WINDFLOAT: A FLOATING SUPPORT STRUCTURE FOR OFFSHORE WIND TURBINES
1970: 3.7 Billion people

Source: NASA
2000: 6.1 Billion people

Source: NASA
Presentation Overview

Offshore Wind
  • Why Offshore Wind
  • Portugal Offshore Wind

WINDPLUS JV

WindFloat
  • WindFloat design
  • Technical development

Portuguese Project

Developments outside Portugal
Principle Power Portugal

Established in October 2009

• A wholly owned subsidiary of Principle Power Inc. (USA)
• WindPlus JV partner

Mission

• To develop WindFloat projects in Portugal

Technology

• Core IP patented, WindFloat system patent pending

WINDPLUS S.A.
A JV between

edp
inovação

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Why Offshore Wind?

• Higher wind resource and less turbulence
• Large ocean areas available
• Best spots in wind onshore are becoming scarce
• Capacity of offshore wind (including deep offshore) is theoretically almost unlimited

Why Floating Offshore Wind?

• Limited shallow water locations
• Most of the resource is in deep waters
• Large ocean areas available
• Less restrictions for offshore deployments and reduced visual impacts
• Huge potential around the world – PT, Spain, UK, France, Germany, Italy, USA
Why Offshore Wind?

**Technical solution**
- Wind Energy conversion stabilized and well known
- Technological challenges:
  - Wind turbine and maritime environment
  - Adapt wind turbine to platform motion
  - O&M operations

**Time to market**
- 5 – 10 years

**Players in the market**
- Number of floating concepts
- Two floating systems already installed

<table>
<thead>
<tr>
<th>Short/Medium Term</th>
<th>Medium/Long Term</th>
</tr>
</thead>
<tbody>
<tr>
<td>• First results of the demonstration stage</td>
<td>• Technology consolidation and cost reduction in deep offshore wind</td>
</tr>
<tr>
<td>• First successful demonstration projects and technology cost reduction</td>
<td>• Large scale deep offshore commercial deployments</td>
</tr>
</tbody>
</table>

**Short Term**
- Onshore wind with high growth rate
- Offshore wind in shallow waters in expansion
- Deep offshore wind in demonstration stage

**Medium Term**
- Onshore wind continues with high growth rate
- Offshore wind increases significantly its growth rate
- Deep offshore wind with first commercial deployments

**Long Term**
- Onshore wind reaches the limit of its potential.
- Offshore wind reduces its growth rate
- Deep offshore wind with high growth rate
The Market

Unaddressed Markets

• Coastal areas with high renewable energy demand
• Best resource is deep-water offshore wind

Target Locations

• Coasts of Portugal, France, Spain, the UK and Japan
• United States
  • West Coast
  • Maine
  • Great Lakes
• North Sea

Market Potential

• > 2,000 GW
Portugal Offshore Wind Potential

- Continental shelf ends near the coast
  - Deep waters (>50m) near the coast
- Good offshore wind resource (load factor > 3000h)
- Grid connection available near the coast
- Ports and docks available along the Portuguese coast

Source: NETI
Portugal Offshore Wind Potential

- Onshore wind energy production limited to ~ 12,000 GWh
- The wind energy penetration will reduce to 17% by 2020\(^{(1)}\)
- If new renewable energies are not introduced to energy mix production

\(^{(1)}\) Assuming growth rate of ~3% in energy consumption

Source: NETI
Portugal Offshore Wind Potential

- The deployment of commercial Offshore Wind farms in transitional waters (>40m, <60m)
- Maintain the wind energy penetration of 20% by 2020 and 2030
- If floating offshore wind is deployed the wind energy penetration will increase significantly

Source: NETI
Water Depth Economics

**Monopiles**
- Basic extension of turbine tower w/ transition piece
- Economically feasible in shallow water depths (10-30m)

**Jackets**
- Economically feasible in transitional water depths (30-50m)
- Derivation of Oil & Gas technology
- Beatrice successfully deployed (2 jackets and RePower 5M)

**Floating**
- Economically feasible in deep water (50-900m)
- Two prototypes have been deployed (Hywind and Blue H)

Source: NREL
WindFloat Characteristics

Depth Insensitivity
- 50 meters and deeper

Turbine Agnostic
- Very low pitch
  - Water-entrapment plates and active ballasting
  - Minimal pitch and yaw operation

Port assembly
- Expands installation weather window
- Eliminates dependence on special installation vessels
WindFloat – Specifications

WindFloat Commercial Specifications

<table>
<thead>
<tr>
<th>Specification</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Power Rating</td>
<td>≈ 5MW</td>
</tr>
<tr>
<td>Hull weight</td>
<td>&lt;2.500 ton</td>
</tr>
<tr>
<td>Rotor diameter</td>
<td>≈ 125 m</td>
</tr>
<tr>
<td>Total Displacement</td>
<td>&lt;8.000 ton</td>
</tr>
<tr>
<td>Hub height</td>
<td>≈ 80 m</td>
</tr>
<tr>
<td>Hull Draft</td>
<td>≈ 25 m</td>
</tr>
<tr>
<td>Nacelle weight</td>
<td>≈ 400 ton</td>
</tr>
<tr>
<td>Operational Depth</td>
<td>≈ 40 m</td>
</tr>
<tr>
<td>Tower weight</td>
<td>≈ 400 ton</td>
</tr>
<tr>
<td>Semi-taught Mooring</td>
<td>≈ 4-6 lines</td>
</tr>
</tbody>
</table>

WindFloat Design Drivers

- **Depth**
  - 50 meters and deeper
- **Stability Performance**
  - Minimal pitch and yaw
  - Water-entrainment plates and active ballast
- **Assembly & Installation**
  - Port assembly
  - No specialized vessels required, using conventional tugs
  - Industry standard mooring equipment
Fabrication & Installation Overview
WindFloat – Development History

January 2003
- MI&T performs Minifloat proof of concept model tests

June 2003
- MI&T files Minifloat patent 1

January 2004
- Wave tank testing of Minifloat I & II concept

June 2004
- Wave tank testing of 1:96th scale Minifloat IV concept at University of California, Berkeley tow tank

August 2004
- Wave tank testing of 1:80th scale Minifloat III concept at Oceanic

August 2006
- Wave tank testing of 1:96th scale Minifloat III concept at University of California, Berkeley tow tank

Minifloat patent 1 issued US7086809, Minifloat patent 2 filed

March 2007
- Minifloat patent 2 issued US7281881

September 2008
- Wave tank testing of 1:96th scale WindFloat model at University of California, Berkeley tow tank

June 2009
- EDP initiates a Pilot Project with a full-scale WindFloat unit

April 2009
- Principle Power purchases outright all intellectual property for WindFloat from MI&T

June 2009
- Principle Power exclusively licenses WindFloat intellectual property from MI&T

June 2009
- EDP and Principle Power sign MOA for phased development of WindFloat technology and commercial deployment of a wind farm up to 150MW

May 2009
- Wave tank testing of 1:67th scale WindFloat model at University of California, Berkeley tow tank

January 2010
- EDP and Principle Power sign MOA for phased development of WindFloat technology and commercial deployment of a wind farm up to 150MW
WindFloat Model Tests
1-year Storm & 100-year Storm
### Floating Offshore Wind Technologies

#### Timeline

**2007**
- Statoil Hydro and Siemens sign agreement for Hywind project for NK 400M
- Sway raises €16.5M in private placement

**2008**
- Blue H half-scale prototype deployed

**2009**
- EDP and Principle Power sign MOA for WindFloat deployment
- Hywind full-scale prototype installation with 2.3MW turbine

<table>
<thead>
<tr>
<th>Trade name</th>
<th>WindFloat</th>
<th>Hywind</th>
<th>Blue H</th>
<th>Sway</th>
</tr>
</thead>
<tbody>
<tr>
<td>Developer</td>
<td>Principle Power (US)</td>
<td>Statoil Hydro (NO)</td>
<td>Blue H (NL)</td>
<td>Norwegian consortium (NO)</td>
</tr>
<tr>
<td>Foundation type</td>
<td>Semi-submersible (moored 4-6 lines)</td>
<td>Spar (moored 3 lines)</td>
<td>Tension Leg Platform</td>
<td>Hybrid Spar/TLP (single tendon)</td>
</tr>
<tr>
<td>Water Depths</td>
<td>&gt; 40 m</td>
<td>&gt;100 m</td>
<td>&gt; 40 m</td>
<td>100 m - 400 m</td>
</tr>
<tr>
<td>Turbine</td>
<td>3-10MW Existing technology</td>
<td>2.3 MW Siemens</td>
<td>2 bladed “Omega” for testing purposes</td>
<td>3 bladed downwind</td>
</tr>
<tr>
<td>Installation</td>
<td>Tow out fully commissioned</td>
<td>Dedicated vessel-tow out and upending</td>
<td>Tow out on buoyancy modules until connection</td>
<td>Dedicated vessel-tow out and upending</td>
</tr>
<tr>
<td>Turbine installation</td>
<td>Onshore</td>
<td>Offshore</td>
<td>Onshore</td>
<td>Offshore</td>
</tr>
<tr>
<td>Strengths</td>
<td>Dynamic motions, installation, overall simplicity of design</td>
<td>Existing turbine and hull technology, well funded</td>
<td>First sub-scale demo deployed</td>
<td>Low steel weight:</td>
</tr>
<tr>
<td>Challenges</td>
<td>Steel cost</td>
<td>Dynamic motions, installation</td>
<td>Mooring cost, turbine design, turbine coupling with tendons</td>
<td>Installation and maintenance, downwind 3-blade turbine</td>
</tr>
<tr>
<td>Stage of Development</td>
<td>Ready for prototype testing</td>
<td>Full-scale prototype installed in 2009</td>
<td>Half-scale prototype installed in 2008</td>
<td>Development of the concept</td>
</tr>
</tbody>
</table>

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Synergies with Oil & Gas Concepts

...An industry of Experience...
- First Floating structures date back to 1977
- New technology developments have traditionally been based on new needs, coming from resources identification
WINDPLUS S.A.

Phase 0 – Pilot
• Single WindFloat with ~ 1MW turbine
• Private & public funding

Phase I – Demonstration
• Single WindFloat with a 5MW turbine
• Equity financing

Phase II – Pre-Commercial
• 2-5 WindFloat units, grid connected, 5MW wind turbines
• Inclusive of transformer/support platform
• Expansion through Equity financing

Phase III – Commercial Expansion
• To reach 150 MW of installed capacity
US Offshore Wind Energy

Source: NREL
US Site Developments

Maine
- Prototype – 1 WindFloat
- Teaming agreement with U of Maine
- Site selection for phased commercial expansion

Tillamook, OR
- Phased - 150MW to 200MW (30-45x5MW WindFloats)
- MOA with Tillamook PUD – executed
Project Development Oregon

WindFloat Oregon
- Strong winds
- Proximity to transmission lines
- Good ports

Utility Interests
- Green pricing/Green credits
- Price stability for customers

Community Interests
- Jobs
- Local Businesses, tourism
- Recreational interests
- Local Fishermen
- Environmental Concerns
Maine Offshore Wind Potential

New England Offshore Mean Wind Speed at 90-m

<table>
<thead>
<tr>
<th>Maine (MW of wind potential)</th>
<th>0-3 nm (state waters)</th>
<th>3-12 nm</th>
<th>12-50 nm</th>
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</thead>
<tbody>
<tr>
<td>Wind</td>
<td>Depth Category (m)</td>
<td>Depth Category (m)</td>
<td>Depth Category (m)</td>
</tr>
<tr>
<td>Class</td>
<td>0-30</td>
<td>30-60</td>
<td>60-900</td>
</tr>
<tr>
<td>4</td>
<td>4,785</td>
<td>2,162</td>
<td>324</td>
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<tr>
<td>5</td>
<td>3,663</td>
<td>2,442</td>
<td>1,112</td>
</tr>
<tr>
<td>6</td>
<td>1,516</td>
<td>2,250</td>
<td>1,487</td>
</tr>
<tr>
<td>7</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

Source: G. Hart, Ocean Energy Institute, Maine

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Thank you