Offshore Renewable Energy and Technology

Jornadas de Engenharia e Tecnologia Maritima

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Utilities are going to experience multiple technology disruptions along the value chain and EDP is already anticipating this trend

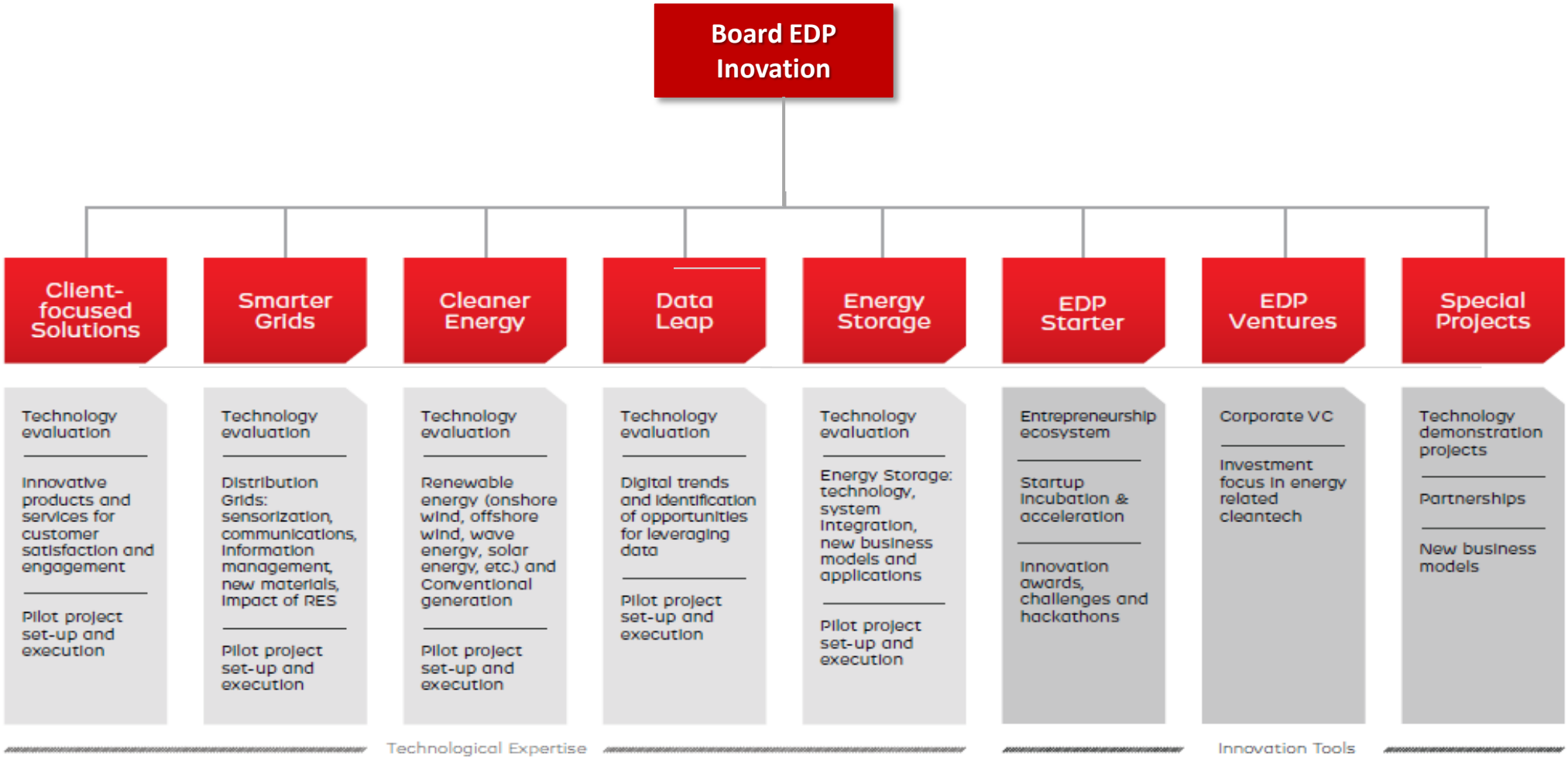
Expected technology evolution along value chain until 2020

	Generation	Distribution	Storage	Retail
Overview of major industry trends	Continued improvement of **RES cost competitiveness** supported by **technology evolution** and **supply chain maturation**	Deployment of **smart grids** to cope with growing energy management challenges (e.g., distributed generation)	**Maturation of power storage technologies**, with **pumped storage** expected to remain the most attractive option, **and further incremental technology improvements to be captured**	Emergence of **new downstream products/ services** (e.g. energy efficiency, distributed generation, data solutions) and **digital retail** as important value pools, mostly **driven by technology disruptions**
Innovation strategy	Increase EDP's competitive edge in renewable energy sources through **selective bet on new technologies and on improved operations**	Establish EDP as a **leading developer of smart grids** infrastructure and **applications with client / operations focus**	**Build options and develop EDP's capabilities** in potentially disruptive segment of the energy value chain	**Improve EDP's commercial portfolio** and client orientation through the **deployment of innovative energy products and services**
Example of Projects	▪ **WindFloat** ▪ Magpower ▪ Access to Energy (A2E)	▪ InovGrid ▪ Predis ▪ Sinapse	▪ Storage Lab ▪ National Hydro Plan	▪ Re:dy ▪ Funciona ▪ Save to Compete

Development of Big Data mechanisms to support innovation across all business areas

SOURCE: EDP Inovação; McKinsey Energy Practice; Team analysis

EDP Innovation was created in 2007 to provide innovative solutions across the EDP Group



Cleaner Energy covers a big spectrum of generation technologies in different stages of development...

Onshore wind
Solar PV
Conventional
Generation

Mature

Wind offshore
(fixed)

Solar CPV

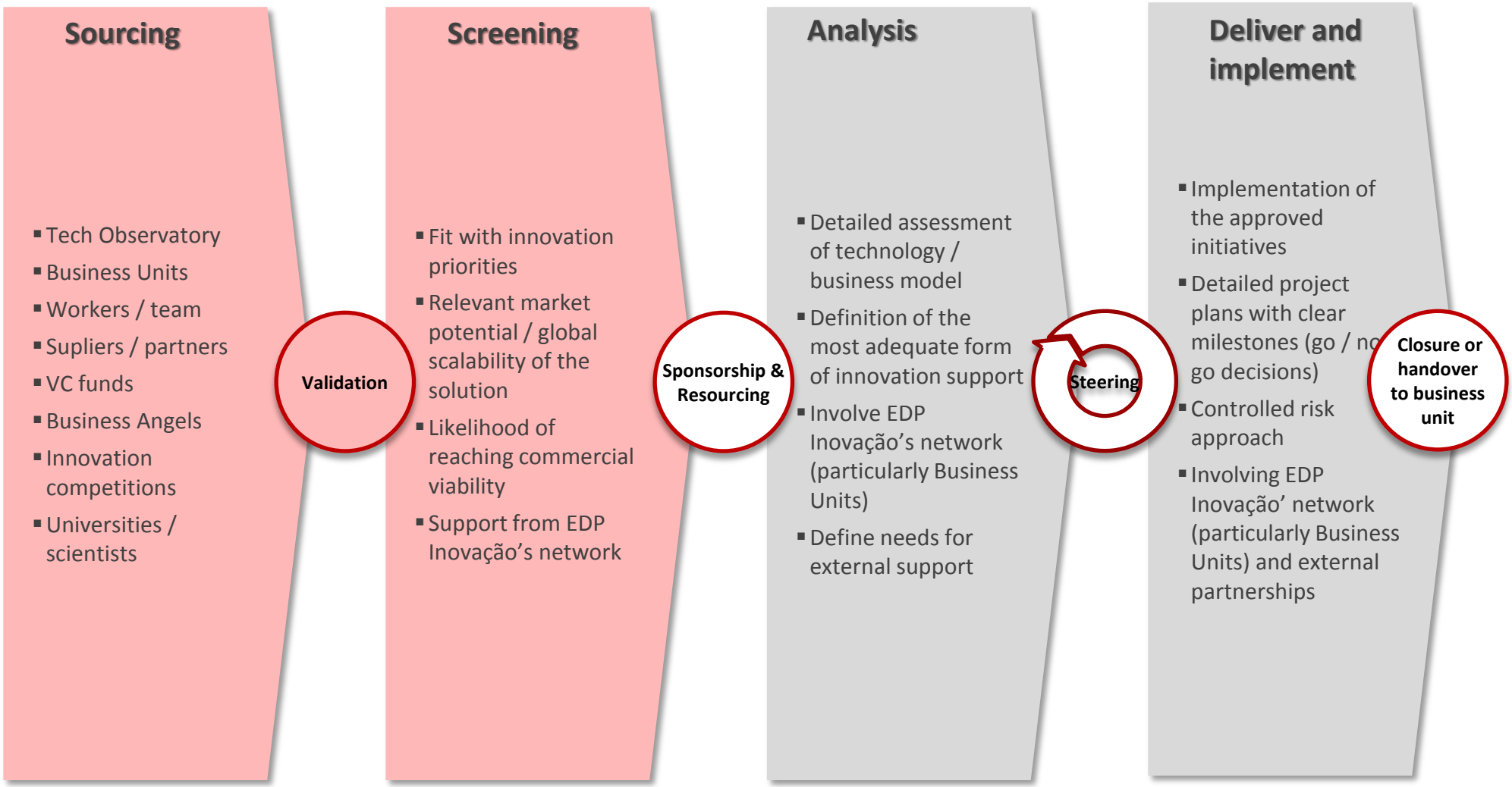
Floating
Offshore wind

HAWE[(1)]
Wave energy

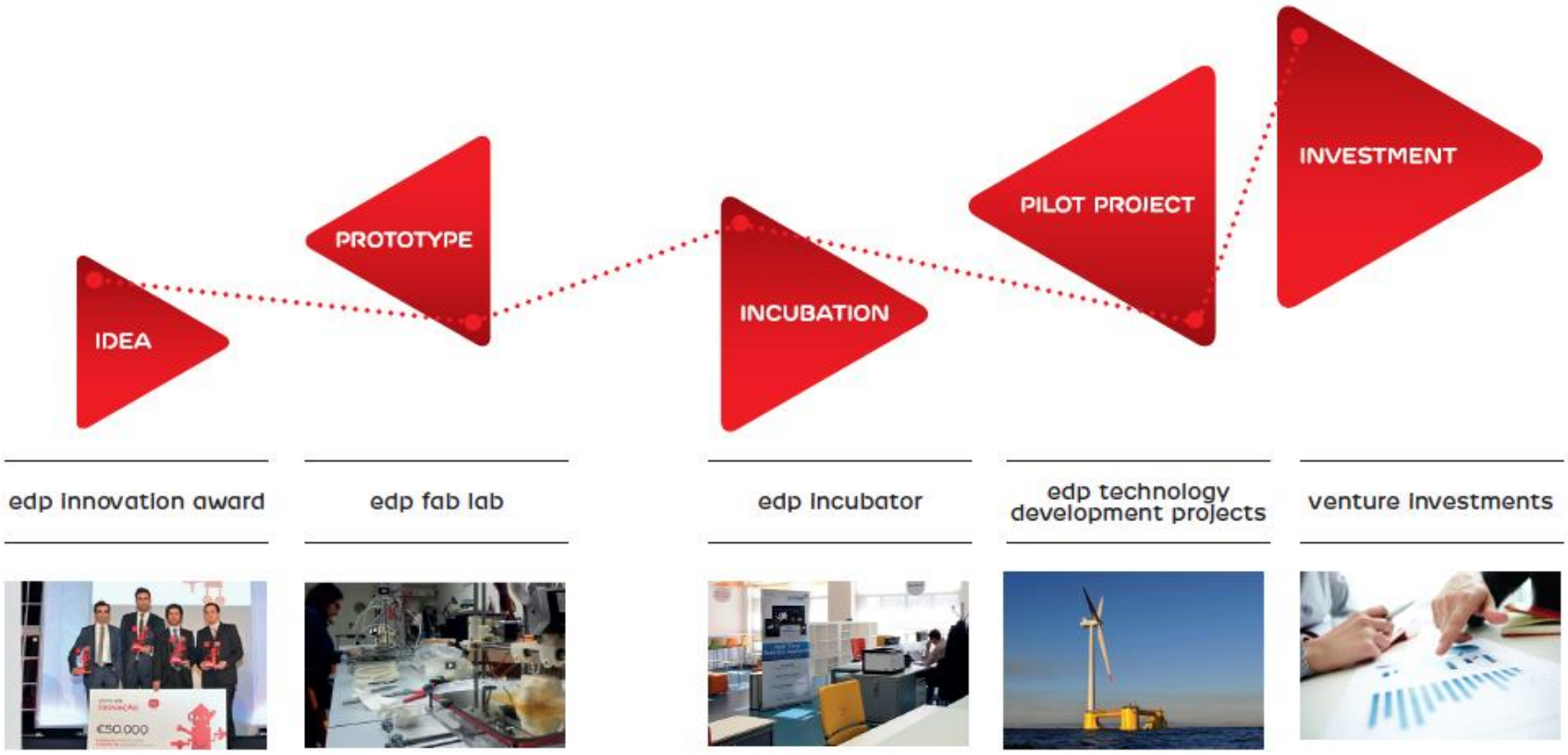
Early stage

[(1)] High Altitude Wind Energy

Innovation projects originated in EDPI and the Business Units are governed by a structured process



EDP Innovation supports technology and has established a business model for development along the entire innovation value chain



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Opportunity to enable a paradigm shift in the growing Offshore Wind Industry and take it to its full potential

ENERGY OUTLOOK

Europe: Offshore wind can play a critical role in Europe's 2030 targets of 40% reduction in Green House emissions and 27% share of renewables - it can deliver up to 65 GW in Europe by 2030, representing 8.4% of Europe's demand EWEA / E&Y 2014

World: "Installed capacity of offshore wind power reaches almost 190 GW in 2040" (Current: 9 GW); "The rate of deployment of offshore wind power (…) depends on the wind power industry being able to achieve significant cost reductions" WEO 2014

KEY OFFSHORE WIND INDUSTRY TRENDS

- Further from shore
- Deeper waters
- Larger Farms

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

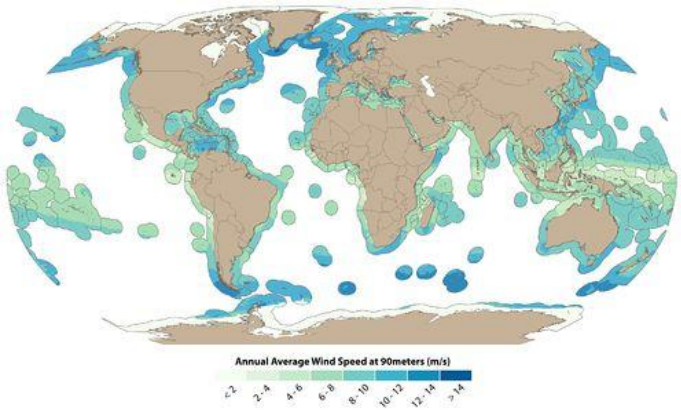
The WindFloat, a Key part of the solution **to bring offshore wind to its potential**

Globally Patented, Proven Floating Technology

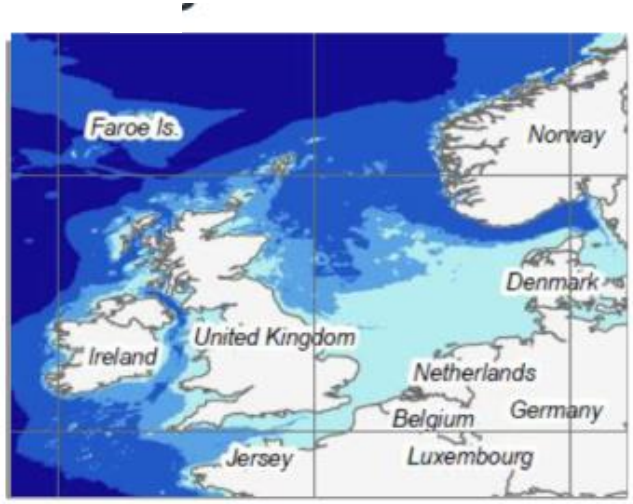
>3y operation

Leading in Cost and Performance; LCOE competitive with currently commercial technologies

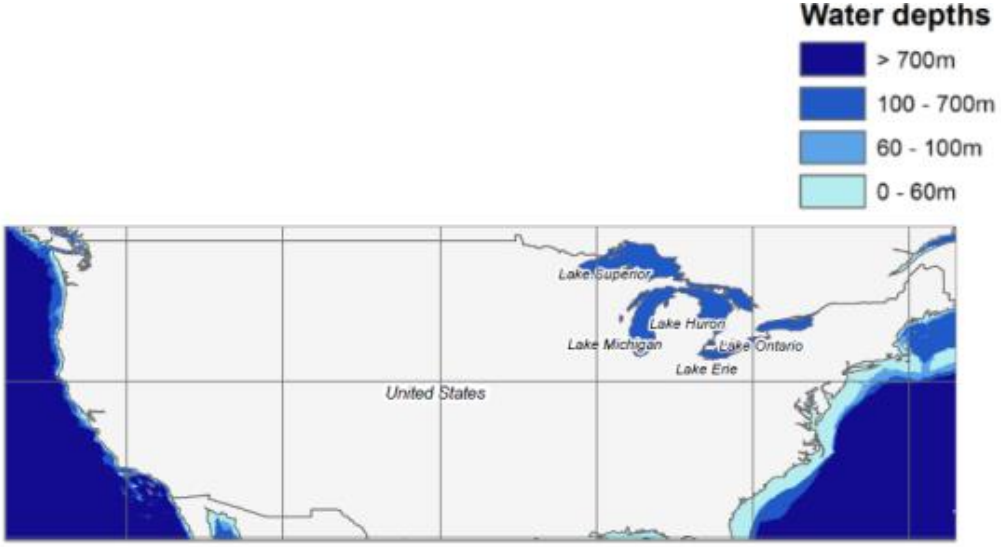
Reduction of Cost and Risk for the Industry



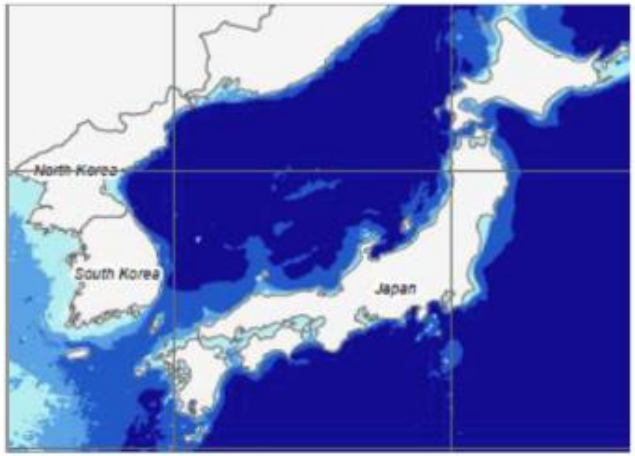
Global Market for Deep Offshore Wind is significant and represents an untapped resource



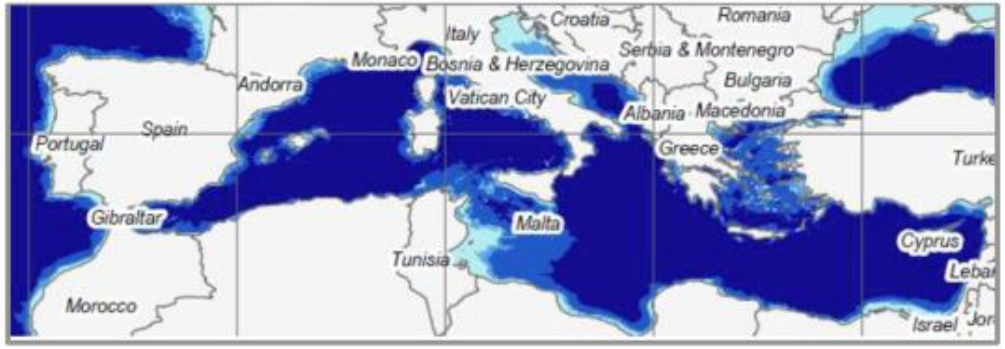
North sea – Norway and UK



US, Atlantic and Pacific coast – and Great Lakes



Japan and Korea



Iberian Peninsula and Mediterranean Sea

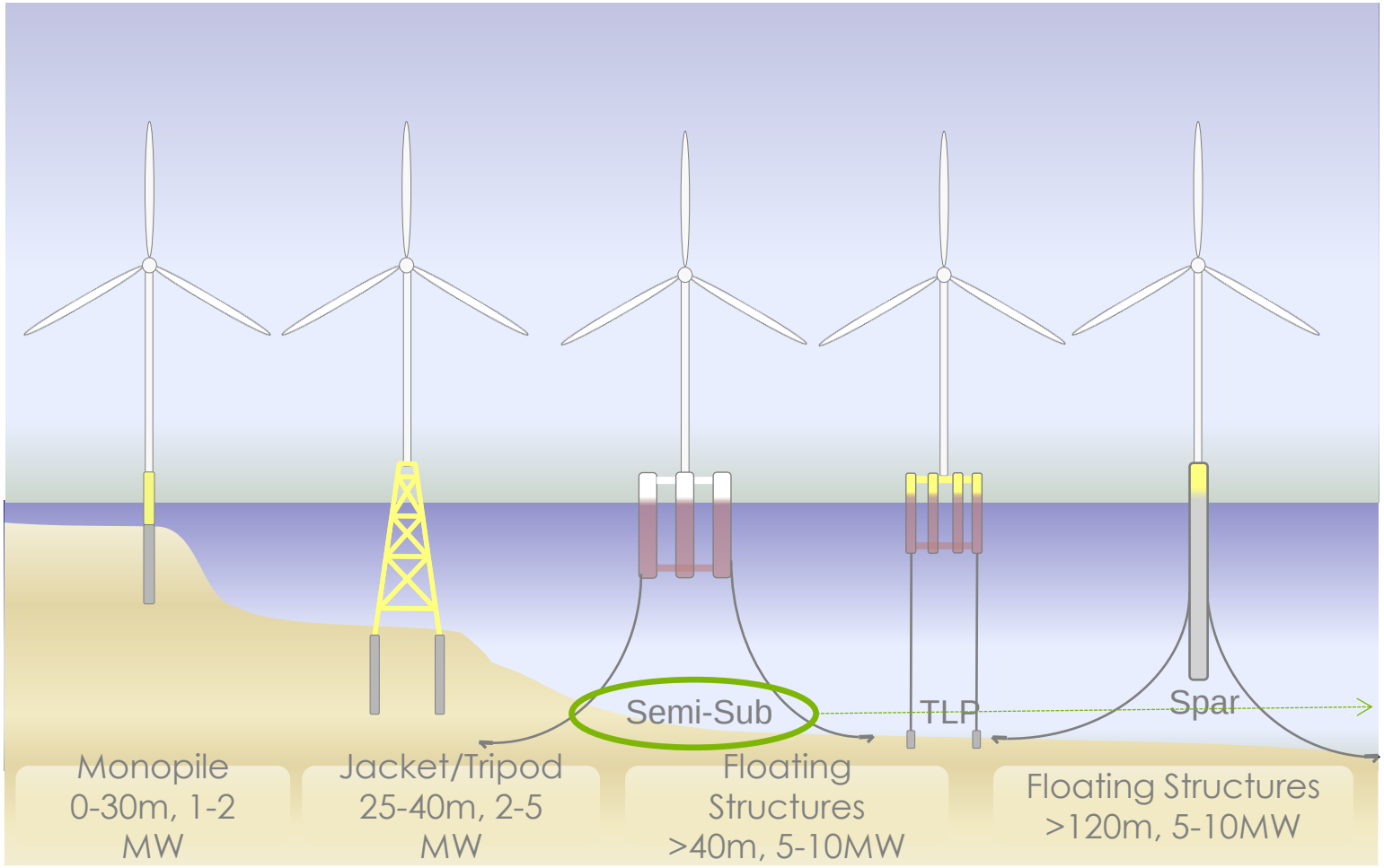
Operational Risks: Floating vs. Fixed structures

Floating presents significant advantages vs. fixed structures

	Description	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 costs and 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 costs and 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 costs and risks** (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**

As the industry moves deeper, floating will be key part of the solution

Offshore wind technology is likely to follow Oil &Gas addressing the deep offshore wind challenges



Semisubmersible advantages vs. alternative technologies

	Rationale	Main disadvantages vs. semisub
 **Spar**	• **Simple Geometry** • **Structural continuity** • **Wave loading** • **Simple Mooring**	• **Requires deep water** (>100m) • **Signficant need of steel** (i.e., higher cost) • **Need for scarce and expensive installation vessels** in very specific low wave sites for turbine installation and large component replacement • **More difficult pitch stability**
 **TLP**	• **Stability** • **Onshore turbine commissioning and wet tow** • **Low water depth**	• **Structural interference** between mooring and turbine natural frequencies • **High mooring cost and higher geological risks** (need to anchor deep into the seabed) • **Fatigue loads** (tidal variation, waves, etc) • **Not suited for really deep water** (>100m)

Off shore wind is here to stay and floating will be a big part of the industry

Why Offshore Wind?

- Higher wind resource and less turbulence
- Large ocean areas available
- Best spots in wind onshore are becoming scarce
- Offshore wind, including deep offshore, has the capacity to deliver high quantities of energy

Why Floating Offshore Wind?

- Limited spots with shallow waters (mostly in the North Sea)
- Most of the resource is in deep waters
- Huge scale ocean areas available
- Less restrictions for offshore deployments and reduced visual impacts
- Enormous potential around the world: PT, Spain, UK, France, Norway, Italy, USA, Canada …

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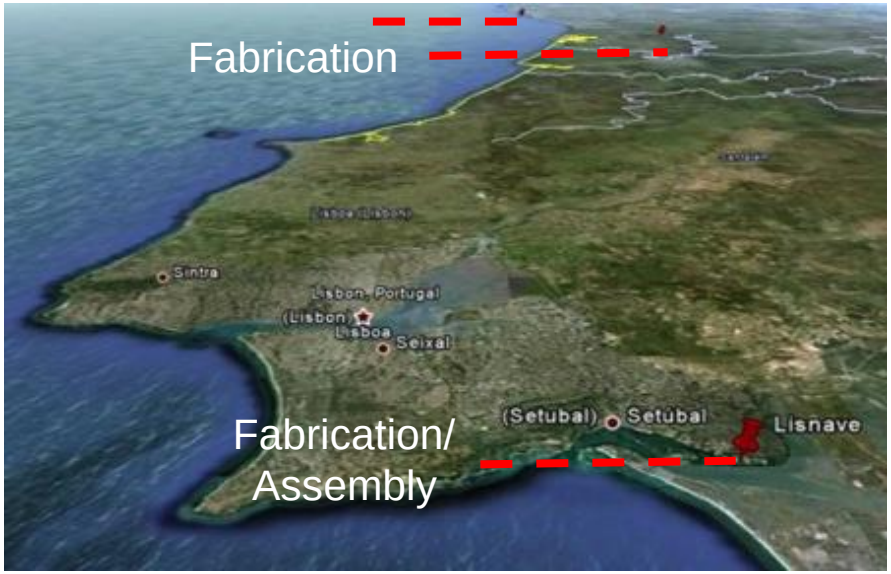
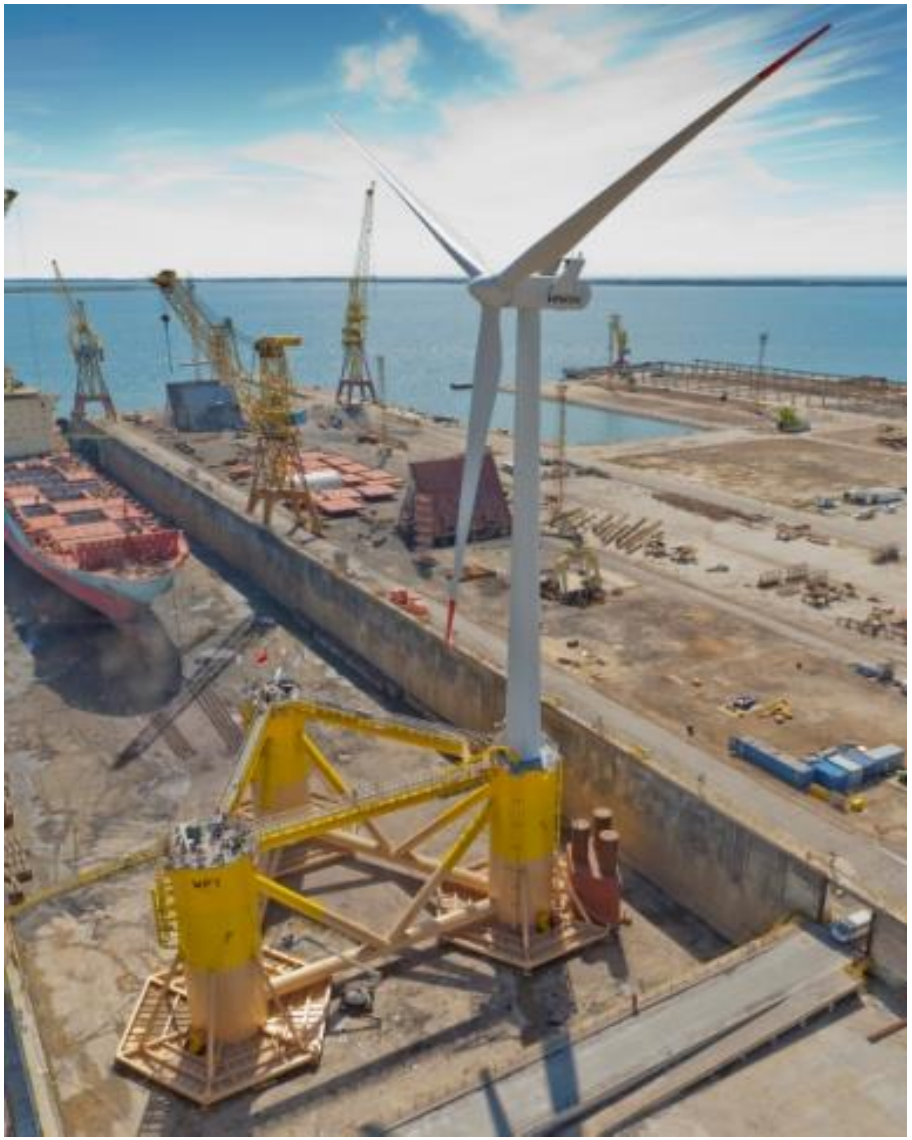
Fabricated and installed in Portugal using local facilities and financing





WindFloat – Overview

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

1 Turbine Agnostic

- Any conventional commercial Turbines
- Minimum redesign in:
  - Control system – software
  - Tower – structural interface

2 Hull Trim System (Active ballast)

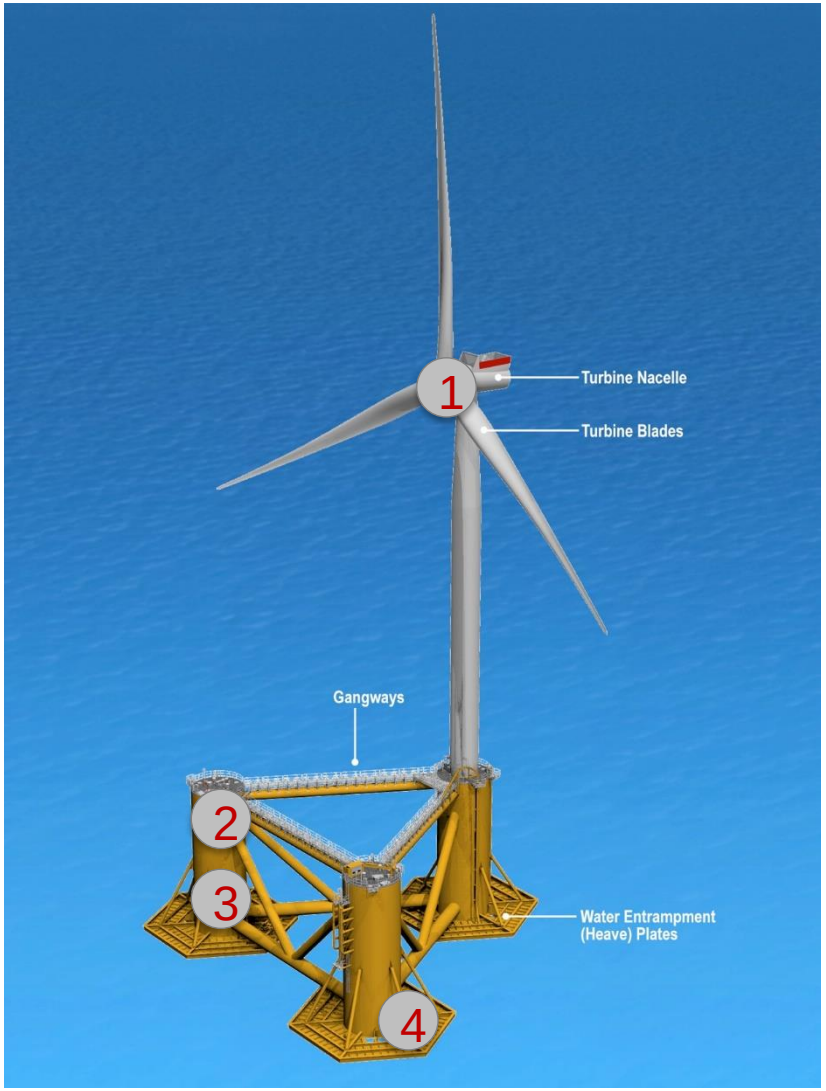
- Displaces some water between columns to compensate for changes in mean wind velocity and direction

3 Water Ballast (Operational draft)

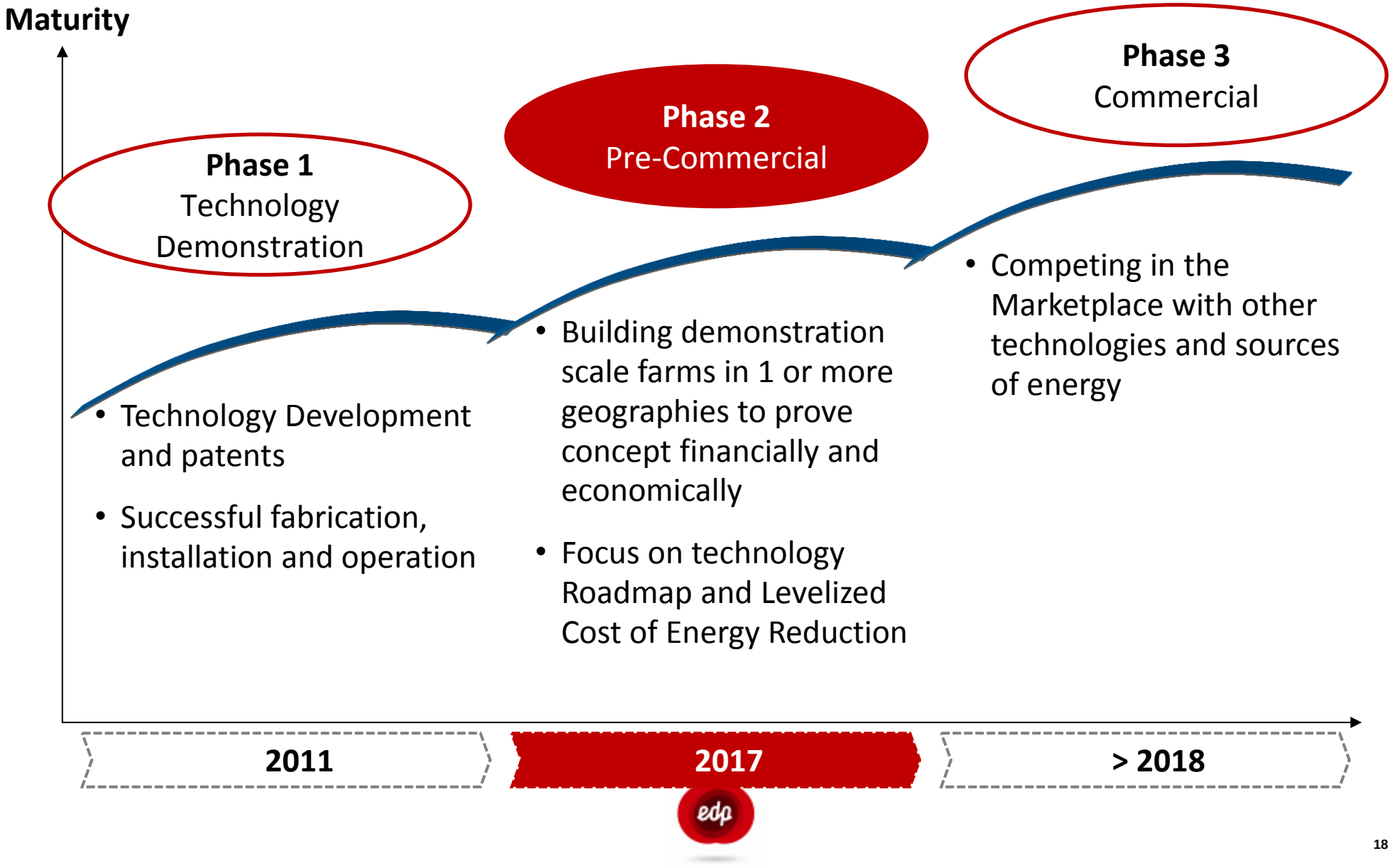
- Located at the bottom of each column and used to achieve operating draft
- More water in the columns not supporting the turbine

4 Heave Plates (Dynamic Stability)

- Move platform natural response above the wave excitation (mass of entrained water)
- Viscous damping reduces wave induced motions



WindFloat is expected to be fully commercial in the near future, providing a differentiating and cost effective solution to the marketplace



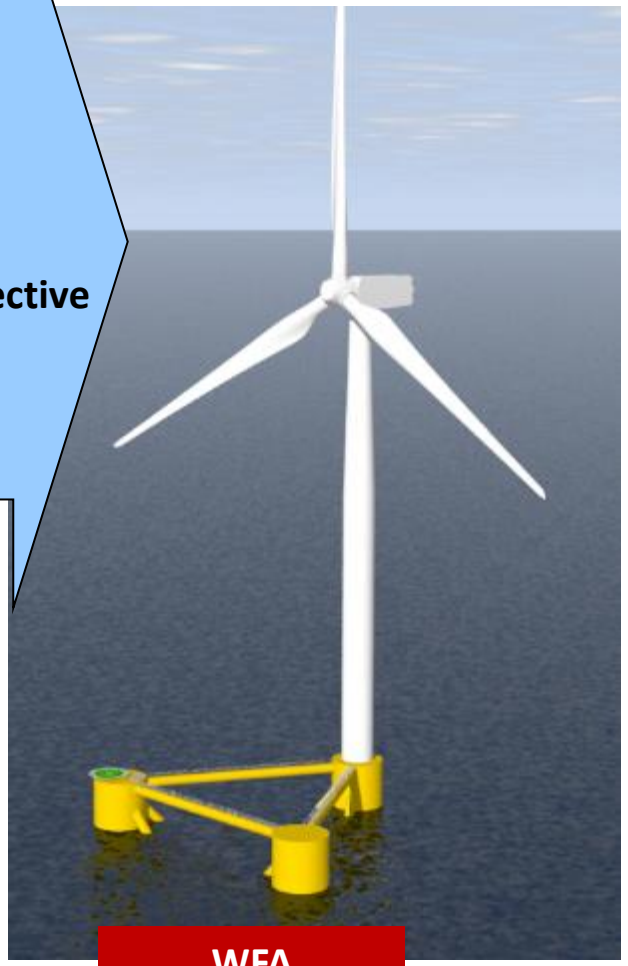
WindFloat Atlantic – Focuses on competitivess (LCOE)

Scale and technical/technology innovations are already delivering important savings

WF1

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

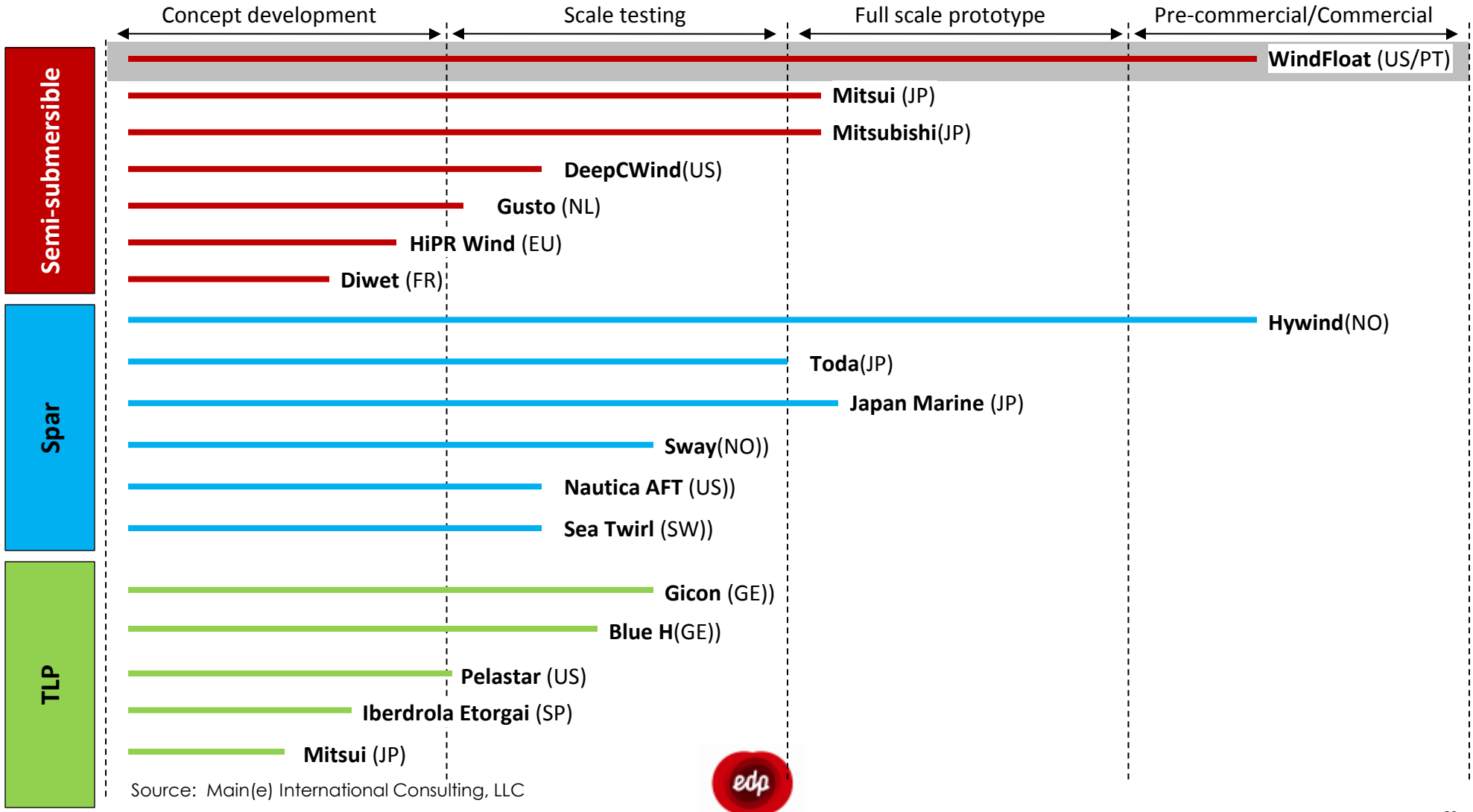
- Capacity: x4
- Production: x4,5
- Steel: x1.65
- Unit cost: x1.75



WFA

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

State of development of selected floating turbine concepts



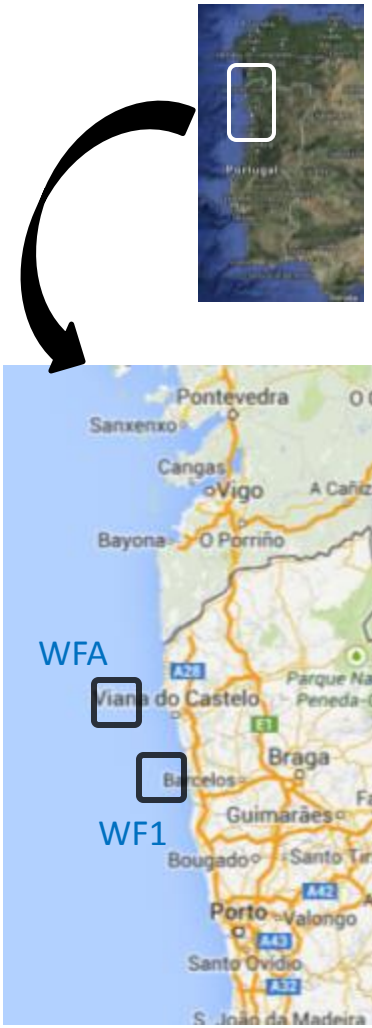
Source: Main(e) International Consulting, LLC

The WindFloat construction and installation video


Thank you

WindFloat Atlantic represents the step before full scale commercial deployment

WindFloat Atlantic focuses on Levilized Cost of Energy (LCOE)



Phase 1: Demonstration ("WF1")
2MW Prototype
(Completed)

- **One pilot WindFloat** successfully completed (named "WF1")
- **Capacity:** 2MW (1 WindFloat unit using an offshore Vestas V80 turbine)
- **Location:** Aguçadoura (40km North of Porto, grid connected, ~6 km of the Portuguese coast, 40 - 50 m water depth)
- **Test period:** started end of 2011
- Initial 2 year test period **extended to 5 years**
- **Tariff if 168€/MWh**
- **Total investment:** 23M€

Phase 2: Pre-commercial ("WindFloat Atlantic-WFA")
25MW Wind farm
2013 – 2018 **(Current)**

- **Capacity:** 25 MW (3 WF units)
- **Location:** Viana do Castelo (75km North of Porto
- **Turbine:** Vestas 8MW
- **Construction:** 2017
- **Offshore installation:** 2018
- **Certified lifetime** (structure and turbine): 25 years
- **Total investment:** ~100M€

Phase 3: Commercial
2018 onwards
(Future)

- **Capacity:** >150MW, gradual build-out (>20 units per wind farm)
- **Turbine:** latest, most efficient and cost-competitive turbine in the market (in principle, similar to WFA)
- **Location:** still to be determined, several countries showing early interest (France, Portugal, UK,…)
- **Construction:** 2018 onwards
- **Certified lifetime** (structure and turbine): 25 years
- **Total investment:** >500M€

Opportunities to Reduce Cost and Risk, promoting a paradigm shift

The ongoing evolution of the technologies is the offshore wind industry are leading to better financiability

Cost

- ✓ Reduce Environmental Impact and Geotechnical Requirements
- ✓ Flexible Site Location / Water Depth independence
- ✓ Serial Production
- ✓ Quayside Commissioning and WTG Installation

Reduction of Cost & Risk

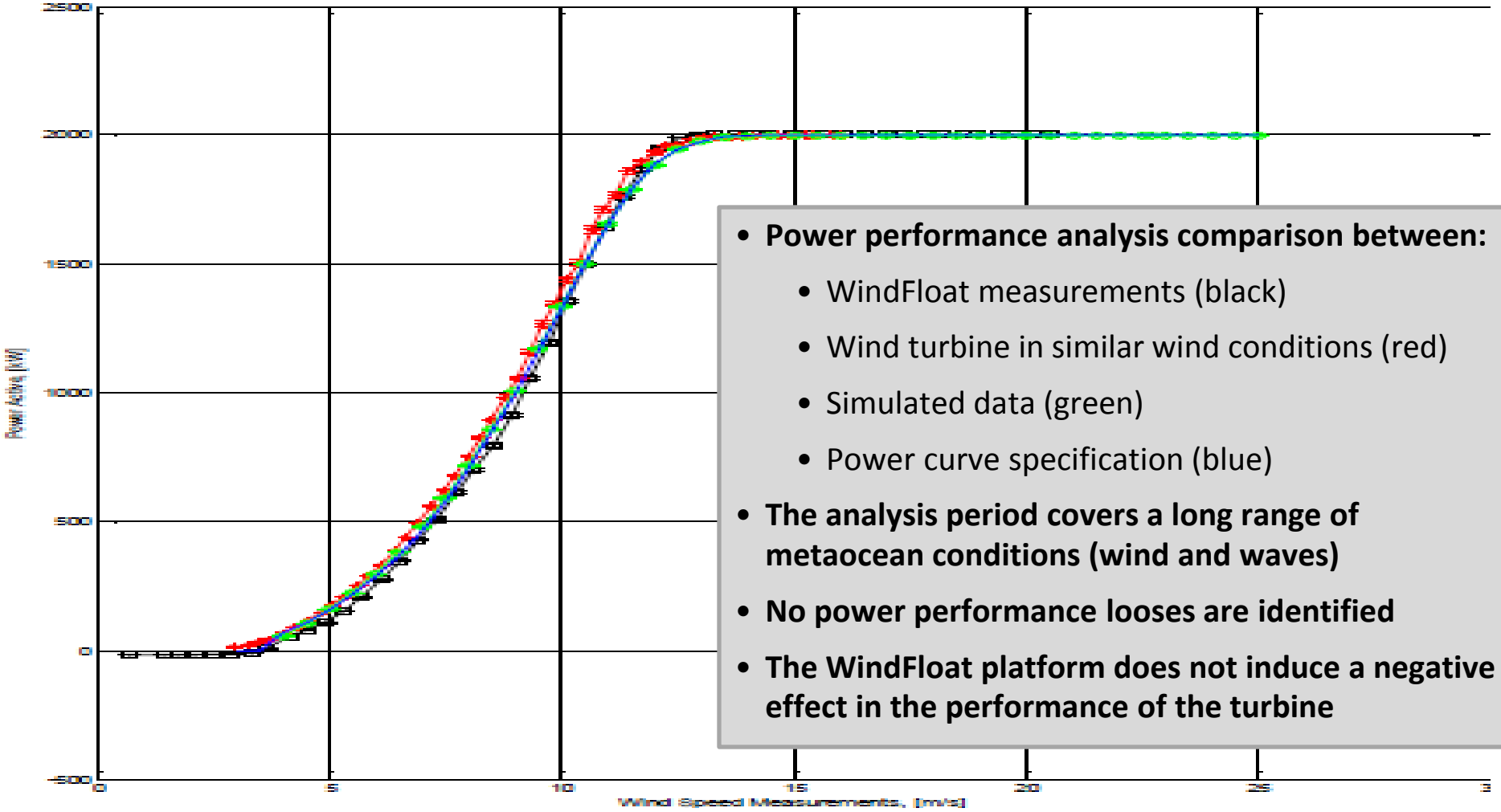
Risk

- ✓ Marine Spread / Existing Vessels
- ✓ Lower Interface Risk with offshore contractor
- ✓ Lower Weather Dependence
- ✓ Return to Shore for Unanticipated Maintenance

Prototype: Performance Demonstration

Power curve has behaved like a fixed turbine

Power Curve performance



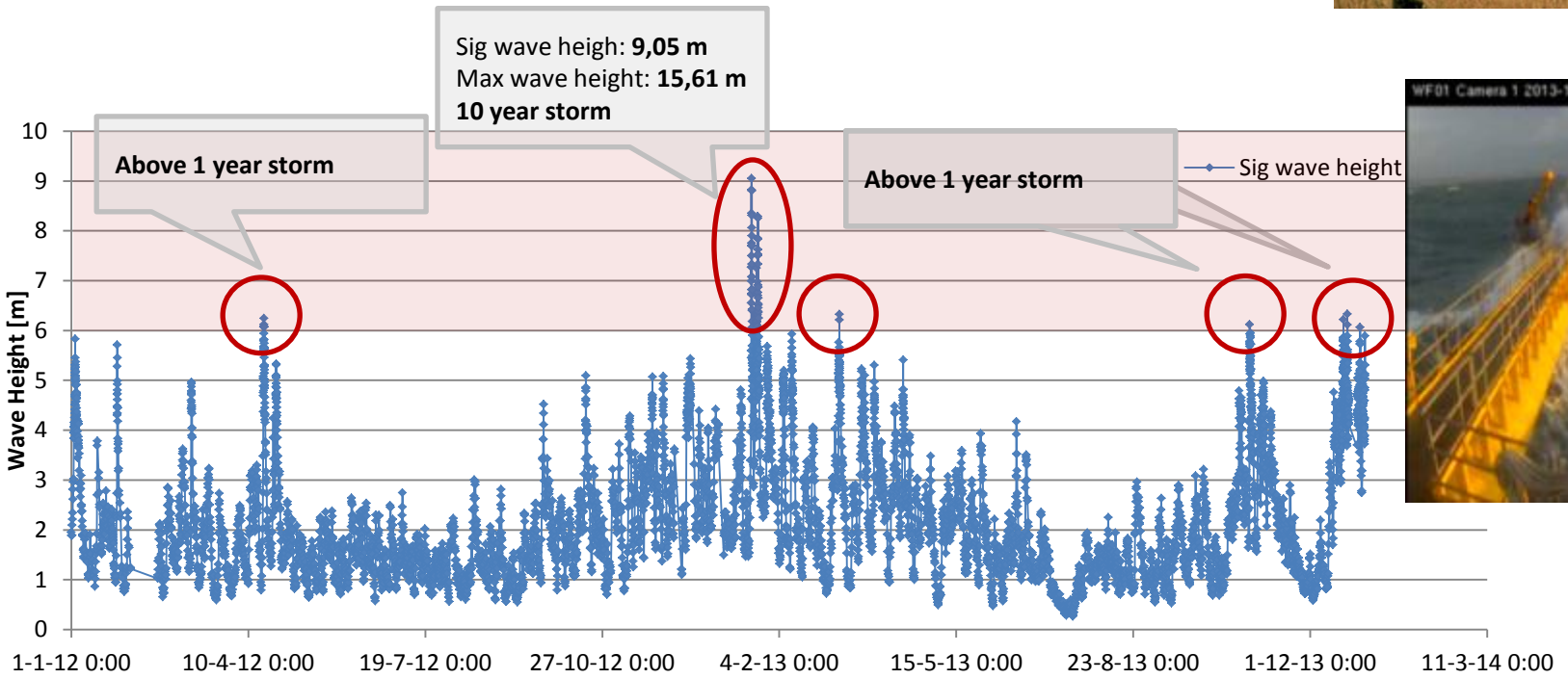
- **Power performance analysis comparison between:**
  - WindFloat measurements (black)
  - Wind turbine in similar wind conditions (red)
  - Simulated data (green)
  - Power curve specification (blue)
- **The analysis period covers a long range of metaocean conditions (wind and waves)**
- **No power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

Prototype: Performance Demonstration

WindFloat 1 has survived particularly adverse conditions

Extreme events

- 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



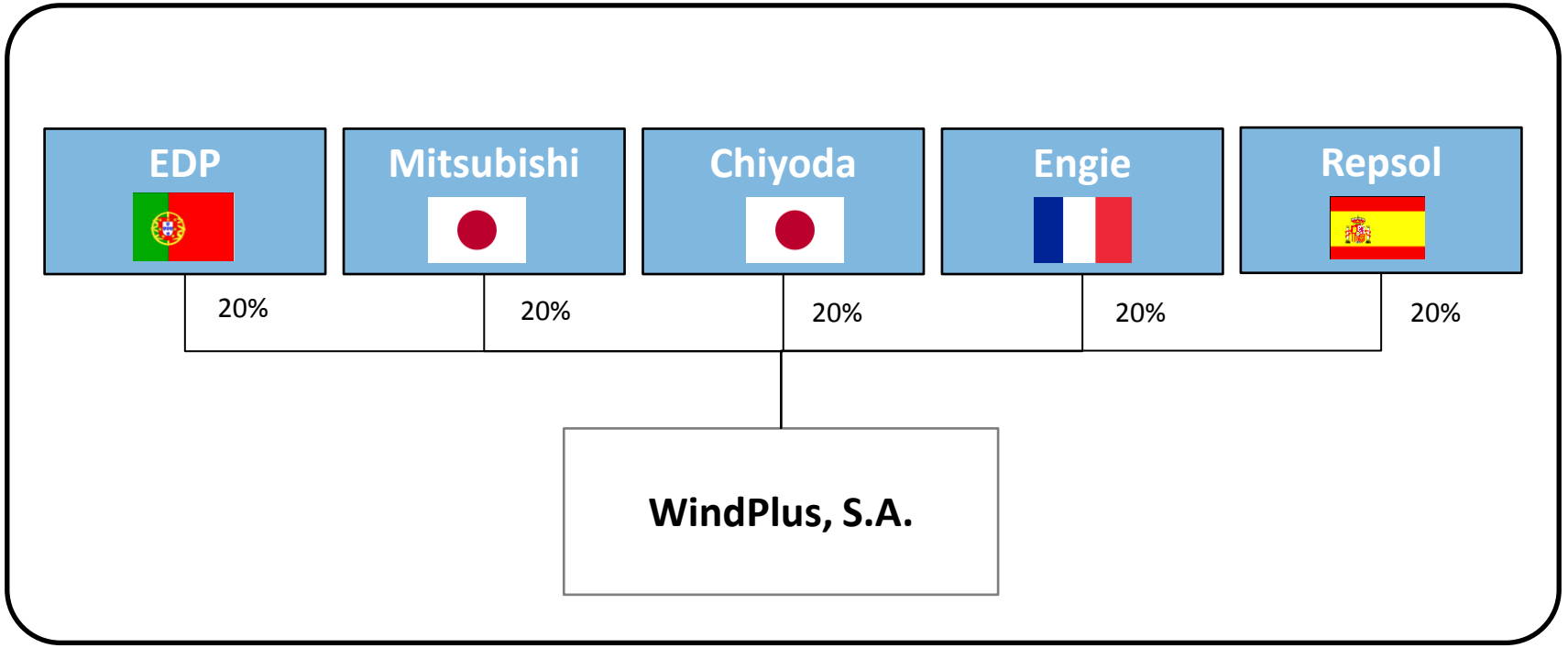
The WindFloat technology was proven in a full scale prototype in northern Portugal

WindFloat Pilot

- **Installation:** October 2011
- **Total capacity:** 2MW
- **Location:** Off the coast of Aguçadoura
- **Distance to coast:** ~6 km
- **Water depth:** ~50 m
- **Turbine:** 2MW offshore Vestas wind turbine
- **Total investment:** €20M
- **Construction:** Lisnave shipyard in Setubal
- **Turbine installation:** Quayside
- **Energy produced to date**: >14GWh

WindFloat Atlantic – premium quality investor group

In October/2015 five new shareholders entered Windplus to develop the Windfloat Atlantic project



- **NER300 awarded €30M to the WindFloat Atlantic project**
- **Negotiations with EIB and other lenders are in an advanced phase**

Renewable power, including offshore technology development, is one of EDP's Innovation priorities

1. Client-focused solutions

Smart Pricing and Bundling
- Develop innovative pricing schemes that leverage on technology / SG
- Explore synergies with innovative gas / electricity bundles

Energy Efficiency
- Home / office / industry Energy Management solutions
- Efficient Lighting Solutions

Increase Electrification
- Electric Mobility
- Other

2. Smarter Grids

Smart Grids
- Adequate smart grid infrastructures
- Software applications leveraging on SG elements to improve operational excellence

Energy Management / Storage
- Energy Storage Solutions
- Other energy management solutions such as DSM, etc.

3. Cleaner Energy

Renewable Energy
- Wind Onshore
- Offshore power production
- Solar: current and new concepts
- Quest for disruptive renewable concepts

Thermal & Big Hydro Generation
- Flexibility and interface with Smart Grids
- Impact mitigation solutions

4. Data leap

Cloud computing
- Provide agility in leveraging IT resources by enabling dynamic management of infrastructure, lowering capital investments

Big data
- Generate business and customer intelligence to help optimize operations and drive creation of new products and services

Web 3.0
- Bring people and technology seamlessly together, bridge business and social and increase productivity in collaborative work

Floating Offshore Wind is an Industry Game-Changer in Two Ways