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EUROPEAN OCEAN ENERGY ROAD MAP

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FOREWORD

This Road Map for Ocean Energy in Europe has been prepared under the contract:

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European Ocean Energy Association would like to thank the European Commission's Directorate General for Transport and Energy (DG TREN) for providing the funding that made this Road Map a reality. The development of the Road Map has helped to define the concrete actions necessary to achieve the next milestone on the path of commercialisation of Ocean Energy in Europe.

The Association would like to extend its appreciation to those who have contributed to the preparation of this Road Map. In particular:

The Board of EU-OEA

The Members of the EU-OEA

The Workshop participants

The ocean energy sector key stakeholders

INTRODUCTION

GOALS AND OBJECTIVES

Climate change and increasing dependence on oil and other fossil fuels require comprehensive and ambitious development of renewable energy sources. The ocean energy sector is one of the renewable energy sectors that has potential for significant contribution towards reduction of greenhouse gas emissions and pollution, as it offers a local and decentralised energy source, will create world-class high-tech industries, and will create economic development in coastal areas.

The EU has compelling reasons for setting up an enabling framework to promote ocean energy. Ocean energy is an indigenous source that does not rely on uncertainties associated with the availability and volatility of fossil fuels. It is thus undisputed that ocean energy, being part of the renewable energies mix, constitutes a key element of a sustainable future.

On April 23, 2009, the European Parliament adapted Directive 2009/28/EC, commonly known as the 'new' RES directive. The Directive sets binding targets on the European Member States to generate 20% of final energy from renewable energy sources by 2020.[1]

Ocean energy industry is only starting to develop. It can only provide small contribution to towards the 2020 targets. While its real potential will take time to develop, it is imperative to start now in order to realise this potential as fast as possible. The objective of this Road Map is to outline the path forward, to establish realistic targets and to define conditions under which such targets would be met by 2050 for the benefit of the EU Member States.

This European Ocean Energy Road Map is an input to the Strategic Energy Technology plan that sets out a long-term vision for ocean energy. It proposes that the ocean energy sector requires support in order for the sector to achieve same results as other new renewable energy sectors. The road map outlines a pathway for advancing ocean energy into EU energy policies and markets. It further suggests legislative framework for the promotion and the use of ocean energy in Europe. In doing so, it will provide the business community with the long term stability it needs to make rational investment decisions in the ocean energy sector to provide European rate payers with a cleaner, more secure and competitive energy future.

This roadmap constitutes a first step in defining the set of action and identifying current challenges and opportunities for an increase in production of ocean energy. The follow-on tasks will include further consultations with technology and product developers, investors, and stakeholders to a) refine and agree on the sector vision; b) work jointly with member states on local and EU-wide targets, c) develop and present a realistic action plan, and d) bring together stakeholders, policy makers and the industrial players to implement the road map.

[1] 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.

One of the opportunities that can accelerate the advancement of ocean energy sector is a European Industrial Initiative (EII) that would bring together industrial players, technology developers and the European Commission. Such initiative would target the deployment of accelerated technologies, deliver progress beyond business as usual, define and realise quantified targets, and contribute to political goals in terms of energy dependency/security and climate change.

Reaching set targets will contribute to major reduction in greenhouse gas emissions, reduce annual fossil fuel consumption, and spur new technologies and European industries. These benefits will come at an additional cost of an overage of €XX-XX million per year from 2010 to 2020, depending on energy prices. With a conducive regulatory framework, heavy investment has been made in the past in conventional energy sources, notably coal and nuclear energy. The time has now come to do the same for ocean energy.

Pursuing an ambitious ocean energy policy for Europe, including a more vigorous and ambitious promotion of renewable energy sources, will require changes in policy. It will entail action at all policy and decision-making levels to provide adequate support for the development of the ocean energy sector that can become a major contributor to the carbon free society and energy independence. This Road Map sets out a framework for such action.

METHODOLOGY

The Road Map was prepared with contributions from the non-members and members of European Ocean Energy Association (EU-OEA), including:

-- Industry representatives;

-- Ocean energy experts;

-- Representatives of international and national organisations dealing with ocean energy;

-- Representatives of governmental and European bodies;

-- Ocean Energy technology developers

The final draft of the Roadmap will be used as an input to the SET plan, including more detail information on the status and challenges of ocean energy technologies.

TOWARD A EUROPEAN INDUSTRIAL INITIATIVE FOR OE

Ocean Energy (OE) has a potential to play an important part in Europe's energy mix toward the EU's 2050 targets for renewable energy as well as providing billions of Euros of investment in Europe and thousands of jobs. A number of the EU member states have been supporting technological development of OE, but have not had much coordination at the European level.

This resulted in a patchwork of initiatives. In order for OE to reach its true potential, it is imperative for the stakeholders throughout Europe join forces and work towards a common goal. This sentiment was strongly expressed during the development of this Road Map

The framework of the European Industrial Initiative lends itself in bringing together OE developers, utilities, and member states at the European level, setting measurable objectives, action items and timelines in order to pool the required resources to advance OE to commercialisation. This should be done through one or a number of large scale OE projects, which will be used to prove the potential of the OE technologies, enable market creation, that in turn would lead to creation of a real industry. The best way to facilitate the development of OE sector is to bring resources towards such large-scale projects that in fact, implies establishing the OE EII.[2] The OE EII will bring the necessary actors together to define, develop and implement mechanisms, leading to commercial size OE projects.

EIIs have been proposed by the European Commission in 2007 based on a number of criteria: the EU added value, the willingness of actors to join forces, the potential market penetration, the potential contribution to CO2 limitation, security of energy supply and competitiveness[3] that would all culminate into a concrete set of measureable actions and moves beyond “business as usual”. As will be seen from this narrative, although OE can fulfill all these criteria, OE is still in its early stage of development and needs extensive effort to reach EU targets. This paper identifies the resource potential and sets achievable targets for installed capacity; it identifies barriers and proposes an action plan to assist the sector in reaching a stage of development that will enable it to profit from a EII.

From analysis of the barriers, presented below, financing has been identified as the top issue, followed by policies. The framework for risk sharing that can be achieved through the industrial initiatives are extremely important[4], as they would make investment security possible and become an important incentive for potential investors towards achieving sustainable penetration of OE in the European energy market.

Therefore, in order to reach the critical mass required for OE to make significant contribution to the European renewable energy market, and to achieve the SET Plan goals for this sector, the best way forward would be the implementation of the European Industrial Initiative. This would require a coordinated effort of primary actors in order to mobilise the critical mass necessary for the project implementation.

[2] European Commission, Presentation SET plan: Presentation 2008 Toward a Low Carbon Future. P.2
[3] European Commission, *Questions and Answers on the European Strategic Energy Technologies (SET) Plan*, Memo 07/494, Brussels 2007, p.4
[4] TP Wind, European Industrial Initiatives, p. 8, 2008,

CURRENT STATUS OF THE OCEAN ENERGY SECTOR

STATE OF THE ART

Ocean Energy resources include energy from Waves, Tides, Currents, temperature gradients and salinity gradients.

The best OE resources within the European Member States are wave and tidal stream and tidal range. These areas have seen the most of technological development. Salinity gradient systems are being developed in Norway and Holland. Ocean thermal resources are not yet available in Europe, but can be harvested at latitudes closer to the Equator with products and technologies developed by European companies.

Tidal energy systems have the longest history with early examples dating back to the 7th century in Northern Ireland. During the middle ages, tidal mills were wide spread in Europe along the coasts of Scotland, Wales, England, Holland, Belgium, France, Spain and Portugal. Many of these were used and renovated during the 17 and 18th century. The touring exhibition “Tide Mills of Western Europe”, supported by the European Commission through its Culture 2000 Programme, presented original tidal locations around Europe (www.moinhosdemare-europa.org).

The largest OE installation to date is the 250 MW La Rance, Tidal Range Energy Plant in France. It has been in operation since 1966 with an annual production of 538 TWh (capacity factor of 0.25). There are other tidal plants of similar operation principle in the planning phases within EU located at suitable estuaries and tidal lagoons. These systems are known as tidal barrages. They consist of dams and reservoirs. Their principles of operation are the same as conventional hydro power plants.

Tidal Energy can also be harvested from currents associated with tidal variations using devices that look like underwater windmills. A number of pilot projects are under development to find the most cost effective method for generation, installation and maintenance.

Wave energy has the largest potential in Europe and worldwide, and can be captured in a number of different ways. Most of the new technology development in Europe has been in wave energy conversion. The state-of-the art of these technologies varies from conceptual designs to small demonstration plants. Harvesting energy further offshore in deeper water requires floating systems. Such devices may be of different types, including point absorbers, attenuators, overtopping, OWC, and others.

European stakeholders are developing several different wave and tidal energy systems. At the same time, specific development zones, including testing facilities and grid infrastructure have been established in Ireland, Norway, Denmark, the UK, Portugal, Finland and Italy. Recently, utilities such as Statkraft, Vatenfall, E.ON, RWE, Dong Energy, EDF, EDP, IBERDROLA have committed financial resources to assessment of various OE technologies.

At the present time, this young industry is moving through the pilot and early commercialisation stage of technological development. It is expected that once systems have demonstrated their performance and survivability in the field, OE will be ready to advance to large-scale demonstration installations. Such projects will require pooled resources between financial community, large industrial players, end-users and the public to share the burden of new technological developments. This, in turn, leads to the need for the European Industrial Initiative.

CHALLENGES

The complexity, novelty and decentralised nature of OE applications result in numerous administrative problems. These include unclear and discouraging authorisation procedures for planning, building and operating systems, differences in standards and certification and incompatible testing regimes for OE technologies. There are also many examples of opaque and discriminating rules for grid access and a general lack of information at all levels including information for suppliers, customers and installers. All of these factors have contributed to inadequate growth in the ocean energies sector.

POLICY ISSUES

OE will take some time to become the least cost option. In order to develop, the sector needs consistent policy measures. These include stability of support schemes, resolution of issues related to authorisations and impact assessment procedures, as well as strong political commitment to advancing OE.

FINANCING ISSUES

Due to high investment costs and uncertain return on investment, OE faces serious financing issues. To date, most of the public assistance funding has been available mostly for basic research and concept designs. This makes it difficult for the sector to develop beyond wave-tank testing, and thus to become a mature industry. Financing of sea-testing and full size prototypes is almost an impossible task.

INFRASTRUCTURE ISSUES

Just as other decentralised renewable energy resources, OE faces 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.

Over the last few years, a number of test sites came on line in Europe. These test sites are intended to provide support infrastructure for testing new OE devices in the field conditions. However, most do not offer sheltered wave climates and prevent developers from testing devices in mild wave-climates. Few developers have been able to take advantage of these test sites due to the lack of adequate financial resources and lack of support mechanisms towards the use of these sites.

STANDARDS AND SUPPLY CHAIN ISSUES

The OE sector features a large diversity of technology applications and concepts. This diversity has an unintended impact on the development of the supply chain that could play a major role in reduction of costs of OE and commercialisation.

Limited involvement of the supply chain is also a result of the lack of standards for the sector. One may argue that offshore industry standards should be applicable to OE as well. Discussions have begun on the development of the OE standards through the International Electrotechnical Commission (IEC) Technical Committee 114 on Marine Energy leading the development of international standards for OE technologies.

FUTURE DEVELOPMENT: SCENARIOS, TARGETS AND PROSPECTS FOR THE OCEAN ENERGY SECTOR

COST ESTIMATES

OE nameplate capacity of a single unit can range from kilowatts to megawatts. Several units installed in the same area would create wave or tidal energy farms generating tens and hundreds of megawatts.

Load factors for wave and tidal power installations are projected to be greater than 2000 hours per year. Salinity gradient systems and thermal energy plants may see operating hours greater then 7000 hours.

It has been noted that the cost of OE is very site and technology specific. Cost figures are still being developed as devices enter long-term energy production stage. Based on the 2005 study by the UK Carbon Trust[5], the cost of wave energy is likely to be between 12p/kWh and 44p/kWh and the cost of tidal energy between 9p/kWh and 18p/kWh. Depending on the exchange rate, the cost of current prototypes in Euros are of the order of 3.500 to 13.000 €/kW. This leads to a cost performance average estimate in the range of 100 to 650 €/MWh, depending on the full load hours, interest rates and depreciation period.

TARGETS FOR INSTALLED CAPACITY

In 2007, countries of the European Union consumed 2,926 TWh of electricity[6]. Electricity production that can be produced economically from OE in EU member states is estimated on the order of 200 TWh/year. Table 1 represents the potential economic contribution from viable OE resources, representing approximately 7% of the theoretical potential.

Table 1 - Economical and technical achievable power from of Ocean Energy

Type of Ocean Energy	Potential Installed Capacity	Projected Load Factors	Projected Electricity Production
Tidal Power/Energy	16 GW	2250 h/year	36,000 GWh/year
Wave Power/Energy	65 GW	2190 h/year	142,350 GWh/year
Osmotic Power/Energy	4 GW	7000 h/year	28,000 GWh/year
Total Ocean Energy	85 GW		206,350 GWh/year

The potential growth of installed generating capacity of OE depends on several factors such as technology readiness, political and economic support structures and incentives, and availability

[5] « Future Marine Energy », The Carbon Trust, 2006 (http://www.carbontrust.co.uk/Publications/publicationdetail.htm?productid=CTC601)

[6] The World Fact Book (https://www.cia.gov/library/publications/the-world-factbook/rankorder/2042rank.html)

of the grid. Table 2 represents the vision of the installed capacity of the OE sector that may be achieved if such factors become reality.

The UKERC report[7] used the MARKAL model to examine the mix of renewable energy sources that may be developed in the UK by 2050 under various technology acceleration methods in response to a political imperative to de-carbonise the UK energy economy by up to 80% compared to 1990 figures.

The presented scenarios for the OE section of the study provide two scenarios for potential market penetration.

- In **Scenario A**, OE is assumed to have an accelerated development rate, supported by projected learning rate of between 10-15% with continued funding support to facilitate technology push and market pull enabling deployment and technology breakthroughs, with other technologies developing in a "business as usual" manner.

- In **Scenario B**, all supply technologies are assumed also to have the accelerated development that OE competes with for market share, while OE is assumed to have the same accelerated development rate, supported by projected learning rate of between 10-15% and continued funding support to facilitate technology push and market pull enabling deployment and technology breakthroughs.

It should be noted that neither of the scenarios anticipate, nor project significant OE installations before 2015; in addition, the total economic OE resource is not projected to being exploited by 2050. The primary difference between the two scenarios is the rate of the installations deployment.

The following Table 2 provides the projected installed capacity from the UK results adjusted to reflect the larger European OE resource potential

Table 2 - Ocean Energy Implementation Scenarios

Year	**2020**	**2025**	**2030**	**2040**	**2050**
Scenario A [GW]	8	15	20	66	85
Scenario B [GW]		12	12	68	85

[7] Mark Winskel, Nils Markusson, Brighid Moran and Henry Jeffrey (Edinburgh University) Gabrial Anandarajah and Nick Hughes (Kings College, London), Chiara Candelise (Imperial College, London), Donna Clarke and Gail Taylor (Southampton), Hannah Chalmers (Surrey University), Geoff Dutton (Rutherford Appleton Laboratories), Paul Howarth (Manchester University), Sophie Jablonski (Imperial College), Christos Kalyvas (Imperial College, London) and David Ward (UKAEA Culham), "Decarbonising the UK Energy System: Accelerated Development of Low Carbon Energy Supply Technologies", UKERC Energy 2050 Research Report No. 2, March 2009

OE resources are mostly found in member states along the Atlantic Arc, the Mediterranean Sea, and the North Sea for Salinity Gradient. As such, it is estimated that 14 of EU-27 countries and two non-EU members will be actively involved in the development of the OE Industry. At this point Belgium, Denmark, Finland, France, Greece, Ireland, Italy, the Netherlands, Portugal, Spain, Sweden, Norway, and the United Kingdom are developing technologies. Countries such as Germany, Poland and Switzerland are involved as component suppliers and with financial investments.

Based on the above scenarios, the potential installed OE capacity in the EU-27 is projected to be between 12 GW and 20 GW by 2030 and 85 GW by 2050. These capacities could generate about 1% and 6% of the projected EU-27 electricity consumption by 2030 and 2050 respectively.

It is the opinion of sector that scenario A represents an achievable target for OE at the European level. Indeed, the French government has already announced an objective of 6GW of OE installed by 2020[8], and the Scottish Marine Energy Group have proposed a scenario of 2GW by the same date. Similar targets are being developed in UK, Ireland and other EU member states with OE resources. This shows that the 8GW target is both politically acceptable and achievable. Furthermore, this target is reached without taking into account future developments in countries with extensive OE resource, such as Ireland, Spain, and Portugal.

Table 3 represents specific installed capacity targets for each type of OE available in within EU.

Table 3

Year	**Units**	**2020**	**2025**	**2030**	**2040**	**2050**
Tidal Current	GW	1.5	2.8	3	12.4	16
Wave	GW	6.1	11.5	15.3	50.5	65
Osmotic	GW	0.4	0.7	0.9	3.1	4
Total Target	GW	8	15	20	66	85

[8] http://www.greenunivers.com/2009/07/grenelle-mer-gossement-9677/

IMPACTS

SOCIAL ECONOMICS – JOB CREATION

Several studies[9] suggest OE has a significant potential for positive economic impact and job creation contribution as outlined in Figure 1.

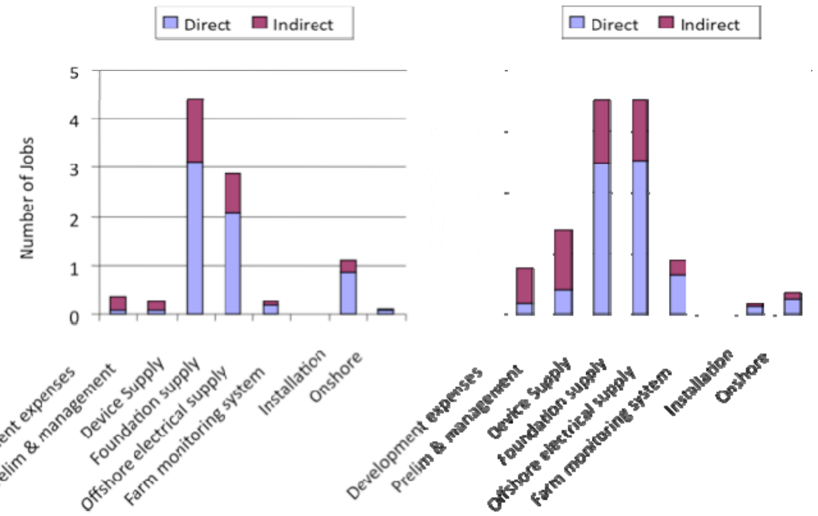

Figure 1 - Job creation by wave and tidal energy for each MW of installed capacity

As the above figure shows, it is anticipated that approximately 10 jobs (direct and indirect) would be created for each MW of OE installed,

In the Scottish Marine Energy Roadmap, the estimates are somewhat lower, but nevertheless significant. The Marine Energy Group indeed estimated that a development of the OE sector to 1GW or 2GW of installed capacity in 2020 would create 5 direct jobs per megawatt.[10] Nonetheless, if indirect jobs are considered, the figure goes up to 12.5 jobs per MW installed. [11]

GREENHOUSE GASES AVOIDANCE

OE technologies can replace fossil fuel-based power plants in the peak to medium scale base load. OE does not emitting particles, CO_2, SO_2 or NO_x.

[9] 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-OE, Project no. 502701, WP5, 2006, 9 pp

[10] FREDS Marine Energy Group (MEG), *Marine Energy Roadmap*, p. 18

[11] Ibid. p. 44

Therefore OE based electricity can replace energy generation from fossil fuels. The typical savings obtained are illustrated in Table 4.

Table 4 – Typical greenhouse gas avoidance from Ocean Energy generation[12]

1 MWh replacement of	CO_2	SO_2	NO_x
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

Considering the non-storable nature of ocean energy, it is unlikely for ocean energy to replace baseload electricity. The IEA electricity mix scenario for Europe 2030 suggests that 300 kg/MWh could be avoided by ocean energy. Therefore, if 20 GW (49 GWh) of OE is installed in Europe by 2030, the avoided CO_2 emission is 14.5 Mt/year.

These figures do not account for the possible needs for fossil fuel based power required to back-up firm wave power capacities. On the other hand, as long as wave energy only contributes 1% to the total electricity consumption this can be ignored

SECURITY OF SUPPLY AND USE OF INDIGENOUS ENERGY RESOURCES

Once in the commercial use, OE will contribute to the EU overall target of providing a more diversified energy mix by using locally available renewable energy sources.

The manufacturing, transporting, installing and operation of OE generating facilities will generate and offer employment to coastal communities, many of which are in remote low employment areas, and can offer job opportunities in areas that experience decline in the offshore oil and gas sector.

Furthermore, the high OE potential that exists in many peripheral regions, such as islands and coastal areas where energy is not always easy to access, could bring a high added value in terms of jobs, economic development and security of supply in areas that still depend greatly on fossil fuels.

ENVIRONMENTAL IMPACT

Assessing environmental impact is a very time consuming and difficult process for installing OE technologies. However, these impacts cannot be overlooked, as OE has a notion of being an environmentally friendly technology. It is nonetheless extremely difficult at this stage to precisely assess the general impacts that all technologies could have.

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

Even though environmental impact assessment is necessary for each project, environmental impact assessments conducted so far for OE projects have shown negligible impacts on the marine environment.

It must nevertheless be pointed out that it is extremely difficult to predict the impacts of full scale installation on the environment, and that therefore the key priority is to continue monitoring and making sure that the OE technologies are as environmentally benign as possible.

SYNERGIES WITH OTHER SECTORS

In order to accelerate the development and penetration of the European energy market, OE may take advantage of other sectors that have developed market viability by engaging in joint development projects. On the other hand, OE should put forth the advantages it could bring to other sectors. This is what we refer to as synergies with other sectors. This should be integrated as a way to overcome both technological and non-technological barriers and to facilitate the sector's development.

Other sectors of renewable energy production, in particular the offshore wind and hydro, share some technical similarities and have to deal with non-technological barriers that are sometimes similar to those encountered by OE. Offshore wind, wave and tidal energy in particular share synergies in relation to governmental marine policies, marine stakeholders and spatial constraints.

The tidal range power plant at La Rance, France is a good example of this, as it shares many aspects of normal hydro-electric plant, and draws many of its characteristics from this very well developed technology. Both hydropower and OE technologies deal with similar technical issues relative to water, and progress in one sector while undoubtedly benefit the other.[13] Moreover the problems linked to grid connection are common to most forms of renewable energy plants, in particular offshore wind, which requires major investment for grid installation. Indeed, some studies show that it could make sense to create spaces combining offshore wind and wave power, share the cost of grid connection, simplify licensing procedures, and make it possible for more power to be installed at one site, thus making the project more economically viable.[14]

Furthermore, it is important to note that most of OE technologies (especially tidal and wave) rely on civil engineering and techniques that are commonly used in shipyards and in the sectors of offshore oil and gas production.[15] Moreover, despite the fact that water is over 800 times denser than air, the technology used for collecting the energy from tidal currents is similar to that of a

[13]B. Pelikan, Ocean Energy- A certain Kind of Hydropower, p.4, http://www.iitr.ac.in/departments/AH/uploads/File/International%20conference%20on%20SHP%20Kandy%20Srilanka%20All%20Details/Papers/Policy,%20Investor%20&%20Operational%20Aspects-C/C23.pdf
[14] http://www.energystocksblog.com/2008/12/17/wind-and-wave-hybrid-a-proven-synergy/
[15] http://www.hydro-gen.fr/index.php?option=com_content&task=view&id=3&Itemid=4

windmill and includes elements from hydroelectric turbines, so developments in technologies for tidal currents turbines could help the sector of wind energy and vice-versa.[16]

The fact that OE power plants are located in a marine environment could help for the production of drinking water through electrolysis for desalinisation of seawater. This could be a major asset for local populations that currently have limited access to drinking water, in particular in Mediterranean and tropical countries, indeed, it has been reported that a 2MW power plant could produce 4300 cubic meters of desalinated water for drinking and irrigation each day.[17] This process has in particular been reported for ocean thermal energy conversion technologies (OTEC), but could possibly be extended to other technologies.

OE technologies could be used for heating and cooling of dwellings near the coastline. The fact that sea water temperature changes with less amplitude than that of the air could be used to cool the air during the day and warm it at night for example. This possible synergy would require further investigation, as little research has yet been carried out, apart from the field of OTEC, where pumping cold water from the depths of the ocean could enable cheap refrigeration and environment-friendly air-conditioning.[18]

Research is underway to develop a new generation of bio fuels that will come from algae cultivated in the ocean. OE devices could potentially be used to grow these new bio fuels, which could be considered as a new form of OE.[19] Furthermore, electricity produced from the ocean could be used to produce hydrogen from seawater, which could also be used as a fuel for vehicles that would replace oil.[20]

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

[16] http://www.marineturbines.com/21/technology/
[17] http://www.nrel.gov/otec/desalination.html
[18] http://www.nrel.gov/otec/refrigeration.html
[19] http://www.underwatertimes.com/news.php?article_id=25107309846
[20] http://www.hydro-gen.fr/index.php?option=com_content&task=view&id=1&Itemid=2&lang=en

RECOMMENDATIONS FOR OCEAN ENERGY INDUSTRY DEVELOPMENT

POLICY ISSUES

On the basis of experience over the past decade, a number of key principles for the future OE policy framework need to be established. With a view to significantly increase the share of OE sources in the EU's energy mix, the following framework should:

-- be based on long term targets and stability of the policy framework for the OE sector,

-- include increased target setting across Member States,

-- be comprehensive, notably encompassing all technologies suitable for Europe,

-- provide for continued efforts to remove unwarranted barriers to OE deployment,

-- take into consideration environmental and social aspects,

-- ensure cost-effectiveness of policies, and

-- be compatible with integration with the energy market.

UNSTABLE AND INCONSISTENT SUPPORT SCHEMES

Support mechanisms for OE sector are most often inconsistent or inadequate. This causes prospective investors to doubt the commitment of the government and therefore not to invest fully into this renewable energy sector. As an example, a well defined and consistent support for OE in Ireland illustrates how a consistent government policy can produce long term effect on development of the sector, which necessary across the board at this stage of OE development.

LONG PERMITTING AND ENVIRONMENTAL IMPACT PROCEDURES.

The permitting and consenting procedures for OE installations are not clearly defined and, in some cases, do not exist, thereby requiring tremendous amount of financial resources to obtain installation of such permits and licenses. It is therefore up to the developers to ensure good project and time management and make sure that permitting procedures are included in the budget and schedule. It should be advocated that these permitting procedures be handled by a single entity that would bring together all necessary agencies.

Environmental Assessments (EA) are part of the permitting procedures. Such assessments and the more comprehensive Environmental Impact Studies (EIS) carry significant importance to assure that any identified environmental impacts are appropriately considered in the interest of the environment and public acceptance of OE as an energy option. Making completed EAs and EISs available to the OE community could increase the effectiveness of such assessments, particularly through shared results, and using them to speed up permitting activities of other projects. The results of assessments in other sectors that could be relevant to OE, such as the offshore wind and oil & gas sectors, should also be used as valuable data to advance the OE sector.

Nevertheless, despite possible action from governments and the public sector, it is up to developers to ensure that permitting and environmental impact assessments are properly accounted for in project schedules and financial projections.

Recommendations

1. Work with national governments and European institutions on the **OE sector needs for sustainable and consistent commitment** that would lead to the industry maturity.

2. Establish **long-term, consistent support schemes** at the national and the EU-wide levels that are required to support technology maturity.

3. **Improve the functioning of the internal electricity market** considering the development of OE. Improved transparency, unbundling, and higher capacity of inter-connectors all improve the opportunity for new innovative renewable energy players to enter the market.

4. Establish **clear permitting and consenting criteria for OE projects**, and do the most to reduce administrative barriers (through standardisation, as mentioned below).

5. Take **full advantage of existing environmental impact assessment results and methodologies** by sharing and centralising data. More precisely, environmental impact assessments made for offshore wind and existing OE installations should be used for the OE sector as examples.

6. Developers must make sure to include **a reasonable time frame for permitting** in their project schedule in order to avoid running out of time or money in the process.

7. Propose strengthening the legal provisions to **remove any unreasonable barrier** to the integration of OE into the EU energy system. Conditions for grid connections and extensions must be simplified. Some Member States have panoply of permission procedures to be complied with in order to construct renewable energy systems. This must be reduced. Red tape for innovative small and medium-sized enterprises must be eliminated.

FINANCING ISSUES

LACK OF PRIVATE SECTOR INVESTMENT

The development of OE is promoted mainly through the financing of research and development. Public funding mechanisms are scarce when it comes to financing of demonstration projects. Private sector investments in OE have occurred, but they are hardly enough and are hard to attract. European utilities are in the best position to be technology enablers by investing capital required to advance new technologies to commercial levels along side with private capital. In order to reach the next level of development, the sector needs both the public and the private sectors to share risks. That can be achieved with a commitment on both sides.

With the use of investor incentive mechanisms, policy makes can leverage public funding together with private capital.

NEED FOR BETTER TARGETING FINANCING

As mentioned above, financing and promotion of OE is often done through financing of research projects. However, the current challenge of OE is not to develop new concepts in laboratories, but rather to demonstrate technologies that have advanced to the pilot stage of their development. In order to do this, more financing should be allocated to the pilot and demonstration stages of OE development at both the national and the EU levels.

As mentioned above, the need to go from a single pilot device installation, to few MW installation at a test site, to farms with tens of MW calls for targeted investment in specific and ambitious projects. This would require a large scale public-private partnership that would act as a showcase for OE, and initiate a market pull.

Recommendations

- Policy makers should put in place **incentives for private bodies to invest in OE technologies** (e.g. tax incentives, which are possibly the most cost efficient policy instrument to promote private investment).
- **Promote few medium-large scale public-private partnership projects** to help the sector attract private investment (market pull).
- Set-up **selective criteria for financing OE research and development** in order to improve and advance those technologies that have passed a pilot demonstration phase, rather than development of new concepts.
- **R&D grants** should be encouraged to address **improvement of existing technologies**.
- Create a **database of possible financing sources** in order to facilitate financing of OE research, development, demonstration and long-term field testing.

INFRASTRUCTURE ISSUES

GRID ACCESS

Looking ahead, one of the main hindering factors for OE expansion will be availability of access to the electricity grid and availability of strong enough grid close to coastal locations. Whilst some sectors facing the same problems, such as offshore wind, are already planning precisely the future grid developments for the next decades, OE has for the moment not been included in these projects. The difficulty for the sector to prove it will be able to deliver energy by 2020 makes it hard to push in favour of its inclusion in offshore grid development planning.

The sector has to work along with both transmission system operators (TSOs), and with other sea users who are participating in the offshore grid planning and will benefit from it. Policy makers also need to ensure that OE is taken into account, so that no option for future energy sources is left out.

TEST SITES

A fair number of test sites are now available for testing OE devices, but they are usually underexploited. This is mainly due to fact that installation of full size devices is very costly. This, in turn, prevents some developers from conducting the necessary testing of their devices, which is the objective of the test sites in the first place. Testing does not generate revenues for technology developers and is therefore another cost. Test sites should establish financial support programs to allow technology testing.

Test sites available today are located in fairly severe wave climates, except for few. Policy makers should constrain sources of public funding to those locations that will be usable by developers.

Recommendations

1. Governments **should encourage grid development in coastal areas with significant OE resources** in order to enable connection of OE devices, which will be installed in the future.
2. The OE sector must engage in **cooperation with stakeholder that are now developing the future offshore grid** in order to have an access to the grid when their technologies are mature.
3. **Test site owners** should be in a position to **offer financial support to developers to use their sites**.
4. **Future test sites locations** should be in **mild wave climates** to allow for testing of less mature technologies.

STANDARDS AND SUPPLY ISSUES

NEED FOR A SUPPLY CHAIN FOR OE COMPONENTS

OE is a developing sector without a dedicated supply chain. This leads to the use of components that may not be ideally suited for use in OE devices. The development of a supply chain would require the sector to be more mature, and the demand to be higher.

LACK OF DESIGN GUIDELINES FOR OE DEVICES

Since OE is a developing industry, there are presently no standards and/or design guidelines, nor are there oversight procedures for certifying authorities. This void has led to a number of device failures that could have been prevented if such guidelines were in place, or if device designers followed standards and procedures from other industries, like the offshore oil & gas, or offshore wind.

TOO MANY OE CONCEPTS

Compared to other renewable energy sectors, OE has too many diverse technology concepts. Partly, this is a result of the funding support schemes that have been available for early stages of research and development. In addition, since OE represents at least five different energy vectors, it will always require different principles for energy capture and conversion. This could be considered as an asset of this sector, as each technology aims to fit specific energy vector and thus could increase the overall generation from OE systems. However, the drawback of this diversity is in ability to advance the OE sector to maturity since the available funding will be spread over larger demand for money, instead of being concentrated in a few technological developments.

RELATIVE LACK OF AVAILABLE SKILLS AND EXPERTISE

The early stage of the industry lends itself to attracting inventors and recent graduates, rather than the experienced and skilled workforce. This, again, results from the inadequate financing that cannot offer skilled workers salaries competitive to those available in the offshore oil & gas or the offshore wind industries.

Recommendations

1. **Promote development of a supply chain for the OE sector** particularly in countries that do not have significant OE resource, but has a strong industrial base (e.g. Germany).

2. **Follow and support** the work of the International Electrotechnical Commission's (IEC) Technical Committee on Marine Energy (TC 114).

3. **Focus research priorities and available funding** towards advancement of few technologies that have passed and demonstrated adequate results through wave tank testing, rather than creation of totally new ideas
4. **Disseminate projects results to the European OE community** to allow better interaction between device-developers (e.g: the Equimar project).
5. **Identify key research and development priorities** for the sector in order to rally the developers toward a common goal.
6. **Develop training** for semi- and highly qualified OE workers
7. **Attract expertise from other sectors** that have long-term experience with offshore technologies.

CONCLUSION AND NEXT STEPS

The OE Road Map presented here sets out an important part of its strategic vision for the OE development in Europe. It seeks to significantly accelerate the growth of the OE sector, and proposes that the EU achieve a contribution of XX% of its energy mix from ocean energy sources by 2050. The EU-OEA will be working with the Member States and the Commission to endorse this target. This will require a substantial strengthening of the Member States and the EU regulatory framework to support the advancement of OE.

Reaching this target is technically and economically viable. Additional average costs compared to conventional supply options will depend on future innovation rates and conventional energy prices and would range between €XX to €XX billion per year. The deployment of OE will contribute towards EU goals for 20% renewable energy target to the annual reduction in CO_2 emissions by approximately XX Mt in 2020, and XX Mt in 2050. The value of this significant reduction in greenhouse gas emissions would nearly cover the total additional cost under high energy prices. At the same time, the EU will strengthen its position on security of supply reducing fossil fuel demand by over XX Mtoe in 2020 and XX Mtoe in 2050.

Member States should engage in a process to share the overall targets for OE, taking into account national circumstances and choices, while at the same time indicating the way in which they intend to make progress in the OE sector once the targets have been agreed upon between the EC and the Member States.

This Road Map strives to create a true European market in which OE technologies can thrive. It will provide the business community with the certainty and stability it needs to make its investment decisions while at the same time asking Member States to support this policy in line with their national circumstances.

The Road Map builds on the reputation and the leading role the EU ocean energy industry sector holds in the world. The objective is to confirm the EU as a world leader in this sector. In view of increased global competition and the fact that other key players are putting in place resources to advance OE development, meeting this objective involves significant challenges for Europe. Failing to rise to this challenge, through inaction or lack of vision, would seriously endanger our leadership in this field, an importance of which reaches far beyond the OE sector.

ANNEXES

1. Action Plan

In order to deal effectively with the issues outlined above, the OE sector needs a precise set of actions that should be implemented and assessed regularly in order to benchmark the progress along the proposed Road Map.

This Action Plan is divided into seven interdependent sections: 1) Creating a market-pull and reducing financial risk at the European and national levels; 2) Promoting accessibility and diversity of OE testing and demonstration sites; 3) Development of an adequate planning and regulatory framework in countries and regions; 4) Development of OE design guidelines, certification procedures and standards; 5) Access to market to OE; 6) Defining and addressing R&D priorities, 7) Training skilled workforce and developing manufacturing capability.

1) Creating a market-pull and reducing financial risk at the European and national levels

- A medium-large scale joint demonstration project would be an effective way to initiate market pull for the OE sector. This should be implemented at the European level through cooperation between public and private bodies of Member States.
- The public sector is not able to take on full financial risk of OE development; therefore, public bodies must share part of this risk.
- Utilities should be encouraged to invest in the development of the OE sector through tax credit and other support mechanisms.
- Establish information exchange platform that will enable advancement of OE systems by benefiting from one another.

2) Promoting accessibility and diversity of OE testing and demonstration sites

- The costs of installing a device in the sea for testing should be reduced through government and European support. This would imply increasing financial support for this phase of research, development and demonstration.
- Future test sites should be installed in sheltered areas to allow testing of less mature technologies in relatively mild wave climates.

3) PUSHING FOR THE DEVELOPMENT OF A SUPPORTIVE PLANNING AND REGULATORY FRAMEWORK IN COUNTRIES AND REGIONS

- A centralised database for environmental assessment reports on coastal and offshore installations should be developed at the European level in order to facilitate dissemination of such information and make further assessments more cost effective.
- Consent procedures for OE should be based on clear criteria, which could be defined at the European and the international level through results sharing as they become available.
- As much as possible, the administrative procedures for permitting should be made clear, and be lead by a single administrative body.

4) DEVELOPING OE CERTIFICATIONS AND STANDARDS

- Following and supporting the work of the International Electrotechnical Commission's (IEC) Technical Comittee on Marine Energy (TC 114).
- Focusing research and development funding towards support and advancement of limited number of wave and tidal stream energy converters with a focus on those that have demonstrated successful results through wave tank testing and are ready for pilot installation.
- Disseminating the results of projects related to standard building in Europe, and applying them to device-development (e.g: the Equimar project).
- Identifying key research and development priorities for the sector in order to rally the developers toward a common goal.

5) PROVIDING ACCESS TO MARKET TO OE

- The OE sector should be included in the process of offshore grid planning, and collaborate with other actors involved such as the offshore wind sector and the Transmission Grid Operators (TSOs).
- The OE sector should lobby European institutions and national governments for the development of a decentralised generation model that would be best suited for OE generation.

6) DEFINING AND ADDRESSING R&D PRIORITIES

- As R&D priorities have been defined by stakeholders, it is now overwhelmingly important to finance these priorities in order to advance the OE industry to the next level.

7) ATTRACTING A SKILLED WORKFORCE AND MANUFACTURING CAPABILITY

- Specialised courses could be organised in order to introduce students to the field of OE.
- The OE sector is in dire need of expertise from other sectors including the maritime and offshore oil and gas sectors.
- The potential and the benefits of OE should also be disseminated through an OE showcase, which would not only be visible to potential investors, but also to skilled workforce who may wish to join the sector.

2. RESEARCH AND DEVELOPMENT PRIORITIES

Since many OE technologies are still at the research and development stage, it is important in order to issue recommendations for the future of the sector to identify R&D priorities. The outcome of a meeting organised by the EU-OEA on the subject will be used here as a basis to outline these priorities.[21] As a result of this meeting; three R&D priority topics were agreed to have high priority by stakeholders: 1) Components, PTO, and new concepts; 2) Deployment and installation methods and tools; and 3) Design and operation tools.

1) COMPONENTS, PTO, AND NEW CONCEPTS

It is extremely important to develop and optimise components used in the OE industry. Test facilities for such uses of standard components should be financed. Key aspects of development of components, PTO and new concepts are to improve efficiency, reduce costs, and improve energy quality and safety.

Importance must be put on funding concepts that have at least passed laboratory testing and preliminary engineering assessment. New concepts considered for funding should also mainly aim at improving survivability, efficiency and cost reduction.

2) DEPLOYMENT AND INSTALLATION METHODS AND TOOLS

A substantial proportion of OE costs are related to deployment and installation. Therefore, these fields should be considered as priorities for the funding of research with a view to increasing efficiency of installation vessels and reducing costs. In the first phase of OE development, investment for such vessel development will be lacking, due to the limited demand. Therefore, funding research for enhancing efficiency and cost effectiveness of these vessels could be a key means of reducing OE installation costs as a whole.

[21] EU-OEA, Stakeholder consultation on ocean energy R&D priorities: 8th September 2009 meeting, Uppsala, Sweden, and responses from email consultation.

Furthermore, the development of offshore moorings, sea-bed foundations, and installation methods are also central to successful OE development, and should therefore be funded in priority.

3) Design and Operation Tools

In order to lower or keep low operation and maintenance costs, it is very important to develop tools that will enable effective and cost efficient operation of devices. This includes energy production and forecasting, cost of electrical cables and moorings, access to devices, survivability, failure estimation, maintenance program, safety, and others.

Another aspect of this topic is to recognise the high priority of developing control tools for OE devices, which will particularly work toward reducing costs of OE. This could be done through projects for automatic control systems, for example, for detecting and estimating failures.

Finally, tools for modelling should be developed in order to design more resistant and efficient devices that will be better adapted to real sea conditions.