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

An Overview

September 2012 Update

Main(e) International Consulting LLC
International Marketing - Business Development - Supply Chain

Content

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

An Overview

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Preface

This September 2012 report is the 11th update of the floating offshore foundations overview by Main(e) International Consulting LLC. This project started because we saw the need for an overview of all floating foundation projects for the offshore wind industry that are known to us and are beyond the basic design stage. If projects in initial design stage were included, then this document would have at least twice as many pages.

The ongoing monitoring and the creation of this overview is solely funded by Main(e) International Consulting LLC and it 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 are compiled by Main(e) International Consulting LLC.

It appears that the subject of floating foundations is attracting increased interest. One indication is the number of emails received from individuals around the world who have come across this report and wish to be added to the distribution list. So are contacts by media representatives who are researching the subject. The most stunning evidence is the fact that this report is now in the top 10 search results for ‘floating foundation’ on Google US, Google Germany and Google Japan.

Because of this wider audience we decided to completely redesign the report and include basic background information for the Japanese, European and US markets. Project information has been set at 1 page per project. The information on those pages has been obtained from the companies’ websites, the media or directly from the project owners. It is therefore all public domain.

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 found on company websites has been used. The presented technology developers offer different amounts 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.

Any specific project inquiries should be directed to the companies directly.

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

About Main(e) International Consulting LLC:

Main(e) International Consulting LLC is an international marketing and business development consultancy, based in Bremen, (Maine), USA. The company provides business development services and support for companies in different sectors, among them the renewable energy sector with focus on wind power.

For more information please visit

www.maine-intl-consulting.com

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 plan to join projects as part of the ZEFIR test station in the Mediterranean. Samsung of Korea are apparently also working on a floating foundation as well as turbine but so far have not officially published anything.

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 2-3 years. Full commercialization of those projects is expected by 2016 or 2017.

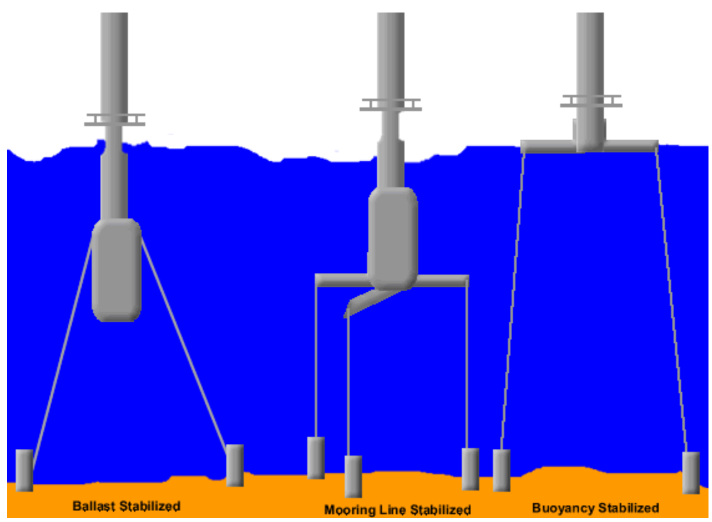
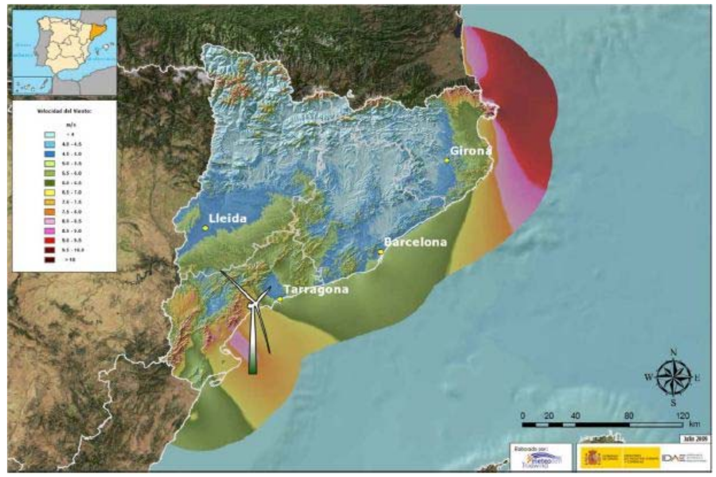


Image Source: http://offshorewind.net/Other_Pages/Turbine-Foundations.html

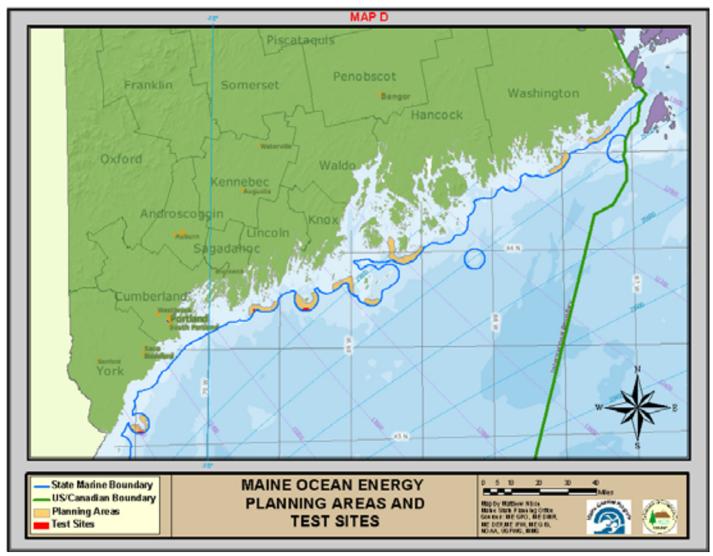
The International Electrotechnical Commission (IEC) in Fall 2011 started a sub working group on 'Design requirements for floating offshore wind turbines' (TC 88) with Mr. Mann-Eung Kim of South Korea as Chair. Other countries represented in the working group through representatives are South Korea (4 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 is 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 includes 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 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.



Location of ZEFIR test area off the coast of Spain



Source: State of Maine Planning Office

List of currently active projects:

Project Name	Country	Technology	Minimum required Water Depth (meter)	Current Development Stage	Pilot Plant Stage
HyWind	Norway	Spar	120 - 700 m	Full Scale testing since Sept 2009	Next generation under development. Planned construction in 2015/2016
WindFloat Floater	USA	Semi Sub	50m	Full Scale esting started Oct 2011	Full Scale Pilot Testing started Oct 2011
Kabashima Hybrid Spar	Japan	Spar	100m	1:2 Scale Pilot with 100kW turbine launched in June 2012.	Full Scale Pilot with 2MW turbine planned for 2013
Mitsui SemiSub	Japan	Semi Sub	N/A	Final Design	Full scale planned for 2013
GICON TLP	Germany	TLP	18m	1:25 Scale Model Test complete; Fabrication Study	Full Scale planned for 2013
HiPR Wind	EU with leadership by Acciona (Spain) and IWES (Germany)	Semi Sub	N/A	Initial Design Phase	Full Scale planned for 2013
Hitachi Semisub	Japan	Floater	N/A	N/a	Full Scale planned for 2013
IHI Advanced Spar	Japan	Spar	N/A	1:50 Scale Model Test complete	Full Scale planned for 2013
Vertiwind Floater	France	Floater	N/A	1:2 Scale Model with 35kW Turbine ready for testing	Full Scale planned for 2013
WinFlo Floater	France	Floater	50m	Fabrication Planning	Full Scale planned for 2013
Blue H TLP	Netherlands	TLP	N/A	Phase 1 Scale Model tested in 2008. Phase 2 Full Scale in Fabrication for Test in 2012.	Phase 3 Full Scale planned for 2014
Poseidon Floating Power	Denmark	Floater	40m	Scale pilot launched.	New Pilot planned for 2014/2015
Pelagic Power	Norway	Floater			Full scale planned for 2014 off the coast of Spain
Nautica AFT	USA	Spar	N/A	Simulations in process	Full Scale planned for 2014
Mitsubishi Floater	Japan	Floater	N/A	unknown	Full scale planned for 2014
IDEOL Floater	Netherlands	Floater	35m	Protoype in 2013	Full Scale planned for 2015
Wind Lens Floater	Japan	Semi Sub	N/A	Scale Pilot Test started in Dec. 2011	N/A
Pelastar TLP	USA	TLP	65m	Design, costing and tank tests completed	Scale Model Testing planned for 2013
Sway Floating Tower	Norway	Spar	55 - 400m	Scale Model Test underway	N/A
Shimizu Semisub	Japan	Semi Sub	25m	Simulation completed	N/A
Mitsui TLP	Japan	TLP	60m	Design for use with 5MW Turbine in Process	N/A
WindSea Floater	Norway	Floater	25-30m	Tank Tests and Simulations completed	N/A
TriFloater Semisub	Netherlands	Semi Sub	50m	Tank Tests completed	N/A
DIWET Semisub	France	Semi Sub	N/A	In Design Phase	N/A
Hexicon Floater	Sweden	Floater	26m	In Design Phase	N/A
Sea Twirl	Sweden	Spar	N/A	Scale Pilot tested	N/A
Sea Breeze	UK	TLP	N/A	N/A	N/A

Source: Main(e) International Consulting LLC

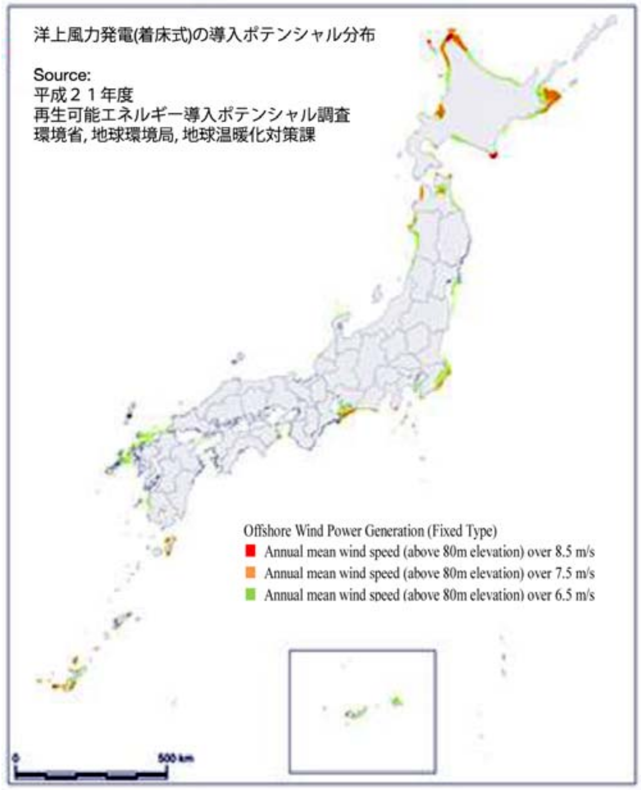
Japanese Floating Projects (浮体式洋上風力発電)

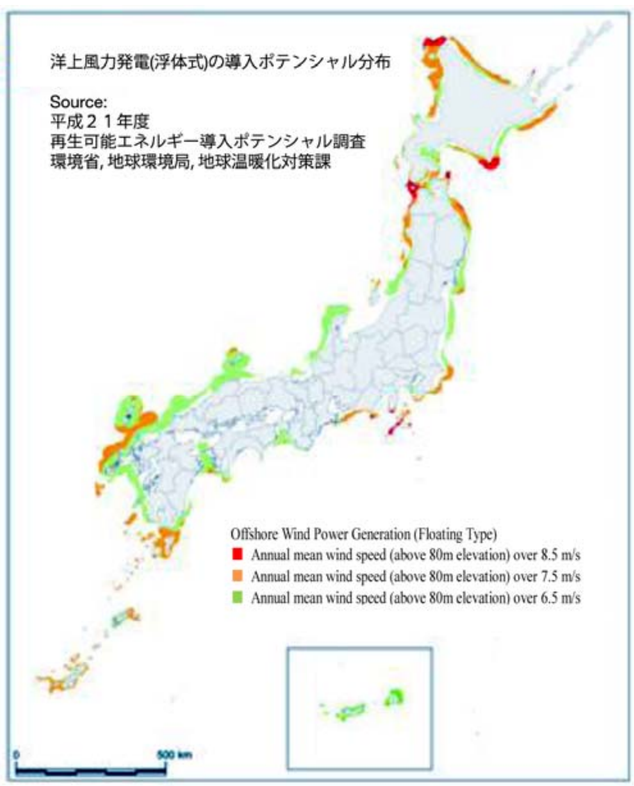
General Background

While Japan has some shallow water offshore wind resources, the majority of Japan's offshore wind areas are in deep water. Japan therefore has more than 20 years of research on floating structures, including for offshore wind. Various designs have been developed to concept stage, including barge designs, semi-submersibles, 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 in Kyushu. A full scale spar is planned for 2013. At the same time, Mitsubishi deployed their 2.4MW offshore turbine on a gravity foundation off Choshi at the entrance of Tokyo Bay. 2013 will see phase I of the Fukushima floating pilot project which is Japanese government funded and will result in a wind park with two turbines each deployed on 3 different floating technologies by 2015. These projects will make Japan a global leader with regards to full scale floating pilot projects.

Japan Fukushima Floating Offshore Pilot Wind Farm

Foundation Type 設備名称	Specification 設備規模	Turbine Type 風車形式	Floating Structure Type 浮体形式	Construction Phase 工期
Floating Substation	25 MVA, 66kV	Substation	Advanced Spar	Phase 1
Semi Submersible Platform	2MW	Downwind Turbine	4 Column Semi Submersible	Phase 1
Semi Submersible Platform	7MW	Hydraulic Turbine	3 Column Semi Submersible	Phase 2
Advanced Spar	7MW	Hydraulic Turbine	Advanced Spar	Phase 2
		Downwind Turbine		





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 wind power with a 20 year power purchase agreement period. It can be assumed that these will also apply to the Fukushima pilot wind park. The budget set aside by the Japanese government for this project is approx. US $160Million. 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: More than 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 Pilot Wind Farm

(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. Phase 2 will be carried out from fiscal year 2013 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

IHI Corporation Marine United: Floating offshore wind power generation facility and for floating substation

Mitsui Engineering & Shipbuilding Co., Ltd.: Floating offshore wind power generation facility

Nippon Steel Corporation: Steel Supply

Japanese Floating Projects

(浮体式洋上風力発電)

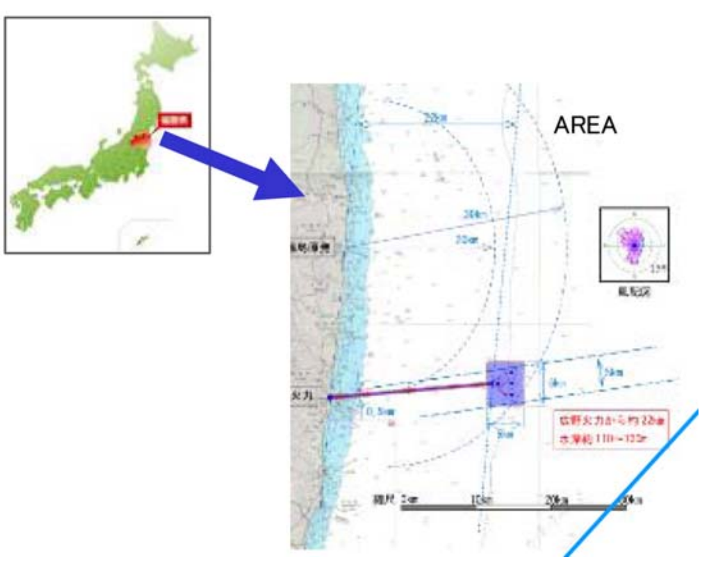
Hitachi, Ltd.: Floating offshore substation

Furukawa Electric Co., Ltd.: Subsea cable

Shimizu Corporation: Construction technology

Mizuho Information & Research Institute, Inc.: Project Management and Administration

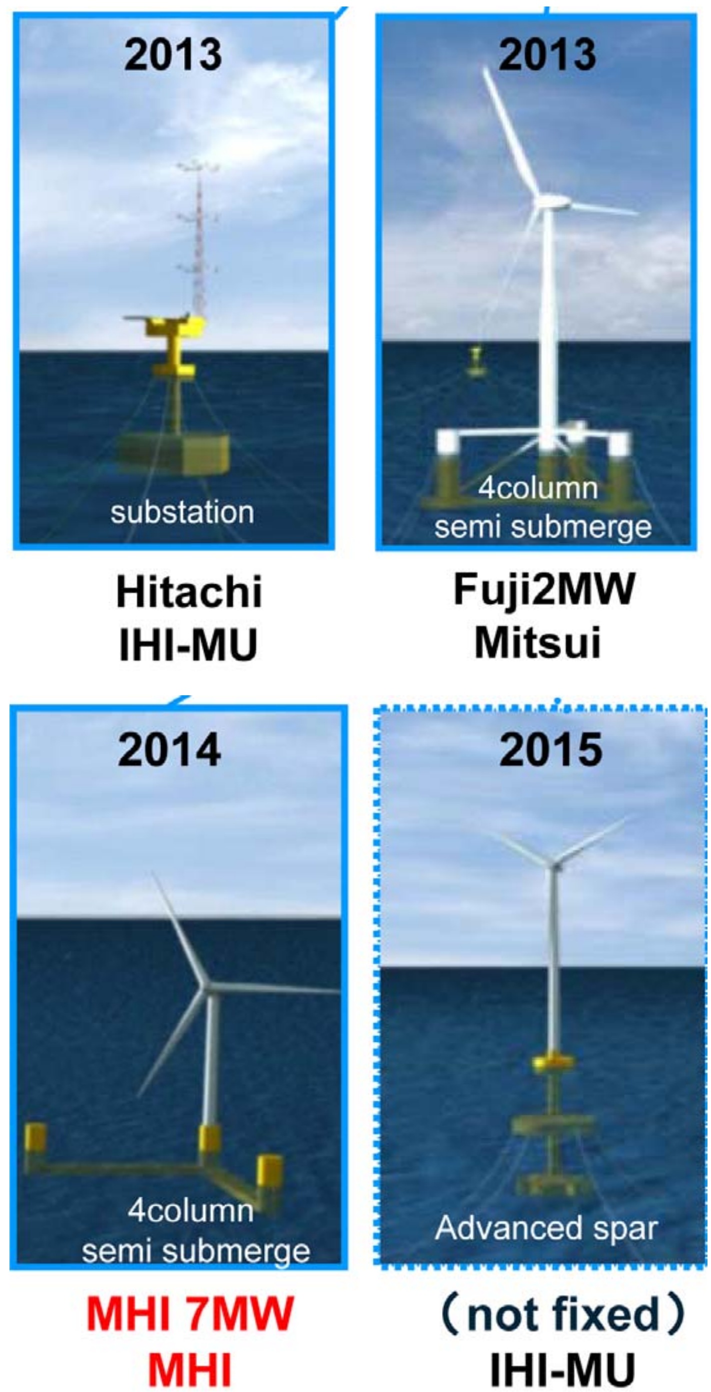
Foundation Type	Specification	Turbine Type	Floating Structure Type	Construction Phase
設備名称	設備規模	風車形式	浮体形式	工期
Floating Substation	25 MVA, 66kV	Substation	Advanced Spar	Phase 1
Semi Submersible Platform	2MW	Downwind Turbine (Fuji/Hitachi)	4 Column Semi Submersible	Phase 1
Semi Submersible Platform	7MW	Hydraulic Turbine (Mitsubishi)	3 Column Semi Submersible	Phase 2
Advanced Spar	7MW	Hydraulic Turbine (Mitsubishi)	Advanced Spar	Phase 2
		Downwind Turbine		



Fukushima Floating Pilot Wind Farm

(Various Technologies)

http://www.marubeni.com



Source: Marubeni ; Mitsubishi Heavy Industries

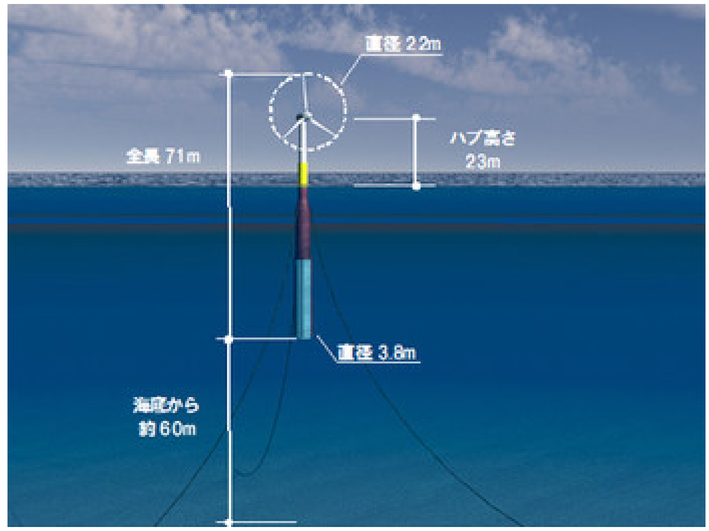
Further details on the individual designs can be found in this report on the respective project pages.

Kabashima Island, Kyushu

(Spar)

http://www.kyoto-u.ac.jp/

Japanese Floating Projects Fact Sheets



<u>Original Consortium Members:</u>

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

<u>Consortium Members for June 2012 and 2013 Pilot:</u>

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 2013 with the full scale pilot.

Turbine manufactured by Japan Steel Works and Hitachi

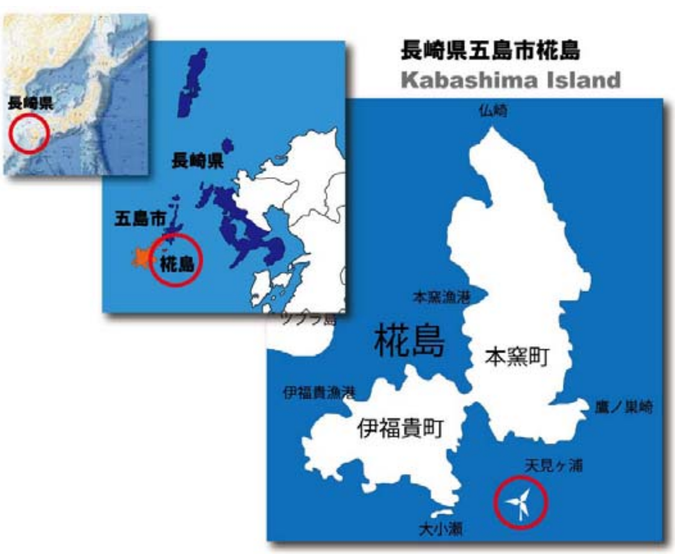
Average wind speed at location of 7.5m/s

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

Pilot funded by the Japanese Government



Japanese Floating Projects Fact Sheets

Wind Lens, Kyushu

(Floater)

http://www.riam.kyushu-u.ac.jp

- 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 60 meters diameter platform with TLP mooring 2km off the coast.

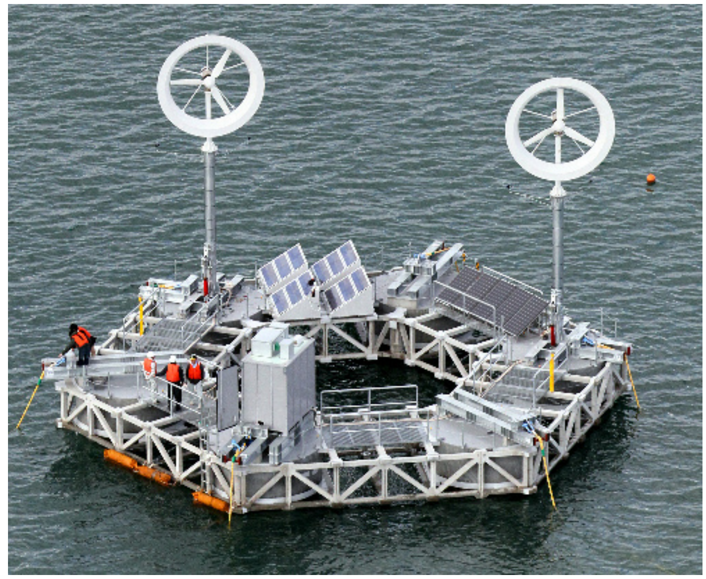
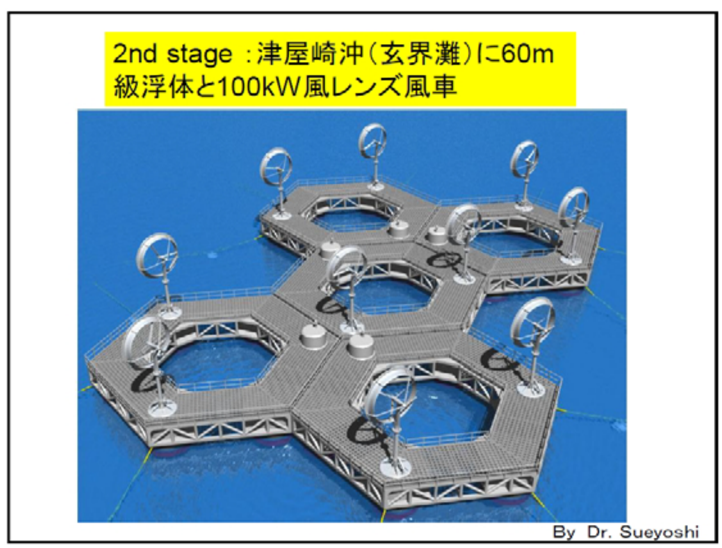


Image Source: Asahi Shimbun, Dec. 5th, 2011



Japanese Floating Projects Fact Sheets

Mitsubishi Heavy Industries (Semisubmersible)

http://www.mhi.co.jp

Mitsubishi Zosen (Mitsubishi Shipbuilding) had been working on 2 different concepts: a semi submersible and a pontoon design. The semisubmersible will be built as part of the Fukushima pilot.

- The R&D work is lead by the shipbuilding division of Mitsubishi HI. The Mitsubishi Wind Power division has some involvement but is not the driver behind this project. Progress had been running in the background.
- An announcement of August 25th, 2011 indicated that Mitsubishi would accelerate their floating platform development but with clear focus on the Japanese market. In February 2012 Marubeni announced that their investment arm will join the Fukushima project.
- On March 6th, 2012 Mitsubishi was included as a member in the Fukushima Floating Offshore Wind Consortium.

Image Source:

海洋開発研究領域

海洋資源利用研究グループ

大川　豊、　矢後　清和

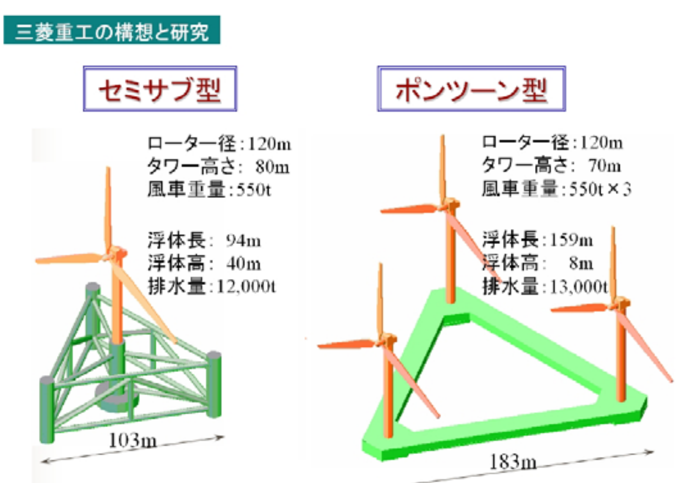


Image Source: Mitsubishi Heavy Industries

Japanese Floating Projects Fact Sheets

IHI Marine United (Advanced Spar) http://www.ihi.co.jp

Design Description as per April 2011 Press Release:

'IHI Marine United Inc. is pleased to announce the completion of the conceptual design of a floating offshore wind sway in collaboration with the University of Tokyo (Professor Hideyuki Suzuki, Graduate School of Frontier Sciences, Tokyo University). This floating foundation is intended for large installations in and outside Japan for offshore wind power.

IHI MU and IHI so far have developed the "no wave shape point 2 (COB: Column Outer Belt)" along with the application of reduction techniques, such as vacillation technology, held by the University of Tokyo. The so-called "Reduced vacillation finn," new technology has been applied by simulation to reduce the floating body sway.

- By reducing the draft to about 50m, maintenance and construction as well as transportation and deployment can be done in vertical state, thus increasing the applicable areas for deployment.

-The structure will also support large wind power generators which increase the demand on stability and loads.

-To see the effect of technology to reduce sway and vacillation, experiments with a 1 / 50 model were done in IHI's tank testing facility.

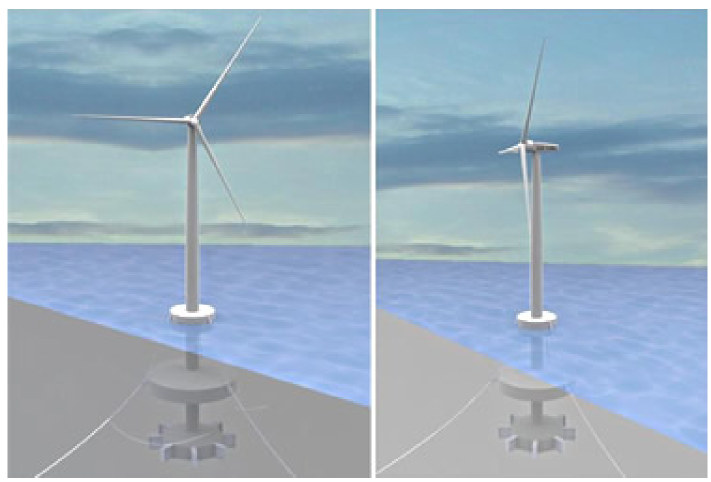
-The newly developed floating platform supports a 2.5MW wind turbine but should also be capable to support larger turbines in the future.

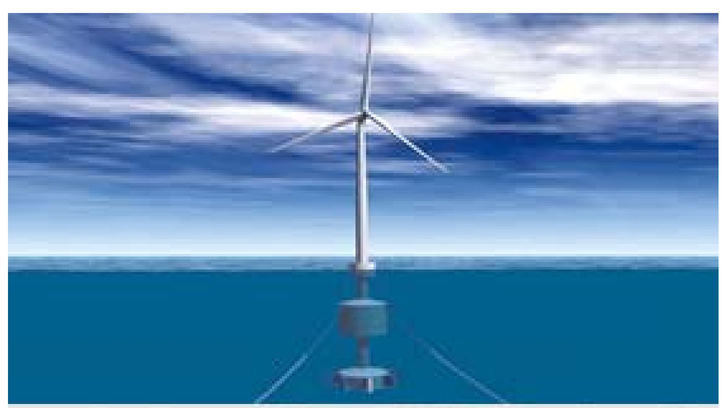
-IHI MU will continue research and development of this floating platform and will proceed with a further detailed design study.'

- 2 scale pilots planned for 2012 in Japan.

In February 2012 IHI announced that they have partnered with Japanese turbine maker JSW for the development and supply of a 2 MW offshore turbine for this floating platform.

The March 2012 Fukushima Consortium Announcements confirmed that IHI's design has been selected for the floating substation and for test with a 7MW turbine. The full scale is planned for 2015; the turbine will be Mitsubishi's new 7MW offshore turbine. The technology will however also be used for a floating substation as starting point for the Fukushima floating pilot wind farm.





IHIMUが開発した低動揺型洋上風力発電浮体

Japanese Floating Projects Fact Sheets

Shimizu Corporation

(Semi Submersible)

http://www.shimz.co.jp

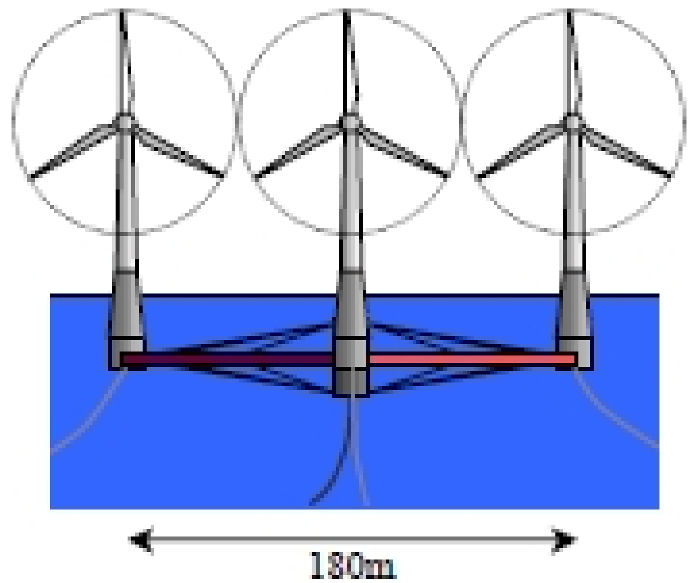
Shimizu Corporation has been jointly working with the University of Tokyo, Tokyo Electric Power Company and Penta Ocean Construction Co. Ltd. on the design of a floating platform.

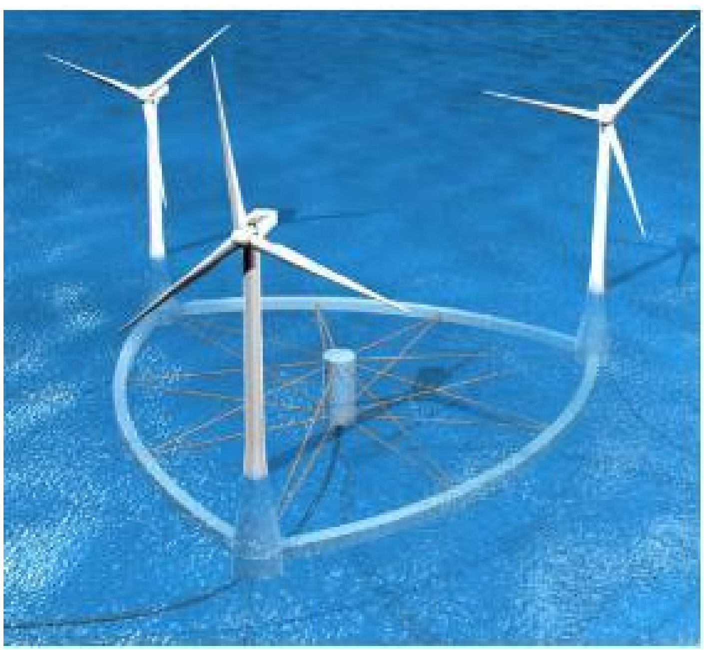
Shimizu's internal Institute of Technology has done numerous research re. offshore wind, including impact of wind and waves on structural integrity.

A development timeline of this project is not known; it is assumed that the Shimizu Consortium also targets 2017 as a target launch date.

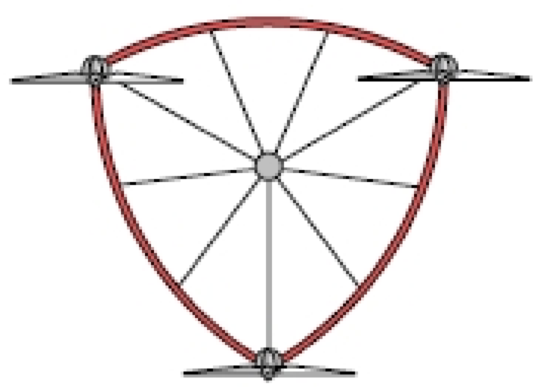
The leading academic advisor is Prof. Ishihara at Tokyo University.

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.



Japanese Floating Projects Fact Sheets

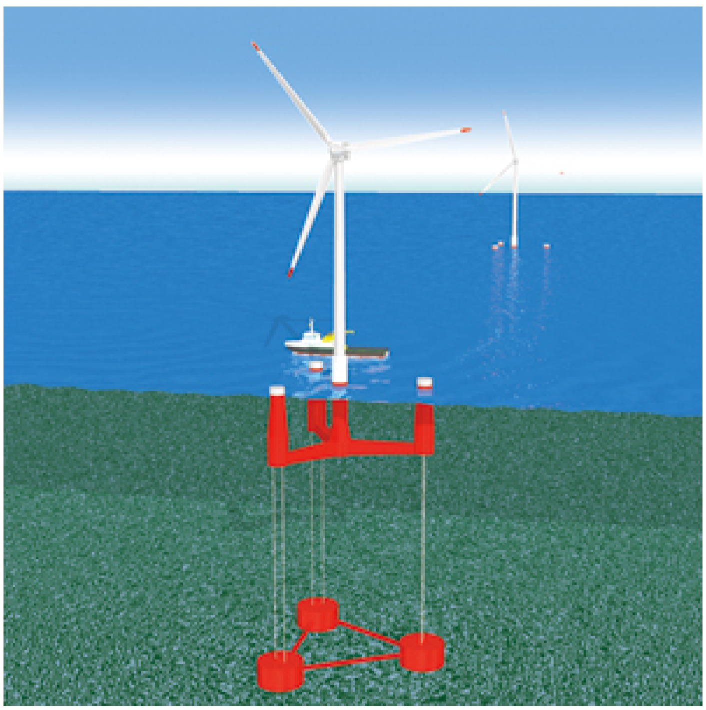
Mitsui Shipbuilding

(TLP)

https://www.mes.co.jp

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.

The Fukushima pilot wind farm has Mitsui listed as supplying a semi submersible. However, the corporate Mitsui site has only info on the TLP.



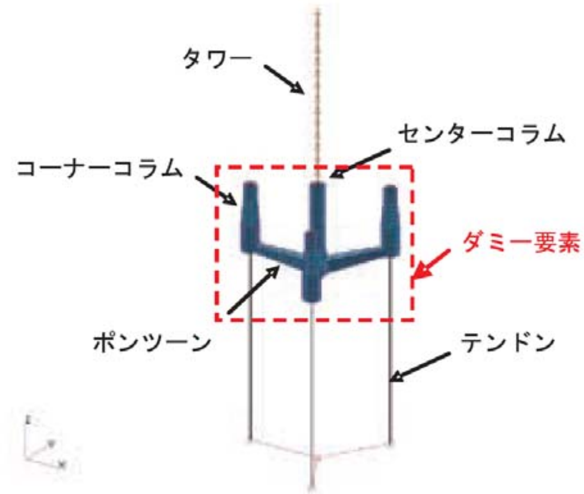


図 7　有限要素解析モデル
Finite Element Analysis Model

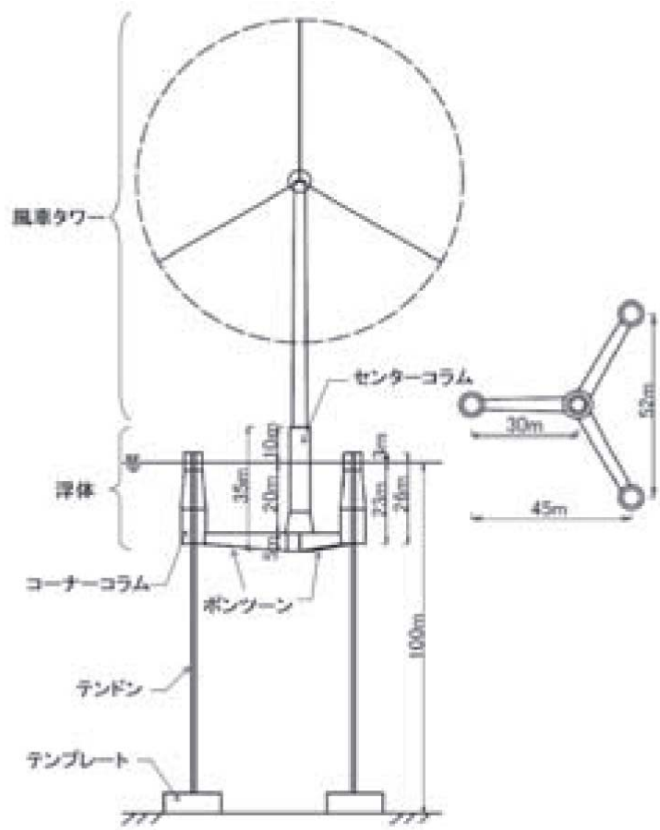


図 1　浮体概略図
Outline of Proposed Floating Structure

Japanese Floating Projects Fact Sheets

National Maritime Research Institute of Japan (Spar) http://www.nmri.go.jp

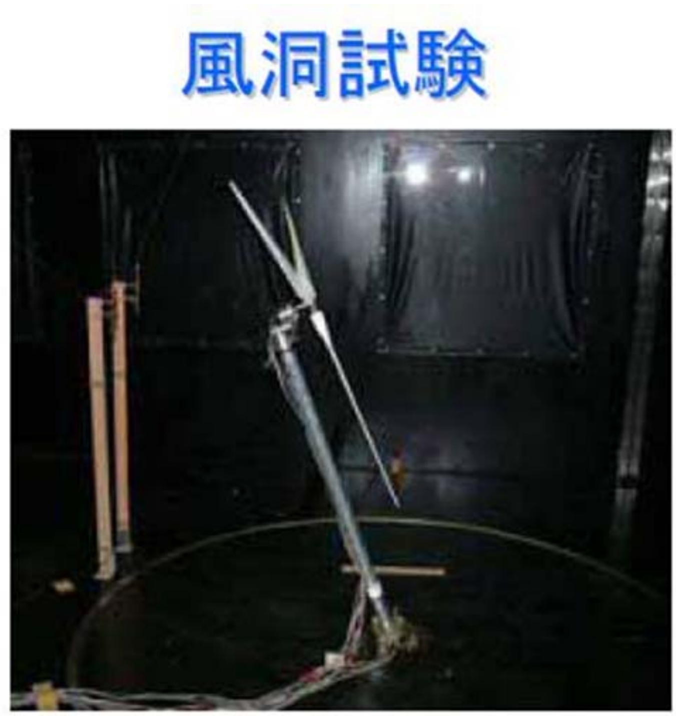
The National Maritime Research Institute of Japan is an independent research institute, funded by the Japanese Government as well as by conducting commissioned research for private entities.

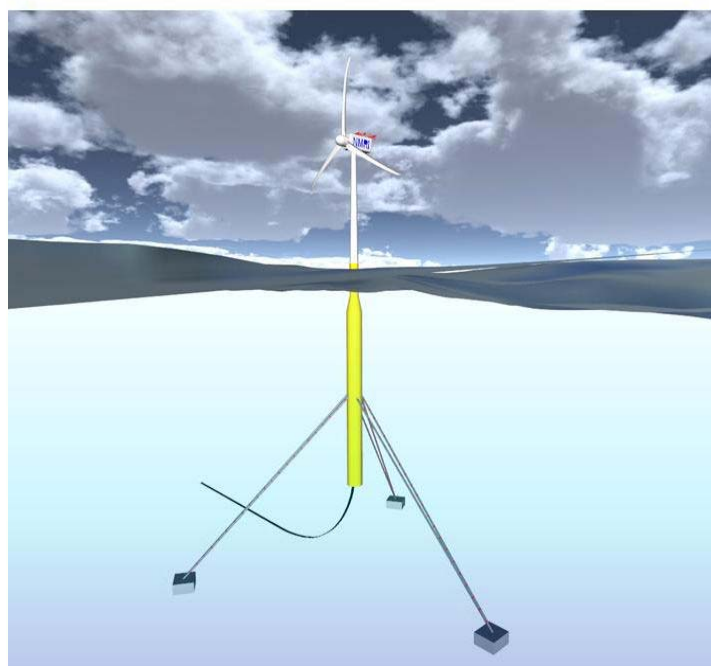
Focus are shipbuilding technology, marine safety and marine environment. The institute has conducted substantial research with regards to floating marine structures, including for offshore wind.

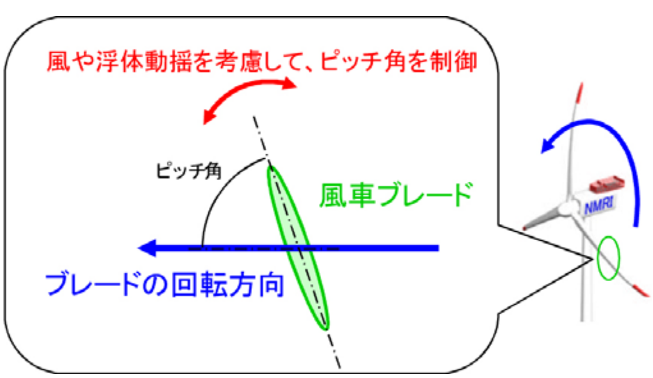
The institute has its own deep water wind and wave tank for testing.

- 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 Floating Projects Fact Sheets

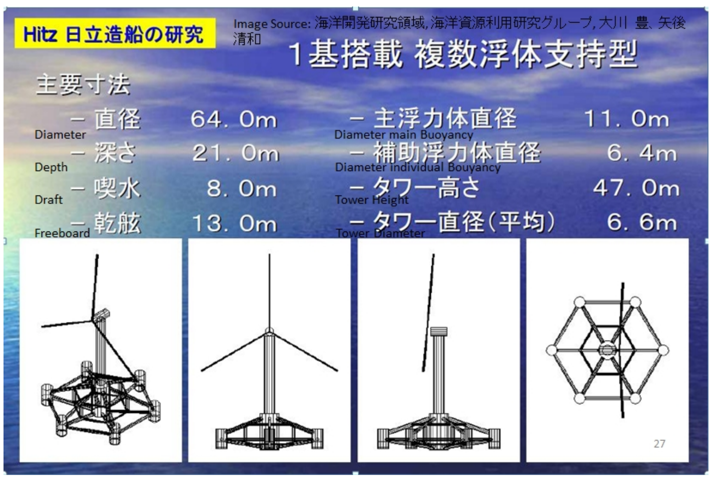
Hitachi Zosen

(Semi Submersible)

http://www.hitachizosen.co.jp

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 with the target to have the platform available by 2013.The key development team members are 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 IHI's floating spar.



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 build 120 billion yen ($1.5 billion) of offshore wind farms 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.

2. 3. Dez. 2011 日本経済新聞

洋上風力発電設備に参入

日立造船 建設費、既存の3割減

日立造船は洋上風力発電プラント事業に参入する。来年以降、安定性が高い独自の浮体を採用するなどして建設コストを3割以上低減できる風力発電プラントを開発。2016年度をめどに商用化、20年度に200億円以上の売り上げを目指す。東日本大震災後、原子力発電の代替電源として風力発電に注目が集まっており、開発余地の大きい洋上風力の引き合いが増えると判断した。

日立造船が商用化を目指すのは、海上に浮かべた浮体の上に風車を固定する「浮体式」と呼ばれるタイプ。世界的にも実証段階の技術で、国内ではIHIなども開発を目指している。日立造船は海洋土木の技術を生かし、競合に比べて水平方向に広い独自の浮体を開発する考え。風車の安定性を高めることで浮体を海底に係留する工事を簡易化、建設コストを既存技術に比べ3割程度削減することを目指す。

日立造船は04年ころ、洋上風力開発に着手し陸上水槽で実証実験などを進めていたが、当時は洋上風力への関心も低く、いったん事業化の取り組みを中断していた。震災後、原発代替電源として大型風力の引き合いが増えているため、プロジェクトを再開する。

今後プラントの詳細設計を詰め14年度以降日本近海で実証を行う。16年度にも出力3000キロワット前後のプラントを商用化、電力会社などに対して受注活動を始める。プラント価格は未定だが1基20億～30億円になると見られる。

洋上風力は建設コストが陸上風力の2倍程度と割高で、国内に本格的な商用発電所はまだないが、欧州などでは多数の稼働実績がある。国内では陸上で安定した風量が得られ、送配電インフラへの接続も容易な大型風力の設置適地は少なくなっている。一方、島国で広い排他的経済水域を持つ日本では洋上風力の設置適地は多いとされる。30年度の日本の国内洋上風力の導入量は、陸上風力の約2倍の約1300万キロワットに達するとの試算もある。

日立造船が商用化を検討する洋上風力発電プラント（イメージ図）

Nikkei Dec. 3rd 2011 - Nikkei Sept 4th, 2012

日本経済新聞 2012年（平成24年）9月4日（火曜日） ©日本経済新聞社2012 （日刊）

9月4日 火曜日

夏商戦さえず エコカー補助金残る【総合】3

洋上風力発電に1200億円

30万キロワット、国内最大級

東芝など6社

日立造船や東芝、JFEスチールなど6社が共同で洋上風力発電事業に参入する。2015年に実証試験用発電所を建設するのを皮切りに、10年間に計1200億円を投じ、30万キロワット分の開発を目指す。日本は欧州に比べて風力開発が遅れていたが、立地に制約の少ない洋上風力開発が進めば、再生可能エネルギーの活用に弾みがつきそうだ。

着床式洋上風力発電のイメージ

再生可能エネルギーのコスト

	発電コスト（1キロワット時当たり,円）
洋上風力	9.4～23.1（着床式）
陸上風力	9.9～17.3
大規模太陽光発電	30.1～45.8

有機EL、テ 韓国LG

European Projects

General Background

European deep water offshore floating platforms were originally dominated by Norwegian companies, due to their need of deep water technology. Other companies such as BlueH from the Netherlands, Nass et Wind of France, GICON of Germany and et.al. also started the development because they see a global market demand.

During the week of December 7th, 2010 a brand new European consortium for the development of floating foundations was announced by Fraunhofer Institute of Germany. Under Fraunhofer's leadership a consortium of major European commercial and academic entities are also developing floating technology.

In January 2011 Technip of France announced their new Vertiwind Consortium.

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 global market opportunity, including in the US and Asia.

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 are now starting to market the technology they own on a global basis.

The UK Energy Technologies Institute (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.

European Projects Fact Sheets

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 is investing about NKr340m ($53.4m) in the project, with Norwegian technology development fund Enova stumping up NKr59m.

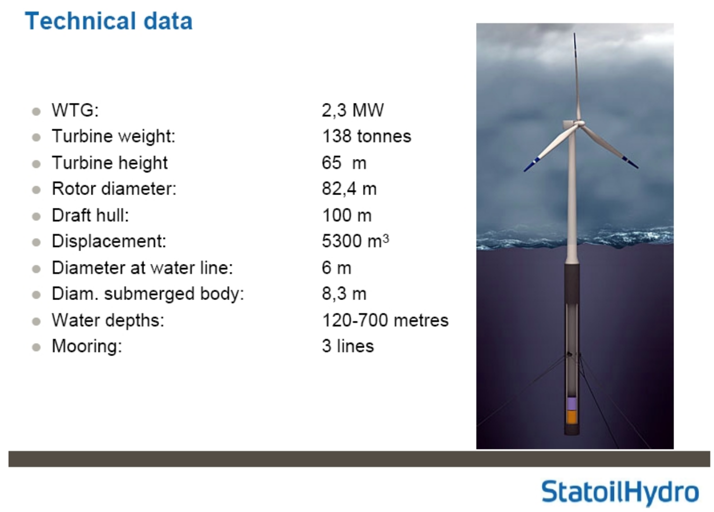
The 5,300 tons unit is a floating structure made up of a steel 'spar' ballast of water and rocks that extends 100 meters below the water-level and is anchored to the seabed by a three-point mooring spread.

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



European Projects Fact Sheets

GICON SOF, Germany

(TLP)

http://www.gicon.de/

GICON, with 270 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.

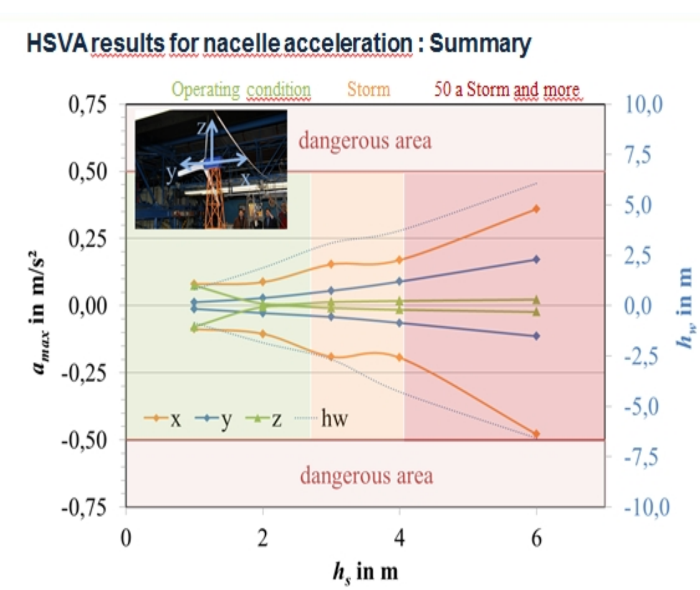
<u>Key Facts:</u>

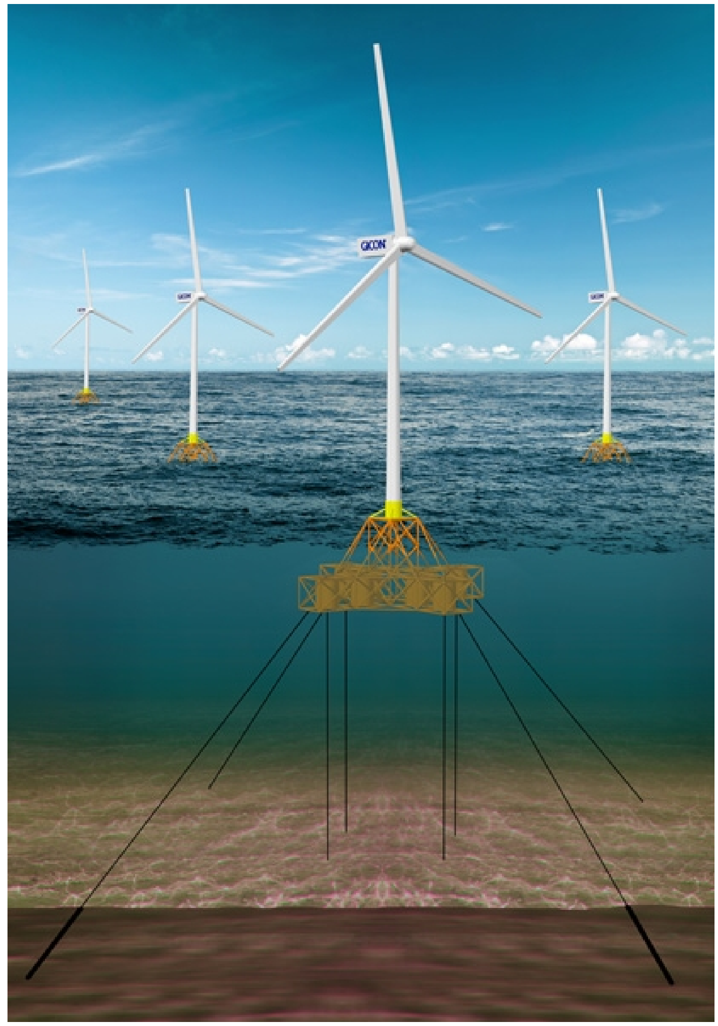
- Deployable in water depths of less than 20 meters to 700+ meters
- Various mooring technology options for different ocean floor conditions
- Low system accelerations and displacements
- Modular design for cost efficient manufacturing

<u>Tank Tests surpass Expectations:</u>

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





A full scale pilot is planned for construction in the German Baltic Sea in 2013.

European Projects Fact Sheets

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 which it intends to complete in 2012 and install in its Tricase, Italy wind farm.

Phase III:

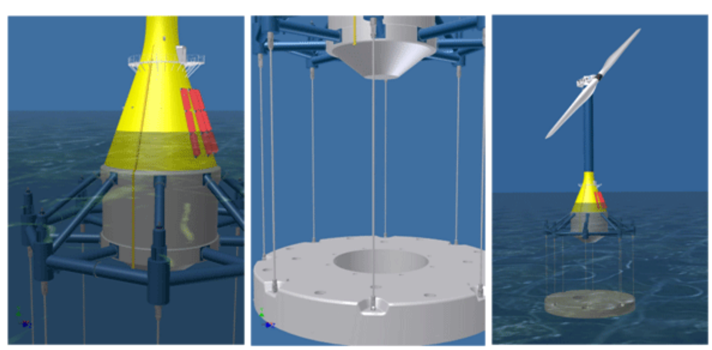
The 2 MW unit will be followed by the deployment of the final proof of concept: a larger pre-production floating turbine in 2014, combining Blue H's platform with a 3 rd party offshore turbine.

Lease applications have also been filed in Massachusetts (USA)

In the mid-term, Blue H will continue to co-develop sites in key markets with specialized site development partners. In order to promote its deep water floating technology, Blue H pioneered and developed by itself one deep-water 90 MW site, the Tricase wind farm, which is close to securing its final permit. Ultimately however, Blue H does not see itself as a developer of sites, expecting the market for deep-water floating platforms to be established before the end of the decade.

Phase 1

Phase 2



Phase 3

European Projects Fact Sheets

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 Industrie, 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

A full scale pilot is planned for 2013 off the coast of southern Brittany, near Lorient port. The Winflo turbine will be mounted on an "innovative free-floating platform" anchored to the seabed, to be deployed at depths of 50-150 meters.

It will carry a lightweight turbine of 2.5MW or 3MW and adapted for marine conditions. Monitoring and some maintenance functions will be carried out electronically using "e-maintenance" technology developed in the naval sector. Vergnet , a French manufacturer of 2 bladed turbines, will design the nacelle, including the rotor and blades.

The budget for the pilot project is over €35 million ; Winflo was officially recognized by Pôle Mer Brittany in November 2008 and has been awarded a grant in 2010 by the French government, thus receiving important funding from the program "Investissements d'Avenir" (French state investment program on strategic topics) ;
A pilot-farm is planned for 2016 with full commercialization by 2018.

European Projects Fact Sheets

Pelagic Power, Norway

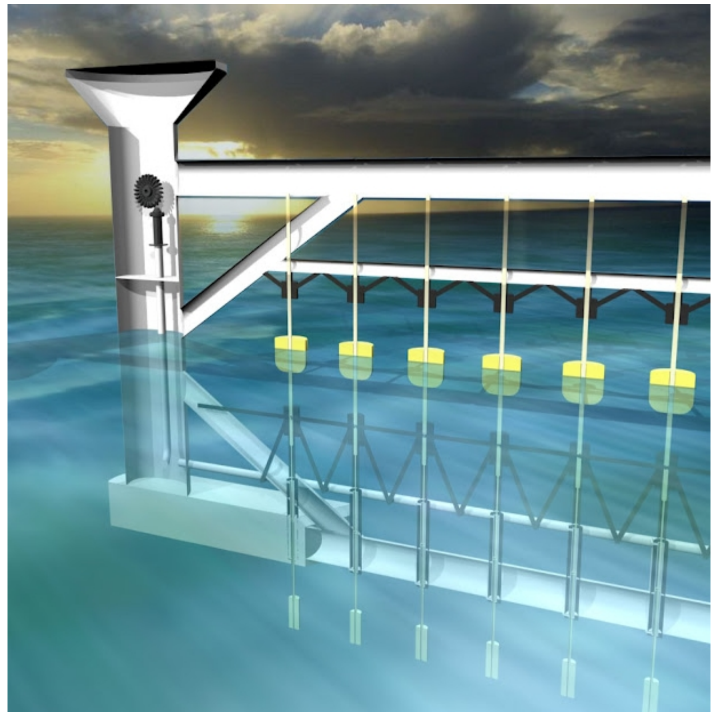
(Floater)

http://www.pelagicpower.no/

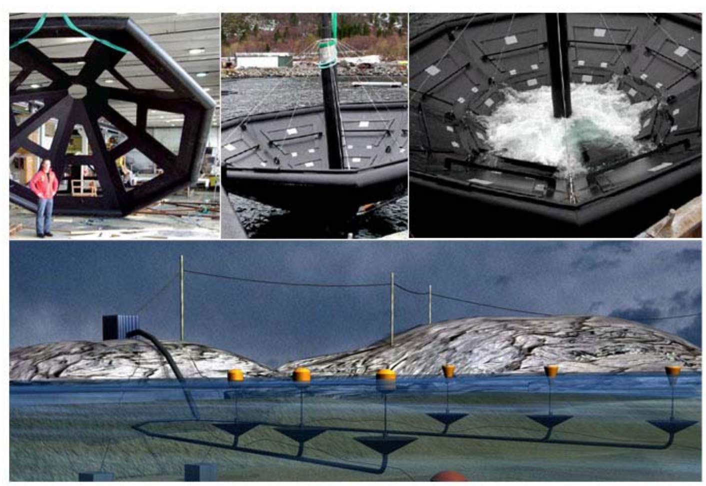
W2Power is designed from first principles as a true hybrid wind & wave energy conversion plant. Two corners of the triangle support one wind turbine each, and the third corner houses the wave energy power take-off using a Pelton turbine, standard in hydro-power applications, driven by three lines of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

Accommodating two 3.6 MW standard offshore wind turbines like 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:



European Projects Fact Sheets

Poseidon, Denmark

(Floater)

http://www.floatingpowerplant.com

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.

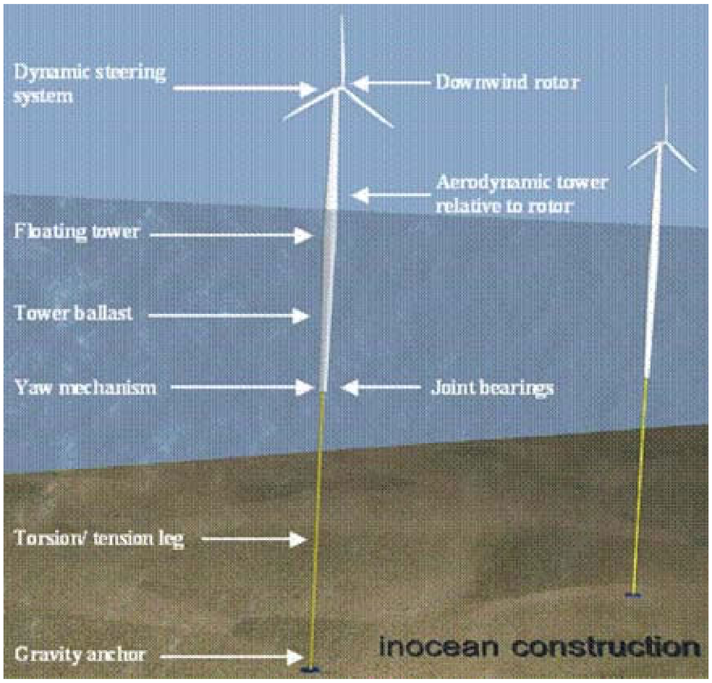
The wind turbine itself will be standard offshore wind turbines.

An actual at-sea grid connected operation took place in 2008 to 2010 in Denmark. In co-operation with Oregon (USA) based Floating Power Inc. Poseidon is looking at a US West Coast pilot. A definite timeline for the project has not been announced.

European Projects Fact Sheets

Sway, Norway
(Floating Tower)
http://www.sway.no/

Sway AS is renewable energy company on course to revolutionize wind energy design, in particular for offshore 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 metres.

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.

European Projects Fact Sheets

Vertiwind, France

(Floater)

http://www.technip.com

Technip, in association with Nénuphar, Converteam and EDF Energies nouvelles is launching 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 continues to contribute to the development of a new and innovative industry and confirms its role as 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.

In August 2011 Technip and Iberdrola signed a memorandum of understanding (MOU) to bid for two of the five offshore areas that the French government has offered for competitive tender in a first phase, totaling 3,000 megawatts (MW). More specifically, this MOU covers the design, engineering and construction of the 2 zones.

Technip is also directing the INFLOW (INdustrialization setup of a FLoating Offshore Wind turbine) demo project that will see the deployment of a commercial size floating vertical axis wind turbine (VAWT) in the Mediterranean Sea near Marseille. Together with a similar turbine prototype to be installed in the course of the predecessor project VERTIWIND, the world's first offshore test site with multiple floating wind turbines will be established. Funded by the European Commission's Seventh Framework Program and running for four years, the main target of INFLOW is to optimize the existing VAWT prototype and to manage all aspects required to initiate a viable industrialization phase, in order to launch a 26MW wind farm and to develop even larger farms in the future (150 MW by 2018).

The consortium partners are: DTU Wind Energy (Denmark), Alstom Hydro (Spain), ALSTOM (Spain), Nenuphar (France), Fraunhofer IWES (Germany), DUCO Ltd. (United Kingdom), EDF Energies Nouvelles (France), Vicinay Cadenas S.A. (Spain) and Vryhof Anchors NV (Netherlands).

Technip is also a member of the Maine (USA) DeepCwind Consortium, lead by the University of Maine.

European Projects Fact Sheets

IDEOL, Netherlands

(Floater)

http://www.ideol-offshore.com

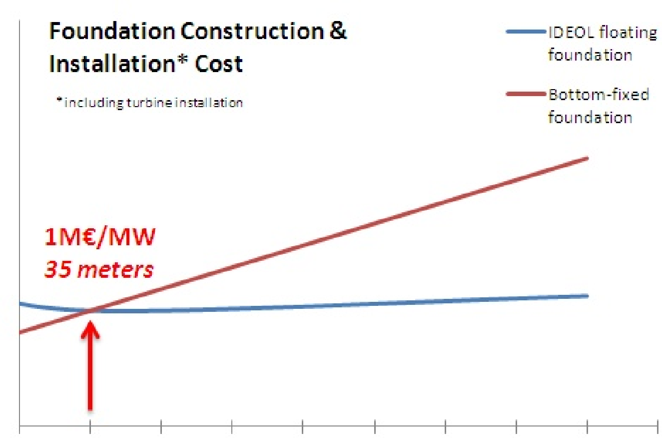
IDEOL is working with industry partners on the launch of a first 5-6 MW prototype offshore in 2013 and a 50 MW pre-series wind farm in 2015.

The company goal is to demonstrate that a floating foundation is an alternative to fixed ones starting from 35-40 meters water depth, and to deploy its products into wind farms currently under development, for construction and operation in 2015 and beyond.

- Target construction and installation cost below 1M€ / MW. Including turbine installation at quayside
- Applicable from 40 meters water depth

A prototype is planned for 2013 and a full scale pilot for 2015.

	Motion average sea conditions turbine in standby	Maximum motion in operation Mediterranean	Maximum motion in operation Central North Sea
Wind	Wind speeds from 5 to 25m/s at hub height Normal turbulence Wind and waves aligned or not (up to 90° misalignment)		
Wave	Hs=2m	Hs=4m	Hs=6.5m
	Range of periods from 3s to 15s		
Heave	2.3m	3.7m	6.0m
Maximum tilt	0.7deg	1.6deg	1.6deg
Maximum list	2.5deg	3.5deg	4.3deg



With a construction and installation cost of about 1 M€/MW, the IDEOL floater solution is an alternative to bottom fixed foundation starting from 35 m water depth. It is fully compatible with the wind turbines available in the market without any major modification, and presents the following advantages compared to other solutions:

- a construction and installation cost twice to three times lower;
- a lower draft, making it possible to use at a broader range of depths;
- smaller dimensions, IDEOL floater featuring a 40 m breadth for a 5MW wind turbine;
- an excellent static stability in normal and extreme conditions, without any ballasting in operation, which is always a source of maintenance problems;
- an easy access for maintenance or inspection;
- a high-local content, which is essential to secure public tenders and subsidies;
- a construction anywhere in the world, on-site without any transport or dedicated dry-docks;
- a carbon content divided by 7.

European Projects Fact Sheets

WindSea, Norway
(Semi Submersible)
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.

Force Technology (owner and leader): Technology Consulting Company. Design, co-ordination, hydrodynamic, steel design and aerodynamics.

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:

Semi submersible 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:

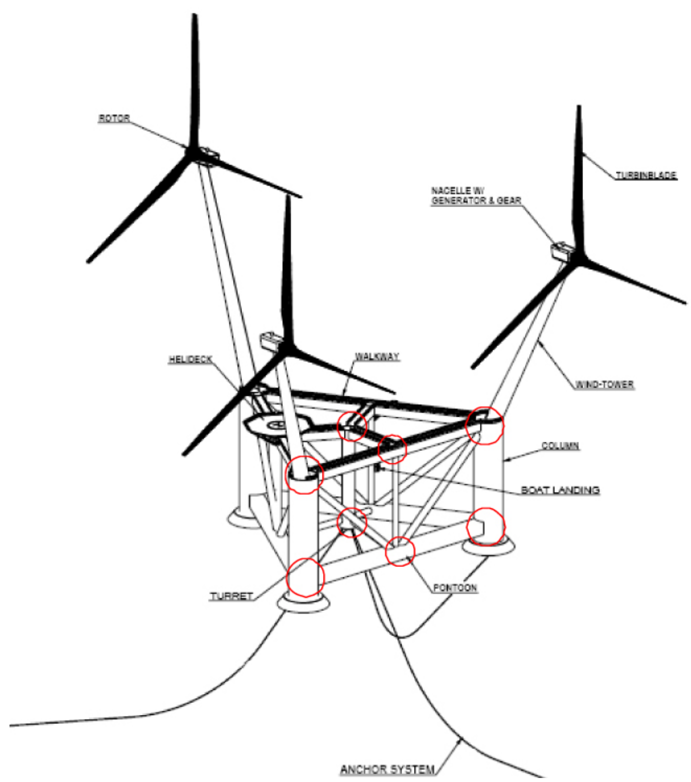
Height upwind turbines above sea level: 71 m

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)



European Projects Fact Sheets

HiPR Wind, Europe

(Semi Submersible)

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.

<u>Status of the design process 11/2011:</u>

☐ 10 partners working under Acciona Energia's lead

☐ Review and evaluation of basic design options completed

☐ Semi-submersible selected

☐ Design framework completed (Met Ocean, wind turbine,…)

☐ Sizing and design completed

☐ Modeling & simulation supported by tank testing

☐ Detailed engineering ongoing

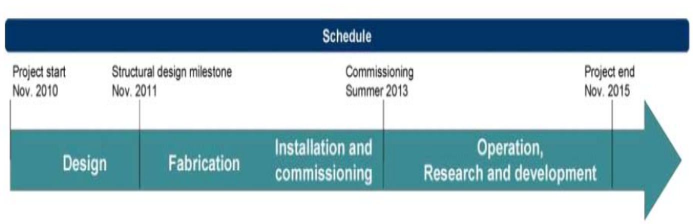
☐ Structural details, moorings, access

☐ Assembly, Installation and Commissioning Procedures

☐ Operation and Maintenance concept

☐ Certification and Permitting requirements for the offshore site (most likely off Bilbao, Spain)

Full scale pilot planned for 2013.



European Projects Fact Sheets

DIWET, France

(TLP)

http://www.bluehgroup.com

Deep-water offshore wind turbine floating on a semi-submerged platform anchored using a tension leg system

DIWET PROJECT PARTNERS:

Companies:

Blue H France, Rennes, project director, develops, manufactures, installs and operates deep-water floating wind turbines,

Timolor, Lorient, engineering, construction and maintenance for shipbuilding and repair and for industry,

Actimar, Brest, operational oceanography services for understanding the marine environment,

Institut de la Corrosion, Brest, research and development, specialist consultancy, testing: corrosion in the marine environment, cathodic protection design, corrosion and cathodic protection monitoring,

Astrium, Bordeaux, subsidiary of EADS, devoted to civil and military space systems and services and development of high-performance composites structures (design, dimensioning, testing and production methods)

Research centers:

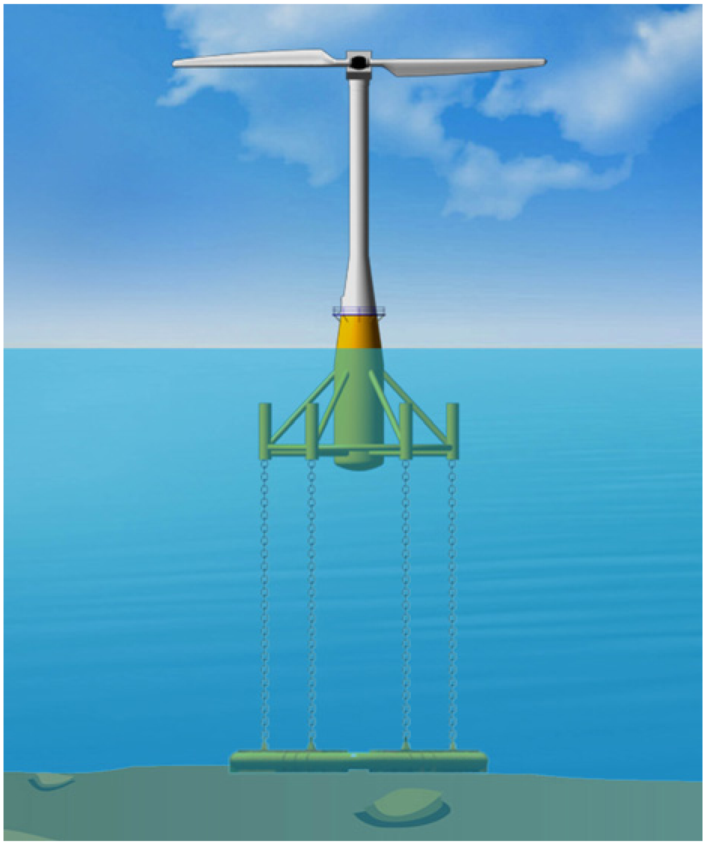
École Centrale de Nantes, ship and offshore hydrodynamics, digital simulation of fluid dynamics and test tank experimentation,

CETIM, (Centre Technique des Industries Mécaniques – Centre for Mechanical Engineering Industries Research), Nantes, design, dimensioning and industrialization of structures made from metals, composites and/or elastomers,

Université de Bretagne occidentale, Laboratoire Brestois de Mécanique et des systèmes (Brest Mechanical Engineering and Systems Research Lab), processes for deploying composite materials.

System is designed to be deployed with a 3.5MW two-blade turbine.

No actual pilot announced.



European Projects Fact Sheets

Xanthus Energy Sea Breeze, UK (TLP)

http://www.xanthusenergy.com/

Description from 2002 Patent Filing:

Floating offshore wind turbine

(57) A floating support structure comprises a watertight hull 1, a gravity or suction foundation comprising one or more components 7 located on the seabed and one or more buoyancy devices 4 connected to said watertight hull and configured to provide excess buoyancy and additional stability. The watertight hull and buoyancy device assembly is tethered to the foundation such that the excess buoyancy is manifested as a force in the tethers. A telescopically extendable shaft 3 extends upwardly from the hull and has a hoist 9 located at the shaft top. A wind turbine 8 may be located at the top of the shaft while a generator may be located in the hull. The structure can be towed with the shaft retracted and subsequently extended and grouted following installation. A method of connection several of the structures using horizontal connectors is also disclosed.

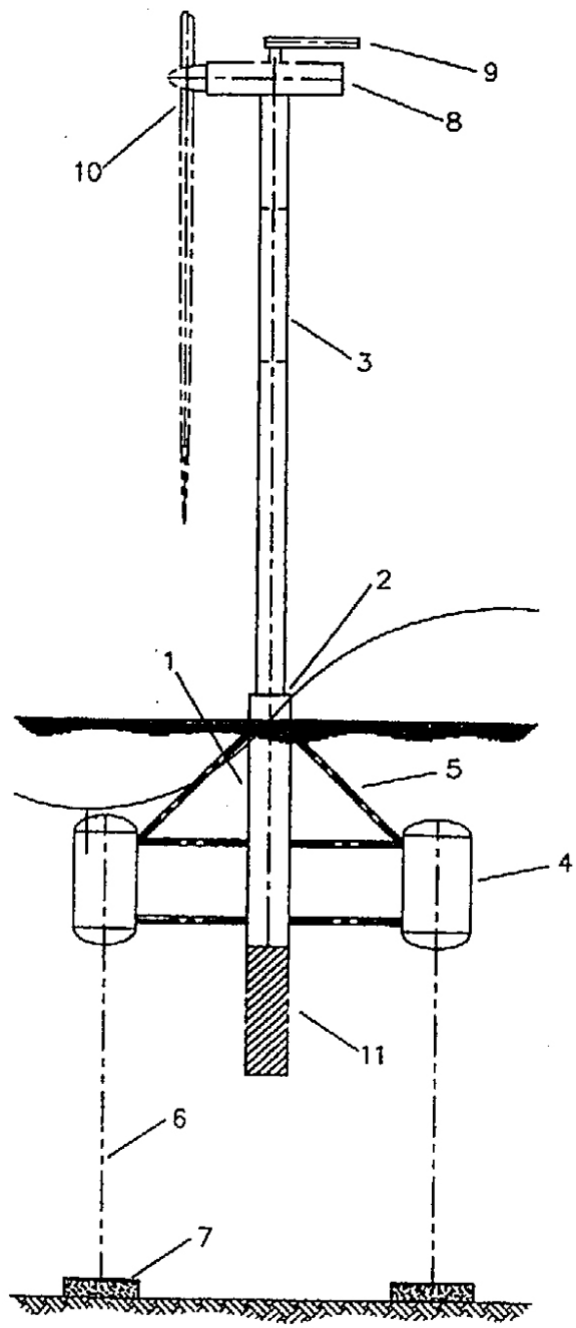


FIGURE 1

Approx. Dimensions:

Nascelle Ht. - 72.75m

Rotor Ø - 90 –100m

Water Depth - 50 m plus

Wave Height - 20m

Floating Structure

Steel Weight 702 tons

Overall Diameter 40.5 meters

Tower Height (above MSL) 72.75 meters

Operating Draft 20 meters

Buoyant Chamber Ø8 meters

Gravity Base Structure

Overall Dimensions 44m x 44m x 3.5m

Weight 2,000 tons approx.

Tether System

Each Outrigger - Multiple Galvanized Wire Ropes

UBS 1200 tons per tether assembly

European Projects Fact Sheets

Sea Twirl, Sweden

(Spar)

http://seatwirl.com/

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 Fact Sheets

Gusto Trifloater, Netherlands (Semisubmersible)

http://www.gustomsc.com

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)

Survival significant wave height	9.4 m
Max. operational sign. wave height	6.5 m
Water depth	100 m
Wind turbine	NREL 5 MW
Hub height above SWL	85 m
Length overall	76 m
Beam overall	87 m
Operational draft	13.2 m
Transit draft	10 m
Wind turbine mass	approx. 600 t
Steel structure mass	approx. 2,000 t
Ballast water (operational)	approx. 1,000 t
Total displacement (operational)	approx. 3,600 t
Mooring system mass (excl. anchors)	approx. 400 t
Extreme static + dynamic roll/pitch	less than 10 deg
Accelerations nacelle (operational)	less than 3 m/sec2

European Projects Fact Sheets

Hexicon, Sweden

(Floater)

http://www.hexicon.eu/

Hexicon is a Swedish company specializing in large-scale, floating platforms for wind and wave power.

The Hexicon concept is supported by the governments of Sweden, Malta and Cyprus under the EU investment program for renewable energy NER300.

In the NER300 application, the following companies act as contractors, subcontractors, consultants and partners to Hexicon:

GENERAL DIMENSIONS - 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

Detailed project timeline not published.

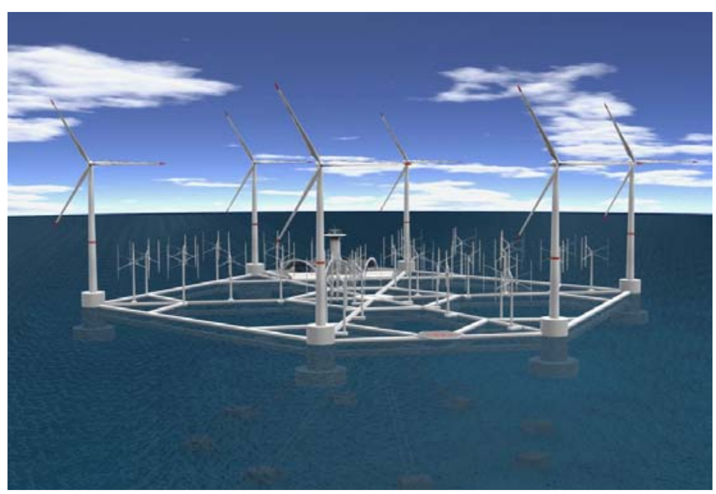
Anticipated prototype/pilot may to be off the coast of Malta.

ENERGY PRODUCTION

Installed effect (wind):

- Horizontal Turbines 6 x 6,5 MW
- Vertical Turbines 30 x 0,5 MW

TOTAL (wind)	54 MW
TOTAL (wave)	15 MW
TOTAL EFFECT:	69 MW



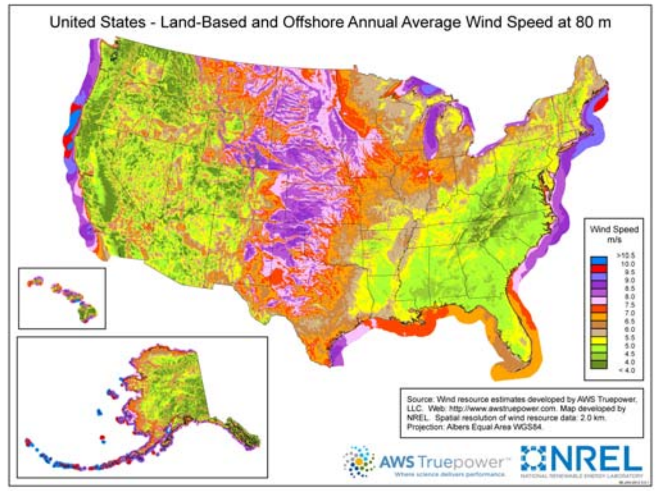
US Projects

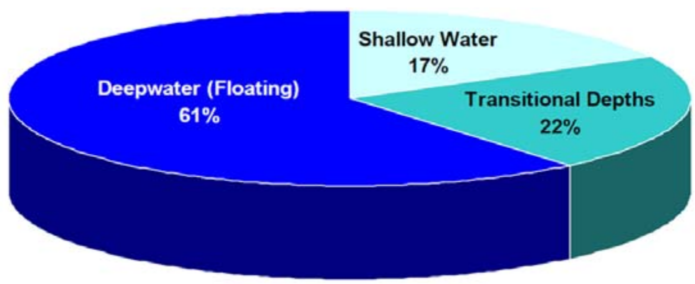
The U.S. Government plans to achieve 20% wind energy by 2030; a target that includes offshore wind energy. However, 61% of the US wind resources are in deep water. That is one reason why the U.S. government as well as the private sector started to look at floating foundation technology. The National 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.

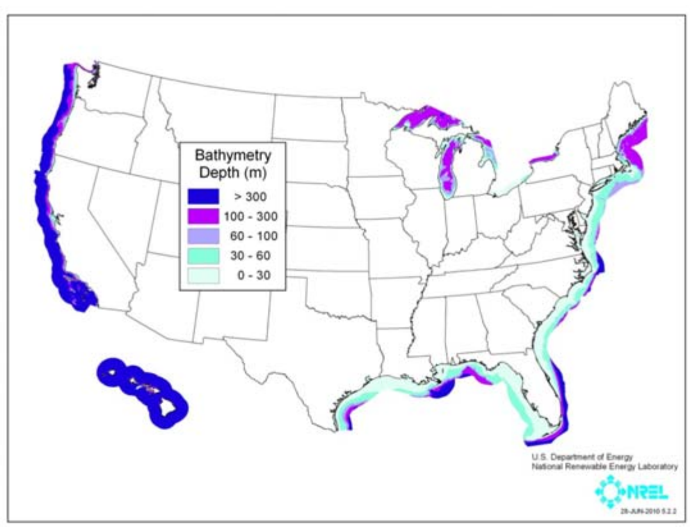
General Background





Approximate percentage of Gross Offshore Wind Resource Area for Three Technology Stages **(based on NREL estimates – 0-50nm from shore, 60% of resource excluded, AK and HI not included, Class 5 winds and above only)**

Source: NREL



US Projects Fact Sheets

WindFloat (US/Portugal)

(Semisubmersible)

http://www.principlepowerinc.com/

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.

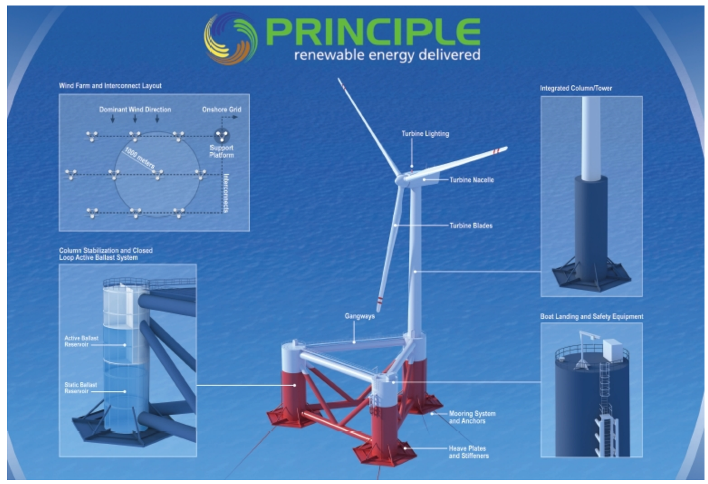
The WindFloat is fitted with patented water entrapment (heave) plates at the base of each column. The plates improve the motion performance of the system significantly due to damping and entrained water effects. This stability performance allows for the use of existing commercial wind turbine technology. 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.

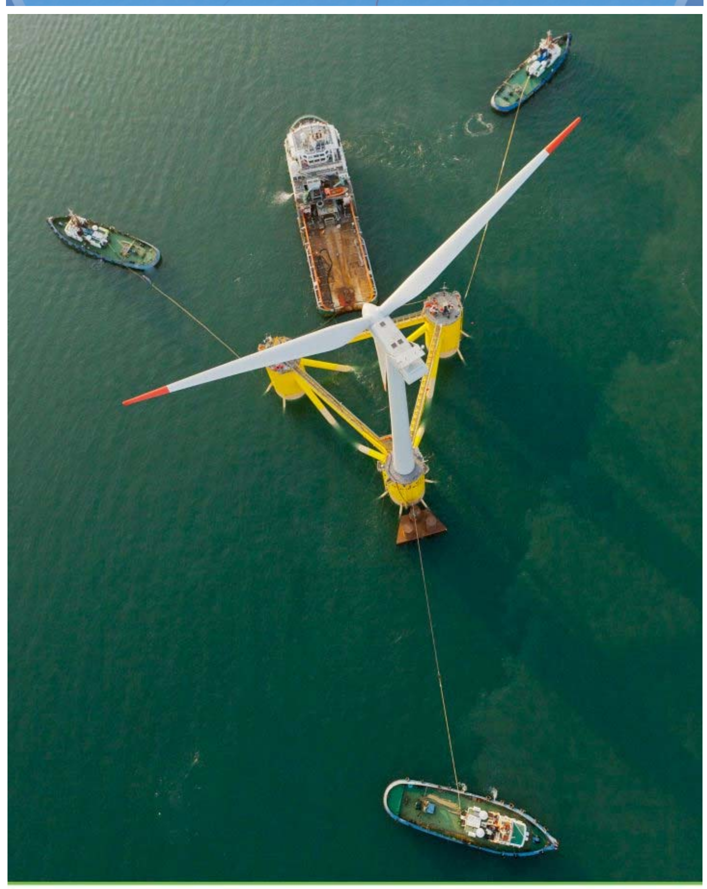
Specifications:

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.





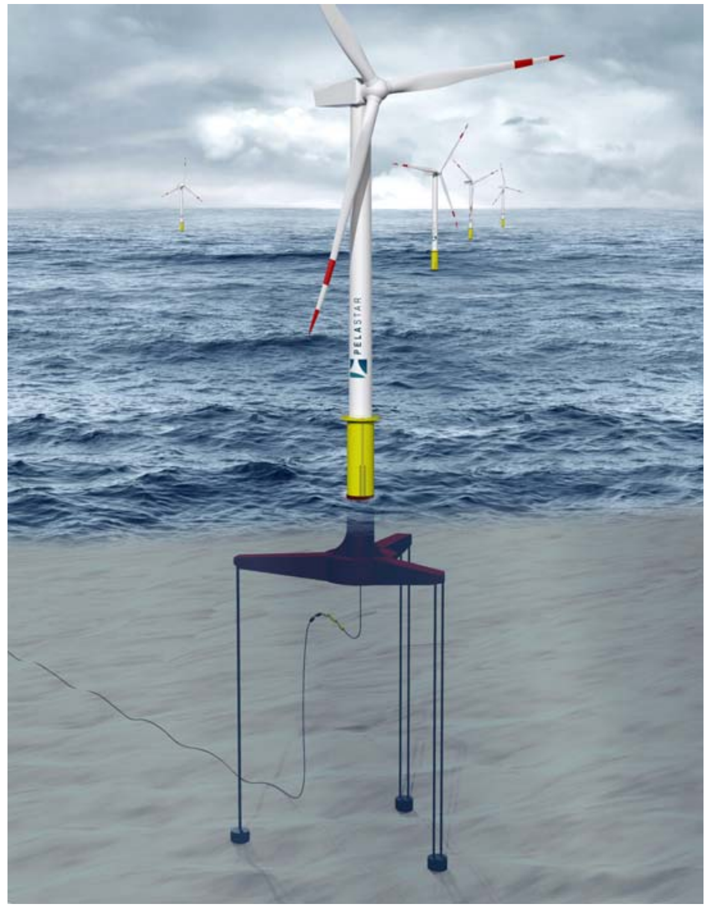
Aguçadoura WindFloat Prototype
October 2011 - Sado River near Setubal, Portugal

US Projects Fact Sheets

Pelastar (US)

(TLP)

http://www.pelastarwind.com/



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

<u>Key Features:</u>

- 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

Details available at http://www.glosten.com/PDFs Glosten_TLTP_Paper_2010.pdf

In July 2011, Glosten Associates announced plans to commercialize their PelaStar floating wind turbine platform, and make the technology available to the global offshore wind energy industry.

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. In this ongoing project, a detailed COE model is being built and vetted with substantial quantities of UK Round 2 and projected UK Round 3 cost data. The COE model is 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.

US Projects Fact Sheets

DeepCwind (US)

(TLP)

http://www.deepcwind.org

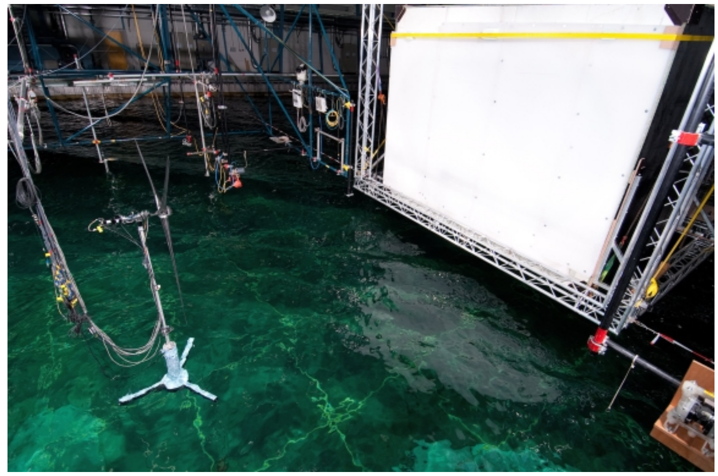
The DeepCwind Consortium's mission is to establish the State of Maine as a national leader in deepwater offshore wind technology through a research initiative funded by the U.S. Department of Energy, the National Science Foundation, and others. The University of Maine-led consortium includes universities, 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.

The primary objectives of the Floating Turbine Design task are to:

1. Partially validate the coupled aeroelastic/ hydrodynamic models developed by NREL.
2. Optimize platform designs by integrating more durable, lighter, hybrid composite materials.
3. Develop a complete design of one or more scale floating turbine platforms, capable of supporting a wind turbine in the 10 kW to 250 kW range for deployment at the University of Maine Deepwater Offshore Wind Test Site in 60 meter deep water.

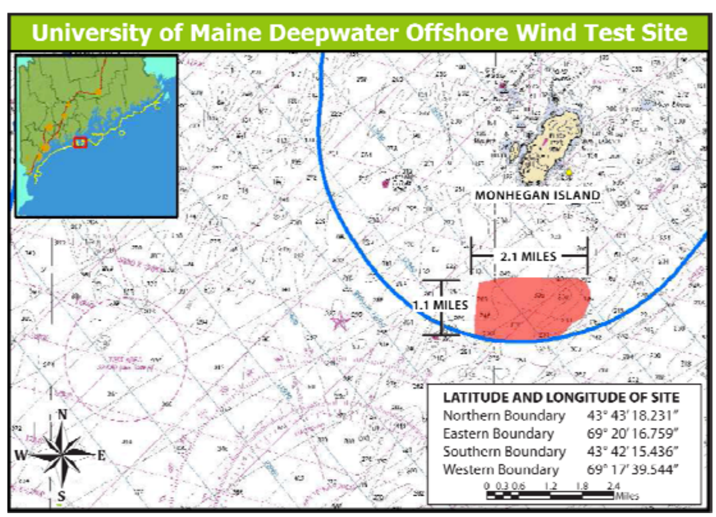
In February 2011 the University of Maine's Advanced Structures and Composites Center and the DeepCwind Consortium released the Maine Offshore Wind Report. The report contains extensive information on the wind conditions in the Gulf of Maine, one the US deep-water wind resource areas.

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.



Source: Marin

Source: University of Maine (AEWC)



Source: State of Maine Planning Office / University of Maine

US Projects Fact Sheets

AFT (US)

(Spar)

http://www.nauticawindpower.com/

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.

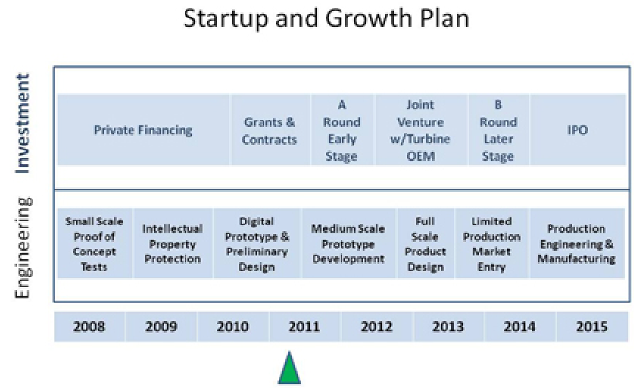
Nautica Windpower has also achieved significant milestones in scale testing of turbines in the actual wind and water environment. Initially, concepts were evaluated using small scale models of the tower in a water tank to investigate the static stability of various buoyant components. Later, larger scale 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.

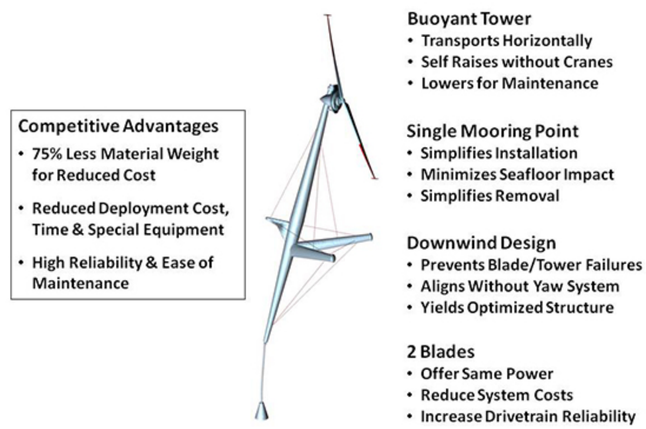
The tests in the Great Lakes demonstrated the outstanding stability of the AFT in rough water with positive clearances between the blades and the water surface for wave heights equal to 1/2 the rotor diameter. Such conditions significantly exceed the hurricane conditions of a full-scale AFT.

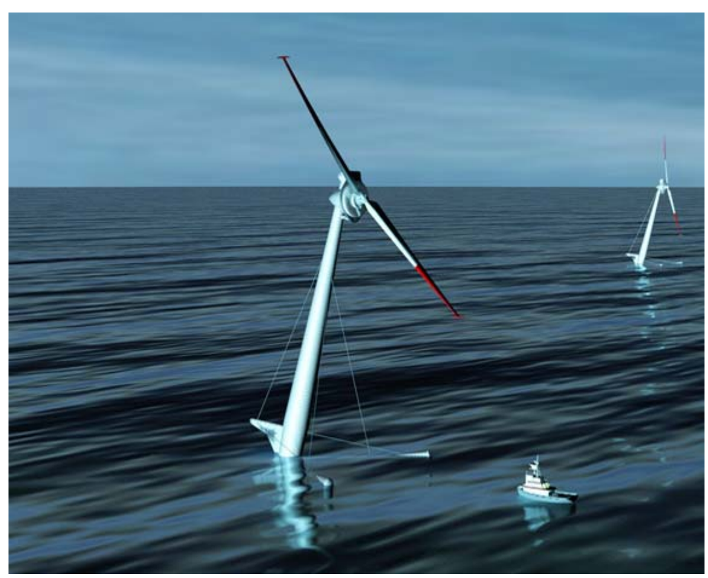
Next: Medium-Scale AFT

Nautical are 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 Windpower expects to enter the market with limited initial sales of a 5 megawatt floating offshore wind turbine in 2014.







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