Floating Offshore Wind Foundations:
Industry Consortia and Projects in the United States, Europe and Japan

An Overview

May 2013 Update
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Preface

The past 7 months since the September 2012 report update have been marked by numerous news. Floating foundations are getting increasing attention within and outside the wind industry. The future of offshore wind is ‘definitely afloat’, according to attendees of the HUSUM 2012 Wind Energy trade fair. A poll conducted by GL Garrad Hassan showed 62% of participants thinking that floating wind turbines will take the lead over conventional turbine foundations within the next 20 years, according to the official press release by Husum Wind. By contrast, only 38% said that conventional structures would not be replaced by new floating technologies within the next two decades.

In November 2012 the U.S. Department of Energy announced $168 million funding for initially 7 Offshore Wind Advanced Technology Demonstration projects. 3 of these 7 projects involve floating foundations and highlight the U.S. Government’s focus on this technology. Eventually only 3 of the 7 projects will receive funding to full installation but the floating projects have as good a chance to be part of this as any conventional foundation project.

In February 2013 Japan hosted the Tokyo Smart Energy Week Exhibition and Conference; this time with participation of the wind power industry, a first for this event. Attendance was good and also gave insight into Japan’s Fukushima Floating Offshore Demonstration Project as well as a new project by MODEC, scheduled for a pilot plant in Fall 2013. The first 2 Fukushima demonstrator installations of 1 floating substation and a 2MW semisubmersible are also scheduled for Fall 2013. In addition, this summer a consortium will install a full scale floating spar off Kabashima Island in Japan. These will be the world’s 3rd full scale floating offshore wind turbine, followed by 2 additional full scale structures and the world’s first floating substation. These projects send the message that Japan has moved into the ranks of the floating offshore leaders.

Europe also shows new momentum, especially UK and Scotland as well as Spain and France. In April 2013 Scotland unveiled a £15m plan for deep-water wind energy development. The Crown Estate plans to develop a floating offshore demonstration project in water depths of ca. 100 meters off Scotland’s west coast. The objective is to have commercially viable technology available by 2020. US technology developers also benefit from UK funding. Principle Power is receiving a development award from the UK Department of Energy and Climate Change. Glosten Associates’ PelaStar TLP has been selected by ETI for a front end engineering design study. Across the channel French developers such as Nass et Wind are moving forward with their full scale pilot plans. In Spain, Iberdrola together with Gamesa and Acciona are moving forward with their developments. All in all the year 2014 looks like it might become a boom year for various European full scale launches if projects stay on track. So whoever still likes to refer to floating offshore wind technology as ‘niche’ and a long way off may want to reconsider this statement.

Floating Offshore Wind Foundations: Industry Consortia and Projects in the United States, Europe and Japan

An Overview

May 2013 Update
The ongoing monitoring and the creation of this overview is solely funded by Main(e) International Consulting LLC and is available at no cost to any interested reader. The images and information on the different projects have been obtained from the official project websites or the media sources as listed. Summarized tables and background info have been compiled by Main(e) International Consulting LLC.

The purpose of this report is to present the growing number of floating foundation projects around the world and by doing so, to highlight the growing global demand and market place. It is not intended to evaluate or rank the various technologies. Therefore in most cases the actual description as well as the data as published by the developers has been used.

The presented technology developers offer different levels of information on their projects and this is the reason why there is not the same amount of information available for each design. In some cases media reports have been used to add information. Non-English language information, especially on the Japanese projects, has been translated and summarized.

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Input and updates to the report are welcome and much appreciated.

Cover Photo courtesy of Bernhard Braun, Cuxhaven (Germany).
Introduction

The Offshore Wind Resources in deep water, but also the currently experienced issues with conventional foundations, are driving the solution requirements for new offshore wind power platforms. The latest monitoring results of European offshore wind farms show the challenges the industry is facing. Ecological impacts as well as foundation technology issues are forcing the sector to look for alternatives. Another key factor is the still very high cost of offshore wind due to e.g. required installations vessels and short construction weather windows. The developers of floating foundation solutions therefore strongly believe that floating technology not only addresses the environmental and technology issues but also the cost issues, especially for water depths beyond 40 meters.

The major reason driving the development of this technology is however the requirement of floating technology is some of the world’s key markets:

- 61% of the US offshore wind resources are in water depths of more than 100 meters. (NREL)
- Nearly all of Japan’s offshore wind resources are in deep water. (NEDO)
- Various European locations such as off the coast of Norway and in the Mediterranean require floating foundation technology due to water depths.
- UK Round 3 contains some lease areas in water depths which may require floating technology.

Research regarding this technology has been ongoing for quite some time. The majority of the existing project teams and consortia have invested on average a minimum of 6 years of R&D efforts; in many cases more. While there are currently more than 25 different foundation projects underway around the world, the number of offshore wind turbine manufacturers that have joined these efforts is still limited though steadily growing. At this point Vestas, Siemens, Areva, Mitsubishi and Fuji Heavy Industries/Hitachi have supplied turbines for floating technology or are actively involved in a project team. Acciona, Alstom and Gamesa have joined projects as consortium members. Samsung of Korea are apparently also working on a floating foundation as well as turbine but so far have not officially released any details.

The active involvement of these major global players is another piece of evidence that floating offshore wind foundation technology has emerged from pure R&D status and is heading towards deployment of a number of pilot plants in Europe and Japan over the next 12-24 months. Full commercialization of those projects is expected by 2016 or 2017.
working group through representatives are South Korea (4 members in addition to the committee chair), Japan (11 members), United States (2 members), France (3 members), Germany (2 members), Norway (1 member), Great Britain (2 members), Spain (2 members) and South Africa (1 member).

The first draft of the technical specifications for floating foundations was planned to be submitted by December 2012.

In addition to the various project teams and consortia a number of governmental and non-governmental organizations issued requests for proposals for floating offshore wind over the past 12 months. ETI of the UK issued a request for proposal in October 2011 with the preference to receive proposals related to tension leg platforms (TLPs). It was followed by the Japanese government proposal for a floating offshore pilot wind farm off the coast of Fukushima which was awarded to a Japanese consortium under the leadership of Marubeni in March 2012. The Institute for Energy Research of Catalonia (IREC) in Spain launched the ZEFIR test area which will also be available to testing of floating foundations. 8 deep water testing sites will be available in 2015. The United States Department of Energy (DOE) issued an RFP for proposals in March 2012; topic area 2 included funding for floating foundation projects though only the initial stage funding is confirmed. Funding beyond phase II will still have to be confirmed by the U.S. Congress. The initially funded floating projects are University of Maine, Statoil Hywind Maine and Principle Power off the Oregon coast. The U.S. State of Maine created 3 designated test areas for deep water offshore wind foundation tests in state waters in 2010. One of these test zones will be used by the University of Maine in 2013 for testing of a scale model.
## Global Floating Offshore Wind Foundation Development

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<td>Next generation under development. Planned construction in 2015/2016</td>
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<td>Principle Power WindFloat</td>
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<td>Full Scale Pilot started operation in Oct 2011 (Portugal). Additional installations planned in EU and USA</td>
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<tr>
<td>Toda Construction et al. Hybrid Spar</td>
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<td>Spar</td>
<td>100m</td>
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<td>Full Scale Pilot with 2MW Hitachi/JSW turbine planned for mid 2013 (off Kessenuma Island, Japan)</td>
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<td>Japan Marine United Advanced Spar</td>
<td>Japan</td>
<td>Spar</td>
<td>50m</td>
<td>1:50 Scale Model Test complete</td>
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<tr>
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<tr>
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<td>DIWET Semisub</td>
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<td>Tank Tests Nov Dec 2012</td>
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<td>Tank Tests completed</td>
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<td>N/A</td>
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<td>Design for use with SWM turbine in Process</td>
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<tr>
<td>Shimizu Semisub</td>
<td>Japan</td>
<td>Semi Sub</td>
<td>25m</td>
<td>Simulation completed</td>
<td>N/A</td>
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<td>Spar</td>
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<td>Scale Model Test underway</td>
<td>N/A</td>
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<tr>
<td>Wind Lens Floater</td>
<td>Japan</td>
<td>Semi Sub</td>
<td>N/A</td>
<td>Scale Pilot Test started in Dec. 2011</td>
<td>N/A</td>
</tr>
<tr>
<td>WindSea Floater</td>
<td>Norway</td>
<td>Floater</td>
<td>25-30m</td>
<td>Tank Tests and Simulations completed</td>
<td>N/A</td>
</tr>
</tbody>
</table>

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Japanese Floating Projects

While Japan has some shallow water offshore wind resources, 80% of Japan’s offshore wind resources are in deep water. Japan therefore has more than 10 years of research on floating structures, including for offshore wind. Various designs have been developed to concept stage, including barge designs, semisubmersibles, spars as well as tension leg platform concepts. The majority of Japanese research has been government funded. Japanese industry was however reluctant to commercialize the various research; the reasons being the absence of Japanese government subsidies for offshore wind and a limited government focus on offshore wind due to strong opposition from the powerful and influential Japanese fishing industry. The Fukushima nuclear accident in March 2011 however changed the dynamics and floating offshore wind is getting a new ‘push’ in Japan, this time with the typical speed always seen in Japan after hitting a major crisis. In November 2011 a first scale model was launched in Hakata Bay in Kyushu. In June 2012 a 1:2 spar design was deployed off Kabashima Island inKyushu. A full scale spar with a 2MW turbine is planned for mid 2013. At the same time, Mitsubishi deployed their 2.4MW offshore turbine on a gravity foundation off Choshi at the entrance of Tokyo Bay and in Kyushu. 2013 will see phase I of the Fukushima floating pilot project with the installation of a floating substation and a semisubmersible foundation. The Fukushima project is largely Japanese government funded and will result in a wind park with 3 different floating technologies by 2015 and full commercialization by 2018. These projects will make Japan a global leader with regards to full scale floating pilot projects.
Japanese Floating Projects
（浮体式洋上風力発電）

On July 1st, 2012 the first Feed in Tariffs went into effect in Japan which include 23 Yen per kWh for onshore wind power with a 20 year power purchase agreement period. A Feed in tariff for offshore wind will be announced in Spring 2014. The budget set aside by the Japanese government for this project is Yen 12.5 Billion (approx. US $123 Million at May 2013 exchange rates). The total project cost is approx. Yen 18.8 Billion (US$ 189 Million). The objective is to lay the foundation for eventually building the world's largest floating offshore wind development and therefore developing power plant component technology for floating offshore wind off the coast of Fukushima Prefecture by conducting an experimental study of power systems to develop a common platform for floating offshore wind power. The Japan Wind Power Association estimates the offshore wind potential that can be realistically used at 608 GW.

Site Conditions:
- Water depth 100-200m
- Annual average wind speed: 7m / s at hub height
- Maximum significant wave height: 7-14m
- Distance offshore: ca. 20km
- Total capacity 15,000 kW or more than six turbines with per-unit output of 2,000 kW

Objectives:
(1) Preliminary survey of floating offshore wind farm
(2) Development of observation and prediction of weather conditions in target site area
(3) Development of systems for floating offshore wind power
(4) Development of transmission and transformation system for floating offshore wind farm
(5) Deployment and maintenance techniques for floating offshore wind farm

Fukushima Floating Offshore Wind Farm Demonstration Project FORWARD (Various Technologies)
http://www.marubeni.com

(6) Coexistence of fishing and navigational safety and environmental impact assessment
(7) Development of common standards and creation of a standard for floating offshore wind

On March 6th, 2012 the Japanese government awarded the project to a consortium of Japanese companies who will construct the floating offshore wind pilot farm off the Fukushima coast.

This research project will include a floating substation as well as different floating wind turbine generators. In phase 1 of this research project to begin in fiscal 2011, 1 floating offshore wind power generator with a 2MW down wind turbine, a 66kV sub-station and subsea cable will be installed in 2013. Phase 2 will be carried out from 2014 to 2015 and 2 floating wind platforms will be added with 7MW turbines.

Assignments per consortium member:
Marubeni Corporation (Project Team Leader): Business research, licensing, environment, fisheries
Tokyo University (Technical Advisor): Observation of floating body dynamics, development of simulation technology
Mitsubishi Corporation: Business research, licensing, environment, fisheries, such as O & M
Mitsubishi Heavy Industries, Ltd.: Floating offshore wind power generation facility
Japan Marine United: Floating offshore wind power generation facility and for floating sub-station
Mitsui Engineering & Shipbuilding Co., Ltd.: Floating offshore wind power generation facility
Nippon Steel Corporation: Steel Supply
**Japanese Projects**
*(浮体式洋上風力発電)*

Hitachi, Ltd.: Floating offshore substation  
Furukawa Electric Co., Ltd.: Subsea cable  
Shimizu Corporation: Construction technology  
Mizuho Information & Research Institute, Inc.: Project Management and Administration

Further details on the individual designs can be found in this report on the respective project pages.

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**Fukushima Floating Offshore Wind Farm Demonstration Project FORWARD**  
*(Various Technologies)*  
http://www.marubeni.com

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<th>Specification</th>
<th>Turbine Type</th>
<th>Floating Structure Type</th>
<th>Construction Phase</th>
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<td>25 MVA, 66kV</td>
<td>Substation</td>
<td>Advanced Spar</td>
<td>Phase 1 (Fall 2013 Installation)</td>
</tr>
<tr>
<td>Semisubmersible Platform</td>
<td>2MW</td>
<td>Downwind Turbine (Fuji/Hitachi)</td>
<td>4 Column Semisubmersible</td>
<td>Phase 1 (Fall 2013 Installation)</td>
</tr>
<tr>
<td>Semisubmersible Platform</td>
<td>7MW</td>
<td>Hydraulic Turbine (Mitsubishi)</td>
<td>3 Column Semisubmersible</td>
<td>Phase 2 (2014-2015)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Downwind Turbine</td>
<td></td>
</tr>
</tbody>
</table>
Japanese Projects

- Project by Kyushu University Division of Renewable Energy Dynamics
- Initial development of wind turbine with the project name ‘wind lens’.
- On December 4th, 2011 the University launched a 1 year test with a scale model of an 18 meter diameter floating platform with two 3kW turbines 600 meters from shore in Hakata Bay. The pilot also includes solar panels.
- Project will be tested and monitored for one year, financed by Japan’s Ministry of the Environment.
- The turbines have been successfully tested in e.g. desert conditions in China. The platform was tested in the university’s own wave tank.
- Stage 2 will be testing of a 80 meters diameter platform with TLP mooring 2km off the coast with 200kW turbine capacity. A date for the next scale pilot has not yet been published.
- The ultimate concept includes wave power in addition to wind and solar power generation.
Japanese Projects

Kabashima Island, Kyushu
(Spar)
http://www.kyoto-u.ac.jp/

Original Consortium Members:
Sasebo Heavy Industries (Shipbuilder), Toda Construction (Construction Company), Nippon Hume (Construction, incl. Piping), Kyoto University, J-Power

Consortium Members for June 2012 and 2013 Pilot:
Ministry of the Environment, Kyoto University Marine Development Co., Ltd., Fuji Heavy Industries Ltd. Co., Toda Construction, National Maritime Research Institute of Japan

Turbine is 100kw (downwind); installation of a 2MW turbine is planned for mid 2013 with the full scale pilot.

Turbine manufactured by Japan Steel Works and Hitachi

Average wind speed at location of 7.5m/s

Average wave height 1 meter

Water depth around 80-100 meters

Bottom of spar uses a ‘super hybrid’ concrete developed by Kyoto University and Toda Construction
Japanese Projects

Japan Marine United’s Advanced Spar was developed in co-operation with the University of Tokyo. According to available documentation, the design includes so-called ‘reduced vacillation fins’ to minimize impact from sway and heaves. The advanced spar will be used for both the floating substation at the Fukushima project as well as with a Mitsubishi’s 7MW wind turbine. The substation will be installed in Fall 2013.

Specs as per documents submitted to METI:

- Tower height 88.8 m
- Hub height 105 meter
- Rotor diameter 167 m
- Spar length 60 m
- Connection tower and foundation height 12 m
Japanese Projects

Mitsui Zosen
(Semisubmersible)
https://www.mes.co.jp

Mitsui Shipbuilding has been developing a number of technologies but focused in the past years on a TLP as well as a Semisubmersible. The semisubmersible will be part of Phase 1 of the Fukushima project and deployed with a 2MW turbine (Fall 2013). Compared to the Mitsui TLP, the company has not published much on this project and therefore only limited information is available.

Foundation Details:

Width 58 m
Total column length 32 m of which 16 will be submerged

Turbine Specs:

• Hub height 60 m
• Blade length ca. 40 m
• Rotor diameter ca. 80 m
• Cut out wind speed 25 m/s
• Cut in wind speed 13 m/s
• RPM 11.1 – 19.6
Japanese Projects

Mitsui Shipbuilding has been developing this TLP in co-operation with Tokyo University, Shimizu Corporation, Maritime Research Institute of Japan and Tokyo Electric Power Company. According to a Mitsui representative, a prototype is planned at some stage.

Mitsui TLP Model as shown at Tokyo Smart Energy Week in February 2013.
Japanese Projects

The SKWID was presented at the Tokyo Smart Energy Week in February 2013. The design is a combination of floating wind and wave generator for e.g. deployment near remote island communities. The company announced:

‘The omnidirectional turbine rotates regardless of the wind direction. Due to the location of the generator, the system has excellent stability with a low center of gravity, as well as excellent maintainability with easy access. The Darrieus’ rectangular swept area catches twice as much wind when compared to the circular swept area of typical onshore wind turbines of the same diameter. The split-cylinder-shaped buckets of the Savonius current turbine can harness any weak current and will rotate in one direction regardless of current direction. This turbine is insensitive to marine growth on the buckets and is harmless to the marine ecosystem, as it rotates slowly at the speed of the current. The floating current power generation part is developed under a joint development agreement with NEDO (New Energy and Industrial Technology Development Organization).

The float structure supports the power generation assembly via a set of rubber mounts like a gimbal to isolate the power generation assembly from the wave motion. The Savonius current turbine acts as a ballast, making the power generation assembly self-righting.’

A demonstration prototype, now under construction, will undergo test runs off Saga Prefecture, western Japan, in late summer 2013:

Turbine tower height 47m
Structure height below water 16m
Turbine capacity 500kW.

Grid connection to Kyushu Denryoku is planned for 2014.
Japanese Projects

Mitsubishi Heavy Industries
(Semisubmersible)
http://www.mhi.co.jp

Mitsubishi worked on several projects over the past years. A semisubmersible will be deployed in 2014/2015 as part of the Fukushima floating offshore wind demonstration project, utilizing Mitsubishi’s 7MW hydraulic turbine.

Turbine Data:
• Hub height 105 m
• Rotor diameter 167 m
• Cut in wind speed 15 m/s
• Cut out wind speed 21 m/s
• RPM 10.3

Foundation Specs:
• Tower height ca. 105 m
• Displacement ca. 26,000 t
• Column diameter 14 m

Image Sources: Mitsubishi Heavy Industries and METI
Japanese Projects

The Hitachi project was started in 2004 by Hitachi’s shipbuilding division. Due to company restructuring the project was canceled and stopped in 2010. In December 2011 Hitachi Zosen announced that they would restart the development. The key development team members are however no longer with the company as Hitachi canceled the development in 2010. Some team members have joined other projects.

Hitachi was included as a consortium partner in the March 2012 Fukushima consortium announcement. However, Hitachi’s role as part of this project is related to the floating substation by providing the substation’s electrical equipment to be used with Japan Marine United’s floating spar. Hitachi had worked on a floater.

On September 4th, 2012 Nikkei Shimbun, Japan’s most important business newspaper, published an article, stating that Hitachi together with other companies such as Toshiba plans to construct 120 billion Yen ($1.5 billion) of offshore wind power in Japan. The seven-member group will complete 7.5 megawatts of pilot plants by 2016 before building the wind farms with a combined capacity of 300 megawatts over 10 years. Hitachi will supply the floating foundation while Toshiba will be in charge of turbine equipment. Toshiba recently purchased 34% of Korean turbine maker Unison, becoming its largest shareholder. A location for the proposed wind farm has yet to be announced.

In November 2012 Hitachi Zozen and Norway’s Statoil entered into a cooperation agreement re. the development of floating offshore wind technology. What this agreement entails is not known. In an interview with Bloomberg in March 4th, 2013 Hitachi advised: ‘We are looking at how we can bring technology cultivated in Norway to Japan. It won’t be that difficult. Both partners want to reduce time to bring the floating offshore technology to reality as much as possible.’

It can therefore be assumed that Hitachi will pursue a floating spar design and is less likely to continue work on the floater.
Japanese Projects

The National Maritime Research Institute of Japan is an independent research institute, funded by the Japanese Government as well as by conducting commissioned research for private entities.

Focus are shipbuilding technology, marine safety and marine environment. The institute has conducted substantial research with regards to floating marine structures, including for offshore wind.

The institute has its own deep water wind and wave tank for testing.

- Initially the concept was for a floating barge/girder.
- Computer simulations showed a number of issues with this approach, especially regarding costs.
- A second approach, a floating spar design, had been worked on as well and is now the main focus.
- Tank tests have been done; next steps are blade design as well as specific pitch and yaw development.

A patent application has been filed. NMRI is also involved in the Kabashima Island Spar project.
Japanese Projects

Shimizu Corporation has been jointly working with the University of Tokyo, Tokyo Electric Power Company and Penta Ocean Construction Co. Ltd. on the design of a floating platform.

Shimizu’s internal Institute of Technology has done numerous research re. offshore wind, including impact of wind and waves on structural integrity.

A development timeline of this project is not known.

Shimizu is part of the Fukushima consortium, in charge of construction technology.

The leading academic advisor is Prof. Ishihara at Tokyo University.

http://windeng.t.u-tokyo.ac.jp/ishihara/

Detailed prototype tests and realization plans are not known at this point. It is however assumed that the project is still ongoing. As a member of the Fukushima consortium, Shimizu Corporation has the opportunity to apply lessons learned from the Fukushima project to their own development.
European Projects

Europe has significant offshore wind resources in water depths of 50m+. Utilization of these resources will require floating foundations. It is not surprising that the European technology developments are therefore led by countries with the highest deep water offshore potential.

European deep water offshore floating platforms were originally dominated by Norwegian developers. Other companies such as Blue H from the Netherlands, Nass et Wind of France, GICON of Germany and et.al. also started the development because they are also aware of the global market conditions. Key drivers for the growing European interest in floating foundations appear to be the cost of installing bottom foundations, the current issues (e.g. pile driving noise, scouring etc.), the need for the technology for some of the UK Round 3 projects (at 40 meters water depth) and the demand for improved manufacturing efficiency.

European turbine OEMs such as Siemens, Vestas, Alstom, Gamesa, Acciona and Areva are now actively involved in various European floating projects. One of the key markets for floating foundation technology is going to be the UK as Round 3 and other future offshore leases will have water depths requiring floating technology. Various UK organizations are therefore supporting technology development: ETI is funding finalization of a TLP design by Glosten Associates. In late 2011 ETI announced plans to invest up to £25m in an offshore wind floating system demonstration project. This project will see the design, construction and installation of a floating system demonstrator by 2016 at a relatively near shore site with high wind speeds up to about 10 meters per second in water between 60 and 100 meters deep. It will be operated for at least two years to show it can generate high levels of electricity, be maintained without using specially designed vessels and to verify the predicted technical and economic performance. The intention is that it would be operated for another eight years to allow further developments to take place. Project will be in three stages:

• Stage 1 involves a competitive front end engineering study –2012/13
• Stage 2 will involve final design, procurement, build and installation of a single system –2013 – 2015/16
• Stage 3 will involves ongoing operation of the demonstrator for several years –Gather data, additional studies, etc. –2015/16 onwards

ETI has selected 2 out of 15 proposals for stage 1 and is working with stakeholders to find a test site with sufficient water depth that will be available by summer 2015. At the end of 2013 ETI will decide which of the two proposals to take to the next stage. In the past ETI also funded part of Blue H’s pilot in 2009/2010.

The UK Department of Energy and Climate Change has announced funding for further advancement of Principle Power’s semisubmersible design.

Scotland’s energy minister will make £15 million available for deep-water wind energy development, including foundation technology. As part of this the UK Crown Estate plans to develop a demonstration wind project in water depth of about 100 meters off

General Background

Source: HiPR Wind
European Projects

Scotland’s west coast.

Another European hub for floating offshore development is Spain where Iberdrola is leading the development of a floating foundation to be used with a 2MW as well as 5MW turbine.

France is gaining traction with 3 floating foundation technologies: a project started by Technip, a foundation project by Nass et Wind and the Ideol floater planned for testing in the Mediterranean.

However, it is fair to say that all projects have representation from various European countries on the project teams and in some cases technology as well as R&D support from across the Atlantic. Glosten Associated and Principle Power are both US companies but are successfully pursuing the European market. Principle Power launched their pilot project off the coast of Portugal in 2011. The U.S. National Renewable Energy Laboratory (NREL) has been the lead research institution for floating foundation technology and is also actively involved in European floating offshore projects due to its expertise.

Except Statoil’s Hywind and Technip’s Vertiwind projects, most European projects were started by medium size companies, investing own capital in the R&D and some government funding. These medium size companies have started to market their technology on a global basis and some are successfully finding investors who provide the necessary funds for prototype construction. Access to capital for demonstration prototype funding is going to be the decisive factor when it comes to the question who among all the developers will actually achieve the commercialization stage.
European Projects

Statoil Hywind, Norway
(Spar)

http://www.statoil.com

The 2.3MW Hywind spar was installed off Karmøy, Norway, in south-east Norway in September 2009. Statoil invested about NKr340m ($53.4m) in the project, with Norwegian technology development fund Enova stumping up NKr59m.

The 5,300 tons unit is a floating structure made up of a steel ‘spar’ ballast of water and rocks that extends 100 meters below the water-level and is anchored to the seabed by a three-point mooring spread.

The turbine was developed and manufactured in Denmark by Siemens Wind Power, while France’s Technip built the floater and compatriot Nexans produced and laid the power cable to land.

The Hywind spar in Norway has a capacity factor of over 40%, according to Statoil. In 2011 Hywind generated 10.1 GWh of electricity which is equal to a capacity factor of 50%. In 2012 the output is a lot lower due to local grid issues.

Potential Additional Test Locations:
- Norway
- Scotland
- Maine (USA) – Lease Application filed

In November 2012 Statoil signed a co-operation agreement with Hitachi in Japan.
Sway AS is renewable energy company engaged in innovative wind energy design, in particular for off-shore installations. In addition to carrying the 10MW turbine under development by Sway, the floating tower is also capable of carrying commercially available offshore wind turbines in the 5MW class. Sway has therefore entered into a partnership with Areva-Multibrid for the adaptation of their 5MW turbine to the floating Sway tower. SWAY's floater technology allows economical extraction of wind power in regions with good wind resources and access to water depths of 80-400m within 50-60km from the coast.

**Partners:**
Statoil, Statkraft, Shell Technology Norway (STN), Lyse, The Research Council of Norway, Inocean

**Current Status:**
A 1/6 scale model that was tested in real life conditions in Hjeltefjorden outside Bergen starting in June 2011 sank in November 2011 due to wave conditions too severe for a scale model. Water entered the J-Tube for the cable connection which caused the system to tilt. Wave and storm surge then increased the water level on the turbine. Data collected by NREL showed wave heights of 6.3 meters.

A new 1/6 scale model was launched in May 2012.

In addition, a “shallow water” Sway version with a shorter and wider tower has been adapted to 55m water depth for installations in the UK and China. For larger water depths the traditional tension leg is used between the tower and the seabed anchor.

In February 2013 Sway announced that together with NREL and other partners, the testing of the prototype was resumed. Operation and yawing and of the turbine are main test tasks for this round of tests.
European Projects

Poseidon utilizes and absorbs the inherent energy from the waves, thereby reducing the height of the waves significantly and creating calm waters behind the front of the plant making the platform easy accessible e.g. for maintenance purposes. Poseidon opens up the possibility for the wind industry to capture the wind energy within deep water environments, by utilizing a floating platform as foundation for wind turbines. The wind turbine itself will be standard offshore wind turbines.

Test Phase 1, conducted 2008/09, had the purpose to document platform stability including the impact of the moving wave absorption floaters on overall platform stability. The test was successful and DTU/Risoe and DHI “green lighted” the installation of wind turbines on the platform.

Test Phase 2, conducted 2009/10, had the purpose to document power to the grid from wind turbines on the floating structure and to document the efficiency of the wave energy absorption floaters expressed as hydrodynamic efficiency to provide background data for the engineering of the final Power Take Off system (PTO).

Test Phase 3, started September 2012 at the test site off Onsevig Harbor, at the north coast of Lolland, Denmark, had the purpose to jointly produce power to the grid – from the wind turbines and the wave absorption floaters. The wave absorption floaters are equipped with a new PTO system designed in cooperation with Siemens Industry, Fritz Schur Energy, Contech and others. The PTO system is a closed hydraulic system, where each floater is an independent energy producing unit. Each float and adjacent PTO system operates at power levels enabling the use of standard power generation components and the “unit” is detachable from the platform to allow for easy towing and in-harbor service.

During September 2012, the platform was re-equipped with wind turbines and the new power module installed. Everything was tested while Poseidon was still in the harbor – one of the beauties for the concept. Once all components and control systems were tested, Poseidon was towed back to its original position at sea at the Onsevig test site to enjoy the Danish energetic autumn storms.

Weight (unballasted): 280 t
Length: 25 m
Width: 37 m
Height (excl. turbines): 6 m
Turbine hub height: 12 m
Draft (avg.): 4.5 m
European Projects

Blue H, Netherlands
(TLP)
http://www.bluehgroup.com/

Phase I:
Prototype Test in Dec. 2007 off the coast of Italy. 2008: Test of 75% size model in deep water (371 ft./113 meter) off the coast of Italy (11.5 miles / 21.3km from shore). After 6 months at sea, the unit was decommissioned early in 2009.

Phase II:
In 2008, Blue H started engineering its second proof of concept, a tension leg platform for a 2 MW floating wind turbine.

Latest Update:
- Proof of the innovation “self installing TLP” and its qualification (QTR).
- Document wave tank scale testing, and design verification
- Design and engineer, manufacture, install and test the full scale 5 MW Demonstrator (2014 and 2015)
- Commercial business (2016 onwards)

Phase 1
European Projects

Winflo, France
(Floater)

http://www.nass-et-wind.com/

Winflo is a French multi-megawatt floating wind turbine technology development project. Coordinated by Nass&Wind, a major player in French wind sector, in close partnership with DCNS, an international industrial player in ship building and marine renewables, and Vergnet, experienced in turbine engineering and manufacturing for harsh environments, the consortium also benefits from the experience of two renowned scientific partners:

IFREMER (Sea Research Institute) and the university ENSTA-Bretagne

Latest update:

In April 2013 Nass et Wind announced the completion of the demonstrator design phase. A full scale prototype will be built in 2013 and deployed in 2014 off Le Croisic on the Brittany peninsula. It will be France’s first floating wind turbine. The water depth at this site is 35m. Although a 2-3MW turbine had been planned for the launch, the demonstrator will use a 1MW two-bladed turbine which is an adapted version of Vergnet’s 1MW Onshore GEV-HP model.

The components will be assembled at Brest in Spring 2014 and then towed to the site for 12-18 months offshore testing. The total budget for the demonstrator is ca. € 40 million.

After successful testing the design will be scaled up for use with a larger turbine; the goal is use with a 5MW turbine which will be deployed near the island of Groix.
GICON®, SOF, Germany
(TLP)
http://www.gicon.de/

European Projects

GICON, with 300 employees one of Germany’s largest privately owned engineering companies, is developing the GICON-SOF (‘Schwimmendes Offshore Fundament’ or ‘Floating Offshore Foundation’). Using the TLP approach, the GICON-SOF can also be deployed in shallow water depths and is therefore a viable alternative to conventional foundations as well as a suitable technology for deep water offshore wind parks.

Key Facts:
- Deployable in water depths of >20 meters to 700 meters
- Various mooring technology options for different ocean floor conditions
- Low system accelerations and displacements
- Modular design for cost efficient manufacturing

Tank Tests surpass Expectations:
In February 2012, GICON tested the SOF at the Hamburg Ship Model Basin HSVA. A 1:25 scale model was exposed to various conditions, simulating operational and transport conditions. The tests included the equivalent of a 20 meter ‘rogue wave’ which the structure weathered without any problems.

Video impressions of the tank tests are available at http://www.gicon.de/en/sof

Final wind and wave tank tests are planned for June 2013.

A full scale pilot is planned for construction in the German Baltic Sea in 2014.
**European Projects**

Technip, in association with Nénuphar, Converteam and EDF Energies nouvelles launched the Vertiwind project to test a pre-industrial prototype of a vertical-axis offshore floating wind turbine. The partners of the project are Seal Engineering, ISITV, IFP Energies nouvelles, Arts et Métiers, Bureau Veritas, Oceanide. Technip is responsible for the design of the floater, mooring system, dynamic electrical connection cable, turbine integration as well as on-site installation.

Technip is a major player in floating offshore wind turbines after the successful design, fabrication and installation of Hywind, the first industrial size floating wind turbine, for Statoil in Norway. Technip is also a member of the Maine (USA) DeepCwind Consortium, lead by the University of Maine.

In 2009 Technip tested together with Nénuphar a 35kW horizontal axis turbine as part of a 1/10 scale test.

A full scale 2MW prototype is planned for deployment in France for 2013/2014.

Demonstrator location: 5km off the city of Fos-sur-Mer (French Mediterranean)
Water depth: 50m
Max wind speed: 43m/s
Max wave Heights: 7m

Turbine Type: 2MW vertical Darrieus type with three 70m tall blades, angled at 120 degrees. Total height of 100m. Omnidirectional without yaw or pitch system.

The next project phase will be part of the EU co-funded INFLOW (INdustrialization setup of a FLoating Offshore Wind turbine) project with the target to install an improved 2MW turbine.

The ultimate goal is a 25MW wind farm under the EU NER300 umbrella. The INFLOW consortium consists of Technip (France), DTU Wind Energy (Denmark), Alstom Hydro España (Spain), Nénuphar (France), Fraunhofer IWES (Germany), DUCO (United Kingdom), EDF Energies Nouvelles (France), Vicinay Cadenas S.A. (Spain), Vryhof Anchors NV (Netherlands), Eiffage Construction Métallique (France)
European Projects

IDEOL, France
(Floater)

http://www.ideol-offshore.com

IDEOL is working with industry partners to launch a test platform with a 2MW Gamesa turbine and a 3MW Acciona turbine by 2015. The demonstrator, based on a patented damping pool system, is being developed in partnership with Gamesa and Stuttgart University. In April 2013 IDEOL announced that they have secured €7m in a second funding round for their 2MW prototype. Other investors are DEMETER PARTNERS, SOFIMAC PARTNERS and SORIDEC.

The IDEOL platform is a ring-shape surface floater with a shallow draught and compact dimensions. The design will use concrete as one of the major materials. Basin test campaigns have been performed with a wide range of wave, wind and current conditions, with waves up to 25m height and wind up to 90 km/h, representative of the most severe operating conditions.

<table>
<thead>
<tr>
<th></th>
<th>Motion average sea conditions in standby</th>
<th>Maximum motion in operation Mediterranean</th>
<th>Maximum motion in operation Central North Sea</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wind</td>
<td>Wind speeds from 5 to 25m/s at hub height</td>
<td>Normal turbulence</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Wind and waves aligned or not (up to 90° misalignment)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Wave</td>
<td>Hs=2m</td>
<td>Hs=4m</td>
<td>Hs=6.3m</td>
</tr>
<tr>
<td></td>
<td>Range of periods from 3s to 15s</td>
<td></td>
<td></td>
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<tr>
<td>Heave</td>
<td>2.3m</td>
<td>3.7m</td>
<td>6.0m</td>
</tr>
<tr>
<td>Maximum tilt</td>
<td>0.7deg</td>
<td>1.6deg</td>
<td>1.5deg</td>
</tr>
<tr>
<td>Maximum list</td>
<td>2.5deg</td>
<td>3.5deg</td>
<td>4.3deg</td>
</tr>
</tbody>
</table>
European Projects

Iberdrola is developing two TLP variants to be used with a 2MW and 5MW turbine. Turbine OEM partners are Acciona and Alstom. The 5MW project is part of the Ocean Lider consortium which received €15million EU funding in addition to the €30 million project budget. The overall project includes R&D related to grid connection, monitoring etc. as well.

In November 2012 Iberdrola conducted tank tests with both designs at Madrid’s CEHIPAR center. Two different designs of floating foundations for wind turbines of 2 MW and 5 MW with a scale of 1/35 and 1/40, respectively. as well as two innovative installation systems for these offshore structures, consisting of a barge / pontoon and float mechanism were tested. The results confirmed the ambitious targets set for these projects, including performance in wave conditions of up to 31 meters height.

Iberdrola floating Turbine Specs:

<table>
<thead>
<tr>
<th></th>
<th>TLP 2MW</th>
<th>TLP 5MW</th>
</tr>
</thead>
<tbody>
<tr>
<td>Water Depths (m) / Hs / Hmax</td>
<td>100 / 10.3 / 20</td>
<td>80 / 15 / 31</td>
</tr>
<tr>
<td>Wind Turbine Type</td>
<td>G-8x2MW</td>
<td>NREL 5MW</td>
</tr>
<tr>
<td>No. of Pontoons</td>
<td>4</td>
<td>4</td>
</tr>
<tr>
<td>No. of Mooring Lines per Pontoon</td>
<td>2</td>
<td>2</td>
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<tr>
<td>Operational Draft (m)</td>
<td>24</td>
<td>39.8</td>
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<tr>
<td>Span / Beam (m)</td>
<td>35</td>
<td>64</td>
</tr>
<tr>
<td>Displacement (ton)</td>
<td>2,534</td>
<td>4,333</td>
</tr>
<tr>
<td>TLP Steel Weight (ton)</td>
<td>750</td>
<td>1,053</td>
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<tr>
<td>Mooring Line Material</td>
<td>Steel</td>
<td>Steel</td>
</tr>
<tr>
<td>Mooring Line Foundation</td>
<td>Suction piles</td>
<td>Suction piles</td>
</tr>
<tr>
<td>Surge mean (oper./survival in m)</td>
<td>(2.3 / 4)</td>
<td>(0.4 / &lt;8)</td>
</tr>
</tbody>
</table>

Iberdrola sees UK Round 4 as one of the key target markets for this technology.
European Projects

HiPR Wind, Spain
(Semisubmersible)
http://www.hyperwind.eu/

High Power, High Reliability Offshore Wind Technology (HiPRWind – read “Hyperwind”) is a new cross-sectorial approach to future wind energy technology. This 5-year project aims to unlock vast new deep-water areas for wind farms by enabling research on very large, floating offshore wind turbines.

Key Project Details:

Project start date: November 1, 2010.
End date: October 31, 2015
Total budget 20 million €, total EU-funding 11 M€
Objective: install and operate a floating MW-class wind turbine for research purpose
Location: BIMEP, off Bilbao, Spain

Foundation Type: Semisubmersible platform
Column distance 35m
Water depth 80m
Steel weight <1000t
Mooring lines: 3
Heave period ~20sec

Turbine Specs: Acciona AW1500: 1.5 MW
DFIG & Gearbox, Hydraulic pitch system
Rotor diameter 77m, Hub height 60m above SWL

Location for 1/10 scale prototype to be installed with 1.5MW turbine (scheduled for mid 2013)
European Projects

Daniel Ehrnberg, founder of Sea Twirl, got the idea during experimental testing at the University of Gothenburg of using water to rotate large wind turbines as well as energy storage. To test the idea he built several prototypes which all have validated the technique with excellent results.

A company was formed in 2010 to drive development forward. The focus was on theoretical calculations, development and to establish partnerships in order to build a third prototype. SeaTwirl prototype III was constructed and tested on the west coast of Sweden (2011). In August 2011 the company built and tested a larger prototype in 1:50 scale. The prototype was successfully tested in rough sea with wind up to 25 m/s and waves between 2 and 3 meters. In parallel, theoretical work and tests in 1:500 scale were conducted as well as more extensive economical evaluations.

The company and experts are now analyzing the successful tests and will form further co-operations for the future development.

SeaTwirl uses a vertical axis wind turbine and a torus ring to enable storage capability. SeaTwirl rotates from the top all the way down to the generator, seen as the blue part below in figure 2, in direct contact to the water. The only thing that is not rotating is the anchorage system and the generator axis at the bottom of the picture. In this way the ocean water is used as a roller-bearing and the weight of the rotating turbine is absorbed by the water. This arrangement also means that there is no need for transmission line, gearbox and that the weight from the generator is placed where it should be, in the bottom.

No next phase prototypes have been announced at this stage.

A large unit could be built with the following specifications:
Rated power: 10 MW, Mean power: 4.5 MW
Yearly production: 39 000 MWh,
Sweep area: 24,000 m2.
Energy storage: 25 000 kWh, could support 8000 households during 1 hour.
Height from water level: 210 m, Depth from water level: 228 m
European Projects

WindSea, Norway
(Semisubmersible)
http://www.windsea.no/

Consortium Members:

NLI (owner and leader): Engineering company focusing on products for the oil and gas industry. Engineering and fabrication, design, turret, mooring lines, fabrication and costs.


Riso DTU: National laboratory for Sustainable Energy (Denmark). Wake calculation.

SeMar: Engineering and consulting. Mooring Lines.

Scana Industrier ASA: Solutions provider. Turret Design.

Moog Inc.: Design, manufacture and integrator of precision motion control systems. Electrical swivel design.

Project Milestones:

• 2005 – First ideas
• 2006 – Initial concept work
• 2007 – Focus on floating technology; establish project team/consortium
• 2008 – Establishment of WindSea AS
• 2009 – Norwegian government funding (US$ 830k)
• 2010 – Patent granted in Norway

Decision to find new partners for further development and commercialization

Actual pilot plant plans not known.

Key Technical Data:

Characteristics:

Semisubmersible platform with 3 columns

Three turbines

The platform is self orientating towards wind

Mooring lines connect to a detachable turret

Cable for power transmission is guided through the turret to the seabed

Dimensions:

Height upwind turbines above sea level: 71 m

Height downwind turbines above sea level: 90 m

Distance between upwind turbines: 103 m

Turbine power: 3,6MW each, total 10,8 MW - rotor diameter: 104 m

Vessel draft: 23m (operation) 7m (at yard)

Weight without turbines: 3,780 tons
European Projects

The Trifloater is a GustoMSC development which was initially developed during a study with ECN, TNO, Delft University of Technology, Marin and Lagerwey. Currently the concept is being further developed with ECN and Marin, financially supported by the Dutch government.

- Consortium of GustoMSC, ECN, TNO, Delft University of Technology, Marin and Lagerwey
- Development started in 2002
- Designed for 50 meter+ water depth and North Sea conditions
- 6 line catenary mooring system
- Flexible export cable
- Latest design for use with 5MW turbine
- May 2011 Tank Test at Marin (Netherlands)

In November 2012 Gusto was acquired by Parcom Capital. What these means for Gusto’s floating development is not known.
European Projects

Pelagic Power, Norway
(Floater)
http://www.pelagicpower.no/

W2Power is designed from first principles as a true hybrid wind & wave energy conversion plant. Two corners of the triangle support one wind turbine each, and the third corner houses the wave energy power take-off using a Pelton turbine, standard in hydro-power applications, driven by three lines of wave-actuated hydraulic pumps mounted on the platform’s sides.

Accommodating two 3.6 MW standard offshore wind turbines such as the Siemens 3.6-107 (107 m rotor diameter, hub height 80-85 m), the Shanghai Electric, or the previous GE 3.6 SL, the platform will be rated at more than 10 MW total in areas with a strong wave climate.

Since its first announcement at All-Energy 2009, the W2Power technology has entered into the validation and engineering stage. Working with leading R&D and industry development partners in a concerted effort, Pelagic Power AS intends to make the new solution be available for wind farm developers when deep-water markets are expected to be opened by 2015.

Project Partners:

Fraunhofer IWS, TWI,(acciona energy)
European Projects

Ocean Breeze is a "floating" deeper water wind turbine foundation system designed for low cost series production using pre fabrication assembly line methods.

<table>
<thead>
<tr>
<th>SPECIFICATION</th>
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<tbody>
<tr>
<td>Nacelle Height (m)</td>
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<tr>
<td>Rotor Diameter (m)</td>
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<td>Water Depth (m)</td>
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<tr>
<td>Wave Height (m)</td>
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<table>
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<th>FLOATING STRUCTURE</th>
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<td>Steel Weight (tons)</td>
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<td>Overall Diameter (m)</td>
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<td>Tower Height above MSL (m)</td>
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<td>Operating Draft (m)</td>
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<td>Buoyant Chamber (m)</td>
<td>4 units at 8m</td>
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<table>
<thead>
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<th>GRAVITY BASE STRUCTURE</th>
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<td>Overall dimensions (m)</td>
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<td>Weight (tons)</td>
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<th>TETHER SYSTEM</th>
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<tbody>
<tr>
<td>Each Outrigger</td>
<td>Multiple galvanized wire ropes</td>
</tr>
<tr>
<td>UBS</td>
<td>1,200 tons per tether assembly</td>
</tr>
</tbody>
</table>

Xanthus Energy Ocean Breeze, UK
(TLP)

http://www.xanthusenergy.com
European Projects

Hexicon, Sweden
(Floater)
http://www.hexicon.eu/

Hexicon is a Swedish design and engineering company developing floating platforms for offshore wind energy production. The Hexicon concept is supported by the governments of Sweden, Malta and Cyprus under the EU investment program for renewable energy NER300.

Compared to an earlier design, Hexicon has redimensioned the unit.

Previously published specs - Model A480:
(Based on horizontal 6,5 MW turbines)
Hexagon diameter:  480 m
Depth molded:       26 m
Full load draught (without azipods): Appr. 18 m
Light ship displacement draught:       Appr. 10 m
Air draught (above DWL):              Appr. 180 m
Light platform/ship displacement:      Appr. 18.000 t
Crew (24/7/365):                 8 x 2
Horizontal Turbines       6 x 6,5 MW
Vertical Turbines          30 x 0,5 MW

Latest Specs:
Platform length:       abt. 700 m
Platform width:        abt. 500 m
Full load draught:     abt. 15 - 20 m
Height over all (incl. turbine blades): abt. 220 m
Lower hub height:      71 m
Upper hub height:      170 m
Light platform displacement: abt. 35 000 t
European Projects

Far Eastern Federal University, School of Engineering is developing a wind turbine concept, the Wind Energy Marine Unit (WEMU). The WEMU turbine features a large-scale (more than 100 m in diameter) ring floating rotor. The WEMU turbine is expected to be capable of reaching multi-MW (>20 MW) with a single unit in deep waters. The research project has been under development for more than 15 years. Comprehensive calculations are complete and a demonstration plant can be built.

WEMU SPECIFICATION

On the basis of research results and preliminary estimations the WEMU specification (shallow- and deep water versions) can be listed in brief as follows:

Diameter, m 50 ~ 300
Blade span, m 20 ~ 60
Depth of installation site, m 5 ~ 700
Range of wind speed, m/s 3 ~ 40
Rated wind speed, m/s 10 ~ 25
Tip speed ratio 0.7 ~ 0.8
Rated power capacity, MW 0.5 ~ 50
Aerodynamic efficiency, % 49 ~ 50
Relative hydrodynamic power loss, % 5 ~ 7
Relative pitch control power loss, % 1.5 ~ 2
US Projects

The U.S. Government plans to achieve 20% wind energy by 2030; a target that includes offshore wind energy. However, 61% of the US wind resources are in deep water. That is one reason why the U.S. government as well as the private sector started to look at floating foundation technology. The National Renewable Energy Laboratory, a U.S. Government Organization, has and continues to play a major role in this area. For more than 35 years the National Renewable Energy Laboratory (NREL) has been the only U.S. national laboratory solely dedicated to advancing renewable energy and energy efficiency technologies from concept to commercial application. NREL is also a research partner of various floating projects, such as in the case of Sway and others.

Floating wind technology plays a major role in achieving the national target, as highlighted in NREL’s report of July 2008 (20% Wind Energy by 2030—Increasing Wind Energy’s Contribution to U.S. Electricity Supply; DOE/GO-102008-2567 • July 2008) Apart from the requirements set by large parts of the U.S. outer continental shelf, NREL also believes that long term, floating technology can significantly reduce the cost of offshore wind power. This is due to e.g. savings made in the area of highly specialized installation vessels which are required for the deployment of conventional foundations that would not be required for floating technology.

The majority of the US population lives on the coasts. Offshore wind therefore makes a lot of sense in these areas as the generation would be relatively close to the load centers. However, all offshore wind resources in Northern New England, the U.S. West Coast and Hawaii are in water depths beyond 60 meters. Conventional foundations are therefore not applicable in those areas.

General Background

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Source: NREL
US Projects

The U.S. Department of Energy plays a key role in the R&D efforts related to offshore wind in general and continues to also place a focus on floating foundation technology. In December 2012, the Department announced funding to seven Advanced Technology Demonstration projects totaling $168 million over six years. The primary goals of these projects are to achieve large cost reductions over existing offshore wind technologies and develop viable and reliable options for the United States. Each project will receive up to $4 million to complete the engineering, site evaluation, and planning phase of their project. Upon completion of this phase, the DOE Wind Program will select up to three of these projects to advance the follow-on design, fabrication, and deployment phases to achieve commercial operation by 2017. These projects will be eligible for up to $47 million over four years, subject to congressional appropriations.

Of the 7 projects a total of 3 involve floating foundation technology:

- Statoil North America of Stamford, Connecticut plans to deploy four 3-megawatt wind turbines on floating spar buoy structures in the Gulf of Maine off Boothbay Harbor at a water depth of approximately 460 feet. These spar buoys will be assembled in harbor to reduce installation costs and then towed to the installation site to access the Gulf of Maine's extensive deep water offshore wind resources.

- The University of Maine plans to install a pilot floating offshore wind farm with two 6-megawatt direct-drive turbines on concrete semi-submersible foundations near Monhegan Island. These concrete foundations could result in improvements in commercial-scale production and provide offshore wind projects with a cost-effective alternative to traditional steel foundations.

- Seattle, Washington-based Principle Power plans to install five semi-submersible floating foundations outfitted with 6-megawatt direct-drive offshore wind turbines. The project will be sited in deep water 10 to 15 miles from Coos Bay, Oregon. Principle Power's semi-submersible foundations will be assembled near the project site in Oregon, helping to reduce installation costs.

These projects are part of the U.S. National Offshore Wind Strategy.
US Projects

Principle Power, based in Seattle, WA, is a technology developer focused on the intermediate and deep-water depth (greater than 40 meters) offshore wind energy market. Principle Power’s enabling product, a floating wind turbine foundation called WindFloat, provides for siting of offshore wind turbines independent of water depth, thus exploiting the world's highest capacity wind resources.

The WindFloat is fitted with patented water entrapment (heave) plates at the base of each column. The plates improve 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, Wind Float’s closed-loop hull trim system mitigates mean wind-induced thrust forces. This secondary system ensures optimal energy conversion efficiency following changes in wind velocity and direction. The design of the WindFloat enables the structure to be fully assembled onshore and towed to its final location. The mooring system employs conventional components such as chain and polyester lines to minimize cost and complexity. Through the use of pre-laid drag embedded anchors, site preparation and impact is minimized.

Specifications:
- Power rating: ≈ 3.0-10MW
- Rotor diameter: ≈ 120-170m
- Turbine hub height: ≈ 80-90 m
- Turbine nacelle weight: ≈ 225-315 tons
- Tower weight: ≈ 180-315 tons
- Hull Draft: ≈ 20 m
- Operational Water Depth: > 50 m
- Conventional mooring components (4 lines)

In February 2011 Principle Power, EDP, InovCapital, Vestas and Partners signed an Agreement for Deployment of First Full-scale 2MW WindFloat off the coast of Portugal. The full scale pilot was launched into the water in October 2011 and has been successfully operating, using a Vestas 2MW turbine. Principle Power is currently also developing further projects in Europe as well as off the Oregon coast. EDP as the majority owner in the company provides significant funding. In addition Principle Power has received further development funding from the U.S. Department of Energy and the UK’s Department of Energy and Climate Change. Siemens will provide the turbines for the Oregon project.
US Projects

The DeepCwind Consortium under the leadership of the University of Maine is one of the key players in the US deep-water offshore wind technology research. The initiative has been funded by the U.S. Department of Energy, the National Science Foundation, and others. The consortium includes universities, nonprofits, and utilities; a wide range of industry leaders in offshore design, offshore construction, and marine structures manufacturing; firms with expertise in wind project siting, environmental analysis, environmental law, composites materials to assist in corrosion-resistant material design and selection, and energy investment; and industry organizations to assist with education and tech transfer activities.

In May 2011 the University of Maine team conducted extensive tank tests of different floating foundation models at the Marin Wind and Wave Test Basin in the Netherlands. Based on these tank tests a design was selected for a 1/8 scale pilot test in the Gulf of Maine, starting in June 2013. The unit will be deployed in a designated test zone in State of Maine waters, off Monhegan Island. It uses a concrete hull and a composite tower with a 20kW turbine. The approximately 65-foot-tall turbine prototype is 1:8th the scale of a 6-megawatt (MW), 423-foot rotor diameter design and will be grid connected. 2 full scale 6MW floating turbines are planned for deployment in 2016.
US Projects

The Glosten PelaStar by engineering firm Glosten Associates of Seattle, WA was developed, starting in 2006.

Key Features:

- Stable, minimal-motion platform suitable for current and future turbine designs
- Complete quayside assembly, enabling economical wind farm developments in distant, deep offshore and previously “undevelopable” areas
- Deep water capacity and cost-competitive with bottom-fixed turbine foundations in water depths 60 meters and greater
- Steel structure designed for typical shipyard fabrication methods
- Class Rules design with a 25-year – or longer – design and fatigue life
- Basic design that adapts to a wide range of turbine sizes, water depths, and environmental conditions
- Mooring system using steel pipe, strand, or synthetic tendons with high vertical load anchors

In late 2011, PelaStar was selected for a grant from the US Department of Energy to reduce the cost of energy (COE) of offshore wind through targeted technological advancement. As part of the project, a detailed COE model was built and vetted with substantial quantities of UK Round 2 and projected UK Round 3 cost data. The COE model was used to identify cost drivers and, therefore, is used to prioritize technological advancements. In 2011, Glosten was selected by the University of Maine for their intermediate-scale floating wind turbine demonstration project. Fourteen finalist designs were evaluated by a panel of wind power and offshore industry experts, as well as leading researchers from the US Department of Energy and NREL. PelaStar was selected and a full design and analysis were completed, culminating in a shipyard design package.

Glosten’s internal research and development effort led to a project for the UK Carbon Trust Offshore Wind Accelerator Program. With Carbon Trust funding, Glosten was able to demonstrate PelaStar’s technical and economic feasibility. In March 2013 the company announced that PelaStar has been awarded a contract from the UK–based Energy Technologies Institute (ETI) for the engineering phase of the floating offshore wind turbine demonstrator. The US$6 million, 12 months contract will complete the Front End Engineering Design (FEED) in advance of construction and deployment of a 6 MW demonstration unit off the south coast of the UK as early as 2015. Upon successful completion of the FEED, the ETI is prepared to commit up to US$31 million to the demonstration project financing package – with ETI financing aimed at accelerating development and deployment of the technologies that can reach the UK’s vast deep-water wind resources and attain the low cost of energy targets required for an economically viable system.

Pelastar (US)
(TLP)

http://www.pelastarwind.com/
US Projects

The Advanced Floating Turbine (AFT) is a hybrid of characteristics from tension leg platform (TLP), and semi-submersible, although it looks like a spar. Nevertheless it should probably be considered primarily a TLP. Nautica Windpower has developed digital prototypes to conduct extensive operational studies and design optimizations. The resulting AFT achieves much lower costs through mass production assembly at the seaport, transport on simple barges and elimination of specialized ships and cranes. A single anchor point to the sea floor also minimizes the high costs of working under the sea.

Nautica Windpower has also achieved significant milestones in scale testing of turbines in the actual wind and water environment. Initially, concepts were evaluated using small scale models of the tower in a water tank to investigate the static stability of various buoyant components. Later, larger scale models of the AFT with a rotor system were created for testing in both the relatively calm water of small ponds and then the large waves (scaled) of the Great Lakes. The tests in the Great Lakes demonstrated the outstanding stability of the AFT in rough water with positive clearances between the blades and the water surface for wave heights equal to 1/2 the rotor diameter. Such conditions significantly exceed the hurricane conditions of a full-scale AFT.

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Next: Medium-Scale AFT

Nautica is currently developing a preliminary engineering design for a medium-scale Advanced Floating Turbine (AFT). An early stage A Round investment will be sought to build and demonstrate the AFT in deep-water off of the coasts of the U.S., Asia, or Europe.

Nautica’s analysis includes extensive studies and calculations related to the structure’s performance in hurricane conditions.

Nautica Windpower AFT (US)
(TLP)

http://www.nauticawindpower.com/