chains, e.g., offshore oil and gas, offshore wind energy and other forms of renewable energy. However, there are challenges to meet and overcome in order to manage to achieve the full potential of the industry. These challenges include creation of a supportive policy environment, industry development, market development, technology development through continued R & D, improved understanding of environmental effects and a clear and supportive planning framework.

Each country, for which ocean energy is a potential supply option, either for domestic production and/or equipment export, must consider these broad challenges and identify appropriate solutions for their national and regional circumstances. For instance, in the UK this was done in the Marine Action Plan 2010, which identifies critical challenges and makes recommendations with regards to who needs to do what actions in order to achieve ambitious deployments of marine energy in the UK. Meanwhile Germany has only moderate wave and tidal energy resources but these technologies offer opportunities for export.

Electricity market access in each country will be influenced by existing and future supply portfolios, emissions targets and ease of grid connection. The last may be influenced by the ability to forecast electricity from ocean power generation and to match it, possibly via hybrid or storage systems, to demand profiles. A key element will be recognition of and accounting for externalities of fossil fuel generation, such as emissions reduction targets and/or carbon taxes.

A crucial element to the uptake of ocean energy must be the limitation and management of environmental effects of ocean energy technologies. The reduction of environmental effects relative to present forms of energy generation must be demonstrable and sustainable. Some forms of renewable energy generation are already being questioned as potentially unsustainable.

Lastly, integrated approaches to planning for ocean energy will emerge as increasing demand for ocean space and resources require more holistic approaches, such as marine spatial planning. Ocean energy may integrate well with other ocean-based activities, e.g., wave and tidal turbine arrays may become de facto marine reserves.

The particular challenges will vary across countries and regions but there are a range of solutions and recommendations, which can aid in overcoming the broad challenges of this emerging sector. Examples of potential solutions being discussed and developed for the ocean energy sector around the world are identified in Figure p.

CHALLENGES	POTENTIAL SOLUTIONS AND RECOMMENDATIONS
POLICY ENVIRONMENT	• Development of an integrated policy framework with ocean energy specific regulations • International guidelines and standards • Regulatory reform and planning leading to efficient and appropriate consenting processes
INDUSTRY DEVELOPMENT	• Strategic supply chain planning, development and growth • Ocean energy infrastructure development • Technical and professional workforce training and development
MARKET DEVELOPMENT	• Development of appropriate tariff support mechanisms to provide clear market signals to the investment community. • Appropriate electricity market access and grid connection access
TECHNOLOGY DEVELOPMENT	• Prototype devices need to be very robust to withstand the marine environment • Demonstration and testing facilities • Research and innovation support and enabling technology support to facilitate cost reduction and performance improvement
ENVIRONMENTAL EFFECTS	• Establish an improved understanding of baseline environment • Strategic environmental research which is enabled by sharing of environmental data • Consider adoption of deploy and monitor schemes to facilitate sector progression • Familiarity in affected communities
PLANNING FRAMEWORK	• Marine spatial planning leading to the development of common approaches to space and resource allocation.

Figure p: Challenges for the ocean energy industry

OES's Strategic Plan

What is OES's Role?

The OES Executive Committee has considered all of the opportunities, synergies, markets, policies and challenges for ocean energy and devised a 5-year Strategic Plan. The Mission set out in this Plan will see OES becoming an ***Authoritative International Voice for Ocean Energy***, working to promote and accelerate the uptake of ocean energy as a sustainable energy supply option.

What is OES's Mission ?

As the ***Authoritative International Voice for Ocean Energy*** we collaborate internationally to accelerate the viability, uptake and acceptance of ocean energy systems in an environmentally acceptable way.

What actions will OES take to deliver its Goals and the International Vision for Ocean Energy ?

The OES Executive Committee has developed a Strategic Plan and a Communications Plan, which have the following actions to:

CONNECT - organisations and individuals working in the ocean energy sector to accelerate development and enhance economic and environmental outcomes.

EDUCATE - people globally on the nature of ocean energy systems, the current status of development and deployment, and the beneficial impacts of such systems, improve skills and enhance research.

INSPIRE - governments, agencies, corporates and individuals to become involved with the development and deployment of ocean energy systems.

FACILITATE - education, research, development and deployment of ocean energy systems in a manner that is beneficial for the environment and provides an economic return for those involved.

In order to achieve the aims of its 5-year Strategic Plan and its Communications Plan, the Executive Committee has recognized four critical success factors, which will enable it to deliver the ***International Vision for Ocean Energy.***

How does OES's Vision for Ocean Energy translate into actions over the next 5 years?

The OES Executive Committee has developed a Vision for its own future, based upon new organisational and brand values. Successful delivery of its Vision will depend on four critical success factors (Figure q):

1. High Quality Information
2. Strong and Effective Communications
3. Effective Organization
4. Shared Capability Growth

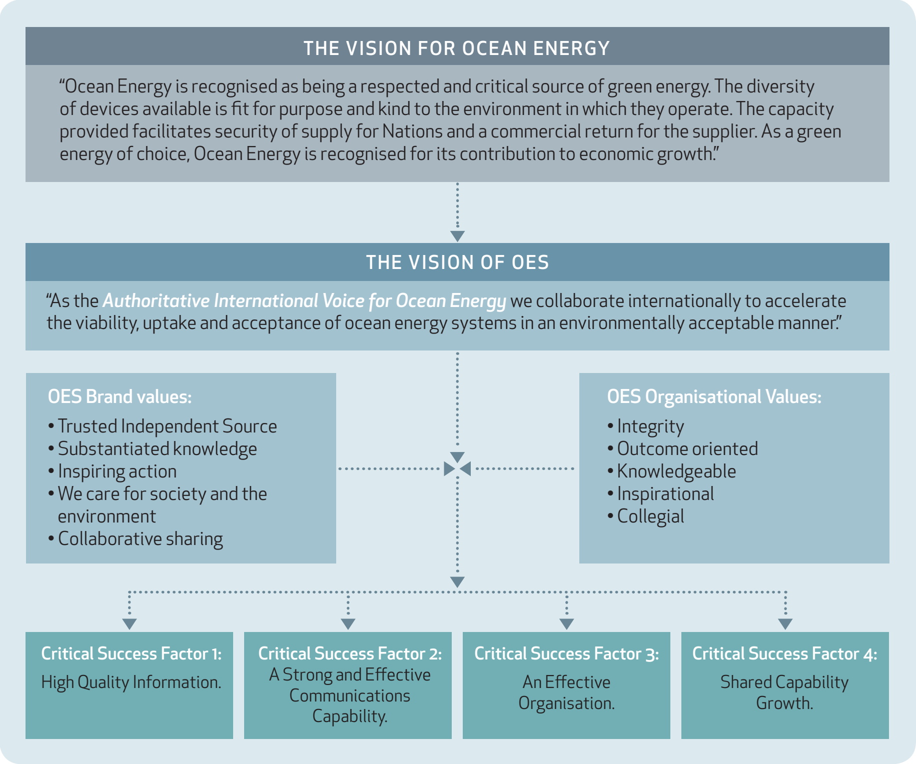


Figure q: OES's Vision and Critical Success Factors

An International Vision for Ocean Energy

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OCEAN ENERGY SYSTEMS

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INDUSTRIAL GOAL

By 2050 ocean energy will have grown to 337 GW of installed wave and tidal energy capacity.

SOCIETAL GOAL

By 2050 ocean energy will have created 1.2 million direct jobs and saved nearly 1.0 billion tonnes of CO_2 emissions.