Innovation Projects
WF Commercial
Lisbon, June 7, 2017
KIC Innoenergy Project

The Project

WindFloat – Path towards Commercialization

Financiability | Competitiveness | Market Opening

WindFloat Proven Technology

2007-2012 | 2013-2018 | > 2018

Work Packages
(2015-2018 Implementation)

- Feasibility Study & Project Management (WP1/WP0)
- Market Competitiveness and Technology Cost Reduction (WP2)
- WindFloat Engineering (WP3)
- Certification of Technology by Independent Entity (WP4)
- Business Development & Technology Dissemination (WP5)
- Complementary Activity - 1st Floating Wind Farm – WindFloat Atlantic (WP6)
WF Commercial Project

**EIT InnoEnergy**
- Priority: sustainable energy
- EIT InnoEnergy’s mission has a high impact on innovation specially in Renewable energies.
- EIT is improving the reliability, integration and commercialization of Offshore wind - very important for Principle Power and WFA

**Scope of the project**
The strategy is to build pre-commercial projects (25-50 MW projects) in different key geographies within the next 3 years. Thereafter, the goal is for the technology to be fully commercial and be included in tenders for offshore wind projects world-wide.

**Objective of the project**
The main focus of the project is to develop the WF technology towards Commercial, evaluate and create opportunities in keys markets by delivering 3 major products:
- WindFloat Technology - A semi-submersible platform for offshore wind energy
- Offshore Wind Technology Consulting Services
- WindFloat Integrated Support Services

To complement those activities, the WFA, a pre-commercial project using the WindFloat technology with 25 MW located in Viana do Castelo, will be deployed taking benefit of the activities developed during the InnoEnergy Project.

**Project 2015-2018**

**Internships**
PPP engages students in the process of technological innovation, working on a technology or process applicable on our business.
Interns are showing creativity, innovation, entrepreneurship skills and competences and for that they are welcome in Principle Power.
The WindFloat, a Key part of the solution...

- Globally Patented, Proven Floating Technology: 5 years 2MW Pilot;
- Projects in Europe, US, Asia, w/ highlight for advanced 25 MW Project in Portugal and 24 MW in France
- Global presence with offices in US, France, Portugal (30 employees)
- Leading in Cost and Performance; LCOE competitive with currently commercial technologies
- Paradigm Shift => Reduction of Cost and Risk for the Industry

... To Bring Offshore Wind to its Global Potential
Floating Offshore Wind is an Industry Game-Changer in Two Ways

Key Industry Trends

- Further from shore
- Deeper waters
- Larger Farms

While... Reduction of costs and risk needed to truly globalize the Industry!

Floating wind: a game changer

Open the market for deep water exploitation (>60m)

- Open coastal markets with high power demand, high prices, high population density and deep waters
- Expanding total market for offshore wind

Substitute existing technologies in transitional waters (40-60m)

- Floating Semi-Sub technologies will be a competitive alternative to current foundations (eg. Jackets / gravity based foundations)
- Opportunity to capture market share from existing technologies
Today, floating Wind has now deployed 20 MW, proving itself as a key RE solution.
Floating is already large market ➔ Close to 400 MW of Demos and 7 GW of Large Scale Projects in development

<table>
<thead>
<tr>
<th>Current MW Installed: 20MW</th>
<th>Current Floating Wind Farms (Announced) under Development</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Demo Projects</td>
</tr>
<tr>
<td></td>
<td>12 MW</td>
</tr>
<tr>
<td>US</td>
<td></td>
</tr>
<tr>
<td>Europe</td>
<td>France, 100-150 MW</td>
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<tr>
<td></td>
<td>UK, 80 MW</td>
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<tr>
<td></td>
<td>Portugal, 25 MW</td>
</tr>
<tr>
<td>Japan</td>
<td>Up to 100 MW</td>
</tr>
<tr>
<td>Taiwan/Korea</td>
<td>Up to 30 MW</td>
</tr>
</tbody>
</table>
Floating and the WindFloat now a Proven technology, Operated for 5 years; Meeting Manufacturers Specification; Producing c. 17GWh of Energy; Tested in Extremes
WindFloat 1 performance proven over 5 years operation

Project Description

- **Vestas 2MW turbine**
- **Operation**
  - ~17 GWh produced in 5 years
  - Operated in Hs of 7 m
  - No production losses overall
  - 17 m waves
  - Reliable O&M and inspection program
- **Decommissioning**
  - July 2016
  - Reversible operation
  - Sole use of local tugs (No AHV)
  - Removal of the turbine at quay side (hull floating)
  - Life extension of the platform possible

Prototype Objectives

- Demonstrate the ability to: Fabricate, commission at quayside and install fully-assembled WindFloat
- Produce power up to the one-year storm
- Survive large winter storms
- Withstand wave- and wind-induced fatigue
- Perform O&M activities on the platform
- Operate the Active Ballast System and other systems and equipment
- Predict the important responses of the system with numerical tools
- Decommissioned safely with minimal budget and negligible impact to the environment
Now implementing demonstration scale projects, with state of the art turbines and optimized designs

WF1

- larger turbines (x3-4)
- design life extension (x5)
- global sizing – “smaller” platform
- structural optimizations
- equipment improvement
- accessibility
- mooring improvements
- installation improvements

Current Generation

- Capacity: \( x4 \)
- Production: \( x4.5 \)
- Unit Cost: \( x1.75 \)
Technology signed off by Key International Certification bodies in different markets, prepared for deployment

**WindFloat Pacific, US**
- US West Coast – high wind, high wave
- 8MW turbine, Turbine TBD
- Approval in Principle
- Full Document and Project Review with no critical findings

**WindFloat Atlantic, Portugal**
- Portugal – medium wind, high wave
- 8 MW turbine, Vestas
- Approval in Principle
- Final stages of full certification / AFC stamped Drawings

**Golfe du Lion, France**
- France – high wind, medium wave
- 6 MW turbine, GE/Alstom
- Approval in Principle issued

**WindFloat Japan**
- Japan – medium wind, medium wave
- 5 MW downwind turbine, Hitachi
- Japan Model Testing performed
- Passed all technical committees with Class NK and NEDO
- Approval in Principle issued
Proving the industry is technically viable; now showing economic and financial viability to be commercial end of decade

- Technology Development and patents
- Successful fabrication, installation and operation

**Phase 1**
Technology Demonstration

**Phase 2**
Pre-Commercial
- Building demonstration scale farms in 1 or more geographies to prove concept financially and economically
- Focus on technology Roadmap and Levelized Cost of Energy Reduction

**Phase 3**
Commercial
- Competing in the Marketplace with other technologies and sources of energy

Maturity

2007-2012

2013-2018/19

> 2018/19
Building on our lessons learned, the WindFloat Atlantic Project will be a key milestone in the floating offshore wind industry.

**Project Overview**

- **Total capacity:** 25MW capacity, (3 X Vestas V164),
- **Location:** 20 km off the coast of Viana do Castelo, in water depth of ~ 100m
- **Interconnection:** to be constructed by REN, allowing a direct connection at 60kV
- **Construction:** shipyards in Portugal (same as WF1). Turbine installation quayside
- **Floating structure certification:** designed for 25 years, certified throughout design, construction and installation by ABS, an independent party
- **Detail design 90% completed** Q2 2016 by PPI Engineering

**First Non-recourse financed FOW project**

- **Equity financing completed in 2015;** 7 project partners
- **Non recourse financing expected completion mid 2017**
  - European Investment Bank – Selected for InnovFin Programme
  - Export Agencies; Commercial Banks
- **Strong Institutional Support:**
  - EU: NER 300; Portugal: Feed-in Tariff, APA
Major customers and partners in different projects globally demonstrate credibility and maturity

<table>
<thead>
<tr>
<th>US</th>
<th>Asia</th>
<th>Europe</th>
</tr>
</thead>
<tbody>
<tr>
<td>VIGOR INDUSTRIAL</td>
<td>MITSUI ENGINEERING &amp; SHIPBUILDING CO., LTD.</td>
<td>edp renewables</td>
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<tr>
<td>CURTIN MARITIME</td>
<td>Mitsubishi Corporation</td>
<td>REPSOL</td>
</tr>
<tr>
<td>DEEPWATER WIND</td>
<td>CHIYODA CORPORATION</td>
<td>GROUPE CAISSE DES DEPOTS</td>
</tr>
<tr>
<td>progression energy™</td>
<td>Marubeni Corporation</td>
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<td></td>
<td>MHI VESTAS OFFSHORE WIND</td>
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<td></td>
<td>New Energy and Industrial Technology Development Organization</td>
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<td>European Investment Bank</td>
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<td>ADENE</td>
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Institutional Support
The WindFloat Atlantic present status and lessons learned identify areas of focus to move to the next Phase

**Project Status**
- Today, all permits are in hand
- All tariffs secured
- Very advanced in procurement
  - Strong certainty on cost
- Strong Financial Model

**First Non-recourse financed FOW project**
- Four Financial Institutions/7 equity participants
  - Structured as it is to expose project to full due diligence
- Now engaged in due diligence
  - Focused on development status and commercial conditions
- Expected Close mid year 2017

**Due Diligence Focus**
- Onshore transmission upgrades that caused delay
- The size of the Wind Farm
  - Deterred the project from getting ‘best’ offers (turbine supply an example)
Different stages of technology development require different types of support; floating ready to move to Commercial

Phase 1
Technology Demonstration
- Government grants
- CapEx support
- Willing equity participants

Phase 2
Pre-Commercial
- Financing for a technology that is not fully mature
- Government should create as stable an environment as possible
  - Permitting
  - Interconnection
  - Offtake

Phase 3
Commercial
- Scale required to meet cost targets/expectations
- Volume for accompanying supply chain investment
- Options to reduce costs and financing
- Projects can take years to develop (2023 – 2035), so SHOULD START BEFORE PHASE 2 ‘FINISHES’

Maturity

2007-2012

2013-2018/19

> 2018/19
Significant innovation under way that will drive WindFloat LCOE below the 100€/MWh target

**General Design**
1. Larger Turbines; power / weight ratio
2. Structural Optimization / Hull weight

**Detailed Design**
3. Optimize Ballast System
4. Optimization of controllers for Loads
5. Challenging Class rules for lighter / cheaper design

**Fabrication**
6. Industrialization / Serial Fabrication/ Minimize downtime (Communications, Access, etc.)

**Operations**
7. Improve reliability
8. Learning by doing / Continuous improvement

**Other WF Innovations**
9. Alternative Steels / Other Materials
10. Mooring Innovations

**Other Offshore Wind Industry Innovations**
(Turbine Performance, Plant Design, Electrical Systems, Supply Chain)

**Target:**
<€100/MWh
By FID 2020
### Government can take action today to effect Project Economics

<table>
<thead>
<tr>
<th></th>
<th>Contributing Factors</th>
<th>Government Action</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Capacity Factor</strong></td>
<td>• Wind resource</td>
<td>• Identify and de-conflict multiple zones for bidding in high wind resource areas (e.g. RSPB endorsement)</td>
</tr>
<tr>
<td></td>
<td>• Grid Connection</td>
<td>• Guarantee grid availability</td>
</tr>
<tr>
<td></td>
<td>• Water depth/distance from shore</td>
<td></td>
</tr>
<tr>
<td><strong>Financing Cost</strong></td>
<td>• Perception of technical risk</td>
<td>• Institute technical qualifications to avoid speculation and delivery risk</td>
</tr>
<tr>
<td></td>
<td>• Development risk</td>
<td>• Require supply chain plan to demonstrate ‘realism’ and localize benefits if desirable</td>
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<tr>
<td></td>
<td></td>
<td>• De-conflict/permit ready identified sites</td>
</tr>
<tr>
<td><strong>Project Scale/Supply Chain Effects</strong></td>
<td>• Visibility and volume in pipeline to drive investment</td>
<td>• Set MW targets now rather than waiting for Phase 2 to complete</td>
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<tr>
<td></td>
<td>• Scale to lower unit costs across CapEx</td>
<td>• Carve outs for Floating OSW</td>
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<tr>
<td></td>
<td></td>
<td>• Enable development of infrastructure – repurpose facilities</td>
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Key Take Aways

1. The WindFloat and other floating wind is already proven technology, and is now proving its financial and economic viability.

2. Reduction of Cost and Risk => Addressing the industry’s challenges while enabling it to reach its full potential.

3. Already several Pre-Commercial Projects ongoing worldwide, expecting to be deploying commercially in the marketplace by end of decade.

4. Floating Wind expected to reach 11 GW by ’26 worldwide and it can play a key role in the energy mix of certain markets.

5. But the Key for market leadership is to continue pace of development and to prepare for commercial projects now; benefits to these investments will extend into the future and accrue to Scotland/UK.
<table>
<thead>
<tr>
<th>Research Project Title</th>
<th>Internship Details</th>
<th>Relevance to PPI R&amp;D / Deliverables</th>
<th>Current Status</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Structural Inspections</strong>&lt;br&gt;&lt;br&gt;Inspection of WindFloat and Incorporated Wind Turbine using Automated Flying Vehicle</td>
<td>Dates: Feb 29&lt;sup&gt;th&lt;/sup&gt; – Aug 31&lt;sup&gt;st&lt;/sup&gt;, 2016&lt;br&gt;Location: Toulouse, France&lt;br&gt;Supervisor: Josh Weinstein&lt;br&gt;Cooperation: Industry partners: Donecle &amp; Tachyssema</td>
<td>Better, faster more reliable inspections&lt;br&gt;- Fits with H2020 proposal to be submitted in September 2021&lt;br&gt;- Thesis report&lt;br&gt;- Proposal for H2020 proposal</td>
<td>Muhammed Junaid&lt;br&gt;- Final thesis delivered&lt;br&gt;- Final Presentation in Paris&lt;br&gt;- Valuable contribution to H2020 project</td>
</tr>
<tr>
<td><strong>Industrialization</strong>&lt;br&gt;&lt;br&gt;Industrialization potential and cost optimization for a commercial floating wind farm.</td>
<td>Dates: April 4&lt;sup&gt;th&lt;/sup&gt;, – September 16&lt;sup&gt;th&lt;/sup&gt;, 2016&lt;br&gt;Location: Lisbon, Portugal&lt;br&gt;Supervisor: Cyril Godreau&lt;br&gt;Cooperation: Ecole Polytechnique, Paris</td>
<td>Part of LCOE reduction effort&lt;br&gt;- Importance for understand the landscape of Fabrication solutions in Europe in terms of large capacity and industrialization&lt;br&gt;- Importance in assessing the cost reduction of a large project&lt;br&gt;- Importance in assessing feasibility to fabricate 40+ units per year&lt;br&gt;- Thesis / reports, maybe conference paper.</td>
<td>Loris Canizares&lt;br&gt;- Completed Fabrication model with ASAM&lt;br&gt;- Completed LCOE Assessment for commercial-scale project in the Mediterranean&lt;br&gt;- Final thesis delivered&lt;br&gt;- Final Presentation in Paris&lt;br&gt;- Contract extension with intention to hire as full time employee in Portugal</td>
</tr>
<tr>
<td><strong>O&amp;M</strong>&lt;br&gt;&lt;br&gt;Installation and O&amp;M optimization of the WindFloat</td>
<td>Dates: April 4&lt;sup&gt;th&lt;/sup&gt;, – September 16&lt;sup&gt;th&lt;/sup&gt;, 2016&lt;br&gt;Location: Lisbon, Portugal&lt;br&gt;Supervisor: Tiago Godinho&lt;br&gt;Cooperation: IST, Portugal</td>
<td>Part of LCOE reduction effort&lt;br&gt;- Information on how to optimize O&amp;M for future WF projects&lt;br&gt;- Direct application to WFA&lt;br&gt;- Thesis / reports, maybe conference paper.</td>
<td>Christian Lorenzo&lt;br&gt;- Updated and improved O&amp;M code (matlab) from WaveEC&lt;br&gt;- Developed input decks for component failures, response strategies, etc. from PPI and external sources&lt;br&gt;- Created series of output graphics/analysis to communicate results&lt;br&gt;- Currently running sensitivity Analysis and Finalizing Results</td>
</tr>
</tbody>
</table>
WF Commercial - InnoEnergy MSc Student Interns 2017

### Research Project

#### Internship Title

**Structural Optimization**

*Structural optimization study of fatigue-driven floating offshore wind turbine foundation structure; WindFloat*

**Dates:** March 6th – August 31st, 2017  
**Location:** Lisbon, Portugal  
**Supervisor:** Cyril Godreau  
**Cooperation:** IST, Portugal

**Relevance to PPI R&D / Deliverables**

**Lighter Stronger Structure**

- Optimization of WindFloat structural elements can result in a lighter and more efficient structure that can deliver equal levels of performance at lower cost
- The project will investigate optimization opportunities using Principle Power’s suite of design software
  - Thesis

**Intern Profile**

**Victor Sanchez**

- Master: KIC RENE  
  - Energy Engineering, UPC-Barcelona  
  - MSc in EE & IT  
- Bachelor: Industrial Engineering (UC3M)  
- Airbus: Trainee – performance and improvement department

#### Internship Title

**Mooring System Optimization**

*Design optimizations of mooring system for floating offshore wind turbine foundation structure; WindFloat*

**Dates:** March 6th – August 31st, 2017  
**Location:** Lisbon, Portugal  
**Supervisor:** Cyril Godreau  
**Cooperation:** IST, Portugal

**Relevance to PPI R&D / Deliverables**

**Efficient Mooring Systems for different conditions**

- Mooring system needs to be optimized to local conditions to minimize LCOE, balancing procurement and install/O&M costs
- Modeling to identify efficient mooring systems for different conditions
- Results inform PPI cost models
  - Thesis / maybe conference paper

**Intern Profile**

**Daniel Toledo Monfort**

- Master: KIC RENE  
  - MSc in Eng. & Energy Mgmt., IST  
  - MSc in Energy Engineering  
  - MSc in Energy Systems  
- Bachelor: Industrial Engineering (UPC)  
- ETSEIB Racing (MotoStudent III Edition): Chassis & Swinging Designer

#### Internship Title

**Fabrication & Logistics Optimization**

*Logistics study to optimize delivery of the WindFloat technology in immature markets*

**Dates:** March 6th – August 31st, 2017  
**Location:** Lisbon, Portugal  
**Supervisor:** Aaron Smith  
**Cooperation:** IST, Portugal

**Relevance to PPI R&D / Deliverables**

**LCOE reduction and BD Support**

- Key challenge for the WindFloat will be to industrialize quickly in markets that lack established offshore wind supply chains (fixed and floating)
- Prospective customers want to see contract delivery/execution plans
- BD efforts seek to get WindFloat accepted for projects in several immature markets; this study will support RFI preparation and response
  - Thesis / maybe conference paper

**Intern Profile**

**Alex Peracaula**

- Master: KIC RENE  
  - MSc Energy Engineering, UPC-Barcelona  
  - MSc in Eng. & Energy Mgmt., IST  
- Bachelor: Industrial Engineering (ETSEIB)  
- Researcher: Advanced Power and Energy Program (APEP) UC Irvine, CA, USA

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- Bachelor: Industrial Engineering (ETSEIB)  
- Researcher: Advanced Power and Energy Program (APEP) UC Irvine, CA, USA
Thank you!

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