



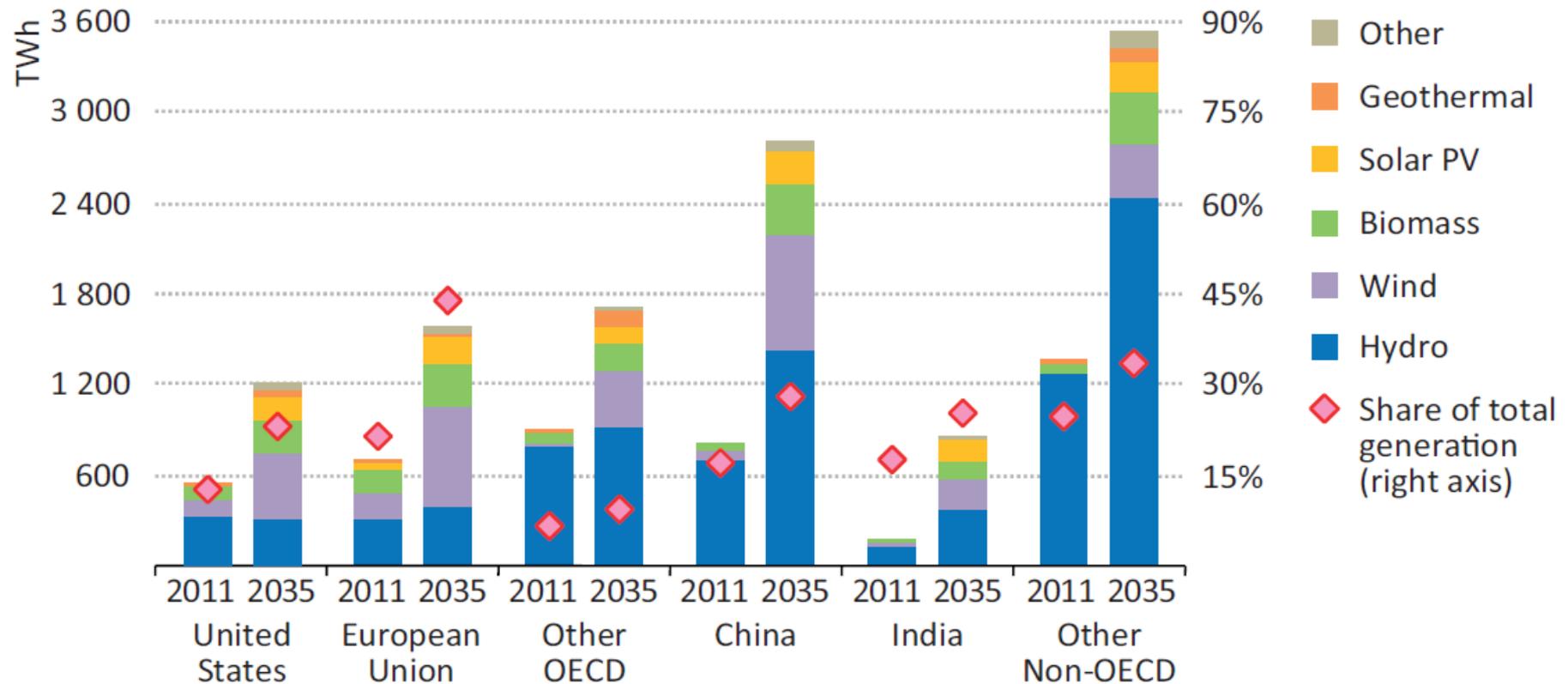
# Is floating offshore wind turbines an option?

The history of Hywind and the way forward.

Finn Gunnar Nielsen, Sr Advisor, Statoil RDI, prof. UiB

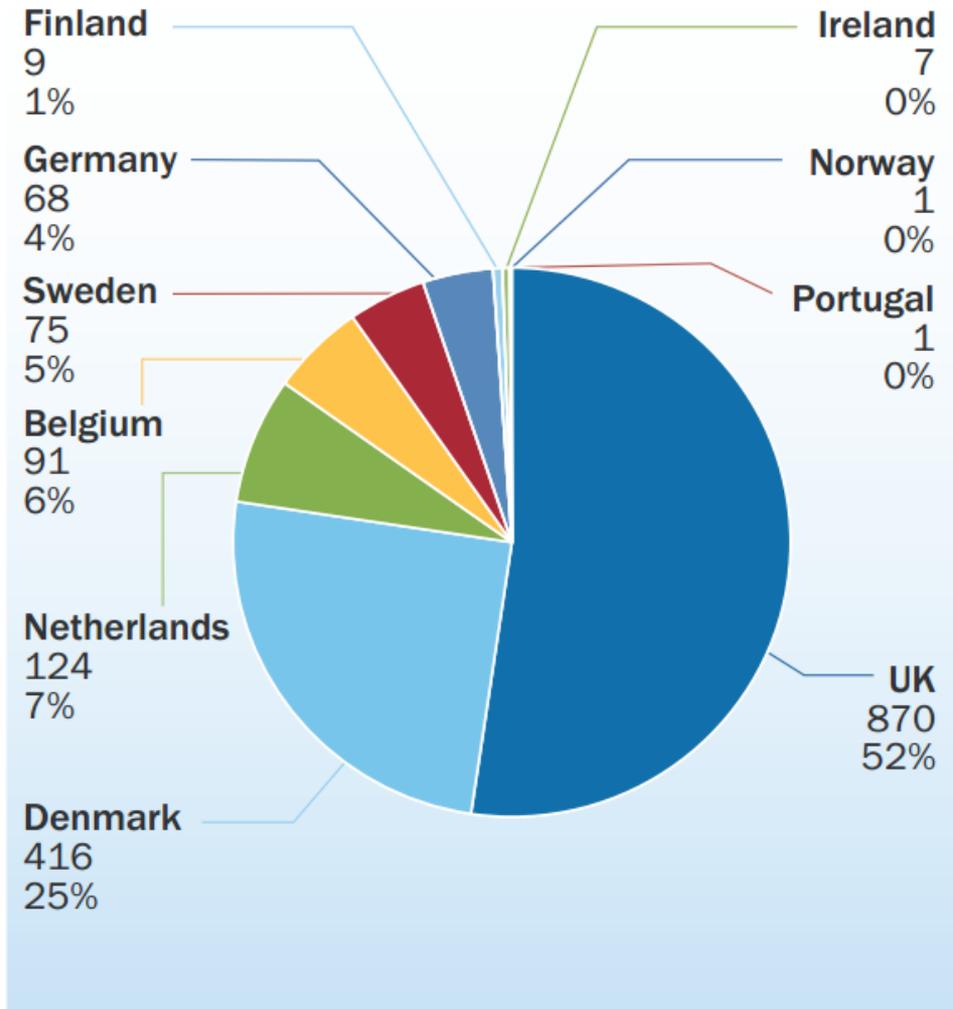
# The role of renewables

**Figure 5.13** ▷ Renewables-based power generation and share of total generation by region in the New Policies Scenario



Source: IEA Energy Outlook 2013

# Installed offshore wind turbines – by country



Globally Land + offshore,  
end 2013:

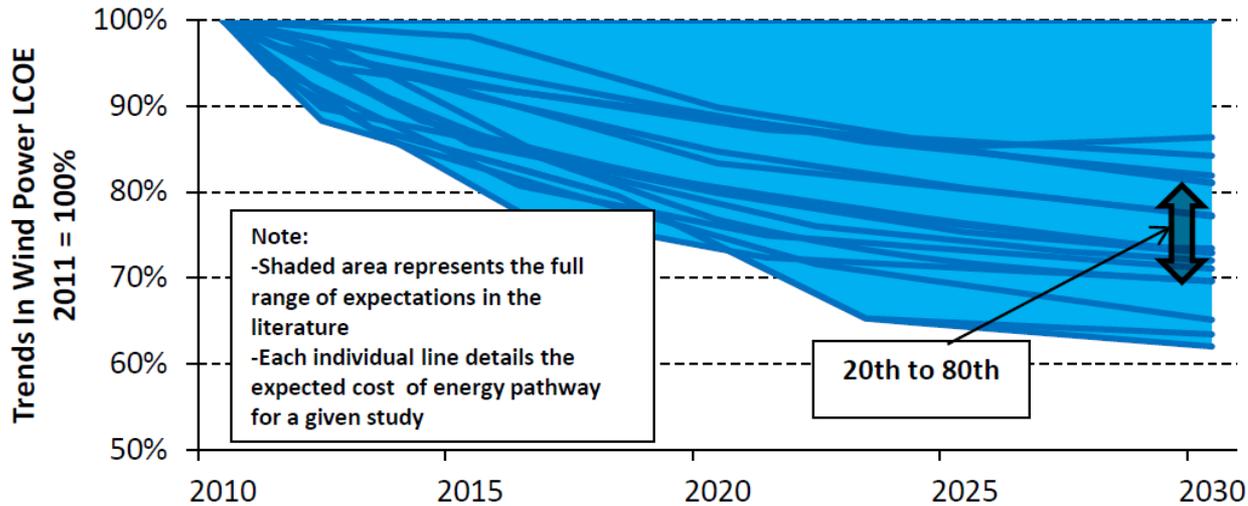
318 GW installed (+11%)

Offshore:

7.0 GW (+30%)

Source: EWEA 2013 /14

# Trends in cost of wind energy



- EU:
  - Security of supply
  - Work places
  - Reduced emissions

Figure ES-3. Estimated range of wind LCOE projections across 18 scenarios

Sources: EREC/GPI 2010, Tidball et al. 2010 (includes modeling scenarios from multiple other sources), U.S. DOE 2008, EIA 2011, Lemming et al. 2009, EWEA 2011, EPRI 2010, Peter and Lehmann 2008, GWEC/GPI 2010, IEA 2009, and European Commission 2007

Source: IEA wind, 2012

# Where we are coming from:

- Deep water
- Harsh environment
- Advanced marine operations
- Advanced projects



# Portfolio: Step wise growth in offshore wind

Offshore wind development based on core competence

2.3MW

Hywind  
Demo



2009-

317MW  
1.1 Twh / yr

Sheringham  
Shoal



2012-

Appr. 407MW

Dudgeon



2012-

30MW / 5 units

Hywind  
Pilot Park



Up to 9GW

Dogger  
Bank



Hywind  
Commercial  
Park

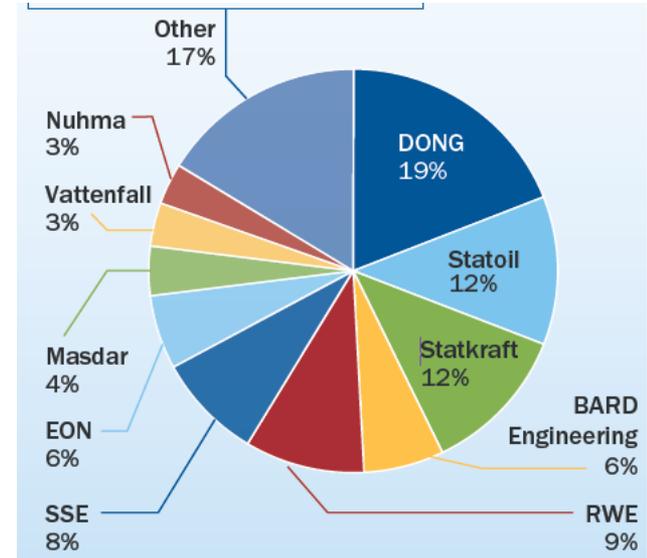


Increase  
Portfolio?



# Sheringham Shoal

- 315 MW of capacity
- Located off the coast of Norfolk, England
- Covers an area of approximately 35 km<sup>2</sup>
- 88 wind turbines, each with a capacity of 3.6 MW.
- Turbine blade length 52 meters (170 feet)
- Turbine tower height 80 meters (262 feet)
- Two offshore substations
- On grid 2012



Share of 2012 installations



# Location of offshore wind farms.

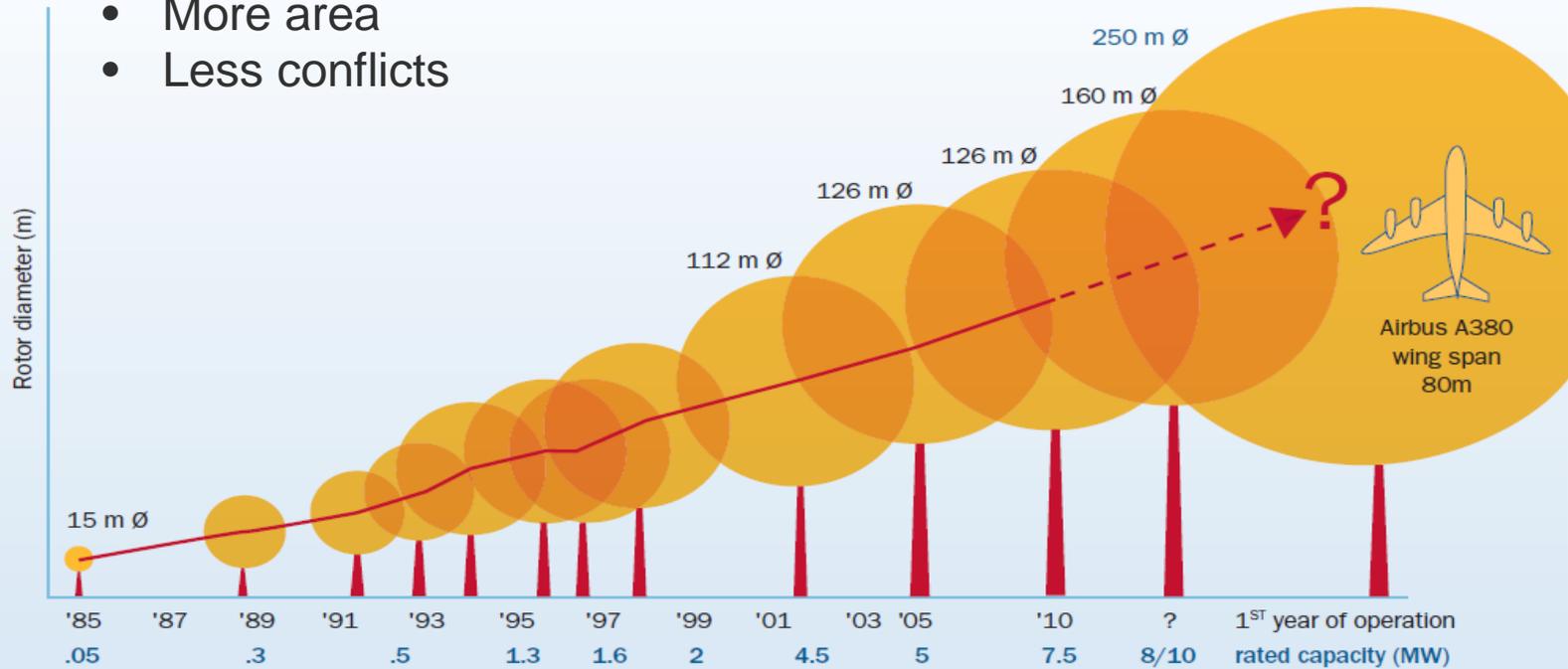
Present and future



Source: [www.4offshore.com](http://www.4offshore.com)

# Why offshore?

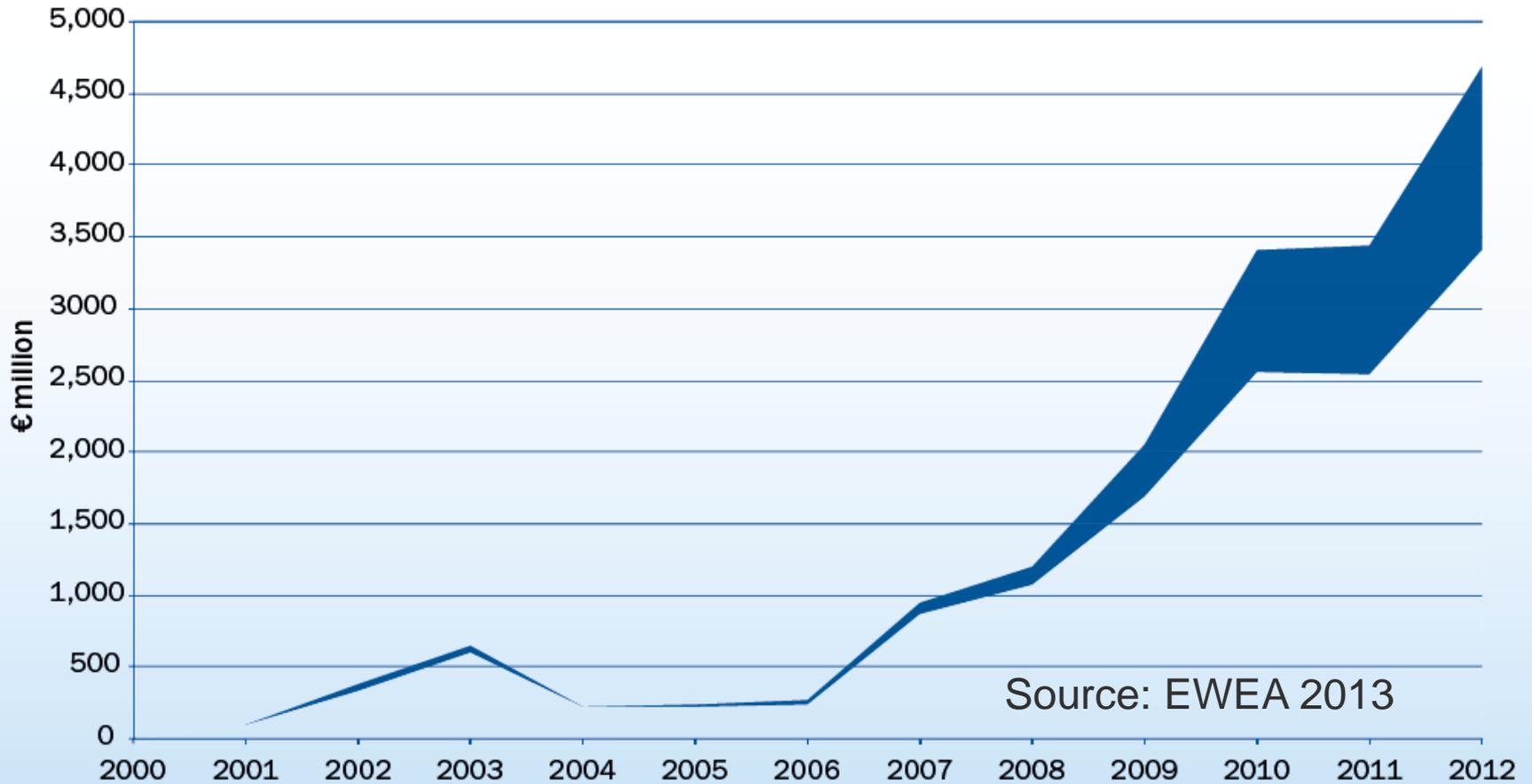
- More wind,  $P = kU^3$
- More area
- Less conflicts



Source: EWEA



# Annual investments in offshore wind farms (Europe)



# Two National centres for offshore wind

Home | Contact | About the centre | Vacancies | News | Norwegian Motion Lab | CMR.MO | Login ProjectPlace



## norcowe

Norwegian Centre for Offshore Wind Energy

>>> | FOCUS AREAS | VISION | PARTNERS | ANNUAL REPORTS/NEWSLETTERS | VIDEOS

**NORCOWE-Day**



Bergen hosted the internal meetings for the members of NORCOWE.  
[read more >>](#)

**FAST workshop**



NORCOWE and NREL hosted FAST workshop in Bergen.  
[read more >>](#)

**Acting Centre Coordinator**



Trygve Toft-Eniksen has now been the acting Centre Coordinator in NORCOWE since August.  
[read more >>](#)

**SMI Bergen**



Presentations and posters from Science Meets Industry Bergen are now available.  
[read more >>](#)

**Operation and maintenance decision analysis for Dudgeon wind park**



A decision methodology based on simulation modelling and analysis was selected to analyse different vessel solutions for O&M.  
The model was first configured to fit the O&M and marine logistics system of Dudgeon Wind Park, a task performed in collaboration with Statoil Wind O&M department.  
[read more >>](#)

Search

**News**

25. 09. 2014  
PhD defence Sung-Jin Choi accomplished...  
[read more >>](#)

04. 07. 2014  
Paper presented at EUROOYN...  
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News archive >>

[Calendar/Upcoming Events](#)

21. oktober 2014  
Offshore Renewable Energy Conference & B2B...  
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29. oktober 2014  
O&M Workshop...  
[read more >>](#)

24. november 2014  
RENEW 2014...  
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Calendar Archive >>

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## NOWITECH

Norwegian Research Centre for Offshore Wind Technology



News

Newsletters

Background

Research Activities

PhD and post doc programme

Organization

International cooperation

Budget and finance

Contacts & People

Partners

Events

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Subscription Newsletter

**NOWITECH Annual Report 2013**

[NOWITECH Annual Report 2013 - print version](#)

[EERA DeepWind'2015 - First announcement and call for papers](#)

**REGISTRATION**

**The objective of NOWITECH is pre-competitive research laying a foundation for industrial value creation and cost-effective offshore wind farms. Emphasis is on "deep-sea" (>30 m) including bottom-fixed and floating wind turbines.**

Work is focused on technical challenges including a strong PhD and post doc programme:

- Integrated numerical design tools for novel offshore wind energy concepts.
- Energy conversion systems using new materials for blades and generators.
- Novel substructures (bottom-fixed and floaters) for offshore wind turbines.
- Grid connection and system integration of large offshore wind farms.
- Operation and maintenance strategies and technologies.
- Assessment of novel concepts by numerical tools and physical experiments.

Total budget (2009-2017) is + NOK 320 millions / M€ 41 / MUS\$ 55 cofunded by the Research Council of Norway and NOWITECH partners.

The application to the Research Council of Norway as approved February 2009 gives the basis for the activities of NOWITECH.

**Winds of change: NOWITECH in International Innovation**

International Innovation is the leading global dissemination resource for the wider scientific, technology and research communities, [www.researchmedia.eu](http://www.researchmedia.eu)

**NOWITECH Leaflet**

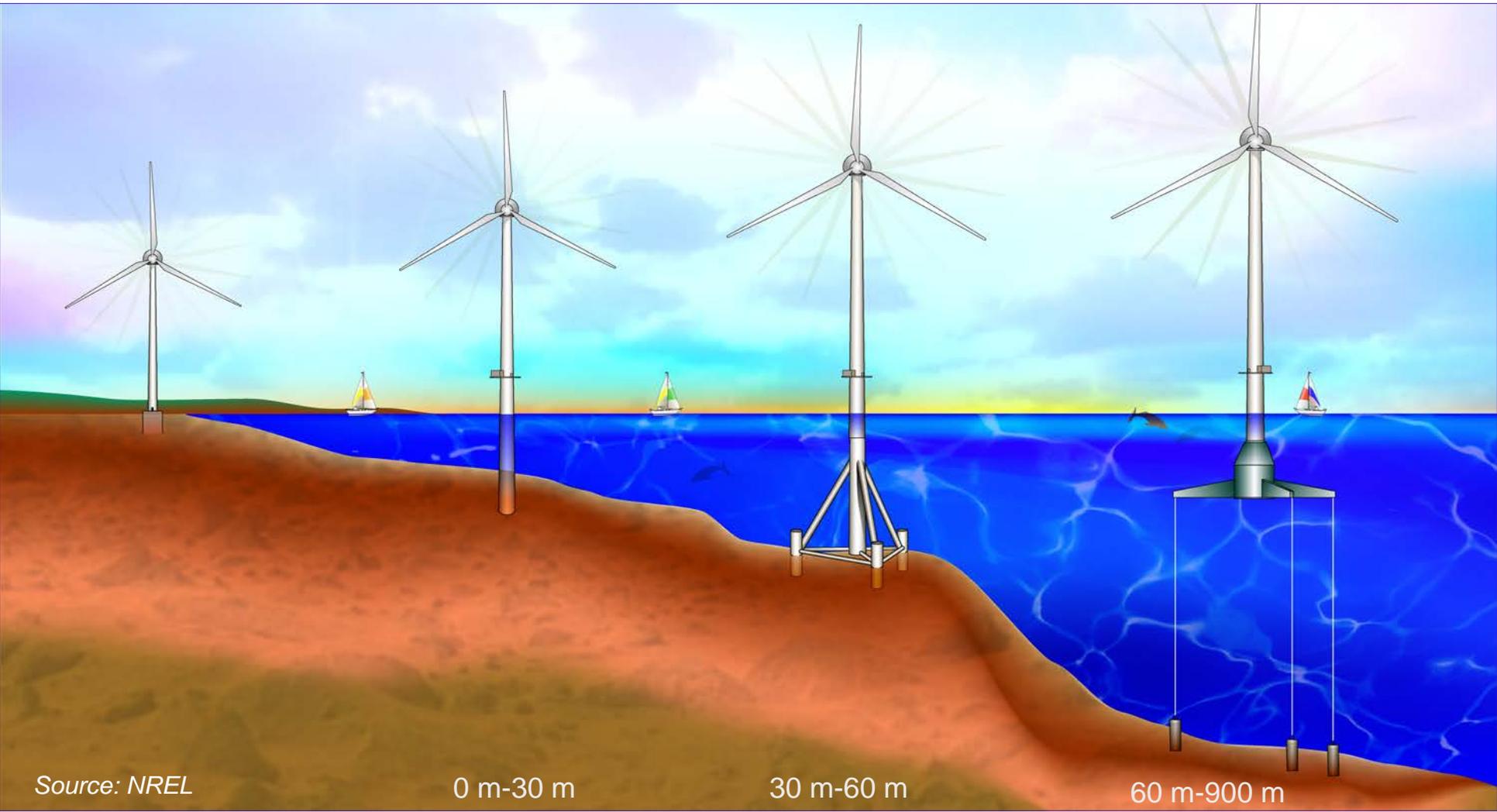
[NOWITECH internal pages \(requires a password\)](#)

[NOWITECH Scientific Committee internal pages \(requires a password\)](#)

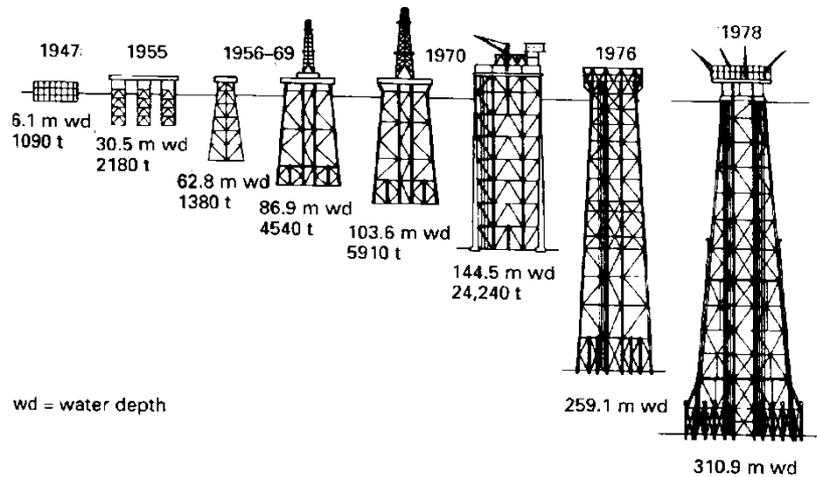
**NEWS**

- Oljekrise kan gi flere grønne jobber (18. september)
- The peer-reviewed papers from the EERA DeepWind'2014 Conference are now published online in Energy Procedia
- PHD disputas torsdag 14. august - Kevin Bain Cox
- NOWITECH Newsletter July 2014
- EERA DeepWind'2015 - First announcement and call for papers
- Well accomplished NOWITECH Day 2014 (19 June)

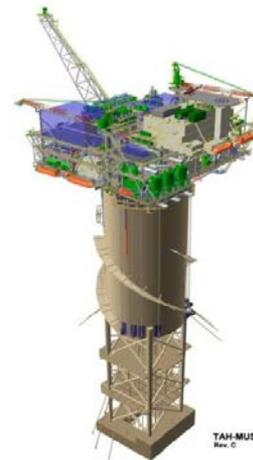
# Wind power. On the move from land to deep water



# The marine industry entered the scene. New concepts to handle the marine environment



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



Tahiti  
TAH-MUS-PIP-XD-TZZ-05-0148  
Rev. C  
August 16, 2008

# Floating wind turbine concepts

## SPAR-BUOY



HyWind



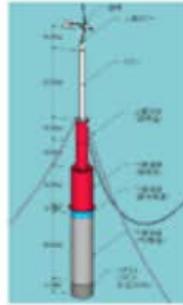
Njord



HIPRWIND



Sway



Sasebo



Nautica AFT



Deepwind

## TLP



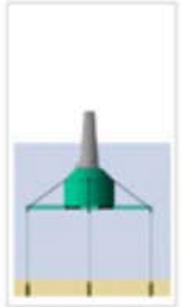
DIWET



MES



PelaStar



NREL

## SEMI-SUBMERSIBLE



Windfloat



WinFlo



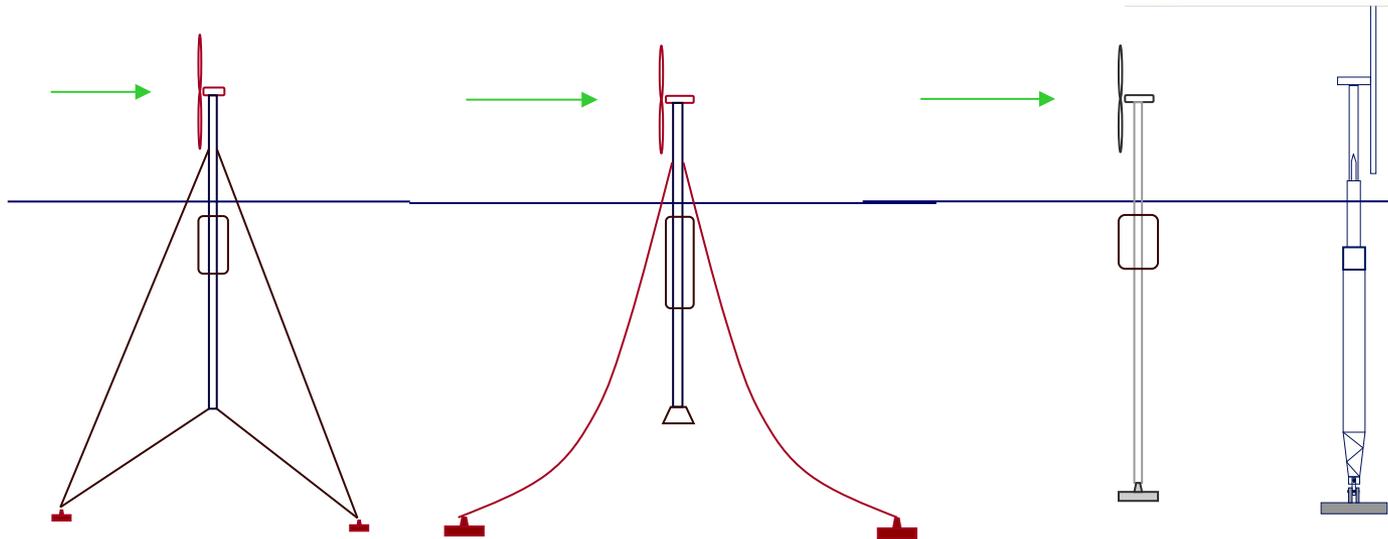
WindSea



Vertiwind

# Hywind - The starting point -2001

- Inspired by floating sailing marks.
  - “Seawind” matured during 2002
- Challenge: Could we supply oil and gas platforms by wind power?



# The Hywind concept

## Key features

Combines known technologies

Designed for harsh environment

”Standard” offshore turbine

Water depth >100 m

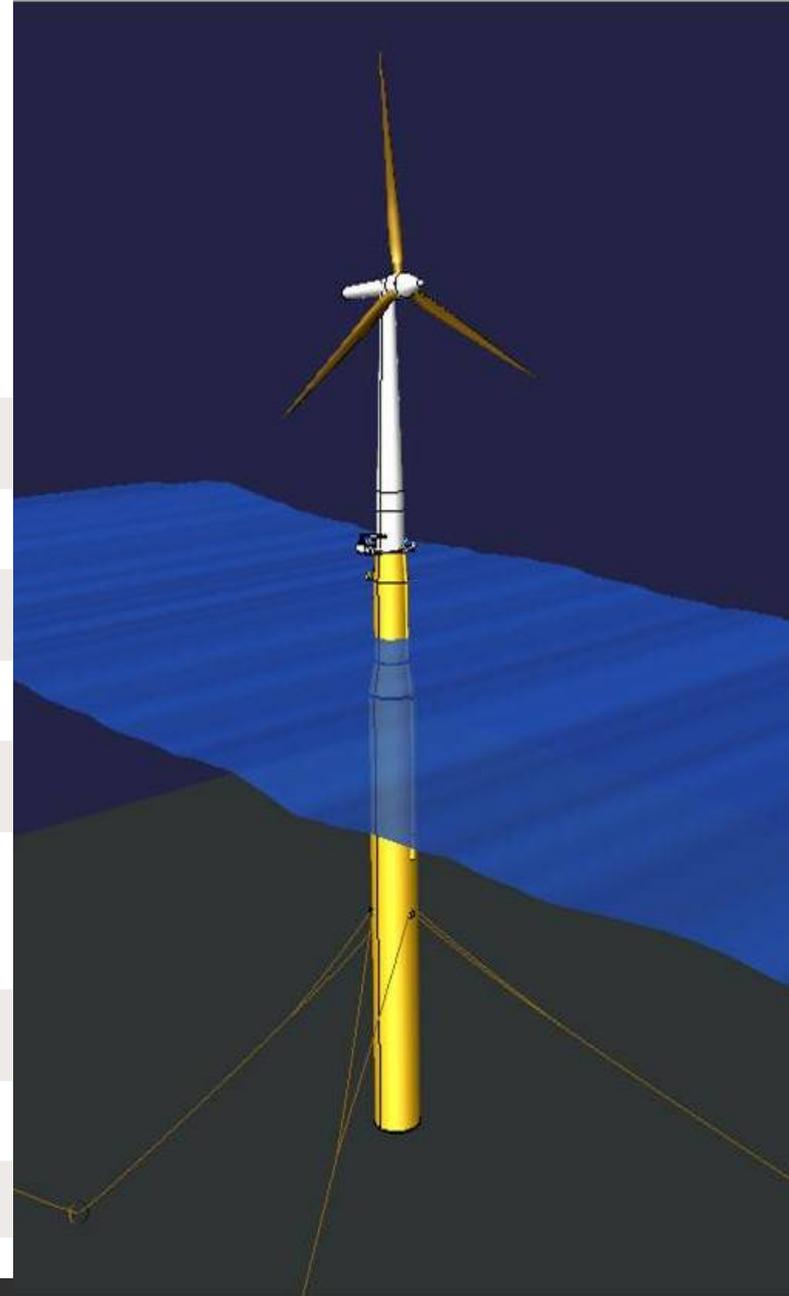
Assembled in sheltered waters, towed to field

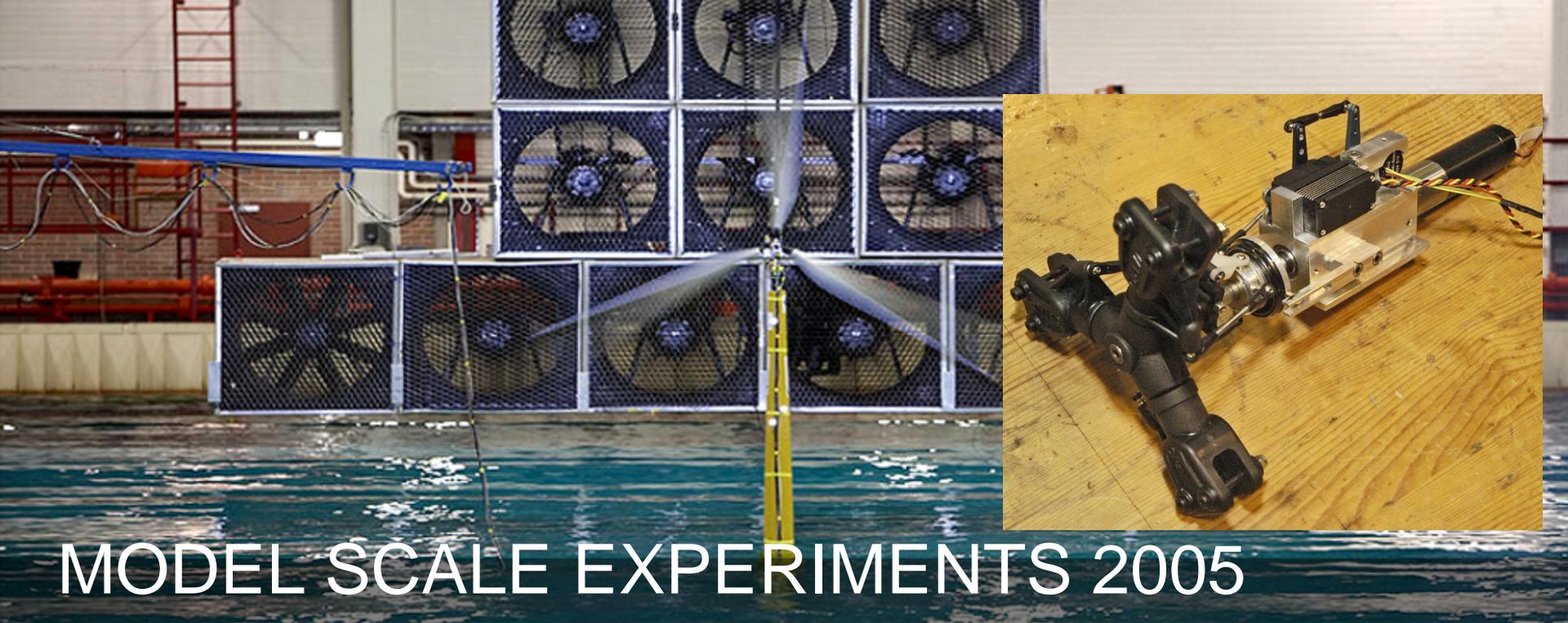
## Relies upon experience from :

Floating platforms

Electrical power production

Onshore wind turbines





# MODEL SCALE EXPERIMENTS 2005

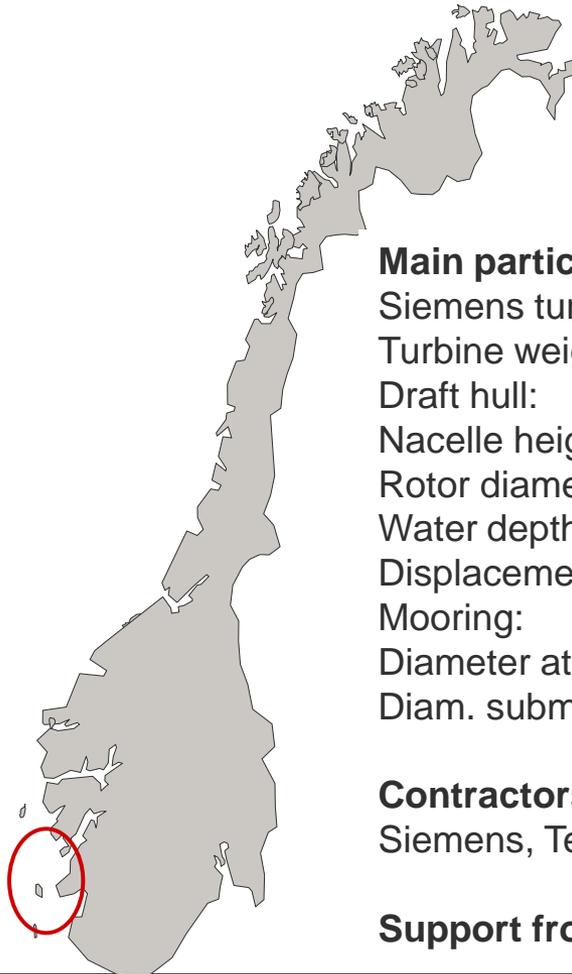
- Demonstration of system behaviour
- Validation of numerical tools
- Model scale 1:47
- Irregular waves, turbulent wind, and various control strategies

# Assembly and installation of Hywind Demo Summer 2009



# Hywind demonstration unit. Installed June 2009

Located 10 km West of Karmøy



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:

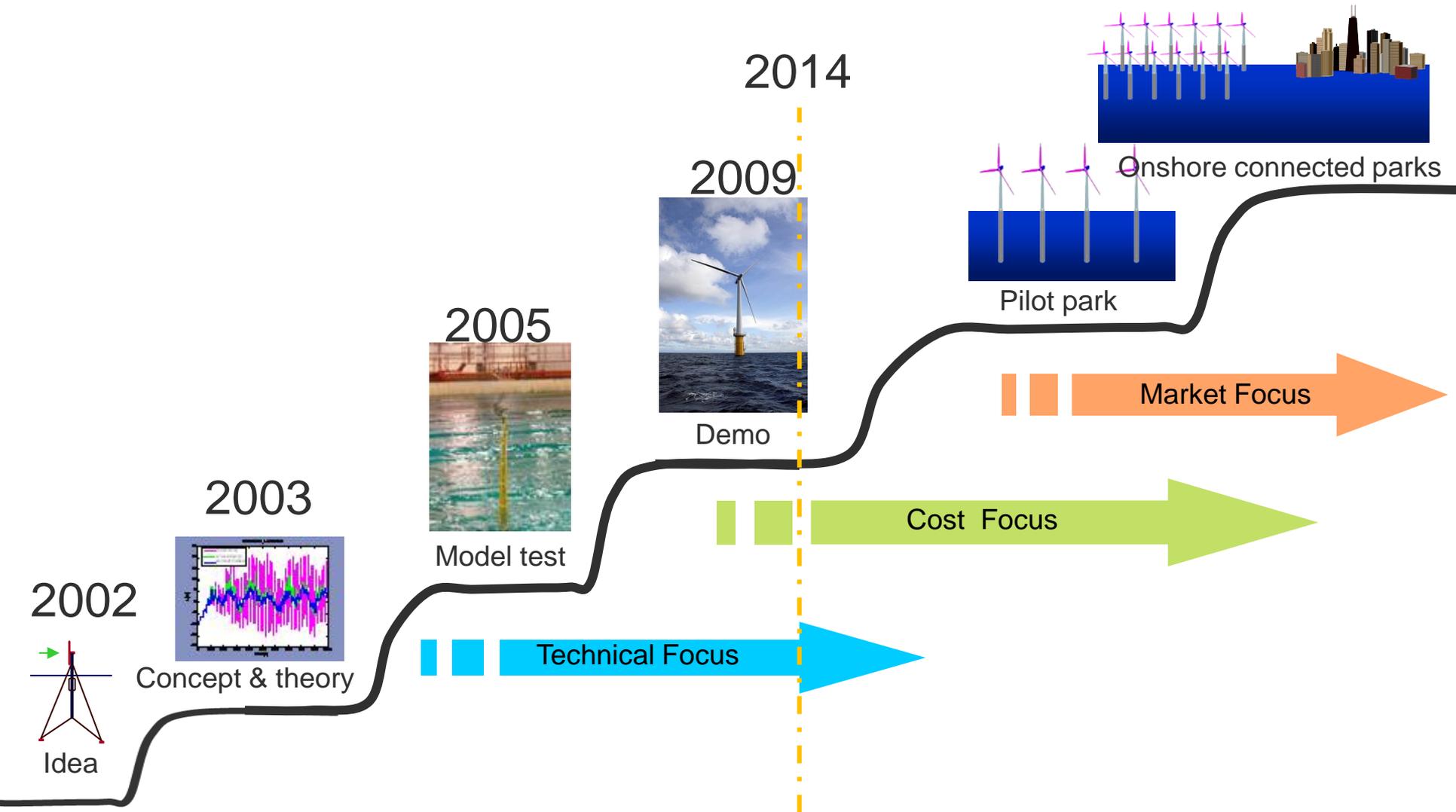
Siemens, Technip, Nexans, Haugaland kraft.

Support from Enova.

# Full scale measurements

- A total of more than 200 sensors:
  - Waves wind and current (magnitude and direction)
  - Motion (6 DOF) and position of floater
  - Mooring line tension
  - Strain gauges at tower and hull (4 levels – bending moments and axial force)
  - Rotor speed, blade pitch and generator power
  - Flap- and edgeways rotor bending moments
  - Motion (tower pitch) / blade pitch controllers

# From idea to commercial concept

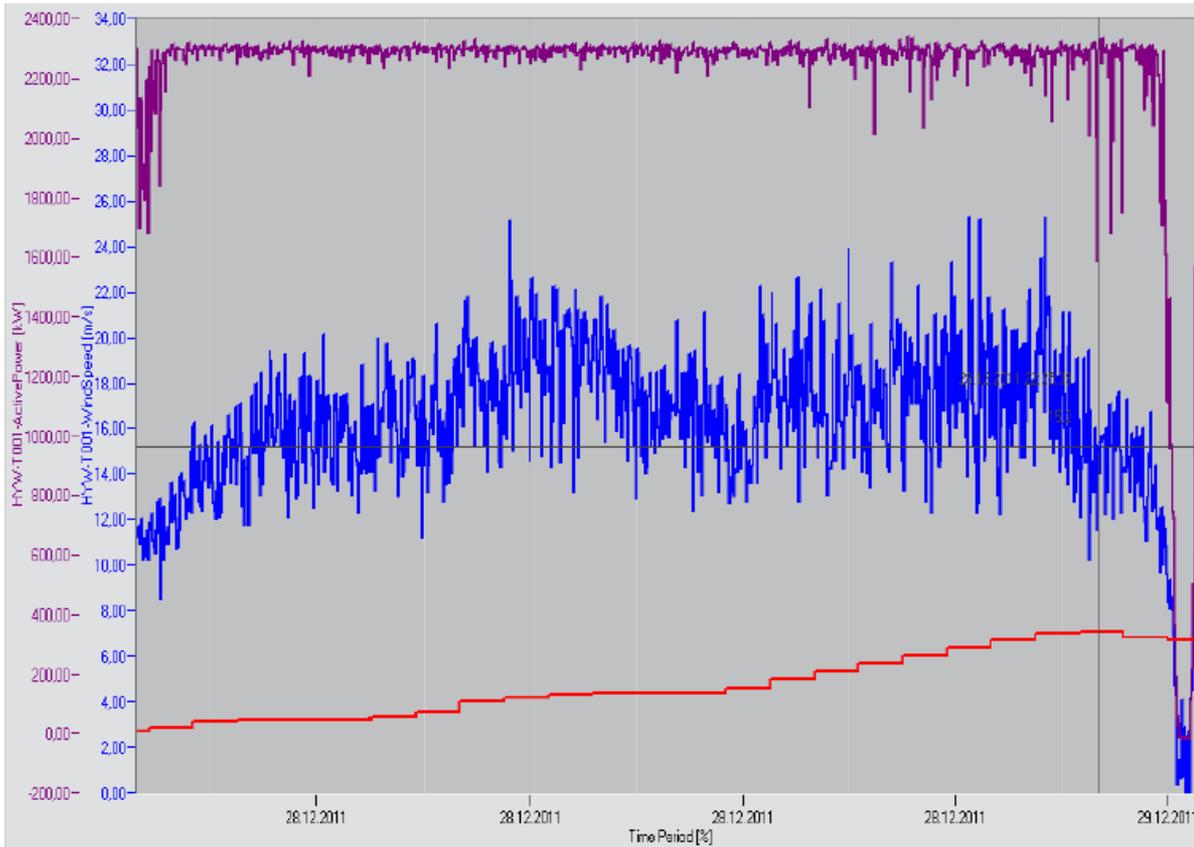


# Operation in harsh environment

- Start of operation Sept 2009.
- Production > 30GWh.
- Max wind velocity: >40 m/sec.
- Max sign wave height: 10.5 m,  
Max wave 19m.



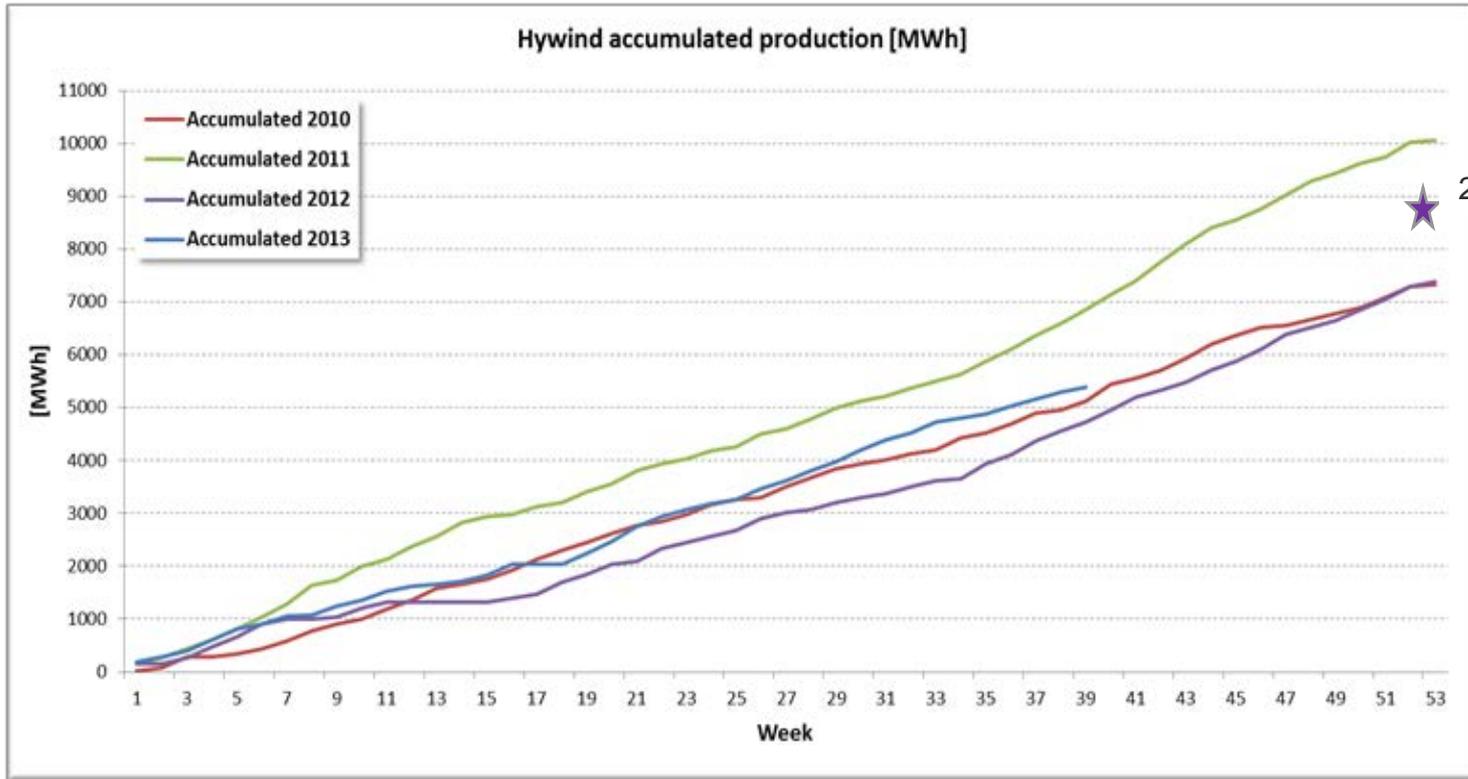
# Production during a storm condition



- 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

Tag	Agg	Current Value	Unit	Timestamp	Quality	Description
<input checked="" type="checkbox"/> HYW-T001-WindSpe...	INT	15.20	m/s	28.12.2011 22:25:39		Wind Speed
<input checked="" type="checkbox"/> HYW-T001-ActivePa...	INT	2298.00	kW	28.12.2011 22:25:39		Active Power Production
<input checked="" type="checkbox"/> HYW-METR-SwAN...	INT	7.10	m	28.12.2011 22:25:39	Warning	Expected Significant wave height

# Hywind performance 2010 – 2013



★ 2012 without fault

2010: Testing

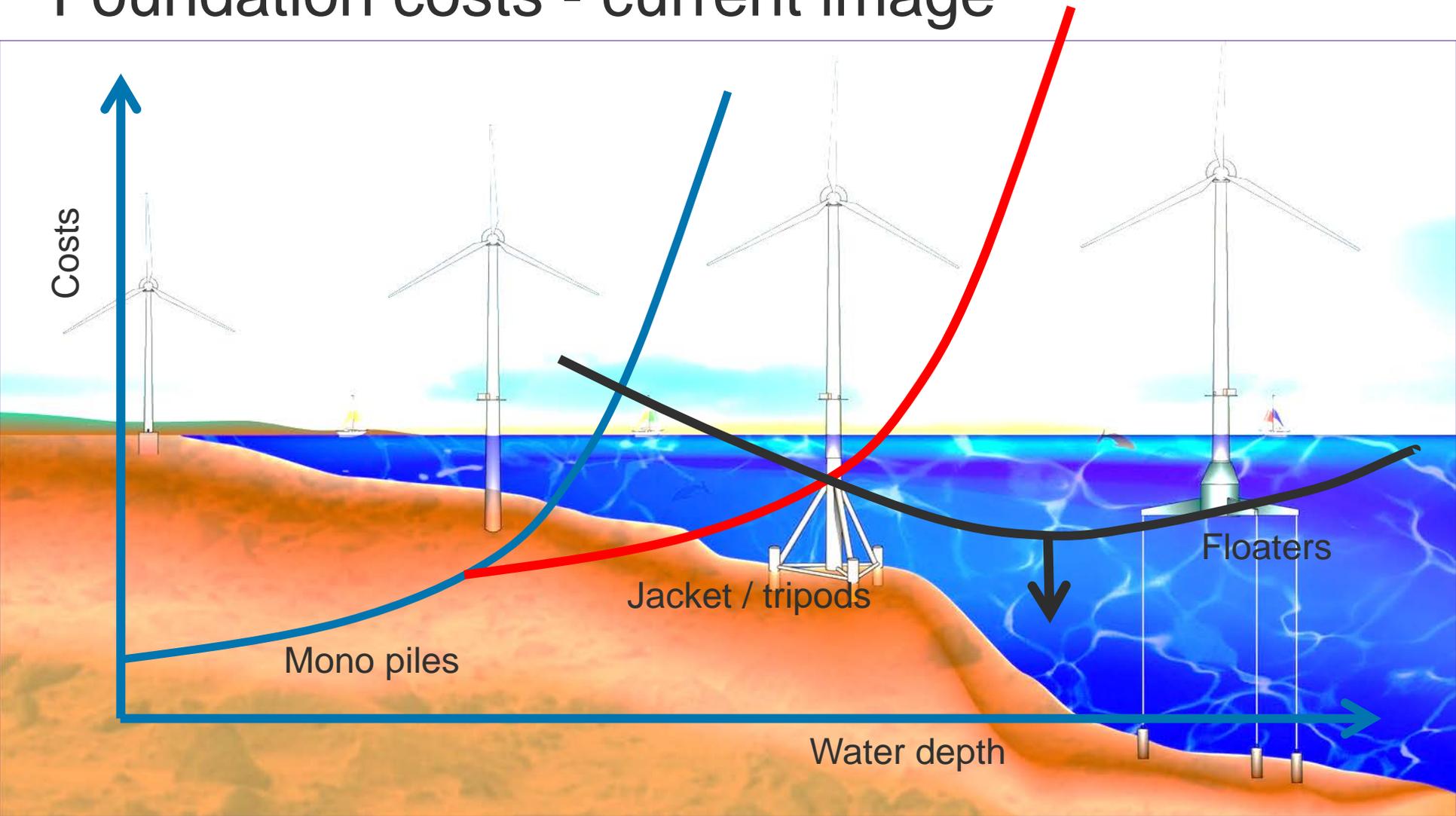
2011: Excellent wind

2012: Unschedule shut down (External grid fault / WoW)

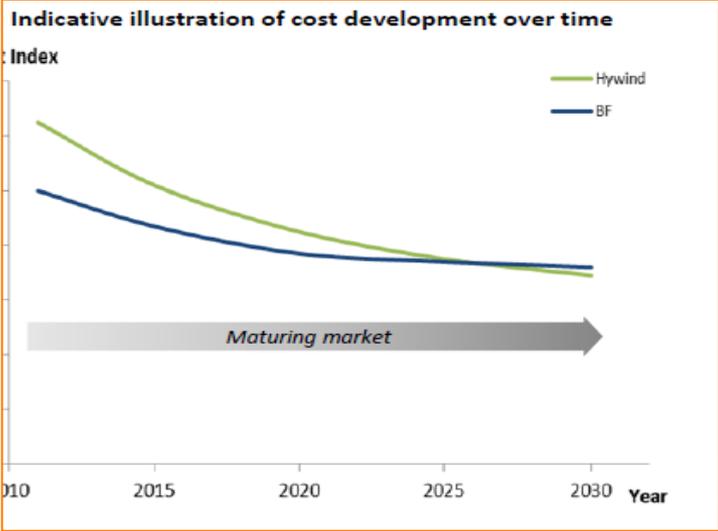
2013: Less than average wind

Expected yearly capacity factor: 0.40 – 0.52

# Foundation costs - current image



# FOW will compete with bottom-fixed offshore wind in a mature market



**Optimised design:**  
Support structure and mooring  
Larger turbines  
Control system  
Higher energy yield

**Reduced production costs:**  
Large volume  
Improved supply chain  
Simplified assembly and installation



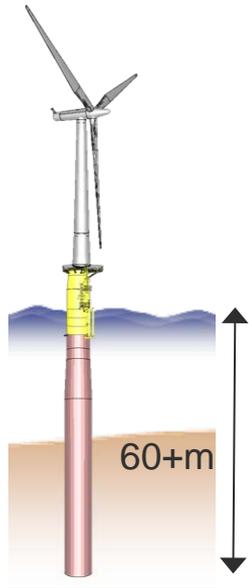
Hywind Demo



Hywind II  
Benign  
conditions



Hywind III  
Harsh  
conditions

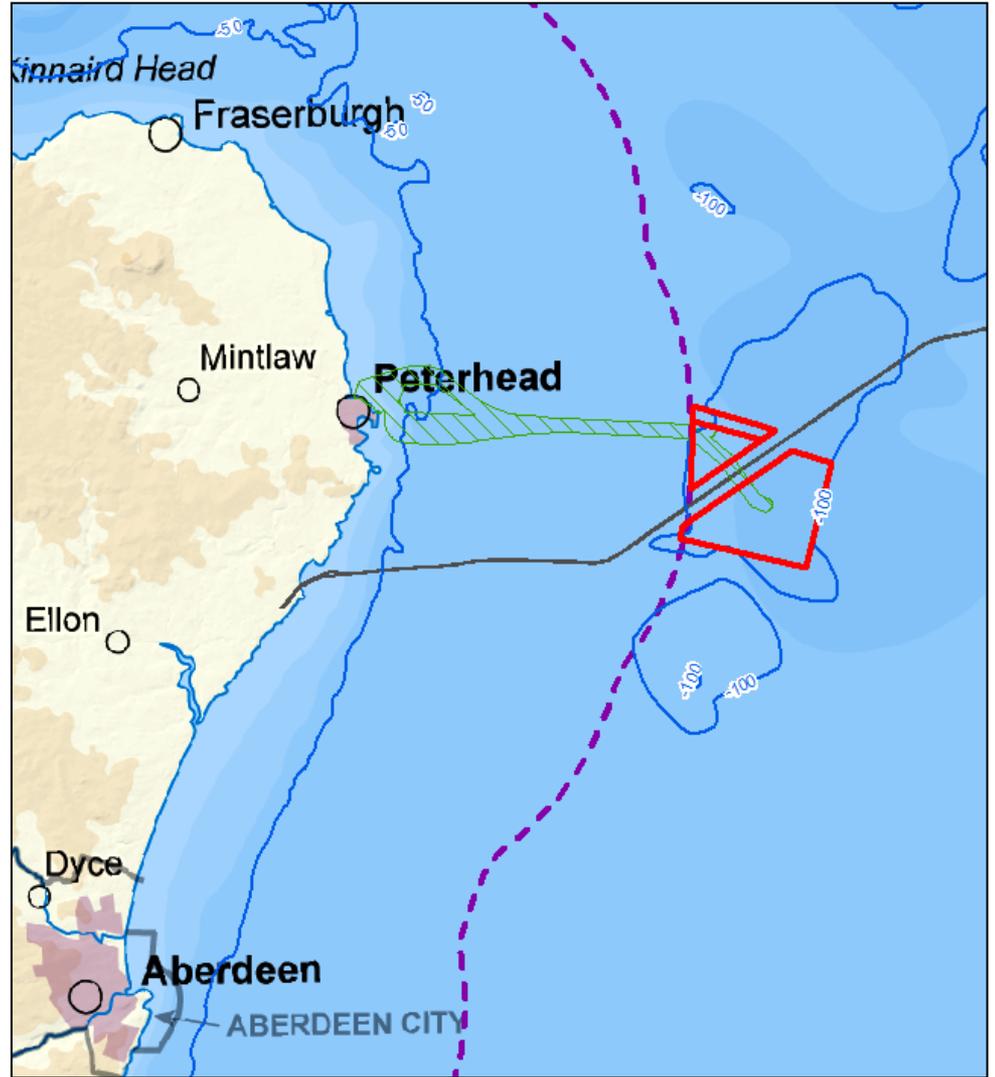


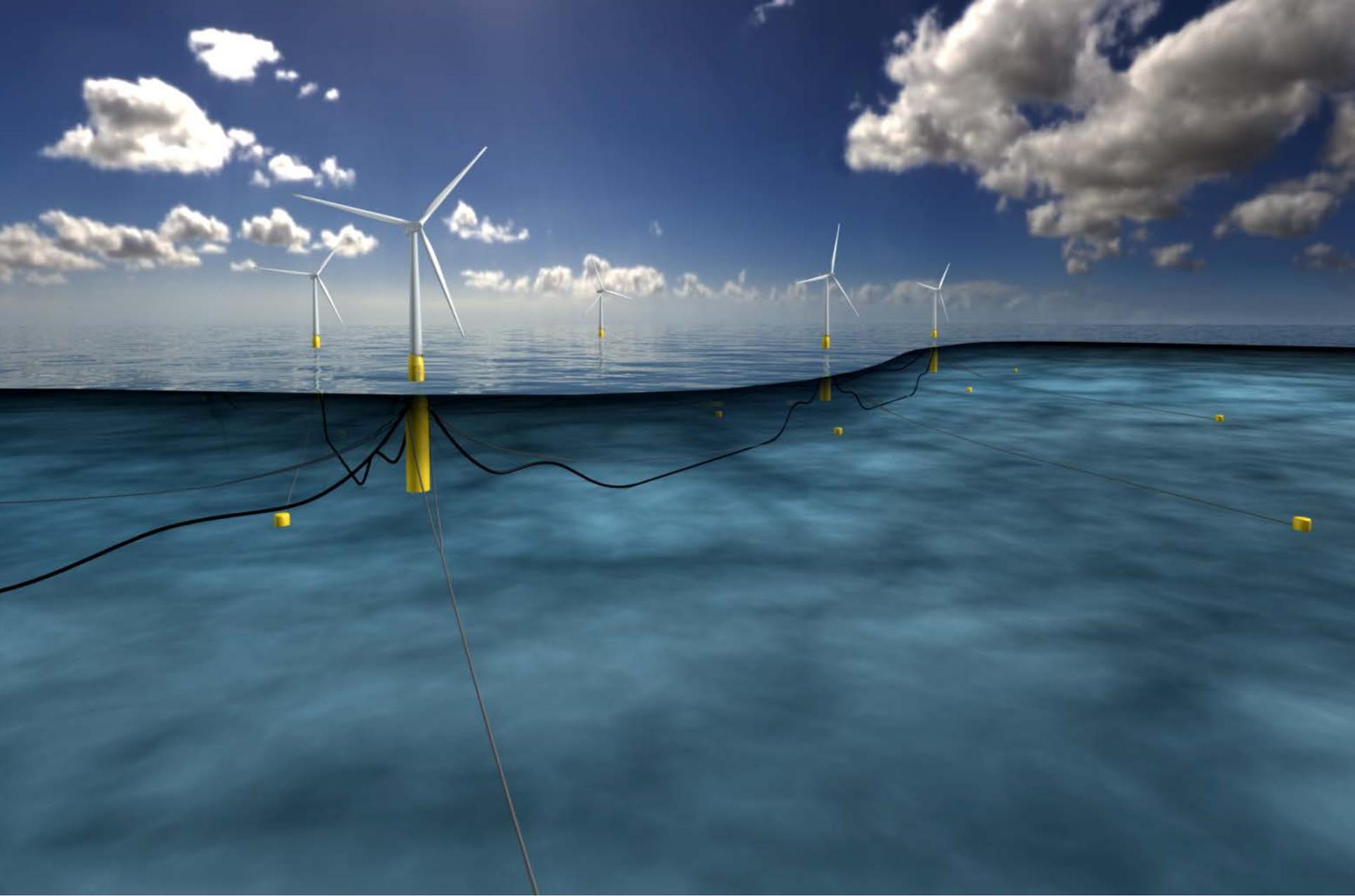
Monopile

# The next steps



# Hywind Scotland - Buchan Deep





There's never been a better  
time for **good ideas**

Is floating offshore wind turbines an option?  
The history of Hywind and

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Senior Advisor / professor  
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[www.statoil.com](http://www.statoil.com)

