The WindFloat Atlantic Project

Lisboa, April 2014

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- **Why deep off-shore?**
- Why floating wind?
- Why Windfloat?
- Results from demonstration project
- Windfloat Atlantic

The evolution of the offshore wind market will inevitably drive to deep water exploration

Europe has much broader wind potential in deep than on shallow waters

EU15 Potential

- Good offshore wind resource (load factor > 3.000h)
- Offshore wind potential is mostly in transitional and deep waters[(1)] (~65 %)
- Energy Potential **>700 TWh** (~220 GW)
- Ports and docks available along European coast

[(1)]Analysis limited to 100m water depths

Depth (m)	0 - 30	40 – 200 +
Offshore potential EU15	77 GW	>140 GW

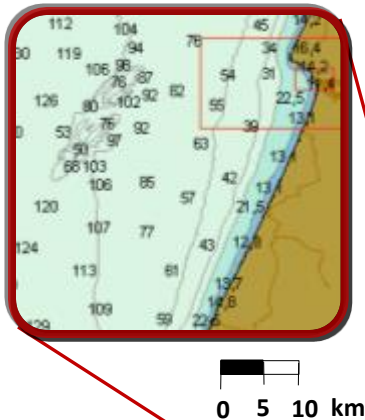
Source: Greenpeace & Garrad Hassan 2004; IEA; Global insight;

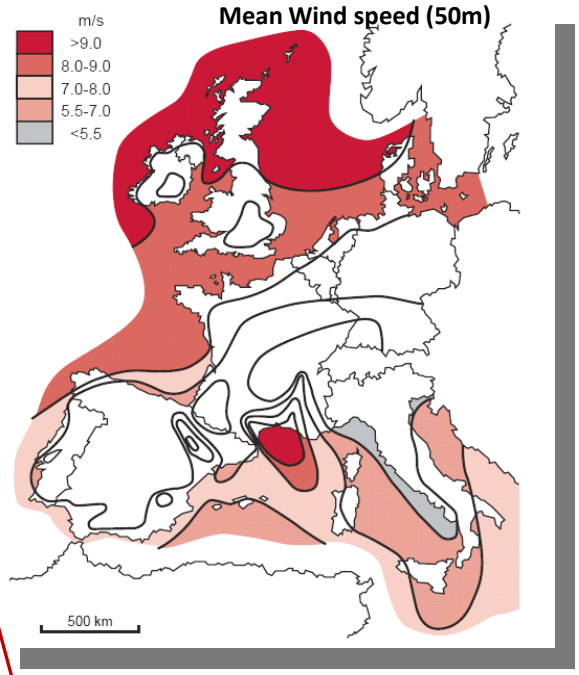
Potential in Portugal, Spain & France

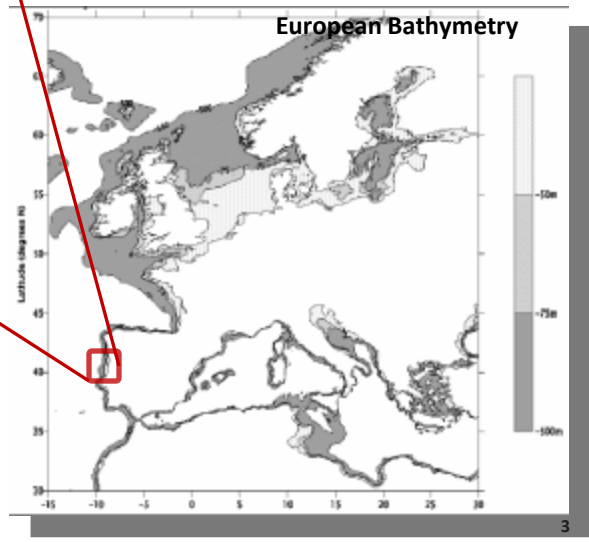
- Continental shelf ends near the coast
- Grid connection available near the coast
- Limited Potential for water depths < 40m
- 250 km of PT Costal Line suitable to be explored

Profondeur (m)		0 - 40	40 – 200 +
Potentiel offshore	FR	80 GW	122 GW
	PT	2 GW	>10 GW
	SP	18 GW	>80 GW

Source: Univ.de Zaragoza – Evaluación Potencial Energías Renovables (2007); FEE



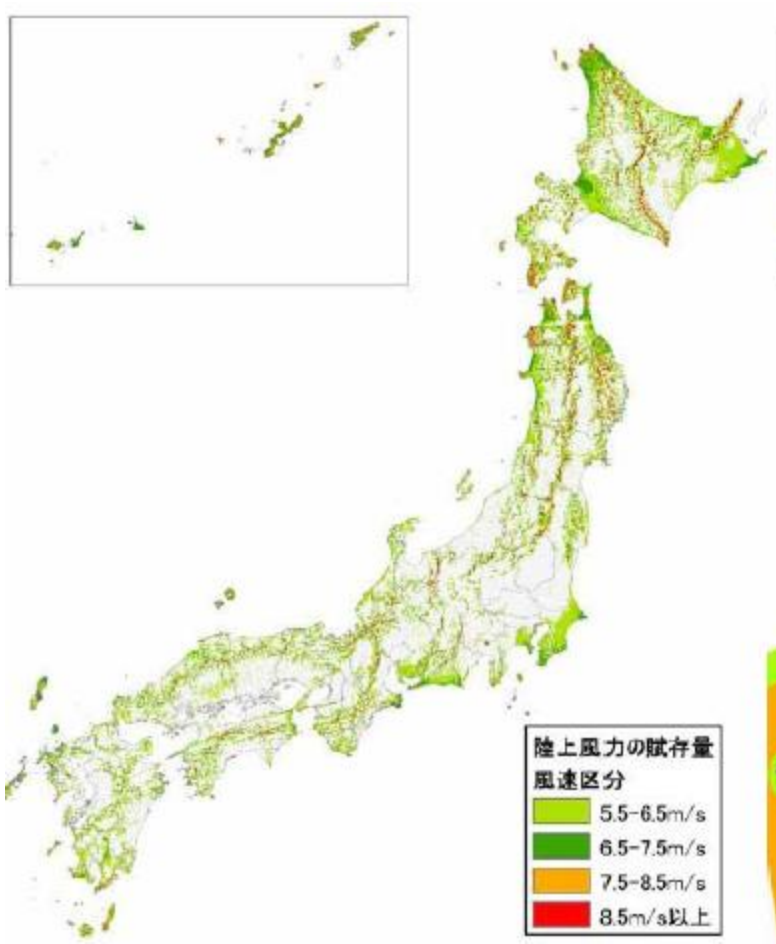




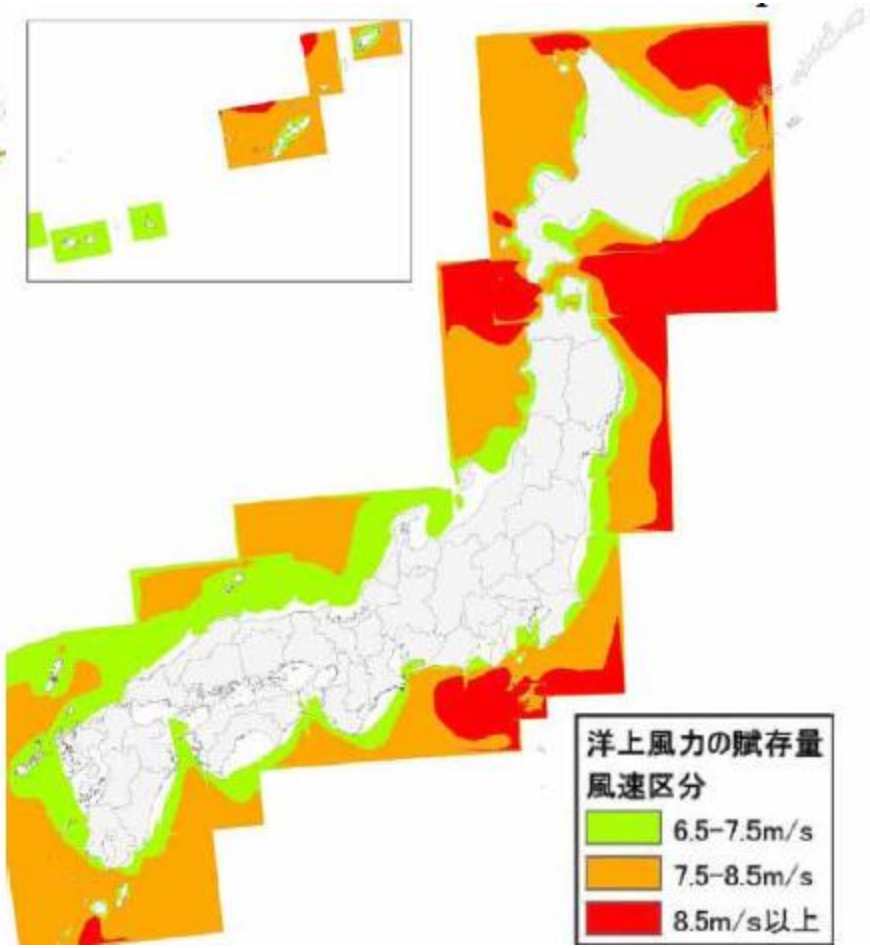
Deep offshore has a strong potential in other geographies as well

Japan has ambitious plans to substitute its large nuclear capacity with offshore wind

Onshore wind ressource in Japan



Offshore wind ressource in Japan



Economic potential: **141GW (almost all floating)**
Total potential: **1600GW**

Source. Chuichi Arakawa – University of Tokyo

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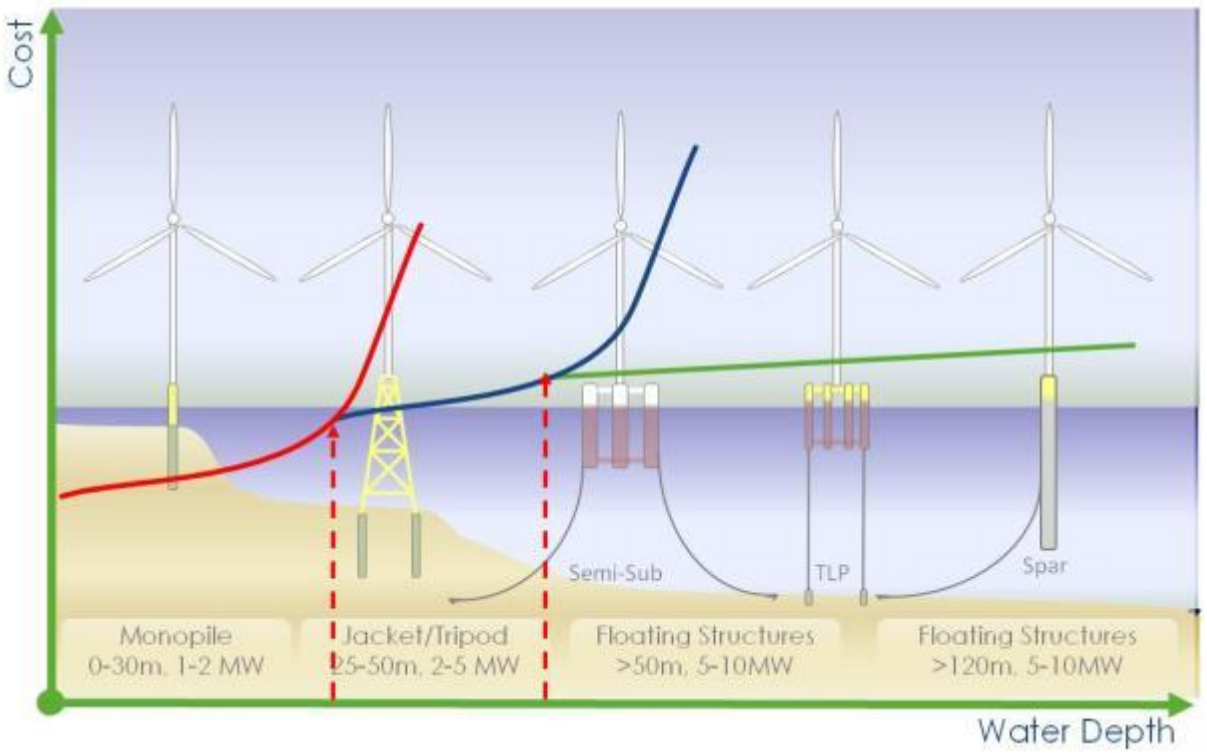
Floating offshore is already the only viable solution at water depths >50m



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)
- Several jackets successfully installed at depths of less than 50m (Beatrice in 2006 was the first project to deploy at 45m)

Other fixed (tripods, tripiles, gravity bases ,…)

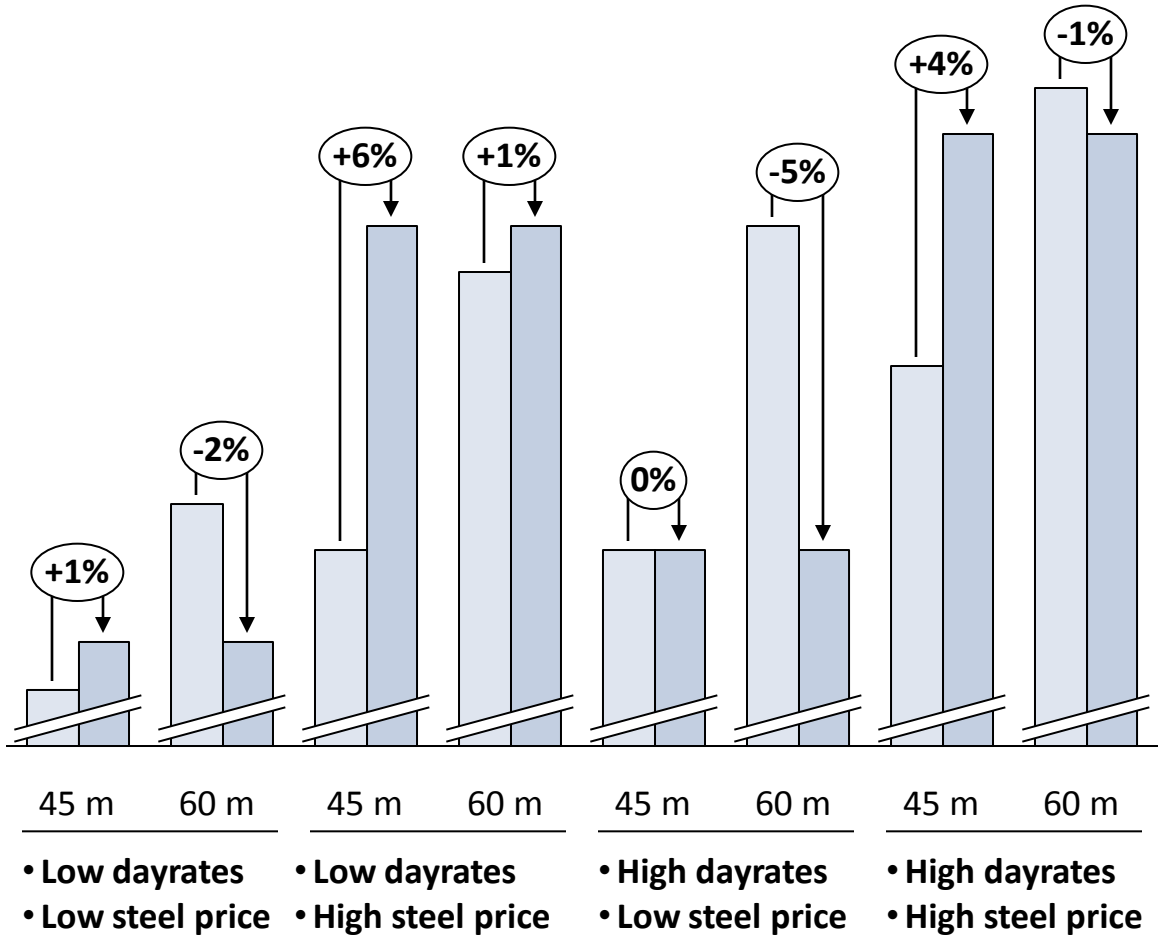
- Very limited experience
- Similar depth limitations as jackets

Floating

- Expected economical feasibility in deep waters (50-?m)
- Still limited experience

Competitiveness of floating offshore increases with water depth and distance to shore

Garrad Hassan's comparison of Jacket foundations and Windfloat under different market conditions



- **Floating solutions demonstrate to be competitive with bottom fixed solutions** already at intermediate depths **(45m)** and the gap increases proportionally to depth.
- **The advantages of floating solutions are observed through out the entire breakdown of the LCOE**, and it is possible to observe that steel prices are the main driver of price for WF. Technology wise Windfloat is mature and stable.

Source: Garrad Hassan

Floating has some clear advantages vs. fixed structures

	Description	Risk implications
Hull/ foundation fabrication	• Fabrication is **fully conducted onshore** • **All structures are alike,** allowing for industrialization and work specialization • Engineering follows **strict guidelines from shipping industry**	• **Lower design risk** • **Lower execution risk** (quality, corrosion, delays, etc.)
Sea bed fixation	• Fixation is conducted using **well-known** (and widely used) **anchoring technology** • **Anchoring works well in virtually all soil conditions** (especially sand and sediments) • **Lower need of detailed sea bed surveying**	• **Lower geotechnical risk** (no risk of foundation settlements)
Installation (Transport and assembling)	• **Shorter weather windows required** to make installation • **Fewer and simpler operations to be conducted offshore** • **No use of special installation vessels** (only widely available tugs)	• **Lower execution risk** (few operations offshore) • **Lower weather risk**
Large correctives (O&M)	• **Shorter weather windows required** to work on the turbine (towing vs. Jack-ups) • **Fewer and simpler operations to be conducted offshore** • **No use of special O&M vessels** (only widely available tugs)	• **Lower execution risk** (few operations offshore) • **Lower weather risk**
Decommis-sioning	• Simple operation • **No impact whatsoever on the site** • **All works done onshore**	• **Lower execution risk** • **Lower third party risk**

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WindFloat Project – Overview

Due to the features of the WindFloat, most of the work is done onshore, reducing risk and cost

Main technology characteristics

Turbine Agnostic

- Conventional turbine (3-blade, upwind)
- Changes required in control system of the turbine

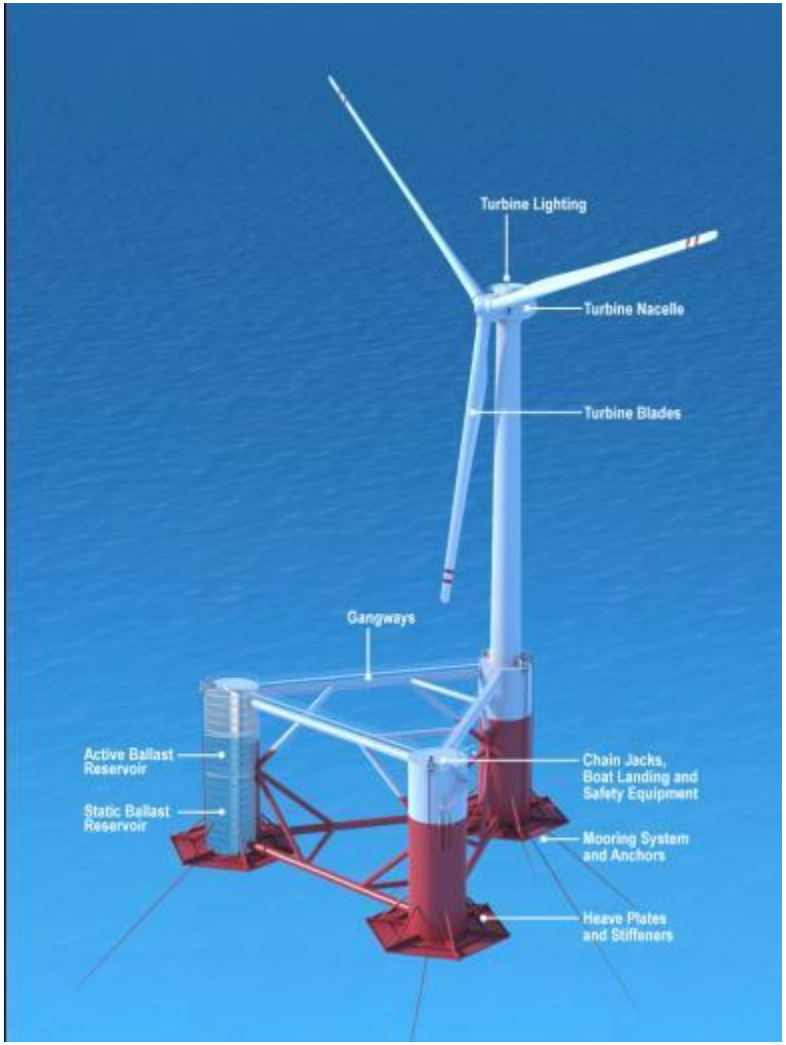
High Stability Performance

- Static Stability - Water Ballast
- Dynamic Stability - Heave Plates and active ballast system
  - Move platform natural response above the wave excitation (entrained water)
  - Viscous damping reduces platform motions
- Efficiency – Closed-loop Active Ballast System

Depth Flexibility (>40m)

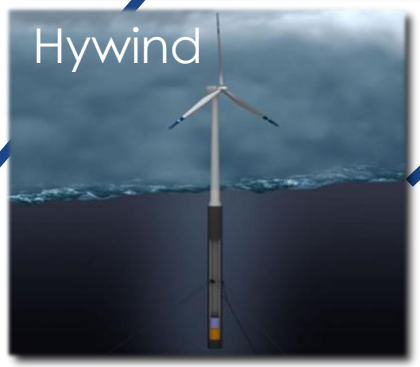
Assembly & Installation

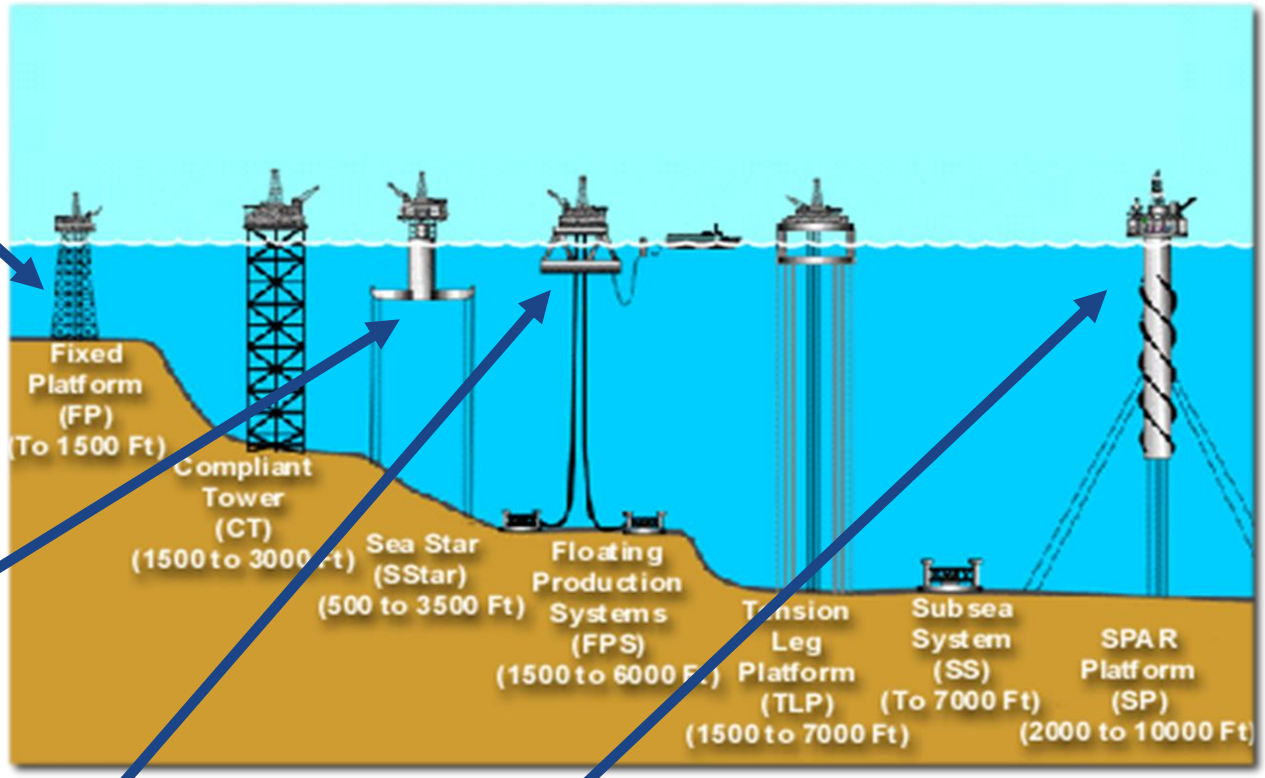
- Port assembly – Reduced risk and cost
- No specialized vessels required, conventional tugs
- Industry standard mooring equipment



Synergies with oil and gas: a Mature Market

Wind floating structures benefit from an extensive experience in the oil and gas business





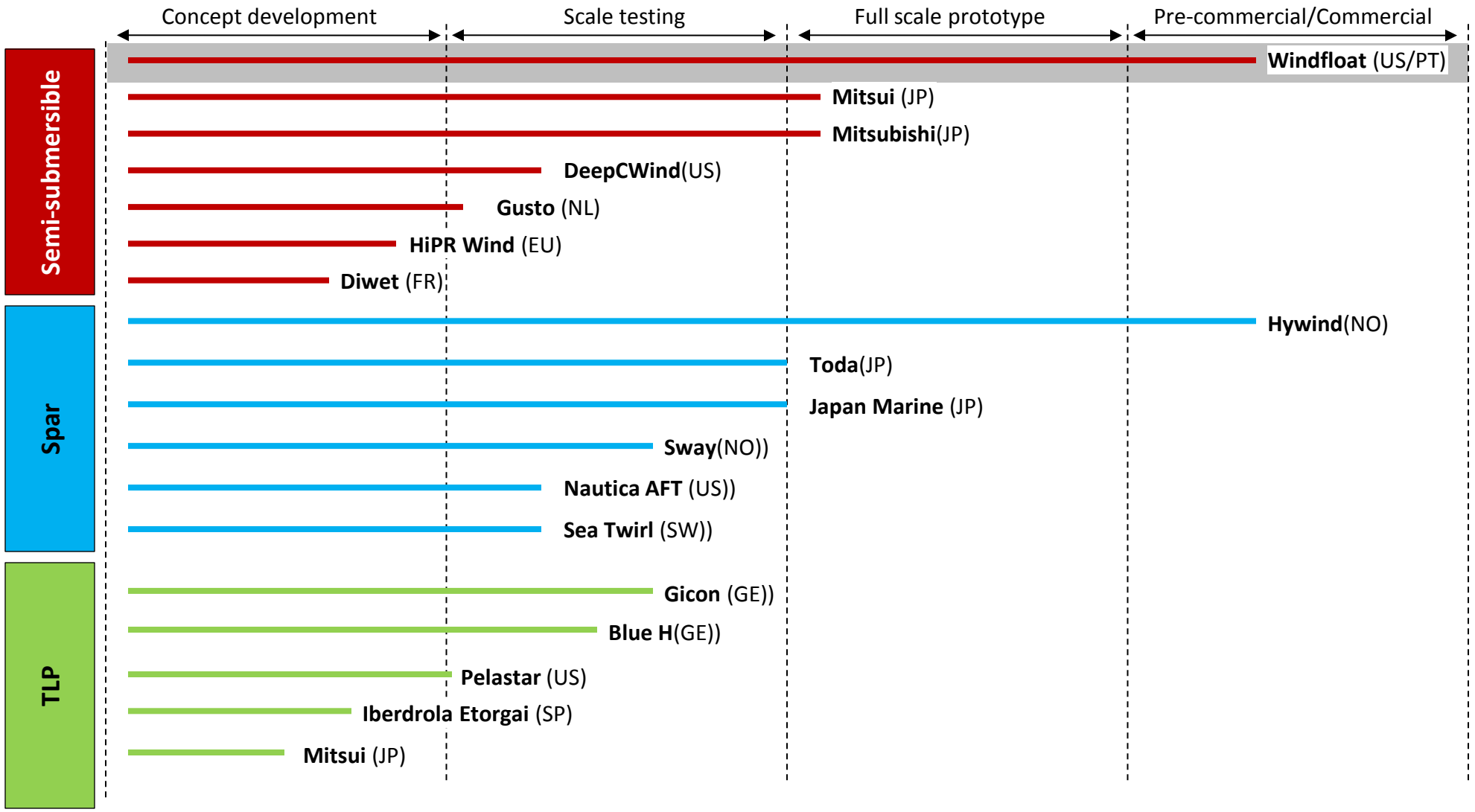
An industry of Experience…

- Floating structures date back to 1960's
- Experience in semi-submersible oil platforms is particularly large:
  - First was built in 1963
  - By 1972 more than 30 units had already been built
  - By 2012, 212 semi-submersible rigs were in operation worldwide and 22 were under construction

Windfloat – comparison with other floating technologies

Windfloat is >2 years ahead in commercial deployment vs. most competitors

State of development of selected floating turbine concepts



WindFloat is widely considered the most advanced floating technology

INTERVIEW: Andrew Garrad

“I’m a Believer.”

A floating future

Arrays of full-size machines are not long from becoming reality for two leading models, Statoil’s Hywind and Principle Power’s WindFloat, and Marubeni’s experimental floating wind farm is taking shape off Fukushima in eastern Japan.

“Even three years ago, if you’d asked me my thoughts on floating wind, I would have said it was something for the distant future,” Garrad says. “Yet here we are with prototypes in operation, prototypes being built, a landmark development off Japan... It is very exciting and it does address some key questions about construction, logistics, installation vessels.”

Source: www.rechargenews.com/magazine/article141412

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WF Project is organized in 3 phases, with a demo phase ongoing and important results achieved and a pre-com phase under development

Phase 1 – Demonstration

Capacity: 2MW WindFloat prototype

Location: Aguçadoura, grid connected

~6 km of coast, 40 - 50 m water depth

Turbine: 2MW offshore wind turbine

Test period: 24+ months

In operation since late 2011

Phase 2 - Pre-commercial (Windlfoat Atlantic)

Capacity: 24-28MW (3-5 WindFloat units)

Location: Portuguese Pilot Zone

Turbine: Multi MW, TBD

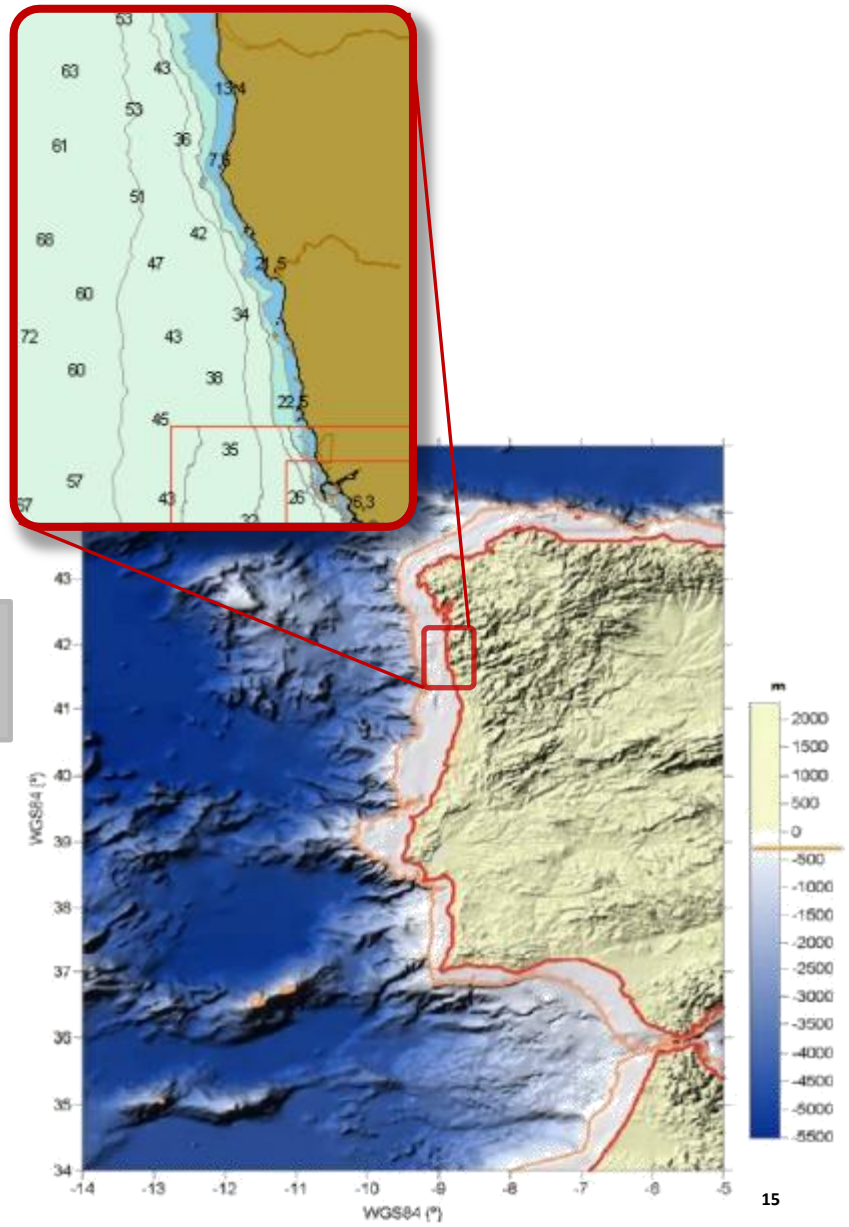
Estimated installation in 2016/2017

Phase 3 - Commercial

Capacity: >150MW, gradual build-out

Location: TBD

Turbine: TBD



Prototype 1 – Early achievements

Survivability and performance is demonstrated in normal and extreme conditions. >8,5 GWh produced.

Dec 2010
Windplus is created

22 Oct 2011
Installation complete

01 Nov 2011
15 meters wave

20 Dec 2011
First Electron produced

03 Jan 2012
Operation in Hs=6m and Hmax=12,6m

edp

PORTUGAL VENTURES

PRINCIPLE renewable energy delivered

ASIVAMATOS GROUP

REPSOL

(Joins in June 2012)

Prototype - Performance Demonstration

WindFloat is fully monitored and will allow comparison with the design models and improve design for next phase

Blade measurements

- Forces at blade root and in the middle of the blade

Wind turbine measurements

- Condition Monitoring System
- Accelerations in nacelle
- Main shaft torque and bending moment

O&M and inspections

- Inspection and maintenance on a six months basis

Tower measurement

- Bending moment at top, middle and base
- Yaw moment at top

Platform measurements

- Accelerations, deformation/torsion, pressure at several locations
- 6 DOF(1) motions

O&M and inspections

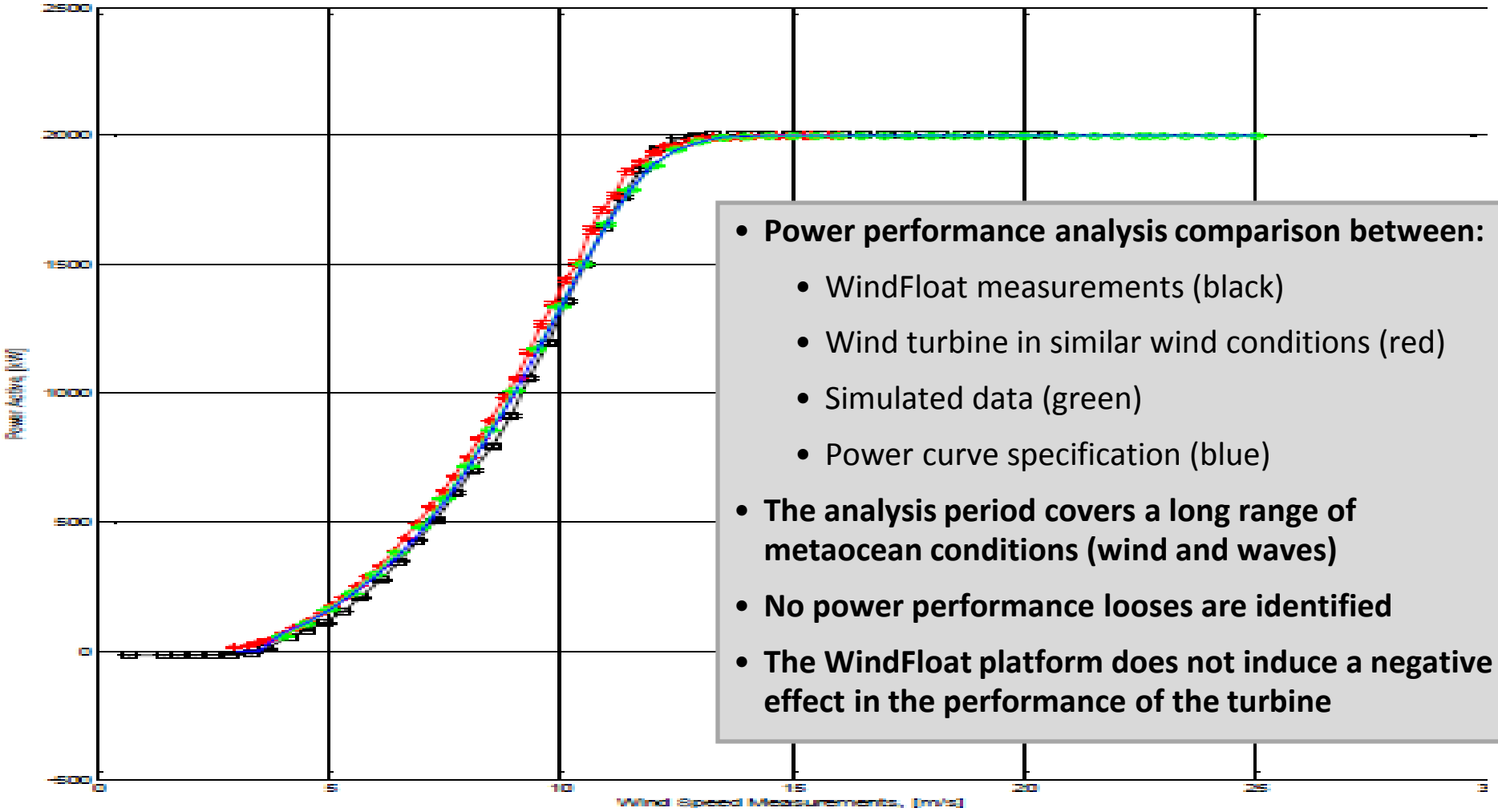
- Structural inspections on a six months basis
- Periodic visits (every 1-2 months) to the platform for routine inspection and maintenance

(1) DOF – Degrees of Freedom

Prototype: synthesis of turbine performance

Power curve has behaved like a fixed turbine

Power Curve performance



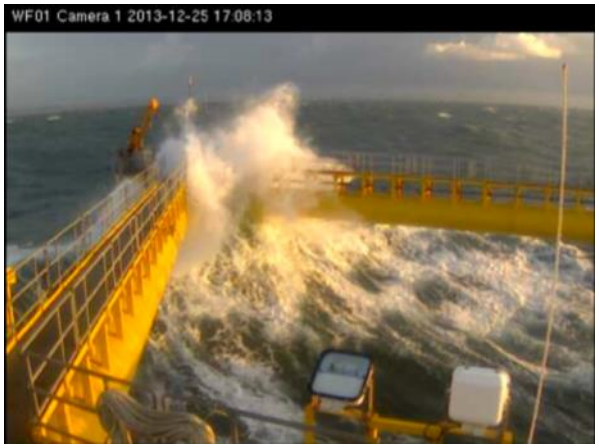
- **Power performance analysis comparison between:**
  - WindFloat measurements (black)
  - Wind turbine in similar wind conditions (red)
  - Simulated data (green)
  - Power curve specification (blue)
- **The analysis period covers a long range of metaocean conditions (wind and waves)**
- **No power performance looses are identified**
- **The WindFloat platform does not induce a negative effect in the performance of the turbine**

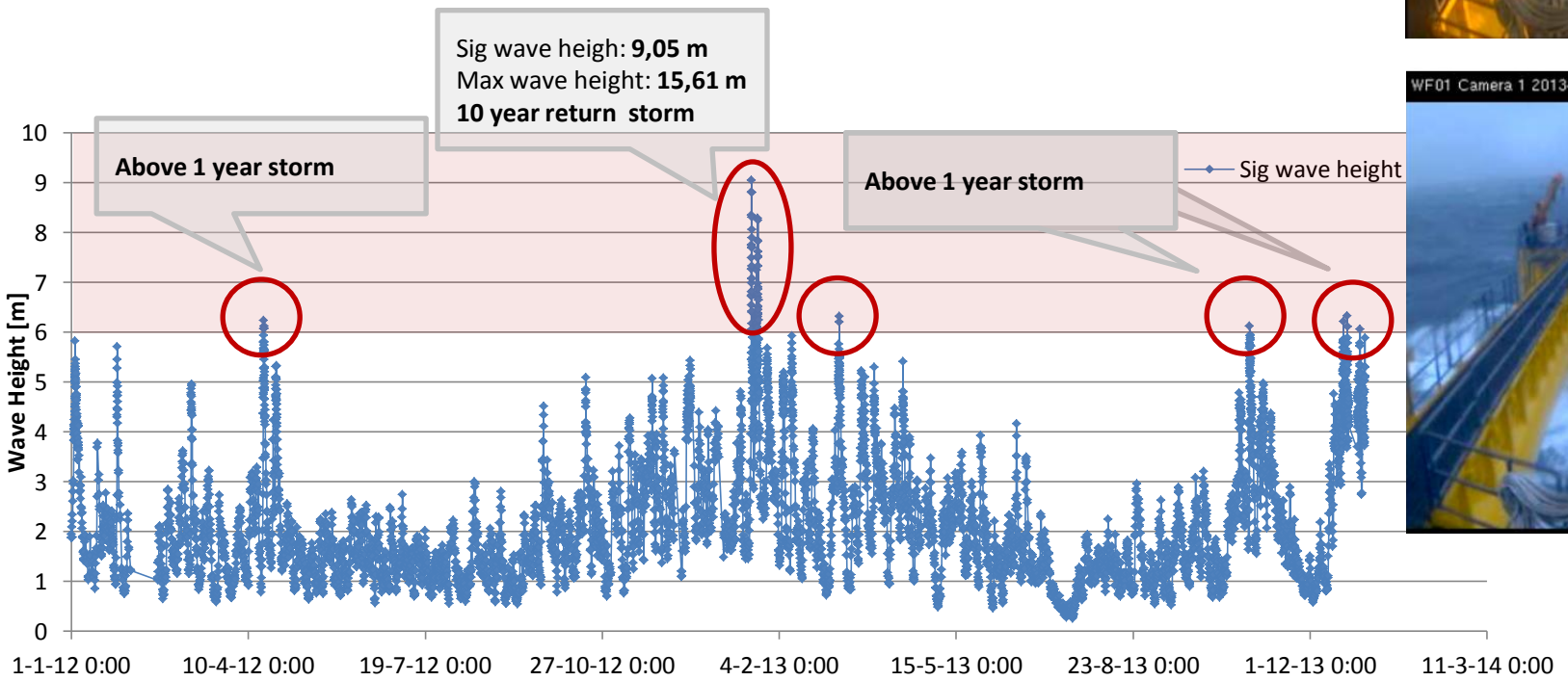
Prototype: synthesis of floating structure performance

WindFloat 1 has survived particularly adverse conditions

Extreme events

- During 2012 and 2013 extreme weather conditions were faced
  - Max wave height up to 16 m
  - The WindFloat did not suffer structural damages
- The WindFloat demonstration project was designed to operate up to 6.6 m significant wave heigh
  - This limit is only exceeded 1% of the time during the year which result in low unavailability due to weather conditions





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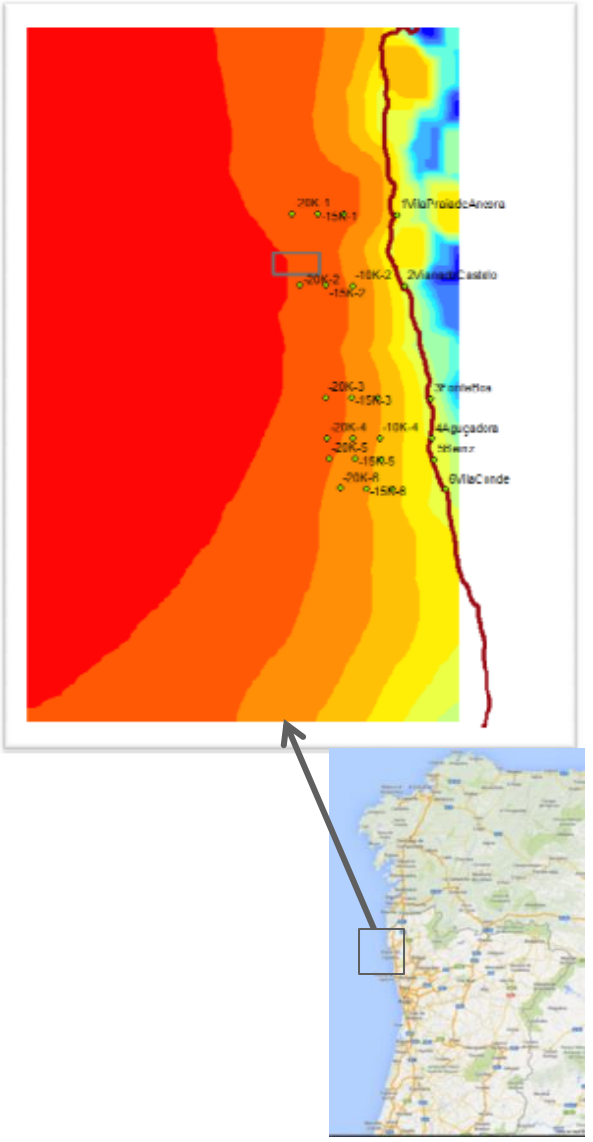
Windfloat Atlantic: Overall project description

Project will take place in the North of Portugal that presents very favorable conditions

- **Total capacity:** 24 to 28 MW capacity, (3 to 5 units equipped with turbines from 5 to 8 MWs)
- **Location:** off the coast of Viana do Castelo
- **Wind resource:** NCF from 34.7 to 39.4% depending on turbine model (using a mesoscale model calibrated at different points close to the site including current pilot project at <30km from future site. A floating Lidar will be installed in 2014 to measure wind on site)
- **Water depth:** ~100m
- **Geology:** sand and sediments, suitable for mooring (geological campaign to be conducted in 2014)
- **No need for offshore substation** (direct connection at 30 or 60kV)
- **Interconnection:** offshore interconnection to be conducted and financed by REN. Proven interconnection capacity onshore, <20m from the shore
- **Total investment:** ~100M€
- **Construction:** several shipyards options available close to final location. Turbine installation quayside
- **Floating structure certification:** will be conducted throughout design, construction and installation by an independent party (e.g., ABS)
- **Projected project lifetime:** 25 years



Windfloat Atlantic: overall project timeline

Commissioning is planned for mid-2017

NON-EXHAUSTIVE