Floating Offshore Wind Industry Overview

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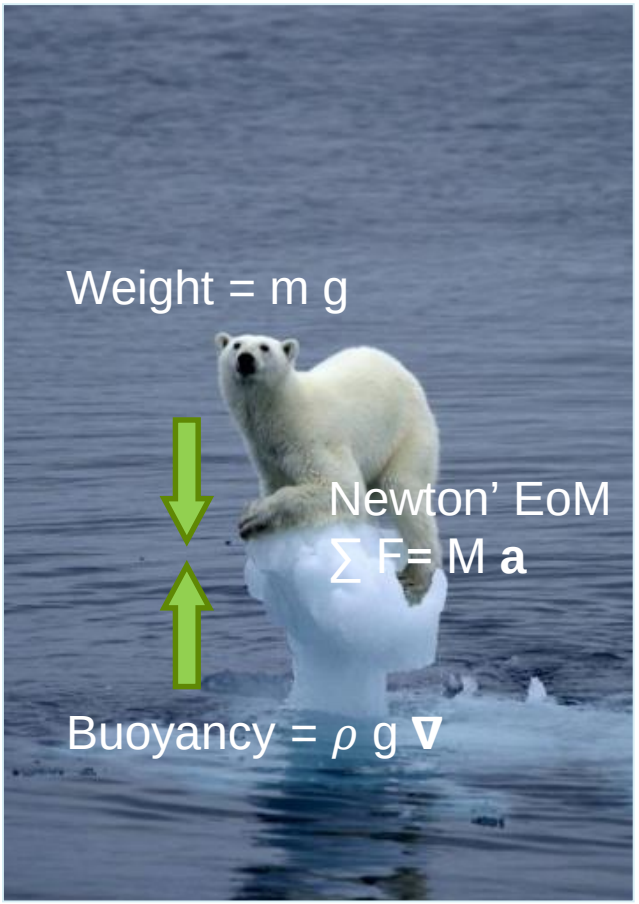
What is the floating offshore wind energy ?

Presentation Overview

- Design Principles
  - Anatomy of a Floating Offshore Wind Turbine (FOWT)
  - Fundamental principles
- Current Technologies
  - Hull types
  - Landscape of FOWT projects
- Existing Projects
  - Installed prototypes
  - Pre-commercial projects
- Final Remarks
  - On the importance of LCOE and bankability
  - Key take-away



Anatomy of a Floating Offshore Wind Turbine

Wind Turbine

- Traditional 3 Blades , - significant industry experience
- Usually very large (164 m diameter for 8MW)
- New options, downwind, 2 bladed, vertical axis…

Tower

- Part of the turbine scope …
- Transmit loads from turbine onto the hull
- Simple beam, industrialization model

Hull

- Provide buoyancy to support tower
- Impose motions / accelerations on turbine
- CAPEX intensive

Electrical Cable

- Connect turbine to grid
- Must have a dynamic component
- High voltage

Mooring Lines or Tendons

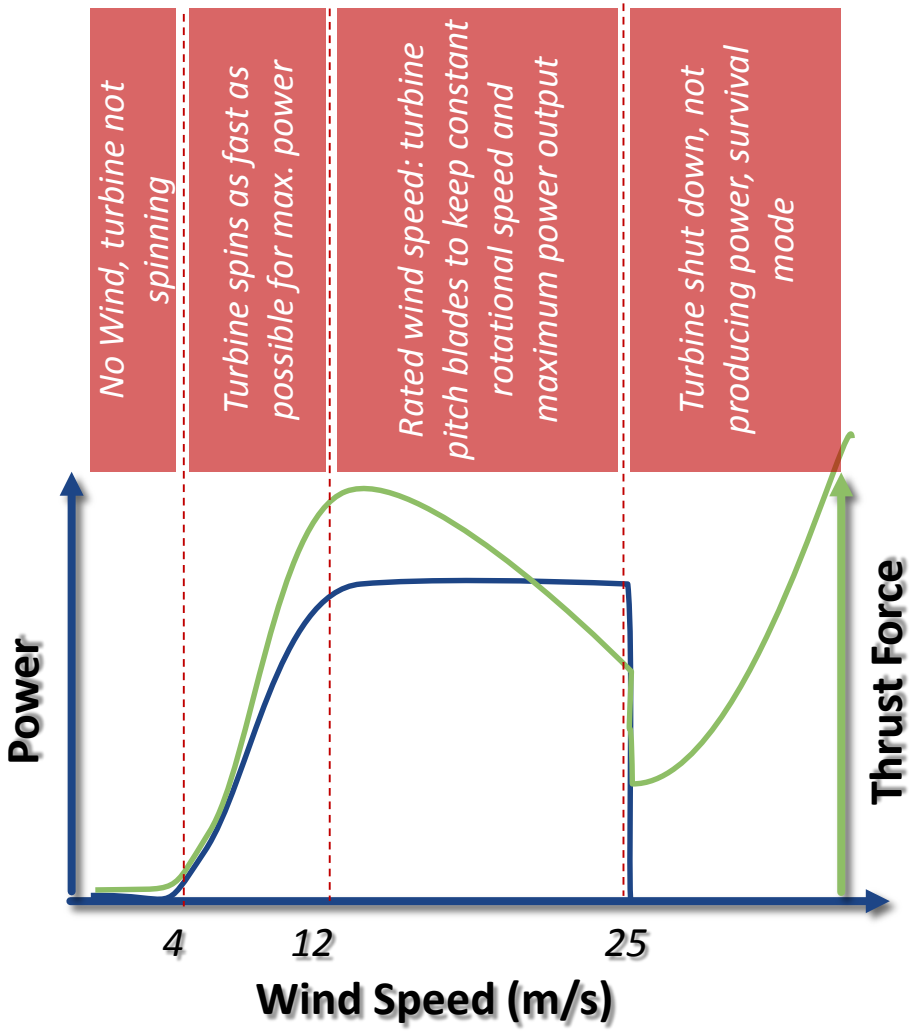
- Ensure station keeping of system
- Define watch circle for cable integrity
- Design to extreme storms

Anchors

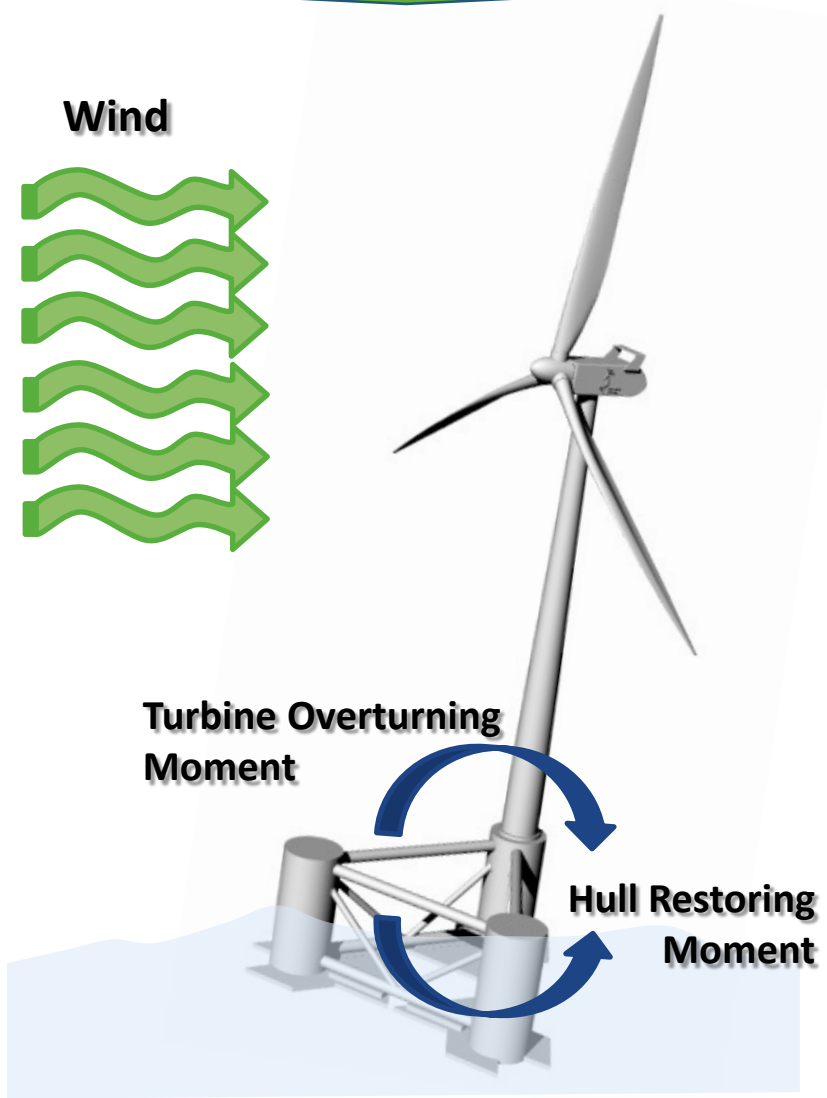
- Anchor point in the sea bed, Geo-reference
- Multiple technologies available
- Installation is expensive

Fundamental Principles

Turbine Loading



Hull Response



Hull & Mooring Engineering Design Cycle

Global Sizing

Turbine Modeling

Stability

Scantling

Mooring Design

Numerical Modeling

Global Performance

Classification

Structural Modeling

Structural Design

MTO and RFQ bid Packages

End of FEED

Detail Design

Hull Class Approval

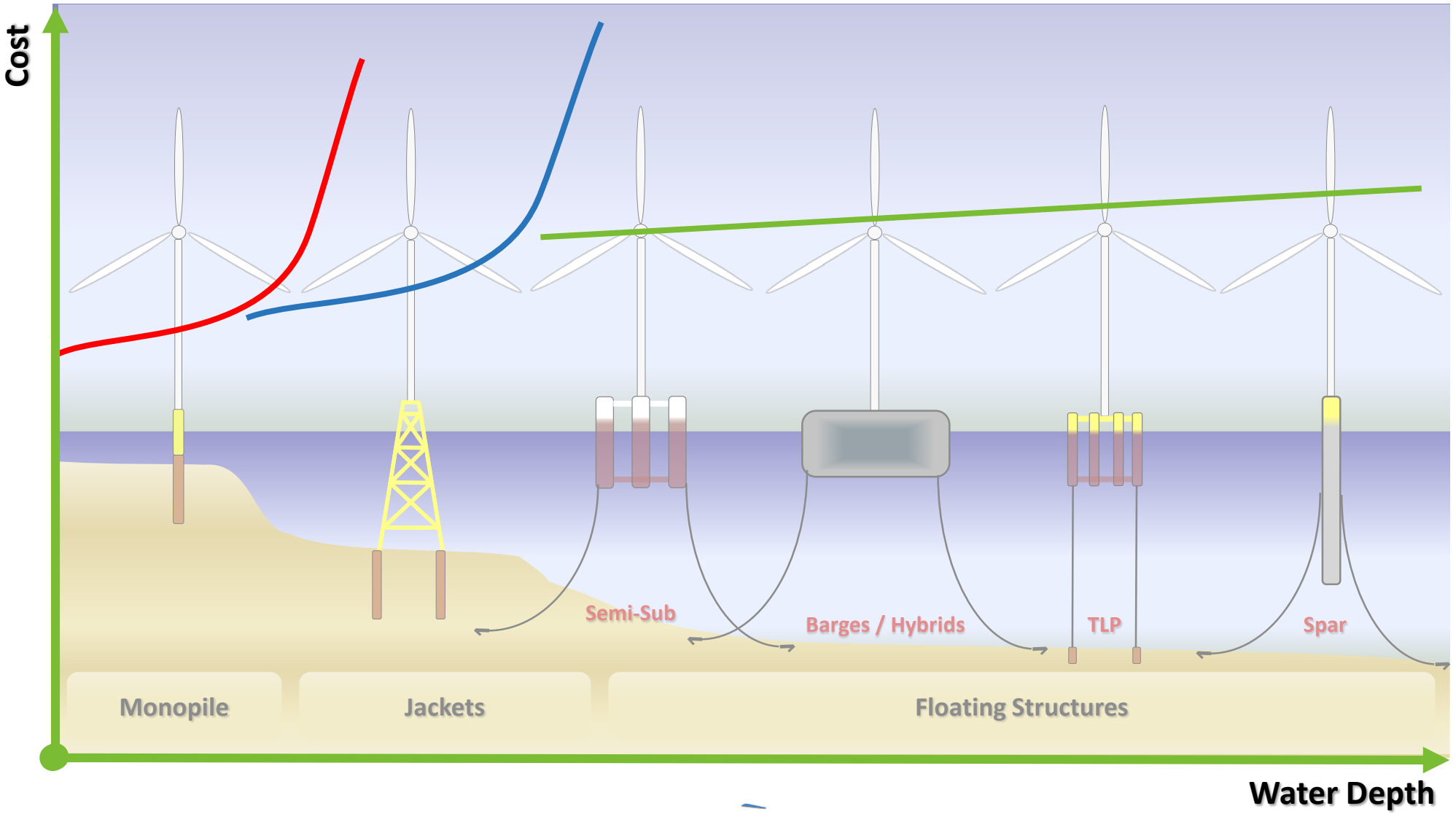
Turbine certification

Structural Design

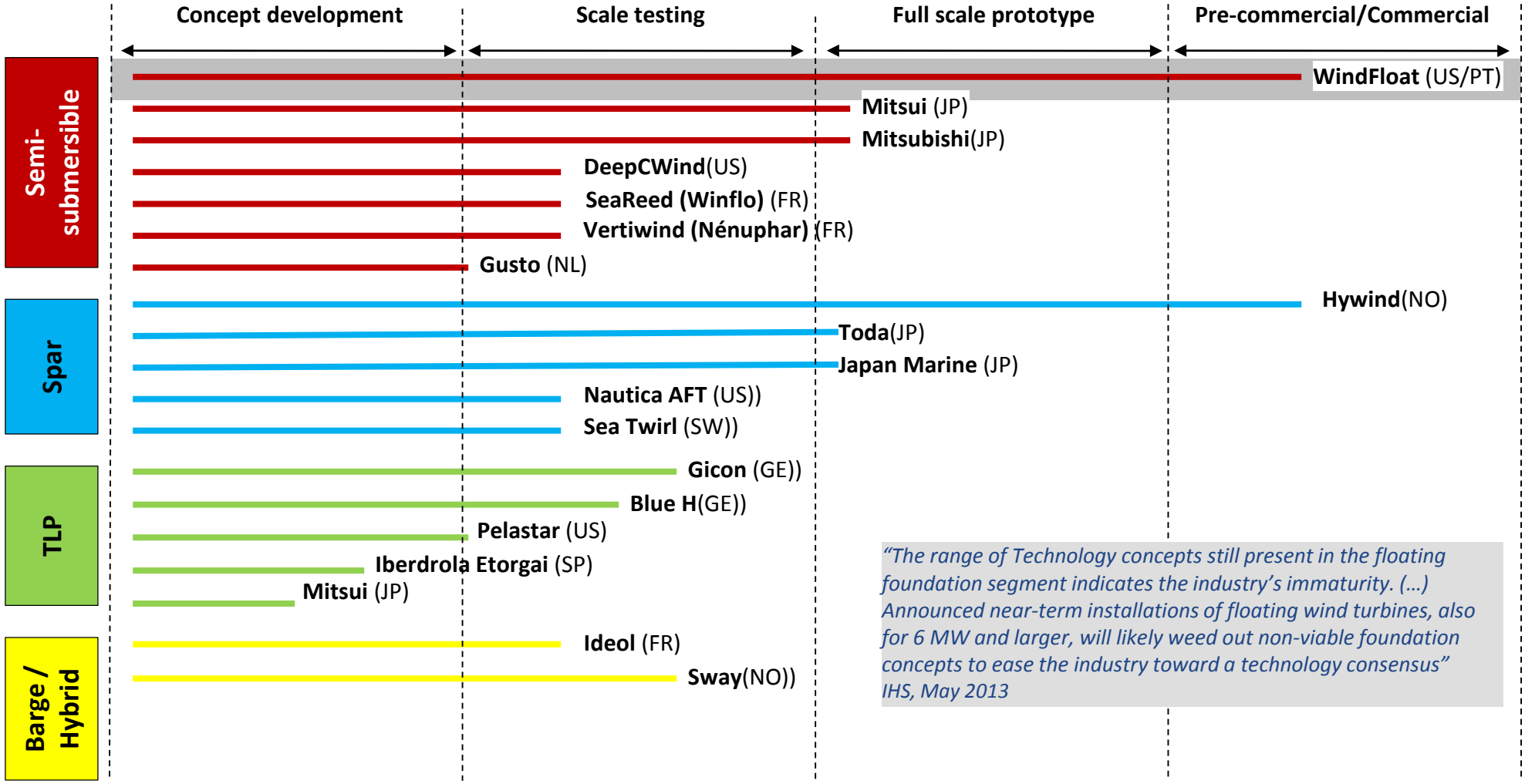
AFC Drawing Set

End of DD

Foundations and Structures



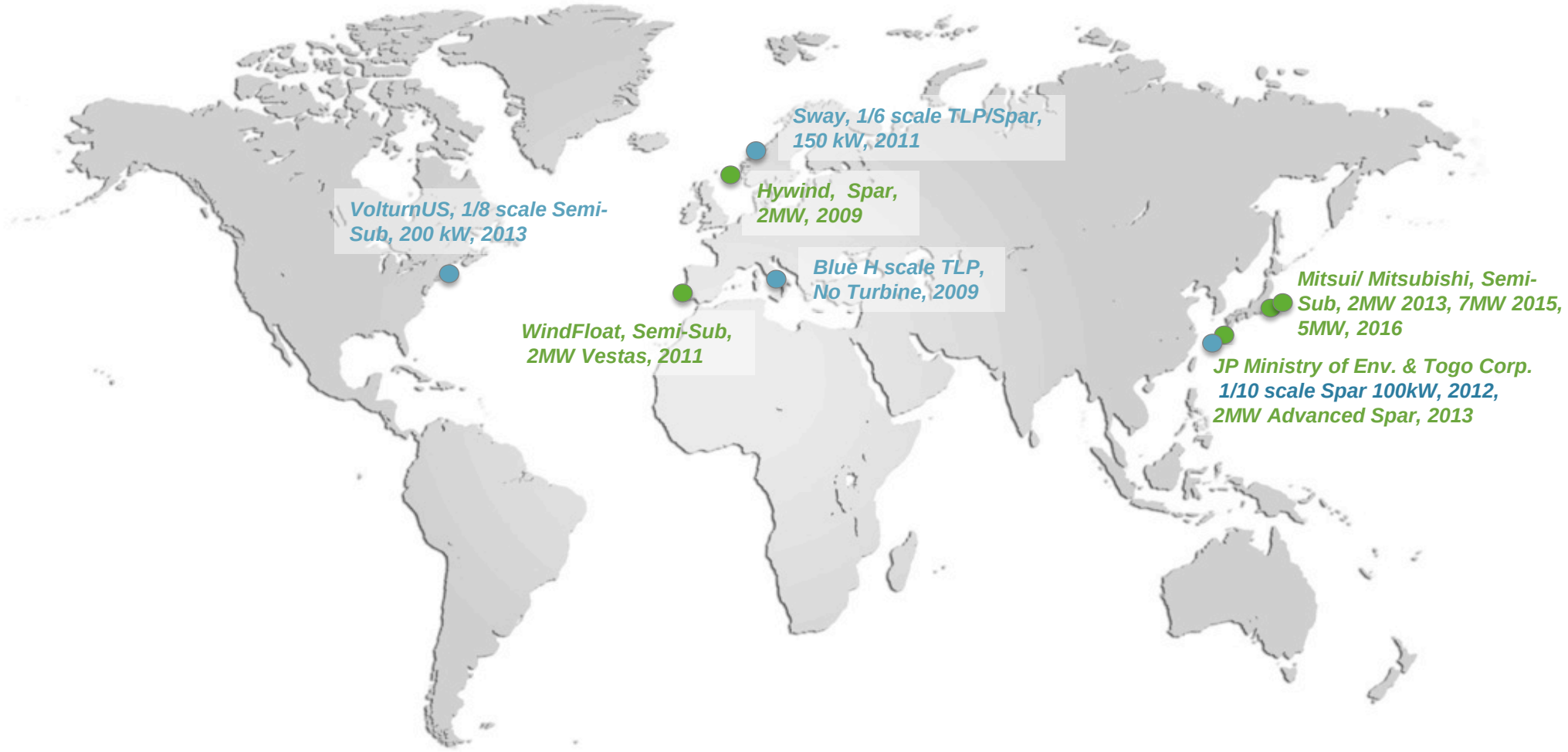
Development Stage of Alternative Floating Technologies



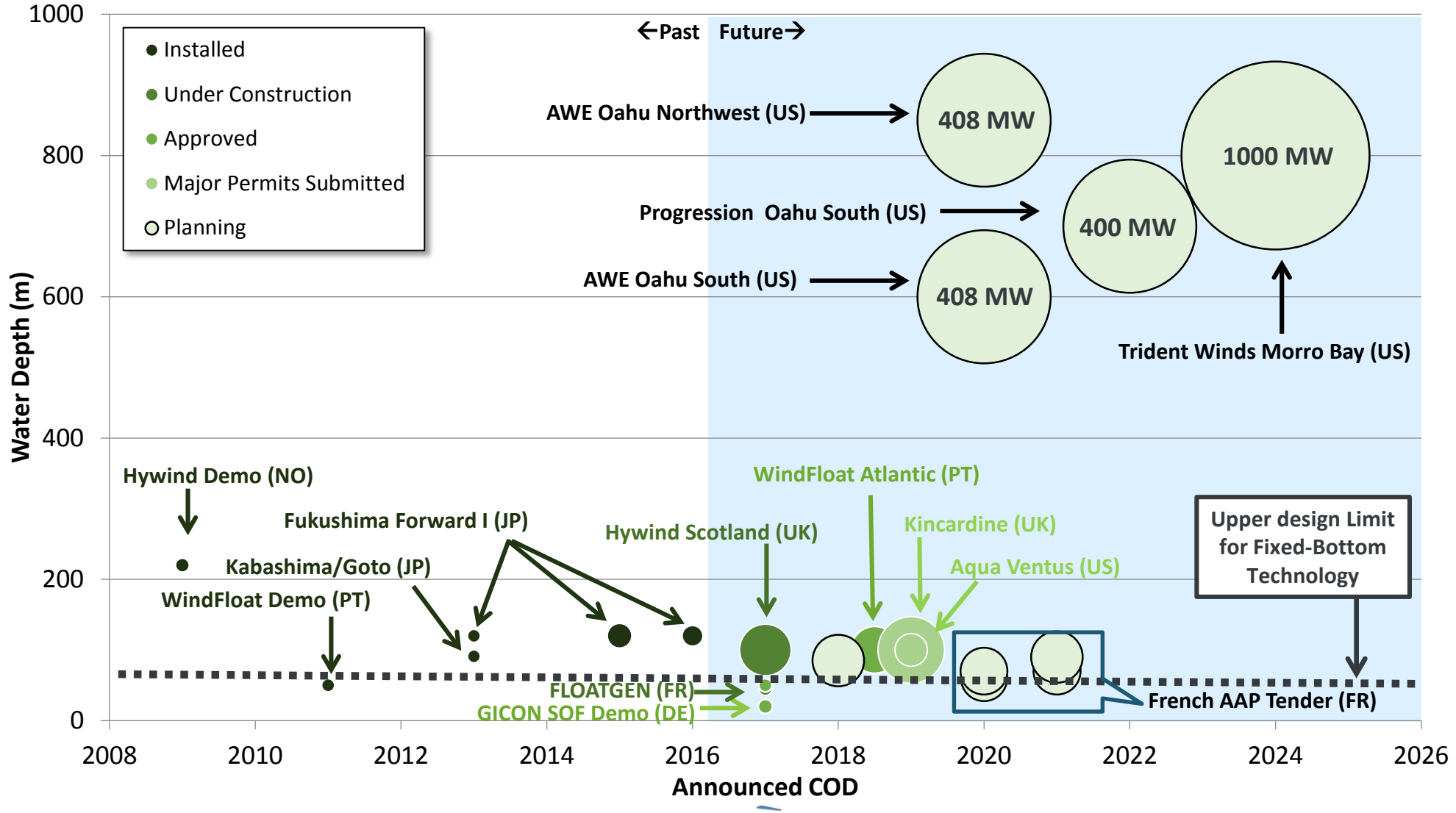
"The range of Technology concepts still present in the floating foundation segment indicates the industry's immaturity. (…) Announced near-term installations of floating wind turbines, also for 6 MW and larger, will likely weed out non-viable foundation concepts to ease the industry toward a technology consensus"
IHS, May 2013

Source: Main(e) International Consulting, LLC

At Present, Only six Full Scale Prototypes Deployed…



… But industry is about to see the first floating windfarms!



Source: NREL

Multi-MW Prototype: Hywind

Key Highlights

- Spar Design
  - Installed in 2009
  - Siemens 2.3 MW
  - Plans for relocation near a O&G platform
- Proved Feasibility
  - Produced ~50 GWH of electricity
  - Availability factors similar to fixed foundations
- Installation
  - Upending in protected area
  - Offshore turbine installation in fjord
  - Tow to site with turbine mounted

Turbine size	2.3 MW
Turbine weight	138tons
Turbine height	65m
Rotor diameter	82.4m
Draft hull	100m
Displacement	5000 m^3
Mooring	Three lines with bridal
Water depths	200 m

Multi-MW Prototype: WindFloat

Key Highlights

- Semi-Submersible Design
  - Installed in 2011
  - Vestas 2 MW
  - Decommissioned in 2016
- Proved “low cost” methodologies
  - Produced ~16 GWh of electricity
  - Significant focus on O&M
- Installation
  - Installed at quay side using dry dock gantry crane
  - Minimal operations offshore
  - Tow to site with turbine

Turbine size	2.0MW
Turbine weight	104 tons
Turbine height	70m
Rotor diameter	80m
Draft hull	13m
Displacement	2300 m^3
Mooring	Four lines
Water depths	45m

Multi-MW Prototype: Toda Corporation Spar

Key Highlights

- Spar Design
  - Installed in 2013
  - Hitachi / JSW Downwind 2 MW
  - Following a 1/10 scale (2009) and ½ scale prototype (2012)
- Demonstrating technologies for Japan
  - Steel and pre-stress concrete

Turbine size	2.0MW
Turbine weight	NA
Turbine height	72
Rotor diameter	~80m
Draft hull	~100m
Hull weight	3400 tons
Mooring	3 lines
Water depths	-

Multi-MW Prototype: Fukushima-Forward / Mirai

Key Highlights

- Semi-Submersible Design
  - Installed in 2013
  - Hitachi Downwind 2 MW
- Demonstrating technologies for Japan
  - Produced since 2013
  - Operated in significant storms
- Installation
  - WT was assembled in shipyard
  - Minimal operations offshore
  - Tow to site with turbine

Turbine size	2.0MW
Turbine weight	NA
Turbine height	65m
Rotor diameter	80m
Draft hull	16m
Displacement	NA
Mooring	Six lines
Water depths	120m

Multi-MW Prototype: Fukushima-Forward / Shinpuu

Key Highlights

- Semi-Submersible Design
  - Installed in 2015
  - MHI 7 MW
- Demonstrating technologies for Japan
  - Largest turbine installed to date
- Installation
  - WT was assembled at quay
  - Minimal operations offshore
  - Tow to site with turbine

Turbine size	7.0MW
Turbine weight	NA
Turbine height	105m
Rotor diameter	167m
Draft hull	17m
Displacement	10,000 tons
Mooring	Eight lines
Water depths	120m

Multi-MW Prototype: Fukushima-Forward / Hamakaze

Key Highlights

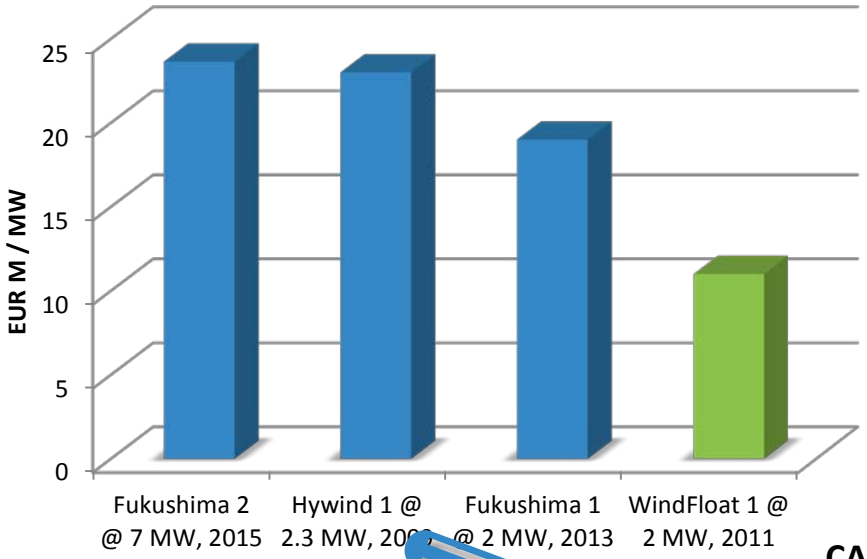
- Advanced Spar Design
  - Hitachi Downwind 5 MW
  - Installed in 2016
- Demonstrating technologies for Japan
  - Shallow water spar
- Installation
  - WT was assembled in calm sea
  - Minimal operations offshore
  - Tow to site with turbine

Turbine size	5.0MW
Turbine weight	NA
Turbine height	86m
Rotor diameter	126m
Draft hull	33m
Displacement	8,000 tons
Mooring	Six lines
Water depths	120m

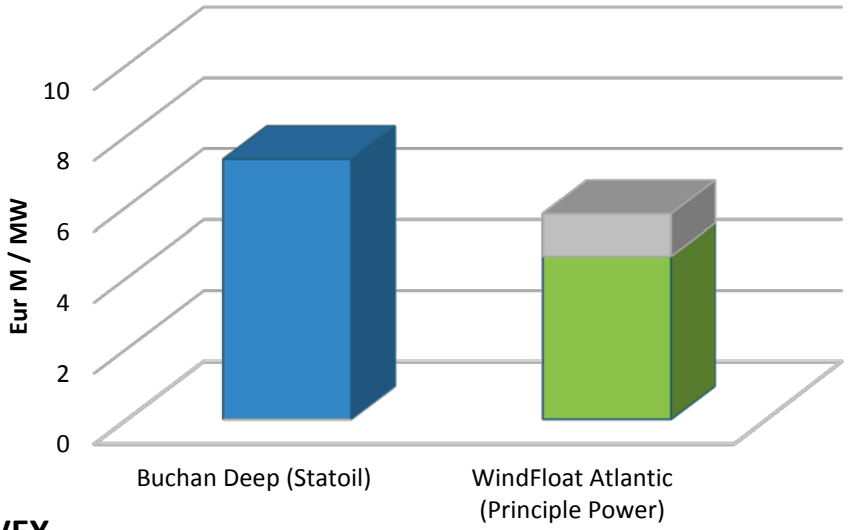
Cost competitiveness among alternative Floating Technologies

Project economics must be demonstrated, early and often…

Historical Cost of Floating Wind Installed



Pre-commercial Projects Comparison



CAPEX + DEVEX

Significant CAPEX and LCOE reduction

Generation

LCOE

Costs

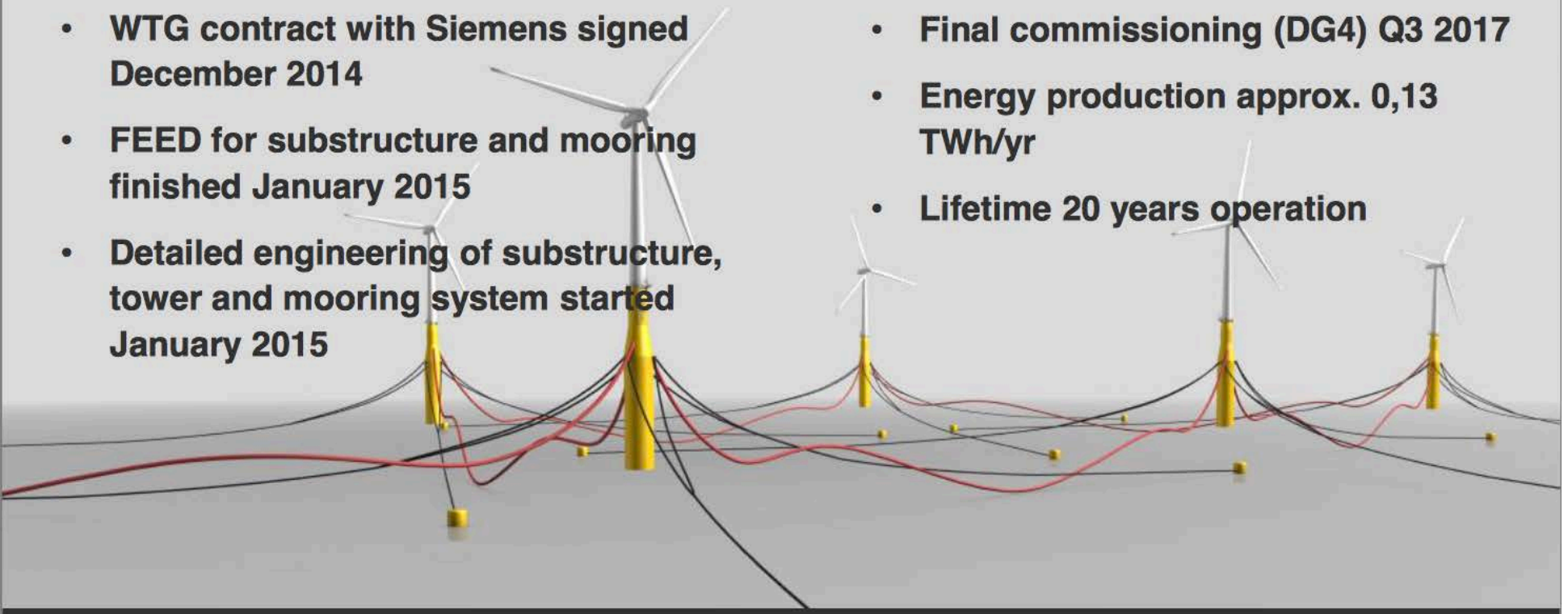
Source: Principle Power and Bloomberg New Energy Finance, December 2015

Upscaling from Demo 2009 to Hywind Scotland 2014

Dimension	Hywind Demo	Hywind Scotland
Mass	5300 tons	~11500 tons
Hub height	~65 m	~100 m
Draught	100 m	~75 - 80 m
Diameter of sub-structure	8.3 m	~14 - 15 m
Water depth	220 m	~95 - 120 m
Rotor diameter	~85 m	154 m
Capacity	2.3 MW	6.0 MW

Hywind Scotland Pilot Park

- 3.5 ROC and grace period of 18 months
- Agreement for Lease signed Nov. 2013
- Grid offer signed December 2014
- WTG contract with Siemens signed December 2014
- FEED for substructure and mooring finished January 2015
- Detailed engineering of substructure, tower and mooring system started January 2015
- Concept selection (DG2) March 2015
- Consent Q4 2015
- FID (DG3) Q4 2015
- Final commissioning (DG4) Q3 2017
- Energy production approx. 0,13 TWh/yr
- Lifetime 20 years operation



Now implementing demonstration scale projects, with state of the art turbines and optimized design

WF1

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

Pre-commercial

- **Capacity:** x4
- **Production:** X4,5
- **Unit Cost:** x1.75

WindFloat Atlantic Project

WF1 outstanding performance has encouraged Windplus to launch Phase 2 (WindFloat Atlantic)

Project Overview

- **Total capacity: 25MW capacity**, (3 units equipped with 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 Q1 2017**
  - European Investment Bank – Selected for InnovFin Programme
  - Export Agencies
  - Commercial Banks
- **Strong Institutional Support:**
  - EU: NER 300
  - Portugal: Feed-in Tariff, APA

OMAE2012-84036 SLIDE …

Future Developments

France

Strong evidence that Global warming may happen before a non- French exclusive call occurs

United States

- From practically no Government Budget, to 150 USM in 2012
- California needs some new bridge work, post 2013

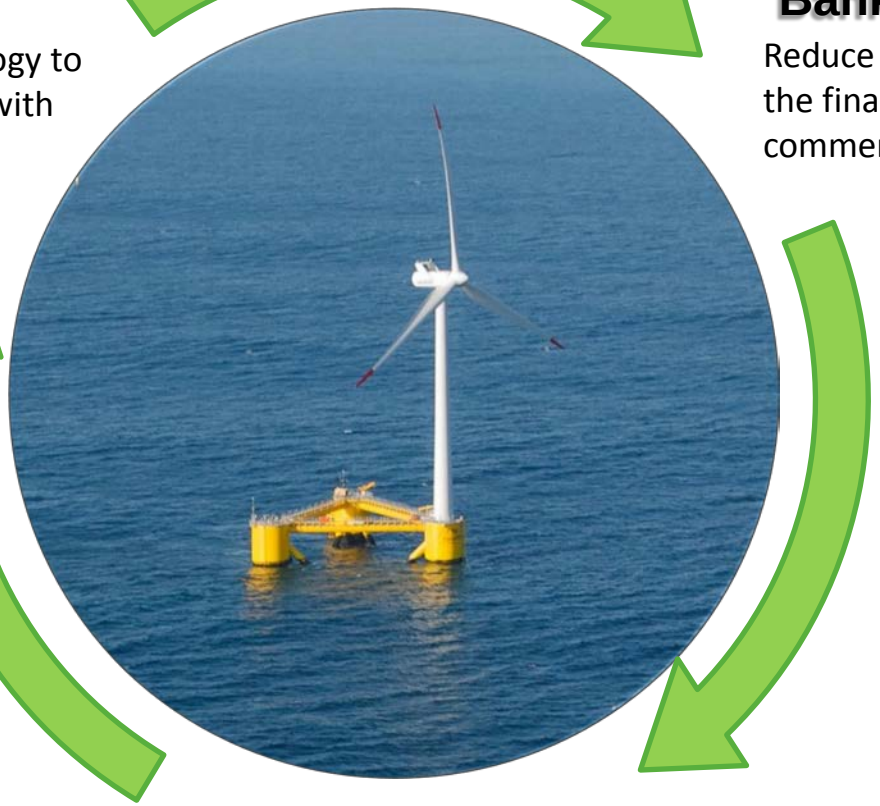
In conclusion

LCOE

Bringing the technology to be cost competitive with other energy sources

Bankability

Reduce the risk to ensured the finance ability of the commercial projects



Technology

Develop a Reliable and full scaled tested solution

Key Take Away

Technology

- No major issues with fabricating a floating structure that supports a large multi-MW wind turbine
- Many prototypes have proven the technical feasibility of various concepts
- Challenge is to lower costs to be competitive in most markets

Current Projects

- Pre-commercial projects will be commissioned in the next few years by technology leaders. Two projects in latest phase of engineering and / or financing and fabrication
- Strong competition from new players validate the importance of the FOWT industry

World Outlook

- Some European countries and Japan have been the early movers
- US is quickly catching up, and may see the first FOW commercial project (>200 MW)
- Secondary markets developing quickly: France, Taiwan, Korea amongst others…