# Hywind – From idea to world's first wind farm based upon floaters

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# Sources


- FGN. Hywind. Deep offshore wind operational experience. Deepwind, Trondheim, Jan. 2013.
- FGN. Update on the Status of the Hywind Concept. Future Offshore Foundations, Bremen, Oct 23 -25 2013.
- Olsen, G.P. Floating offshore wind in Statoil, Energy Lab, May 2017
- Statoil.com web-site.
- Private photos by FGN.

# The road from here…


Source: Statoil

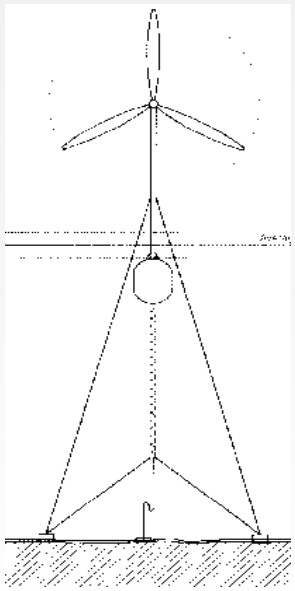
# Via …

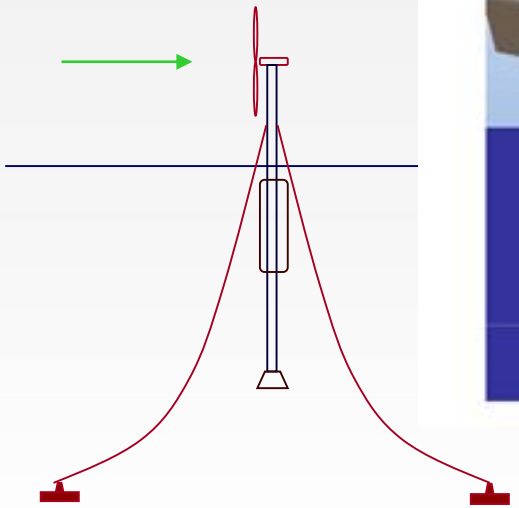

Source: Statoil

# …to here

# An idea is born

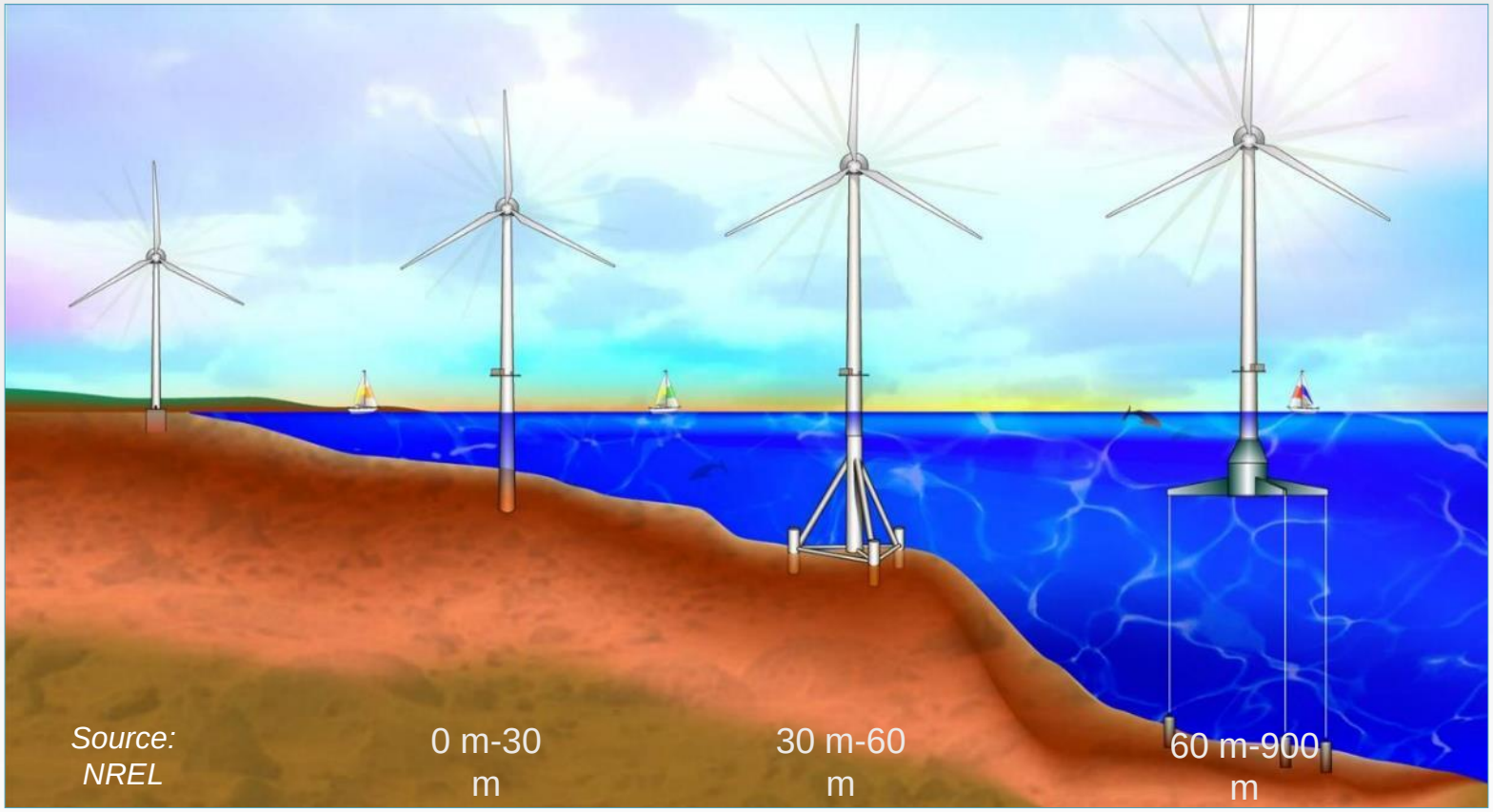
- Inspired by floating sailing marks.
  - Could we power offshore installations?



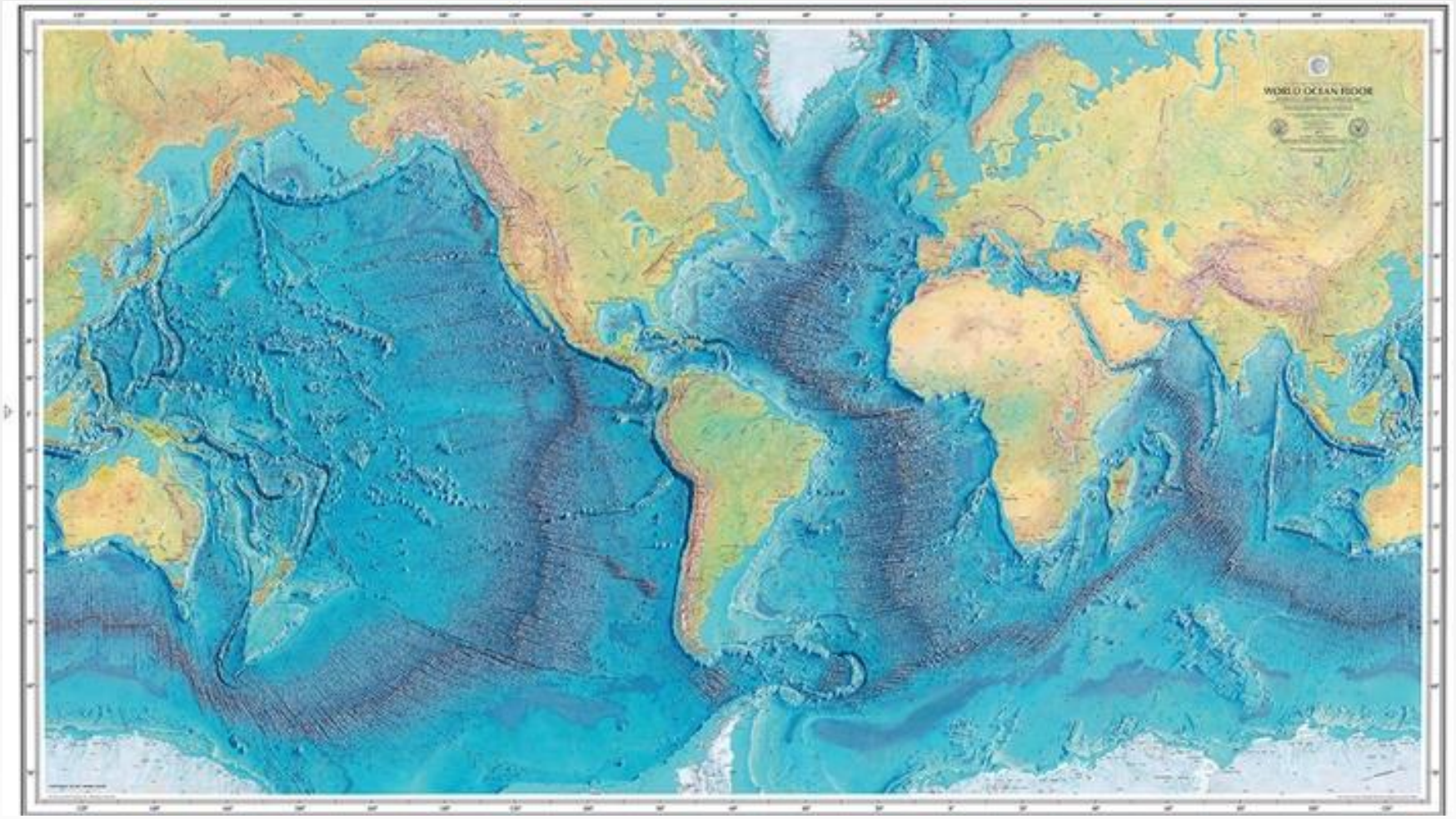



Source: Statoil

# On the move from land to deep water



# Shallow water – a scarce resource




Source: http://d3lp4xedbqa8a5.cloudfront.net/s3/digital-cougar-assets/AusGeo/2015/04/07/55431/world-map-ocean-tharp.jpg

# Evolution versus disruption

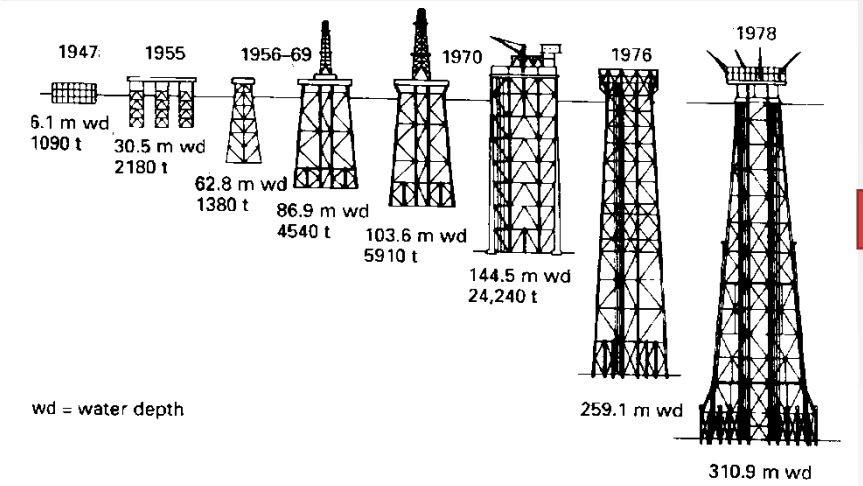
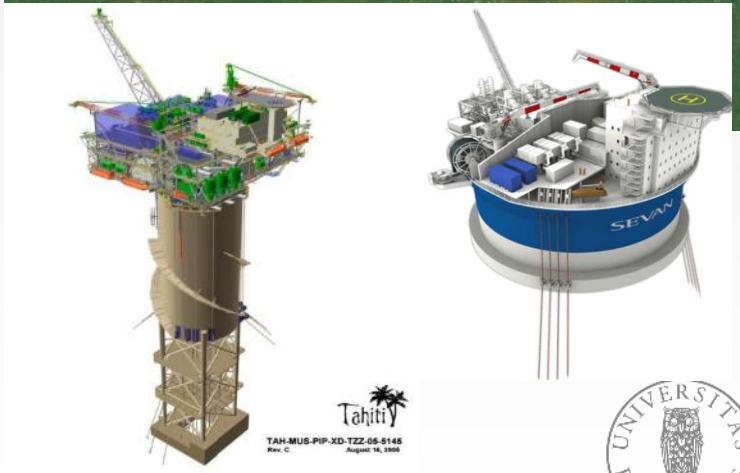



**Figure 2.5** Evolution of deep water production capability (from Lee 1980)

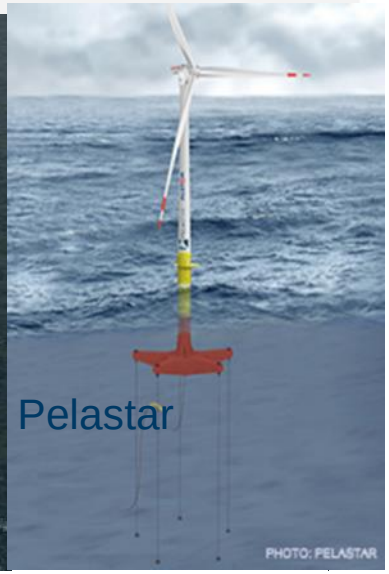



# Various floater concepts



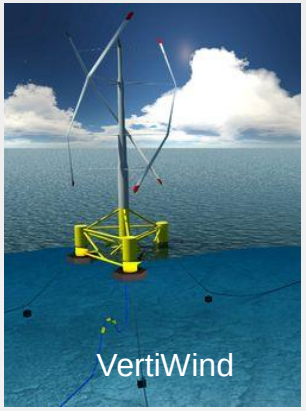






# And many more…


WindSea havvindmølle. Illustrasjon: FORCE Technology.





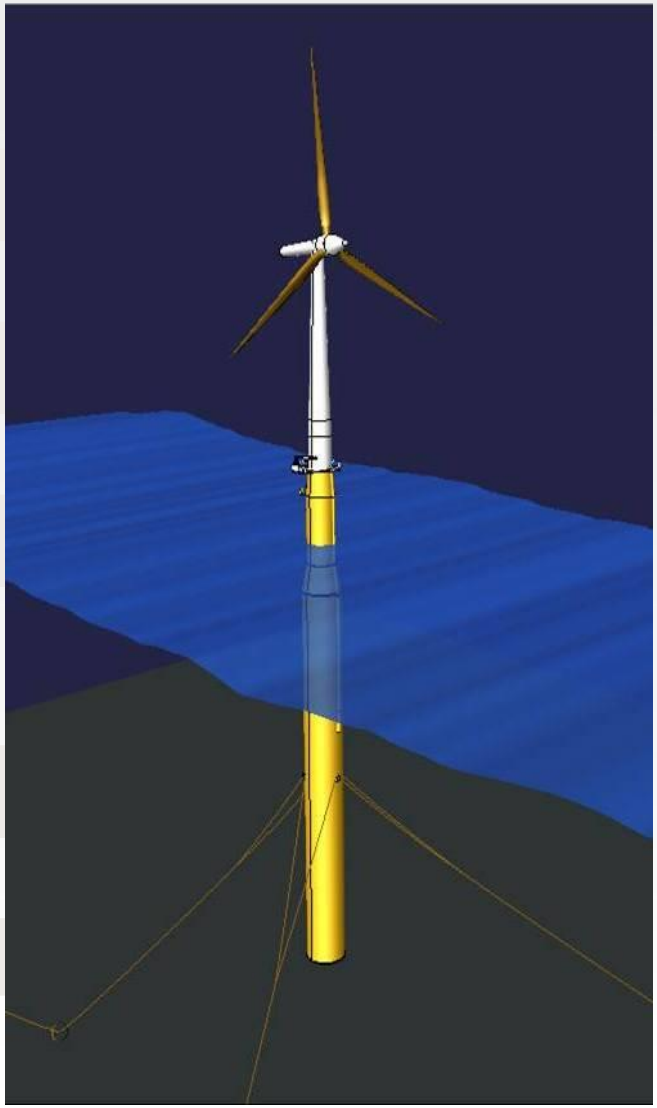

# The Hywind concept

## Key features

- Combines known technologies
- Designed for harsh environment
- ”Standard” offshore turbine
- Water depth >100 m
- Assembled in sheltered waters, towed to field

## Relies upon experience from :

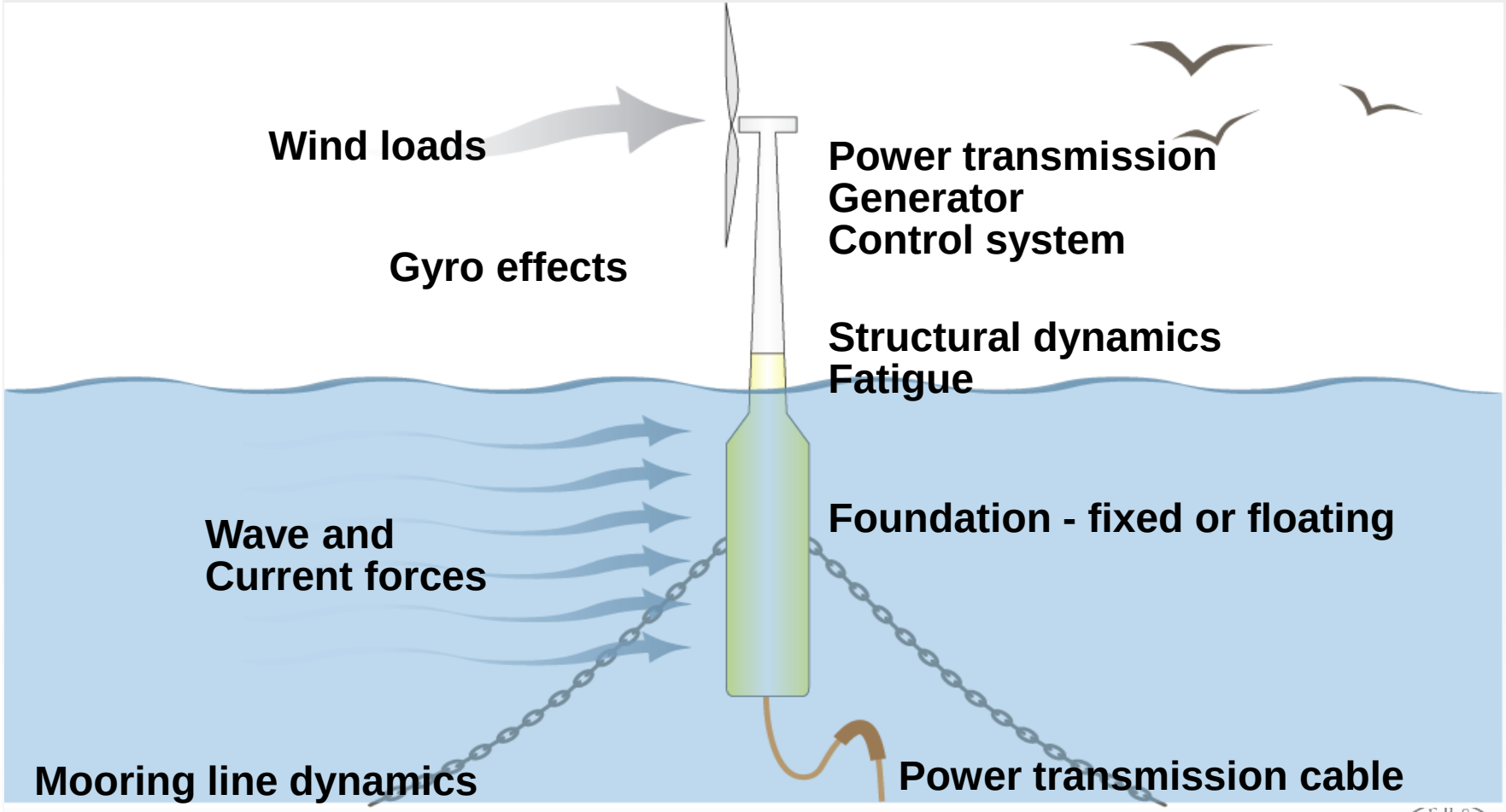
- Floating platforms
- Electrical power production
- Onshore wind turbines

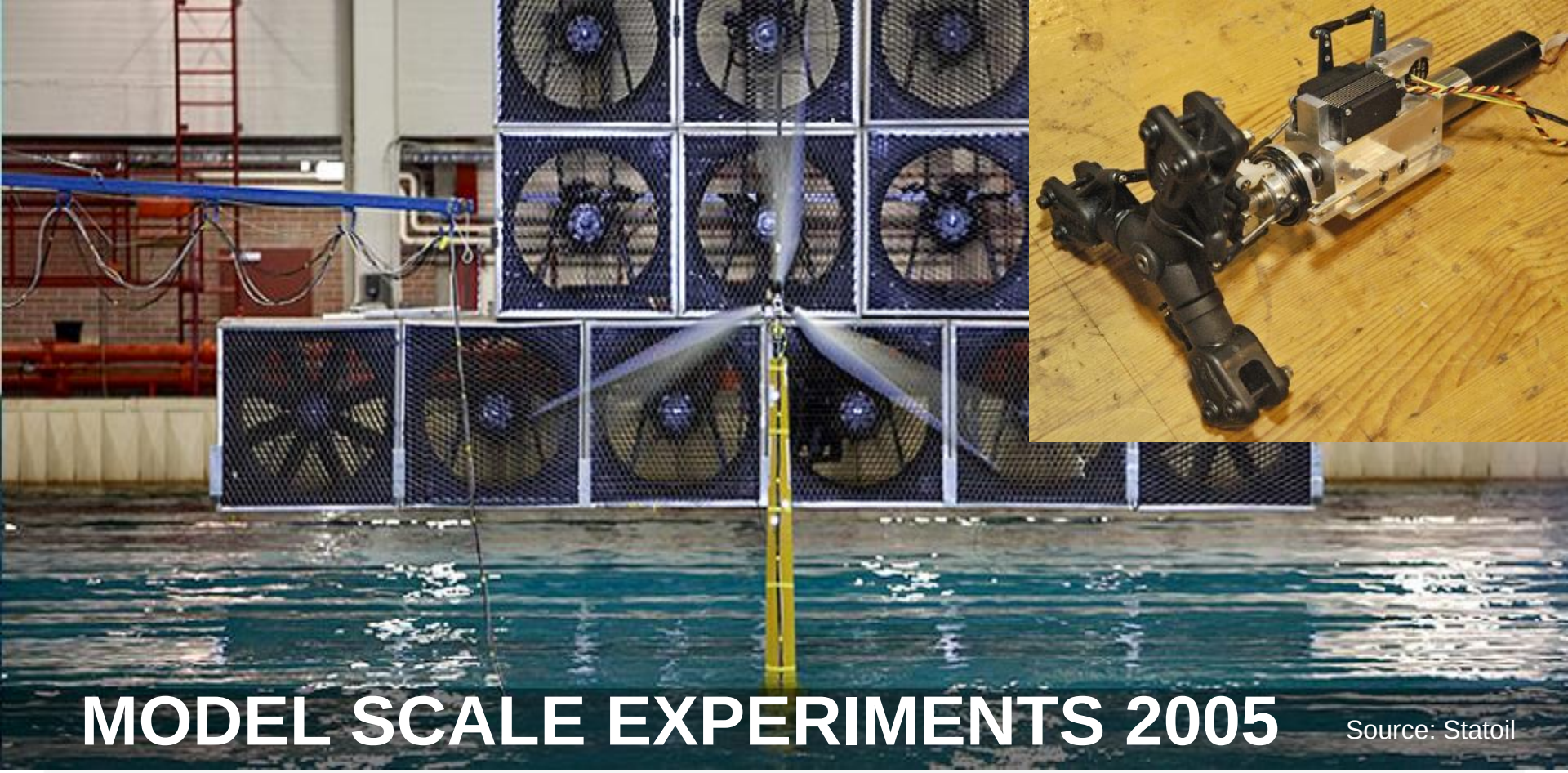


Source: Statoil

# Offshore wind turbines.

## Challenging dynamic system





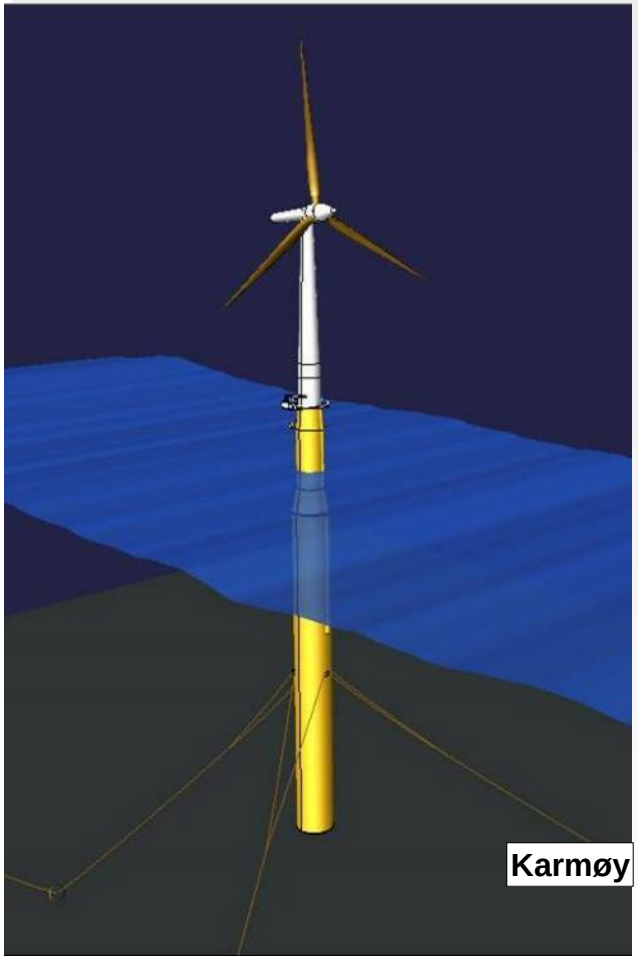
# MODEL SCALE EXPERIMENTS 2005

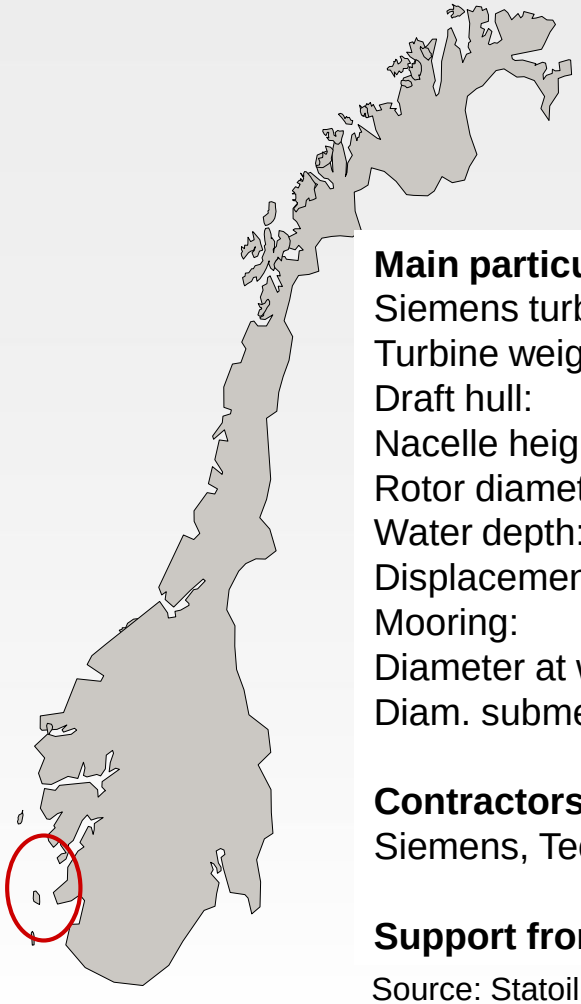
Source: Statoil

- Demonstration of system behaviour
- Validation of numerical tools
- Model scale 1:47
- Irregular waves, turbulent wind, and various control strategies

# Hywind demonstration unit.

## Installed June 2009. Located10 km West of Karmøy



**Main particulars**

| | |
|---|---|
| Siemens turbine: | 2.3 MW |
| Turbine weight: | 138 tons |
| Draft hull: | 100 m |
| Nacelle height: | 65 m |
| Rotor diameter: | 82.4 m |
| Water depth: | 150–700 m |
| Displacement: | 5300 t |
| Mooring: | 3 lines |
| Diameter at water line: | 6 m |
| Diam. submerged body: | 8.3 m |

**Contractors:**
Siemens, Technip, Nexans, Haugaland kraft.

**Support from Enova.**

Source: Statoil

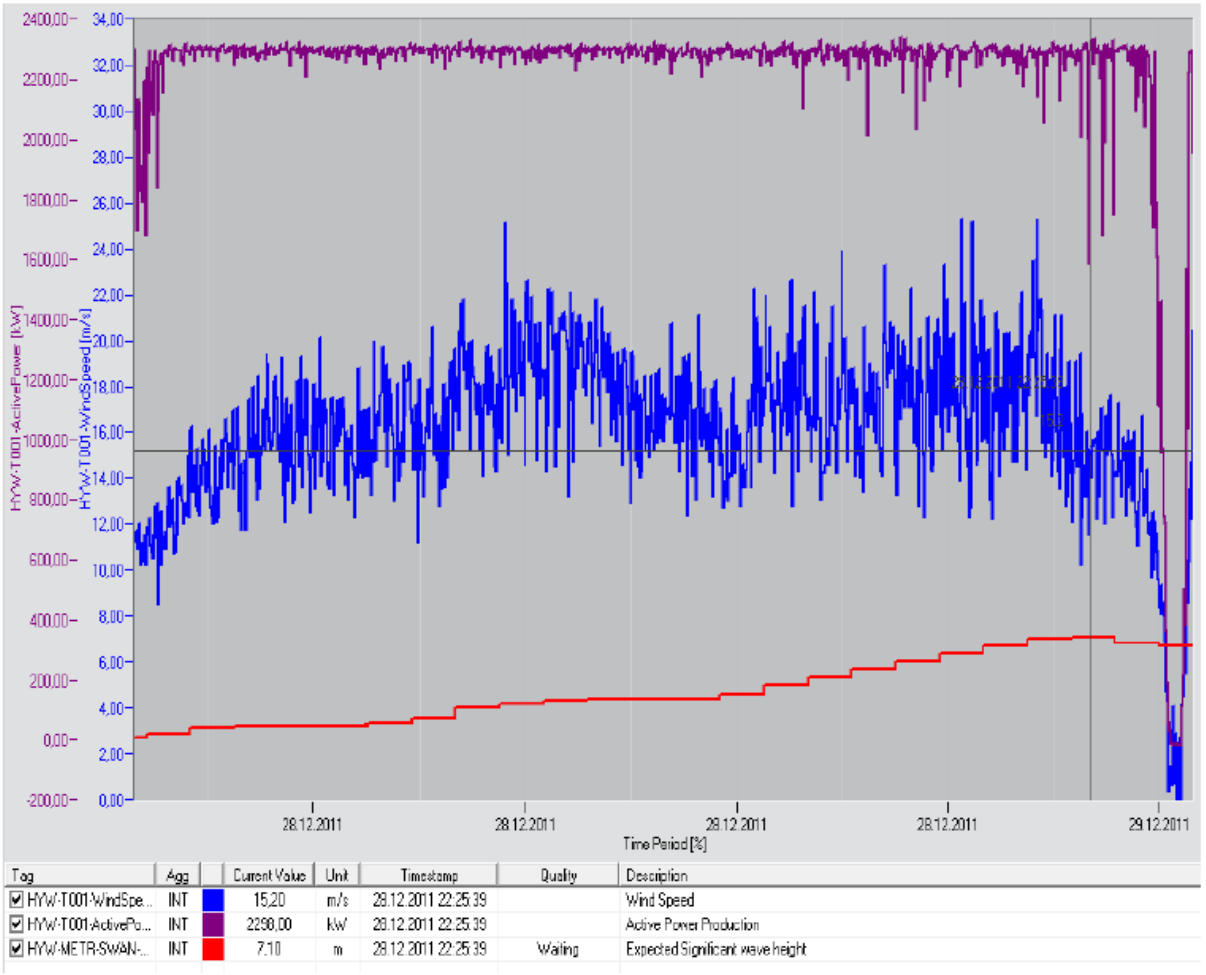
# Assembly and installation of Hywind Demo.

## Summer 2009

# Operation in harsh environment

- Max wind velocity: 40 m/sec
- Max sign wave height:  10.5 m

# Production during a storm condition



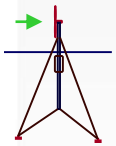

| Tag | Agg | Current Value | Unit | Timestamp | Quality | Description |
|---|---|---|---|---|---|---|
| HYW-T001-WindSpe... | INT | 15,20 | m/s | 28.12.2011 22:25:39 | | Wind Speed |
| HYW-T001-ActivePo... | INT | 2298,00 | kW | 28.12.2011 22:25:39 | | Active Power Production |
| HYW-METR-SWAN-... | INT | 7,10 | m | 28.12.2011 22:25:39 | Waiting | Expected Significant wave height |

- 24 hour period during storm “Dagmar”, Dec 2011
- Avg. wind speed 16 m/sec
- Max wind speed 24 m/sec
- Max significant wave height 7.1m
- Power production 96.7% of rated

Source: Statoil

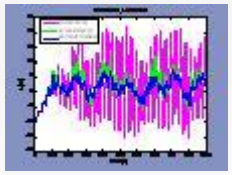
# From idea to commercial concept

2002



Idea

2003



Concept & theory

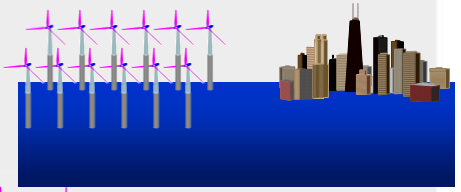
2005

Model test

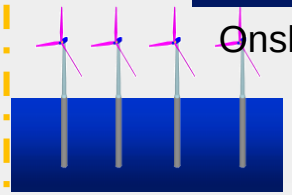
2009

Demo

2017



Onshore connected parks



Pilot park

Technical Focus

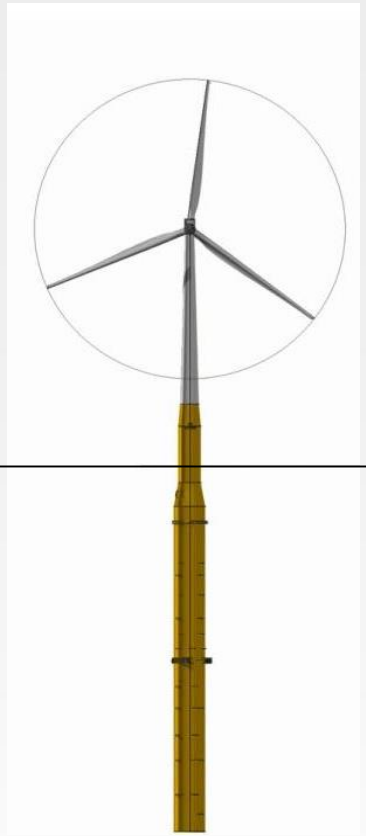
Cost Focus

Market Focus

Source: Statoil

# Optimization of hull design

## Experience and improved tools



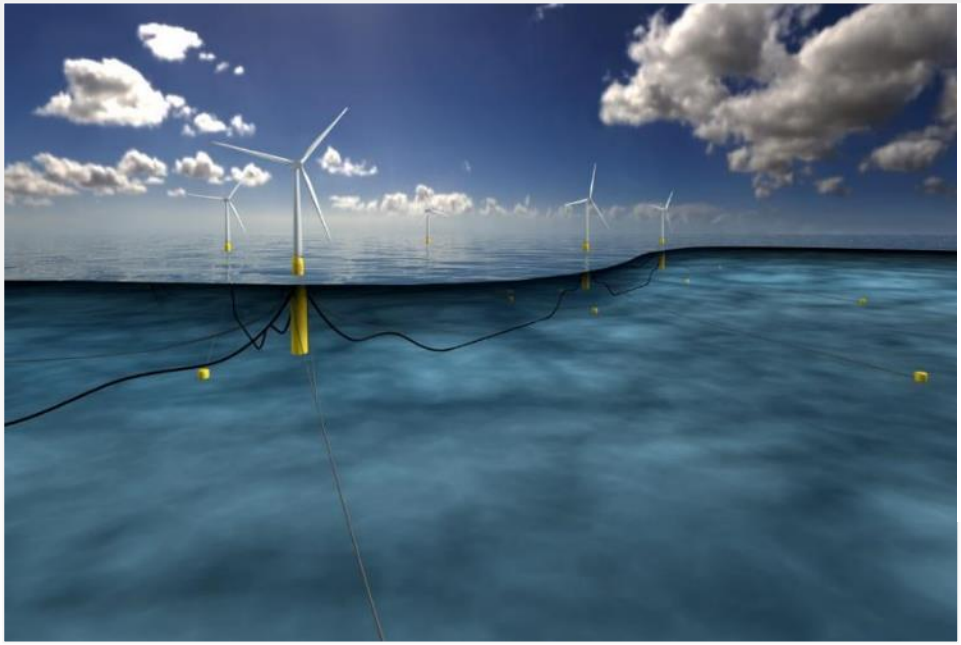
Hywind Demo 2.3MW

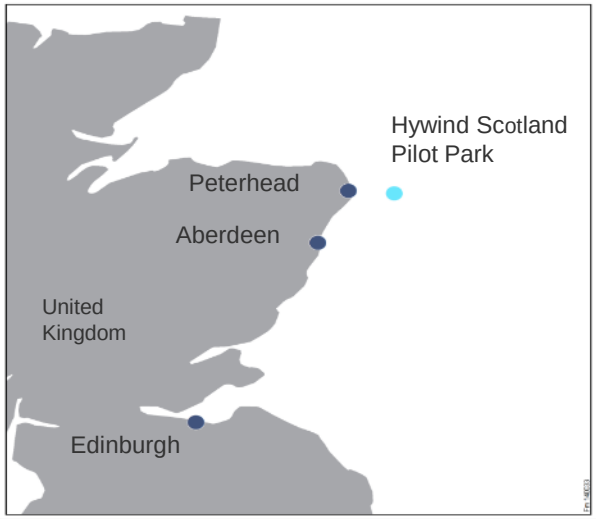
Hywind 6MW

# Hywind Scotland Pilot Park

**Primary objective:**
**Demonstrate cost efficient solution and lower risk for commercial scale floating wind farms**

- 5 x 6 MW turbines
- Location: Buchan Deep outside Peterhead
- Agreement for lease with The Crown Estate in 2013
- Consent in 2015
- First deliveries to grid 2017






Source: Statoil

# Assembly at Stord, May 2017



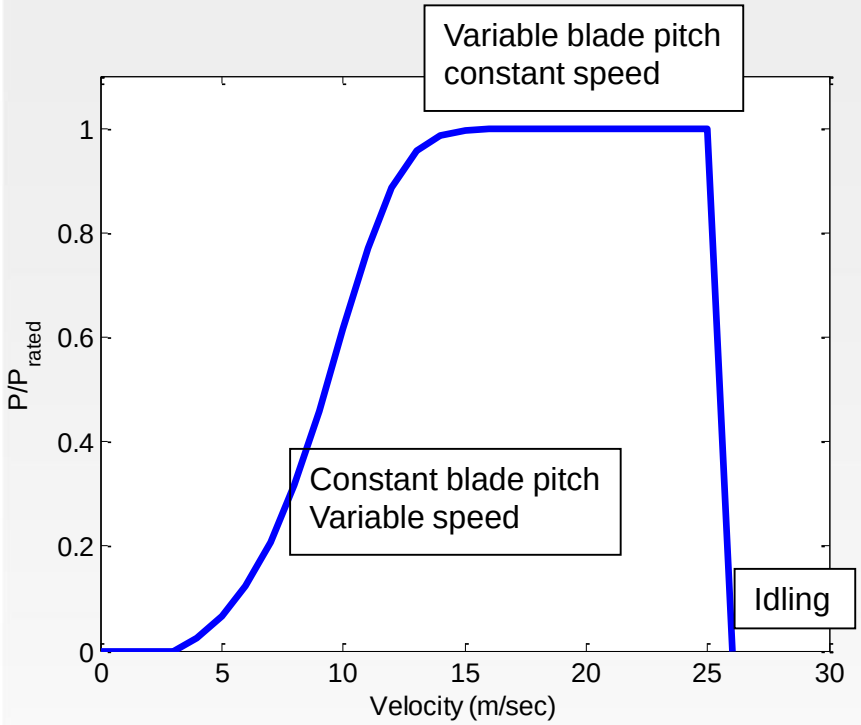


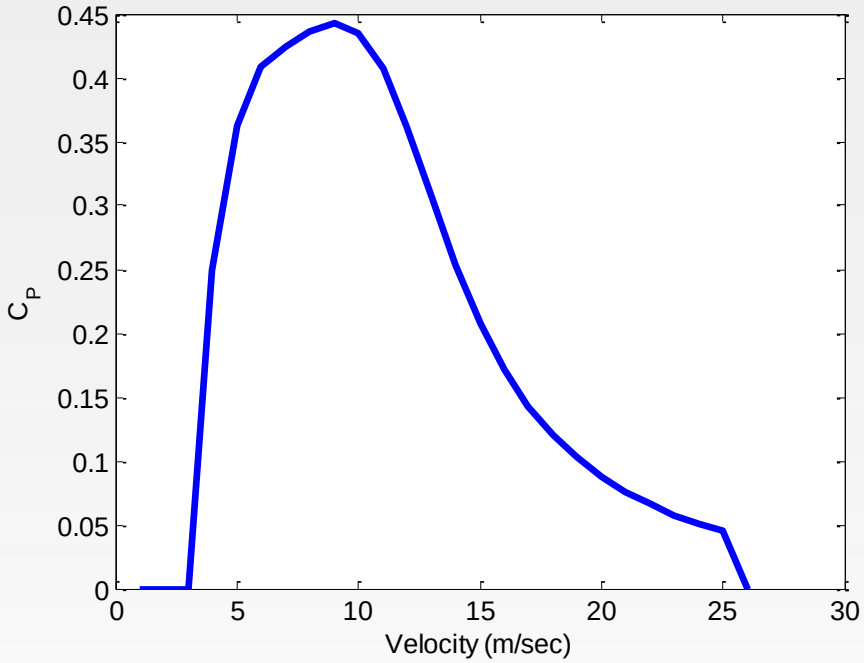

# Hywind installed on site, August 2017

Source: https://www.tu.no/artikler/her-er-den-forste-dronevideoen-av-verdens-forste-flytende-vindpark/403837

# Control challenge

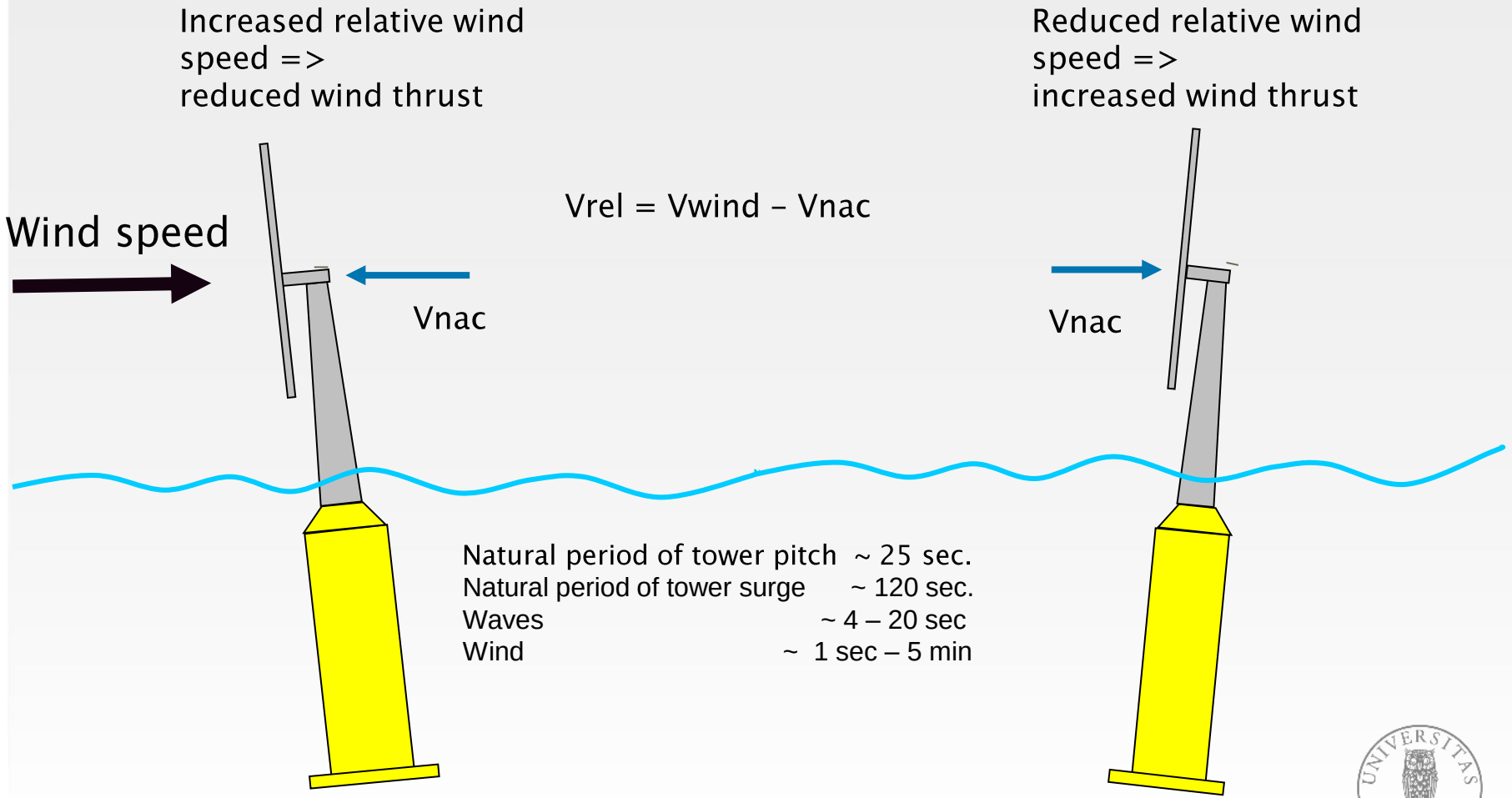
# Real turbines – power curves and power coefficient



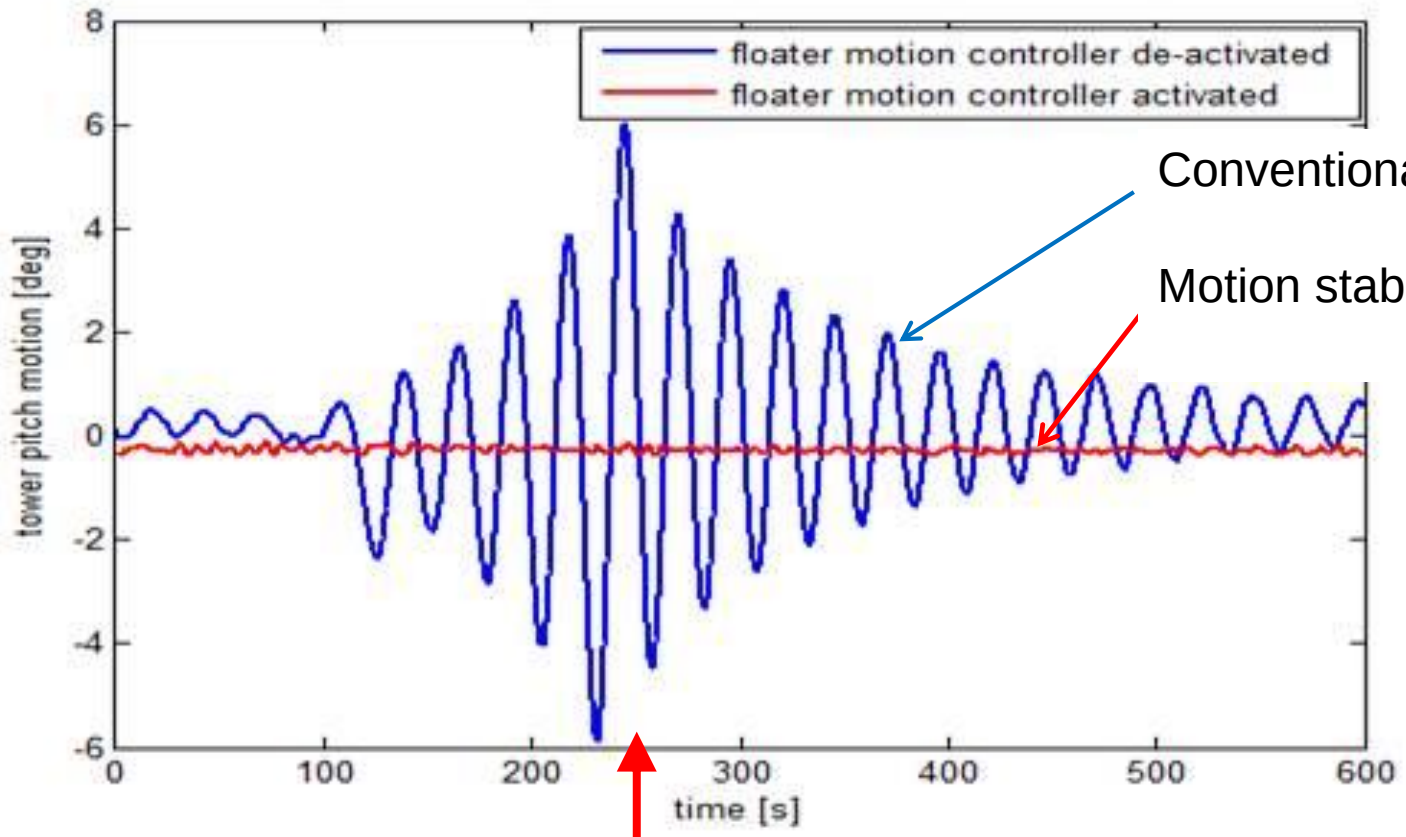



# Wind turbine thrust.

## Conventional Control, over rated speed.



# Motion controller for floating foundation




Conventional controller

Motion stabilizing controller

Shut down

Source: Statoil

# Marine operations – challenges…


Eco-Lighthouse®