Deep water

The next step for offshore wind energy

A report by the European Wind Energy Association - July 2013

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Foreword

We have the wind in our sails: let the future be blue.

With the maritime economy we can pull Europe out of recession.

Europe is the most maritime of all continents. The European seas and oceans offer considerable and untapped economic potential. Nevertheless, they also pose a formidable policy challenge to decision makers.

We the European Commission, and the Member States, want to take up this challenge. The maritime economy can no longer remain on the sidelines of the 2020 strategy. We are in times that require new thinking and the maritime dimension must be integrated into the European vision for green growth.

It is my pleasure to introduce this report which is a testimony of the dynamism and confidence of the offshore wind industry, which will unlock its market potential in the Northern Seas and Atlantic and Mediterranean basins, which all have deep water.

It is also a testimony to the fact that there are still areas with a massive potential for innovation and green-blue growth, requiring considerable coordination effort at national and European level.

Offshore wind plays a key role in the maritime economy. It is an emerging and booming industry, ready to renew the industrial fabric of our regions and create jobs. By 2020, offshore wind could grow substantially, providing electricity to almost 39 million households, if we support its development. And this will go much further beyond 2020, in part thanks to the deployment of floating offshore turbines.

In the Limassol declaration, the European Commission and the Member States have recognised the enormous potential for innovation and competitiveness in the maritime sectors, specifically offshore wind. More importantly, we have committed to supporting its development with a dynamic agenda. In the Blue Growth Communication, we are putting specific sectorial initiatives in place, along with maritime spatial planning and the marine knowledge initiative. These measures will support the growth of the blue economy.

However, these are the first steps on a long road, placing the maritime dimension at the heart of all our efforts.

Further work must be done to develop new and bold economic thinking so that all the maritime sectors meet their innovation and competitiveness potential.

As this report shows, innovation and competitiveness will only flourish if all pillars of the European energy, industrial, environment and research policy are linked and framed in a comprehensive 2030 vision.

I know I can count on the European Commission, the Member States, the European Parliament and all the stakeholders to help develop the new economic thinking that can take us into a sustainable blue future.

Maria Damanaki,
European Commissioner for
Maritime Affairs and Fisheries

Content

EXECUTIVE SUMMARY

'In terms of growth and job creation part of the answer is certainly through the blue economy. This sector is booming, and at times of crisis and pressure, this is rare good news'

Jose Manuel Barroso, President of the European Commission – 8 October 2012

Europe's seas and oceans are rich in opportunities and sources of employment for our economy. Covering around 70% of the surface of the Earth – the 'blue planet' - their potential for economic growth and competitiveness needs to be tapped. However, this will not happen without proactive thinking from European and national decision makers. They must develop a dynamic maritime and research agenda to support what is known as the 'blue economy'.

Offshore wind is a strong asset in the European maritime economy. Employing 58,000 people in 2012, it is a promising industry with the potential to transform and decarbonise the electricity system. It can create considerable economic growth that benefits the whole of society as well as maritime regions and other maritime sectors.

It is still a young technology facing considerable challenges. Political and economic support is needed for large scale deployment, so a European industrial strategy should be developed to ensure that offshore wind can meet its potential.

Offshore wind is one of the fastest growing maritime sectors. Its installed capacity was 5 GW at end 2012, and by 2020 this could be eight times higher, at 40 GW, meeting 4% of European electricity demand. By 2030, offshore wind capacity could total 150 GW, meeting 14% of the EU's total electricity consumption.

However, for this to happen, a supportive legislative framework is needed, and new offshore designs must be developed for deep water in order to tap the large wind potential of the Atlantic, Mediterranean and deep North Sea waters. Current commercial substructures are economically limited to maximum water depths of 40m to 50m. The 'deep offshore' environment starts at water depths greater than 50m.

This report is based on the work of the 'Deep offshore and new foundation concepts' Task Force, part of the European Wind Energy Association's (EWEA) Offshore Wind Industry Group. The Task Force evaluates the current situation and the steps that are needed for the large scale deployment of deep offshore wind energy.

Between October 2011 and June 2012, 16 leading European companies researching or operating deep offshore projects met to identify challenges and provide recommendations to the industry and policy makers[1].

The analysis found that:

- **Deep offshore designs are necessary to unlock the promising offshore market potential in the Atlantic, Mediterranean and deep North Sea waters.**
- **Deep offshore designs constitute an export opportunity.** As deep offshore capacity increases, expertise, skills and technologies developed in Europe can be exported across the globe, initially to Japan and the US.
- The energy produced from turbines in deep waters in the North Sea alone **could meet the EU's electricity consumption four times over**.
- Deep offshore designs are competitive in terms of the levelised cost of energy (LCOE) with bottom-fixed foundations in more than 50m water depth. **The technology is still at a very early stage of development and in order to achieve commercial and large-scale deployment, the sector must overcome technical, economic and political challenges**.
- If the challenges are overcome, **the first deep offshore wind farms could be installed and grid connected by 2017.**

[1] The Task Force 'Deep offshore and new foundation concepts' included representatives from: Acciona, Alstom, Blue H, Catalonian Institute for Energy Research, National Renewable Energy Centre of Spain (CENER), Det Norske Veritas (DNV), EDF, Energias de Portugal (EDP), Hexicon, IDEOL, Nass & Wind, National Technical University of Athens, Principle Power, Risø DTU, Statoil, The Glosten Associates and Vattenfall.

Recommendations

The following recommendations are based on the results of the analysis:

Political recommendations:

- A clear and stable legislative framework post 2020 based on a binding 2030 renewable energy target is needed to drive deep offshore wind development and deployment.
- A cohesive European industrial strategy guiding offshore wind development is necessary. It will support deep offshore from R&D to deployment.
- Licensing and permitting procedures should be simplified to minimise lead time deployment. The capacity of permitting bodies should be enhanced to handle the growth in deep offshore projects.
- Public support for R&D should be increased to maintain European technology and market leadership in deep offshore designs.
- Strong collaboration between the different players (and sometimes competitors) should be encouraged through new project partnerships. Exchange of experience and data is crucial and will benefit all stakeholders.
- The European Wind Initiative (EWI), with the network and R&D forum TP Wind, should continue and be allocated sufficient funding to ensure their recommendations can be implemented.
- New standards specific to wind floating systems must be developed to help reach commercial maturity.
- Deep offshore projects with the correct risk perception should be ensured access to financing.

Economic recommendations:

- Ports must provide enough space to accommodate installation vessels and component storage.
- Self-installing systems must be developed to minimise installation costs.
- Suitable training courses should be developed to remedy the shortage of skilled professionals.

Technical recommendations:

- Modelling tools and numerical codes that simulate the whole structure's behaviour should be developed and validated to improve design.
- Wind turbine design and size must be optimised for use on floating support structures.
- There is a need to develop sufficient and appropriate control systems.
- More research must be done on mooring and anchoring systems. The industry could benefit from the experience of the oil and gas sector.
- New measuring techniques and tools should be developed to assess the wind and wave conditions at wind farm locations.
- More research is required into wake and turbulence effects and how they affect the load and motions of floating platforms. This can be achieved by deploying floating demonstration farms of around four or five units rather than exclusively single unit prototypes.
- More test sites (small scale and large scale) should be developed to ensure the reliability and cost competitiveness of the deep offshore designs.

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1 UNLOCKING OFFSHORE WIND MARKET POTENTIAL

1.1 Offshore wind market - 2012

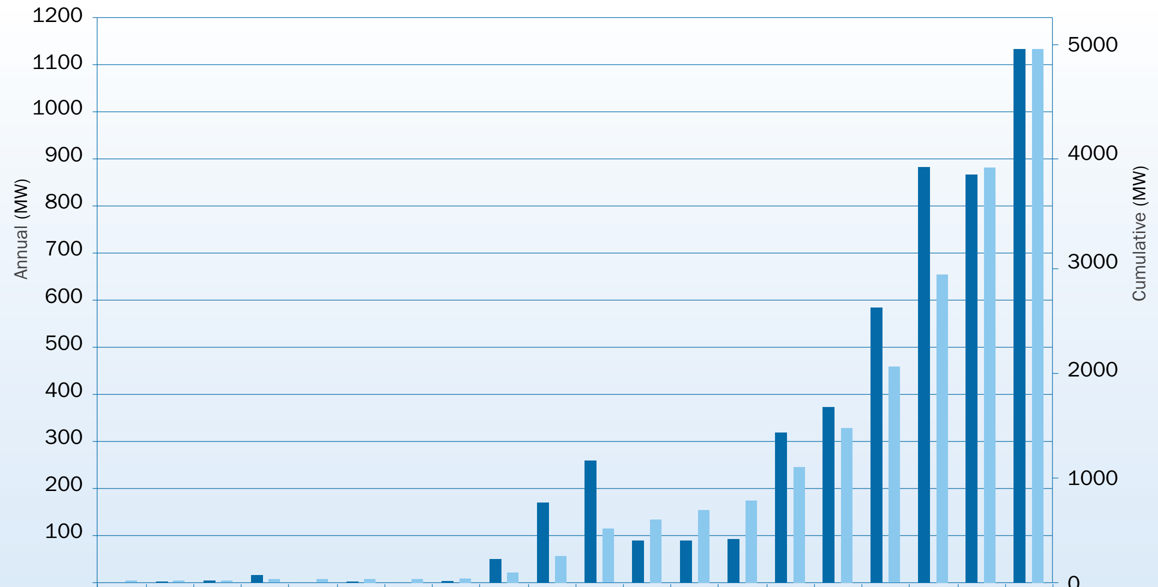
In Europe, every year since 2000, new offshore wind turbines have been coming online. At the end of 2012 there were 1,662 turbines totalling 5 GW of installed offshore wind capacity spread across 55 wind farms in 10 European countries (Figure 1). They produced 18 TWh, enough electricity to power almost five million households.

Offshore wind represents 10% of the annual wind energy installations across Europe. This is only the beginning of major global industrial development, led by Europe.

Most of the offshore projects (3.2 GW or 65% of total capacity) are located in the North Sea. 16% of total capacity is located in the Baltic Sea and 19% in the Atlantic. There are currently no offshore wind farms in the Mediterranean, because the water is deep, and current commercial substructures are limited to 40m to 50m maximum depths. This restricts the potential to exploit offshore wind development in the Mediterranean.

With the exception of two turbines, Europe's grid connected offshore wind turbines rely on fixed foundations, and the vast majority of those on monopile foundations. Gravity based substructures are the second most common foundation type, followed by space frame structures.

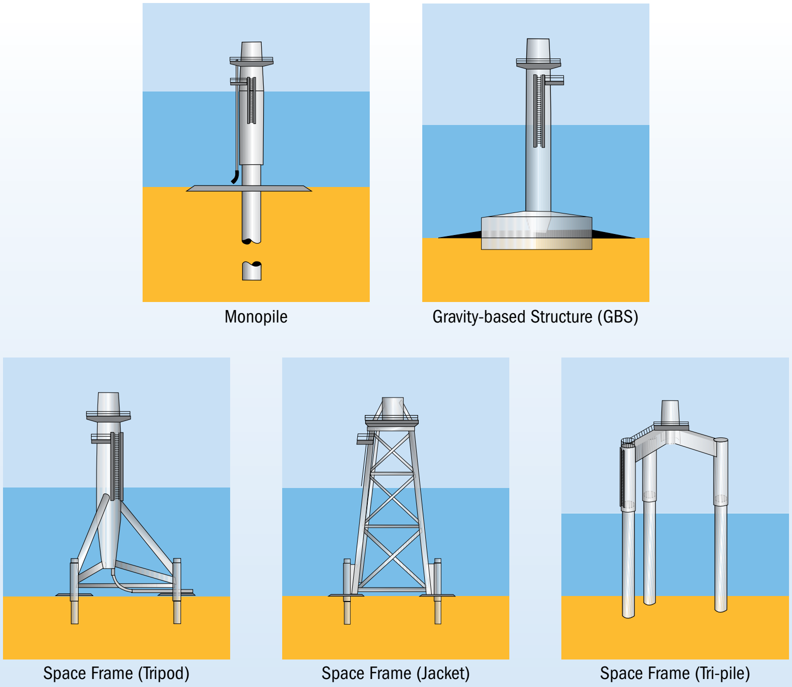
FIGURE 1 ANNUAL AND CUMULATIVE INSTALLATIONS OF OFFSHORE WIND IN EUROPE (MW)



	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
Annual	0	2	5	17	0	3	0	4	51	170	276	90	90	93	318	373	577	883	874	1,166
Cumulative	5	7	12	29	29	32	32	36	86	256	532	622	712	804	1,123	1,496	2,073	2,956	3,829	4,995

Source: EWEA

FIGURE 2 TYPICAL FIXED OFFSHORE FOUNDATIONS



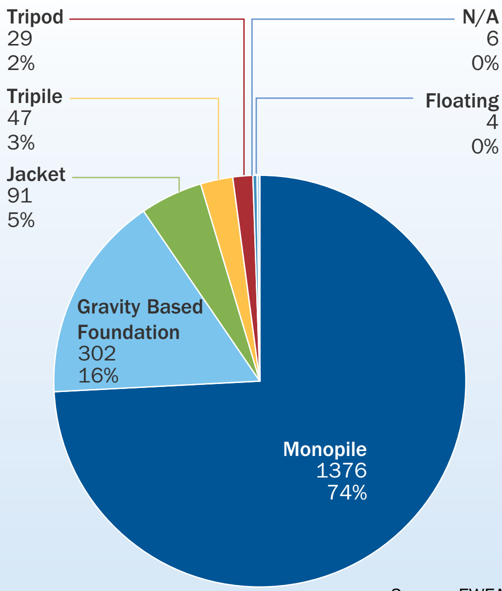
Source: EWEA

At the end of 2012, there were two full scale grid connected offshore wind turbines on floating sub-structures, Hywind and Windfloat. Both are located in Europe, one in the North Sea and one in the Atlantic.

- Hywind is developed by Statoil, with a 2.3 MW Siemens turbine. Installed in Norway in 2009, it is the first large scale floating wind structure installed in the world.
- Windfloat, the second large scale floating system, was installed off the Portuguese coast in 2011 and started to produce energy in 2012. Developed by Principle Power and EDP, it is equipped with a 2 MW Vestas wind turbine.

Seven experimental floating substructures (four in Europe, two in Japan and one in the US) are in a test phase: SeaTwirl, SWAY, Blue H and Poseidon in Europe, Kabashima Island concept and WindLens in Japan and DeepCwind floating turbine in the US. In addition FLiDAR is a floating Lidar, an offshore meteorological station designed for marine renewable energy technologies such as offshore wind, wave and tidal[2].

FIGURE 3 SHARE OF SUBSTRUCTURE TYPES FOR ONLINE WIND FARMS, END 2012 (UNITS)



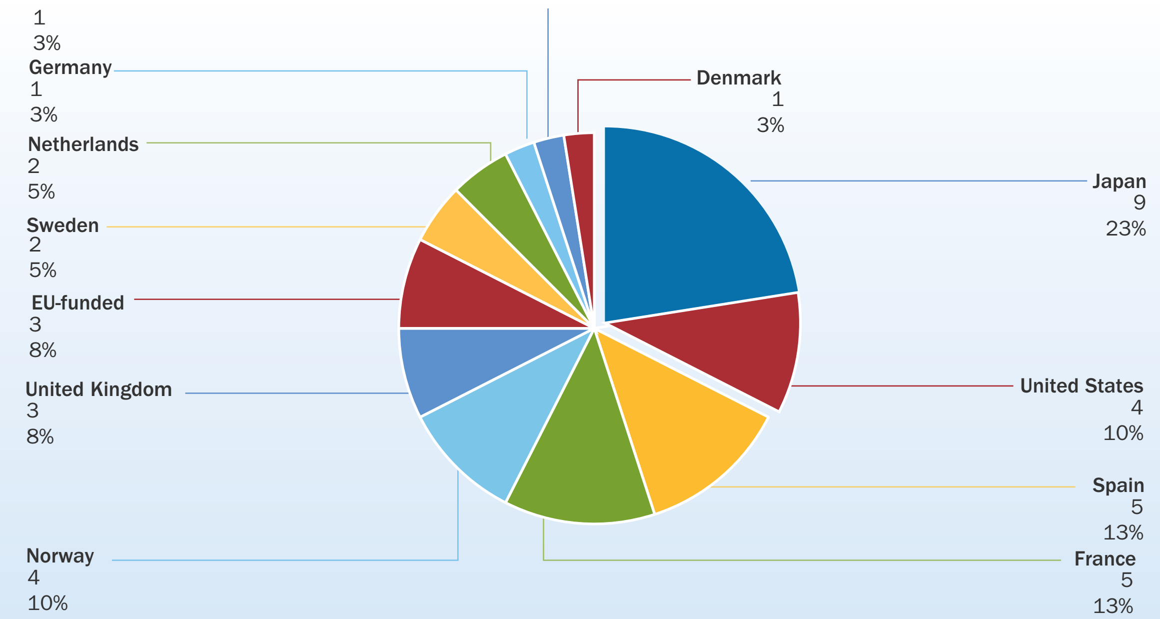
Source: EWEA

[2] http://www.3e.eu/sectors/flidar-floating-lidar

- SeaTwirl was installed and tested in Sweden, and subsequently decommissioned.
- SWAY, developed by SWAY, was installed in Norway. The experimental concept, a 1:6 downscaled model is not grid connected.
- The first phase of Blue H was installed in the summer of 2008 along with a small wind turbine in 113 m deep water, 11.5 nautical miles (21.3 km) off the coast of southern Italy, near the site of the future offshore Tricase project. After six months at sea, the unit was decommissioned early in 2009.
- Poseidon 37, constructed by Floating Power Plant, was installed and tested in 2008 at Vindeby offshore wind farm, off the coast of Lolland in Denmark.
- DeepCwind consortium installed a 20 kW floating wind turbine in the Gulf of Maine in June 2013.
- In Kabashima Island (Japan) a 100 kW wind turbine is grid connected and undergoing testing.
- In Hakata Bay, a scale model with two wind turbines of 3 kW each on one floater are installed and grid connected.

The European offshore wind industry is in its infancy and has huge potential for cost reductions and technological innovation. It is increasingly developing deep offshore designs for water depths of over 50m to unlock market potential. EWEA notes that in addition to two full scale deep offshore turbines at the end of 2012, there are three grid connected experimental floating substructures and thirty five deep water designs under development worldwide. Of all forty projects identified, either grid connected systems or under developement, twenty-seven (more than 60%) are located in Europe, in nine countries: Denmark, France, Germany, the Netherlands, Norway, Portugal, Spain, Sweden and the UK. Four (10%) are in the US and nine (23%) in Japan.

FIGURE 4 LOCATION OF DEEP WATER WIND ENERGY DESIGNS (BASED ON NUMBER OF PROJECTS ANNOUNCED)



Source: EWEA

1.2 Market trends - moving into deeper waters with bigger turbines

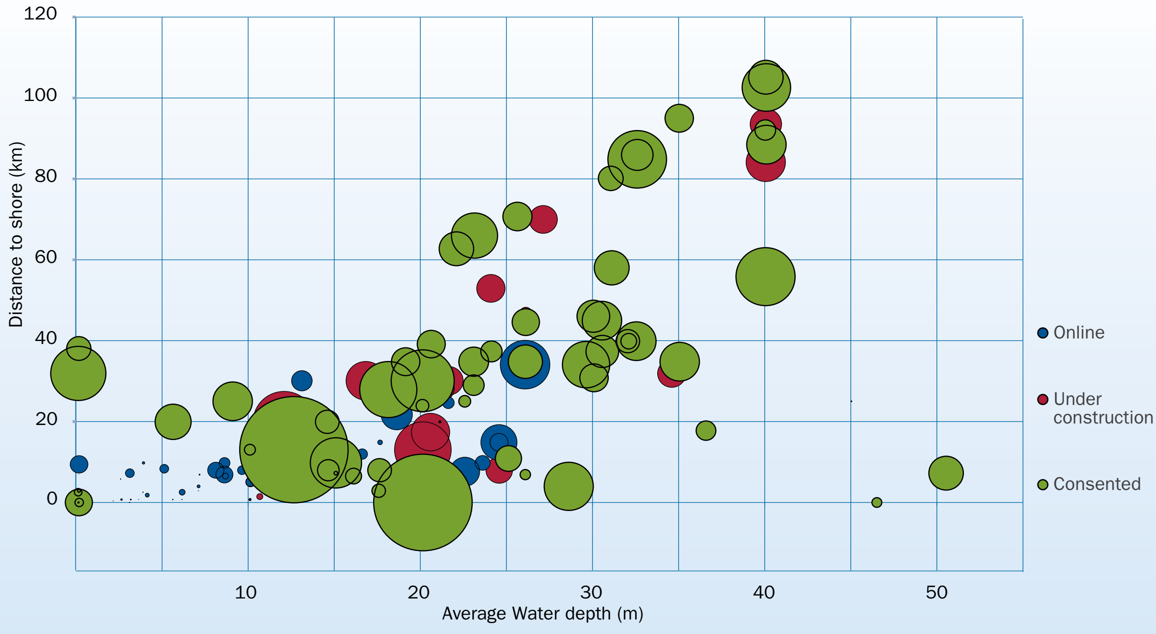
As the industry evolves, offshore wind farms are built further from the coast and in deeper waters. This reflects national maritime spatial planning and wind farm developers' desire to harness better energy resources out at sea.

In 2012 the average water depth of offshore wind farms was 22m. The average distance to shore was 29km. It is clear from projects under construction, consented or planned, that average water depth and distance to shore will increase. Projects announced are up to 200km from shore and in water depths of up to 215m.

Alongside the trend towards deeper waters, the offshore wind sector is also developing larger turbines. The average size of the turbines grid connected during 2012 was 4 MW, up from 3.6 MW in 2011.

In 2012, of the 38 new offshore wind turbine models announced, only 9 (24%) had rated capacities of less than 5 MW. The remaining 29 (76%) were larger machines. Deep offshore designs will need to adapt to these increased turbine sizes to achieve the optimal balance between power production and cost.

FIGURE 5 AVERAGE WATER DEPTH AND DISTANCE TO SHORE FOR ONLINE, UNDER CONSTRUCTION AND CONSENTED OFFSHORE WIND FARMS (BUBBLE SIZE REPRESENTS THE TOTAL CAPACITY OF THE WIND FARM)



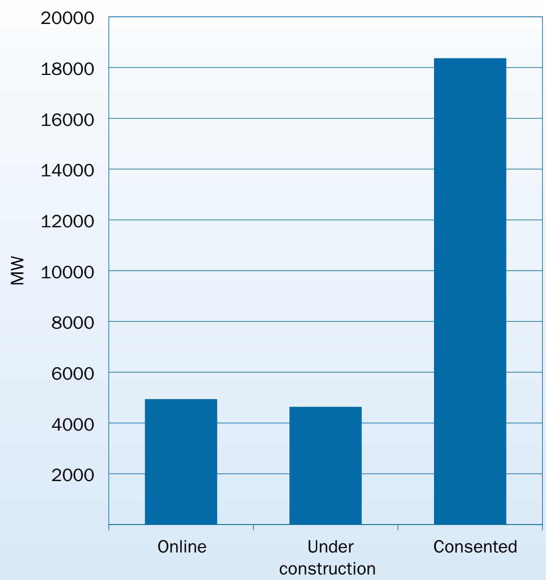
Source: EWEA

1.3 Market outlook

At end 2012, there was just under 5 GW of installed offshore wind energy capacity in Europe. A further 4,460 MW were under construction and around 18,000 MW consented.

EWEA forecasts that by 2020, 40 GW offshore wind capacity could be operational in European waters, producing 148 TWh provided that the right framework conditions are in place. This is enough to power the equivalent of 39 million households. By 2020 offshore wind will represent 30% of the new installation annual wind market.

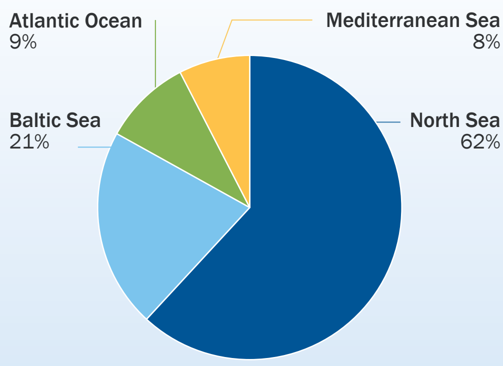
FIGURE 6 OFFSHORE MARKET PROJECTS ONLINE, UNDER CONSTRUCTION AND CONSENTED (MW)



Source: EWEA

Up to 2020, most of these developments will remain in the North Sea and Baltic Sea. Analysis of the consented wind farm pipeline shows that 62% of total consented capacity is in the North Sea. The Mediterranean could begin exploiting its offshore potential (8% of consented capacity) in that time frame, along with the Baltic Sea (21% of consented capacity).

FIGURE 7 SHARE OF CONSENTED OFFSHORE WIND FARMS BY SEA BASIN (MW)



Source: EWEA

By 2030, EWEA forecasts 150 GW of installed offshore wind capacity, enough to power 145 million households. Offshore wind will represent 60% of the new annual installations, exceeding the onshore market.

EWEA has identified 141 GW of projects in European waters, which are either online, under construction, consented or planned. Of these, 22 GW (16%) will be in the Atlantic and 16 GW (11%) in the Mediterranean Sea, where waters are typically deeper. To exploit this potential in the Atlantic, Mediterranean and deeper parts of the North Sea such as the Norwegian coast, deep offshore designs are required.

Finally, by 2050 offshore wind could reach 460 GW, producing 1,813 TWh and contributing to a European power supply met 50% by wind. This exponential growth is only achievable through the deployment of deep offshore designs.

Estimating the potential

Using only North Sea sites with water over 50m deep as an example, the potential for deep offshore wind energy is vast. 66% of the North Sea has a water depth between 50m and 220m and could therefore be used to deploy the deep offshore designs.

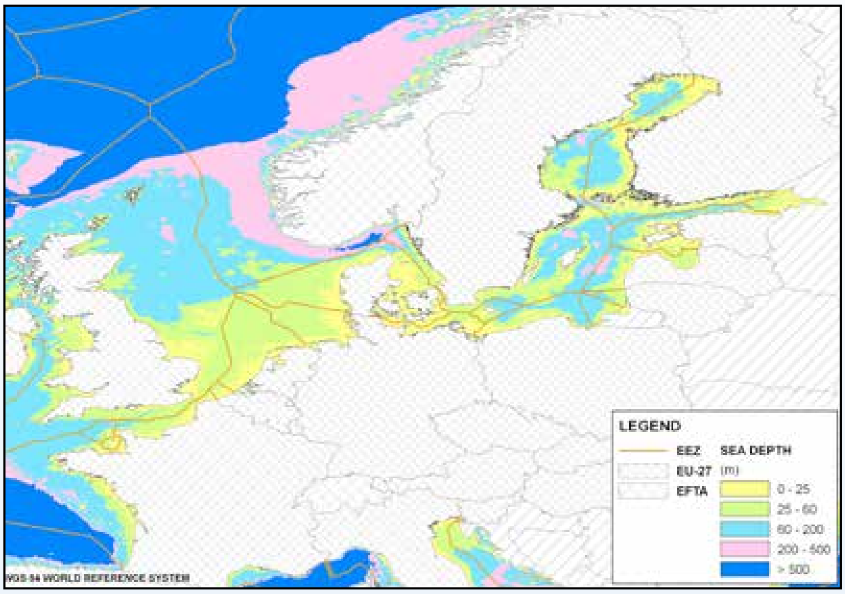
For illustration purposes only, assuming 6 MW wind turbines, the energy produced in this area could meet today's EU electricity consumption four times over.

In 2050, using 10 MW turbines, the energy produced in this area could meet the EU's electricity consumption by even more than four times over[3].

If floating turbines in the North Sea alone can exceed Europe's demand by this amount, the potential once suitable areas of the Atlantic and Mediterranean seas are included is many times greater.

Portugal has a vast maritime area in the Atlantic, where winds are particularly strong and both France and Spain have deep waters close to shore in both the Mediterranean and Atlantic seas. There is, therefore, a huge potential for deep water offshore wind farms. Moreover, in all three countries, industry is developing (and testing in the case of Portugal) deep water concepts. In Malta plans for a deep water offshore wind farm at Sikka-l Badja have been drawn up as have plans for a floating wind farm of the Apulia coast in Italy, where, in 2008 a scaled-down floating turbine was tested off the port of Tricase.

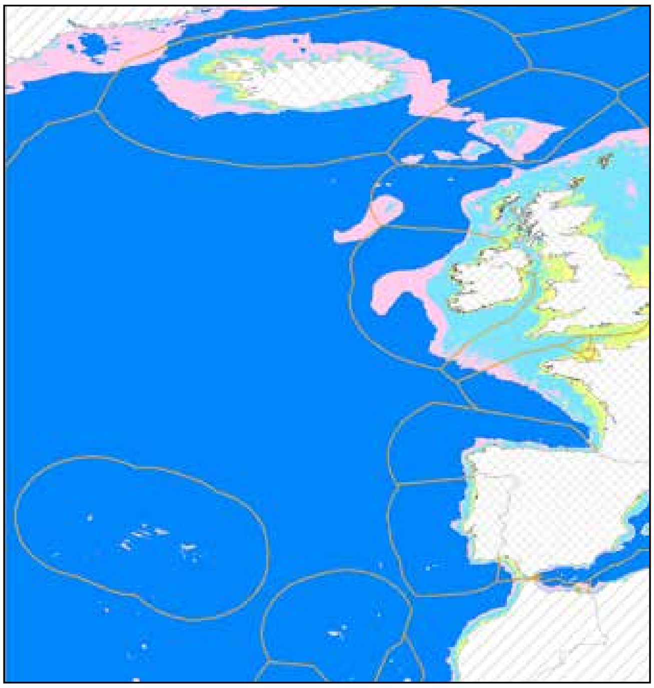
FIGURE 8 MAP SHOWING SEA DEPTH THROUGHOUT THE NORTH SEA AND BALTIC AREA



Source: ORECCA

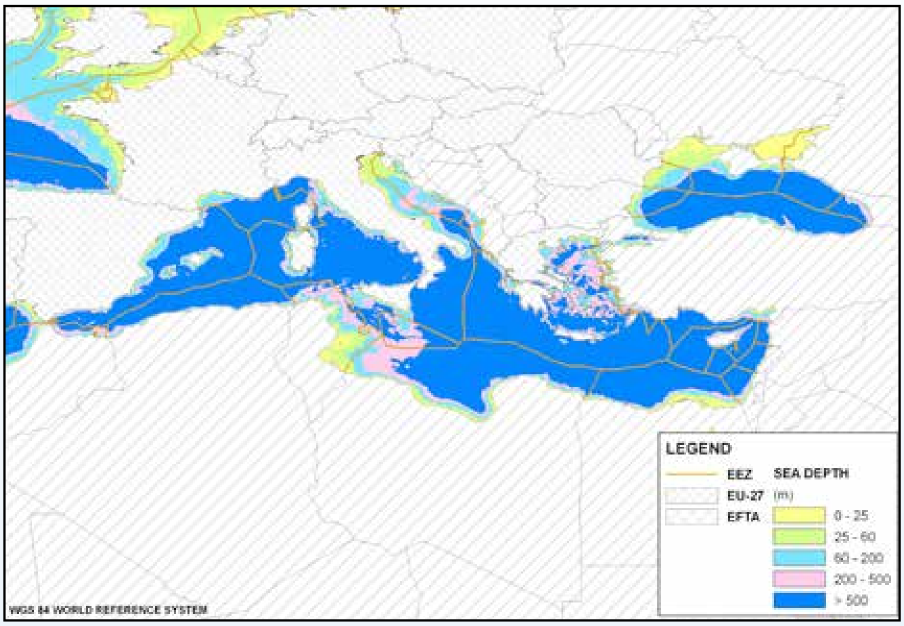
3 Source: Electricity consumption for 2050: European Commission Low Carbon Roadmap 2050

FIGURE 9 MAP SHOWING SEA DEPTH THROUGHOUT THE ATLANTIC OCEAN AREA



Source: ORECCA

FIGURE 10 MAP SHOWING SEA DEPTH THROUGHOUT THE MEDITERRANEAN AND BLACK SEA AREA



Source: ORECCA

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2 THE INTRODUCTION OF DEEP OFFSHORE DESIGNS

An increasing number of offshore wind deep water substructure designs are being developed and tested across Europe. The offshore wind industry could envisage moving to larger scale development in deep European waters, provided R&D gets the funding to speed up the demonstration of the deep offshore designs and facilitate their commercialisation.

Definitions: substructures and designs maturity

Deep water substructures are new and therefore need to go through different stages of development before coming onto the market.

To date, deep water substructures are mainly based on floating platform designs.

The different stages are:

- R&D stage: research and development on various designs using modelling tools.
- Demonstration stage: numerical demonstration of concept feasibility including dedicated experiments.
- Pilot stage: testing a downscaled model in a controlled environment to provide realistic indicators for feasibility and cost effectiveness (SWAY, Blue H, Poseidon 37).
- Prototype stage: testing a full scale model to assess its concept maturity before commercialisation (Hywind, Windfloat).
- Pre-production: deploying a limited number of full scale devices in one location to validate overall system principles, manufacturing and installation methods.
- Serial (commercial) production stage: commercial deployment following pre-commercial deployment, within a wind farm layout.

2.1 State of the art

The concept of a floating wind turbine has existed since the early 1970s, but the industry only started researching it in the mid-1990s.

In 2008, Blue H technologies installed the first test floating wind turbine off the Italian coast. The turbine had a rated capacity of 80 kW and after a year of testing and data collection it was decommissioned.

A year later the Poseidon 37 project followed, a 37m-wide wave energy plant and floating wind turbine foundation tested at DONG's offshore wind farm at Onsevig.

In 2009, Statoil installed the world's first large scale grid connected floating wind turbine, Hywind, in Norway, with a 2.3 MW Siemens turbine.

The second large scale floating system, WindFloat, developed by Principle Power in partnership with EDP and Repsol, was installed off the Portuguese coast in 2011. Equipped with a 2 MW Vestas wind turbine, the installation started producing energy in 2012.

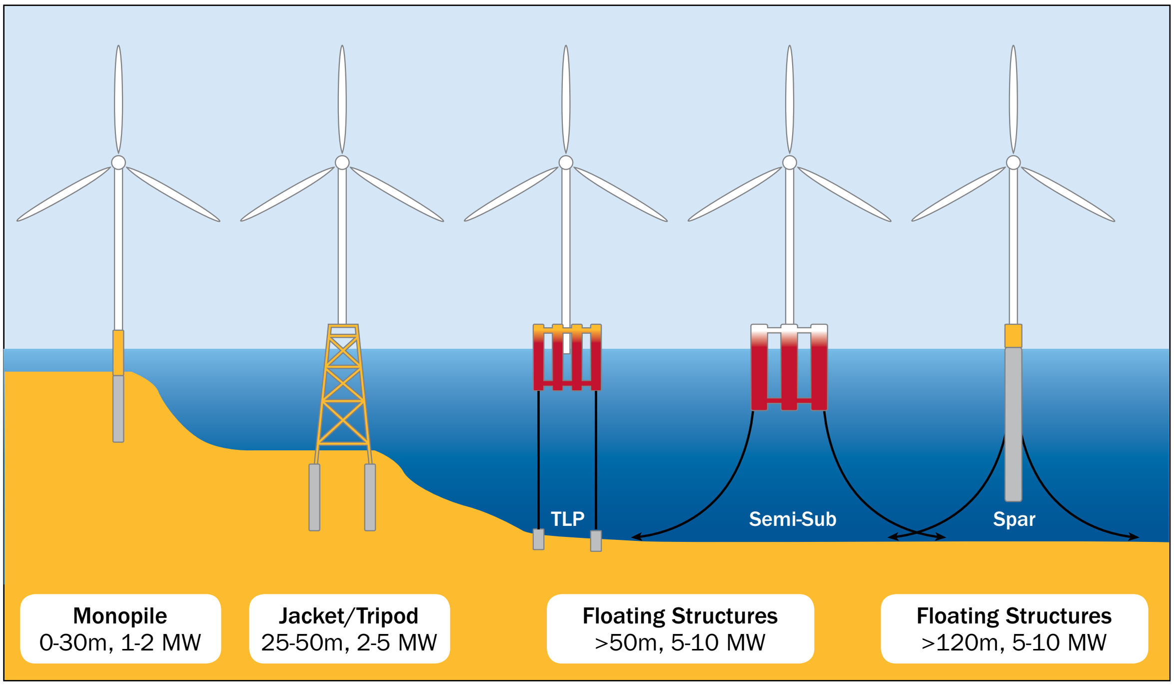
2011 was the best year on record for deep offshore development with two floating substructures tested, SeaTwirl and SWAY, in addition to the grid connected Windfloat project.

Currently, offshore wind farms have been using three main types of deep offshore foundations, adapted from the offshore oil and gas industry:

- Spar Buoy: a very large cylindrical buoy stabilises the wind turbine using ballast. The centre of gravity is much lower in the water than the centre of buoyancy. Whereas the lower parts of the structure are heavy, the upper parts are usually empty elements near the surface, raising the centre of buoyancy. The Hywind concept consists of this slender, ballast-stabilised cylinder structure.
- Tension Leg Platform: a very buoyant structure is semi submerged. Tensioned mooring lines are attached to it and anchored on the seabed to add buoyancy and stability.
- Semi-submersible: combining the main principles of the two previous designs, a semi submerged structure is added to reach the necessary stability. WindFloat uses this technology.

The table 1 outlines the deep offshore wind designs and projects developed in Europe, Japan and the US:

FIGURE 11 OFFSHORE WIND FOUNDATIONS



Source: Principle Power

TABLE 1 STATE OF THE ART FOR DEEP OFFSHORE WIND DESIGNS

No.	Project name	Company	Type of floater	Demo/Pilot		Prototype		Pre-Production/Serial		
				Scale	Year	Turbine size (MW)	Date of deployment	Turbine size (MW)	Provisional date of deployment	Origin
Grid connected systems										
1	Hywind	Statoil	Spar buoy			2.3 MW	2009-2012	3-7 MW	2016	Norway
2	WindFloat	Principle Power	Semi - submersible			2 MW	2011	5-7MW	2017	Portugal
3	DeepCWind Floating wind	Consortium made up of University of Maine, Advanced Structures and Composites Center (AEWC), Seawall, Maine Maritime Academy, Technip, National Renewable Energy Laboratory (NREL), MARIN, etc.	Design of one or more full scale floating wind turbine platforms	Scale models tested in tank	2011	Scale model (20kW) in near shore waters	2013	6 MW	2017	US
4	Kabashima Island, Kyushu	Ministry of Environment, Kyoto University, Fuji Heavy Industries, Toda Construction, National Maritime research Institute of Japan (turbine constructed by Japan Steel Works and Hitachi)	Spar	100 kW	2012	2 MW	2013			Japan
5	Hakata Bay Wind Lens, Kyushu	Kyushu University	Floater	2x3 kW	2011					Japan
Designs/Projects under development										
1	Advanced Floating Turbine	Nautica Windpower	Buoyant tower and downwind turbine				2012	5 MW	2014	US
2	Aero-generator X	Wind Power Ltd, Arup				10 MW	2013			UK
3	Azimut	Consortium of Spanish wind energy industry headed by Gamesa	Generating the know-how required to develop a large scale marine wind turbine			15 MW				Spain
4	Blue H TLP	Blue H	Submerged deepwater platform			5-7 MW	2015	5-7 MW	2016	Netherlands
5	Deepwind	EU project	Floating and rotating foundation plus vertical wind turbine			1 kW	2012	5 MW		Europe

No.	Project name	Company	Type of floater	Demo/Pilot		Prototype		Pre-Production/Serial		
				Scale	Year	Turbine size (MW)	Date of deployment	Turbine size (MW)	Provisional date of deployment	Origin
6	Deepwater Innovative Wind Energy Technology (DIWET) Semisub	Pole Mer	Semi - submersible floater							France
7	Eolia Renovables de Inversiones (EOLIA)	Acciona Energy	SPAR, Tension leg platform (TLP) and semisubmersible	Tanks testing on 1:40 scale three floating wind turbine models	2011			5 MW		Spain
8	PelastarWave-Hub	The Glosten Associates	Floating platform system demonstrator			6 MW	2016			UK
9	IDEOL	IDEOL	Concrete floater	Tank test	2012	5-6 MW	2013	50 MW pre - series wind farm	2015	France
10	FLOTTEK	Consortium led by Gamesa, including Iberdrola	Tension leg turbine platform			2 MW				Spain
11	GICON TLP	GICON et al	Modular tension leg platform	1:25 Tank test	2013	2 MW	2014		2014	Germany
12	Floating Haliade	Alstom	Tension leg buoy (TLB) for water depths between 50m to 80m and TLP for water depths between 80m to 300m			6 MW				France
13	FLOATGEN	Gamesa, IDEOL, Stuttgart University, Acciona Windpower, Navantia, Olav Olsen, RSK Environment Ltd, Greenovate! Europe, Acciona Energy	Ring shaped surface floating platform Semi-submersible			2 MW and 3 MW	2015			Spain
14	Hexicon platform	Hexicon	Floater					54 MW wind and 15 MW wave	2014-2015	Sweden

No.	Project name	Company	Type of floater	Demo/Pilot		Prototype		Pre-Production/Serial		
				Scale	Year	Turbine size (MW)	Date of deployment	Turbine size (MW)	Provisional date of deployment	Origin
15	HiPRwind	EU project							2016	Europe
16	Marina platform	EU project	Deepwater platforms that integrate (in a single infrastructure) a range of energy such as wind, wave, or sea currents						2014	Europe
17	Karmøy	SWAY	Spar buoy	1:6 down-scaled model	2011	2.3 MW		2.5-5 MW		Norway
18	Ocean Breeze	Xanthus Energy	Taut tethered buoyant	Tank Test	2011					UK
19	Pelagic Power	W2power	Hybrid wind and wave energy conversion plant					2x3.6 MW	2015	Norway
20	Poseidon Floating power	Floating Power	Semi - submersible			6 MW	2014			Denmark
21	Sea Twirl	Sea Twirl	Floating spar and vertical wind turbine	1:50 model						Sweden
22	Trifloater Semi-sub	Gusto	Semi - submersible					5 MW		Netherlands
23	Titan 200 Deep offshore platform	Offshore wind power systems of Texas	Self-installing floating platform							US
24	Vertiwind	Technip/Nenuphar/EDF EN	Semi - submersible			2 MW	2013	2 MW	2016	France
25	University of Maine	University of Maine, Renewegy	Semi-submersible tri-floater	20kW	2013					US
26	WindSea floater	Force Technology, NLI Innovation	Semi-submersible vessel with 3 corner columns	Tank test		3x1 MW		3x3.6 MW		Norway
27	WINFLO	Nass & Wind/DCNS	Semi - submersible			1 MW	2013	2.5 MW	2016	France

No.	Project name	Company	Type of floater	Demo/Pilot		Prototype		Pre-Production/Serial		
				Scale	Year	Turbine size (MW)	Date of deployment	Turbine size (MW)	Provisional date of deployment	Origin
28	ZÈFIR test station	Catalonia institute for Energy Research, Gamesa, Alstom, Acciona	The development of a new, highly complex technology for deep water offshore wind turbines			20 MW bottom fixed and 50 MW (e.g 6-8) floating wind turbines	2013 bottom fixed, 2015-2016 floating		Test wind farm, not commercial	Spain
29	Fukushima Offshore Wind	Fukushima Offshore Wind Consortium (Mitsubishi, Hitachi, Marubeni Corporation, Tokyo University, Japan Marine United, Mitsui Engineering & Shipbuilding, Nippon Steel, Shimizu Corporation)	Semi-submersible			2MW	2013			Japan
30			Advanced spar			7MW	2014-2015			Japan
31			Semi-submersible			7MW	2014-2015			Japan
32	Shimizu Corporation	Shimizu Corporation, University of Tokyo, Tokyo Electric Power Company, Penta Ocean Construction	Semi - submersible						2017	Japan
33	Mitsui Zosen		Tension Leg Platform							Japan
34	National Maritime Research Institute of Japan		Spar							Japan
35	Hitachi Zosen	Hitachi Zosen, Toshiba	Semi- submersible			7.5 MW	2016			Japan

Source: Task Force EWEA

2.2 Europe's first mover advantage

Currently all deep offshore grid connected full scale turbines are located in European waters. Their development, testing and installation attract global attention as they signal that European countries are coming closer to scaling up to achieve commercial development. The European lead is closely followed by American and Asian companies keen on deploying the technology in their domestic markets.

Although European companies lead globally, they are in a technology race with the United States and Japan. It is therefore essential that these European companies benefit from national and European R&D support to maintain their leadership and take advantage of the significant potential of the domestic market and the export opportunities that derive from being a first mover.

Europe

The number of deep offshore demonstration projects in Europe, Asia and the US are signs of the technology race between Europe, the United States and Japan. The projects also highlight the race within Europe between countries that appreciate the huge potential of the deep offshore wind resource and are keen to be first movers.

Europe accounts for more than 90% of the world's installed offshore wind capacity. This technological and market leadership is supported by the European Wind Initiative (EWI), a wind energy research and development programme created to take the European wind industry to the next stage[4].

The EWI focuses on developing wind energy technology, testing facilities, streamlining manufacturing processes and maintaining Europe's global technology leadership. Cost effective deep offshore development is one of its technology objectives for the 2013-2015 period. Specifically, the single largest EWI project in the offshore sector, HIPRwind, focuses on the demonstration of floating solutions for the deployment of deep water turbines.

In addition, to promote innovation, the European funding programme 'NER300'[5] supports the most promising demonstration projects with the largest replication potential, in partnership with Member States. In 2012, out of 23 renewable energy projects selected in the first call, two were floating offshore demonstration projects, Vertimed in France and WindFloat in Portugal.

National developments

At national level various European countries are supporting deep offshore wind deployment, through demonstration projects that will take designs from the research stage to commercial deployment. Following successful demonstration projects, an increasing number of European governments are launching programmes to scale up the industry. Programmes range from single prototypes to demonstration farms and pre-series production. The first deep offshore wind farms could be installed and grid connected by 2017.

Among the Member States, the **United Kingdom** has a strong interest in deep offshore development. The UK's Energy Technology Institute (ETI) launched a major programme on reducing offshore costs through innovation. Deep offshore designs are included and £25m (€29.6m) is earmarked for a floating offshore wind demonstration project. As part of this programme, in 2013, the ETI confirmed that the demonstration project led by the Glosten Associates and featuring a 6 MW Alstom turbine will be developed in Wave Hub off the coast of Cornwall by 2016.

The Crown Estate has also announced a new leasing programme to showcase technological advancements and drive further cost reduction. For the first time, a leasing round for floating offshore wind technology was included. Some projects could start construction as soon as 2017[6].

In addition, the Scottish government recently unveiled a £15m (€17.8m) fund to finance new deep water foundation technology and help the industry transcend

[4] http://www.ewea.org/fileadmin/ewea_documents/documents/publications/EWI/EWI_2010_final.pdf
[5] http://ec.europa.eu/clima/funding/ner300-1/index_en.htm
[6] http://www.thecrownestate.co.uk/news-media/news/2013/leasing-round-announced-to-accelerate-testing-of-emerging-offshore-wind-technologies-including-floating/

its embryonic deep water phase. The programme is designed to support demonstration projects, ready for installation between 2015 and 2017[7]. Potential projects include Statoil's plan to install up to five Hywind floating prototypes off Peterhead. The Scottish government has introduced a higher level of support under the Renewables Obligation for innovative offshore wind generation in Scottish waters, including floating wind[8]. New guidance for sites suitable for testing deep water wind generation technology is expected.

Finally, in 2012, the UK and the US signed a Memorandum of Understanding to accelerate the deployment of floating offshore wind.

France is also at the forefront of deep offshore wind development. There are currently three main demonstration programmes: WINFLO, Vertiwind and IDEOL. The first two projects receive funding from the 'Grand Emprunt'[9] investment programme. In 2012, the Vertimed project, developed by the Vertiwind consortium, was selected for European funding under the NER300 programme[10].This project will form a 26 MW array and help establish a deep offshore industry in the country.

If the demonstration projects are successful, the government could support the scaling up of the prototypes through a specific call for projects[11].

Portugal is home to the second large scale grid connected floating system, WindFloat. With a European Economic Exclusive Zone 15 times larger than its total land area, the country is keen to exploit its deep water offshore wind resource. In 2012, following the successful first phase of the WindFloat project, the Portuguese government committed to support the second phase of the project, awarded funding by the European Commission under the NER300 scheme. The total capacity of the second (pre-commercial) phase of the project is planned to be approximately 27 MW or greater, using the next generation of multi-megawatt offshore wind turbines. A third (commercial phase) is planned to increase the wind farm capacity to 150 MW.

Spain is positioning itself for floating wind in the Mediterranean Sea and other coastal areas, with Spanish companies such as Gamesa and Acciona involved in deep offshore projects. The EU-funded HIPRwind project will lay the foundations for the delivery of complete, fully functioning industrial scale offshore wind turbines capable of generating between 10 MW and 20 MW of energy. A test platform will be constructed off the Bay of Biscay.

The ZEFIR project is also an array project: six to eight floating turbines with a maximum capacity of 50 MW will be installed at the end of 2013[12].

Further prototypes are also being developed in **Germany**, **Sweden** and the **Netherlands**.

Finally, **Norway** is a pioneer in floating wind power. Although it has rough weather and wave conditions, deep sea areas and considerable, low cost hydropower resources, Norway installed the world's first large scale demonstration project, Hywind. Starting with a 2.3 MW Siemens turbine, the concept will be equipped with a 5-7 MW turbine by 2016. The technology will be exported to the US for the Hywind Maine array, which will feature four 3 MW turbines and use floating spar buoy structures at a depth of about 140m. Opportunities could also arise in Japan, with the Hitachi consortium.

The SWAY project, featuring a spar buoy, was also installed in Norway.

In conclusion, the extensive list of deep offshore activities shows the dynamism of European countries and companies keen to prepare for the future offshore wind market. The technology race is on within Europe. Several European countries are allocating money and suitable sites to develop offshore wind farms in deep waters, using innovative designs. The next step for the industry is scaling up and progressing from single prototypes to demonstration farms and pre-series production.

[7] http://www.scottish-enterprise.com/news/2013/04/fund-to-build-offshore-wind-industry-on-strong-foundations.aspx
[8] Demonstration projects using new-to market turbines will receive 2.5ROCs per MWh of electricity generated. Projects using floating turbines will receive 3.5ROCs.
[9] The 'Grand Emprunt' is a loan from the French government to finance five key areas: education, R&D, industry and SMEs, sustainable development and numerical technologies. http://www.emprunt-national-2010.fr/
[10] See note 4.
[11] (2013) 'Rapport de la mission d'étude sur les energies marines renouvelables': in 2014-2015, a call for floating pilot wind farms could be published. By 2025, the first 100-300 MW floating wind farms could be operational.
[12] The ZEFIR project involves the Catalonian Institute for Energy Research (IREC), Gamesa, Alstom, Acciona and other partners.

This leadership in innovation must be encouraged at European and national level so that domestic wind resources can be better exploited and the European industry can benefit from export opportunities.

The United States

The offshore wind potential in the US is immense, due to long coastlines and a good wind resource. The latter is not only vast but is located close to the main consumption centres as coastal areas are the most populated parts of the country.

Offshore wind projects are envisaged in most US coastal regions including the Great Lakes, the Gulf of Mexico and the West coast.

Although there is an estimated offshore wind resource of around 4,150 GW, more than half of this capacity is in waters deeper than 60m, making near-term development unlikely[13].

There are no offshore wind farms in the US to date. Nevertheless, significant efforts are under way to research and develop deep offshore designs.

In 2010, the Department of Energy (DOE) launched the Offshore Wind Innovation and Demonstration Initiative to help advance commercial offshore wind development in the United States.

In 2011, President Obama's State of the Union Address called for 80% of the nation's electricity to be generated from clean energy sources, including wind, by the year 2035.

The state of Maine in particular is encouraging deep water substructure development, with a goal of 5 GW of floating offshore wind capacity by 2030. Three test sites have already been designated and, in 2009, the University of Maine received $8.5m funding from the DOE to develop the next generation of offshore wind platforms.

TABLE 2 OFFSHORE WIND POTENTIAL FOR AREAS UP TO 50 NAUTICAL MILES FROM SHORE WITH AVERAGE WIND SPEEDS OF 7 M/S OR GREATER AT 90M ELEVATION

Region	0-30 m depth	30-60 m depth	>60 m depth	Total
New England	100.2	136.2	250.4	486.8
Mid-Atlantic	298.1	179.1	92.5	569.7
South Atlantic Bight	134.1	48.8	7.7	190.7
California	4.4	10.5	573	587.8
Pasific Northwest	15.1	21.3	305.3	341.7
Great Lakes	176.7	106.4	459.4	742.5
Gulf of Mexico	340.3	120.1	133.3	593.7
Hawaii	2.3	5.5	629.6	637.4
Total (GW)	1.071.2	628	2,451.1	4,150.3

Source: W. Musial 2010

The consortium DeepCWind[14], spearheaded by the University of Maine has since then brought together around 30 companies to build a deep water floating offshore turbine prototype. The first 20 kW prototype went online in June 2013.

In 2012, the DOE announced a further $168m funding over six years for seven offshore wind demonstration projects. For the first phase of this six-year initiative, three are floating projects[15].

[13] Department of Energy (2011) 'A National Offshore Wind Strategy: Creating an Offshore Wind Energy Industry in the United States'.

[14] The consortium led by the University of Maine includes universities, non-profits, and utilities; a wide range of industry leaders in offshore design, offshore construction, and marine structure manufacturing; firms with expertise in wind project siting, environmental analysis, environmental law, energy investment and composite materials to assist in corrosion resistant material design and selection, as well as industry organisations to assist with education and technology transfer activities.

[15] The three floating projects are:
- The 30 MW WindFloat Pacific Demonstration project which will be developed by Principle Power in partnership with Siemens. Located in the Pacific Ocean, it will feature five semi-submersible floating foundations fitted with 6 MW direct-drive offshore wind turbines.
- The 12 MW Hywind Maine project will be developed by Statoil and will feature four 3 MW turbines and use floating spar buoy structures at a depth of about 140 metres. These will be assembled in harbour to reduce installation costs and then towed to the installation site to access the Gulf of Maine's extensive deep water offshore wind resources.
- For the DeepCWind consortium, the University of Maine plans to install the pilot floating offshore wind farm with two 6 MW direct drive turbines on concrete semi-submersible foundations.

Japan

Japan has the world's sixth largest Exclusive Economic Zone (EEZ) and has a strong maritime industry. It has very good wind resources, but needs to develop deep offshore technology in order to exploit its domestic offshore wind energy resource, as more than 80% is located in deep waters.

Japan has had more than twenty years of public funded research on deep offshore structures.

In March 2011, following the nuclear accident at Fukushima, the Japanese government decided to boost renewables and cut back on the use of nuclear power. Offshore wind is now on the political agenda and a feed-in tariff has been put in place.

Although there are no official targets for offshore wind, it was estimated that around 5 GW - 6 GW offshore wind could be installed by 2030. However, with the government now in power, Japan's long term energy and climate change strategies are likely to be reassessed.

Currently there are two scale models grid connected in Japan. In Hakata Bay, the WindLens project which carries two wind turbines of 3 kW each and in the Kabashima Island, a 100 kW wind turbine on a spar. At the end of the summer 2013, the wind turbine in Kabashima should be replaced by a full scale grid connected 2 MW wind turbine[16].

In addition three national offshore wind projects have been announced, one is considering using floating substructures[17].

[16] This is a demonstration project supported by the Japanese Ministry of the Environment. In 2012, a floating 100 kW turbine (spar buoy) was installed off Nagasaki in Kabashima island and it is grid connected. The project will now be upgraded to a Fuji Heavy Industries 2 MW wind turbine following initial operation and data collection.

[17] The project is supported by Japan's Ministry of Economy, Trade and Industry. It is a $250m demonstration off the coast of Fukushima involving the installation of several floating offshore turbines. Three types of floating substructures will be used with two different turbine sizes, including 2 MW (phase 1) and 7 MW (phase 2).
The consortium is led by Marubeni Corporation and includes Mitsubishi and Hitachi. Mitsubishi has announced plans for the development of a new 7 MW turbine with a hydraulic drive, designed to operate on semi-submersible floating platforms in deep water off the coast of Fukushima. With this project, the consortium ultimately aims to reach 1 GW of floating capacity.
'Floating Offshore Wind Foundations: Industry Consortia and Projects in the United States, Europe and Japan'. Market Report by Annette Bossler, Main(e) International Consulting LLC, May 2013. http://maine-intl-consulting.com/resources/Floating+Offshore+Wind+Platforms+Consortia+for+web.pdf

3 DEPLOYING DEEP OFFSHORE TECHNOLOGIES – KEY CHALLENGES

To date, deep water substructures have mainly been based on floating platform designs. Even if floating deep offshore wind designs do not pose significantly bigger or different challenges than fixed-bottom solutions, the designs are in their infancy and need continuous support to develop.

3.1 Technical and infrastructure challenges

Resource assessment, grid connection and wind farm operation are significant challenges for offshore wind power. This also applies to deep offshore projects. However, for the latter, the foundation, communications and control systems may pose an extra technical challenge.

Modelling and numerical tools

Offshore wind is a young industry which began in 1991 when the first wind farm was installed off the Danish coast. While onshore wind technology was initially used to supply this niche market, the offshore wind market is increasingly developing specific products with design driving the supply chain towards specialisation. Many products and techniques are adapted from other industries, particularly onshore wind and oil and gas.

A new generation of modelling and numerical design tools was developed to address unique offshore wind turbine technology requirements, including installation and operations in an extremely hostile sea environment.

Because deep offshore designs are at an early stage of development, modelling remains one of the main challenges. Experimental floating structures and complete prototypes will be needed to validate the new numerical software tools used to simulate the behaviour of floating concepts.

Modelling tools combining the turbine and substructure operating conditions are not currently validated for deep offshore designs. In order to ensure successful modelling, the software should be able to analyse the interaction between the aerodynamic and structural behaviour of the foundation (including the moorings) and the turbine simultaneously.

Ensuring that the model is sufficiently developed is an additional challenge.

Modelling tools and numerical codes that simulate whole structure behaviour should be developed and validated to allow for an improved design. This will be a first step towards deep offshore development.

Optimised wind turbines for floating support structures

Integration of the wind turbine with the deep offshore platform - or the ‘superstructure’ design - is another important technical issue that has a significant impact on project costs - and, therefore, on the cost of energy. Installing a “normal” offshore turbine on a floating substructure is a first step, but may not be the only solution. To improve the economics of deep offshore designs, it will be essential to develop technology to optimise system architecture.

Wind turbine designs should be optimised for use on floating substructures. If the total system - wind turbine and substructure - is effectively optimised, deep water technologies will become competitive. Turbine size plays an important role in determining this, so it needs to be carefully considered.

In 2012, the average size of offshore turbines newly connected to the grid was 4 MW, up from 3.6 MW in 2011. Moreover, out of the 38 new models announced, only 9 (24%) are less than 5 MW, the other 29 (76%) consisting of bigger machines. Deep offshore designs will need to adapt to this trend. For the designs to be more viable larger wind turbines should be used and new materials developed.

Additionally, typology - the combination of site and technology specific variables (e.g water depth, size of turbine) - is the basic parameter for every different concept and site. The choice of substructure is closely linked to the operation of the wind turbine. The design of the substructure is usually restricted by how the turbine has to be controlled.

Controlled motions and the way they affect system performance and strategies for controlling the rotor, are linked to the dynamic response of the floating structure. This will impose restrictions on the overall design. For example, semi-submersible and tension leg platform (TLP) designs might appear more expensive but could lead to low response configurations and to more stable operating situations, close to those for onshore wind. On the other hand, the spar–buoy must be designed to combine successful response levels as well as small effects on the system's aerodynamics. Imposing an active control on the turbine itself can result in significant cost reductions and improved performance, given that it improves the whole system's stability.

Special attention should be paid to developing sufficient and appropriate control systems. These should work on stabilising the structure and enhancing energy production, minimising loads and losses.

Connection to the grid

The challenges facing floating offshore wind farms' grid connection from substation to shore, do not significantly differ from those for fixed foundations. The distance from the shore and the availability of networks at the point of connection remain a potential bottleneck. However, as far as cable technology is concerned, the dynamic section of the cables (the section that has to move) is an important issue. The motion induced by the turbine and the non-fixed foundation can put additional loads on the cables.

In water depths of more than 100m, the array cable layout could also pose technical problems. With an array cable laid on the seabed or submerged at around 50m, a longer cable would be needed, which could lead to the cable moving. Studies of dynamic response of the cables and evaluation of cost effective solutions need to be developed.

While more research is required on mooring and anchoring systems, the deep offshore wind industry should be able to benefit from the experience gained in the oil and gas sector, where these systems have been used for many years. Increased exchange of knowledge and cooperation with the oil and gas industry would help develop deep offshore faster and more cost effectively.

In conclusion, deep offshore designs are still in their infancy. Commercialisation can be expected over the next five to six years but much innovation is still required to ensure design reliability and commercial viability.

As for the other offshore wind technologies, it is essential that scale-down testing and large test sites, such as Alpha Ventus in Germany are developed to validate new designs and test turbine components and substructures. Test sites that can incorporate large wind turbines with water depths of over 60m would help to cut costs and improve the reliability of deep offshore designs.

3.2 The economics of deep offshore projects

Installation, operations and maintenance

The supply chain and port infrastructure requirements are similar for all types of offshore wind substructures. In common with fixed-bottom foundations, building a strong supply chain remains a priority for deep offshore deployment. Ports must allow for increased throughput and provide enough space to accommodate installation and component storage.

Infrastructure for the serial production of floating offshore components needs to be built, as is the case for fixed-bottom foundations.

Supply chain and port infrastructure requirements for floating turbines may be similar to those of fixed-bottom offshore wind, but the economics of deep offshore projects are different in terms of installation and operations and maintenance (O&M) costs.

Offshore wind is a capital intensive technology, and installation costs are an important cost. But that is not the case for most of the deep offshore designs, which can be assembled onshore then towed out to sea. This reduces the need to use vessels, cutting overall installation costs.

It also reduces installation lead times as the deep offshore designs are less dependent on weather and sea conditions. The industry is, however, trying to minimise installation costs and must continue to develop self-installing and port assembled systems.

Handling and installing mooring lines and anchors may be the main installation challenge. Attention needs to be paid to what equipment is used. The moorings and anchors must be designed to ensure the concept's stability throughout its lifetime. Hooking up mooring lines to the floating platform is one of the most difficult phases of the installation process. Significant experience is being transferred from the oil and gas sector to reduce design and installation risks to the mooring systems of floating structures.

For O&M and logistics, the deep offshore turbine's motion remains the main challenge, although the inspection of the mooring lines and anchor system could also involve much effort and cost.

However, most deep offshore wind designs could be assembled onshore and transferred to the site. In the case of a failure the whole structure could be transported for repair to an onshore location by tug boats. This would avoid using expensive vessels such as jack-up barges.

Some deep offshore wind designs also include a large platform where machinery as well as crew can remain available for O&M on site.

Assessing the costs of the deep offshore designs

Offshore wind is still in its infancy, and therefore has high costs.

Cost reduction is one of the main challenges for the industry and much work is being done to address it.

Large scale development of the technology, along with the support of a secure and stable regulatory framework, will help reduce costs. However, innovation must also be geared towards reducing turbine, foundation and other component costs. It is therefore essential to ensure sufficient public R&D financing to enable the offshore vision to become reality.

The production and installation of substructures represents up to 20% of the capital expenditure (CAPEX) of offshore wind farms. Offshore wind costs can, therefore, be considerably reduced if substructure costs are reduced. This can be achieved through demonstrating new designs with low installation and production costs.

Along with the focus on reliable and cost effective solutions for bottom-fixed substructures for the near term market in deeper waters, cost effective floating substructures must be developed to secure a larger scale offshore wind market.

Floating offshore substructure costs mainly consist of the platform and the anchoring system. These costs are similar to those for fixed-bottom solutions installed in deep waters.

The major difference between the two solutions is in the design and installation costs where floating offshore designs are expected to be cheaper.

Overall, floating offshore designs are also expected to produce more energy, as they can accommodate bigger turbines that lower the final cost per MWh. This is currently being investigated in the SWAY project focusing on a 10 MW turbine for floating foundations and by the EU HiPRwind project - a five year project, funded by the European Framework Programme, on large floating offshore turbines.

The EWEA Offshore Wind Industry Working Group (OWIG) - made up of EWEA members gathered in the Task Force ‘Deep offshore and new foundation concepts’ - has evaluated deep offshore concept cost. It has taken account that most of the designs are still at an early stage of development and that some designs (such as Hexicon) do not fall in the usual category of one wind turbine with a floating foundation. They include other types of power generation such as wave energy.

To evaluate the economics of floating designs, EWEA performed a comparison with jacket foundations, whose technical characteristics allow for installation in water depths of up to 45-50m. The findings show that floating offshore wind designs are competitive in terms of LCOE with existing jacket foundations from around 50m water depths.

For a 100 MW wind farm, equipped with 5 MW turbines and installed in water depths of 100m, the CAPEX for floating designs is similar to the CAPEX of farms using jackets or tripod foundations at 50m water depths. Similarly the cost of energy produced by the floating designs would be competitive with the fixed-bottom foundations solution. A study from GL Garrad Hassan showed that the levelised cost of energy (LCOE) of a 500 MW wind farm in water depths of 50m would be €128/kWh, lower than the current average levelised cost of fixed-bottom foundation wind farms in shallower waters[18].

The offshore industry is gradually leaving shallow waters behind. Deep offshore designs, although in their infancy, are not only innovative but competitive at a water depth above 50m. It is feasible to develop them and the offshore wind industry must continue investing in R&D to optimise the exploitation of this widely available marine resource at an affordable cost of energy.

The European wind industry has been preparing for this, investing considerably more in R&D than the average for all other sectors of the EU economy. In 2010, R&D expenditure was 5.1% of the industry’s turnover, compared to an economy-wide expenditure of 2.1%[19]. This commitment to R&D is even more striking amongst wind turbine manufacturers, who reported R&D expenditure in 2010 of over 10%. These efforts deserve support from national and European R&D programmes, to accelerate development of innovative technology, including deep water wind energy solutions.

3.3 Non-market barriers

Stability and clarity of the legislative framework

Reaching 2020 targets and committing to 2030 renewable energy targets

Regulatory uncertainty is the main non-technological barrier threatening deep offshore wind deployment.

Although the technology is still in its infancy with only two full scale floating systems grid connected in the world, deep offshore designs are rapidly developing with potential commercialisation in the next five to six years. The offshore wind industry is investing considerably in R&D and currently in Europe alone, around 25 projects are under development, in addition to the grid-connected ones.

However, deep offshore wind development depends on numerous factors and crucially on a stable and clear regulatory framework post 2020. Although Europe’s seas and oceans offer enormous opportunities for innovation, growth and employment, their promise will not be realised without a dynamic agenda at national and European level.

The European Union and its Member States must not only achieve their 2020 targets but also commit to a 2030 renewable energy target. This combined with

[18] Garrad Hassan (2012) ‘Cost of energy of floating wind’.
[19] Green Growth: the impact of wind energy on jobs and the economy, 2012, EWEA.

tailored market and regulatory frameworks for deep offshore wind will create the necessary confidence for industry and financial players.

Maritime spatial planning

Spatial planning is a key element of the regulatory framework. Increased activity within Europe's marine waters has led to increased spatial demands and therefore growing competition between sea users.

Offshore wind development is often caught between conflicting uses, interest groups and rules from different sectors and jurisdictions. This creates uncertainty, increases the risks of delays or failure of offshore wind projects and impairs the sector's growth potential.

The decision to carry out maritime spatial planning (MSP) and to dedicate zones for offshore wind developments and electricity interconnectors therefore sends positive signals to the industry. Spatial planning provides stability and clarity for investors as well as helping reduce project costs.

Although a few European countries currently have defined dedicated offshore areas, most countries use existing marine planning laws, which can delay projects considerably. As a developing and unique energy source, offshore wind is often excluded from the legislative framework. Planning delays can increase the costs of offshore wind significantly and effective planning will ease permitting and licensing procedures.

In the case of deep offshore wind, there is a clear need for simplification of the licencing and permitting procedures to minimise deployment lead times. Permitting bodies need sufficient capacity to handle the expected growth in deep offshore projects.

Provided there is appropriate siting of wind farms and careful spatial planning, the local marine environment can benefit from the existence of offshore wind farms in many ways. For example, excessive trawling is a severe threat to fish and invertebrates. Trawling, however, is limited inside wind farms in most EU countries. The parts of offshore energy devices that are surface orientated or under the water, such as foundations and moorings, can serve as Fish Aggregation Devices (FAD). They act as artificial reefs and contribute to increasing maritime flora and fauna.

Challenges to commercialisation

Technology risk perception

Deep offshore wind is at an early stage of development, with only two recent large scale grid connected projects across the globe, both in Europe.

Analysis carried out by the Offshore Wind Industry Group at EWEA indicates that the costs of dedicated deep water substructures should be comparable in terms of LCOE with existing fixed-bottom structures from 50m water depths, a finding confirmed by the floating designs currently being tested in Europe. Although these designs will contribute to future cost reductions in large scale offshore development, much remains to be done before commercial scale is achieved.

Investors might still be reluctant to invest and feel more comfortable with "well known" fixed foundations.

There is a growing risk perception reflecting with the increasing scale and complexity of the projects and there is, therefore, a need for the offshore industry to concentrate its efforts on increasing the reliability of the technology and minimising costs to move to commercialisation. This will contribute to a reduction in the finance community's perception of risk.

Public support from R&D to deployment is key to offshore technology development, including deep offshore. R&D and innovation support must not only facilitate technology development but also favour its demonstration, allowing developers and associated companies to test new technologies before commercial deployment. This will reduce development risks and capital costs and provide an opportunity to test the reliability in real time and in a "real" environment.

Large demonstration projects with significant high cost hardware and risk are difficult to finance and this is where both the EU and national public support is necessary, to alleviate the risk and thereby to attract private investments.

The NER300 programme is a good example of a financing instrument jointly managed by the European Commission, European Investment Bank and Member States to support the demonstration of deep offshore technology and facilitate the move towards commercialisation[20]. In the first call for proposals it awarded €64m to the demonstration of two offshore wind floating structures, WindFloat and VertiMed.

Standardisation and cooperation

As a new sector, there are no specific standards adapted to the deep offshore designs.

Certification bodies have addressed the issue by blending offshore wind fixed-bottom and offshore oil and gas standards. However, this has resulted in unnecessary structure over-dimensioning (additional and unnecessary safety design features) and, thus, overall cost increases.

New standards must be developed specific to floating systems. These are essential to reach commercial maturity. Currently such standards are under development by several bodies, such as Det Norske Veritas (DNV), International Electrotechnical Commission (IEC) and American Bureau of Shipping (ABS).

Furthermore, cooperation between the different supply chain players is important, especially for the development of deep offshore designs. It is necessary to adopt an integrated approach to the links between the R&D community and the industry. This will help develop reliable, innovative and marketable designs.

Strong collaboration between the different players (and sometimes competitors) should be encouraged through new project partnerships. Exchange of experience, lessons learned and data is crucial and will prove beneficial to all stakeholders.

The European Wind Initiative (EWI), with the network and R&D forum TP Wind, has proved to be a good platform to take the wind industry and the deep offshore industry to the next stage. It should be continued and sufficient funding allocated to ensure its implementation.

Because floating wind substructures have a lot in common with oil and gas floating substructures, transfer of knowledge between both sectors should be considered and promoted at EU level.

This cooperation could be framed by a European Industrial Strategy for wind power coordinated by the European Commission's DG Enterprise. Reinforced by the industrial strategies developed at national and regional levels, the strategy would provide a comprehensive vision of the offshore wind sector's development, and could contain a deep offshore element. It would be composed of four work streams: technology innovation, supply chain expansion, skills and financing. It would focus on delivering cost reductions, integrating the specific technical, economic and political recommendations made for deep offshore wind.

[20] "NER300" is a financing instrument managed jointly by the European Commission, European Investment Bank and Member States. Article 10(a) 8 of the revised Emissions Trading Directive 2009/29/EC contains the provision to set aside 300m allowances (rights to emit one tonne of carbon dioxide) in the New Entrants' Reserve of the European Emissions Trading Scheme. This is for subsidising installations of innovative renewable energy technology and carbon capture and storage (CCS).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4 RECOMMENDATIONS

Offshore wind is still a young technology facing considerable challenges that require political and economic support to reach maturity through large scale deployment. This is particularly true for floating technology. While it does not pose significantly bigger or different challenges than fixed-bottom solutions, it would particularly benefit from political support. This could be encouraged by ambitious 2030 targets for renewable energy, as well as a European wind industrial strategy that drives its development from R&D to deployment.

Political recommendations:

- A clear and stable legislative framework post 2020 based on a binding 2030 renewable energy target is necessary to encourage deep offshore wind development and deployment.
- A cohesive European industrial strategy guiding offshore wind development is necessary. It will support deep offshore from R&D to deployment.
- Licensing and permitting procedures should be simplified to minimise lead time deployment. The capacity of permitting bodies should be enhanced to handle the expected growth in deep offshore projects.
- Public support for R&D should continue and increase to maintain European technology and market leadership in deep offshore designs.
- Strong collaboration between the different players (and sometimes competitors) should be encouraged through new project partnerships. Exchange of experience, lessons learned and data is crucial and beneficial to all stakeholders.
- The European Wind Initiative (EWI), with the network and R&D forum TP Wind should be continued and allocated sufficient funding to ensure their recommendations are implemented.
- New standards specific to wind floating systems must be developed to help reach commercial maturity.
- Access to financing should be ensured for deep offshore projects where a correct risk perception has been applied.

Economic recommendations:

- Ports must provide enough space to accommodate installation vessels and component storage.
- Self-installing systems must be developed to minimise installation costs.
- Training courses should be developed to remedy to the shortage of skilled professionals.
-

Technical recommendations:

- Modelling tools and numerical codes that simulate the whole structure's behaviour should be developed and validated to allow for an improved design.
- Wind turbine design and size must be optimised for use on floating support structures.
- There is a need to develop sufficient and appropriate control systems.
- More research must be done on mooring and anchoring systems with the industry benefiting from the experience of the oil and gas sector.
- New measuring techniques and tools should be developed to assess the wind and wave conditions at the wind farm locations.
- More research is required into wake and turbulence effects and how they impact the load and motions of floating platforms. This can be achieved by deploying floating demonstration farms of around four or five units, not exclusively single unit prototypes.
- More test sites (small scale and large scale) should be developed to ensure the reliability and cost competitiveness of the deep offshore designs.

ANNEX

Hywind

DESCRIPTIONS PROVIDED BY THE PROJECTS

Design name	Hywind
Company	Statoil
Manufacturer	Siemens
Type of floater	Spar-buoy
Turbine capacity	2.3 MW (prototype) 3-7 MW (commercial)
Prototype installed	2009, West coast of Norway
Commercial installation	2015-2016
Origin	Norway

The Hywind design consists of a slender, ballast-stabilised cylinder structure. The spar-type floater has a low water plane area that minimises wave induced loading, and a simple structure that minimises production cost. It can be used with any qualified offshore wind turbine. The mooring system consists of three mooring lines connected to the hull by means of bridles that prevent excessive rotation about the vertical axis (yaw motion). The mooring system has inherent design redundancy, with adequate reserve strength in case of a mooring line failure.

The 2.3 MW Hywind demo was installed in Norway in 2009 - the world's first full scale floating offshore wind turbine. The unit is located at a water depth of 200m, 10km off Norway's west coast. It has been thoroughly inspected after the first and second years in service, and no signs of deterioration, damage, or wear connected to being on a floater have been reported. Statoil now considers the design to be technically verified. The floater design has been optimised and up-scaled for deployment with multi-MW turbines in the 3 MW to 7 MW range. The next step will be to test the design in a pilot farm with four to five units.

WindFloat

DESCRIPTIONS PROVIDED BY THE PROJECTS

Design name	WindFloat
Company	Principle Power, EDP, Repsol
Manufacturer	Vestas
Substructure	Semi-submersible
Turbine capacity	2 MW (prototype) 5-7 MW (commercial)
Prototype installed	2011, Portugal
Commercial installation	2017
Origin	Portugal

The WindFloat design consists of a semi-submersible floater fitted with patented water entrapment (heave) plates at the base of each column. The plate improves the motion performance of the system significantly due to damping and entrained water effects. This stability performance allows for the use of existing commercial wind turbine technology. In addition, WindFloat's closed loop hull trim system mitigates average wind induced thrust forces. This secondary system ensures optimal energy conversion efficiency following changes in wind velocity and directions.

The mooring system employs conventional components such as chain and polyester lines to minimise cost and complexity. Through the use of pre-laid drag embedded anchors, site preparation and impact is minimised.

In 2011, WindFloat was installed off the Portuguese coast. Equipped with a 2 MW Vestas wind turbine, the installation started producing energy in 2012. The next step will be to build a 27 MW array off Portugal, with the support of the NER300 funding. Another 30 MW demonstration project is also planned off Oregon in the Pacific Ocean.

Blue H TLP

DESCRIPTIONS PROVIDED BY THE PROJECTS

Design name	Blue H TLP
Company	Blue H
Substructure	Submerged deepwater platform
Turbine capacity	5-7 MW (commercial)
Prototype installed	2015
Commercial installation	2016
Origin	Netherlands

The submerged deepwater platform consists of a hollow body. This provides the buoyancy, by being held "semi-submerged" under water by chains or tethers connecting the buoyant body to a counterweight that lies on the seabed.

With the buoyant body held semi-submerged in the water, the necessary uplifting force is created, keeping the chains constantly tensioned.

In 2007, Blue H technologies installed the first test floating wind turbine in Italy. It generated 80 kW and after a year of testing and data collection it was decommissioned.

Blue H Engineering is now executing the design, engineering works and related applied research for the development of a generic 5 MW model, based on proven Tension Leg Platform technology. This will offer a more stable floating foundation for commercially available 5-7 MW wind turbines. The manufacturing demonstrator is planned for 2015 and the commercial model is planned for 2016.

Floating Haliade 150

DESCRIPTIONS PROVIDED BY THE PROJECTS

Design name	Floating Haliade
Company	Alstom
Manufacturer	Alstom
Substructure	Tension Leg Buoy (for water depths between 50m-80m) Tension Leg Platform (for water depths between 80m-300m)
Turbine capacity	6 MW

Alstom has been developing its floating Haliade 150-6 MW based on a Tension stabilised concept. The most suitable configurations are TLB for water depths between 50m to 80m, or TLP for water depths between 80m to 300m.

Alstom R&D activities started with the Azimut Offshore Wind Energy 2020 Project [2010-2013], jointly with Acciona & Gamesa, and with an objective to develop know-how for constructing large scale marine wind turbines and develop 15 MW floating offshore wind turbines overcoming financial and technical challenges.

A partnership between b_Tech and the MIT has been developing know how to model tension leg platforms (TLP's) and developing robust and reliable tools to design TLPs. A grant has been awarded by the US Department of Energy to work on energy cost reduction through advanced control strategies for energy improvement.

WINFLO

DESCRIPTIONS PROVIDED BY THE PROJECTS

Design name	Wind turbine with INnovative design for Floating Lightweight Offshore
Company	Nass & Wind, DCNS and Vergnet
Type of floater	Semi-submersible
Turbine capacity	1 MW (prototype) 2.5 MW (commercial)
Prototype installed	2013
Commercial installation	2016
Origin	France

The project includes a floating platform, based on a semi-submersible unit concept, with a wind turbine specifically designed for offshore floating specifications (sea and moving conditions) and an anchoring system with few constraints suitable to all types of seabed.

After two periods of successful tank tests (2010 & 2011), the WINFLO life sized demonstrator will be tested in sea conditions in 2013. After a one year testing period, it will be followed by a pilot farm built in 2016. The machine will be manufactured in pre-series and marketed from 2016 onwards.

The programme is coordinated by Nass & Wind Industrie, a major player in the offshore wind sector, in close partnership with DCNS, an international ship building and marine renewables company, and Vergnet, experienced in turbine engineering and manufacturing for harsh environments. The consortium also includes two experienced scientific partners: IFREMER (Sea Research Institute) and the university ENSTA-Bretagne.

Officially recognised by the Pôle Mer Bretagne in 2008, WINFLO has also been guaranteed the financial support from the ADEME, the French Environment and Energy Management Agency, under a state investment programme.

PelaStar

DESCRIPTIONS PROVIDED BY THE PROJECTS

Design name	PelaStar
Company	The Glosten Associates
Substructure	Tension-leg turbine platform
Turbine capacity	1:50 (demonstration/pilot) 2.5 MW (commercial)
Demonstration/pilot	2011
Commercial installation	2015-2017
Origin	United States

PelaStar is a tension-leg platform (TLP) integrating proven TLP technology. It is widely used in the offshore oil and gas industry, and is being adapted for the offshore wind industry.

PelaStar's features include:

- Simplicity of design – an optimised steel structure with no mechanical systems.
- Minimal motions and accelerations at the turbine – there are no pitch, roll, or heave that degrades performance and increases wear on components.
- Efficient quayside assembly, turbine testing, and partial commissioning reduces offshore work, weather delays, and the need for expensive offshore equipment.
- The tendons, with their vertical orientation under the hull, create a compact footprint that reduces the risk of underwater interferences.
- Technology focused on reducing the cost of energy has produced the lowest capital costs for floating designs.

The PelaStar TLP is designed to support 5 MW to 10 MW turbines in 50m to 200m water depths.

Model testing at 1:50 scale was completed in 2011. A full-scale, 6 MW turbine demonstration is planned for 2015, with a multi-unit pilot project following in 2017.

IDEOL

DESCRIPTIONS PROVIDED BY THE PROJECTS

Design name	IDEOL
Company	IDEOL
Substructure	Concrete floater
Turbine capacity	5-6 MW (prototype)
Demonstration/pilot	2014
Origin	France

Based on a concrete hull built in partnership with major civil engineering companies, IDEOL scales from small to very large wind farms. On-site construction, high local content and versatile construction methods are used, depending on site conditions and local procurement options.

IDEOL has developed and patented the Damping Pool® system. Its floating foundation can be used with any commercial offshore wind turbines, without modification. Damping Pool® enables reduction of floater motions by using the hydrodynamic properties of water mass entrapped into a central well. Oscillations are, by design, opposed to the excitation force generated by the waves.

IDEOL is currently working with partners on the construction and installation of two commercial scale demonstrators in 2014.

Hexicon Energy Design

DESCRIPTIONS PROVIDED BY THE PROJECTS

Design name	Hexicon Energy Design
Company	Hexicon
Substructure	Floater
Capacity	54 MW (wind) 15 MW (wave)
Commercialisation	2014-2015
Origin	Sweden

The Hexicon Energy Design is based on a floating platform which incorporates existing and verified off-shore technologies and applications. The towers are installed directly onto the platform, enabling the installation of wave generator applications.

1. Centralized swivel system enabling the entire platform to turn around its axis and align itself automatically with the wind while moored
2. Turbines with proven track record
3. Propulsion and dynamic positioning by use of thrusters
4. Tension mooring system (no anchor chains)
5. Protective hull system
6. Electric feeder cable and swivel hook-ups, including the substation, are located above water surface
7. Docking and service facilities located at rear of platform, including heliport designated area
8. 24/7 management, surveillance, maintenance and accommodation area

HiPRwind – EU project

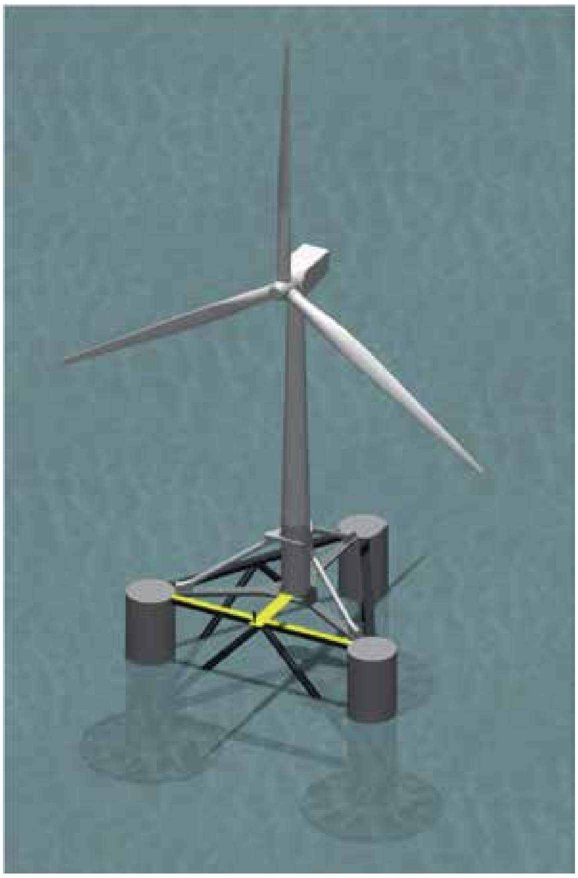
DESCRIPTIONS PROVIDED BY THE PROJECTS

Design name	HiPRwind – EU project
Coordinator	Fraunhofer IWES
Programme	Framework Programme 7
Budget	€19.8m (EU support: €11m)
Period	2010-2015
Origin	Europe

The HiPRwind project is creating and testing novel, cost effective approaches to deepwater offshore wind energy developments. In order to gain real sea experience and data, a fully functional floating megawatt-scale wind turbine will be deployed at an ocean test site off the coast of Spain and used as an experimentation platform. This installation is approximately on a 1:10 scale of the future commercial floating wind systems for deep offshore.

As the world's first large scale, shared access real sea research and test facility, HiPRwind will facilitate the study of new floater designs, installation methods, control engineering solutions and grid integration aspects of deep water wind. R&D includes high reliability power electronic components, new concepts for large rotors, control systems, condition and structural health monitoring. Built in active control features will reduce dynamic loads on the floater to save weight and cost compared to existing designs.

R&D results will be shared with the offshore wind technology community.



ZÈFIR Test Station

DESCRIPTIONS PROVIDED BY THE PROJECTS

Design name	ZÈFIR Test Station
Sponsors	IREC, Alstom, Enel Green-power, Gas Natural Fenosa, Acciona, Barlovento, COMSA EMTE, EDP, Enerfin, Elenor Energias Renovables, FCC, Gamesa, Iberdrola, Normawind, Prysmian, Renovis, Siemens, Vortex
Origin	Spain

The ZÈFIR Test Station is an international research facility that will be used for the testing of offshore wind turbines in deep waters. It is located off the coast of Ametlla de Mar and it will be constructed in two phases. The first will consist of the installation of a maximum of four wind turbines anchored to the seabed at a distance of 3.5km from the coast, with a total power output of no more than 20 MW, whilst the second will involve a maximum of eight floating wind turbines that will be installed around 30km from the coast, which together will provide a maximum power output of 50 MW.

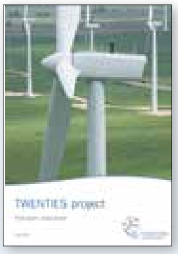
Goals

- To reduce the costs of building offshore wind farms and develop technologies enabling them to be installed in deep waters.
- To conduct research into these applications.
- To increase the understanding of the science and technology behind wind energy by the industrial sector associated with the research centres involved.
- To create new opportunities for the businesses participating in the project.
- To establish a leading international centre that can attract investment from the sector.
- To create an environment for promoting university training programmes that attract people into R&D.
- To ensure that Catalonia, and Tarragona in particular, become an international hub for offshore wind energy.
- To raise awareness of the project's environmental impact and its location in the Gulf of Sant Jordi, off the coast of L'Ametlla de Mar.

	Phase 1	Phase 2
Water depth	40m	≈ 100m
Distance from coast	3km	≈ 30km
Number of wind turbines	4	8
Power installed	20 MW	50 MW
Type of foundation	Piled/GBS	Floating

The first phase of the ZÈFIR project will enable Spanish manufacturers to test their prototype offshore wind turbines, with the advantage of easy access as they will be located relatively close to the coast on water navigable all year round.

Latest reports published by EWEA



Twenties

The aim of the TWENTIES project is to advance the development and deployment of new technologies which facilitate the widespread integration of more onshore and offshore wind power into the European electricity system by 2020 and beyond.

PUBLICATION DATE: June 2013

DOWNLOAD THE PDF HERE:
www.ewea.org/report/twenties

EWEA annual report 2012: United in tough times

In 2012, Europe's wind energy industry was plunged into a crisis of regulatory uncertainty as governments, seeing renewables as an easy target for austerity measures, slashed or changed their support. Despite this, 2012 marked a historic milestone: reaching 100 GW of wind power capacity in the EU, meeting the power needs of 57 million households, equivalent to the output of 39 nuclear power plants – a remarkable success which was achieved during a period of extraordinary growth founded on firm political support.

PUBLICATION DATE: June 2013

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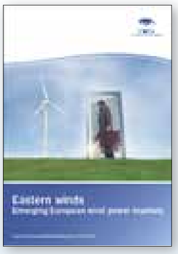

Eastern Winds: Emerging European wind power markets

Eastern Winds examines the frontier of wind power development in Europe. The report deals with the prospects for wind power in central and eastern Europe, tackles financing and provides an in-depth analysis of 12 emerging wind power markets. Eastern Winds is also a tool for decision-makers highlighting bottlenecks, regulatory challenges and providing policy recommendations.

PUBLICATION DATE: February 2013

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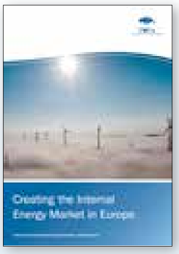
www.ewea.org/report/eastern-winds

The European Wind Initiative

"The European Wind Initiative - Wind Power Research and Development to 2020" is an updated summary of the 10 year wind energy research strategy. The pamphlet summarises the EWI implementation activities, the progress made so far and suggests funding recommendations in line with the upcoming EU Multiannual Budget 2014-2020.

PUBLICATION DATE: January 2013

DOWNLOAD THE PDF HERE:
www.ewea.org/report/european-wind-initiative



Creating the Internal Energy Market in Europe

A report on EU electricity market rules, which must reflect the energy generation mix of the future and help usher in a flexible power system with a large-scale uptake of wind power and other renewable energy sources

PUBLICATION DATE: September 2012

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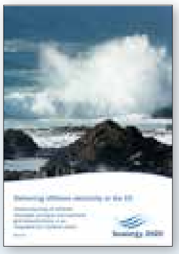
www.ewea.org/report/internal-energy-market



SEANERGY 2020 Report

Spatial planning of offshore renewable energies and electricity grid infrastructures in an integrated EU maritime policy

PUBLICATION DATE: July 2012

DOWNLOAD THE PDF HERE:
www.ewea.org/report/seanergy-2020

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About EWEA

EWEA is the voice of the wind industry, actively promoting wind power in Europe and worldwide. It has over 700 members from almost 60 countries, including wind turbine manufacturers with a leading share of the world wind power market, plus component suppliers, research institutes, national wind and renewables associations, developers, contractors, electricity providers, finance and insurance companies, and consultants. This combined strength makes EWEA the world's largest and most powerful wind energy network.

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