Vessels and platforms for the emerging wind and wave power market
Cis Galicia 2010
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1. Offshore Wind Vessels

1.1. Introduction

With barely no new orders after the end of 2012, these are challenging times for European shipyards, and many of them are already wondering where they could find new market opportunities.

Offshore wind energy is a brand new industry with a huge growth potential. Only in Europe it grew by 56% in 2009. There are currently 830 offshore wind turbines now installed and connected to the grid, totalling 2,063 MW in 39 wind farms in nine European countries.

The European Wind Energy Association (EWEA) figures reveal that this is a fast-growing industry.

In 2010 a further 1,000 MW of offshore wind is expected to be installed, up 71% from the installations in 2009. Currently there are 16 offshore wind farms under construction, totalling over 3,500 MW and a further 52 wind farms have been fully consented, totalling more than 16,000 MW.

The development of large-scale offshore wind farms will require a significant flow of resources. In opposition to land-based installations, which are usually located in areas away from where production and assembly operations take place, offshore wind turbines and their components can be manufactured and installed in the harbour or in some other facilities nearby. This could facilitate transport from the place of production to the place of installation, thus avoiding the need to send big components by road. The offshore wind energy industry could invest over 150 million dollars in building offshore projects. Such offshore wind farms could in turn provide huge economic advantages to the local communities, by creating well-paid industrial employment throughout the region with the aim of expanding the manufacturing industry.

The offshore wind industry has gained new momentum in the past decades. The largest wind farm in the world was recently opened by Ventall Group off the UK coast. Offshore's Global Offshore Wind Farms Map and Database.

A primary challenge for offshore wind energy is cost reduction. Developing the necessary support infrastructure implies one-time costs for customized vessels, port and harbour upgrades, new manufacturing facilities, and workforce training. In general, capital costs are twice as high as land-based, but this may be partially offset by potentially higher energy yields – as much as 30% or more. As was experienced with land-based wind systems over the past two decades, offshore wind costs are expected to drop with greater experience, increased deployment, and improved technology. To make offshore wind energy more cost effective, some manufacturers are designing larger wind turbines capable of generating more electricity per turbine.

The graph below shows the projects available, the turbine supply and the estimated fleet capacity for the installation of these wind farms based on the estimated MW per year.

The lack of adequate vessels for the transportation, construction, installation and maintenance of offshore wind turbines may be a short-term barrier to develop these projects. Today oil and gas tankers are the most typically used vessels for the offshore wind industry, since they share some of the necessary features for the construction and installation phases. At least some modifications and improvements are required – as necessary – and they are not always available for the wind industry, due to the increasing demand of offshore oil exploration.

Leading installation contractors will be in extremely high demand in the future, due to their proven track records and the efficiency of their specialist vessels.
Some of the developers of these wind energy projects are taking measures to minimise the estimated risk of vessel supply by looking for long-term vessel hire agreements to cover a range of projects.

**Centrica Plc**, the leading energy supplier in the UK, managed to hire a vessel without crew for a two-year period, starting from January 2007. The contract establishes that the vessel may be used in projects run by Centrica for a number of years. The initial agreement implies that Centrica has a vessel available for the installation and maintenance of an offshore wind farm and Centrica provides subcontractors with this vessel for construction works.

Back in 2006 **DONG Energy** was also known to be looking for a vessel capable of installing 5 MW turbines for a project in Denmark and to carry on with other projects. In July 2009, Dong Energy bought **A2Sea**, the leading installation company.

The first heavy lift ships used by the offshore wind industry in Europe were built after the installation of offshore wind farms intensified.

In the year 2000, for example, the first shipowning company serving the offshore wind industry was created in Denmark. **A2Sea** had a market share of 60 per cent and since July 2009 has been 100% owned by **DONG Energy Power** (one of the leading energy suppliers in Northern Europe), but in November 2010 **Siemens Wind Power** (the world’s leading supplier of a wide range of products, solutions and services for power generation, transmission and distribution as well as for the production, conversion and transport of the primary fuels oil and gas) entered as part-owner.

There is a huge fleet of standard jack-up vessels (mainly used in the oil and gas industry) which could perform offshore wind energy works.

Each vessel may cost up to 200 million euros, totalling an investment of 2.4 billion euros. Accessing capital for building vessels requires strong and stable market conditions which can ensure return on investment. A five year ahead market visibility is needed to ensure financing. And looking at the current financial situation, financing these vessels becomes quite an issue.

### 1.2. Vessels for the installation of offshore wind farms

According to a 2009 EWEA report, these are the type of vessels required for building offshore wind farms.

<table>
<thead>
<tr>
<th>Vessel type</th>
<th>Vessel supply</th>
</tr>
</thead>
<tbody>
<tr>
<td>Survey vessels</td>
<td>Currently sufficient for market.</td>
</tr>
<tr>
<td>Used to survey the sea floor in preparation for the installation of an offshore wind farm. Smaller survey vessels are used to perform Environmental Impact Assessment studies and post-evaluation.</td>
<td></td>
</tr>
<tr>
<td>Turbine Installation Vessels</td>
<td>Three out of four in operation, three being built, 12 needed in total.</td>
</tr>
<tr>
<td>Custom built self propelled installation vessels that can carry multiple turbines at a time.</td>
<td>Extremely difficult to finance in the current climate.</td>
</tr>
<tr>
<td>Construction support vessels</td>
<td>Sufficient but supply dependent on demand from oil and gas sector.</td>
</tr>
<tr>
<td>Used to assist in the construction of offshore wind parks. Includes motorised and non-motorised jack up barges, barges, pontoons and platforms.</td>
<td></td>
</tr>
<tr>
<td>Work boats</td>
<td>Sufficient vessels.</td>
</tr>
<tr>
<td>Support the work of other vessels by providing supplies of tools and consumables to other boats.</td>
<td></td>
</tr>
<tr>
<td>Cable Laying vessels</td>
<td>Sufficient vessels.</td>
</tr>
<tr>
<td>For laying cables securely on the seabed.</td>
<td></td>
</tr>
<tr>
<td>Crew transfer vessels</td>
<td>Sufficient vessels.</td>
</tr>
<tr>
<td>To transfer crew and technicians.</td>
<td></td>
</tr>
</tbody>
</table>

**Vessels and platforms for the emerging wind and wave power market**
1.3. **Vessel types currently used in the offshore wind industry** *(source: 4coffshore)*

<table>
<thead>
<tr>
<th>Vessel Name</th>
<th>Company</th>
<th>Type</th>
<th>Turntable/Carousel</th>
<th>Max. Draft</th>
<th>Experience</th>
</tr>
</thead>
<tbody>
<tr>
<td>AMT Discoverer</td>
<td>Anchor Marine, Transportation</td>
<td>Cable lay barge</td>
<td>5500 Tones</td>
<td>6 m</td>
<td>Greater Gabbard, Rhyl Flats, Thanet</td>
</tr>
<tr>
<td>AMT Explorer</td>
<td>Anchor Marine, Transportation</td>
<td>Cable lay barge</td>
<td>7000 Tones</td>
<td>3 m</td>
<td>Rhyl Flats</td>
</tr>
<tr>
<td>Eide Barge 28</td>
<td>Eide Marine Services A/S</td>
<td>Cable lay barge</td>
<td>4600 Tones</td>
<td>Max. Draft:</td>
<td>Gunfleet Sands</td>
</tr>
<tr>
<td>Eide Barge 32</td>
<td>Eide Marine Services A/S</td>
<td>Cable lay barge</td>
<td>2600 Tones</td>
<td>5 m</td>
<td></td>
</tr>
<tr>
<td>Henry P. Lading</td>
<td>JD - Contractor A/S</td>
<td>Cable lay barge</td>
<td>1800 Tones</td>
<td>3 m</td>
<td>Horns Rev, Tuno Knob, Horns Rev 2, Rødsand 1</td>
</tr>
<tr>
<td>Polar Prince</td>
<td>Subocean</td>
<td>Cable lay barge</td>
<td>700 Tones</td>
<td>7 m</td>
<td>Greater Gabbard, Thanet</td>
</tr>
<tr>
<td>UR 101</td>
<td>Subocean</td>
<td>Cable lay barge</td>
<td>1000 Tones</td>
<td>5 m</td>
<td>Inner Dowsing, Lynn, Robin Rigg, Thanet</td>
</tr>
<tr>
<td>CS FU AN (formally CS Wave Mercury, Lodbrog &amp; Mercandian President)</td>
<td>North Sea Shipping</td>
<td>Cable laying ship</td>
<td></td>
<td>6 m</td>
<td></td>
</tr>
<tr>
<td>CS Fu Hai</td>
<td>SBSS</td>
<td>Cable laying ship</td>
<td></td>
<td>9 m</td>
<td></td>
</tr>
<tr>
<td>Vessel Name</td>
<td>Company</td>
<td>Type</td>
<td>Turntable/Carousel (Tonnes)</td>
<td>Max. Draft (m)</td>
<td>Experience</td>
</tr>
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<td>-----------------------------------------------------------------------------</td>
</tr>
<tr>
<td>CS Pleijel</td>
<td>Baltic Offshore</td>
<td>Cable laying ship</td>
<td>900</td>
<td></td>
<td>Experience: Lillgrund</td>
</tr>
<tr>
<td>CS Sovereign</td>
<td>North Sea Shipping</td>
<td>Cable laying ship</td>
<td>7000</td>
<td>9</td>
<td>Experience: Thornton Bank phase I, Horns Rev 2, Primes Amaliawindpark, Barrow, Beatrice Demonstration</td>
</tr>
<tr>
<td>Maersk Recorder</td>
<td>CTC Marine Ltd</td>
<td>Cable laying ship</td>
<td>2000</td>
<td>9</td>
<td>Max.Draft:</td>
</tr>
<tr>
<td>Maersk Responder</td>
<td>CTC Marine Ltd</td>
<td>Cable laying ship</td>
<td>2000</td>
<td>9</td>
<td>Max.Draft:</td>
</tr>
<tr>
<td>Nexans Skagerrak</td>
<td>Nexans</td>
<td>Cable laying ship</td>
<td>7000</td>
<td>9</td>
<td>Experience: Belwind Phase I</td>
</tr>
<tr>
<td>Team Oman (formally Team Sea Spider)</td>
<td>NICO Middle East Ltd</td>
<td>Cable laying ship</td>
<td>4800</td>
<td>4</td>
<td>Experience: Horns Rev 2, Sheringham Shoal</td>
</tr>
<tr>
<td>Rambiz</td>
<td>Scaldis</td>
<td>Catamaran</td>
<td>3300</td>
<td></td>
<td>Experience: Thornton Bank phase I, Inngoy Nordsee Ost, Nysted, Redsand II, Gunfleet Sands, Ormonde, Walney Phase 1, Beatrice Demonstration</td>
</tr>
<tr>
<td>Svanen</td>
<td>Ballast Nedam</td>
<td>Catamaran</td>
<td>8700</td>
<td></td>
<td>Experience: Belwind Phase I, Anholt, Offshore Windpark Egmond aan Zee, Gunfleet Sands, Rhyl Flats, Sheringham Shoal, Walney Phase 2</td>
</tr>
<tr>
<td>MV NICO</td>
<td>CT Offshore A/S</td>
<td>Fast supply vessel</td>
<td>25</td>
<td>2</td>
<td>Max.Draft:</td>
</tr>
<tr>
<td>Upstalsboom</td>
<td>Prokon Nord</td>
<td>Jack-up</td>
<td></td>
<td></td>
<td>Max.Draft:</td>
</tr>
<tr>
<td>Vessel</td>
<td>Owner</td>
<td>Type</td>
<td>Max. Lift</td>
<td>Max. Draft</td>
<td>Experience</td>
</tr>
<tr>
<td>--------</td>
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<td>------------</td>
</tr>
<tr>
<td>Buzzard</td>
<td>GeoSea / Deme</td>
<td>Jack-up</td>
<td>3 m</td>
<td>3 m</td>
<td>Thornton Bank phase I, Alpha Ventus, Horns Rev</td>
</tr>
<tr>
<td>Endeavour</td>
<td>Gulf Marine Services</td>
<td>Jack-up</td>
<td>300 Tonnes</td>
<td>4 m</td>
<td></td>
</tr>
<tr>
<td>Endurance</td>
<td>Gulf Marine Services</td>
<td>Jack-up</td>
<td>300 Tonnes</td>
<td>4 m</td>
<td></td>
</tr>
<tr>
<td>Goliath</td>
<td>GeoSea / Deme</td>
<td>Jack-up</td>
<td>300 Tonnes</td>
<td>4 m</td>
<td>Alpha Ventus, Walney Phase 1</td>
</tr>
<tr>
<td>JB - 114</td>
<td>Jack-up Barge BV</td>
<td>Jack-up</td>
<td>300 Tonnes</td>
<td>4 m</td>
<td>Belwind Phase I, Alpha Ventus</td>
</tr>
<tr>
<td>JB - 115</td>
<td>Jack-up Barge BV</td>
<td>Jack-up</td>
<td>300 Tonnes</td>
<td>4 m</td>
<td>Belwind Phase I, Alpha Ventus</td>
</tr>
<tr>
<td>JB - 116</td>
<td>Jack-up Barge BV</td>
<td>Jack-up</td>
<td>300 Tonnes</td>
<td>4 m</td>
<td></td>
</tr>
<tr>
<td>JB - 117</td>
<td>Jack-up Barge BV</td>
<td>Jack-up</td>
<td>1000 Tonnes</td>
<td>4 m</td>
<td></td>
</tr>
</tbody>
</table>

*Vessels and platforms for the emerging wind and wave power market*
<table>
<thead>
<tr>
<th>Vessel Name</th>
<th>Owner</th>
<th>Type</th>
<th>Max. Lift</th>
<th>Max. Draft</th>
<th>Experience</th>
</tr>
</thead>
<tbody>
<tr>
<td>KS Titan 2</td>
<td>KS Energy Services</td>
<td>Jack-up</td>
<td>300 Tonnes</td>
<td>3 m</td>
<td>Gunfleet Sands</td>
</tr>
<tr>
<td>Lisa-A</td>
<td>Hapo International Barges/Smit</td>
<td>Jack-up</td>
<td>600 Tonnes</td>
<td>4 m</td>
<td>Burbo Bank, Rhyl Flats</td>
</tr>
<tr>
<td>Norma</td>
<td>GeoSea / Deme</td>
<td>Jack-up</td>
<td>440 Tonnes</td>
<td>3 m</td>
<td></td>
</tr>
<tr>
<td>Odin</td>
<td>Hochtief Construction</td>
<td>Jack-up</td>
<td>300 Tonnes</td>
<td>6 m</td>
<td>Alpha Ventus</td>
</tr>
<tr>
<td>Pauline (SEA-900)</td>
<td>Besix</td>
<td>Jack-up</td>
<td></td>
<td>2 m</td>
<td>Barrow</td>
</tr>
<tr>
<td>Sea Jack (formally the Jumping Jack)</td>
<td>A2SEA/DONG</td>
<td>Jack-up</td>
<td>800 Tonnes</td>
<td>4 m</td>
<td>Horns Rev 2, Arklow Bank Phase 1, Prinses Amaliawindpark, Burbo Bank, Docking Shoal, Greater Gabbard, Ormonde, Race Bank, Scroby Sands, Thanet</td>
</tr>
<tr>
<td>Seabreeze 1</td>
<td>RWEI (RWE Innogy)</td>
<td>Jack-up</td>
<td></td>
<td></td>
<td>Innogy Nordsee Ost</td>
</tr>
<tr>
<td>Vessel Name</td>
<td>Owner/Operator</td>
<td>Type</td>
<td>Max. Lift</td>
<td>Max. Draft</td>
<td>Experience</td>
</tr>
<tr>
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<td>------------------------------------------------</td>
</tr>
<tr>
<td><strong>Seabreeze 2</strong></td>
<td><strong>RWEI (RWE Innogy)</strong></td>
<td>Jack-up</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Seacore Excalibur</strong></td>
<td><strong>(formerly the Wijslift 6)</strong></td>
<td>Jack-up</td>
<td>220 Tonnes</td>
<td></td>
<td><strong>Greater Gabbard, Gunfleet Sands, Gwynt Y Mor, Kentish Flats, London Array Phase 1, North Hoyle, Cromer</strong></td>
</tr>
<tr>
<td><strong>Seafox 1</strong></td>
<td><strong>Workfox BV Ltd</strong></td>
<td>Jack-up</td>
<td>300 Tonnes</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Seafox 2</strong></td>
<td><strong>Workfox BV Ltd</strong></td>
<td>Jack-up</td>
<td>280 Tonnes</td>
<td>4 m</td>
<td></td>
</tr>
<tr>
<td><strong>Thor</strong></td>
<td><strong>Hochtief Construction</strong></td>
<td>Jack-up</td>
<td>500 Tonnes</td>
<td>7 m</td>
<td><strong>Rødsand II</strong></td>
</tr>
<tr>
<td><strong>Vagant (SEA-800)</strong></td>
<td><strong>GeoSea / Deme</strong></td>
<td>Jack-up</td>
<td></td>
<td>4 m</td>
<td><strong>Thornton Bank phase I, Samso, Walney Phase 1</strong></td>
</tr>
<tr>
<td><strong>Wind (NG-600)</strong></td>
<td><strong>Dansk bjergning og bugsering</strong></td>
<td>Jack-up</td>
<td></td>
<td>2 m</td>
<td><strong>Horns Rev</strong></td>
</tr>
<tr>
<td><strong>Beluga Hochtief Offshore</strong></td>
<td><strong>(Newbuild 1)</strong></td>
<td>Jack-up vessel</td>
<td>1500 Tonnes</td>
<td>7 m</td>
<td><strong>Global Tech I</strong></td>
</tr>
<tr>
<td><strong>Beluga Hochtief Offshore</strong></td>
<td><strong>(Newbuild 2)</strong></td>
<td>Jack-up vessel</td>
<td>1500 Tonnes</td>
<td>7 m</td>
<td></td>
</tr>
<tr>
<td><strong>Beluga Hochtief Offshore</strong></td>
<td><strong>(Newbuild 3)</strong></td>
<td>Jack-up vessel</td>
<td>1500 Tonnes</td>
<td>7 m</td>
<td></td>
</tr>
<tr>
<td>Vessels and platforms for the emerging wind and wave power market</td>
<td></td>
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</tr>
</tbody>
</table>
| **Beluga Hochtief Offshore**  
**Newbuild 4** | Jack-up vessel  
Max.Lift: 1500 Tonnes  
Max.Draft: 7 m |
| **Deepwater Installer**  
Gaoh Offshore | Jack-up vessel  
Max.Lift: 1600 Tonnes  
Max.Draft: 6 m |
| **Haven**  
(formally called L205, service jack 1 and JackTel)  
Master Marine | Jack-up vessel  
Max.Lift:  
Max.Draft: 7 m  
Type: Jack-up vessel |
| **MPI Resolution**  
MPI | Jack-up vessel  
Max.Lift: 300 Tonnes  
Max.Draft: 4 m  
Experience: Barrow, Burbo Bank, Gunfleet Sands, Inner Dowsing, Kentish Flats, Lincs, Lynn, North Hoyle, Rhyl Flats, Robin Rigg, Thanet |
| **MV Adventure**  
MPI / Vroon | Jack-up vessel  
Max.Lift: 1000 Tonnes  
Max.Draft: 6 m  
Experience: London Array Phase 1 |
| **MV Discovery**  
MPI / Vroon | Jack-up vessel  
Max.Lift: 1000 Tonnes  
Max.Draft: 6 m |
| **New Build (NG-9000)**  
Fred Olsen Windcarrier  
(owned by Granger Rolf ASA and Bonheur ASA) | Jack-up vessel  
Max.Lift: 800 Tonnes  
Max.Draft: 6 m |
| **New Build (NG-9000)**  
Fred Olsen Windcarrier  
(owned by Granger Rolf ASA and Bonheur ASA) | Jack-up vessel  
Max.Lift: 800 Tonnes  
Max.Draft: 6 m |
| **Nora**  
(formally called L206 and Service Jack 2)  
Master Marine | Jack-up vessel  
Max.Lift: 1500 Tonnes  
Max.Draft: 7 m  
Experience: Sheringham Shoal |
| **Sea Energy**  
(formally Ocean Adv)  
A2SEA/DONG | Jack-up vessel  
Max.Lift: 450 Tonnes  
Max.Draft: 4 m  
Experience: Arkona Becken Sudost, Horns Rev, Nysted, Prinses Amaliawindpark, Offshore Windpark Egmond aan Zee, Kentish Flats, Robin Rigg, Scroby Sands |
| **Sea Installer**  
A2SEA/DONG | Jack-up vessel  
Max.Lift: 900 Tonnes  
Max.Draft: |
| **Sea Power**  
A2SEA/DONG | Jack-up vessel  
Max.Lift: 450 Tonnes  
Max.Draft: 4 m  
Experience: Alpha Ventus, EnBW Baltic 1, Horns Rev, Frederikshavn, Horns Rev 2, Rødsand II, Arklow Bank Phase |
<table>
<thead>
<tr>
<th>Vessels</th>
<th>Jack-up vessel</th>
<th>Max.Lift</th>
<th>Max.Draft</th>
<th>Experience</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Seafax 5</strong>&lt;br&gt;Workfox BV Ltd</td>
<td>Jack-up vessel</td>
<td>1200 T</td>
<td>Max.Draft:</td>
<td><strong>1. Offshore Windpark Egmond aan Zee, Lillgrund, Kentish Flats</strong></td>
</tr>
<tr>
<td><strong>Seajacks Kraken</strong>&lt;br&gt;Seajacks (Purchased by Riverstone Holdings LLC)</td>
<td>Jack-up vessel</td>
<td>300 T</td>
<td>4 m</td>
<td>Experience: <strong>Walney Phase 1, Walney Phase 2</strong></td>
</tr>
<tr>
<td><strong>Seajacks Leviathan</strong>&lt;br&gt;Seajacks (Purchased by Riverstone Holdings LLC)</td>
<td>Jack-up vessel</td>
<td>300 T</td>
<td>4 m</td>
<td>Experience: <strong>Greater Gabbard, Walney Phase 2</strong></td>
</tr>
<tr>
<td><strong>Seaworker (formally JB - 109 purchased from jack up barge B.V. in 2008)</strong>&lt;br&gt;A2SEA/DONG</td>
<td>Jack-up vessel</td>
<td>400 T</td>
<td>Max.Draft:</td>
<td>Experience: <strong>EnBW Baltic 1, Gunfleet Sands, London Array Phase 1, Robin Rigg, Walney Phase 1</strong></td>
</tr>
<tr>
<td><strong>Swire Blue Ocean</strong>&lt;br&gt;Swire Blue Ocean</td>
<td>Jack-up vessel</td>
<td>1200 T</td>
<td>6 m</td>
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<tr>
<td><strong>Wind Lift 1</strong>&lt;br&gt;Bard Engineering</td>
<td>Jack-up vessel</td>
<td>500 T</td>
<td>6 m</td>
<td>Experience: <strong>BARD Offshore 1</strong></td>
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<td><strong>Zaratan</strong>&lt;br&gt;Seajacks (Purchased by Riverstone Holdings LLC)</td>
<td>Jack-up vessel</td>
<td>800 T</td>
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<td><strong>Aenergy Borealis</strong>&lt;br&gt;Aenergy</td>
<td>Monohull</td>
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<td>12 m</td>
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<td>Vessel Name</td>
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<td>Type</td>
<td>Max. Lift</td>
<td>Max. Draft</td>
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<td>DB 30</td>
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<td>Monohull</td>
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<td>J.Ray McDermott</td>
<td>Monohull</td>
<td>6350 Tonnes</td>
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<td>Oleg Strashnov</td>
<td>Seaway Heavy Lifting</td>
<td>Monohull</td>
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<td>OSA Goliath</td>
<td>Coastline Maritime</td>
<td>Monohull</td>
<td>2000 Tonnes</td>
<td>10 m</td>
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<td>OSA Highlander</td>
<td>Scottish Highlands International</td>
<td>Monohull</td>
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<td>Saipem 3000</td>
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<td>Monohull</td>
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<td>Sapura 3000</td>
<td>Sapura / Acergy</td>
<td>Monohull</td>
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<td>Stanislav Yudin</td>
<td>Seaway Heavy Lifting</td>
<td>Monohull</td>
<td>2500 Tonnes</td>
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<tr>
<td>Asian Hercules II</td>
<td>Asian Lift (Smit and Keppel Fels)</td>
<td>Monohull</td>
<td>3200 Tonnes</td>
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Vessels and platforms for the emerging wind and wave power market
<table>
<thead>
<tr>
<th>Vessel Name</th>
<th>Type</th>
<th>Max Lift</th>
<th>Max Draft</th>
<th>Experience</th>
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<tr>
<td>ENAK</td>
<td>Monohull - Floating sheerleg crane</td>
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<td>2 m</td>
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<tr>
<td>Bugsier Shipping &amp; Salvage</td>
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<tr>
<td>Matador 3 Bonn &amp; Mees</td>
<td>Monohull - Floating sheerleg crane</td>
<td>1500 Tonnes</td>
<td>6 m</td>
<td>EnBW Baltic 1, Horns Rev 2, Barrow, Greater Gabbard</td>
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<tr>
<td>Mersey Mammoth Peel Ports</td>
<td>Monohull - Floating sheerleg crane</td>
<td>250 Tonnes</td>
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<td>Samson Danish Salvage &amp; Towing Company DBB</td>
<td>Monohull - Floating sheerleg crane</td>
<td>900 Tonnes</td>
<td>6 m</td>
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<tr>
<td>Taklift 4 Smit</td>
<td>Monohull - Floating sheerleg crane</td>
<td>1600 Tonnes</td>
<td>6 m</td>
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<td>Nautilus Maxi Seløy under water service A/S</td>
<td>Multi purpose / cable lay barge</td>
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<td>Liligrund</td>
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<td>Oceanteam Installer Oceanteam</td>
<td>Multi purpose / cable lay barge</td>
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<tr>
<td>Pontra Maris Stemat Marine Services</td>
<td>Multi purpose / cable lay barge</td>
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<td></td>
<td>Horns Rev 2, Barrow, Kentish Flats, North Hoyle</td>
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<td>Stemat 82 Stemat Marine Services</td>
<td>Multi purpose / cable lay barge</td>
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<td>Alpha Ventus, Horns Rev 2, Walney Phase 1</td>
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<td>Vessel Name</td>
<td>Company</td>
<td>Description</td>
<td>Details</td>
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<td><strong>Stemat Oslo</strong>&lt;br&gt;Stemat Marine Services</td>
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<td><strong>Aker Connector</strong>&lt;br&gt;Aker Solutions</td>
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<td><strong>Atlantic Guardian</strong>&lt;br&gt;ATL Guardian AS</td>
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<td><strong>Cable Innovator</strong>&lt;br&gt;Global Marine Systems</td>
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<td><strong>CS Wave Sentinel</strong>&lt;br&gt;North Sea Shipping</td>
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<td><strong>CS Wave Venture</strong>&lt;br&gt;North Sea Shipping</td>
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<td><strong>Far Saga</strong>&lt;br&gt;Acergy</td>
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<td><strong>M/V Volantis</strong>&lt;br&gt;Volstad Maritime AS</td>
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<td><strong>MV SIA (formally the Claymore)</strong>&lt;br&gt;CT Offshore A/S</td>
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**Vessels and platforms for the emerging wind and wave power market**
<table>
<thead>
<tr>
<th>Vessel Name</th>
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<th>Type</th>
<th>Max. Lift</th>
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<th>Experience</th>
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<td>Siem Carrier</td>
<td>Siem Offshore inc</td>
<td>Multi purpose offshore support vessel</td>
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<td>Stemat Spirit</td>
<td>Stemat Marine Services</td>
<td>Multi purpose offshore support vessel</td>
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<td></td>
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<td></td>
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<td>Max. Draft: 5 m</td>
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<td>Balder</td>
<td>Heerema Marine Contractors</td>
<td>Semi-submersible floating platform</td>
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<td>DB 101</td>
<td>J.Ray McDermott</td>
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<td>Max. Lift: 38 m</td>
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<td>Saipem 7000</td>
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<td>Alpha Ventus</td>
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<td>Acergy Discovery</td>
<td>Acergy</td>
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<td></td>
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</tr>
<tr>
<td>Acergy Pertinacia</td>
<td>Acergy</td>
<td>Subsea Construction Vessel</td>
<td>2400 Tonnes</td>
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<td>Turntable/Carousel: Max. Draft: 7 m</td>
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<tr>
<td>Fairplayer</td>
<td>Jumbo Shipping</td>
<td>Subsea Construction Vessel</td>
<td>1800 Tonnes</td>
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Vessels and platforms for the emerging wind and wave power market
New ship designs for offshore wind farms

The target of 40 GW of offshore wind in the EU by 2020 requires that new offshore installation vessels be built. These new vessels must have a capacity for at least 10 turbines, 10 blade sets and 10 sections, and twelve installation vessels will be required.

To increase the number of days of operation to 260-290 a year, such vessels must be able to install offshore wind farms in medium water depths (30-40m and beyond) and operate in very harsh conditions. At the very best, these vessels should be able to carry assembled subsystems, or even a set of assembled turbines, in order to limit the number of operations performed at sea.

These types of vessel, e.g. the Gaoh, are currently being developed. The Gaoh is designed to lift 18 x 3,6 MW turbines at 45m depths, including sea bed penetration.

It belongs to Gaoh Offshore Limited, a Credit Suisse owned company which has specialized in the installation of wind farms offshore.

IHC Merwede is getting ready for the expansion of the offshore wind industry. The Dutch company is building new vessels which include new innovative technologies related to turbine installation artwork, Jacket Installation, Blade Installation System, Turbine Installation Vessel.

Vroon has recently ordered two installation vessels—the MPI ADVENTURE and the MPI DISCOVERY—, currently under construction at the Cosco Nantong Shipyard in China, and two additional offshore wind farm service vessels: HULL No. SCC028 and HULL No. SCC037. They will be built at the South Boats Medina Shipyard on the Isle of Wight, UK in 2011.

The first Norwegian purpose built boat has already been ordered at a yard — Måløy Verft — by Offshore Windservice ApS, a Danish company that owns and operates services vessels for the offshore windmill industry. The vessel will be named «FOB Swath» and is the first 27-meter semi-submersible catamaran specifically designed to operate in offshore wind farms. The boat is 27 metres long, 9.6 meters wide and will weigh around 60 tons. It can accommodate 24 service
personnel and carry up to 10 tons of weight. The project is expected to be completed in October 2010.

HOCHTIEF and Beluga Shipping (Beluga Hochtief) have commissioned the construction of 3 jack-up vessels from the Polish shipyard Crist.

Master Marine has recently commissioned the construction of a self-contained jack-up vessel, Nora, to Drydocks World at its Graha shipyard in Indonesia. It was designed by Global Maritime. Nora is 111.8 m long and capable of carrying up to 260 people. The vessel’s service jacks are self-driven and equipped with DP2, two pedestal crane each with 750-tonne capacity and a large open deck area of 2,500 sq. m.
Fred. Olsen Windcarrier AS was established in the beginning of 2008 to meet the increasing demand for offshore wind turbine installation vessels and related marine service vessels. In February 2010 the company placed an order with the Lamprell shipyard for two self elevating installation vessels.

Turbine Transfers Ltd, one of the leading providers of support vessels to the offshore windfarm industry, based in Holyhead, has chosen BMT Nigel Gee Ltd as the designers of its new series of multi-purpose Wind Farm Support Vessels: Turbine Access System, 17m Wind Farm Support Vessel E4079, 20m Wind Farm Support Vessel E4079, and 24 m Wind Farm Support Vessel E4079.
DONG Energy recently acquired A2Sea, and is currently designing the “SEA INSTALLER”, an offshore wind turbine installation jack-up vessel.

BARD and RWE Innogy are currently building their own customized installation vessels.

Voith is developing a new marine propulsion system for installation into a special vessel used for setting up offshore wind parks.
Seajacks also intends to construct two new jack-up vessels by 2012. Offshore Wind Power Marine Services will build the CSS Accommodator and it ensures the construction of new vessels by announcing a joint venture with Brook Henderson Group.

The Ulstein Group started as a small ship repair yard and gradually became a trendsetter in ship design. As regards the offshore wind industry, Ulstein Group introduced two new wind installation concepts: the Windlifter and F2F.

Austral is an Australian company which has recently unveiled a new range of high speed transfer vessels specifically designed for the offshore wind farm industry.

In the UK, Submarine Technology Limited launched Neptune, an access system for the offshore wind energy industry.

WindFlip is a specialized barge for transporting a fully assembled offshore wind turbine. The concept was developed by a group of students at the Norwegian University of Science and Technology.

In the US, Bluewater Wind intends to construct three wind turbine installation vessels at Aker Philadelphia Shipyard. The total project cost is $450 million.

Glosten Associates is a participant in a separate plan to construct similar vessels at the Keppel AmFELS shipyard in Brownsville, Texas. That group is trying to raise all of the investment money privately and plans to start with just one boat. The vessel would be purpose-built for transporting and installing wind turbines, plus conducting major maintenance and repairs. Code-named the KATI, it is designed to be able to transport three 6-MW wind units at a time and install them in water as deep as 200 feet.

1.4. Offshore wind vessels: patents

The patents listed below are from the Espacenet database, which allows us to search patents worldwide through more than 40 million documents.
The search was conducted by combining the keywords “vessel” and “wind turbines” and the IPC (International Patent Classification) codes referring to this technology. In this case, the following codes:

- **B63B 35/00**
Vessels or like floating structures adapted for special purposes (vessels characterised by load-accommodating arrangements B63B 25/00; fire-fighting vessels A62C 29/00; submarines, mine-layers, or mine-sweepersB63G; large containers for use in or under water B65D 88/78)

- **B66C**
CRANES; LOAD-ENGAGING ELEMENTS OR DEVICES CRANES, CAPSTANS, WINCHES, OR TACKLES (rope, cable, or chain winding mechanisms, braking or detent devices therefor B66D; specially adapted for nuclear reactors G21)

- **E02B 17/00**
Artificial islands mounted on piles or like supports, e.g. platforms on raisable legs; Construction methods therefor (fenders E02B 3/26; anchoring floating platforms B63B 21/00; floating platforms, e.g. anchored, B63B 35/44; independent underwater structures E02D 29/00)

- **F03D**
WIND MOTORS

Thirty-one patents were found, four of which were issued by Vestas Wind Systems. There are also other wind energy companies with a significant number of patents, such as Gene Electric and Tokyo Electric Power.

2008 was the year when more patents were filed (10 patents), while in 2010 there was only one patent filed by China’s Wuchang shipyard.

It is worth noting that the Chinese Wuchang Shipbuilding Industry Shipyard is the only shipyard holding a patent for this type of boats.

In the tables listing the patent titles you will find a hyperlink which grants access to a summary page. This summary page was obtained from the public access Espacenet patent database.
<table>
<thead>
<tr>
<th>Patent ID</th>
<th>Title</th>
<th>Inventor/Company</th>
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<tbody>
<tr>
<td>US2010170429(A1)</td>
<td>Method for Transporting, Erecting and Replacing a Nacelle Including the Rotor of an Offshore Wind Turbine and Watercraft for Carrying Out the Method</td>
<td>AERODYN ENG GMBH [DE]</td>
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<td>CN101318542(A)</td>
<td>Integral safety carrying method on the sea for wind power generator set</td>
<td>CHINA NAT OFFSHORE OIL CORP [CN]</td>
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<tr>
<td>US7112010(B1)</td>
<td>Apparatus, systems and methods for erecting an offshore wind turbine assembly</td>
<td>GEIGER WILLIAM CLYDE [US]</td>
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<td>CN101602395(A)</td>
<td>System and method for transporting wind turbine tower sections on a shipping vessel</td>
<td>GEN ELECTRIC [US]</td>
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<td>US2009028647(A1)</td>
<td>Installation Of Offshore Structures</td>
<td>IHC ENGINEERING BUSINESS LTD [GB]</td>
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<tr>
<td>EP2251254(A1)</td>
<td>Installation vessel for offshore wind turbines</td>
<td>LEENARS Cees Eugen Jochem [NL]</td>
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<td>WO2010048560(A2)</td>
<td>OFFSHORE WIND TURBINES AND DEPLOYMENT METHODS THEREFOR</td>
<td>LEW HOLDINGS LLC [US]; WEAVER LLOYD E [US]</td>
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<td>WO2009068031(A1)</td>
<td>SEABORNE TRANSPORTATION OF WIND TURBINE BLADES</td>
<td>LM GLASFIBER AS [DK]; GRABAU Peter [DK]</td>
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<td>EP1611005(A2)</td>
<td>A VESSEL FOR TRANSPORTING WIND TURBINES, METHODS OF MOVING A WIND TURBINE, AND A WIND TURBINE FOR AN OFF-SHORE WIND FARM</td>
<td>LOGIMA V S Vend EriK Hansen</td>
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<td>US2004042876(A1)</td>
<td>Method and apparatus for placing at least one wind turbine on open water</td>
<td>MAMMOET MARINE V V I O [NL]</td>
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<td>CN101778757(A)</td>
<td>Construction method and construction rig of floating wind turbine generator</td>
<td>MITSUBISHI HEAVY IND LTD</td>
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<td>US2005163616(A1)</td>
<td>Methods of mounting a wind turbine, a wind turbine foundation and a wind turbine assembly</td>
<td>MORTENSEN HENRIK K, VESTAS WIND SYSTEMS A/S</td>
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<td>WO2010062188(A1)</td>
<td>A MARINE TRANSPORT SYSTEM AND METHOD FOR USING SAME</td>
<td>NORWIND AS [NO]; OSTVIK IVAN [NO]; ARNESEN TRYGVE [NO]</td>
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<td>JP2009013829(A)</td>
<td>CATAMARAN FOR INSTALLING OFFSHORE WIND POWER GENERATION DEVICE AND INSTALLATION METHOD OF THE OFFSHORE WIND POWER GENERATION DEVICE</td>
<td>PENTA OCEAN CONSTRUCTION; TOKYO ELECTRIC POWER CO</td>
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<td>WO2004070119(A1)</td>
<td>METHOD FOR OFFSHORE INSTALLATION OF A WIND TURBINE</td>
<td>SAIPEM SA [FR]; FARGIER CYRILLE [FR]; GOALABRE JEAN-YVES [FR]</td>
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<td>DE10332382(A1)</td>
<td>Erection device for a wind energy installation has a mast, a transport platform, a mounting unit, a supporting structure and deflection pulleys</td>
<td>SCHIFFAHRTSKONTOR ALTES LAND G [DE]</td>
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<td>WO2009121792(A2)</td>
<td>MAINTENANCE PLATFORM FOR WIND TURBINES</td>
<td>SKYSPIDER APS [DK]; LOTT KENNETH SKOVBO [DK]</td>
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<td>GB2462602(A)</td>
<td>Towing an offshore wind turbine in an inclined position</td>
<td>STATOILHYDRO ASA [NO]</td>
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<td>WO2009153530(A2)</td>
<td>STRUCTURE FOR THE OFFSHORE INSTALLATION OF AT LEAST ONE WIND TURBINE OR UNDERWATER GENERATOR, AND</td>
<td>TECHNIP FRANCE [FR]; CHOLLEY JEAN-MARC [FR];</td>
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</table>

*Vessels and platforms for the emerging wind and wave power market*
1.5. Offshore wind vessels: scientific papers

Dp pipe-laying and crane barge: procedure for defining operational window and capability plots using dynamic simulations

Author(s): Tannuri EA, Silva JLB, Oshiro AT, Saad AC  Book Group Author(s): ASME  Source: OMAE 2009, VOL 1 - OFFSHORE TECHNOLOGY  Pages: 579-588

Published: 2009

Conference Information: 28th International Conference on Ocean, Offshore and Arctic Engineering Honolulu, HI, MAY 31-JUN 05, 2009 ASME, Ocean, Offshore & Arctic Engn Div

Abstract: Special station-keeping requirements must be defined for a safe operation of a DP pipe-laying and crane barge. When a pipe is being laid in shallow waters, small displacements of the launching ramp may induce large forces on the pipe or even to deviate it from the defined route. Offshore crane operations are performed in close proximity with other vessel or platform, and large loads are transported in a pendulum configuration. Again, a precise positioning of the barge is required, in order to avoid unsafe relative motions, as well as keep the load being transported on a stable position.

Due to these special DP requirements, it has been shown in the present work that a simple static analysis of the DP System is not adequate in this case. Dynamic effects related to wind gusts, slow drift forces, propellers response, DP filtering and time-delay must be considered since the initial stages of DP specification. The common approach of considering an amount of 20% extra power to compensate for dynamic effects may underestimate the necessary power.

A fully non-linear dynamic simulator was then used to carry out a complete analysis of the barge. Thrust utilization capability plots were obtained for the DP design environmental condition,
considering the occurrence of a single failure. After that, an analysis of the environmental conditions in the Brazilian waters was carried out, and a comprehensive set of more than 1700 conditions were obtained. Dynamic simulations were then used to define the operational window of the barge as well as the estimated downtime for each operation. The barge is also able to operate in a DP-mooring assisted mode. The simulations were used to define under which operational and environmental conditions that such mode must be used.

Vessel adapted for multiple installation and salvage

**Author(s):** Cholley JM, Tcherniguin N, Thomas PA

**Source:** OMAE 2008: PROCEEDINGS OF THE 27TH INTERNATIONAL CONFERENCE ON OFFSHORE MECHANICS AND ARCTIC ENGINEERING - 2008, VOL 1  **Pages:** 751-758  **Published:** 2008

**Conference Information:** 27th International Conference on Offshore Mechanics and Arctic Engineering

Estoril, PORTUGAL, JUN 15-20, 2008

ASME, Ocean, Offshore & Arctic Engn Div

**Abstract:** For offshore developments, the installation of production decks onto floaters (e.g. spars for deep water developments) or fixed platforms using a heavy lift derrick barge is now well established, though, for high payloads, this requires multiple lifts and hence extensive offshore hook-up. As demand for lift vessels increases, their availability to match a specific project's schedule cannot be guaranteed. Consequently, an alternative deck installation vessel design has been developed for not only installing decks onto floaters, but also onto high air gap (circa 20 m) fixed platforms. This paper will present this new design.

The new vessel design consists of a linked catamaran shaped vessel with dimensions that permit it to go around the floater hull or jacket so that the deck can be lowered and stabbed.

The procedure for lowering is based on motorized "legs" to achieve a rapid weight transfer in severe sea-states and also permits the deck to be raised up once at site to achieve a high air gap installation on a fixed substructure.

This new vessel design greatly extends the geographical range for deck installation using the float-over method and offers a cost effective alternative to relying on crane vessels for installation.

Additionally, the vessel can perform a range of other tasks, particularly relating to decommissioning of facilities, or offshore wind-farm turbine installation

Developing the offshore energy future: Purpose-built vessels for the offshore wind industry

**Author(s):** Thomsen KE (Thomsen, Kurt E.)

**Source:** MARINE TECHNOLOGY SOCIETY JOURNAL  **Volume:** 42  **Issue:** 2  **Pages:** 51-52  **Published:** SUM 2008

**Document Type:** Editorial Material

Language: English

Publisher: MARINE TECHNOLOGY SOC INC, 5565 STERRETT PLACE, STE 108, COLUMBIA, MD 21044 USA
Development of heavy steel plate for Mayflower Resolution, special purpose vessel for erection of offshore wind towers

Author(s): Schutz W, Schroter F

Source: MATERIALS SCIENCE AND TECHNOLOGY  Volume: 21  Issue: 5  Pages: 590-596

Published: MAY 2005

Abstract: Special problems necessitate special solutions! Installation vessels for the erection of offshore wind towers are subject to extremely demanding design and structural specifications. Such projects are made possible only by the use of high strength, fine grained structural steels possessing good toughness properties even at extremely low temperatures; in addition, such steels must also offer good workability. Such steel plate material exhibits mechanical properties greatly superior to those possessed by conventional shipbuilding plate. This article focuses on the material for such an installation vessel and the underlying steel development work performed at AG der Dillinger Huttenwerke.

Shanhaiguan Shipyard to build unique wind turbine installation vessel

Author(s): [Anon]

Source: NAVAL ARCHITECT  Pages: 32-32

Published: FEB 2002

Document Type: Article

Language: English

Publisher: ROYAL INST NAVAL ARCHITECTS, 10 UPPER BELGRAVE ST, LONDON SW1X 8BQ, ENGLAND

IDS Number: 529KQ

ISSN: 0306-0209

Criterion of offshore jacket launching analysis

Author(s): Jo CH, Kim KS, Kim JH, Lee SH

Editor(s): Chung JS; Sayed M; Saeki H; Setoguchi T


Published: 2001

Conference Information: 11th International Offshore and Polar Engineering Conference (ISOPE-2001)

STAVANGER, NORWAY, JUN 17-22, 2001

Int Soc Offshore & Polar Engineers; Canadian Assoc Petr Producers; Amer Soc Civil Engineers, Engn Mech Div; Korea Comm Ocean Resources & Engn; Canadian Soc Civil Engineers, Engn Mech Div; Chinese Soc Ocean Engineers; Chinese Soc Naval Architects & Marine Engineers; Chinese Soc Theoret & Appl Mech; Russian Acad Sci; Singapore Struct Steel Soc; Norwegian Petr Soc; Inst Engineers Australia; Kansai Soc Naval Architects; IRO; Tech Res Ctr Finland; Soc Mat Sci; Offshore Engn Soc; Ukraine Soc Mech Engineers; IFREMER; Scott Polar Res Inst; Inst Engineers Indones; Brazilian Soc Naval Architects & Marine Engineers; Korean Soc Civil Engineers

Abstract: In the large offshore structure installation, a launching process is considered one of the most critical operations. As the size of structure increases, it limits the availability of offshore crane facilities. So often large jackets are installed by launching method. This method is also utilized to other type of large structures offshore. As the structure approaches to the tilt beam in the launching
barge, it reaches a critical load and there are parameters affecting on launching procedure. The major influential parameters are trim, draft of barge, center of gravity, center of buoyancy and reserved buoyancy of jacket. As increasing of trim and draft structural loads tend to decrease. The trim is found to be more contributing than draft on structural load, therefore the trim should be increased so as to decrease structural loads and to avoid stalling of structure and submergence of stem. During the launching process, the distance between jacket and seabed should be investigated which differs from the amount of reserved buoyancy and launching condition of barge. In this paper, the effects of parameters on launching process are intensively examined by numerical modeling.

1.6. Offshore wind vessels: projects

Technologies to improve offshore wind farms operation

Abstract: A London-based university has developed technologies for the maintenance and operation of offshore wind farms. Their technologies allow improved transmission of electricity between the offshore site and the shore. They also offer knowledge transfer for the assessment of offshore wind farms maintenance strategy. They are seeking companies and research institutions interested in partnering for further co-development of these technologies.

The London-based university has expertise in the development of technologies to improve the feasibility of offshore wind farm projects in terms of their operation and maintenance, and the high power transmission from the offshore generating sites to shore. The operation and maintenance of offshore wind farms is significantly more demanding and more expensive than equivalent onshore wind farm projects. The selection of the appropriate maintenance strategy and operational management is key to the feasibility of the business. The research group offers knowledge transfer for assessing operational strategies and providing technical assistance to optimise the strategies.

The group has designed a Wind Farm Support Vessel consisting of a low-draft crane vessel with jack-up stabilisers designed to provide support to the offshore farms. The vessel, capable of maximum speed of 23 knots, transports maintenance team to offshore wind farms together with their equipment and spares including turbine blades. The vessel has accommodation for 24 personnel and is capable of conducting all the maintenance required on a wind turbine, including blade changes, for periods of up to 28 days.

The research group develops technologies to improve the transmission of electricity from the offshore generating sites to shore. The group has carried out studies on the performance of different types of offshore power transmission methods in order to advance the design of offshore power cables. They also have technology to optimise the performance of the cable risers used in the offshore. These cable risers can face problems in interconnecting floating platforms with shore based electrical distribution systems. Unlike static high-voltage cables laid on the seabed, dynamic cable risers are subject to movement both from the surface-generating vessel, from vortex-induced vibration and water movements. Their technologies improve, for instance, the cables resistance to insulation cracking, which may result from such movement.

Main Advantages:

- Multidisciplinary team.
- Experience in collaboration with multinational teams.
- Experience in participating in EU Framework Programmes.

Innovative aspects:

- Novel ship design solutions implemented in the design of a wind farm support vessel.
- Optimisation of the high-power cables to optimise the quality of the transmitted electrical waveforms.
Development of dynamic cable riser for offshore use; designed improvements in the electro-mechanical performance of high power cable risers to develop new applications for the offshore dynamic environment.

Stage of development: Prototype/demonstrator available for testing

Property rights: Secret know-how

Collaboration sought: Information exchange/Training, Other

Collaboration Detail: - Type of partner sought: Industry, university, research centres - Specific area of activity of the partner: Offshore wind farms - Task to be performed: Codevelopment of these technologies for further improvement and/or adaptation to specific projects.

Market applications: Wind energy, Manufacturing technologies

Innovative personnel transfer system for offshore demands (offshore wind turbines, lighthouses, platforms)

Quality validation date: 2005-07-04

Abstract: A German company is developing a Personnel Transfer System (PTS), a solution to increase the accessibility of offshore structures in the sea. The PTS can be used by up to 3.0 m significant wave height and up to 8 bf wind. The design parameters are 500 kg capacity with 15 m range. By reducing the range the capacity could increase to 2 t for transfer of heavy goods. Commercial agreements with technical assistance with offshore project developers, manufacturers of wind turbines are sought.

The access to offshore constructions is the most important moment for all O&M (Operations and Maintenance) and repair work activities for such structures. However, the accessibility to structure is limited by wave height. Manoeuvres with boats and vessels with a direct contact between structure and the vessel or boat are limited to wave heights up to app. 1,5 meters. For the North Sea this is equivalent to 54% accessibility per annum (during winter time 35-40%; summer time 75-80%). For supply work of many single structures, e.g. an offshore wind farm, this accessibility is inadequate. As result of such a low accessibility the technical availability for an offshore wind farm will be reduced by 15 - 20 % and this leads to dramatic effects for the organisation of work: concentration of service work and annual inspections in the summer, while the maintenance crews are not fully employed during winter.

The PTS (Personnel Transfer System) is a radio-controlled two-armed hydraulic boom, which will be installed on every single offshore installation. The principle of the transfer is similar to helicopter transfer. For this transport the person uses a belt system and connects this to the transfer hook. With the PTS a vessel only has to hold position close to the offshore structure with a safety distance of at east 5 meters. Then the person to be transferred steers the transfer hook of the PTS via radio control to the aft deck of the vessel. The person connects himself to the hook - supported by the automated wave compensation of the PTS - and can lift the PTS as the vessel is on top of a wave. By lifting the boom and spooling the cable simultaneously the person is hoisted very quickly away from the vessel to a landing point on the service platform. Then the person can use the PTS for material transfer works.

The PTS has a turning angle of 270° and can lift up to two tons of weight within a range of 8 meters. This modus can be used for the transport of heavy goods at a wave height of max 1.5 meters. The fully stretched PTS can lift up to 500 kg within a range of 15 meters. This modus can be used for the transport of persons or light goods at maximum wave height of 3 meters.

By implementing this new approach for the access of offshore structures the annual average accessibility increases to app. 88%. Even in wintertime this value is not below 75%. Beside the advantage of a broader time frame for maintenance works this approach lowers the risks of getting injured while transferring from the vessel to the offshore structure.

Main Advantages:

Vessels and platforms for the emerging wind and wave power market
Increased accessibility for offshore structures.
Decreased risks of getting injured.
Seasonal work could be avoided, which will additionally increase the acceptance of offshore wind farms.

Innovative aspects:

- The PTS is a radio-controlled two-armed hydraulic boom with automated wave compensation, which will be installed on every single offshore installation. The principle of the transfer is similar to helicopter transfer.
- The PTS is universally usable and can be mounted on top of transformer stations at sea as well as on top of foundations of offshore wind mills or on lighthouses.

**Stage of development:** Experimental development stage (laboratory prototype)

**Property rights:** Patent(s) granted

**Collaboration sought:** Licence agreement, Marketing agreement, Information exchange/Training, Other

**Collaboration Detail:** - Type of partner sought:
Manufacturer of wind turbines, operator of wind parks, offshore project developer.

- **Specific area of activity of the partner:**
Offshore projects.

- **Task to be performed:**
Using and testing this system. The company offers engineering support and technical training.

**Market applications:** Wind energy, Offshore technology

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**Tie Down System; a tethering, adjustable device, connected between a floater and suction anchors in the seabed, pre-tensioned almost eliminating vessel vertical motion**

**Quality validation date:** 2004-04-14

**Abstract:** Tie Down System (TDS) is a device consisting of tethers; adjustable in length; connected between a floater and suction anchors in the seabed; pre-tensioned and those almost eliminating vessel vertical motions for operation in the open sea. Suction anchors and tethers are deployed and recovered by apparatus on vessel.

The marine vessel will prior to and during the load transfer operation of construction element in open sea (to/from fixed structures) be vertically moored and be tied down to suction anchors and thus have the motion characteristics of a tension leg platform (TLP). Heave; pitch and roll motions will almost be eliminated (only residual vessel motions from elasticity in tendons remain) which are essential during initial touch and connection between load-transfer system on the vessel and the Topside. The impact load in the Topside from kinetic energy of the vessel is; due to the above; nearly eliminated.

The TDS consists of traction winches; storage reels; steel wire ropes (tethers); blocks and sheaves; hydraulic jacks and suction anchors.

The hydraulic jacks of the TDS supporting the upper blocks on the vessel can work in four different modes:

- Constant tension mode whilst deploying and recovery of the suction anchors.
- None return valve mode during the pre-tensioning phase of the tendons.
- Locked mode during load-transfer and initial lift off of Topside from Jacket.
Controlled quick release mode during final separation of Topside from Jacket and thus avoid pounding between the Topside (resting on the vessel) and the substructure.

During the study of the Tie Down System we have aimed at making the hydraulic system as simple as possible; and at using "proven in practice" solutions to the largest possible extent. An important feature to be mentioned is that the main operations of the cylinders do not require "active control" with the associated control equipment; software and high power flows. This approach greatly enhances the safety of the system; equipment; payload and the people.

We have also made some continuous improvement of the TDS structural design through this RTD work and have ended up with a modular system for each anchor position; where each module contains two traction winches; two storage reels; one A-frame; four hydraulic cylinders; two block and tackle systems; one suction anchor and drive and control systems for the above components.

Each tie down system shall be remote operated from an operation control centre and the anchors shall be deployed and recovered simultaneously in order to save operational time and decrease the required weather window.

The TDS will improve for safety of personnel and material by almost eliminating the vertical motions. A simpler and less expensive hull shape is possible for load transfer of construction elements in open sea due to the feature of the TDS.

The system can also be deployed on existing tonnage and Company Jumbo shipping are now evaluating to install a TDS on one of there heavy lift transportation vessels in order to be able installing offshore wind turbines and oil and gas platforms.

**Stage of development:** Prototype/demonstrator available for testing

**Property rights:** Patent(s) granted

**Collaboration sought:** Licence agreement, Venture capital/spin-off funding, Available for consultancy

**Collaboration Detail:** Our intension is to become a service provider; together with a partner; for installation and removal of offshore oil and gas platforms were we are part owner in a heavy lift vessel outfitted with a TDS for safe and cost effective installation/ removal operation.

We are also interested providing our technology rights to a marine service company against a license fee and consultancy services in the detailed development phase as well as project execution phase (operation of the OCDV).

The Tie down System (TDS) can be used in different offshore applications where it is required to eliminate vertical motions of a floater whilst performing load transfer of construction elements between the floater and a fixed structure or to seabed.

Examples are offshore installation or removal of oil and gas platforms; installation of offshore wind farms; installation and removal of sub sea systems on the seabed.

The benefit using the technology is to reduce risk for damage of construction elements to be installed or removed by eliminating vessel vertical motions and thus ensures a soft landing when installing (and soft initial contact between structure and floater when removing).

Beside being the owner of the technology rights; Master Marine can offer a detailed know how of the system; good knowledge about the decommissioning market in Europe and good contacts to decommissioning managers at the oil companies.

Further Master Marine has been working with proposals for installation of offshore wind-farms and have good contacts to wind farm operators.

The partner should be an industrial investor with experience from the offshore oil and gas industry; willing to be part owner of an offshore construction and decommissioning vessel (OCDV). The partner should further be interested in delivering platform installation and removal services to the offshore industry.
Market applications: Aviation medicine, Manufacturing technologies, Aerospace, Construction industry, Ship, boat building

Source of support: CEC

Offshore construction and decommissioning vessel ('OCDV')

Start date: 2000-02-01
End date: 2004-01-31
Project Acronym: OCDV
Project status: Completed

Coordinator
Organization name: MASTER MARINE AS
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NORGE
Region: OSLO OG AKERSHUS Akershus

Organization Type: Other

Description

Objective: Objectives and problems to be solved: The objective of the Project is to develop a concept for a new type of Offshore Construction and Decommissioning Vessel (OCDV) devoted to safe, environmentally friendly and cost-effective removal and (re-) installation of offshore platforms and subset facilities. The key target is to prove the feasibility of the concept by obtaining Classification Approval of the Main Hull Scantlings, and by developing researched and viable design solutions for the main components and systems of the vessel. The development of the OCDV is based on an existing concept idea, where the OCDV takes the form of a U-shaped semi-submersible vessel which is equipped with a tie-down system to reduce and control its swell and wave induced vertical motions. The overall target of the Project is to conclude the vessel’s operational methodology and workability, its main dimensions and its key operational equipment. The uniqueness of the Project is based upon the concept of removing (or installing) the topsides as one entity, carrying them from below. The proposed method of decommissioning allows the possibility for refurbishment and reuse of the offshore installations. Further, the method will maximise the safety of decommissioning personnel whilst minimising the potential risk of accidents and environmental damage by moving the major part of the dismantling (and hook-up) work from offshore to onshore. Additionally, the method provides an opportunity for development of marginal fields by providing low-cost, reused topsides facilities. Description of work: The work will be initiated by preliminary analysis and design/layout activities of the vessel hull combined with developing an outline method statement describing how the offshore operations shall be performed. At the same time functional requirements for - and initial design of - the vessel’s key equipment shall be established. Based upon this initial study, the hydrostatic and hydrodynamic analyses will provide critical parameters and criteria for the structural design of the vessel and its systems. In parallel, a model of the vessel will be tested in an environmental tank to establish vessel performance and behaviour in various simulated sea-states. The results of the analyses and model tests will be used to perform the finite element analysis for computation of structural forces in hull and equipment under all global design conditions. Based on these forces, the hull design will be concluded and the main scantling drawings will be prepared and presented to the classification society for review and approval. At the same time research and development of a gendering system for horizontal positioning of the OCDV, of the retractable topsides support beams, and of the innovative...
hydraulic/mechanical tie-down system (tendons), including the design of the suction anchors and the study of their geographical applicability, will be conducted. The work has been split into 15 thematic work packages, and five main milestones have been identified, addressing critical intermediate results. Expected results and Exploitation Plans: The outcome of the work will be a detailed concept design for a vessel capable of handling the topside weights of about 90% of existing North Sea platforms. The subsequent phase will cover the detailed engineering and construction of the vessel. In a third phase, a consortium will be established around the OCDV capable of delivering a complete decommissioning package.

**Results for this Project**

- **Active suction anchor.** A bottom foundation able to take large vertical pulling forces, consisting of a cylinder with covered top and a pump running to create and maintain the vertical holding capacity.
  14/04/04

- **Horizontal Positioning System (HPS),** a device controlling a floater position and orientation relative an offshore structure, minimising vessel surge-, sway- and yaw-motions.
  14/04/04

- **Load Transfer System (LTS),** a system developed to carry construction elements from underneath, in several lifting points in a “moon pool” of a U-shaped heavy lift vessel.
  14/04/04

- **Tie Down System;** a tethering, adjustable device, connected between a floater and suction anchors in the seabed, pre-tensioned almost eliminating vessel vertical motion.
  14/04/04

- **U-shaped hull of Offshore Construction and Decommissioning Vessel (OCDV)**
  14/04/04

**Documents for this Project**

- **Offshore Construction and Decommissioning Vessel - OCDV**
  27/04/06

**Mooring device for offshore wind turbines**

**Quality validation date:** 2002-01-08

**Abstract**

The Mooring Device solves the problem of mooring a boat to an offshore wind turbine in the open sea.

Mounted on the boat, it can serve a multitude of wind turbines with minor installations on each wind turbine tower. Due to its design, the locking mechanism automatically will be guided into the right position for clutching the steel wire proved around the wind turbine tower.

The device provides a flexible connection between the tower and the boat, with several degrees of freedom for the boat to ride the waves. Due to the geometry of the arrangement, the relative movements between the gangway and the tower platform will be small even in rough sea conditions. Thus personnel, in a safe and comfortable way, may embark and disembark the wind turbine. When leaving the site, the locking mechanism is opened remotely.

**Stage of development:** Guidelines, methodologies, technical drawings

**Property rights:** Patent(s) applied for but not yet granted

**Collaboration sought:** Further research or development support, Licence agreement, Marketing agreement

**Collaboration Detail:** Detailed design for equipment on boat and wind turbines available.

**Market applications:** Wind energy, Renewable energy, Offshore technology

**Source of support:** National

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2. Offshore Floating Wind Power Platforms

2.1. Introduction

Offshore wind facilities are currently in operation in shallow and coastal waters, but there is a trend towards installing them in the deeper waters of the outer continental shelf. At large water depths though, today’s solutions (monopiles and gravity) are no longer technically viable.

Although the technology is not sufficiently mature yet to support deep water wind farms (>40 m), the guess is that it will evolve from offshore oil and gas technology.

A key advantage of using floating wind platforms is that they allow developers of wind farm projects access to deeper waters. Since most of the technology for floating platforms comes from the oil industry, it is not entirely surprising that Norwegian energy giant Statoil is investing in a 2.3 MW floating wind project 10 kilometres off the coast of Norway.

Three primary floating platform concepts were developed based on floating platform designs: the ‘ballast stabilized’ or ‘spar buoy’, the ‘buoyancy stabilized’ or barge system, and the ‘tension-leg platform’ or ‘mooring line stabilized’ platform. Each design uses a different method to achieve static stability. Although the optimum platform does not yet exist, designers tend to choose those which are easier to install and which minimize general turbine load increase compared to a land-based reference turbine load.

One of the main conclusions we can draw is that future technologies for deep water platforms shall not necessarily be more costly than fixed-bottom systems, since those can be produced in bulk and fully assembled onshore, thus saving the huge costs of building them in the open sea. Further research is needed to verify the feasibility of such low-cost floating wind turbines. New technology will be required to face such low costs and implement simple mooring systems. Developing such technologies involves a complex and high risk, but also has a high profit potential.

The designs presented below are the ones most typically under study today.

Floating deepwater platform concepts: (1) semisubmersible Dutch tri-floater (Bulder et al. 2002); (2) spar buoy with two tiers of guy wires (Lee 2005); (3) three-arm mono-hull tension-leg platform (TLP) by Glosten Associates (2010); (4) concrete TLP with gravity anchor (Fulton, Malcolm, and Moroz 2006); (5) deepwater spar (Sway 2010).
2.2. New platform designs

“Poseidon” by Floating Power Plant (Denmark)

The Danish Floating Power Plant developed "Poseidon", a concept for a floating power plant that transforms wave energy into electricity. The power plant furthermore serves as a floating foundation for offshore windmills. See the video from Poseidon’s initial test.

“SMWS” by Moellgaard Energy (Denmark)
The **SMWS** concept (Semi-Submersible Multiple Wind-Turbine System) was developed by **Moellgaard Energy**. It consists of a giant triangular tubular steel structure designed to carry three wind turbines mounted at the corners. The structure can float at depths of 16 m beneath the surface. One corner is being anchored to the seabed with mooring lines and the entire structure can swivel around the anchored corner. Thus the structure and the turbines are always facing the wind in the most efficient direction and adjusted to the best position to catch the wind. Also, by this kind of positioning, there is no need for swiveling turbines, which can significantly reduce the costs of an offshore plant.

**The “Hexicon Platform” by Hexicon (Sweden)**

The **Hexicon** 360 m diameter platform can accommodate six to eight large turbines, and can host a capacity of 20-40 MW. The platform is designed to withstand extreme weather by redirecting waves through a specially designed hull that keeps the entire platform stable, and according to Hexicon the concept can operate for 50-60 years without much need for maintenance. The concept is designed to be constructed offshore and assembled onsite, and it allows addition or replacement with more efficient turbines as they are made available.

**“Hywind” by StatoilHydro (Norway)**

The **StatoilHydro** **Hywind** floating structure consists of a steel cylinder filled with a ballast of water and rocks. It extends 100 metres beneath the sea surface and is attached to the seabed by using three anchor points. The wind turbine can be located in waters with depths ranging from 120 to 700 metres.

StatoilHydro inaugurated a full-scale **Hywind pilot** last year outside Karmøy island in the North Sea. The turbine mounted on the pilot is manufactured by Siemens.
“Njord” by Njord Floating Wind Power Platform (Norway)

In Norway, with great know-how in offshore technology, the University of Bergen spin-off Njord Floating Wind Power Platform is developing a new concept for floating platforms. The concept will be lighter and require less depth than other floating platforms.

The project is currently conducting model tests in wave tanks at the Norwegian Marine Technology Research Institute. More results from the tests will be presented at the project conference.

“Sway Floater” by Sway (Norway)

The patented SWAY system is based on a floating tower which extends far below the water surface. The tower consists of a floating pole with ballast in the lower end, similar to a floating bottle. The tower, which is filled with ballast, has its centre of gravity located far below the centre of buoyancy of the tower. This gives the tower sufficient stability to resist the large loads produced by the wind turbine mounted on top of it. The floating tower is anchored to the seabed with a single pipe and a suction anchor. When the wind hits the rotor the tower is tilting some 5-8 degrees. When the wind changes direction, the entire tower turns around a subsea swivel.
“WindSea floating windmill system” by Windsea (Norway)

Developed by Windsea, the WindSea floater is a semi-submersible vessel type with three corner columns. Each column supports one windmill. The semi-submersible vessel is moored to the sea bottom and the mooring lines are connected to a turret at the vessel geometric centre, allowing the vessel to rotate. The vessel is therefore able to always orient the turbines optimally towards the incoming wind.

“WindFloat” by Marine Innovation & Technology and Principle Power

WindFloat, conceived by Marine Innovation & Technology and exclusively licensed to Principle Power, is a floating foundation for offshore wind turbines with a simple, elegant, patented design.

The innovative features of the WindFloat dampen wave and turbine motion, enabling wind turbines to be sited in deep waters, previously inaccessible locations with superior wind resources and water depths of 50 metres and above. Its economic efficiency is furthermore maximized by reducing the need to operate at sea during the final assembly and deployment stages.
“Titan” Wind Turbine Platform by Offshore Wind Power Systems (Texas)


Wind Lens floating farms (Japan)

The Wind Lens is a new design for deep-water wind turbine technology developed by The Research Institute for Applied Mechanics. The idea is that it should not only be able to increase energy output three-fold, but also reduce the noise pollution associated with traditional wind turbines.

The Wind Lens focuses the power of the wind to the centre of the hoop, thus intensifying the generated power.

The system was revealed at the Yokohama Renewable Energy International Exhibition 2010 and will probably be installed off the coast of Japan within the next two years.
2.3. Wind power platforms: patents

The search was conducted by combining the keywords “floating” and “wind turbines”, plus “foundations” and “offshore wind”.

In this case, the IPC (International Patent Classification) codes referring to this technology were the following:

- **F03B 13/00**
  Adaptations of machines or engines for special use; Combinations of machines or engines with driving or driven apparatus (if the apparatus aspect are predominant, see the relevant places for such apparatus, e.g. H02K 7/18); Power stations or aggregates (hydraulic engineering aspects E02B; incorporating only machines or engines of positive-displacement type F03C)

- **E02B 17/00**
  Artificial islands mounted on piles or like supports, e.g. platforms on raisable legs; Construction methods therefor (fenders E02B 3/26; anchoring floating platforms B63B 21/00; floating platforms, e.g. anchored, B63B 35/44; independent underwater structures E02D 29/00)

- **F03D**
  WIND MOTORS

There are many patents related to offshore wind power platforms. Some of the applicants which are worth highlighting are Ocean Wind Technology, which holds five patents; Norsk Hydro ÅS, which holds three; the American Florida Turbine Tech, which holds two; and Blue H Intellectual Properties, also holding two.

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<thead>
<tr>
<th>Titulo</th>
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<tr>
<td>WO2010106208(A2)</td>
<td>FLOATING PLATFORM FOR EXTRACTING WIND ENERGY</td>
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<td>DE102004042066(A1)</td>
<td>Foundation platform for offshore wind turbine in sea depths of 30 to 50 metres</td>
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<td>EP2080899(A1)</td>
<td>An offshore wind turbine with a rotor integrated with a floating and rotating foundation</td>
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<td>Floating wind pump, to regenerate and oxygenate bodies of water, has a lightweight wind turbine to drive a submerged screw through a speed decoupler to operate in light winds and be protected against strong wind damage</td>
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<td>US2010003134(A1)</td>
<td>Wind and wave power generation</td>
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<td>US2006062676(A1)</td>
<td>Method for realising a submerged floating foundation with blocked vertical thrust for the coordinated production of mariculture and electrical energy using wind in open sea conditions and submergeable floating foundation for carrying loads to be used in s</td>
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<td>SUBMERGED FLOATING FOUNDATION WITH BLOCKED VERTICAL THRUST AS SUPPORT BASE FOR WIND TURBINE, ELECTROLYSER AND OTHER EQUIPMENT, COMBINED WITH FISH FARMING</td>
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<td>WO2008122004(A2)</td>
<td>ASSEMBLY, TRANSPORTATION AND INSTALLATION OF DEEPWATER WINDPOWER PLANT</td>
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<td>Wave and wind power generation system</td>
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<td>OFFSHORE STRUCTURE SUPPORT AND FOUNDATION FOR USE WITH A WIND TURBINE AND AN ASSOCIATED METHOD OF ASSEMBLY</td>
<td>KEYSTONE ENGINEERING INC [US]; HALL RUDOLPH A [US]; SHAW RALPH L [US]</td>
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<td>Construction method and construction rig of floating wind turbine generator</td>
<td>MITSUBISHI HEAVY IND LTD</td>
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<td>JP200806396 (A)</td>
<td>OCEAN FLOAT TYPE WIND AND WATER TURBINE FLUID EXTRACTING POWER GENERATING FACILITIES</td>
<td>MURAHARA MASATAKA; SEKI KAZUICHI</td>
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<td>MOVABLE MARINE WIND POWER GENERATOR</td>
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<td>ANCHORING ARRANGEMENT FOR FLOATING WIND TURBINE INSTALLATIONS</td>
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<td>OCEAN TECHNOLOGIES LTD [GB]; BONE DAVID [GB]</td>
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<td>CN101545462 (A)</td>
<td>A steel-concrete combined weight type offshore wind fan foundation structure</td>
<td>OCEAN UNIV CHINA</td>
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<td>COLUMN-STABILIZED OFFSHORE PLATFORM WITH WATER-ENTRAPMENT PLATES AND ASYMMETRIC MOORING SYSTEM FOR SUPPORT OF OFFSHORE WIND TURBINES</td>
<td>PRINCIPLE POWER INC [US]; RODDIER DOMINIQUE [US]; CERMELLI CHRISTIAN [US]</td>
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<td>WO2010021655</td>
<td>DEEP OFFSHORE FLOATING WIND TURBINE AND METHOD OF DEEP OFFSHORE FLOATING WIND TURBINE ASSEMBLY, TRANSPORTATION, INSTALLATION AND OPERATION</td>
<td>ROZNITSKY SAMUEL [US]; ROZNITSKY MOSHE [US]; ROZNITSKY YOEL [US]; ROZNITSKY HILELA [US]</td>
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<td>Buoyant assembly and working platform for offshore wind and water turbines, has squat room and working areas process devices provided at board, and deck formed as helipad, where devices are provided with tanks or storage systems</td>
<td>SCHOPF WALTER [DE]</td>
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<td>EP1666722</td>
<td>Fixing system for floating wind generators</td>
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<td>FLOATING DEVICE FOR WIND-POWER GENERATION</td>
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<td>Arrangement for stabilization of a floating foundation</td>
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<td>WO2010018359</td>
<td>METHOD AND APPARATUS FOR TOWING OFFSHORE WIND TURBINES,</td>
<td>STATOILHYDRO ASA [NO]; NIELSEN FINN GUNNAR [NO]; JACKSON ROBERT [GB]</td>
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<td>JP2006070775</td>
<td>METHOD FOR USING WIND POWER GENERATION IN BARGE TYPE PLANT SYSTEM, ELECTROLYZING SEAWATER AND PRODUCING HYDROGEN</td>
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<td>FOUNDATION BASE FOR MOUNTING WIND TURBINES IN AN AQUATIC BED AND METHOD FOR MANUFACTURING SAID FOUNDATION</td>
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2.4. Wind power platforms: scientific papers

Dynamic Response of Floating Wind Turbine

**Author(s):** Karimirad, M  
**Source:** SCIENTIA IRANICA TRANSACTION B-MECHANICAL ENGINEERING  
**Volume:** 17  **Issue:** 2  
**Pages:** 146-156  
**Published:** MAR-APR 2010

**Abstract:** Like other offshore structures, floating wind turbines are subjected to stochastic wave and wind loads that cause a dynamic response in the structures. Wind turbines should be designed for different conditions, such as Operational and Survival conditions. In high sea states, the response can be quite different from the operational condition. The present paper deals with coupled wave and wind induced motion in harsh conditions, up to 15 In significant wave height and 50 m/sec average wind speed. There are several ways to deal with the dynamic response of floating wind turbines. The Coupled Time domain dynamic response analysis for a moored spar wind turbine subjected to wave and wind loads is carried out using Deep C. DeepC is well known software for calculating the coupled dynamic response of moored floating structures. The aerodynamic forces on a parked wind turbine are calculated, based on the strip theory, and imported to the DeepC through a MATLAB interface. At each time step, the relative wind velocity, based on the response of the structure, is calculated.

Foundation Design: A Comparison of Oil and Gas Platforms with Offshore Wind Turbines

**Author(s):** Schneider, James A., Senders, Marc  
**Source:** MARINE TECHNOLOGY SOCIETY JOURNAL  
**Volume:** 44  **Issue:** 1  
**Pages:** 32-51  
**Published:** JAN-FEB 2010

**Abstract:** The offshore oil and gas (O&G) industry has over 70 years of experience developing innovative structures and foundation concepts for engineering in the marine environment. The evolution of these structures has strongly been influenced by water depth as well as soil conditions in the area of initial developments. As the offshore wind industry expands from the glacial soil deposits of the North and Baltic Seas, experience from the O&G industry can be used to aid a smooth transition to new areas. This paper presents an introduction to-issues that influence how design and construction experience from the O&G industry can be used to aid foundation design for offshore wind energy converters. A history of the evolution of foundation and substructure concepts in the Gulf of Mexico and North Sea is presented, followed by a discussion of soil behavior and the influence of regional geology on these developments. Mechanisms that influence the resistance of shallow and deep foundations for fixed and floating offshore structures are outlined so that areas of empiricism within offshore design codes can be identified and properly modified for application to offshore wind turbine foundations. It is concluded that there are distinct differences between offshore O&G and offshore wind turbine foundations, and application of continued research into foundation behavior is necessary for rational, reliable, and cost-effective design.

Individual blade pitch control of floating offshore wind turbines

**Author(s):** Namik, H, Stol K  
**Source:** WIND ENERGY  
**Volume:** 13  **Issue:** 1  
**Pages:** 74-85  
**Published:** JAN 2010
Abstract: Floating wind turbines offer a feasible solution for going further offshore into deeper waters. However, using a floating platform introduces additional motions that must be taken into account in the design stage. Therefore, the control system becomes an important component in controlling these motions. Several controllers have been developed specifically for floating wind turbines. Some controllers were designed to avoid structural resonance, while others were used to regulate rotor speed and platform pitching. The development of a periodic state space controller that utilizes individual blade pitching to improve power output and reduce platform motions in above rated wind speed region is presented. Individual blade pitching creates asymmetric acrodynamic loads in addition to the symmetric loads created by collective blade pitching to increase the platform restoring moments. Simulation results using a high-fidelity non-linear turbine model show that the individual blade pitch controller reduces power fluctuations, platform rolling rate and platform pitching rate by 44%, 39% and 43%, respectively, relative to a baseline controller (gain scheduled proportional-integral blade pitch controller) developed specifically for floating wind turbine systems. Turbine fatigue loads were also reduced; tower side-side fatigue loads were reduced by 39%. Copyright (C) 2009 John Wiley & Sons, Ltd.

Design of support structures for offshore wind turbines - Interfaces between project owner, turbine manufacturer, authorities and designer

Author(s): Seidel, Marc

Source: STAHLBAU  Volume: 79  Issue: 9  Pages: 631-636

Published: SEP 2010

Abstract: Design of support structures for offshore wind turbines is a challenging subject both technically and logistically. Many stakeholders are involved in this process, which have many technical and commercial interfaces. Managing these interfaces can involve special technical approaches and procedures, some of which are discussed in this paper. It is of great benefit to the project, if these interfaces are managed well.

WindFloat: A floating foundation for offshore wind turbines

Author(s): Dominique Roddier, Christian Cermelli, Alexia Aubault, and Alla Weinstein

JOURNAL OF RENEWABLE AND SUSTAINABLE ENERGY 2,

A practical formulation for estimating the extreme vector excursion of a floating structure

Author(s): Low YM (Low, Y. M.)

Source: OCEAN ENGINEERING  Volume: 37  Issue: 13  Pages: 1149-1158

Published: SEP 2010

Abstract: In the design of a moored floating structure, the traditional approach is to assess the extreme surge and sway responses separately. This paper highlights the importance of considering the extreme lateral excursion, based on the vector sum of the surge and sway offsets, and an approximate formula is developed for this purpose. The method allows for first- and second-order platform motions, as well as mean offsets. The extreme vector excursion is expressed as a simple function of the maximum surge and sway responses, and the correlation coefficient between the two motions. The proposed approximation is benchmarked against more rigorous methods, including time domain simulation. It is found that provided the estimates for the surge and sway extremes are precise, the formula itself does not induce significant errors in the extreme vector excursion. Moreover, it is observed that the prediction tends to be conservative. The practicality of the proposed formulation makes it amenable for incorporation into an existing design code or analysis procedure. (C) 2010 Elsevier Ltd. All rights reserved.
Windfloat: a floating foundation for offshore wind turbines part iii: structural analysis

**Author(s):** Aubault, Alexia, Cermelli, Christian, Roddier, Dominique

**Book Group Author(s):** ASME

**Source:** OMAE 2009, VOL 1 - OFFSHORE TECHNOLOGY  **Pages:** 213-220  **Published:** 2009

**Conference Information:** 28th International Conference on Ocean, Offshore and Arctic Engineering Honolulu, HI, MAY 31-JUN 05, 2009

ASME, Ocean, Offshore & Arctic Engn Div

**Abstract:** Wind Float is a floating foundation for large offshore wind turbines. This paper describes the structural engineering that was performed as part of the feasibility study conducted for qualification of the technology. Specifically, the preliminary scantling is described and the strength and fatigue analysis methodologies are explained, focusing on the following aspects; the coupling between the wind turbine and the hull; the interface between the hydrodynamic loading and the structural response.

Prior to reading this manuscript, the reader is strongly encouraged to read the related paper, which focuses on the design basis for the Wind Float, and explores the requirements that must be addressed by the design teams in this new field. An additional paper in this series describes the hydrodynamic analysis and experimental validations.

Dynamics of Offshore Floating Wind Turbines-Model Development and Verification

**Author(s):** Jonkman, Jason M.

**Source:** WIND ENERGY  **Volume:** 12  **Issue:** 5  **Special Issue:** Sp. Iss. SI  **Pages:** 459-492  **Published:** JUL 2009

**Abstract:** The vast deepwater wind resource represents a potential to use offshore floating wind turbines to power much of the world with renewable energy. Many floating wind turbine concepts have been proposed, but dynamics models, which account for the wind inflow, aerodynamics, elasticity and controls of the wind turbine, along with the incident waves, sea current, hydrodynamics, and platform and mooring dynamics of the floater, were needed to determine their technical and economic feasibility. This work presents the development of a comprehensive simulation tool for modelling the coupled dynamic response of offshore floating wind turbines and the verification of the simulation tool through model-to-model comparisons. The fully coupled time-domain aero-hydro-servo-elastic simulation tool was developed with enough sophistication to address limitations of previous studies and has features required to perform loads analyses for a variety of rotor-nacelle assembly, tower, support platform and mooring system configurations. The developed hydrodynamics module accounts for linear hydrostatic restoring, non-linear viscous drag; the added-mass and damping contributions from linear wave radiation, including free-surface memory effects; and the incident-wave excitation from linear diffraction in regular or irregular seas. The developed mooring line module is quasi-static and accounts for the elastic stretching of an array of homogenous taut or slack catenary lines with seabed interaction. The hydrodynamics module, the moorings module, and the overall simulation tool were tested by comparing to results of other models, including frequency domain models. The favourable results of all the verification exercises provided confidence to perform more thorough analyses. Copyright (C) 2009 John Wiley & Sons, Ltd.

Status, plans and technologies for offshore wind turbines in Europe and North America

**Author(s):** Breton, Simon-Philippe, Moe, Geir

**Source:** RENEWABLE ENERGY  **Volume:** 34  **Issue:** 3  **Pages:** 646-654  **Published:** MAR 2009

**Abstract:** The worldwide demand for renewable energy is increasing rapidly because of the climate problem, and also because oil resources are limited. Wind energy appears as a clean and good
solution to cope with a great part of this energy demand. In Denmark for example, 20% of the electricity is produced from wind, and plans are towards reaching 50%. As space is becoming scarce for the installation of onshore wind turbines, offshore wind energy, when possible, seems as a good alternative. This work describes, for Europe and North America, the potential for offshore wind energy, the current status of this technology, and existing plans for the development of offshore wind parks. It also presents existing as well as promising new solutions for offshore wind energy. (C) 2008 Elsevier Ltd. All rights reserved.

**Life cycle assessment of a floating offshore wind turbine**

**Author(s):** Weinzellet, Jan, Reenaas, Marte, Solli, Christian, Hertwich, Edgar G.

**Source:** RENEWABLE ENERGY  **Volume:** 34  **Issue:** 3  **Pages:** 742-747

**Published:** MAR 2009

**Abstract:** A development in wind energy technology towards higher nominal power of the wind turbines is related to the shift of the turbines to better wind conditions. After the shift from onshore to offshore areas, there has been an effort to move further from the sea coast to the deep water areas, which requires floating windmills. Such a concept brings additional environmental impact through higher material demand. To evaluate additional environmental burdens and to find out whether they can be rebalanced or even offset by better wind conditions, a prospective life cycle assessment (LCA) study of one floating concept has been performed and the results are presented in this paper. A comparison with existing LCA studies of conventional offshore wind power and electricity from a natural gas combined cycle is presented. The results indicate similar environmental impacts of electricity production using floating wind power plants as using non-floating offshore wind power plants. The most important stage in the life cycle of the wind power plants is the production of materials. Credits that are connected to recycling these materials at the end-of-life of the power plant are substantial. (C) 2008 Elsevier Ltd. All rights reserved.

**Floating offshore wind turbines: responses in a seastate pareto optimal designs and economic assessment**

**Author(s):** Sclavounos, Paul, Tracy, Christopher, Lee, Sungho

**Book Group Author(s):** ASME

**Source:** PROCEEDINGS OF THE 27TH INTERNATIONAL CONFERENCE ON OFFSHORE MECHANICS AND ARCTIC ENGINEERING - 2008, VOL 6  **Pages:** 31-41

**Published:** 2008

**Conference Information:** 27th International Conference on Offshore Mechanics and Arctic Engineering

Estoril, PORTUGAL, JUN 15-20, 2008

ASME, Ocean, Offshore, & Arct Engn Div

**Abstract:** Wind is the fastest growing renewable energy source, increasing at an annual rate of 25% with a worldwide installed capacity of 74 GW in 2007. The vast majority of wind power is generated from onshore wind farms. Their growth is however limited by the lack of inexpensive land near major population centers and the visual pollution caused by large wind turbines.

Wind energy generated from offshore wind farms is the next frontier. Large sea areas with stronger and steadier winds are available for wind farm development and 5MW wind turbine towers located 20 miles from the coastline are invisible. Current offshore wind turbines are supported by monopoles driven into the seafloor at coastal sites a few miles from shore and in water depths of 10-15m. The primary impediment to their growth is visual pollution and the prohibitive cost of seafloor mounted monopoles in larger water depths.
This paper presents a fully coupled dynamic analysis of floating wind turbines that enables a parametric design study of floating wind turbine concepts and mooring systems. Pareto optimal designs are presented that possess a favorable combination of nacelle acceleration, mooring system tension and displacement of the floating structure supporting a five megawatt wind turbine. All concepts are selected so that they float stably while in tow to the offshore wind farm site and prior to their connection to the mooring system. A fully coupled dynamic analysis is carried out out of the wind turbine, floater and mooring system in wind and a sea state based on standard computer programs used by the offshore and wind industries. The results of the parametric study are designs that show Pareto fronts for mean square acceleration of the turbine versus key cost drivers for the offshore structure that include the weight of the floating structure and the static plus dynamic mooring line tension.

Pareto optimal structures are generally either a narrow deep drafted spar, or a shallow drafted barge ballasted with concrete.

The mooring systems include both tension leg and catenary mooring systems. In some of the designs, the RMS acceleration of the wind turbine nacelle can be as low as 0.03 g in a sea state with a significant wave height of ten meters and water depths of up to 200 meters. These structures meet design requirements while possessing a favorable combination of nacelle acceleration, total mooring system tension and weight of the floating structure. Their economic assessment is also discussed drawing upon a recent financial analysis of a proposed offshore wind farm.

**Modal dynamics of large wind turbines with different support structures**

**Author(s):** Bir, Gunjit, Jonkman, Jason  
**Book Group Author(s):** ASME  
**Source:** PROCEEDINGS OF THE 27TH INTERNATIONAL CONFERENCE ON OFFSHORE MECHANICS AND ARCTIC ENGINEERING - 2008, VOL 6  
**Pages:** 669-679  
**Published:** 2008  
**Conference Information:** 27th International Conference on Offshore Mechanics and Arctic Engineering  
Estoril, PORTUGAL, JUN 15-20, 2008  
ASME, Ocean, Offshore, & Arct Engn Div  
**Abstract:** This paper presents modal dynamics of floating-platform-supported and monopile-supported offshore turbines, which are gaining attention for their ability to capture the immense wind resources available over coastal waters. Minimal dynamic loads and the absence of instability are imperative to the success of these turbines. Modal dynamics determine both loads and instabilities to a large extent, and therefore must always be analyzed. Also, to model the turbine, several aeroelastic computer codes require modes of the major components, e.g., the rotor blades and the rotor-nacelle support structure. To compute such modes, we used a recently developed finite-element code called BModes. The code provides coupled modes either for the rotating blades or for the support structure. A coupled mode implies presence of coupled flexural, axial, and torsion motions in a natural mode of vibration. In this paper, we use BModes to provide modes only for flexible towers, which carry head mass (rotor-nacelle subassembly modeled as a rigid body) and are mounted atop either a floating platform or a soil-supported monopile. The code accounts for the effects of hydrodynamic inertia, hydrostatic restoring, and mooring lines stiffness on the floating platform. It also accounts for the distributed hydrodynamic mass on the submerged part of the tower and for the elastic foundation surrounding the monopile. Results are obtained for three turbine configurations: land-based turbine, floating-platform-supported turbine, and monopile-supported turbine. Three foundation models are used for the monopile configuration. Results show that the hydrodynamic and elastic-foundation effects strongly influence the turbine modal dynamics.

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*Vessels and platforms for the emerging wind and wave power market* 44
Floating offshore wind turbines

Author(s): Sclavounos, Paul

Source: MARINE TECHNOLOGY SOCIETY JOURNAL  Volume: 42  Issue: 2  Pages: 39-43

Published: SUM 2008

Abstract: Wind is a rapidly growing renewable energy source, increasing at an annual rate of 30%, with the vast majority of wind power generated from onshore wind farms. The growth of these facilities, however, is limited by the lack of inexpensive land near major population centers and the visual impact caused by large wind turbines.

Wind energy generated from floating offshore wind farms is the next frontier. Vast sea areas with stronger and steadier winds are available for wind farm development and 5 MW wind turbine towers located 20 miles from the coastline are invisible. Current offshore wind turbines are supported by monopoles driven into the seafloor or other bottom mounted structures at coastal sites a few miles from shore and in water depths of 10-15 m. The primary impediment to their growth is their prohibitive cost as the water depth increases.

This article discusses the technologies and the economics associated with the development of motion resistant floating offshore wind turbines drawing upon a seven-year research effort at MIT. Two families of floater concepts are discussed, inspired by developments in the oil and gas industry for the deep water exploration of hydrocarbon reservoirs. The interaction of the floater response dynamics in severe weather with that of the wind turbine system is addressed and the impact of this coupling on the design of the new generation of multi-megawatt wind turbines for offshore deployment is discussed. The primary economic drivers affecting the development of utility scale floating offshore wind farms are also addressed.

Development of the floating structure for the Sailing-type Offshore Wind Farm

Author(s): Manabe, Hideo, Uehiro, Takeshi, Utiyama, Masahiro, Esaki, Hiroshi, Kinoshita, Takeshi, Takagi K, Okamura H, Satou, Masuho

Book Group Author(s): IEEE


Conference Information: International Conference OCEANS 2008 and MTS/IEEE Kobe Techno-Ocean '08
Kobe, JAPAN, APR 08-11, 2008

Marine Technol Soc; IEEE Ocean Engn Soc; MTS Japan Sect; IEEE OES Japan Sect; Techno Ocean Network; Kobe Convent & Visitors Assoc; Japan Agcy Marine Earth Sci & Technol; AESTO; NEC Corp; Off Naval Res Global; Alec Elect Co Ltd; Hakodate Dock Co Ltd; Imabari Shipbuilding Co Ltd; Namura Shipbuilding Co Ltd; Oshima Shipbuilding Co Ltd; Sanoyas Hishino Meisho Corp; Sasebo Heavy Industries Co Ltd; Shin Kurushima Dockyard Co Ltd; Toyohashi Shipbuilding Co Ltd; Tsuneishi Holdings Corp

Abstract: Feasibility studies for the sailing-type offshore wind farm have been carried out by National Institute for Environmental Studies. This system is composed of a very large floating offshore structure with sails and a lot of wind turbines on the structure. Conventional catenary mooring system is no longer practical for station-keeping a kilometer sized floating structures in over hundreds meters of water depth. This floating structure sails around EEZ of Japan seeking appropriate breezeing and avoiding meeting heavy storm. This floating structure has self-mobile and station-keeping capability using the sail control system and semi-sub hull structure.

This paper presents the development of this floating structure based on the hydro-elastic response analysis in waves and structural optimization.
Load on turbine blade induced by motion of floating platform and design requirement for the platform

Author(s): Suzuki, Hideyuki, Sato, Akira

Book Group Author(s): ASME

Source: Proceedings of the 26th International Conference on Offshore Mechanics and Arctic Engineering, Vol 5  Pages: 519-525  Published: 2007

Conference Information: 26th International Conference on Offshore Mechanics and Arctic Engineering
San Diego, CA, JUN 10-15, 2007

Abstract: Due to the limited land area and mountainous topography, Japan is not necessarily suited for land-based wind power generation. But potential of offshore wind energy around the country is huge and has ability to supply whole electricity of the country. Development of offshore wind energy is also a promising solution for establishing sustainable society in the country. Water depth around the country generally becomes sharply deeper with distance from the shoreline and floating platform is necessary to deploy wind turbines. This paper investigates effect of motion of floating platform on the strength of turbine blade, a key issue in designing floating wind turbine, and design requirement for floating platform was discussed. Inertial load induced in the turbine blade by the motion of platform and rotation of turbine was formulated. The formulated load on the blade was verified by experiment with rotating rod on the oscillating tower. Two analysis codes, structural analysis code of turbine blade and motion analysis code of SPAR type floating platform, were developed. The effect of platform motion on the bending moment induced in the blade was investigated using the codes and design requirements for the platform were investigated from a viewpoint of maximum load and fatigue load. From a series of analysis on 5MW wind turbine showed that maximum load on blade is increased by 10% for pitching with amplitude of 5degrees but sectional C, modulus must be increased by 50% for fatigue. It is concluded that the increase of maximum load on the blade due to the motion of floating platform is not serious but fatigue load can be significant. Design requirement for the motion of floating platform will be that the amplitude of pitching motion should be less than a few degrees so that the land-based wind turbine can be installed on the floating platform with minimum modification.

Technology for offshore wind turbines

Author(s): Moe, G., Niedzwiecki JM, Long H, Lubbadl R, Breton SP

Editor(s): Chakrabarti SK; Brebbia CA


Conference Information: 4th International Conference on Fluid Structure Interaction Incorportating the Free and Moving Boundary Problems Seminar
New Forest, ENGLAND, MAY 14-16, 2007
Wessex Inst Technol; WIT Transact Built Environm

Abstract: A selective and incomplete review of the status of the development of offshore wind turbines is given. The main focus is on state of the art and emerging solutions, and emphasis is on solutions for deep water.

Design, fabrication and installation of the offshore wind turbine REpower 5M

Author(s): Seidel, Marc

Source: STAHLBAU  Volume: 76  Issue: 9  Pages: 650-656  Published: SEP 2007
**Abstract:** In summer 2006 the first 5 MW offshore wind turbine has been installed in 45 m water depth in Scotland. The large water depth and other difficult site conditions, like harsh wave climate and unfavourable soil conditions, made numerous innovations for the support structures and installation necessary. This paper describes design, fabrication and installation of the jacket structures which have been developed. Furthermore the installation methodology for the turbine for which a floating crane instead of a fixed platform was used, is described. The knowledge gained from this project will enable realization of offshore windfarms in water depth beyond 20 m.

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**Report on the research project OWID - Offshore wind design parameter**

**Author(s):** Neumann T, Emeis S, Illig C  
**Editor(s):** Peinke J; Schaumann P; Barth S 
**Source:** Wind Energy  
**Pages:** 81-85  
**Published:** 2007 

**Conference Information:** EUROMECH Colloquium 464b on Wind Energy  
Carl VonOssietzky Univ Oldenburg, Oldenburg, GERMANY, OCT 04-07, 2005

**Abstract:** The chapter gives an overview of the research project OWID that has been launched in mid-2005. Aim of the project is to make proposals to improve offshore related standards and guidelines on the basis of measured FINO1 data and CFD calculations. Some examples for the motivation of the research project and a first glance on some preliminary results are given.

The FINO1 platform [1, 2], which is installed in 2003 about 45 km off the island Borkum, is equipped with a met mast with a height of about 100m and records the long-term meteorological and oceanographic conditions in the North Sea.

Within the project OWID the FINO-data are used to reduce incomplete knowledge when adapting wind turbines to the maritime conditions. We start with a thorough evaluation of the acquired FINO1 data with the focus on the mechanical loads a future wind turbine is exposed to. In addition to the undisturbed wind field the disturbed wind stream within the wake field is simulated by CFD models as we think that the major part of the load originates in the wake fields. Both undisturbed and disturbed wind fields are used to calculate the loads on a realistic offshore wind turbine with regard to the lay out and the life time.

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**Floating windfarms for shallow offshore sites**

**Author(s):** Henderson AR, Zaaijer M, Bulder B, Pierik J, Huijsmans R, van Hees M, Snijders E, Wijnants GH, Wolf MJ  
**Editor(s):** Chung JS; Izumiyama K; Sayed M; Hong SW 
**Source:** PROCEEDINGS OF THE FOURTEENTH (2004) INTERNATIONAL OFFSHORE AND POLAR ENGINEERING CONFERENCE, VOL 1  
**Book Series:** International Offshore and Polar Engineering Conference Proceedings  
**Pages:** 120-127  
**Published:** 2004 

**Conference Information:** 14th International Offshore and Polar Engineering Conference (ISOPE 2004)  
Toulon, FRANCE, MAY 23-28, 2004  
Int Soc Offshore & Polar Engineers

**Abstract:** Offshore wind energy appears to be on the verge of a phase of enormous expansion to becoming a significant source of electricity for a number of countries in northern Europe. Two major offshore windfarms at Horns Rev and Nysted are now in operation and dozens further projects are in various stages of preparation with a significant number now having planning permission and firm construction dates. The projects built to date have been in shallow seas, of up to around 20m in
depth in the North and Baltic seas, with the planned projects extending the range to new seas and greater depths. However, numerous challenges remain in the greater depths, in particular relating to the necessary size of the support structures, the resulting wave loads, handling equipment and natural frequencies. At one point, the inherent advantages associated with a floating support structure (of compliance due to the flexible attachment to the ground) will match the additional costs due to complexity and novelty. Questions of course remain under what conditions this will be (water depth, sea climate, distance to shore) and whether offshore wind energy can be proven to be economic at all under such greater challenges. Significant technical and cost challenges will remain, in particular regarding:

- minimising wave induced motion
- the additional complexity for the wind turbine design process
- understanding the coupling between the support structure and the wind turbine
- the construction, installation and O & M procedures.

On the positive side, these challenges are accompanied by new opportunities for systems and procedures that the use of a floating support structure allows. The research project being reported on within this paper has focused on the shallow seas of around 50 m water depth in the Dutch sector of the North Sea. For floating support structures, at these depths, additional challenges beyond those listed above include:

- achieving stability,
- designing appropriate moorings (paradoxically it being more difficult to moor a vessel in the shallowest waters).

This paper provides an overview of a feasibility study, DrijfWind or FloatWind performed in the Netherlands, describing the concept generation, evaluation and selection process, reporting on ancillary issues such as grid connection and O & M and providing a report of the in-depth analysis of the concept selected to be most suitable for the conditions considered, this being a triple floater shown below, Fig. 1. The conclusions are that although, in this case, this technology may not yet be ready for commercial application, the margin to economic viability is closing.

On the modelling of a floating offshore wind turbine

**Author(s):** Henderson AR, Patel MH

**Source:** WIND ENERGY  **Volume:** 6  **Issue:** 1  **Pages:** 53-86

**Published:** JAN-MAR 2003

**Abstract:** The location of wind turbines on floating structures offshore would allow an immense resource to be tapped without the drawbacks large developments can have on public opinion. There are, however, potentially significant technical and cost drawbacks. This article describes the theory and results of research work aimed at developing analytical tools for evaluating the performance of floating offshore wind farms. The principal problem addressed here is the development of analytical tools for modelling the turbine loads and fatigue damage due to the vessel motion. The effect that the motion would have on the wind turbine is found by calculating the aerodynamic and inertial loads on the blades in a two-dimensional state domain representing the blade and the vessel motion respectively. Using a double Fourier transform, discrete deterministic frequency spectra of the loads are found and the fatigue damage is evaluated. Undertaking the calculations for vessel motion in each degree of freedom allows appropriate weightings to be developed, which can be used for the optimization of candidate supporting vessels by evaluating the motion response directly. Copyright (C) 2003 John Wiley Sons, Ltd.

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Floating **wind turbines**.

Placement of the first floating aerogenerator prototype. **Idermar**

Initial design of tlp for offshore wind farm. **Tension Leg Platform.**

Floating Wind Turbines. by Paul D. Sclavounos Professor of Mechanical Engineering and Naval Architecture **MIT Department of Mechanical Engineering**

A Novel Concept for Floating Offshore Wind Turbines. **Depwind**

Research Centre for Offshore Wind Technology. **Project**

Prospects for floating offshore wind energy. **Paper**

A quantitative comparison of three floating wind turbines Jason Jonkman, NREL. **Presentation**

VAWT for offshore - pros and cons. Dr. Olimpo Anaya-Lara and prof Bill Leithead, Univ. of Strathclyde. **Presentation**

State-of-the-art design practices for offshore wind farms. Peter Hauge Madsen, RISØ DTU. **Presentation**

Dominique Roddier1, Christian Cermelli2, Alexia Aubault2, and Alla Weinstein1. **WindFloat:** A floating foundation for offshore wind turbines


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Brett Andersen. **A Comparison of Two and Three Bladed Floating Wind Turbines.**
3. Wave Power Generation

3.1. Introduction

Wave power or wave energy is the energy that could be generated using the power of the waves found at the surface of the ocean.

In terms of the system which allows current positioning, it can either be a gravity structure which sits on the sea bottom or a piled foundation driven into the seabed, similar to the huge offshore wind turbines and floating or semi-submersible platforms. In any case, wave power systems must always have an adequate mooring system, the most common being:

- a Floating Point Absorber (AquaBuOY),
- a Floating Attenuator (Pelamis),
- an Oscillating Water Column Terminator (Oceanlinx),
- and a Floating Overtopping Terminator (Wave Dragon).

There are currently thousands of concepts and patents about the technology to transform wave energy:

- subscale or full scale laboratory model testing (hundreds)
- short-term tests in natural waters (about a dozen)
- long-term testing of full-scale prototypes in natural waters (only a few)

3.2. Technological developments

Wave energy capture technology is currently being developed, with several pilot projects under study. There are about thirty pilot converters which are actually producing electricity, either in isolation or connected to the grid, and which clearly contrast with any other type of renewable energy potential.

The first technologies developed to harness wave energy, as well as many others which were deployed later on, are based on the Oscillating Water Column (OWC) principle, whereby a rising and falling water surface moving in an air compression chamber produces an oscillating air current which flows through a reversible turbine that drives power generation.

**OWC devices can in turn be classified, according to their installation typology, into:**

**Stationary devices**, which include the Pico and Limpet OWC plants (isolated structures) and the Mutriku device (OWC breakwater).

**Floating devices**, which include the Migthy Wale device, the largest floating oscillating device worldwide. This prototype has a displacement of 4400 tons and measures 50m long by 30m wide.
A second group of technologies includes what are known as overtopping wave energy converters. These devices harness the potential and/or kinetic energy from incoming waves. They are specifically designed in such a way that they have some reservoirs which are filled by incoming waves to levels above the average surrounding ocean (overtopping). The waves impact their articulate or flexible structure, thus increasing their mechanical energy.

**Overtopping WECs can also be classified into:**

*Stationary devices*, which function similarly to hydroelectric power stations. The waves captured by the device surge up a ramp into a reservoir, which is positioned several metres above sea level. Once in the reservoir, the water is funneled into some turbines coupled to generators which produce electricity. After the waves flow through the turbines, they continue through the ocean. Some examples of these overtopping converters are the [Seawave Slot-Cone Generator SSG](#) and the [TAPCHAN](#), or tapered channel systems.

*Floating devices*, which are operated in a way similar to stationary converters. Their advantage is that they also allow power storage. Floating devices include the [Wave Dragon](#), a floating slack-moored energy converter which consists of two wave reflectors that direct the waves towards a ramp. The water is then let out of the Wave Dragon reservoir through a Kaplan turbine thus generating electricity. There is only one 237-ton Wave Dragon prototype, which is anchored off the coast of Denmark. It had permission for test and electricity production until the end of 2009. [Waveplane](#) had permission to test until August 2009.

The third group of technologies for exploiting this wave energy potential encompasses what are known as *floating devices* which, through a horizontal swell motion, act as servomechanisms operating some power generating equipment. One of the most significant examples of this is the [PELAMIS](#) wave power converter. The machine sits ‘snake-like’ on the surface of the water, comprising a number of cylindrical sections joined together by hinged joints. The motion at each joint is resisted by hydraulic cylinders which pump fluid into high pressure accumulators allowing
electrical generation to be smooth and continuous. A Pelamis farm is currently being installed off the northwest coast of Portugal. It has an installed capacity of 2.25 MW and three four-cylinder sets with a capacity of 750 KW, a displacement of 700 tons and 150 m total length each. The farm was meant to generate electricity into the grid by September this year. Its estimated cost is £4 million.

Iberdrola and Tecnalia Corporación Tecnológica have installed a similar system off the coast of Guipúzcoa. The initiative has a budget of 4.5 million euros, and is the first prototype for producing wave energy in this area.

The last group of wave energy converters consists of floating or submerged systems which convert vertical motion caused by the ocean into electricity, either using a linear generator or by pumping air into a pneumatic device.

As an example of this kind of technology we could mention OPT’s (Ocean Power Technologies) buoy. OPT has deployed its first PowerBuoy under contract with Iberdrola and its partners, at a site approximately three miles off the coast of Santona, Spain. The power generating site will consist of ten 40 KW and nine 150+ KW buoys. One 40 KW buoy has currently been installed.

The Archimedes Wave Swing by AWS Ocean Energy is also worth mentioning. Each AWS machine is an 800 ton cylinder tethered to the seabed by cables which keep it over 20 feet below the surface of the sea.

It is a submerged offshore device activated by the fluctuations of static pressure caused by the surface waves. Consequently, the device is subject to a vertical oscillation and/or rotational movement while in operation. Basically, the AWS has an air-filled cylindrical chamber which varies in volume according to the pressure difference acting on its top.

The lid, called the floater, is a heaving body which compresses the air within the cylinder and triggers a pneumatic power generator. A pilot prototype was installed off Orkney, Scotland.
3.3. Current status worldwide

Several companies throughout the world started to design and deploy the first wave energy converters by the 1990’s. The sections below give a general overview of what is being done in some countries.

3.3.1 Countries

Australia

Ocean Power Technologies is developing a project in Portland with funding from the Australian Government. OPT’s technology, consisting of a series of “PowerBuoys”, is typically located 2-3 miles offshore. A PowerBuoy is a structure similar to a buoy (a point absorber) which moves up and down with the waves. The resulting mechanical energy is converted into electrical energy using a power take-off, an electric generator and an electronic control system, all of them sealed within the PowerBuoy.

The one-third scale model of the Oceanlinx floating wave energy technology, dubbed the MK3PC, was tested for three months, in 2010, and operated successfully until its moorings were damaged in extreme sea conditions in May.

The first ocean deployment of BioPower Systems technology is planned to occur near Port Fairy, Victoria, and currently the conversion modules are being tested in a factory.

Wave Rider Energy Pty Ltd is planning to launch a pilot plant in South Australia.

Carnegie Corporation continues to develop its projects:
- **Perth Wave Energy Project**, Western Australia
- **La Réunion Wave Energy Project** (Stage 1) Schematic
- **Ireland Wave Energy** Project

The **Perpetuwave** prototype captures wave energy through a series of articulated arms mounted on the bottom or a larger floating craft. Each of the articulated arms has a float mounted on the end, and as waves pass under the larger craft the articulated arms are forced to move up and down with the waves. The mechanical energy in the arms is converted on board into electricity.

**New Zealand**

The New Zealand Government continues to fund three marine energy projects: **The Wave Energy Technology** - New Zealand (WET-NZ) R&D program conducted by two parties, **Industrial Research Limited** and **Power Projects Limited**, and two other R&D projects conducted by the National Institute of Water and Atmospheric Research on tidal energy optimization and on extreme wave statistics.

WET-NZ’s 2 kW 1:4 scale prototype was deployed in late November 2009. Final design for the 20 kW 1:2 scale prototype has been completed and building is planned to start in November.

**Chatham Islands Marine Energy** is waiting for resource consent. The project consists in a Wavegen LIMPET type device to be installed on the main Chatham island (800 km east of NZ).
Israel

S.D.E. is a world leader in the planning, building and marketing of power stations, producing power from sea waves. SDE’s method consists of using sea wave motion to generate hydraulic pressure, which is then transformed into electricity. The system takes advantage of the wave’s speed, height, depth, rise and fall, and the flow beneath the approaching wave, thus producing energy. A full-scale model was operated in Israel and produced 40ekW for almost one year.

Korea

The ocean energy research activity in Korea has been increased steeply in recent years.

Several wave projects are presently running with funding from the Ministry of Land, Transport and Maritime Affairs (MLTM), or from the Ministry of Knowledge Economy (MKE).

The Yongso 500kW Oscillating Water Column (OWC) pilot plant developed by the Maritime & Ocean Engineering Research Institute (MOERI) is expected to be installed on Jeju island in 2011.

Indonesia

Many of the projects currently under development are not specifically related to wave energy, but to wave and tidal current energy systems. Recent developments in ocean energy include, among others, a marine current project operated by the Indonesian Hydrodynamics Laboratory and an Oscillating Water Column (OWC) in Yogyakarta, coordinated by BPPT.

Portugal

The 400kW Oscillating Water Column (OWC) pilot plant on the island of Pico, Azores, is one of the most significant Portuguese projects. It continues to be a platform of world-wide significance for the technology learning process, R&D activities and training. The plant is designed to host a second turbo-generation group, which made it possible to be included in a European infrastructures network (MariNET) of large importance to the sector.

Vessels and platforms for the emerging wind and wave power market
**Eneólica** initiated a wave energy project in Peniche (Central Portugal) with the Finnish technology WaveRoller with European funding. AW-Energy started the construction of the prototype and baseline environmental studies were initiated in 2010 by the Wave Energy Centre.

**Spain**

Several wave energy projects are still in progress: the Biscay Marine Energy Platform (bimep), Mutriku OWC breakwater and the "PIPO" wave energy converter on the Canary Islands (Welcome project).

**Norway**

**Langlee Wave Power** received support from the Research Council of Norway for its development.

**Sweden**

The wave energy Lysekil project (2006-2010), consisting of ten linear generators, led by Uppsala University, has presently four linear generators installed.

The wave energy Islandsberg project (2007-2010), led by Seabased AB (4x20 kW and 1x50 kW) to be grid connected, has just launched one generator.

**Denmark**

Several Danish wave energy companies are pursuing their developments: **Wave Star A/S** prototype has been operating in the North Sea in Hanstholm during 2010.
Floating Power Plant started a second test period in the spring of 2010 including the installation of 3 wind turbines for testing the combination of wind and wave power.

The Dexa wave energy device has operated during 10 months in Nissum Bredning and presently a larger scale model is prepared for testing at DanWEC Hanstholm.

A 1:10 scale model of the Leacon device is under construction and is now expected to be installed in the spring of 2011 in Nissum Bredning.

United Kingdom
The European Marine Energy Centre (EMEC) provides information about projects in the field of wave and tidal energy.

Aquamarine’s device, Oyster 1, installed in EMEC in 2009, is currently undergoing sea trials and planning the design of the next-generation Oyster 2.
The Pelamis P2 750 kW machine, manufactured by Pelamis Wave Power Ltd, completed its first set of trials in the outer reaches of the Firth of Forth.

The pioneering Wave Hub marine energy project is creating the world’s largest test site for wave energy technology by building a grid-connected socket on the seabed off the coast of Cornwall in South West England, to which wave power devices can be connected and their performance evaluated. There are four berths available each covering two square kilometers. Wave Hub will have an initial maximum capacity of 20MW but has been designed with the potential to scale up to 50MW in the future.

Ireland

SEAI is developing a full scale ocean site — The Atlantic Marine Energy Test Site (AMETS) — located west of Belmullet.

Some wave energy test sites have also been in place in Galway Bay.

Ocean Energy Ltd, is currently testing the Seilean wave energy prototype in Galway Bay. It was deployed from December 2006 and successfully withstood severe winter storms. The project is now in phase two, testing offshore in deeper waters – which includes the turbine installation phase.

Wavebob Ltd, were the first company to use the OE test site. They deployed a prototype at the site in 2006 and a second, with modifications, in 2007.
United States of America

Oregon State University (OSU) and University of Washington (UW) in partnership are developing the Northwest National Marine Renewable Energy Center (NNMREC) to support wave and tidal energy development for the United States.

Ocean Power Technologies, Inc, signed an agreement with eleven federal and state agencies and three non-governmental stakeholders for its utility-scale wave power project in Reedsport, Oregon.

In 2010, the Department of Energy made 20 Advanced Water Power Technology Development awards, including funding for advanced design and manufacturing technologies for composite materials, conceptual design and modelling for ocean thermal energy conversion (OTEC), advanced power converters and power take off mechanisms. The wave energy projects granted an award were:

- **Columbia Power Technologies, Inc** will optimize, demonstrate, and validate an intermediate-scale wave energy conversion device in preparation for a full-scale ocean demonstration. Improvements in energy capture of this device will occur through research into hydrodynamics and advanced controls to better match the wave regime.
  
  DOE share: up to $750,000; Duration: up to 2 years

- **Re Vision Consulting, LLC** (Sacramento, CA) will develop life-cycle cost profiles for different site and wave, tidal, ocean current and in-stream hydrokinetic technology combinations using baseline representative commercial project development data from specific sites.
  
  DOE share: up to $500,000; Duration: up to one year

- **Pacific Energy Ventures (Portland, OR)** will test a limited range acoustic deterrent system at an open water location near a proposed Oregon State University project site with the purpose of discouraging migrating gray whales from entering wave energy parks in order to minimize the risk of mortality.
  
  DOE share: up to $600,000; Duration: up to one year

- **Columbia Power Technologies, Inc (Charlottesville, VA)** will perform benchmark laboratory experiments and numerical modeling of the near-field and far-field impacts of wave
scattering from an array of wave energy devices. This will provide the information needed to design arrays balancing performance with the mitigation of far-field impacts.

DOE share: up to $600,000; Duration: up to one year

- **Principle Power, Inc** (Seattle, WA) will design, validate, and determine the levelized cost of electricity for an innovative floating support structure that combines a number of wave and wind energy power take-off mechanisms, which will defray the mooring and installation costs associated with higher power output.

DOE share: up to $750,000; Duration: up to 2 years

### 3.3.2 Wave energy developers

<table>
<thead>
<tr>
<th>Company</th>
<th>Technology</th>
<th>Device type</th>
<th>Country base</th>
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<tr>
<td>Able Technologies L.L.C.</td>
<td>Electric Generating Wave Pipe</td>
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<td>Applied Technologies Company Ltd</td>
<td>Float Wave Electric Power Station</td>
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<td>Aquamarine Power</td>
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<td>Archimedes Wave Swing</td>
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<td>BioPower Systems Pty Ltd</td>
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<td>Bourne Energy</td>
<td>OceanStar ocean power system</td>
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*Vessels and platforms for the emerging wind and wave power market*
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<td>Rothman Energy Systems</td>
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<td>SurfPower</td>
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<td>SEEWEC Consortium</td>
<td>FO3 device, previously as Buldra</td>
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<td>Union Electrica Fenosa of Spain</td>
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<td>Wave Energy</td>
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<td>Wave Energy Centre (WaVEC)</td>
<td>Pico plant</td>
<td>D</td>
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*Vessels and platforms for the emerging wind and wave power market*
### 3.3.3 Main wave energy devices

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<td>AWS (Archimedes Wave Swing)</td>
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<td>BioWAVE™</td>
<td>BioPower Systems Pty. Ltd</td>
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<td>Australia</td>
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<td>Brandl Motor</td>
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<td>Germany</td>
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<td>CETO</td>
<td>Seapower Pacific Pty Ltd</td>
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<td>Direct Drive Permanent Magnet Linear Generator Buoy / Permanent Magnet Rack and Pinion Generator Buoy / Contactless Force Transmission Generator Buoy</td>
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<td>Fobox AS</td>
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<td>University of Manchester Intellectual Property Ltd (UMIP)</td>
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<td>Pico plant</td>
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<td>University of Edinburgh</td>
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<td>Onshore</td>
<td>Norway</td>
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<td>Shoreline OWC</td>
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<td>SeaRev (Consortium being built, starting from Ecole Centrale de Nantes)</td>
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<td>Wave Catcher</td>
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</tbody>
</table>
### Platform designs

**VersaBuoy Applications**

![VersaBuoy Applications](image)

**Wave Star A/S**

The Pneumatically Stabilized Platform or **PSP**

![Wave Star](image)

**Langlee Wave Power.** [The Langlee E2](link)
Oceanlinx. MK3PC

University of Manchester. Manchester (UK) Bobber

Buldra

Vessels and platforms for the emerging wind and wave power market
3.5. European projects

**Aqua-RET - Aquatic Renewable Energy Technologies**

Aqua-RET is an EU-funded Leonardo da Vinci project that will develop a group of marine renewable energy e-learning sessions to inform the general public and stimulate companies to intervene in the marine renewable energy industry. The project started in October 2006 and will continue for a period of 24 months. It gathers entities and institutes of countries such as Cyprus, Greece, Romania, Scotland and Ireland, besides Portugal.

Through e-learning modules using the latest multimedia tools, the user is informed about the existing marine renewable energy technologies, how aquatic renewable energy technologies work, how they fit into the landscape and how they benefit the economy.

For detailed information on wave energy technologies, go to [this section](#).

**Aqua-RET 2** is currently running (2009-2011).

Standardisation of Point Absorber Wave Energy Convertors by Demonstration. [STANDPOINT](#)

**Start date**: 2009-11-16

**End date**: 2012-11-15

**Project Acronym**: STANDPOINT

**Project status**: Execution

Coordinator

**Organization name**: WAVEBOB LTD

**Contact person**

<table>
<thead>
<tr>
<th>Name</th>
<th>Address</th>
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<tbody>
<tr>
<td>Andrew PARISH (Mr)</td>
<td>H3 Maynooth Business Campus</td>
</tr>
</tbody>
</table>
Description

Objective: In contrast to other renewable energy sources, wave energy conversion is currently at a stage of evolution where it is being demonstrated using a wide range of very diverse technologies and a de facto standard approach is yet to emerge. A fully functional, but reduced scale prototype Wavebob wave energy converter (WEC) has already been deployed in the Atlantic Ocean.

STANDPOINT will seek to demonstrate this WEC technology at full size for a further long term Atlantic Ocean deployment, 12 months of which will occur within the timeframe of the STANDPOINT project. Unlike its smaller-scale scale predecessor, it is intended that this pre-commercial WEC will be grid-connected. The intended location for the deployment is off the Portuguese coast. The indicative dimensions of the WEC for a full-scale deployment in this part of the Atlantic are 14 m diameter, 40 m draft. The WEC will have a nominal output of 1.2MW from 4 power take-off (PTO) sets: three using proven hydraulic technology and one using a newly developed and innovative linear generator technology.

There are 6 partners from 5 member states, including a Certification Body who will develop and disseminate rules and guidelines for wave energy converters. Innovative SMEs (including the co-ordinator) will demonstrate recently patented technology, in which they lead the state-of-the-art. A large power generation company, and various sub-contractors will work together to implement this ambitious full-scale demonstration.

The aim is to establish the offshore tuneable-resonance point absorber as the winning wave energy conversion technique by demonstrating the superiority of its power take-off technology, adaptability to changing sea conditions, reliability and survivability.

**Demonstration & Deployment of a Commerical Scale Wave Energy Converter with an innovative Real Time Wave by Wave Tuning System.** [WAVEPORT]

**Start date:** 2010-02-01

**End date:** 2014-01-31

**Project Acronym:** WAVEPORT

**Project status:** Execution

**Coordinator**

**Organization name:** THE UK INTELLIGENT SYSTEMS RESEARCH INSTITUTE LIMITED

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**Objective:** In the Atlantic arc from Iceland to Portugal, Europe has some of the best natural wave resources in the world; with the total potential European ocean wave power estimated to be in the range 150 - 240 TWh per annum. The main barrier to wave energy expansion is the lack of a large, commercial-scale demonstration of the technology. In addition, the efficiency of devices is limited and needs to be improved.

The WAVEPORT project aims to address this shortfall by demonstrating a large scale grid connected, 600kW peak generator rated, point absorber Wave Energy Converter - for which a smaller scale prototype has already been tested.
WAVEPORT will also expedite the development of alternative devices by installing a ten port open platform 1.5MW rated underwater substation pod for the validation of future wave energy converters. To address the need for improved efficiency; a novel Real-Time Wave-by-Wave tuning system will be developed and demonstrated.

Our aims are:

- Reduce the capital infrastructure cost of the WEC device to less than 2000/kW by 2020.
- Accelerate the development of a wavefarm site within the Santona site in Spain, to 90 MW by 2020 generating over 500 GWh per annum, offsetting approx 215,000 tonnes of CO2 per annum
- Accelerate the development of European wave farms to 0.97 GW by 2020 generating over 6 TWh offsetting approx. 2.6 mT of CO2 per annum
- Facilitating an open platform approach for utilities and WEC developers through the use of the Underwater Sub-Station Pod, further reducing the risks associated with investment in this technology
- Reduce the cost of Wave energy generated electricity to 4.3 c /kWh by 2020
- Improvement on the energy efficiency of wave energy devices by at least 35 % (loading factor to at least 75%) by utilising the Real-Time Wave-by-Wave tuning system.
- Create 7600 jobs in the renewable energy sector over the period to 2020 by developing a European based wave energy industry worth 1.9 billion in cumulative sales

Off-shore Renewable Energy Conversion platforms Coordination Action. ORECCA

Start date: 2010-03-01
End date: 2011-08-31
Project Acronym: ORECCA
Project status: Execution

Coordinator

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Organization Type:

Objective: The objectives are to create a framework for knowledge sharing and to develop a research roadmap for activities in the context of offshore renewable energy (RE). In particular, the project will stimulate collaboration in research activities leading towards innovative, cost efficient and environmentally benign offshore RE conversion platforms for wind, wave and other ocean energy resources, for their combined use as well as for the complementary use such as aquaculture and monitoring of the sea environment. The use of the offshore resources for RE generation is a relatively new field of interest.

ORECCA will overcome the knowledge fragmentation existing in Europe and stimulate the key experts to provide useful inputs to industries, research organizations and policy makers (stakeholders) on the necessary next steps to foster the development of the ocean energy sector in a sustainable and environmentally friendly way. A focus will be given to respect the strategies developed towards an integrated European maritime policy. The project will define the technological state of the art, describe the existing economical and legislative framework and identify barriers, constraints and needs within.

Vessels and platforms for the emerging wind and wave power market
ORECCA will enable collaboration of the stakeholders and will define the framework for future exploitation of offshore RE sources by defining 2 approaches: pilot testing of technologies at an initial stage and large scale deployment of offshore RE farms at a mature stage.

ORECCA will finally develop a vision including different technical options for deployment of offshore energy conversion platforms for different target areas in the European seas and deliver integrated roadmaps for the stakeholders.

These will define the strategic investment opportunities, the R&D priorities and the regulatory and socio-economics aspects that need to be addressed in the short to the medium term to achieve a vision and a strategy for a European policy towards the development of the offshore RE sector.

**Marine renewable integrated application platform.** **MARINA PLATFORM**

**Start date:** 2010-01-01  
**End date:** 2014-06-30  
**Project Acronym:** MARINA PLATFORM  
**Project status:** Execution  

**Coordinator**

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**URL:** Organization Type:

**Description**

**Objective:** MARINA is a European project dedicated to bringing offshore renewable energy applications closer to the market by creating new infrastructures for both offshore wind and ocean energy converters. It addresses the need for creating a cost-efficient technology development basis to kick-start growth of the nascent European marine renewable energy (MRE) industry in the deep offshore a major future global market.

The project combines deep-water engineering experience from European oil & gas developments during the last 40 years, state-of-the-art concepts for offshore wind energy, and the most promising concepts in today's R&D pipeline on wave energy and other marine renewables. The MARINA project is designed to capitalise on the vast body of proven marine technological knowledge gained in one of the world's most hostile off-shore operating environments: the Northern European seas.

MARINA will bolt this practical technology skill set onto the research base of the emerging but still marginal EU MRE industry and ensure its continued world-leading role. The MARINA project is therefore of major strategic significance for Europe.

**Simple underwater generation of renewable energy.** **SURGE**

**Start date:** 2009-10-05  
**End date:** 2012-10-04  
**Project Acronym:** SURGE  
**Project status:** Execution  

**Coordinator**

**Organization name:** AW-ENERGY OY  
**Contact person**  
**Address**
Objective: AW Energy Oy/s WaveRoller is the original concept to tame the surge in the nearshore areas. Although the major wave energy potential is clearly offshore in larger depths, apparently there still exist major drawbacks for the commercial-scale deployment of offshore devices, due to the necessity to rely on offshore maritime technologies, which on one hand are rather expensive and on the other hand are yet to prove their suitability for wave energy applications. For this reason, it shall be worth-while to assess the value of on- and near-shore devices in particular in the present development phase: it is possible to use lower-cost modular technology and the devices are also much easier to maintain due to the proximity to the shoreline.

WaveRoller is a unique, proven and patented product design for near-shore bottom wave (surge) energy conversion, and it was the first solution of its type (invented 1993 by Finnish professional diver). The detailed engineering, construction, deployment and monitoring of the simple and robust near-shore wave energy concept WaveRoller north of the Portuguese coastal town Peniche is an important step towards the large-scale reality of submerged near-shore wave energy utilisation. In addition to of the robust component and structural design, easy manufacturability and assembly, extensive technical and environmental monitoring activities will assure the appropriate assessment of the demonstration plant.

The development of a novel rare-earth magnet based wave power conversion system – Snapper

Start date: 2009-09-01
End date: 2011-08-31
Project Acronym: SNAPPER
Project status: Execution
Coordinator

Objective: Our concept is a step change in enabling cost effective marine energy renewable capture. It is the development a novel low cost, high efficiency linear generator for marine wave energy extraction, (Snapper). Initially embedded within Point Absorbers and then transferable to other marine energy type capture devices, both wave and tidal, with energy efficiency of the generator of between 75%-80%. The primary advantage of the Snapper technology extending it beyond the state of the art is its ability to act as a magnetic gearing system. This leads to a significant reduction of the mass of the materials needed within the electrical generator, especially rare early magnets. This will result in a cost saving, based on the raw materials from over 40k to under 7k for a 175KW electrical machine. This will enable a step change in the economic potential for the conversion of wave energy into electricity. To achieve this our technological objectives are: 1) To provide a low friction interface; a coefficient of friction (of not greater than 0.2%) between the translator and the stator with a design lifetime of 20 years operation, 2) To achieve a robustness of design according to six
To achieve environmental protection of the development against marine environments; up to a depth of 60m (6 BAR), wave loading (25 year storm event), salinity (3.5%), anticorrosion (5 year) and biofouling (5 year); and, 4) ensuring that the development is intrinsically environmentally benign. We will also ensure that the system is grid compatible i.e. can be connected to an electrical distribution grid.

**Equitable testing and evaluation of marine energy extraction devices in terms of performance, cost and environmental impact.** **EQUIMAR**

**Start date:** 2008-04-15  
**End date:** 2011-04-14  
**Project Acronym:** EQUIMAR  
**Project status:** Execution

**Coordinator**

**Organization name:** THE UNIVERSITY OF EDINBURGH  
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**Region:** SCOTLAND BORDERS-CENTRAL-FIFE-LOTHIAN-TAYSIDE Lothian  
**Organization Type:** Education

**Description**

**Objective:** EquiMar will deliver a suite of protocols for the equitable evaluation of marine energy converters (based on either tidal or wave energy). These protocols will harmonise testing and evaluation procedures across the wide variety of devices presently available with the aim of accelerating adoption through technology matching and improved understanding of the environmental and economic impacts associated with the deployment of arrays of devices. EquiMar will assess devices through a suite of protocols covering site selection, device engineering design, the scaling up of designs, the deployment of arrays of devices, the environmental impact, in terms of both biological & coastal processes, and economic issues. A series of protocols will be developed through a robust, auditable process and disseminated to the wider community.

**Initial training network for wave energy research professionals.** **WAVETRAIN 2**

**Start date:** 2008-10-01  
**End date:** 2012-06-30  
**Project Acronym:** WAVETRAIN 2  
**Project status:** Execution

**Coordinator**

**Organization name:** WAVE ENERGY CENTRE - CENTRO DE ENERGIA DAS ONDAS  
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**Location:** Rua Sa da Bandeira PORTO PORTUGAL  
**Region:** CONTINENTE NORTE Grande Porto  
**Organization Type:**

**Description**

**Objective:** The proposed action builds strongly up on the logics of its predecessor with the same name. The overall objective is to create a pool of specialised wave energy research professionals to...
support an emerging industry in a field with a very strong anticipated growth and no dedicated existing training curriculum. Although most jobs can be done being a trained engineer in one of the adjacent fields, the existence of interdisciplinary skilled researchers trained in direct connection to the technology development is vital for successful development.

In the predecessor, almost all fellows where immediately absorbed by industrial players in the field or continued research in the host institution. The work plan for WAVETRAIN 2 fellows is specifically directed towards a wide range of challenges that industrial-scale wave energy implementation faces in the present situation, with some bias towards technical issues, from hydrodynamic and PTO (Power-Take-Off) design, to instrumentation issues and energy storage and cost reduction show to be critical for successful deployment.

**Components for ocean renewable energy systems. CORES**

**Start date:** 2008-04-01  
**End date:** 2011-03-31  
**Project Acronym:** CORES  
**Project status:** Execution  

**Coordinator**  
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**Description**  
**Objective:** Wave Energy Convertors are at an early stage of development. First generation devices have been deployed at the shoreline and normally consist of Oscillating Water Column Systems. In order for these systems to progress towards full commercial realisation they must develop into suited to mass production. This project follows the successful FP6 funding round in which several fixed Oscillating Water Columns Wave Energy Convertors (OWC WECs) were funded at Demonstration level.

These systems are now evolving from fixed to floating devices in deeper water, further offshore. This brings new challenges which this project aims to address. The project will concentrate on the development of new concepts and components for power-take-off, control, moorings, risers, data acquisition and instrumentation based on floating OWC systems. However, the components and concepts developed will have relevance to other floating device types. This project is proposed to run over 3 years. The project brings together a mix of RTD performers and SMEs selected from across the European Union for their track records, complementarity and relevant experience.

**Fluid-structure interactions in offshore engineering. OFFSHORE FSI**

**Start date:** 2008-08-01  
**End date:** 2010-11-30  
**Project Acronym:** OFFSHORE FSI  
**Project status:** Execution  

**Coordinator**  
**Organization name:** UNIVERSITAT ROVIRA I VIRGILI  
**Contact person**  
**Address**
Objective: Fluid-structure interaction (FSI) is a multidisciplinary field which involves fluid mechanics, structural mechanics and vibrations, complex techniques for instrumentation and data analysis and numerical methods applied to computational fluid and solid mechanics. Two main FSI topics will be investigated during the course of the fellowship: Wave impact mechanics and vortex-induced vibrations (VIV) on offshore structures. There is a need for data collection regarding deformation of bluff body shapes under wave impacts, for different wave heights, lengths, steepness, and the geometry and immersion of the impacted structures. Surface vessels, floating production systems, and new offshore energy generation devices (wind turbines, wave energy devices) are the main applications.

Nereida MOWC: OWC integration in the new mutriku breakwater. NEREIDA MOWC

Start date: 2007-07-03
End date: 2010-07-02

Project Acronym: NEREIDA MOWC
Project status: Completed

Coordinator

Organization name: ENTE VASCO DE LA ENERGIA

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URL: Organization Type: Other

Description

Objective: The NEREIDA MOWC project is intended to demonstrate the successful incorporation of OWC technology with Wells turbine power take-off into a newly constructed rubble mound breakwater in Mutriku, in the north coast of Spain, being be the first breakwater wave energy project in Europe and showing its viability for future commercial projects. Eight OWC cells will be constructed to give an active collector length of close to 100 metres. Power take-off involves multiple turbines, each turbine being rated at 15kWe. Two turbines will be fitted to each OWC cell giving 16 turbines in total and a total installed power of 250 kW. The application of this technology at Mutriku will not only demonstrate the functional synergy between breakwaters and OWC systems but will do so in a location which, in contrast to previous European wave energy demonstrators, is in a urban location.

Development and validation of technical and economic feasibility of a multi MW Wave Dragon offshore wave energy converter. WAVE DRAGON MW

Start date: 2006-04-01
End date: 2009-03-31

Project Acronym: WAVE DRAGON MW
Project status: Completed
Coordinator
Objective: The Wave Dragon is a slack-moored wave energy converter of the overtopping type. It is by far the most powerful wave energy converter and at the same time one of the most energy efficient and economic devices under development today. Since March 2003 a 20kW scale 1:4.5 prototype of a 7MW Wave Dragon has been tested as the world’s first floating grid connected wave energy converter.

The project will develop the Wave Dragon technology further from the tested all steel-built 20kW prototype to a full size composite built 7MW unit and by testing validate the technical and economic feasibility.

The RTD-part of the project will:

- Develop Wave Dragon’s energy absorbing structure, the low head turbine power take-off system and the control systems. An additional reservoir placed above the existing reservoir level will also be developed. The result of these changes to the overall design will be a significant increase in power production and a reduction in O&M cost. The development of the 7MW unit will be based on the knowledge base established through the tests with the 20kW prototype and the design process will comprise several innovative elements utilizing the O&M experience from the 20kW prototype tests.

- Develop cost effective construction methods and establish the optimal combination of in situ cast concrete, post-stressed reinforcement and pre-stressed concrete elements

- Develop new supplementary environmental friendly water hydraulic power take-off systems

- Demonstrate reliable and cost effective installation procedures and O&M schemes

- Establish the necessary basis for design codes and recommendations for floating multi MW wave energy converters.

The test program will demonstrate the availability, power production predictability, power production capability and medium to long term electricity generation costs at 0.052EUR/kWh in a wave climate of 24kW/m, which could be found relatively close to the cost at the major part of the Atlantic coast.

Sustainable Economically Efficient Wave Energy Converter. SEEWEC

Start date: 2005-10-01

End date: 2009-03-31

Project Acronym: SEEWEC

Project status: Completed

Coordinator

Organization name: UNIVERSITEIT GENT

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Objective: The SEEWEC project presents a robust floating wave energy converter: the FO³, meant to be installed near shore and intended to lead to competitive and economically effective exploitation of wave energy along European coasts. The FO³ is designed to deliver electricity at a lower cost than offshore wind farms. For its design, key knowledge from the past is taken into account.

The general objective of SEEWEC is to assist in the development of a 2nd generation FO³ wave energy converter through extensive use of the experience from monitoring a 1:3 laboratory rig and a 1st generation 1:1 prototype. The project will focus on cost effective solutions and design for large scale (mass) manufacturing.

The specific objectives of SEEWEC are:

- To gain knowledge about the FO³ performance in real sea conditions through field monitoring of the 1:3 scale laboratory rig and the full scale first generation device;
- To refine the platform design: refine the device towards a second generation envisaged for commercial use. This objective includes the enhancement of the wave converter’s survivability and safety of performance and also the optimization of wave energy absorption;
- To choose and develop composite material for eggs, rig and other selected components; and design material manufacturing process for cost effective large scale production;
- To optimize the power conversion solution: this includes an optimization of power generation and transmission system;
- To define the deployment mode of platforms into a farm: define lay-out of platforms in a multi-unit plant for optimum energy absorption potential and safety;
- To enhance survivability of the wave converter: covers both overall survivability of the platform(s) and operational safety of working components

The expected results of SEEWEC is an optimized design for a 2nd generation full scale FO³ converter which will over time have an installed cost per kW which is lower than the equivalent for offshore wind energy.

Full-scale demonstration of robust and high-efficiency wave energy converter. WAVESSG
Start date: 2005-12-01
End date: 2008-05-31
Project Acronym: WAVESSG
Project status: Completed
Coordinator
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Description
Objective: WEAS currently carries out a separate pilot project of the SSG wave converter at the small island of Kvitsoy, Norway. The full-scale technical prototype of the SSG includes three reservoirs for capturing the ocean energy and is constructed as a robust shore line device. The
patented multi-reservoir concept ensures that a variety of waves are utilized for energy production, resulting in a high degree of efficiency. The pilot project regards a 10 m wide civil structure module of the SSG (without turbine and generator) and will be completed in 2006. Concurrently, WEAS in co-operation with NTNU performs a development study of a new multi-level water turbine (MST), specifically designed for the SSG converter. The main objective of the present project is to operate at full-scale one module of the SSG converter in 19 kW/m wave climate, including turbine, generator and control system. The specific objectives of the project are: - To design a full-scale 150 kW technical prototype of the innovative MST turbine technology - To manufacture, test and install a full-scale 150 kW technical prototype of the innovative MST turbine technology into the SSG structure - To design a full-scale 150 kW generator and control system equipment - Measure performance data of the SSG wave energy converter including the structure in a period of up to six months for reliability and life time assessment - To manufacture, test and install a full-scale generator and control system equipment for grid connection and annual production of 200,000 kWh of renewable and pollution-free electricity, corresponding to 20,000 kWh/m - Obtain a hydraulic efficiency of at least 39 % for the shoreline application - Obtain a wave-to-wire efficiency of more than 25 % during the test period - Obtain 96 % avail ability of plant - Obtain 85 % availability of production The success of the project will be measured against the last five specific objectives mentioned at the end of the project.

Wave pump submergible power generator. WAVEGEN
Start date: 2005-09-01
End date: 2007-12-31
Project Acronym: WAVEGEN
Project status: Completed
Coordinator
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Organization Type: Research,Industry

Objective: The search for a cost effective and reliable product able to open the wave energy market and make it grow into a profitable opportunity, especially for SMEs, did not get to a satisfying result do far; the WAVEGEN project proposes to develop a modular, very low impact, off-shore wave energy converter, created from the integration of the WAVEPUMP technology with a novel sub-sea power generation hydraulic turbine. A system with inherent characteristics of modularity, scalability and substantial absence of visual impact can be produced, achieving a competitive cost per energy unit produced.

Co-ordinated Action on Ocean Energy. CA-OE
Start date: 2004-10-01
End date: 2007-12-31
Project Acronym: CA-OE
Project status: Completed
Coordinator
Organization name: RAMBOLL DANMARK A/S
**Objective:** Ocean energy industries and research organisations are at present small and scattered. Nevertheless between 5 and 10 different large scale Ocean Energy systems including new and unproven technology are in the process of seeking funding and private investors to carry out the development required from scale models to working prototypes at sea. Different principles for wave energy conversion and tidal stream systems are preparing and being installed for prototype testing at different sites within Europe and several other principles are investigated at a more fundamental level.

In general the public is not aware of the development of Ocean Energy exploitation. There is a need to make a united effort from the developers and research community to present the various principles and results in a co-ordinated manner with public appeal.

In order to disseminate the knowledge and promote the technologies the co-ordinated Action on Ocean Energy will organize dedicated interactive workshops, as vehicles to enable co-operation between the interested European parties in the sector of Ocean Energy.

The main deliverables are the workshop proceedings and expert evaluation reports from the five workshops.

1 modeling of Ocean Energy Systems
2 Component Technology and Power Take-off
3 System design Construction of Ocean Energy Systems
4 Performance Monitoring of Ocean Energy Systems
5 Environmental Economics, Development Policy and Promotion of Opportunities

The main objectives are to develop a common knowledge base necessary for coherent development R&D policies to bring a coordinated approach within key areas of ocean energy research and development, to provide a forum for longer term marketing of promising research deliverables, revise and implement standards related to monitoring performance and presentation of results, safety on structural and electrical system design.

**Research Training Network Towards Competitive Ocean Wave Energy. WAVETRAIN**

**Start date:** 2004-06-01

**End date:** 2008-02-29

**Project Acronym:** WAVETRAIN

**Project status:** Completed

**Coordinator**

**Organization name:** INSTITUTO SUPERIOR TECNICO.

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Sea testing and optimisation of power production on a scale 1: 4,5 test rig of the offshore wave energy converter wave dragon **(WAVEDRAGON 1:4.5)**

**Start date:** 2002-10-01  
**End date:** 2005-06-30  
**Project Acronym:** WAVEDRAGON 1:4.5  
**Project status:** Completed

Coordinator

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**URL:**

**Organization Type:** Industry

**Description**

**Objective:**

The primary objectives are to contribute to the EU goals of:  
- Reaching a 12% share of renewable energy sources of total energy consumption and a 22% share of gross electricity consumption from renewable energy sources by 2010.  
- Reducing the greenhouse gas emission by 8% by 2010 based on the 1990 level.  
- Contributing to improving European self-sufficiency and diversification of energy supply.  

The objectives are reached through long-term field-testing on a grid connected overtopping wave energy converter with all systems installed. The power of the scale prototype corresponds to a 4-10 MW full-scale prototype. The Wave Dragon is a slack moored wave energy converter that can be deployed in large parks wherever a sufficient wave climate and a water depth of more than 20 m are found - typically this is the case in the North Sea and in the Atlantic.  

The basic test rig construction (267 tonnes) is provided through a project sponsored by the Danish Energy Authority. After designing and installing 6 additional turbines required for the RTD activities, a number of scientific issues that cannot be fully explored through laboratory testing are investigated:  
- Long-term field testing of turbine operation  
- Control strategy testing and optimisation  
- Power monitoring and evaluation  
- Stress and strain measurements & analysis  
- Mooring and cable systems analysis.  

Measured results will be compared to previous laboratory test results by calibrating and validating the model tools developed in the previous EU CRAFT project (JOR3-CT98-7027). The test site is in protected waters in Nissum Bredning, Denmark, where the wave climate resembles North Sea conditions (scale 1:4.5). The most promising European markets and their characteristics are assessed, and regional market characteristics assessed. Environmental impact assessment and life cycle analysis are performed. Dissemination includes the international audience, national and international networks within wave power, and key players in the long-term implementation strategy.  

Power production is graphically presented at the project web site, where also video clips are available. Expected Results and Exploitation Plans: A power production price of 0.11 /kWh will be documented at project finalisation with a long-term production price of 0.04 /kWh foreseen. A full-scale prototype demonstration in exposed waters is expected from 2006, marking the start-up of large-scale commercial exploitation of offshore wave power. The deployment of Wave Dragon will - through the already formed development company - contribute to the establishment of a completely new industry like the wind industry offering new opportunities for the declining European oil and gas offshore industry. The long-term employment in Europe is foreseen to 6,000, with an installed power of 2,400 MW expected by 2016.
Turbine efficiency project for swilling waterflows

Start date: 2001-09-26
End date: 2002-04-25

Project Acronym:

Project status: Completed

Coordinator

Organization name: WAVEPLANE INTERNATIONAL A/S
Contact person: Erik SKAARUP
Name: Erik SKAARUP
Address: Tagesmindevej 1
Tel: 2820
Fax: DANMARK
E-mail: Region: DANMARK Danmark København og Frederiksberg Kommuner
URL: Organization Type: Other

Description

Objective: The objective of this project is to use waves in order to achieve an efficient production of electricity by using a wave energy device called the Wave Plane (WP). The WP is a wave energy aggregate that through its physical shape transforms the pulsating waves into a steady fast rotating waterfows. During tests, the WP has demonstrated that it can absorb 22% of the total wave energy, thus holding a great potential, if, however, a suitable turbine is developed. None of the turbines available today, are able to efficiently utilize the fast rotating water flows that the WP generates. The aim of the project is to develop a turbine especially for the rotating water flows and thereby reach an electricity production cost from the WP of 0.5 euro/kwh. The new turbine is expected to be able to obtain 75-85% of the energy at hand, where the traditional turbines only are able to obtain app. 25-30%. To construct a new turbine the proposing partners will need 4-5 other partners with specific skills in the areas of modelling and simulation, measurement and testing, electrical (generator), and engineering.

Establishment of a european thematic network on wave energy (wave energy network)

Start date: 2000-04-01
End date: 2003-03-31

Project Acronym:

Project status: Completed

Coordinator

Organization name: AEA TECHNOLOGY PLC
Contact person: Graham DEENIE (Mr)
Name: Graham DEENIE (Mr)
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Tel: OX11 0QJ
Fax: DIDCOT, HARWELL, CHILTON
E-mail: Region: SOUTH EAST (UK) BERKSHIRE, BUCKINGHAMSHIRE, OXFORDSHIRE Oxfordshire
URL: Organization Type: Research, Other

Description

Objective: The members of the network will produce 26 deliverables mostly reports covering a range of subjects. These include: safety issues; environmental and technical considerations including grid connection; operating and maintenance standards; and planning issues. In addition, the Network will produce methodologies for plant control, monitoring and structural design. A web site will be set up to disseminate information on different devices and literature will be produced for the public, investors and industry.
Objective:

General information: Objectives of the Project

The primary objective of the SEAFLOW project is to develop and demonstrate the world’s first commercial scale, grid-connected marine current turbine. The axial flow, horizontal axis turbine, which is expected to have a rotor diameter of 15m will be mounted on a monopile set into a socket in the seabed in a water depth of 20 to 30m. The unit will have a rated power of about 300kW (depending on local site conditions) which will give essential experience for the introduction of slightly larger commercial systems at a later date. The top of the monopile is likely to be surface piercing (i.e. will remain above sea level).

A central aim is to move towards developing engineering capabilities needed for delivering economically viable marine current turbine technology. Key technical requirements are to seek adequate reliability and durability combined with efficient performance, while keeping costs low. Technical Approach

The main thrust of the work involves two key activity streams: firstly the conceptualisation, detail design and manufacture of the turbine system itself and secondly site selection, survey and preparation (the site will be in UK coastal waters, and chosen to offer a peak current speed in the range 2 - 3m/s). Following from this there will be the installation and operational phase.

The major components will be designed by the consortium partners. The system needs to be sufficiently robust to withstand the rigours of installation in a hostile sea environment. The installation process will be undertaken from a jack-up-platform which provides a stable base, even in adverse sea conditions. A socket will be drilled in the seabed to accommodate the mounting pile which will be manoeuvred using a crane and firmly grouted in position. The remaining components will be manipulated into position on the pile from the jack-up platform and close-quarter support vessels.

Following installation and preliminary system testing the grid-connection will be established via an appropriate transformer, marine cable and land-line. There will then be a series of short daylight runs to establish the device is performing satisfactorily, prior to initiation of unattended service.
Routine maintenance will be undertaken at regular periods; possible design enhancements / operational adjustment may also be required, depending on system reliability and performance.

Expected Achievements

The entire project will last 36 months. On the basis of the proposed rotor diameter and anticipated flow characteristics, the peak power output of the device is expected to be in the order of 300kW. The energy output of the device is expected to be of the order of 1000MWh/year. The project will also serve to address the following questions:-

Confirmation of the proposed methodology for installing, maintaining and removing a submarine turbine of 15m in diameter without the need for costly manned underwater operations

Assessment of techniques to mitigate detrimental performance due to marine growth

Confirmation of the effectiveness of an innovative system for yawing such a turbine to face the current from either direction and to stop the system in an emergency

Assessment of extreme loadings, dynamic problems (such as vibrations), cavitation effects on the rotor.

It is expected that the project will lead directly to a second phase involving the development of a full-scale demonstration of a multi-megawatt cluster of turbines. This in turn could lead to commercial exploitation of the technology within a lead-time of about six to ten years.

Documents for this Project

SEAFLOW - Pilot project for the exploitation of marine currents, Project Synapses, EUR 21616 05/06/06

Low-pressure turbines and control equipment for wave energy converter. WAVE DRAGON

Start date: 1999-01-01
End date: 2000-12-31
Project Acronym: WAVE DRAGON
Project status: Completed

Coordinator


Contact person

Name: Erik FRIIS-MADSEN
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E-mail: Region: DANMARK København og Frederiksberg Kommuner
URL: Organization Type: Other

Description

General information: The project proposal is prepared with the help of an Exploratory Award JO-ST-30 65 that include a Research Feasibility Study. The project objective is to develop a technique where existing hydro turbines can be used in offshore wave energy converters (WEC) of the slack moored run-up type with some modification. Turbines and control equipment will be optimised for the use in the Wave Dragon - a 4 MW offshore wave energy converter. The European wave energy resource is very large, close to the coastline it is about 1000 TWh per year. Due to fact that offshore WEC’s could be placed in several lines with distances of 20 -30 km without loosing much efficiency because the wind generated waves are rebuilding their strength between the WEC lines, the recoverable resource (including machine efficiencies) is of the same magnitude. The resource is therefore not a restraint in the development of wave energy. The prime proposer has developed the Wave Dragon, and international patent application was published in 1996. This WEC combines known techniques in a new way that should lead to a competitive price for the power production price from this renewable energy source, mainly because the capital and maintenance cost are
small in comparison with the known designs of offshore WEC's. The design facilitates power production under North Sea conditions more than 95% of the average year. Low-head turbines of the cross-flow type and the Kaplan/propeller types have been in commercial use in hydroelectric plants through decades and have an extremely long service life, but their working conditions are normally quite steady water flows and pressures. The existing turbines and the control equipment are not suitable for use in WEC's, because pressure and water flow are strongly and rapidly fluctuating in offshore WEC's. The scientific and the technical work consists of the following major elements: - Establishing reliable inflow data for the reservoir of the WEC by carrying out model test in scale 1:40 in the wave basin at Hydro Maritime Research Centre in Cork, Ireland. - Developing a strategy for the choice of turbines and their regulation including the instrumentation and the automatic control system. - Establishing the realistic outflow data and energy efficiency of the WEC by carrying out model tests on a cross section of the reservoir in scale 1:10. The model will be equipped with a scale turbine and tested in a large wave tank at the Danish Maritime Institute to simulate the working conditions on the WEC in 5 meter high waves, where the max. power of 4 MW will be generated. - Establishing the strategy for the choice of generators (AC/DC) and systems for transmission of the power to the seashore and further to the grid.

When the research project has been completed, the results will enable the next phase - a rather expensive test of a model in scale 1:3 or a prototype in scale 1:1 of the development of the WEC before the possibility of a large scale utilisation of the huge wave energy potential is possible. Next step after prototype tests will be to establish a power plant in the order of 600 MW in the North Sea.

**Wave energy device - broad band seapower energy recovery buoy**

**Start date:** 1999-01-01  
**End date:** 2001-02-28  
**Project status:** Completed

**Coordinator**

- **Organization name:** Starweld Limited  
- **Contact person:** Clive WEST  
- **Address:** Guilford Road, TR27 4PZ, Hayle, UNITED KINGDOM

**Performance improvement of OWC power equipment**

**Start date:** 1999-01-01  
**End date:** 2002-06-30  
**Project status:** Completed

**Coordinator**

- **Organization name:** INSTITUTO SUPERIOR TECNICO  
- **Contact person:** Antonio F.O. FALCAO  
- **Address:** DEPARTMENT OF MECHANICAL ENGINEERING, Avenida Rovisco Pais, Pav. Mecanica 1-2*, 1049-001, LISBOA, PORTUGAL

**Vessels and platforms for the emerging wind and wave power market**
General information: Objectives

The project concerns the marketability enhancement of wave power technology, especially shoreline and near-shore plants of the oscillating water column type. This is done in two complementary ways. The first one is to reduce the unit cost of the electrical energy produced, by improving the performance of the plant's equipment (namely the turbine) at no extra cost. The second one consists in improving the plant's integration into the grid, especially in small isolated grids where wave energy could find its first commercial application.

Demonstration at full scale is an essential component of the project. This is done on an existing 400 kW wave energy pilot plant located in the island of Pico, Azores, as well as on the local grid.

Technical approach

The response of the Wells turbine (by far the most widely used air turbine in oscillating water columns) to the varying power level of the waves is to be improved. The project addresses this in different manners.

Firstly by using variable-pitch rotor blades and developing adequate procedures for the blade angle control. A sub-optimal method for the control of the variable-pitch-rotor-blade Wells turbine is to be developed and implemented in the Programmable Logic Controller (PLC) of the 400 kW turbo-generator set (variable-pitch Wells turbine) of the Pico pilot plant. Full-scale tests in real sea conditions will be performed to fully exploit the capabilities of the variable-pitch turbine and deal with the control problems it poses.

A different approach consists in using advanced Computational Fluid Dynamics tools to design turbine rotor blades capable of higher tip speed and better aerodynamic performance. A second-generation 400 kW Wells turbine rotor is to be designed, manufactured and tested at the Pico pilot plant.

Expected achievements and exploitation

In any case, the use of variable rotational speed may provide an additional improvement in the response of the turbine. A rotational speed control optimization algorithm is to be devised for the Wells turbine based on a theoretical model of the energy chain conversion of the plant (from waves to wire) subject to operational constraints imposed by the plant equipment and the grid. The control optimization algorithm is to be implemented in the PLC of the Pico pilot plant, to assess and demonstrate its capabilities by monitoring the performance of the plant.

In generating electrical energy from a random source such as sea waves, it is imperative that the power generated is acceptable to the supply authority. The project addresses the grid integration of wave power plants. Special attention is devoted to small isolated grids. It is planned that, from the work undertaken on this study, an approach to the various problems will be adopted which will prove acceptable to other installations throughout the world.

The achievement of the objectives listed above should result in the following industrial benefits to manufacturers and users of wave power plants: (i) An increase in the annual electrical energy production and the number of hours the plant operates per year, at little or no extra costs. (ii) A reduction in the size and cost of the mechanical and electrical equipment. (iii) A better understanding of the interaction between plant and grid, and an improvement in the quality of the electrical power supplied to the grid; this is especially important in small isolated grids.

It is expected that, by the end of this project, an improvement in the competitiveness of shoreline and near-shore wave energy plants will be achieved.

Islay wave power plant. LIMPET

Start date: 1998-11-01
End date: 2001-10-31
Project Acronym: LIMPET
Project status: Completed

Coordinator
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Fax: +44-1232-663754
E-mail: Contact
Region: NORTHERN IRELAND
URL: Organization Type: Education

Description
General information: Objectives of the Project

- To construct one shoreline oscillating water column wave power device with three columns giving a plane water area of 170m².
- To install one counter rotating Wells turbine generator module with two generators of 250kW each giving a combined name plate capacity of 500kW with a peak electrical output of 750kW which in conjunction with pressure relief, will accommodate pneumatic powers up to 3MW,
- Connect to the electrical distribution grid and run the plant as a power station during the final phase of the work producing an average annual output of up to 1,800MWhrs in a year with an average resource of 20kW/m, - fully instrument the plant, monitor the performance of the power transform wave to wire and compare with the predicted values obtained from the physical and mathematical models,
- Provide the necessary information to improve the design of future wave power plant with a view to commercialisation of the technology both in Europe and World wide.

Technical Approach
A novel construction method will be adopted in which the water column chambers will be cast on a slipway formed in the coastal rock 10m in from the shoreline. Thus the construction site will be protected from most sea conditions by the natural solid rock wall which will be removed when construction is complete. The water column chambers will be constructed using a combination of steel-concrete composite sections, modular pre-cast units and in-situ concrete to demonstrate how units could be mass produced in future replications using a standard design.

The turbine will comprise a pair of Wells rotors mounted on individual generators allowed to counter rotate. A modular construction approach will be used with interchangeable parts. Ease of maintenance, robust construction and duplicated fail-safe systems are prerequisites of the design. The pneumatic power supplied to the turbines will be limited by a pressure relief system in the plenum chambers thus limiting stall on the blades.

Expected achievements

- A working wave power generating station capable of supplying 1,800MWhrs of electrical output in a year with an average annual wave climate of 20kW/m, - a better knowledge of power train matching, system control, component design, environmental impact and performance prediction which is essential for the successful commercial replication of wave power technology.

Significance of the project
The project will provide a significant step towards the commercial exploitation of wave power technology as the plant will comprise standardised elements which can be replicated and combined to provide stations of variable capacity for different sites and wave climates.
performance and quality of output are key features of the project in conjunction with the demonstration of novel construction methods and manufacturing processes.

**Documents for this Project**

Islay LIMPET wave power plant. Publishable report 02/09/03

**WAVEPLAM**

Although wave energy cannot currently compete economically against mature technologies, the European wave energy resource has a great potential contribution in the electricity market, and at a technical level, different solutions, which offer a level of technical maturity comparable to other RES with a larger presence on the market, are currently being tested.

The purpose of WAVEPLAM is to develop tools, establish methods and standards, and create conditions to speed up the introduction of ocean energy onto the European renewable energy market, tackling in advance non-technological barriers and conditioning factors that may arise when these technologies are available for large-scale development.

### 3.6. Wave power platforms: patents

The patents listed below are from the Espacenet database, which allows us to search patents worldwide through more than 40 million documents.

The search was conducted by combining the keywords “floating”, “wave” and “platform”.

In this case, the IPC (International Patent Classification) codes referring to this technology were the following:

- **F03B 13/00**
  - Adaptations of machines or engines for special use; Combinations of machines or engines with driving or driven apparatus (if the apparatus aspect are predominant, see the relevant places for such apparatus, e.g. H02K 7/18); Power stations or aggregates (hydraulic engineering aspects E02B; incorporating only machines or engines of positive-displacement type F03C)

- **E02B 9/08**
  - Tide or wave power plants (water-pressure machines, tide or wave motors F03B)

It is worth mentioning that throughout the 2000-2010 period, 2010 was the year when more wave power platform patents were filed (14), followed by 9 in 2009 and 6 in 2008 and 2007, respectively. This clearly indicates that wave power technology is rapidly gaining in importance worldwide, and that more wave platform patents will probably be filed in the next few years.

<table>
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<th>Patent ID</th>
<th>Date</th>
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<th>Inventor(s)</th>
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<td>CA2700787</td>
<td>2010-10-20</td>
<td>POWER STATION ON A SUBMERGED FLOATING PLATFORM</td>
<td>TORRES MARTINEZ D MANUEL [ES]</td>
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<td>GB2468979</td>
<td>2010-09-29</td>
<td>Wave power station</td>
<td>ATANASOV ATANAS [BG]</td>
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<td>US2010237623</td>
<td>2010-09-23</td>
<td>OFFSHORE FLOATING OCEAN ENERGY SYSTEM</td>
<td>FLOAT, INCORPORATED</td>
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<td>WO2010104487</td>
<td>2010-09-16</td>
<td>WAVE POWER MODULE AND THE METHOD IT WORKS</td>
<td>VOVK VOLODYMYR [UA]</td>
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<td>CN101705903</td>
<td>2010-05-12</td>
<td>Impeller-type sea wave power generation device</td>
<td>ZHENGQUAN ZHANG</td>
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<td>WO2010081961</td>
<td>2010-07-22</td>
<td>DEVICE FOR RECOVERING SEA WAVE ENERGY</td>
<td>HILDEBRAND GEORGES [FR]; GRAND BERNARD [FR]</td>
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<td>Patent/Invention</td>
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<td>GB2467026 (A) 2010-07-21</td>
<td>Wave energy converter with articulated floats and mast</td>
<td>OMER BNDEAN ABDULKADIR [GB]</td>
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<td>FR2935158 (A1) 2010-02-26</td>
<td>Ocean wave profile and vertical energy capturing device for producing electricity, has striker with upper end supporting electrical generator whose axle has vane driven permanently by fork finger displaced by swiveling movement of platform.</td>
<td>HILDEBRAND GEORGES [FR]; GRAND BERNARD [FR]</td>
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<td>CN101649803 (A) 2010-02-17</td>
<td>Maritime renewable energy transfer device and system</td>
<td>SHANGHAI OCEAN UNIVERSITY</td>
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<td>CN101624960 (A) 2010-01-13</td>
<td>Wave energy conversion system</td>
<td>XUWEN XU</td>
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<td>CN101624959 (A) 2010-01-13</td>
<td>Water chamber type floating platform and wave energy generating set</td>
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<td>WO2010005405 (A2) 2010-01-14</td>
<td>PRODUCING ENERGY FROM WAVE WITH FREE SURFACE EFFECT / DIFFERENCE OF LEVEL</td>
<td>MENGENECIOGLU Murat [TR]</td>
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<td>CN101614180 (A) 2009-12-30</td>
<td>Composite type device utilizing ocean wave energy for generating electricity</td>
<td>ADVANCED MANUFACTURE TECHNOLOG</td>
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<td>US2009322092 (A1) 2009-12-31</td>
<td>Wave action electric generating system</td>
<td>WERJEFELT ALEXANDER K [US]</td>
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<td>WO2009148296 (A2) 2009-12-10</td>
<td>WAVE ENERGY CONVERSION PLANT</td>
<td>CHUA SUI KWANG [MY]</td>
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<td>WO2009114918 (A2) 2009-09-24</td>
<td>MARITIME GENERATOR</td>
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<td>Floating cofferdam type wave generating set</td>
<td>UNIV ZHEJIANG [CN]</td>
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<td>GB2458310 (A) 2009-09-16</td>
<td>Wave energy converter with swinging mass</td>
<td>TAYLOR CHRISTOPHER [GB]</td>
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<td>DE102007060267 (A1) 2009-06-18</td>
<td>Energy platform is fastened to fastening device by chains or ropes at bottom of sea and is quickly positioned in wind direction in optimal manner or in secure position by control chains</td>
<td>HILT JAKOB [DE]</td>
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<td>CN101457732 (A) 2009-06-17</td>
<td>Wave power generation equipment</td>
<td>GEZHI HIGH SCHOOL SHANGHAI [CN]</td>
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<td>GB2453670 (A) 2009-04-15</td>
<td>Double acting floating wave powered pump</td>
<td>DARTMOUTH WAVE ENERGY LTD [GB]</td>
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<td>CN201148935 (Y) 2008-11-12</td>
<td>Sea wave power generator</td>
<td>XUEFU YAN [CN]</td>
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<td>CN201133322 (Y) 2008-10-15</td>
<td>Sea wave generating platform</td>
<td>XINGUANG LIU [CN]</td>
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<td>GR20070100061 (A) 2008-09-19</td>
<td>WATER WAVE POWER-GENERATING MECHANISM</td>
<td>GRIGORIADIS DAMIANOS PANAGIOTI</td>
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<td>BG1079 (U1) 2008-06-30</td>
<td>WAVE POWER STATION</td>
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<td>FR2908479 (A1) 2008-05-16</td>
<td>Wave energy collecting device for producing electric energy, has pivot to orient platform housing annexed installations, motivators comprising energy transformation system at front of platform, and cable passing through pivot or trunnion.</td>
<td>THURIES EDMOND [BG]</td>
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<td>US2008084069 (A1) 2008-04-10</td>
<td>Wave Power Generating Device</td>
<td>LEE WANG [CN]</td>
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<td>WO2007146542 (A2) 2007-12-21</td>
<td>WAVE-POWER SYSTEM AND METHOD FOR GENERATING ENERGY AT CONSTANT ROTATIONAL SPEED AT VARIABLE SIGNIFICANT WAVE HEIGHTS AND PERIODS</td>
<td>NOVA OCEANIC ENERGY SYSTEMS INC [US]</td>
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<td>WO2007130334 (A2) 2007-11-15</td>
<td>HEAVE PLATE WITH IMPROVED CHARACTERISTICS</td>
<td>OCEAN POWER TECHNOLOGIES INC [US]; POWERS WILLIAM B [US]; GERBER JAMES [US]; BULL</td>
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<td>Inventor/Assignee</td>
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<td>SEA WAVE POWER GENERATION</td>
<td>CHATZILAKOS KONSTANTINOS ATHAN</td>
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<td>CN1800629 (A) 2006-07-12</td>
<td>Electricity generating device by using ocean wave energy</td>
<td>SONG LANFANG [CN]</td>
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<td>CN2763566 (Y) 2006-03-08</td>
<td>Float platform swing-arm type multi-group automatic circulation cave power generator</td>
<td>LI MAO [CN]</td>
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<td>FR2864586 (A1) 2005-07-01</td>
<td>Ocean wave vertical energy capturing device for hydroelectric turbine, has rectangular floating platform buoy subjected to oscillation-pivoting inclinations around its vertical axis by oscillations of roll and pitch of ocean wave.</td>
<td>HILDEBRAND GEORGES [FR]</td>
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<td>CN1710274 (A) 2005-12-21</td>
<td>Water-wave buoyancy electric generation apparatus</td>
<td>SUN ZHIYONG [CN]</td>
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<td>UA56481 (C2) 2005-03-15</td>
<td>APPLIANCE FOR TRANSFORMATION OF WAVE POWER OF WATER SURFACE</td>
<td>OVSIAKIN VIACHESLAV VIKTORY [UA]</td>
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<td>CN2665394 (Y) 2004-12-22</td>
<td>Hydraulic wave power generation platform</td>
<td>ZOU CHANGZHEN [CN]</td>
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<td>US2004239120 (A1) 2004-12-02</td>
<td>Apparatus of converting ocean wave energy into electric power</td>
<td>YI JWO-HWU, ; KUN SHAN UNIVERSITY</td>
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<td>DE10300599 (A1) 2004-07-22</td>
<td>Multi-hull ocean-going ship with movable float body wave power plant, converts float body movement relative to columns caused by wave motion to energy available on board, including for ship’s drive</td>
<td>SOMMER JOERG [DE]</td>
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<td>US2003146628 (A1) 2003-08-07</td>
<td>Floating platform to obtain electric power</td>
<td>SANCHEZ GOMEZ GINES</td>
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<td>US2002131824 (A1) 2002-09-19</td>
<td>Floating platform to obtain electric power from sea waves</td>
<td>SANCHEZ GOMEZ GINES [ES]</td>
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<tr>
<td>CN2506785 (Y) 2002-08-21</td>
<td>Sea wave powering device</td>
<td>YANG GENGNIAN [CN]</td>
<td></td>
</tr>
<tr>
<td>DE10046293 (A1) 2002-03-28</td>
<td>Production of electric power from wave movement at water surface, comprises platform anchored by one or more columns at floor of sea and floating body connected with drive shaft.</td>
<td>SCHAAF JOHANNES [DE]</td>
<td></td>
</tr>
<tr>
<td>GB2356430 (A) 2001-05-23</td>
<td>Wave energy convertor</td>
<td>LYNE WILLIAM GEORGE [GB]</td>
<td></td>
</tr>
<tr>
<td>CN2373590 (Y) 2000-04-12</td>
<td>Sea-wave double-oscillating power machine</td>
<td>WANG XIN BIAO [CN]</td>
<td></td>
</tr>
</tbody>
</table>

Table 3: Wave power platforms: patents

### 3.7. References

- Generic and Site–related Wave Energy Data. [September 2010](#)

*Vessels and platforms for the emerging wind and wave power market* 88
• Wave Energy Converters (WECs)
• International Energy Agency Implementing Agreement on Ocean Energy Systems. POTENTIAL OPPORTUNITIES AND DIFFERENCES ASSOCIATED WITH INTEGRATION OF OCEAN WAVE AND MARINE CURRENT ENERGY PLANTS IN COMPARISON TO WIND ENERGY. March 2009
• International Energy Agency Implementing Agreement on Ocean Energy Systems. DYNAMIC CHARACTERISTICS OF WAVE AND TIDAL ENERGY CONVERTERS & A RECOMMENDED STRUCTURE FOR DEVELOPMENT OF A GENERIC MODEL FOR GRID CONNECTION. July 2010
• Ocean Waves and wave energy device design. Document
• The Proceedings of The Twentieth (2010) International. OFFSHORE AND POLAR ENGINEERING CONFERENCE
• Una aproximación al aprovechamiento de la energía de las olas para la generación de electricidad. Julia Fernández Chozas. 2008
• Guidelines on design and operation of wave energy converters. A guide to assessment and application of engineering standards and recommended practices for wave energy conversion devices. Commissioned by the Carbon Trust and carried out by Det Norske Veritas. May 2005
• Wave Energy Today - A community for professionals who have one aim – to drive Wave Energy to commercialisation. We will be the main provider of original, pertinent and independent information that provides a truly 360 perspective of the Wave Energy market.
• Wave Power A visual directory of ocean wave power websites.
• PESWiki.com Directory: Ocean Wave Energy
• www.awsocean.com/archimedes_waveswing.aspx
• www.pelamiswave.com
• www.aw-energy.com
• www.wavestarenergy.com
• www.danwec.com
• www.wavegen.co.uk/index.html
• www.aquamarinepower.com
• www.emec.org.uk
• www.wavegen.co.uk/index.html
• www.aquamarinepower.com
• www.emec.org.uk
4. Multi-Use Offshore Platforms

Combining wave and wind energy in a hybrid power generation system appears to be economically and technically feasible. Waves are a more steady energy source than wind. When the wind suddenly drops the waves keep on surging past. Moreover, wave power is even more complementary to wind power – in high winds the wind turbines have to brake or stop to avoid breaking.

4.1. European projects

Besides the European projects listed in this report, which refer to wave and wind energy and may also include references to multi-use offshore platforms, the section below lists a series of project ideas submitted to the call for proposals “The ocean of tomorrow 2011”, which took place on 9 September 2010.

Under the heading Multi-use offshore platforms (€14 million), the proposed project ideas were:

- Mediterranean offshore platform. Pole Mer PACA. Florian Carré. [Pdf]
- SEASTENFLEX. IDESA. Andrés Castro. [Pdf, Consortium Proposal].
- Presentation as2con Info day. as2con - alveus ltd. Teuta Duletic. [Pdf].
- Impact analysis on the environment. Oldenburg University. Christopher Haut. [Pdf].
- PLOCAN: A MULTI-USE OFFSHORE PLATFORM. PLOCAN. Jose Joaquin Hernandez Brito. [Pdf].
- WavEC-an integrated view on Marine Renewables. Wave Energy Centre – WavEC. Alex Raventos. [Pdf].
- INSEAN: maritime engineering research center. INSEAN. Francesco Salvatore. [Pdf].
- The EPHESUS: An Integrated Ocean Farm System. Ege University. Gamze Turan. [Pdf].
- Proposal for multi-use offshore platforms. TECNALIA. Jose Luis Villate. [Pdf].
- The Innovation Dimension: Knowledge Mgmt. AquaTT Limited. David Murphy. [Pdf].
4.2. Multi-use offshore platforms: patents

The patents listed below are from the Espacenet database, which allows us to search patents worldwide through more than 40 million documents.

The search was conducted by combining the keywords “floating” and “wind turbines” plus “wave” and “wind” and “platform”.

In this case, the IPC (International Patent Classification) codes referring to this technology were the following:

- F03B 13/--
- Adaptations of machines or engines for special use; Combinations of machines or engines with driving or driven apparatus (if the apparatus aspect are predominant, see the relevant places for such apparatus, e.g. H02K 7/18); Power stations or aggregates (hydraulic engineering aspects E02B; incorporating only machines or engines of positive-displacement type F03C)
- F03D

WIND MOTORS

- E02B 9/08

Tide or wave power plants (water-pressure machines, tide or wave motors F03B)

It is important to highlight that throughout the 2000-2010 period only 14 patents were found. This does not necessarily mean that no patents are being filed in this field, but rather that it is from 2008 that more patents are being issued. We will probably see a lot more patents filed from 2011. We must also not forget that from the moment we file a patent until the time when it is granted quite a long time may go by.

<table>
<thead>
<tr>
<th>Patent Number</th>
<th>Title</th>
<th>Inventor(s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>CN101813062(A)</td>
<td>Power generating platform unit plant for coaxially collecting sea wind, sea wave and sea current energy</td>
<td>JING WU; MINGMAO WU</td>
</tr>
<tr>
<td>US2010003134(A1)</td>
<td>Wind and wave power generation</td>
<td>ITI SCOTLAND LTD [GB]; EDWARDS JAMES IAN [GB]</td>
</tr>
<tr>
<td>CN101611226(A)</td>
<td>Energy extraction method and apparatus</td>
<td>SEADOV PTY LTD</td>
</tr>
<tr>
<td>DE102008029984(A1)</td>
<td>Buoyant assembly- and working platform for offshore-wind- and water turbines, has squad room and working areas process devices provided at board, and deck formed as helipad, where devices are provided with tanks or storage systems</td>
<td>SCHOPF WALTER [DE]</td>
</tr>
<tr>
<td>CN101493078(A)</td>
<td>Offshore power generation platform unit plant</td>
<td>MINGMAO WU [CN]</td>
</tr>
<tr>
<td>US2008231053(A1)</td>
<td>Apparatus For Production of Hydrogen Gas Using Wind and Wave Action</td>
<td>BURTCH JOHN CHRISTOPHER [CA]</td>
</tr>
<tr>
<td>PT1375912(E)</td>
<td>MARINE PLATFORM FOR WIND AND WAVE POWER CONVERSION</td>
<td>INMOBILIARIA MR S A [ES]</td>
</tr>
<tr>
<td>CN293754(Y)</td>
<td>Ocean comprehesvie energy generating equipment</td>
<td>WU MINGMAO [CN]</td>
</tr>
<tr>
<td>CN1948752(A)</td>
<td>Submerged floating type wind wave power generation ship</td>
<td>GUO SHIGUANG [CN]</td>
</tr>
</tbody>
</table>
### 4.3. Multi-use offshore platform designs

**Grays Harbor Ocean Energy Company, hybrid wave and wind power - and more**

Table 4: Multi-use offshore platforms: patents

<table>
<thead>
<tr>
<th>Patent Number</th>
<th>Description</th>
<th>Inventor(s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>CN2828356(Y)</td>
<td>Submerged floating wind wave generating ship</td>
<td>GUO SHIGUANG [CN]</td>
</tr>
<tr>
<td>UA76955(C2)</td>
<td>COMPLEX FOR PRODUCTION OF HYDROGEN AND FUEL ELEMENTS</td>
<td>NESTERENKO IHOR MYKHAILOVYCH [UA]</td>
</tr>
<tr>
<td>GB2383978(A)</td>
<td>Platform provided with a plurality of renewable energy converter systems</td>
<td>MICHAELIS DOMINIC [FR]</td>
</tr>
</tbody>
</table>

**Harnessing nature’s force**

A Seattle-based developer is seeking permits to study sites where it could build offshore wave- and wind-power installations. Two of them are in New England waters.

<table>
<thead>
<tr>
<th>Study sites</th>
<th>100-square-mile sites</th>
</tr>
</thead>
<tbody>
<tr>
<td>CONNECTICUT</td>
<td>Block Island</td>
</tr>
<tr>
<td>RHODE ISLAND</td>
<td>Block Island</td>
</tr>
<tr>
<td>MASSACHUSETTS</td>
<td>Nantucket</td>
</tr>
<tr>
<td>Long Island</td>
<td>25 MILES</td>
</tr>
<tr>
<td>Atlantic Ocean</td>
<td></td>
</tr>
</tbody>
</table>

If built, both sites would have 100 platforms, each supporting a wind turbine. The legs of each platform would generate additional power by harnessing wave motion.

**Wave turbine at top of platform leg**

When the wave passes, air rises higher down the hollow leg.

Perforations allow water in the leg to rise and fall with waves.

Air is trapped in the hollow leg.

As a wave rises, it pushes air up the hollow leg.

Turbo blades are shaped to turn the same direction whether air is moving up or down.

SOURCE: Grays Harbor Ocean Energy Company; ESRI, TeleAtlas, USGS

DAVID BUTLER/SEATTLE POST-TRADE
PropertyInvesting.net team. **WIWASOTI** Wind, Wave, Solar, Tidal energy system

**Green Ocean Energy, Wave Treader**

*Vessels and platforms for the emerging wind and wave power market*
Ocean Thermal Energy Conversion (OTEC), “energy islands”

**Poseidon, Wind and Hydro Power Plant**

**Hexicon, floating offshore wind and wave generation platform**
Wind Lens

The Wind Lens is a new design for deep-water wind turbine technology developed by The Research Institute for Applied Mechanics. The idea is that it should not only be able to increase energy output three-fold, but also reduce the noise pollution associated with traditional wind turbines.

The Ocean Energy Rig
The **OWWE** (Ocean Wave and Wind Energy)

Green Ocean Energy, **Wave Treader**
5. Environmental & Socio-Economic Impact Assessment of Vessels and Platforms Through Life-Cycle Analysis and Dismantling Costs Assessment

It is impossible to offer a detailed study in this section, since multiple variables are involved in offshore platform and vessel feasibility. Thus environmental and socio-economic impact assessments which look at life-cycle analysis and dismantling costs vary depending on the project, the materials used, the site, the design chosen, and so on.

5.1. European projects

Review of and recommendations for external conditions

Quality validation date: 2006-12-06

Abstract

Scientific aspects of the result:

At the project outset, there were many uncertainties regarding the offshore environment for the combined action of wind and waves. Existing standards for offshore purposes have been reviewed and compared in order to provide recommendations relevant for offshore turbines that are subject to wind and waves loads of comparable size.

Social and commercial aspects of the result:

There has been an immediate need for the project. Currently and over the next few years, the expansion in offshore wind energy, especially in Europe, accelerates and at project start there were no thorough and coherent guidelines for the design of offshore wind power plants. The existing offshore standards are not suitable to cover the offshore wind energy technology.

A combination of these offshore standards and the existing onshore wind energy standards is a very complex process and significant technology gaps exist. One of the major tasks of the project has been the attempt to combine the practices of wind turbines engineering and offshore engineering. According to the main results stated in the executive summary the project has succeeded in this, and thus it is the view of the project partners that the project outcome has aided a development with the potential of preventing erroneous decision-making on large investments in Europe on a technical weak basis.

Potential applications for and End users of the result:

End-users are designers of offshore wind turbines i.e. manufactures, certifying bodies, writers of standards and regulations, and possibly owners and operators of offshore wind farms.

Innovative features:

Recommendations regarding environmental models resulting from the review.

Stage of development: Guidelines, methodologies, technical drawings
**Stage description:** Partly included in draft standard for IEC.

**Collaboration sought:** Further research or development support, Financial support, Available for consultancy

**Collaboration Detail:** Broad knowledge on combined wind and wave environmental conditions combined with years of experience with offshore wind turbines is offered. The results have already been submitted to the IEC working group 3, which is responsible for the upcoming offshore standard. In addition to this the further use of this result may be benefiting the general offshore wind turbine industry.

Potential partners must have a solid scientific/technical background and expertise in design and operation of offshore wind turbines. Experience in modelling of offshore environmental conditions is essential and knowledge of offshore wind turbine modelling is desirable. Input from skilled designers is relevant.

**Market applications:** Steam distribution, quality

**Source of support:** CEC, International non-CEC

**This promising result was selected to be showcased as an offer:** [Wave turbines get wind knowledge](#)

**Related Programme(s)/Projects**

<table>
<thead>
<tr>
<th>Programme</th>
<th>Project reference</th>
<th>Project title</th>
</tr>
</thead>
<tbody>
<tr>
<td>EESD</td>
<td>ENKS-CT-2000-00322</td>
<td>Recommendations for design of offshore wind turbines (RECOFF)</td>
</tr>
</tbody>
</table>

Results for this Project

- Design load cases and structural integrity 21/09/2005
- Extrapolation of extreme response 21/09/2005
- Lumping of fatigue loads 21/09/2005
- Operation and maintenance 06/12/2006
- Probabilistic methods 21/09/2005
- Review of and recommendations for external conditions 06/12/2006

**Environmental Impact Assessment of the "LabBuoy" wave energy converter**

**Quality validation date:** 2006-08-01

**Abstract**

Today, the environmental impact of any energy installation becomes a major issue of consideration already in the early planning phases of a project. Within the EU, an Environmental Impact Assessment (EIA) must be carried out before public approval for larger projects can be granted. The minimum requirements of the EIA are specified in the EC Council Directive 85/337/EEC amended in Directive 97/11/EC. The directives require that private and public projects, which are likely to have significant effects on the environment, must be subject to an assessment of their potential effects on the environment before they can be allowed to proceed.

An EIA shall identify, describe and assess the direct and indirect effects of a project on the following factors:

- Human beings, fauna and flora;
- Soil, water, air, climate and the landscape;
- Material assets and the cultural heritage;
- The interaction between these factors mentioned.

The directives lay down rules for the EIA procedure, which includes a requirement for public participation: the results are to be made public, and the views of the public taken into consideration in the consenting procedure.
Despite the substantial non-pollution benefits of renewable energy technologies there are other environmental impact burdens that these benign power plants must address. Past experience, in particular with hydro and wind developments, has indicated that these considerations can be important and create a somewhat ambiguous situation towards such technologies in terms of the environmental protection or damage.

Wave energy technologies are still in the phase of emergence. Up to date only a few large scale prototypes are in operation worldwide.

The experiences with the environmental effects of wave energy converters are therefore very limited, and every trial to assess these effects quantitatively seems impossible at present. Different independent studies conducted in the past are therefore either of qualitative nature or they are drafting data and facts from adjacent RES technologies, mainly from offshore wind. But also this technology is comparably new and the figure of its environmental impact is incomplete.

An important technique for assessing quantitatively the environmental consequences associated with a product over its entire life cycle is Life Cycle Analysis (LCA). LCA became popular in the early nineties and emerged in response to increased environmental awareness of the general public, industry and governments. The precursors of LCA were global modelling studies and energy audits of the late 1960s and early 1970s. These attempted to assess the resource cost and environmental implications of different patterns of human behavior.

The most important applications of LCA are:

- Analysis of the contribution of the life cycle stages to the overall environmental load, usually with the aim to prioritise improvements on products or processes;
- Comparison between products for internal or external communications.

There are four ISO standards specifically designed for LCA application:

- ISO 14040: which regulates the principles and framework of LCA
- ISO 14041: regulating the goal and scope definition and inventory analysis
- ISO 14042: regulating life cycle impact assessment, and
- ISO 14043: regulating interpretation of results

In the present project Life Cycle Analysis of a fictive Labbouy plant of 100 devices with average annual power output of 0.5 MW was carried out. With this analysis valuable, quantitative results have been obtained. In particular, the impact of the technology on specific areas of major environmental concern could be quantified. The technology components of comparably high environmental damage have been identified, and their configuration should be reconsidered in future projects.

The expertise in LCA gained in the course of the project is also applicable to adjacent RES technologies. The knowledge accumulated and methods developed allow the result owners to expand their activities in this field to other WEC technologies and RES sectors.

Collaboration sought: Further research or development support

Market applications: Combined heat, power, Steam distribution, quality, Recycling technologies, Manufacturing technologies, Electrical equipment

Source of support: CEC

This promising result was selected to be showcased as an offer: Environmental effects of wave energy conversion

Related Programme(s)/Projects

<table>
<thead>
<tr>
<th>Programme</th>
<th>Project reference</th>
<th>Project title</th>
</tr>
</thead>
<tbody>
<tr>
<td>EESD</td>
<td>ENK6-CT-2001</td>
<td>Economically efficient floating device for wave power conversion into electricity.</td>
</tr>
</tbody>
</table>
Abstract

It was the particular mission of the project 'Structural and Economic Optimization of Bottom-Mounted Offshore Wind Energy Converters' (Opti-OWECS) to extend the state-of-the-art, to determine required methods and to demonstrate practical solutions which will significantly reduce the electricity cost. This will facilitate the exploitation of true offshore sites on a commercial base in a medium time scale of 5 to 10 years from now.

In several fields, e.g. support structure design, installation of the offshore wind energy converters, operation and maintenance, dynamics of the entire offshore wind energy converter, structural reliability considerations, etc., the study demonstrated new propositions which will contribute significantly to a mature offshore wind energy technology. This was achieved due to a smooth cooperation of leading industrial engineers and researchers from the wind energy field, offshore technology and power management.

Moreover, an innovative design methodology devoted particularly to offshore wind energy conversion systems (OWECS) was developed and successfully demonstrated. The so-called 'integrated OWECS design approach' considers the components of an offshore wind farm as parts of an entire system. Therefore interactions between sub-systems are considered in a complete and practical form as possible so that the design solution is governed by overall criteria such as: levelised production costs, adaptation to the actual site conditions, dynamics of the entire system, installation effort as well as OWECS availability.

Furthermore, a novel OWECS cost model was developed which led among other work of the project to the identification of the main cost drivers, i.e. annual mean wind speed, distance from shore, operation and maintenance aspects including wind turbine reliability and availability. A link between these results and a database of the offshore wind energy potential in Europe, developed by the previous Joule project JOUR 0072, facilitated the first estimate of energy cost consistent over entire regions of Northern Europe.

Collaboration sought: Information exchange/Training

Market applications: Wind energy, Renewable energy

Related Programme(s)/Projects

<table>
<thead>
<tr>
<th>Programme</th>
<th>Project reference</th>
<th>Project title</th>
</tr>
</thead>
<tbody>
<tr>
<td>NNE-JOULE C</td>
<td>JOR3950087</td>
<td>Structural and economic optimization of bottom-mounted offshore wind energy converters</td>
</tr>
</tbody>
</table>

Results for this Project

Structural and Economic Optimisation of Bottom-Mounted Offshore Wind Energy Converters; Opti-OWECS 21/09/2000

Documents for this Project

Cost optimizing of large-scale offshore wind farms

Quality validation date: 2000-09-21

Abstract

The project comprises investigation of the technical and economical possibilities of large-scale offshore wind farms at 3 locations in the eastern Danish waters: Rødsand and Gedser Rev located south of the islands of Falster, Lolland and Omø Stågrunde located south-west of the island of Zealand plus experiences obtained from British and German offshore wind energy projects.

The project has been performed by SK Power Company i/s, represented by SEAS A.m.b.A., Wind Power Department, together with 5 European partners.

The project included wind and wave measurements at the above 3 locations, data collection, data processing, meteorological analysis, modelling of wind turbine structure, studies of grid connection, design and optimisation of foundations plus estimates of investments and operation and maintenance costs.

The overall conclusions of the project include:

- Areas are available for large scale offshore wind farms in the Danish waters.
- A large wind potential is found on the sites.
- Park layouts for projects consisting of around 100 wind turbines each has been developed.
- Design of the foundations has been optimized radically compared to previous designs.
- A large potential for optimizing of the wind turbine design and operation has been found.
- Grid connection of the first proposed large wind farms is possible with only minor reinforcement of the transmission system.
- The visual impact is not prohibitive for the projects.
- A production cost of 4-5 ECUcent/kWh is competitive with current onshore projects.
- The planned accuracy of ?10% on cost estimates during the project was not achieved. This accuracy would have required a continuous data-set from all offshore masts for at least one year. However, the planned accuracy is expected to be achieved in short time after the finalization of the project.
- The environmental issues were initially not planned to be studied in details, however, especially the possible visual impacts of the proposed projects proved to be of major importance for the local acceptance of the projects.

Collaboration sought: Information exchange/Training

Market applications: Wind energy

Related Programme(s)/Projects

<table>
<thead>
<tr>
<th>Programme</th>
<th>Project reference</th>
<th>Project title</th>
</tr>
</thead>
<tbody>
<tr>
<td>NNE-JOULE C</td>
<td>JOR3950089</td>
<td>Cost optimizing of large-scale offshore wind farms</td>
</tr>
</tbody>
</table>

Results for this Project

Cost optimizing of large-scale offshore wind farms 21/09/2000

Documents for this Project

REPORT: Cost optimizing of large-scale offshore wind farms 14/09/2000
5.2. Miscellaneous

The references listed below include finalised studies regarding already completed projects, as well as other relevant studies.

- Greater Gabbard offshore. Wind Farm project
  **DECOMMISSIONING PROGRAMME**
- The Sheringham Shoal Offshore Wind Farm
  **Decommissioning programme**
- Offshore Windfarm **Decommissioning**: A proposal for guidelines to be included in the European Maritime Policy
- Developing Wind Energy In The Outer Moray Firth
  **Environmental Impact Assessment**
- Beatrice Offshore Wind Farm: **Environmental Scoping Report**
- Strategic Environmental Assessment (SEA) of Offshore Wind and Marine **Renewable Energy in Northern Ireland**
  **Volume 1**
  **Volume 2**
- Wave Hub. **Environmental Statement**
- Environmental and Ecological Effects Of Ocean Renewable Energy Development. **A Current Synthesis**
- Environmental Assessment of Renewable Energy in the Marine **Environment**
- Europe's onshore and offshore wind energy potential. **An assessment of environmental and economic constraints**
- A Quantitative Comparison of the Responses of **Three Floating Platforms**
- Scotland’s offshore wind route map developing. Scotland’s offshore wind industry to **2020**
- Cape Wind Energy Project. **USA**
- Development of an **Operations and Maintenance** Cost Model to Identify Cost of Energy Savings for Low Wind Speed Turbines
- Feasibility study on floating offshore windenergy in **shallow water**
- The Offshore Valuation. **A valuation of the UK’s offshore** renewable energy resourc
- Calculating Wind Integration Costs: **Separating Wind Energy Value from Integration Cost Impacts**
- **2009** wind technologies market report
- **Guidelines for the use of metocean data through the life cycle of a marine renewable energy development**
- **Protocol to develop an environmental impact study of wave energy converters**
- **Technoeconomic Environmental and Risk Analysis of Marine Gas Turbine Power Plants**
- **Wave Hub Technical Feasibility Study**
- **Integrated Design Methodology for Offshore Wind Energy Conversion Systems**
- **Port and Infrastructure Analysis for Offshore Wind Energy Development**
European Study. Established three offshore research platforms, noise emissions. Conducted by Germany. [The FINO Project]
Energy capture performance. Costs of wave and tidal stream energy. [Pdf]
Capital, operating and maintenance costs. [Pdf]
MEC cost estimation methodology. [Web]
Life-cycle energy and emissions of marine energy devices. [Pdf]
Engineering testing of marine energy devices. [Pdf]
Guidelines on standards for marine energy devices. [Web]
6. Conclusions

The aim of this report is to compile all the information available about the state of the art in ocean wave and wind energy.

As we have seen, offshore wind power is being strongly emphasized, with governments providing funding and power generation companies seeing bright prospects for the future of this energy source.

The target of 40 GW of offshore wind in the EU by 2020 requires that new offshore installation vessels be built. These new vessels must have a capacity for at least 10 turbines, 10 blade sets and 10 tower sections, and new installation vessels will be required.

To increase the number of days of operation to 260-290 a year, such vessels must be able to install offshore wind farms in medium water depths (30-40m and beyond) and operate in very harsh conditions. At the very best, these vessels should be able to carry assembled subsystems, or even a set of assembled turbines, in order to limit the number of operations performed at sea.

Power companies are building their own installation vessels or acquiring other companies specialized in offshore wind farm installations.

Regarding wind and wave power platforms, as well as multi-use offshore platforms, one of the main conclusions we can draw is that future technologies for deep water platforms shall not necessarily be more costly than fixed-bottom systems, since those can be produced in bulk and fully assembled onshore, thus saving the huge costs of building them in the open sea. Further research is needed to verify the feasibility of such low-cost floating wind turbines. New technology will be required to face such low costs and implement simple mooring systems. Developing such technologies involves a complex and high risk, but also has a high profit potential.

There are currently many platform concepts and patents available, but none of them at a commercial stage.

The U.S. Department of Energy has a specific web site devoted to its Wind & Water Power Program where you can find a list of all the types of platforms and technologies available to generate this kind of energy. Only one is commercially available — the Pelamis —, while the others are design concepts, design details, scale models (30 approx.), open water system testings (40 approx.) and tank system testings (23 approx.).

The EU 7th Framework Programme awards some specific funding to multi-use offshore platforms, and many European companies are interested in collaborating in this kind of projects.

But this is only the beginning. A new emerging market is booming. The question is whether the European shipbuilding industry will be able to acknowledge the possibilities of this new emerging market, innovate and develop new concepts. And, of course, bring them to the market.