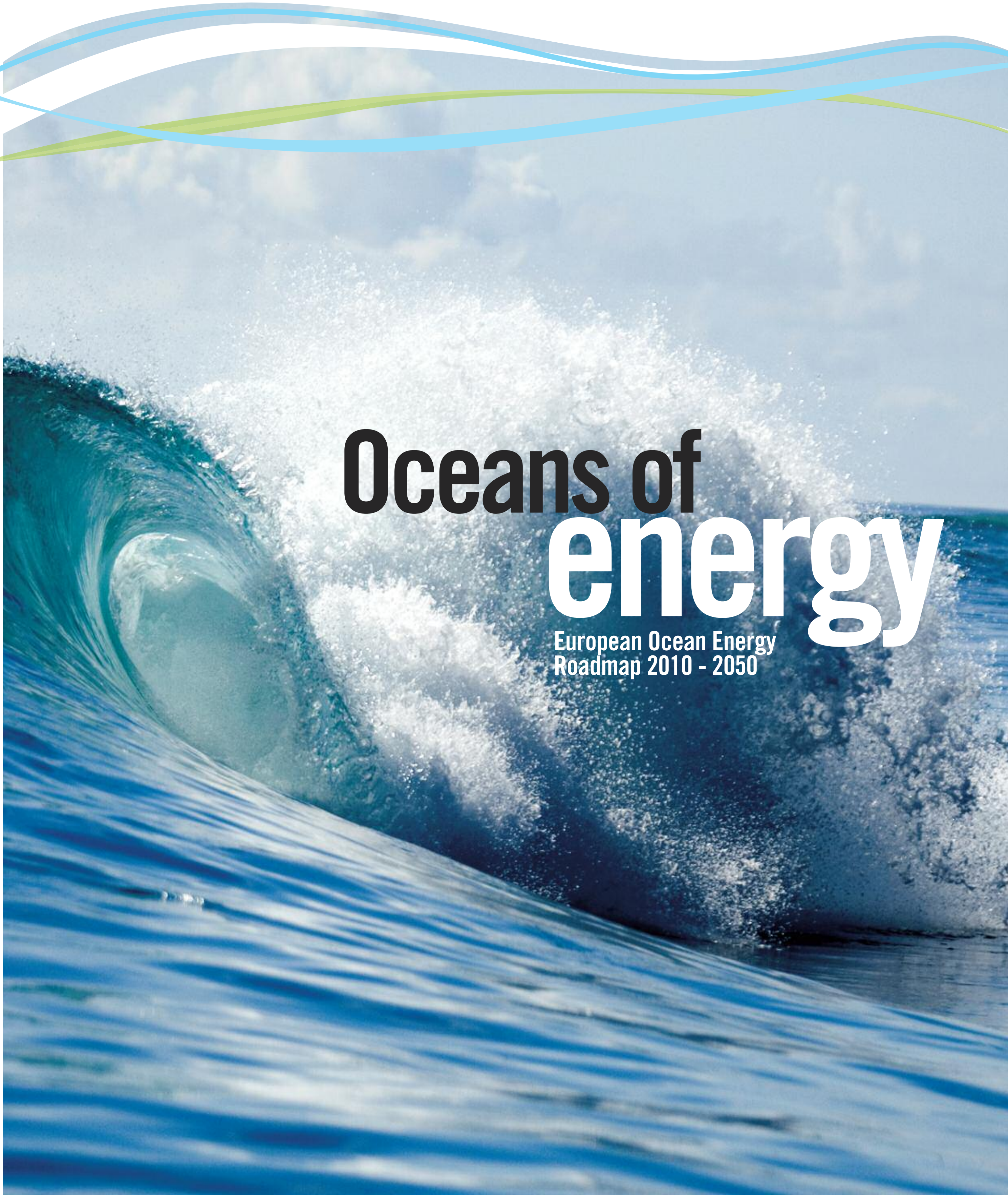
EUROPEAN
ocean energy
ASSOCIATION



Oceans of energy

European Ocean Energy Roadmap 2010 - 2050

Acknowledgement

The European Ocean Energy Association (EU-OEA) would like to thank the European Commission's Directorate General for Energy (DG ENER) for providing the funding that made this Roadmap a reality. The development of the Roadmap has helped to define the concrete actions necessary to achieve the next set of milestones on the path to commercialisation of ocean energy in Europe.

The Association would like to extend its appreciation to those who have contributed to the preparation of this Roadmap.

In particular:

- The Board of EU-OEA;
- The Members of the EU-OEA;
- The Roadmap Workshop participants;
- The ocean energy sector key stakeholders;
- Industry representatives;
- Ocean energy experts;
- Representatives of national organisations dealing with ocean energy;
- Representatives of European bodies;
- Ocean energy technology developers.

In addition to these contributions, a number of reports related to offshore renewables and ocean energy were used, such as: The Carbon Trust's "MARINE ENERGY CHALLENGE"; the Forum for Renewable Energy Development in Scotland's (FREDS) Marine Energy Group's (MEG) "MARINE ENERGY ROADMAP"; The European Wind Energy Association's (EWEA) 2007 report "DELIVERING OFFSHORE WIND POWER IN EUROPE" and 2009 report "OCEANS OF OPPORTUNITIES"; The British Wind Energy Association's (now known as RenewableUK) "THE BENEFITS OF MARINE TECHNOLOGIES WITHIN A DIVERSIFIED RENEWABLES MIX" and "MARINE RENEWABLE ENERGY, STATE OF THE INDUSTRY REPORT – October 2009".

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Oceans of energy European Ocean Energy Roadmap 2010-2050
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Foreword

European policy-makers are facing a challenging strategy – a balancing act of combating climate change and securing the energy supply, while ensuring global cost competitiveness. The ocean can become a major element of this strategy: ocean energy. Europe has the oldest maritime industry, vast ocean energy resources and it is a pioneer in ocean energy technologies. It is well positioned to lead the world in harvesting ocean energy. Now is the time for the EU to act in a coordinated manner in order to develop these technologies to their full potential and consequently export them around the globe.

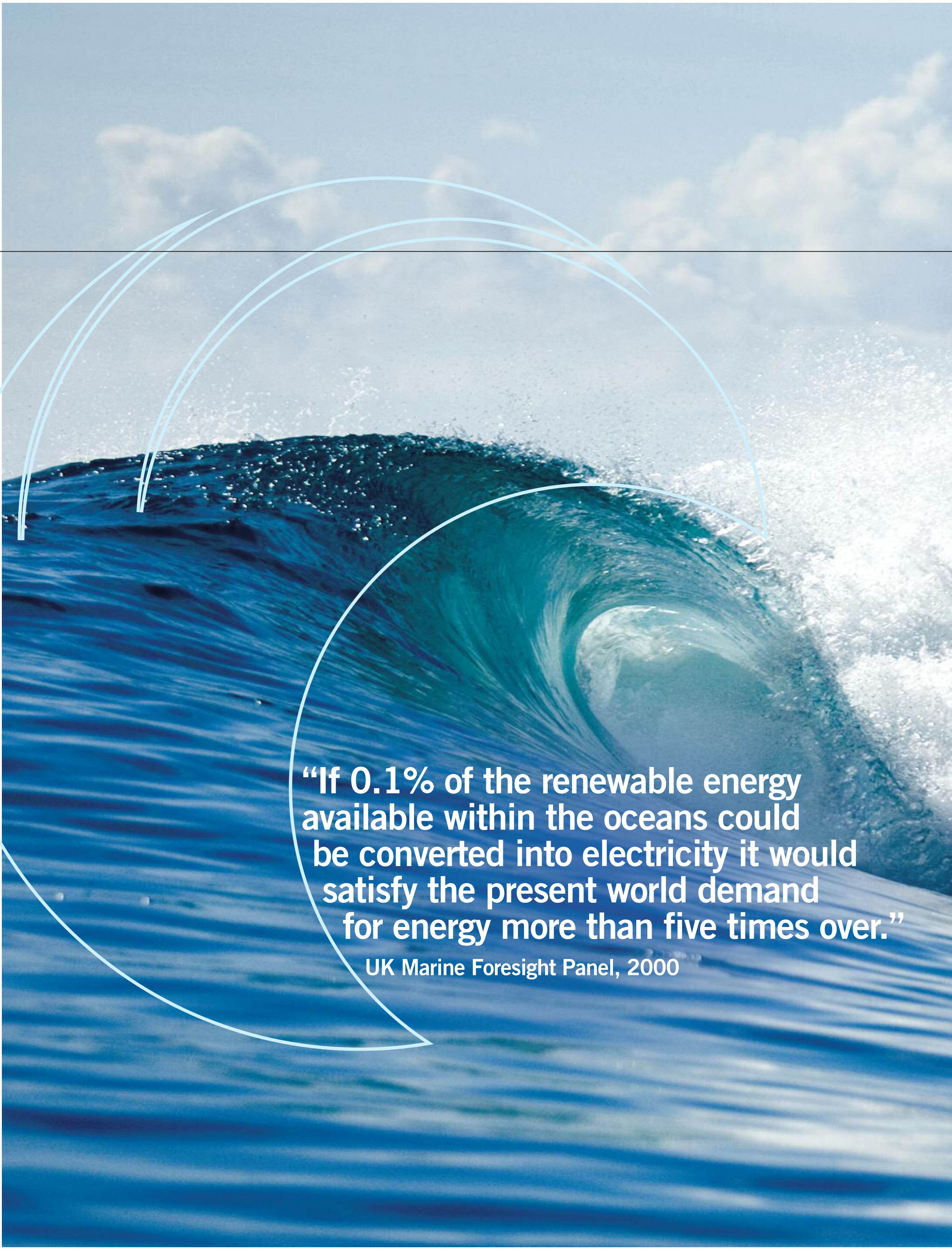
Ocean energy technologies are maturing, but their development needs to be accelerated by a policy framework, equivalent to that which promoted the offshore oil and gas sector from the 1960s onwards and, more recently, the offshore wind sector.

This Roadmap is the work of the European Ocean Energy Association; it is intended to map out the potential development of ocean energy up to 2020 and beyond to 2050. The Roadmap identifies issues and barriers surrounding the sector. We intend this document to be the first step towards a similar policy framework that European countries implemented for offshore oil and gas and offshore wind.

Ocean energy is a European matter, whether there is a coastline or not. Ocean energy offers a domestic energy resource for the EU which, to-date, has been largely untapped. Companies that make up the ocean energy sector recognise the challenges that need to be overcome to make the vision a reality. They are ready to invest the time and money required to advance the European ocean energy industry. This roadmap calls on the EU Member States and the European Commission to provide strong policy measures and adequate support for the sector to realise its full potential.

Alla Weinstein
President

Nathalie Rousseau
Executive Director


"If 0.1% of the renewable energy available within the oceans could be converted into electricity it would satisfy the present world demand for energy more than five times over."
UK Marine Foresight Panel, 2000

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Executive summary

The Roadmap for the development of the ocean energy industry in Europe provides a set of steps which, once implemented, would facilitate exploitation of the vast European ocean energy resources and enable the realisation of 3.6 GW of installed capacity by 2020, and close to 188 GW by 2050.

Table 1 quantifies the potential benefits of developing a European ocean energy sector in 2020 and 2050. Based on these projections, the ocean energy sector could generate significant levels of employment, contribute to carbon reduction targets and drive major investment.

A number of EU Member States have put in place attractive financial incentives, in terms of both revenue support and capital grants, and have developed world-class testing facilities for ocean energy.

Currently all the major utilities are engaged in the industry, either by investing in technology or projects, or by committing resources to draw up strategies that best support the ocean energy industry. They are serious about the development of the European ocean energy industry and recognise that, as the ultimate end-customers of ocean energy technology, they have a major role to play in early-stage development. Major manufacturers are expressing interest in the industry by investing directly in technology development.

To realise this potential and secure the associated benefits, the industry must overcome a number of challenges. A new generation of full-scale ocean energy conversion devices will have to be installed and demonstrate their operational capabilities in the next few years. Manufacturing processes need to be developed, automated and optimised with knowledge transfer from, and industrial cooperation with, other sectors, primarily offshore wind and offshore oil and gas. Electricity network connections will also have to be planned to enable major ocean energy power delivery.

A comprehensive research programme to constantly improve the technical and economic performance of ocean energy conversion devices will support industry development. It will also

Table 1 ESTIMATED BENEFITS OF DEVELOPING A WORLD LEADING EUROPEAN OCEAN ENERGY INDUSTRY

Installed Capacity / GW	Direct Jobs[1]	Total Jobs (Direct & Indirect)[2]	CO_2 avoided Mt/year[3]	Investment €m.[4]
3.6 (in 2020)	26,000	40,000	2.61	8,544
188 (in 2050)	314,213	471,320	136.3	451,104

1. *FREDS, Marine Energy Group, Roadmap, 2009*
2. *FREDS, Marine Energy Group, Roadmap, 2009*
3. *Fakta om Vindenergi, Faktablad M2, Januar 2007, www.dkvind.dk*
4. *FREDS, Marine Energy Group, Roadmap, 2009*

KEY TARGETS:
> SATISFYING 15% OF THE EU ENERGY DEMAND
> CREATING APPROXIMATIVELY 470,000 NEW JOBS
> AVOIDING 136 MT/MWH OF CO_2

be necessary to integrate previously mapped ocean resources and transmission capacity potentials in Europe.

Risk reduction will be required to leverage private investment into the ocean energy industry; this can be achieved by appropriate fiscal policies (grant support and market pull). Revenue incentives are important, however, they are currently insufficient and will not work in isolation from capital support measures in the early stages of industry growth. It is anticipated that costs will reach mature levels after a number of commercial scale developments utilising technologies of similar generic design have been installed.

It is the opinion of the European Ocean Energy Association (EU-OEA) that a joint private/public effort, such as the establishment of a European Industrial Initiative, is critical for the development of the European ocean energy industry. A European Industrial Initiative would bring together the necessary critical mass of private/public resources to advance the industry to full commercialisation. The inclusion of ocean energy within the upcoming framework programme will enable it to leverage private investment, accelerating development and achieving the associated benefits of a thriving ocean energy industry.

The EU-OEA has committed itself to supporting and facilitating the development of such a European Industrial Initiative. An initial step should be the establishment of the Strategic Ocean Energy Platform that will gather key industrial players and achieve the critical mass required to set out the industrial and technological objectives for a joint European Industrial Initiative.

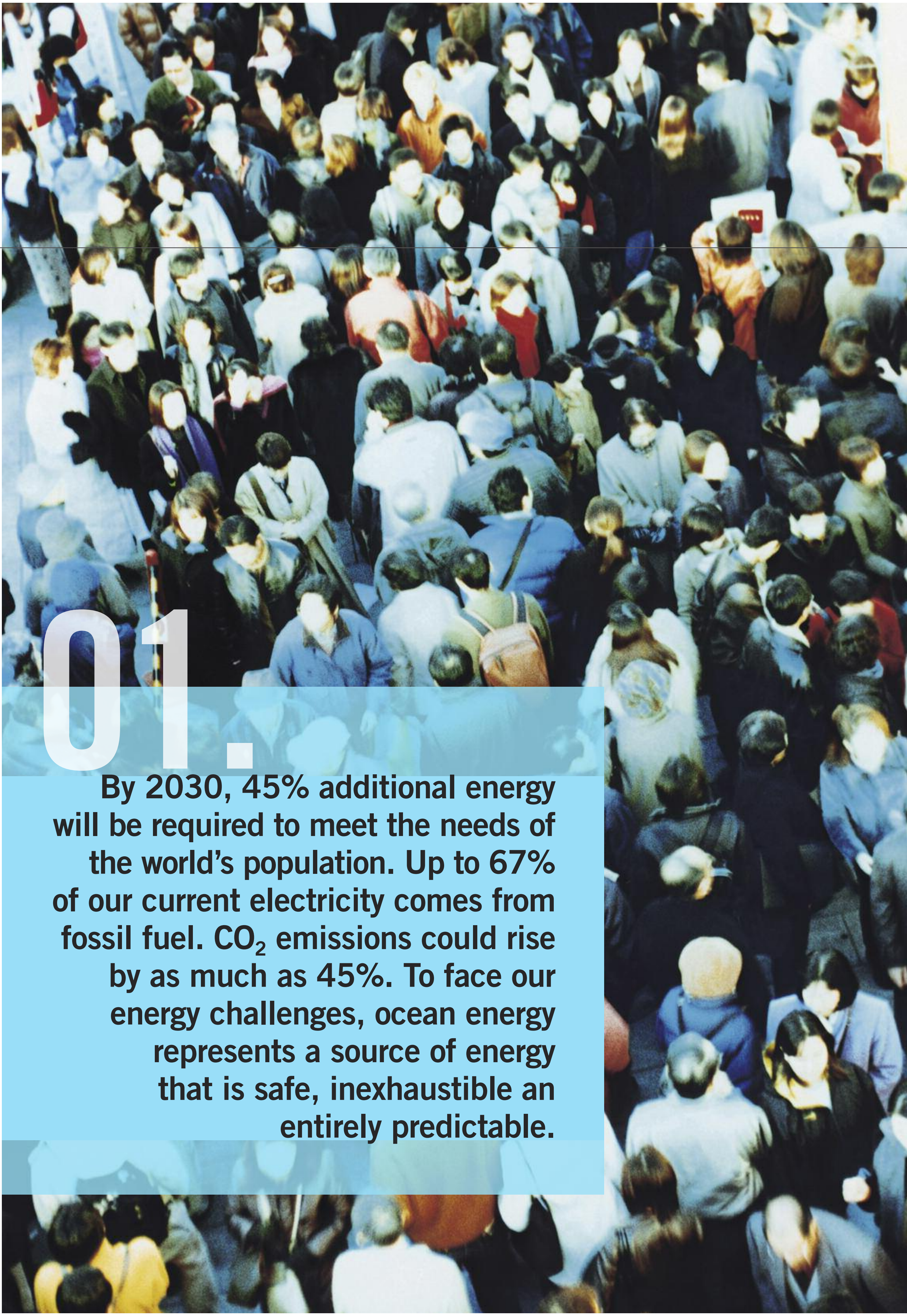
The establishment of a Strategic Ocean Energy Platform and a European Industrial Initiative are therefore the key recommendations of this Roadmap. ■

KEY OBJECTIVES OF A EUROPEAN INDUSTRIAL INITIATIVE FOR OCEAN ENERGY

To demonstrate the operational competitiveness of power generated from ocean energy, to enable the exploitation of the ocean energy resources, and to facilitate grid integration of ocean power.

This will be achieved by:

- **Continued prototype testing, and installation and operation of commercial scale ocean energy projects.**
- **Delivery of significant infrastructure and financial support.**
- **Ensuring grid availability at the interconnection points of ocean energy projects and transmission lines.**
- **Assessing and mapping European ocean energy resources across Europe and reducing the forecasting uncertainties of ocean energy production.**



01.

By 2030, 45% additional energy will be required to meet the needs of the world's population. Up to 67% of our current electricity comes from fossil fuel. CO_2 emissions could rise by as much as 45%. To face our energy challenges, ocean energy represents a source of energy that is safe, inexhaustible an entirely predictable.

// OCEAN ENERGY HAS AN ESSENTIAL ROLE TO PLAY IN RESPONSE TO INCREASING ENERGY NEEDS AND CO_2 REDUCTION. //

The scope for ocean energy

Climate change and an increasing dependency on imported energy by the European Member States require the comprehensive and ambitious development of renewable energy sources. Ocean energy is a renewable energy that has great potential for a significant contribution to the reduction of greenhouse gas emissions, can produce 15% of the European electricity mix, offers a local and decentralised energy source, creates world-class high-tech industries, and generates significant economic development.

The European Union (EU) has compelling reasons for setting up an enabling framework to promote ocean energy.

To reach the ambitious renewable energy targets set by the EU, it is undisputable that ocean energy, being part of the renewable energy mix, constitutes a key element of a sustainable future.

Setting out a long-term vision for ocean energy

This European Ocean Energy Roadmap sets a long-term vision for this emerging sector. It aims to highlight to policy-makers at EU and national levels that the ocean energy sector requires support in order to achieve its potential and demonstrate results and benefits similar to, or better than other renewable energy sectors. The Roadmap outlines a path forward for advancing ocean energy policies, markets and technologies. It further suggests a legislative framework for the promotion and use of ocean energy in Europe that will provide the business community with the long-term stability it needs to make rational investment decisions in the sector, providing European rate-payers with a cleaner, more secure and competitive energy future and economic development.

The Roadmap for the development of the ocean energy industry in Europe aims to advance development of ocean energy technologies, to enable the exploitation of vast European resources of wave, tidal and osmotic energy, to facilitate grid integration of ocean power, and to enable the industry to reach 3.6 GW of installed capacity by 2020 and close to 188 GW by 2050.

Ocean energy represents an untapped renewable energy source for Europe. As the sector continues its development from the pre-commercial stage, it is able to take advantage of certain developments offered by the offshore wind industry, namely the infrastructure, supply chain, grid connection and understanding of the environmental impacts. In the same way as offshore wind became a natural progression of onshore wind, taking approximately the same period of time to become commercially viable, ocean energy is projected to follow a similar development cycle. Furthermore, ocean energy offers additional benefits when compared with offshore wind – good predictability and forward-looking forecasting, reduced visual impact, and potentially higher load factors.

…/…

Directive 2009/28/EC of the European Parliament and of the Council of 23 April 2009 on the promotion of the use of energy from renewable sources, Article 3-1.

By 2020, Ocean energy could generate 3.6 GW, or 9 TWh/y. Enough to power 1,788,554 three-bedroom homes every year.

The need for a European Industrial Initiative

It is the opinion of the authors that a joint industrial/public effort, such as the establishment of a European Industrial Initiative, is critical for the development of the European ocean energy industry. A European Industrial Initiative would bring together the necessary critical mass of private/public resources to advance the industry to contribution potential. While offshore wind could reach saturation by around 2035, ocean energy could provide continuous expansion of offshore renewable energy generation by bringing on line approximately 188 GW of installed capacity, or 15% of projected European consumption.

Currently all the major utilities are serious about the development of the European ocean energy industry and recognise that, as the ultimate end-customers of ocean energy technology, they have a major role to play in its early-stage development. Major manufacturers are also expressing interest in the industry by investing directly in technology development.

Achieving these objectives presents a range of challenges. Since the industry is at a development stage, component manufacturing, transportation, installation, operation and maintenance must be further defined. Offshore wind will provide valuable experience that can be leveraged for the rapid advancement of ocean energy. In addition, connections to electricity networks will have to be planned to enable the delivery of generated power and the full operation of the electrical networks with supply from a variable power source. ■

THE EUROPEAN INDUSTRIAL INITIATIVE ON OCEAN ENERGY IS NECESSARY TO:

- Integrate previously mapped ocean resources and transmission capacity potentials in Europe through coordinated campaigns and to develop spatial planning tools;
- Increase the number of offshore and onshore testing facilities to test ocean energy device components, subsystems and systems;
- Deploy demonstration ocean energy projects with a minimum installed capacity of 40 MW;
- Develop new manufacturing processes to reach high volume productions;
- Develop installation, operation and maintenance methodologies to provide further cost reduction;
- Demonstrate grid integration techniques at an industrial scale;
- Establish a comprehensive research programme to constantly improve the technical and economic performance of ocean energy conversion devices, which will serve as a backbone for the industry's advancement.

Pursuing an ambitious ocean energy policy for Europe would require taking proactive initiatives at every policy and decision-making level to provide adequate support for the development of an ocean energy sector that can become a major contributor to the carbon free society and energy independence, whilst spurring innovation and economic development. This Roadmap defines the initial framework for such initiatives.

OE Buoy " Sealeán", developed by Ocean Energy Ltd. with a financial support from Sustainable Energy Ireland

Seabased, developed by Seabased AB.

02.

The rapid development of ocean energy technology is moving it towards an emerging European industry.

Kobold Turbine, developed by Ponte Di Archimede.

// OCEAN ENERGY RESOURCES INCLUDE WAVES, TIDES, BOTH CURRENT AND RANGE, OCEAN CURRENTS, TEMPERATURE GRADIENTS AND SALINITY GRADIENTS (OSMOTIC). //

Ocean energy in Europe

The European ocean energy industry is developing rapidly with new players constantly entering the field, including increased involvement of industrial organisations. Major utilities and large industrial companies are now engaged in a number of projects, currently under development or in the planning stages. Industrial players and stable partnerships have the capacity to mobilise the necessary resources to advance these projects to the commercial phase.

Forms of ocean energy

Ocean energy resources include energy from waves, tides, both current and range, ocean currents, temperature gradients and salinity gradients (osmotic).

The best ocean energy resources within the European Member States are wave, tidal current and tidal range. Systems developed for harvesting these resources have seen the most technological advancement.

Wave energy has the largest potential in Europe and worldwide and can be captured in a number of different ways including through point absorbers, attenuators, overtopping, oscillating wave surge convertors, and oscillating water columns.

These state-of-the art technologies can be demonstrated at full scale.

Several tidal plants are in the planning phase within the European Union, located at suitable estuaries and tidal lagoons. These tidal barrage installations consist of dams and reservoirs with the same operational principle as conventional hydro power plants.

A number of pilot tidal stream projects are under development to find the most cost effective method for generation, installation and maintenance.

Osmotic systems are being developed in Norway and in the Netherlands. Ocean thermal resources are available in a few European countries in addition to overseas territories located closer to the Equator.

The latest publication of the "STATE OF THE ART OF OCEAN ENERGY", produced by the European Ocean Energy Association on an annual basis and available on the Association's website, provides more in-depth analysis of ocean energy technological advancements.

European stakeholders are developing several different wave and tidal energy systems. Specific development zones, including testing facilities, grid infrastructure and licensing rounds are available to developers in Ireland, Norway, Denmark, the UK, Portugal, Finland, Spain, France and Italy.

Ocean energy is ready for large scale installations

It is expected that once systems have demonstrated their operational performance and survivability in the field, ocean energy will be ready to advance to large-scale pre-commercial installations. Such projects will require pooled resources from the financial community, large industrial players, end-users and the public, in order to share the burden of new technological developments.

.../...

Directive 2009/28/EC of the European Parliament and of the Council of 23 April 2009 on the promotion of the use of energy from renewable sources, Article 3-1.

State of the art

Europe has recently experienced a number of projects where developers have been supported by big utilities. The examples seen below showcase some of these advancements.

Wave Dragon, developed by Wave Dragon ApS.

Wave Dragon - Wave Dragon is a floating, slack-moored energy converter of the overtopping type that can be deployed in a single unit or in arrays of Wave Dragon units in groups resulting in a power plant with a capacity comparable to traditional fossil based power plant. Wave Dragon has applied for deploying a 7 MW device of the coast of Wales, UK in 2011.

Source: www.wavedragon.net

Pulse tidal, developed by IT Power.

Pulse tidal - Twin hydrofoils positioned across the tidal flow are pushed up or down by moving water according to the angle of the foil in the water. This movement drives a conventional generator situated above the water surface. Pulse Tidal is supported by Marubeni Corporation, it Power as company shareholders.

Source: www.pulsegeneration.co.uk/?q=node/34

SYNERGIES WITH RENEWABLE ENERGY SOURCES

To accelerate the development of, and penetration into, the European energy market, ocean energy can take advantage of lessons learnt from other sectors that have developed market viability. These should be integrated as a path to overcoming both technological and non-technological barriers and to facilitate the sector's development.

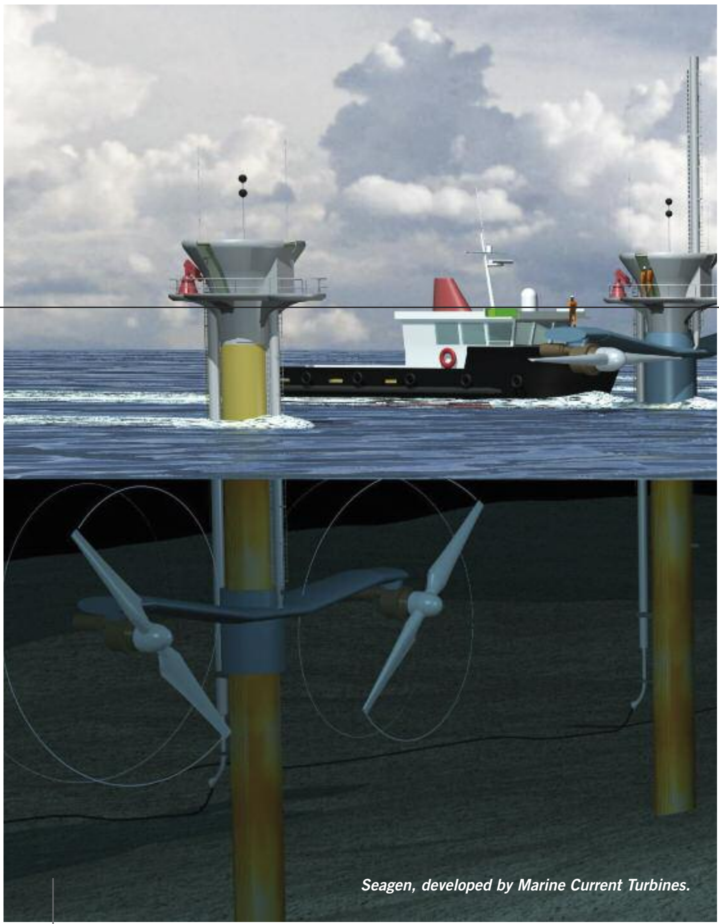
Other sectors of renewable energy production, in particular offshore wind and hydro, share some technical similarities and have to address similar issues relating to permiting or grid connection as those encountered by ocean energy.

> **Grid connection** issues are common to most forms of renewable energy plant, in particular offshore wind which requires major investment for infrastructure upgrades.

> **Offshore wind**, wave and tidal energy in particular share synergies in relation to governmental marine policies, marine stakeholders and spatial constraints. More specifically, ocean energy development should be included in maritime spatial planning, which is taking place increasingly at a European level.

> Ocean energy technologies (especially tidal range) rely on civil **engineering and fabrication techniques** that are commonly used in the shipbuilding industry and the offshore oil and gas sector.[5]

> Within a much longer-term view, ocean energy power plants could be used for the production of drinking water through desalinisation. This could be a major asset for local populations that have limited access to **drinking water**, in particular in Mediterranean and tropical countries. Some studies suggest that a 2 MW power plant could produce 4,300 cubic meters of desalinated water for drinking and irrigation each day.[6] This process has been reported particularly for ocean thermal energy conversion, but could possibly be extended to other technologies.



Seagen, developed by Marine Current Turbines.

Osmotic Power Prototype, developed by Statkraft.

SeaGen - Tidal turbines work much like submerged windmills, but driven by flowing water rather than air. They can be installed in the sea at places with high tidal current velocities, or in places with fast enough continuous ocean currents. Marine Current Turbines is supported in part by EDF and ESB International, both European utilities.

Source: www.marineturbines.com/21/technology/

Statkraft - Freshwater and salt water are channelled into separate chambers, separated by an artificial membrane. The salt molecules in the seawater draw the freshwater through the membrane by osmosis, causing the pressure on the seawater side to increase to the equivalent of a 120 metres waterfall. This pressure can be used in a turbine to make electricity.

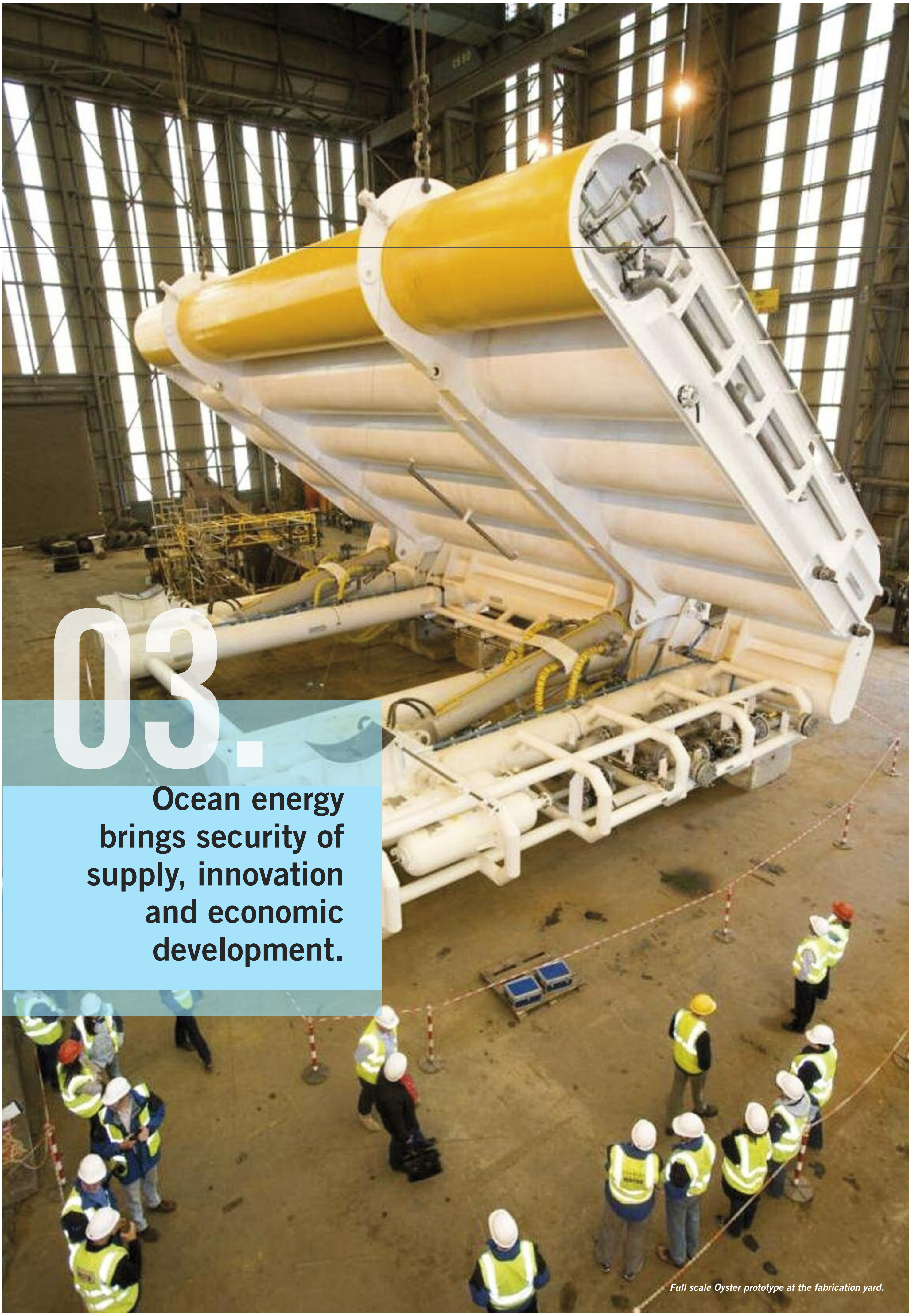
Source: www.statkraft.com/energy-sources/osmotic-power/osmotic-power-in-brief/

> Looking further into the future, ocean energy could be used for **heating and cooling** of buildings near the coastline. This possible synergy would require further investigation, as little research has yet been carried out, apart from in the field of ocean thermal energy conversion (OTEC), where pumping cold water from the depths of the ocean could enable cheap refrigeration and environment-friendly air-conditioning.[7]

> Early stage research is underway to develop a new generation of **bio-fuels** that will come from algae cultivated in the ocean. Ocean energy devices could potentially be used to grow these new bio-fuels.[8] Furthermore, electricity produced from the ocean could be used to produce hydrogen from seawater, which could also be used as a fuel for vehicles replacing oil.[9]

Finally, other applications of ocean energy production should be researched, as they may constitute important opportunities for future development of the sector.

[5] *http://www.hydro-gen.fr/index.php?option=com_content&task=view&id=3&Itemid=4*
[6] *http://www.nrel.gov/otec/desalination.html*
[7] *http://www.nrel.gov/otec/refrigeration.html*
[8] *http://www.underwatertimes.com/news.php?article_id=25107309846*
[9] *http://www.hydro-gen.fr/index.php?option=com_content&task=view&id=1&Itemid=2&lang=en*



03.

Ocean energy brings security of supply, innovation and economic development.

Full scale Oyster prototype at the fabrication yard.

// OCEAN ENERGY GENERATION CAN REPLACE FOSSIL FUEL-BASED POWER PLANTS IN THE PEAK TO MEDIUM SCALE BASELOAD. //

An ocean of benefits

The benefits of securing a productive ocean energy industry are many.

Ocean energy can:

- boost renewable energy generation;
- help achieve EU carbon reduction targets;
- maintain security of supply;
- deliver economic benefits in the form of employment and investment.

The European energy challenge

Energy is essential for Europe to function. All EU Member States face the challenges of climate change, increasing dependence on imported energy and higher energy prices. Moreover, the interdependence of EU Member States for energy, as for many other areas, is increasing – a power failure in one country has immediate effects in other countries. It is clear that a radical change is required in the way energy is produced, distributed and consumed. This means transforming Europe into a highly efficient, sustainable energy economy.

Europe's dependence on imported energy has risen from 20% at the signing of the Treaty of Rome in 1957 to its present level of 50%, and the European Commission forecasts that imports will reach 70% by 2030. If energy trends and policies remain as they are, the EU's reliance on imports will jump to 84% for gas consumption and 93% for oil by 2035. Europe is already paying the price of energy dependence. According to the European Commission, the EU's gas import bill alone increases by €15 billion annually for every $20 increase in price of a barrel of oil. Hence, the past few years' increase in oil prices from $20 to $80 (November 2007) has added €45 billion to the EU's annual gas import bill.

Climate change

With the adoption of the new "ENERGY FROM RENEWABLE SOURCES" directive by the European Parliament and the European Council, the EU has committed to reducing its greenhouse gas emissions by 20% by 2020. Every source of electrical power generation will need to be considered and used under this framework and ocean energy should be one of them.

Ocean energy generation can replace fossil fuel-based power plants in the peak to medium scale baseload. Ocean energy does not emit particles, CO_2, SO_2 or NO_X. Therefore electricity produced from ocean energy resources is suitable to replace energy generation from fossil fuels. The typical savings obtained are illustrated in Table 2.

It has been estimated that 300 kg of CO_2 could be avoided for each MWh generated by ocean energy. Therefore, for 20 GW (49 TWh/year) of installed ocean energy, the CO_2 emissions avoided could be 14.5 Mt/year.

These figures do not account for the baseload fossil fuel-produced power necessary to firm up ocean energy intermittency.

.../...

Table 2 TYPICAL GREENHOUSE GAS AVOIDANCE FROM OCEAN ENERGY GENERATION[10]

1 MWh avoidance of	CO_2	SO_2	NOx
Coal	780 kg	0,13 kg	1,17 kg
Oil	878 kg	2,63 kg	3,48 kg
Gas	415 kg	0,00 kg	0,92 kg

[10] *Fakta om Vindenergi, Faktablad M2, Januar 2007, www.dkvind.dk*

0.1% OF THE THEORETICAL POTENTIAL FOR ALL OCEAN ENERGY TECHNOLOGIES IS ESTIMATED AT OVER 5 TIMES THE CURRENT GLOBAL ENERGY CONSUMPTION.

On the other hand, as long as ocean energy contributes approximately only 1% to the total electricity consumption, this can be ignored.

A diversified, local energy mix

Ocean energy can contribute to the EU overall targets of providing a more diversified energy mix by using a locally available, renewable energy source.

A diversified energy mix, both geographically and technologically, can resolve the issue of variability. Ocean energy can bring added value to the European Union's energy mix. Indeed, it has been established that wind and ocean energy are complementary. A recent Renewable UK study concluded that diversifying the renewable energy mix by including a greater proportion of marine energy would reduce requirements for reserve capacity and lead to annual savings in relation to the annual wholesale cost of electricity.[11]

Towards a knowledge-based economy

Ocean energy technologies are at the forefront of innovation. Even technologies that have been used in marine applications require further development and testing in order to optimise their use in ocean energy devices.

The European Union committed to developing innovation and competitiveness as the basis of the continent's economy at the Lisbon European Council in 2000. It calls for establishing "the most dynamic and knowledge-based economy in the world capable of sustainable economic growth with more and better jobs and greater social cohesion and respect"[12] within the European Union. Promoting ocean energy is in line with the Lisbon Strategy:

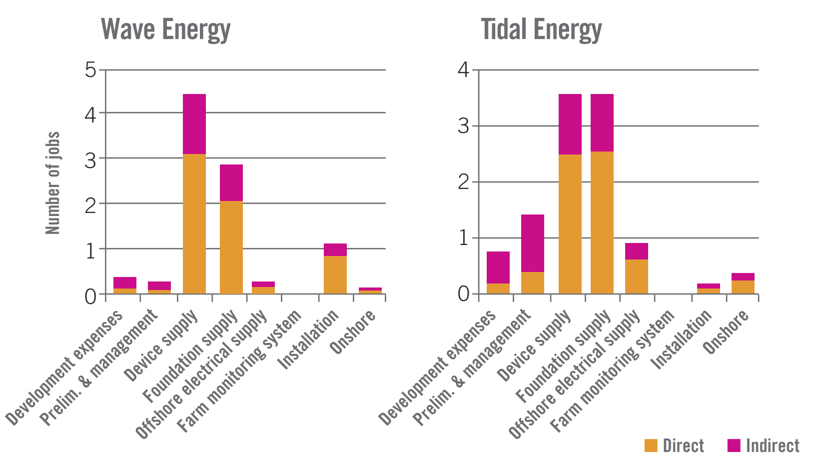
- First, the development of state-of-the-art technologies for harnessing ocean energy supports a knowledge-based economy, positioning the EU to develop a strong competitive industry, and emerge as a world leader.
- Secondly, the development of the ocean energy sector would lead to the creation of a supply chain which could cross the whole of Europe, even in countries with no or little coastline. This would be a major benefit for the continent's economy as a whole, and is again in line with the Lisbon Strategy for growth and jobs.
- Finally, ocean energy is a renewable source of energy that provides a contribution to climate change mitigation.

Ocean energy should be considered a priority for European Union policy makers, as it could be one of the key assets in fulfilling the EU goals for the 21st century.

A new flow of job creation

Ocean energy is well positioned to contribute to regional development in Europe, especially in remote and coastal areas. The manufacturing, transportation, installation, operation and maintenance of ocean energy facilities

Fig. 1 JOB CREATION PER MW OF OCEAN ENERGY INSTALLED CAPACITY



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[11] The Benefits of Marine Technologies within a Diversified Renewables Mix, Redpoint Energy Limited for BWEA, April 2009. An annual saving of £0.9bn is equal to 3.3% of the annual wholesale cost of electricity. These figures are derived from hypothetical years in the future, with annual demands of 400TWh, of which 39% is met by generation of renewables. These savings are derived from a 60/40 percentage split of wind/marine energy.

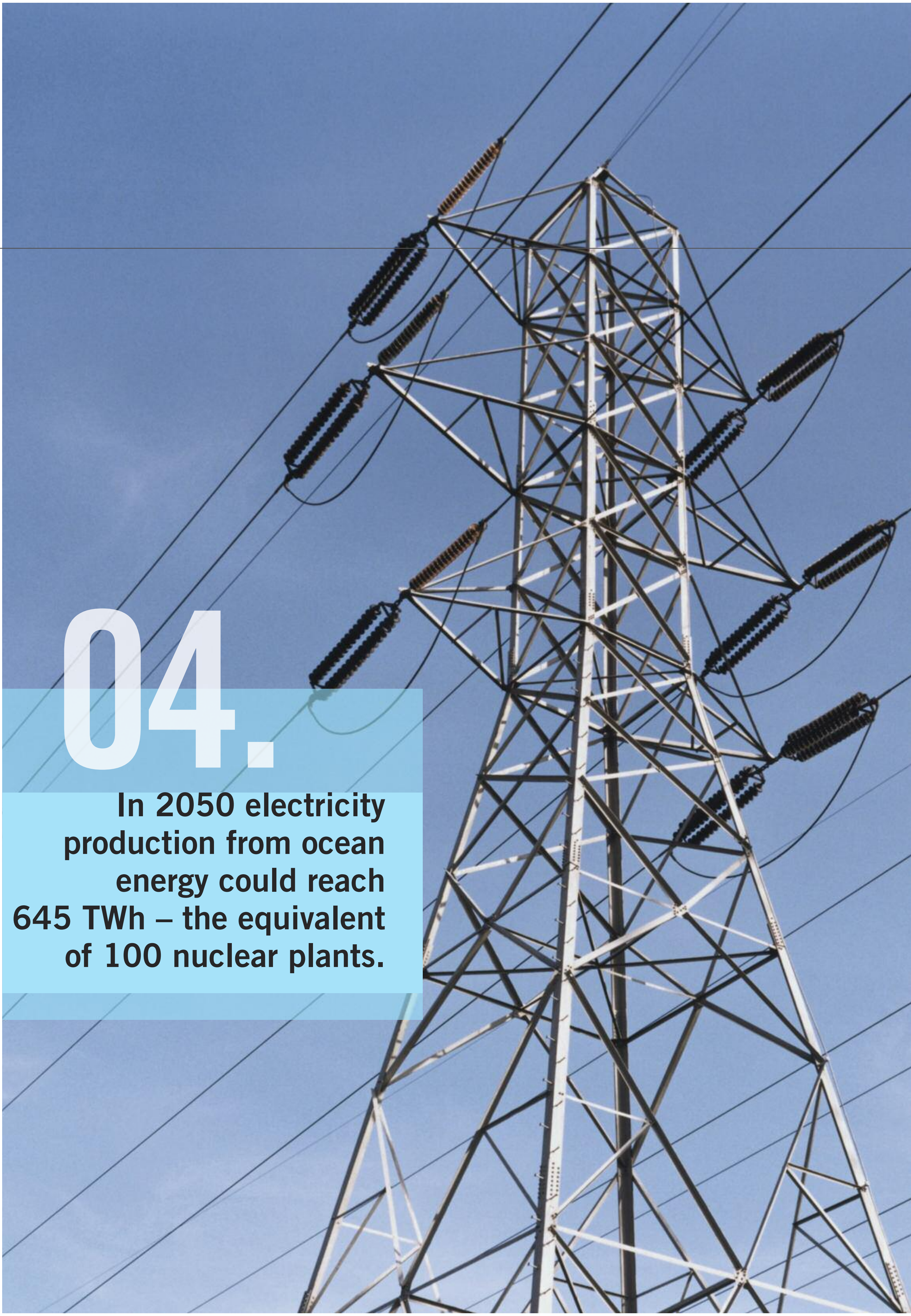
[12] Lisbon European Council 23-24 March 2000 Presidency Conclusions

DEVELOPING OCEAN ENERGY TO 3.6 GW COULD BRING 40,000 NEW JOBS. MORE PEOPLE THAN THE WHOLE EUROPEAN COMMISSION IN BRUSSELS.

will generate revenue and employment.
For example, the Scottish Government's Marine Energy Group Roadmap suggests that the marine energy industry could provide up to 12,500 jobs, contributing £2.5 billion to the Scottish economy by 2020. The installation of one full-scale wave energy device in the Orkney Islands in Scotland has resulted in direct spend of more than €1million in the local economy.
Studies[13] suggest that ocean energy has a significant potential for positive economic impact and job creation as presented in Figure 1.
It is anticipated that approximately 10 to 12 direct and indirect jobs would be created for each MW of ocean energy installed.[14]
Parallels can also be drawn with the growth of the wind industry. Export of clean technology now accounts for €7.1 billion annually in Denmark, while in Germany export of wind technology alone is worth over €5.1 billion.
Based on the projections for installed capacity, as stated in Table 1 (page 6), by 2020 the ocean energy sector will generate over 26,000 direct and 13,000 indirect jobs, for a total of close to 40,000. By 2050 these numbers would increase to 314,213, 157,107 and 471,320 respectively. ■

Oyster device being hausted by the heavy lift sheerleg crane to take out to sea.

[13] *Batten, W. M. J & Bahaj, A. B.: An assessment of growth scenarios and implications for ocean energy industries in Europe, Sustainable Energy Research Group, School of Civil Engineering and the Environment, University of Southampton, Report for CA-ocean energy, Project no. 502701, WP5, 2006, 9 pp*
[14] *Ibid, p. 44*



04.

In 2050 electricity production from ocean energy could reach 645 TWh – the equivalent of 100 nuclear plants.

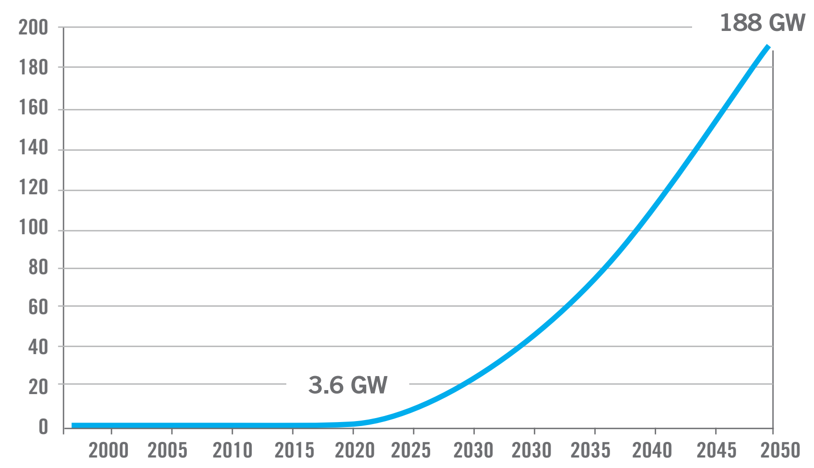
// THE POTENTIAL GROWTH OF OCEAN ENERGY INSTALLED CAPACITY DEPENDS ON TECHNOLOGICAL READINESS, POLITICAL AND ECONOMIC SUPPORT, AND AVAILABILITY OF THE GRID. //

Markets sail to ocean energy's true potential

In 2007 the countries of the European Union consumed 2,926 TWh of electricity.[15] Ocean energy generation has a potential to reach 3.6 GW of installed capacity by 2020 and close to 188 GW by 2050 (Figure 2). This represents over 9 TWh/ year by 2020 and over 645 TWh/year by 2050, amounting to 0.3% and 15% of the projected EU-27 electricity demand by 2020 and 2050 respectively.

The potential growth of ocean energy installed generating capacity depends on several factors such as technological readiness, political and economic support structures and incentives, and availability of the grid.
Ocean energy resources are available in EU Member States along the Atlantic Arch, the Mediterranean Sea and the North Sea.

Figure 2 PROJECTED OCEAN ENERGY INSTALLED CAPACITY



As such, fourteen EU Member States and two Associated countries will be actively involved in the development of the ocean energy industry. At this point Belgium, Denmark, Finland, France, Greece, Ireland, Italy, the Netherlands, Portugal, Spain, Sweden, Norway, and the United Kingdom are actively involved in technology and project development. Countries such as Germany, Poland and Switzerland are involved as component suppliers and as financial investors.
The numbers presented above are achievable targets for ocean energy at the European level. The French Government has recently announced an objective of 800 MW of installed ocean energy by 2020.[16] The Scottish Marine Energy Group has proposed a scenario of 2 GW of installed capacity by the same date. Similar targets are being developed in the UK, Ireland and other EU Member States with ocean energy resources. This indicates that stated targets are both politically acceptable and achievable. (Figure 4)

15. *The World Fact Book (https://www.cia.gov/library/publications/the-world-factbook/rankorder/2042rank.html)*
16. *http://www.greenunivers.com/2009/07/grenelle-mer-gossement-9677/*

Tidal energy could provide a source of stable and predictable electricity twice a day.

Wave Energy has the largest potential in Europe and Worldwide.

Osmotic and Ocean thermal energy conversion technologies could be produce electricity at all times of day and night.

Ocean energy can grow at the same speed as wind

The 2009 European Wind Energy Association report "OCEANS OF OPPORTUNITIES" indicates that offshore wind growth is following a similar deployment rate curve as that of onshore wind (Figure 3) if this latter curve is properly displaced on the time axis. This is important when predicting the possible cumulative deployed growth for ocean energy.

This historical wind growth rate can be extrapolated to project a similar growth rate for ocean energy as for the offshore wind sector.

The onshore wind supply chain grew with the growth of the industry. The offshore wind industry benefits from the existing onshore wind and offshore oil and gas supply chain, with the exception of dedicated, expensive installation vessels that are in short supply. Furthermore onshore wind (and to some extent offshore wind) started in a relatively small number of countries.

The national targets presented in Figure 4 indicate that a significant number of EU Member States have established targets for ocean energy. These targets, the availability of test sites for prototype development, the installation of ocean energy demonstration farms in EU Member States and in Norway, as well as past deployments, indicate supply chain development and market readiness. ■

Armoured sub sea cables.

Figure 3 ONSHORE, OFFSHORE WIND & OCEAN ENERGY PROJECTED GROWTH

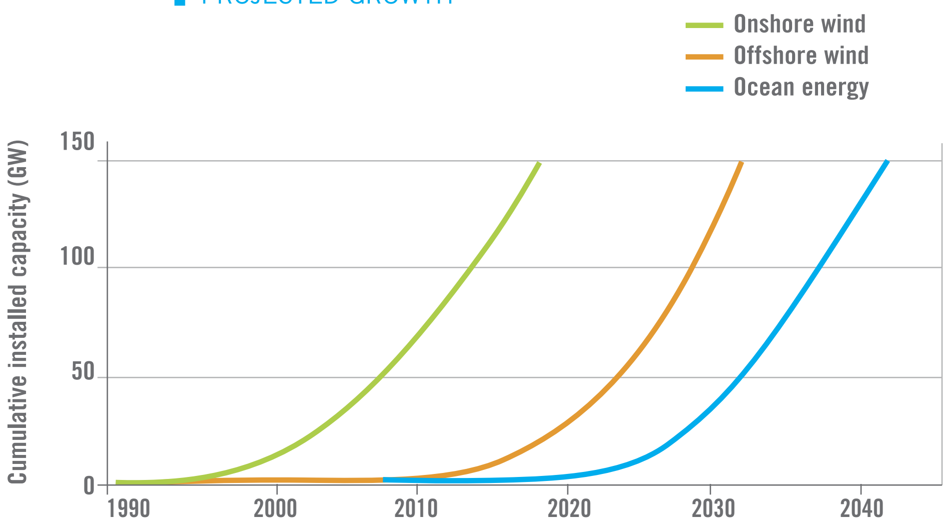
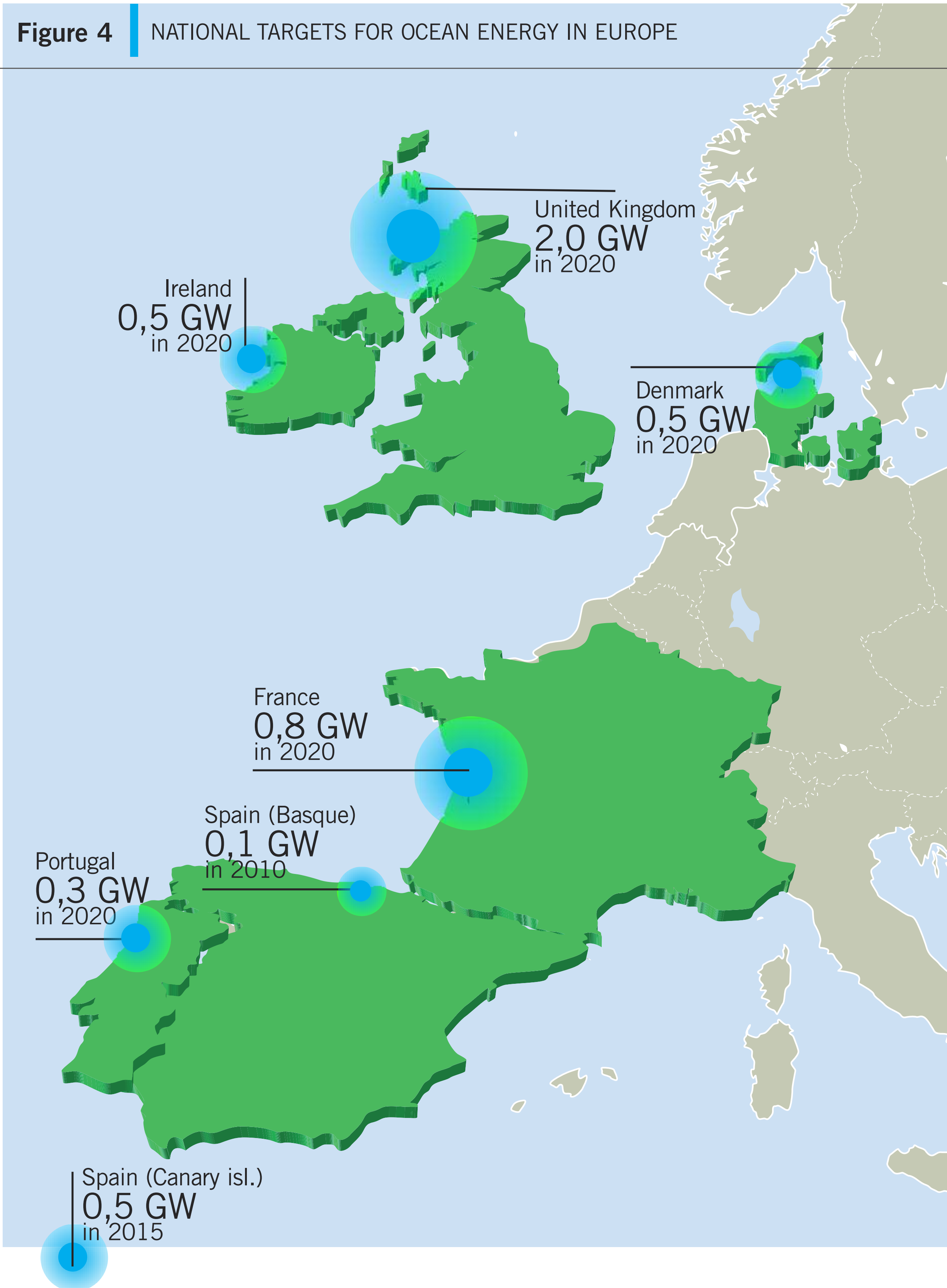


Figure 4 NATIONAL TARGETS FOR OCEAN ENERGY IN EUROPE



05.

To achieve ocean energy's true potential, existing barriers need to be eliminated as rapidly as possible.

// HINDRANCES TO THE YOUNG INDUSTRY HAVE BEEN ORGANISED IN FOUR CATEGORIES: POLICY, MARKETS, R&D, AND ENVIRONMENTAL & PERMITING PRACTICES. //

Challenges & opportunities

The ocean energy industry is at the forefront of industrial development. Recent initiatives throughout the EU geared towards clean energy generation have created significant opportunities for the ocean energy sector. These programs are mainly linked to European and national commitments to promote clean energy generating technologies to assist EU Member States in reducing the generation of greenhouse gasses and reduce their dependency on imported energy.

A number of barriers hinder the ability of ocean energy to reach its true potential. If the ocean energy industry is to develop to the levels envisioned by the EU Member States, these barriers need to be eliminated as quickly as possible. Such barriers include siting and licensing issues, access to project finance, competitive non discriminatory access to the grid, skilled personnel and management, technological development, lack of standards and certification, as well as supply chain and environmental issues.

The challenges and opportunities have been organised into four categories:

- Policy
- Markets & Access to Financial Resources
- Research and Development
- Environmental Requirements and Permiting Practices

Policy

According to the European Commission, the 20% binding target by 2020 implies that 35% of electricity has to be generated from renewable energy sources. This number increases in percentage terms beyond 2020, the time frame when ocean energy is poised to make a significant contribution. Strong policy measures are required to achieve these contributions.

For some EU Member States, ocean energy represents a significant source of renewable energy. In order to develop, the sector needs consistent polices. These include the availability of financial support mechanisms, notably revenue incentives and capital funding at European and national levels, streamlined licensing and permiting procedures, as well as strong political commitment to support the advancement of ocean energy.

Opportunities

Establishing a European policy framework for ocean energy

To guarantee investor confidence and to develop ocean energy demonstration installations, the sector needs a strong and stable political framework. The framework should be based on the following principles: legislation and policy (specifically payment mechanisms), grid access, environmental policies and R&D programs. Such a framework will support the EU Member States that have included ocean energy in their national action plans containing sector targets and quantification of the expected contribution of ocean energy power. The framework should provide a means to develop ocean energy power effectively and include:

- A streamlined approach to accessing financing mechanisms and schemes;
- The need for long-term grid access planning;
- The importance of more efficient consent procedures which build on past experience and are in proportion to the scale of the project;
- The establishment and use of marine spatial planning to identify optimal installation sites.

Furthermore, there is a need for increased cooperation through working groups from public administrations and the ocean energy industry to identify potential barriers and limitations and to suggest measures to remove these.

The supply chain in regions with ocean energy - the Atlantic Arch, the North Sea and the Mediterranean

Development of a commercial ocean energy industry will require establishment of a secure supply chain. The needs of the sector should be included in supply chain plans for future growth. Together, EU Member States bordering on the Atlantic Ocean, the North Sea and the Mediterranean should address the needs of an ocean energy sector supply chain capable of supporting European needs. This should focus on knowledge transfer from existing supply chains, notably those of the oil and gas sector.

Regulations, governmental and European policies

Achieving a mature, cost-competitive ocean energy industry will require technological advancement and policies that support creation of the new industry. Many of the challenges require an integrated approach. Public acceptance of ocean energy facilities can only be achieved with a streamlined and transparent licensing and permiting process that ensures public benefit from the use of the resource.

Given the cross-border nature of ocean energy, its development will interact with European policies dealing with spatial planning. In particular, the impact of maritime and spatial planning policies on ocean energy needs to be addressed early on. Policies regarding shipping and navigation will have to take ocean energy into account and EU Member States will have to decide how they wish to manage the interaction between the new industry and their national security needs.

Planning for the ocean energy industry in relation to other established uses of the sea

While policies for other industrial uses of the sea (e.g. offshore oil and gas development, shipping, fishing, aquaculture, etc.) are well established, ocean energy represents an uncharted territory for regulators and policy makers. Regulatory bodies have been using existing regulatory frameworks to permit proposed ocean energy projects, but additional strategic planning and resource management strategies are needed to address the specific requirements of a commercial ocean energy industry.

Timely involvement of the Transmission System Operators, health and safety bodies, and environmental authorities are among the key elements for the success of future ocean energy installations. In addition, cooperation with existing sea users is required to minimise conflicts and emphasise the synergies and opportunities provided by ocean energy. These industries also have key experience and expertise that the ocean energy sector needs to develop cost effectively and safely. Simplified and streamlined processes and procedures for the consent and permiting of ocean energy installations should form the basis for ocean energy policies.

Market

Achieving 3.6 GW of installed capacity by 2020 and approximately 188 GW by 2050 represents a high potential and, at the same time, significant challenge. Ocean energy systems will have to be fabricated, transported, installed, operated and maintained. The industrial sector, utilities and financial markets are starting to plan for this potential and to address these challenges. In particular the market will need to be prepared to invest the sums required to develop ocean energy projects of 100 MW over the next decade.

As with any new industry sector, ocean energy has yet to reach maturity. Ocean energy is ready for the installation of demonstration and pre-commercial projects that represent high-risk investments and uncertain returns. This requires risk sharing between the private and the public sector.

After demonstration and pre-commercial phases of development, ocean energy systems will be able to secure financing based on revenue support when output can be predicted. Eventually ocean energy installations will be able to avail themselves of project financing mechanisms. At the same time, supply chain companies will be able to plan for the upcoming requirements of ocean energy systems.

A recently published report by RenewableUK (THE NEXT STEPS – AN INDUSTRY RESPONSE TO THE MARINE ENERGY ACTION PLAN[17]) provides a proposal of how ocean energy could potentially be made more attractive to the investment community:

- Revenue incentives are important; however they are currently insufficient and will not work in isolation from capital support measures in the early stages of industry growth.
- Revenue incentives are powerful where energy production can be predicted reasonably accurately. When marine energy devices become ready for deployment in small arrays, revenue incentives play an important part in making the projects economically viable and offset operation and maintenance cost risk.
- Even with sufficient revenue incentive, an upfront capital grant will also be required to de-risk investment in the first arrays. Under this scenario, a marine energy project starts to become attractive to utilities. To secure investment from utilities, ocean energy offerings have to be on a par with alternative options. In particular, device manufacturers have to be able to offer potential utility investors:

a) sufficient operating experience to offer guarantees in performance and reliability and b) involvement of major manufacturers able to underpin these guarantees both technically and financially.

Opportunities

Establishing stable, long-term markets for ocean energy in Europe.

EU Member States and the European Commission must work together to ensure that the market for ocean energy in Europe is stable with a long-term vision.

Coordination of policies to support the sector is necessary to allow investments to be made, even at this early stage of development, by encouraging private/ public partnerships. EU Member States must coordinate the regulatory and market conditions to facilitate the advancement from pre-commercial to commercial ocean energy installations that deliver energy to the European grid.

Establishing the supply chain for a timely and sustainable flow of projects.

From initial site selection to device installation and operation, the ocean energy industry covers a wide range of disciplines, expertise and industrial sectors. Each type of installation, from offshore installations at 50 - 60 metres in depth to shore-based or near-shore systems, will present its own specific challenges

This will call on expertise from adjacent industries, such as offshore oil and gas and the offshore wind sector, for construction and maintenance at sea requiring specialised equipment and expertise. All the players have to plan and invest to meet the challenge of large-scale ocean energy deployment.

Grid accessibility

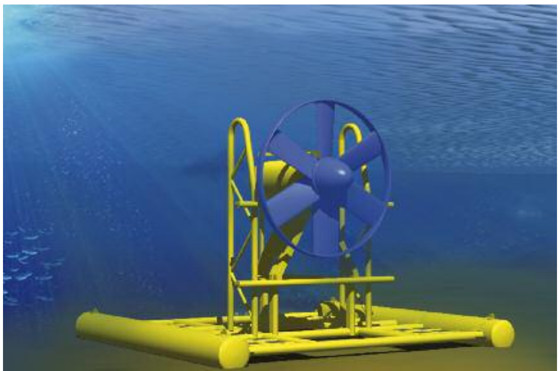
In the same way as other decentralised renewable energy resources, ocean energy faces a lack of adequate grid access. The sector needs to engage in the ongoing dialog on the development of the European grid for offshore energy sources.

Creating comparable European training and qualification standards to ensure sufficient workforce capacity and human resources, and to increase cross border cooperation.

New requirements regarding employee qualifications in the areas of project management, national and international law, quality assurance, occupational health and safety, and technical English are evident in almost all sectors of the value-added chain. Deficits in the European market can be attributed to a lack of compatability and transferability of national professional qualifications, certificates and standards.

Work initiated by the International Electrotechnical Commission (IEC) Technical Committee 114[18] on Marine Energy in 2007 will lead to the development of international standards for ocean energy systems. Work in progress on ocean energy systems includes: relevant terminology, design requirements, resource characterisation and its assessment, and the evaluation of performance of ocean energy converters in the open sea.

17. http://www.decc.gov.uk/en/content/cms/what_we_do/uk_supply/energy_mix/renewable/explained/wave_tidal/funding/marine_action_/marine_action_.aspx
18. http://www.iec.ch/dyn/www/f?p=102:17:0::::FSP_SEARCH_TC:114


Sabella SAS. Developed by Hydrohelix Energies.

Research & Development

Ocean energy technologies are advancing toward a larger scale. Research is needed to enable cost effective, large-scale deployment of these technologies. In 2009, the European Ocean Energy Association conducted a workshop to define R&D priorities. The prime focus of all R&D efforts for ocean energy should be to advance technological development to pilot installations and demonstration projects that, in turn, allow collection of field data for further research and development.

Opportunities

Conducting research programmes through dedicated joint calls organised by the EU, encouraging demonstration programmes of full-scale projects, coastal onshore prototype test sites and facilities

Over the last few years, a number of real sea test sites have either come on line or are in the process of being developed in Europe. These include the European Marine Energy Centre (EMEC) in Scotland, Wave Hub in England, Belmullet in Ireland. These test sites are intended to provide support infrastructure and aid prototype deployment. Few developers, however, have been able to take advantage of these test sites due to the lack of adequate private finance and public support mechanisms.

Onshore testing facilities that can provide tank testing and accelerated life-time assessment are essential in de-risking the technology.

A European Industrial Initiative could be a mechanism for securing long-term public-private partnerships. Such an initiative could accelerate the pace of innovation and address the fragmentation of the market and R&D efforts across Europe – private and public – by means of a common and compelling Strategic Research Agenda. One of the first steps in this initiative could be pan-European demonstration projects funded partly by the EU and interested EU Member States alongside industry.

Increasing ocean energy R&D support at EU and national levels

Collaborative efforts and increasing targeted EU and national funds are crucial for advancing ocean energy technology. It is vital that suitable resources are put into R&D at both EU and EU Member State level. Coordination between EU and national research programmes and between various stake-holders, such as research institutes, universities, industry and consultancy firms, should be encouraged and supported.

The strategic research agenda for ocean energy should be developed to guide R&D efforts in the key areas of: a) components and power take-off; b) deployment and installation methods; and c) development of design, operation and maintenance tools; with an objective of technological advancement from R&D to demonstration, pre-commercial and, finally, to commercialisation.

The European Commission must take into account sector opinions in formulating its R&D priorities for ocean energy.

Increasing R&D cooperation between industries and with public authorities

The European Industrial Initiative has to have a strategic goal to enhance coope-ration between the various stakeholders.

The strategic research agenda, which forms the basis of the European Industrial Initiative, and the market deployment strategy will include the long-term priorities of resource assessment and forecasting, ocean energy integration with the grid, offshore deployment, operations and maintenance, electricity market evolution, policy recommenda-tions, long-term revenue support mechanisms and environmental impact assessment optimisation.

Increasing cooperation between national and European technology platforms

Several EU Member States, including the UK, Ireland, Denmark, Sweden, Spain, Portugal and Germany, have conducted comprehensive research programmes on ocean energy. These initiatives will need to be integrated into the Europe-wide strategic research agenda and imple-mented through the European Industrial Initiative.

Environment & Planning

Ocean energy systems are anticipated to have negligible environmental impact. However, they may have an impact on the fishing and shipping industries by creating restrictions around ocean energy installations.

Assessing environmental impact is both a time-consuming and expensive process. Although ocean energy is believed to be an environmentally-friendly technology, it is nonetheless not possible at this stage to precisely assess all the possible impacts from the various technologies.

An effective way of implementing maritime spatial planning at EU level should follow the "ROADMAP FOR MARITIME SPATIAL PLANNING: ACHIEVING COMMON PRINCIPLES IN THE EU" developed by the European Commission. Ocean energy development needs to be considered together with other users of space in order to limit conflicts in use and to increase public support for these promising technologies. Even before ocean energy farms are constructed, there are a considerable number of issues to be resolved regarding site selection, including legal rights and coastal zoning.

Beyond technical and economic issues, the sustainability of the ocean energy industry should take into account environmental compatibility and impact mitigation as high design priorities, and improvement in the understanding of the interactions between ocean energy systems and marine ecosystems.

Demonstrating the compatibility of ocean energy systems with ecological systems and human uses of the ocean will be required for ocean energy development to proceed with the necessary public support.

Opportunities

EU Member States should strive for common regulatory regime and legislative framework for coastal areas

A stable, predictable policy framework is very important for an emerging industry as it reduces risk and promotes private investment.

The sea has no borders, although EU Member States have their own systems of seabed ownership and regulation. There is a requirement for a common understanding and application of existing EU environmental regulations to ensure that rules are applied consistently. This will allow project developers to predict with confidence whether a particular project can be undertaken in an environmentally acceptable manner.

Establishment and implementation of marine spatial planning

Suitable areas and locations for ocean energy in the marine environment may compete with other uses of the sea, such as nature conservation, fisheries, transport, tourism and military interests. To achieve optimal site selection, marine spatial planning instruments are needed to help resolve potential conflicts and regulate the competing uses of the seas through a transparent decision-making process.

Expanding existing cooperation on environmental research to more EU Member States

The body of knowledge on the impact of ocean energy on the marine environment is still very limited. It is important that existing and generated knowledge in different EU Member States is shared efficiently, so that research is not duplicated and best practices can be disseminated quickly.

The scope of cooperation on environmental issues could be widened to include technologically-orientated aspects. The impacts of such initiatives should be fully investigated. ■

06.

A European Industrial Initiative would bring together the necessary critical mass of private/public resources to advance the industry to full commercialisation.

// A JOINT PRIVATE/PUBLIC EFFORT IS CRITICAL FOR THE DEVELOPMENT OF THE EUROPEAN OCEAN ENERGY INDUSTRY. //

European industrial initiative

In November 2007, the European Commission adopted a proposal for a European strategic energy technology plan to help the European Union position itself to develop technologies needed to meet its political objectives and to ensure its companies can benefit from the opportunities of a new approach to energy.

This plan stated, among others, the need to create European Industrial Initiatives to strengthen energy research and innovation by bringing together appropriate resources and actors in a particular industrial sector.

It is the opinion of the European Ocean Energy Association (EU-OEA) that such an initiative is critical for the development of the European ocean energy industry as it would bring together the necessary critical mass of private/public resources to advance the industry to full commercialisation.

The European Industrial Initiative for ocean energy could be summarized in four areas: objectives, actions to be taken, estimated costs and strategic key performance indicators.

Strategic objective

To demonstrate operational competitiveness of power generated from ocean energy, to enable the exploitation of ocean energy resources, and to facilitate integration of ocean power into the grid.

Industrial sector objective

To install 3.6 GW of generating capacity from ocean energy systems by 2020, completing the key milestones in Figure 5, and to reach 188 GW of installed capacity by 2050.

Technology objectives

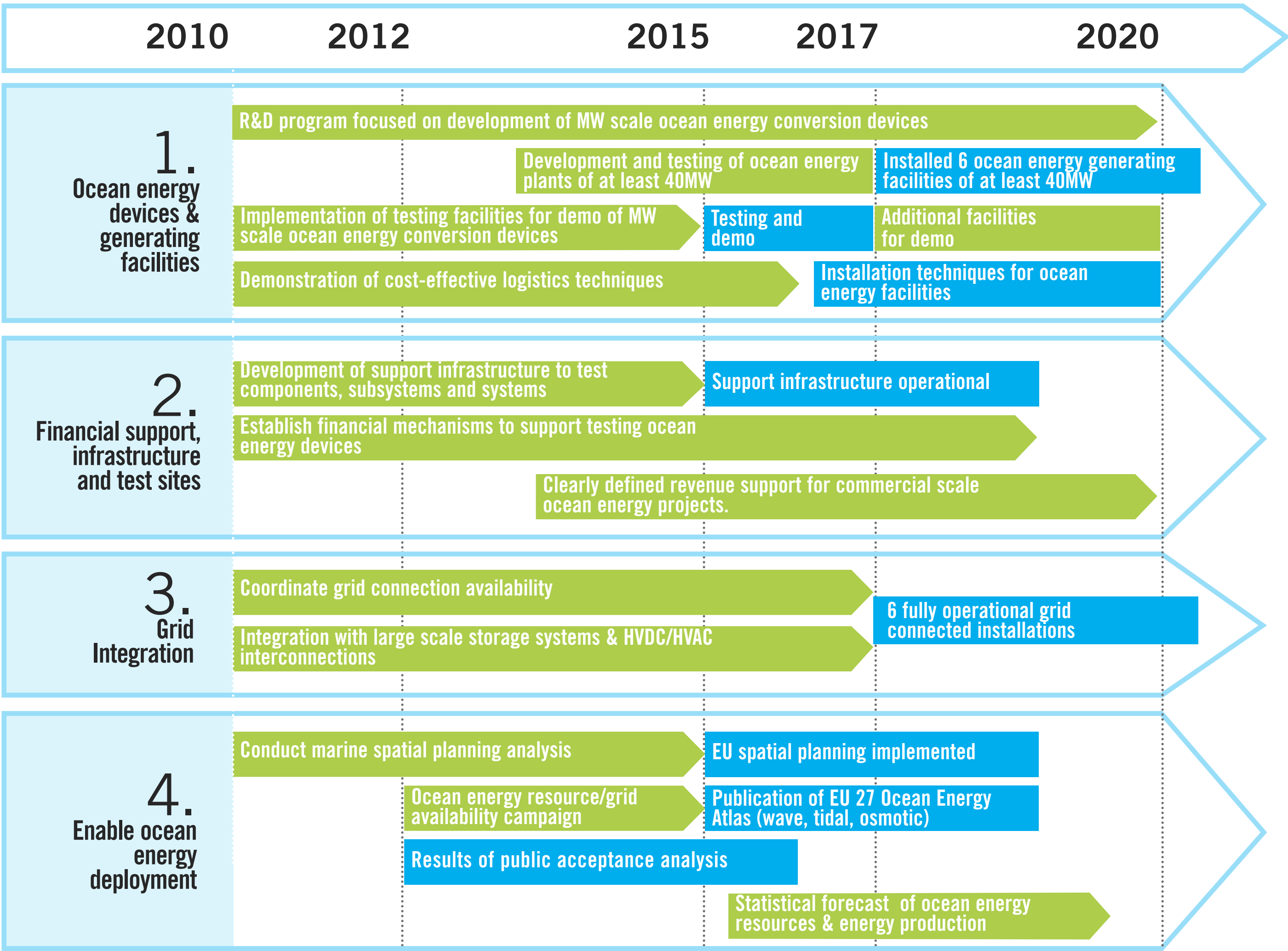
1. **Installation of ocean energy generating facilities with a combined minimum capacity of more than 240 MW:**
   - develop large-scale (MW level) ocean energy conversion devices.
   - improve power output, survivability, and mean time between failures through second-generation designs, controls and monitoring systems.
   - develop manufacturing processes through cross-industrial cooperation with the maritime and offshore oil and gas sectors.
   - develop cost-effective logistics techniques for transportation, installation, operation and maintenance of ocean energy device systems at high resource sites.

2. **Support for infrastructure and test sites:**
   - develop and/or refine test sites for testing ocean energy conversion devices in real operating environments.
   - develop financial support mechanisms to allow the use of existing centres for testing new prototypes.
   - develop support infrastructure, vessels and supply chain for cost-effective installation of ocean energy facilities.

3. **Grid availability and integration of a variable electricity supply**
   - ensure grid availability for ocean energy facilities at interconnection points and transmission lines.

4. **Resource assessment and spatial planning to support ocean energy deployment.**
   - assess and map ocean resources across Europe and reduce forecasting uncertainties of ocean energy production.
   - develop spatial planning methodologies and tools taking into account environmental and social aspects.
   - address and analyse social acceptance of ocean energy projects including promotion of best practices.

Figure 5 | OCEAN ENERGY ROADMAP



ACTIONS

> **Develop full-scale MW range ocean energy devices:**
An R&D programme focused on new ocean energy conversion designs with MW scale capacity, materials and components addressing cost reduction and improved survivability, coupled with a demonstration programme dedicated to the development and testing of a large-scale prototype (1-2 MW).
– A network of European onshore and offshore test sites to test and assess efficiency and reliability of ocean energy components, sub-systems and systems through accelerated life-cycle testing.
– An EU cross-industrial cooperation and demonstration programme drawing on the knowledge of other industrial sectors for mass production of ocean systems focused on increased component and system reliability, advanced manufacturing and rapid installation techniques.

> **Ocean energy technology development targeting improved generation capabilities:**
– A development and demonstration programme for new ocean energy devices to demonstrate improved power production capabilities.
– A development programme to address manufacturing processes for ocean energy devices.

> **Grid integration techniques for large-scale penetration of variable electricity supply.**
– Identify best ocean energy resource locations and match them with the available transmissions infrastructure.
– Assess best connection methodologies for connecting moving ocean energy devices with the electrical export cable.
– Work with grid owners to assure adequate planning for grid availability of ocean energy systems.

> **Resource assessment and spatial planning to support ocean energy deployment within sustainable development.**

> **An R&D programme for forecasting distribution of ocean resources and energy production that includes:**
– Ocean measurement campaigns.
–Database on ocean data, environmental and other constraints.
– Spatial planning tools and methodologies for improved designs and production.

ESTIMATED COSTS TO REACH 240 MW OF INSTALLED CAPACITY

Technology objectives	Estimated Total Cost (M€)	Estimated European Commission Contribution (M€)
1. Install at least 240MW of ocean energy generation capacity	2000	700
2. Develop/operate/support use of ocean energy test sites	300	150
3. Grid integration & revenue support mechanisms	250	100
4. R&D	100	50
Total	2 650	1 000

STRATEGIC KEY PERFORMANCE INDICATORS

Ocean energy installations delivering 9 TWh to the European grid by 2020.

Activities	Strategic key performance indicators
1. New MW range devices and components	Individual ocean energy devices are able to produce > 1MW of power by 2020
	Transportation costs for ocean energy systems are reduced by 10% and compared to oil and gas industry, by 50% by 2020
2. Ocean energy generating technologies	Survivability and service life increased to match the offshore oil & gas sectors.
	Installation costs of ocean energy systems reduced by 30% by 2020 compared to the offshore oil & gas sectors.
	Maintenance costs of ocean energy systems reduced by 50% by 2020 compared to initial installations.
3. Grid integration	Identified grid connection points/constraints with at least five EU Member States
4. Resource assessment and spatial planning	Ocean resources and conditions capable of being predicted with a sufficient certainty to secure project finance.

The EU-OEA has committed itself to supporting and facilitating the development of such an European Industrial Initiative. An initial step should be the establishment of the Strategic Ocean Energy Platform that will gather key industrial actors and achieve the critical mass required to set out the industrial and technological objectives for a joint European Industrial Initiative.

The establishment of a European Industrial Initiative and a Strategic Ocean Energy Platform are therefore the key recommendations of this Roadmap. ■

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