Experiences from Hywind Scotland and The Way Forward for Floating Offshore Wind

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Expanding a competitive offshore wind portfolio

Hywind Scotland
start up 2017

Dudgeon
start up 2017

Baltyk II & III - first entry into Poland in 2018

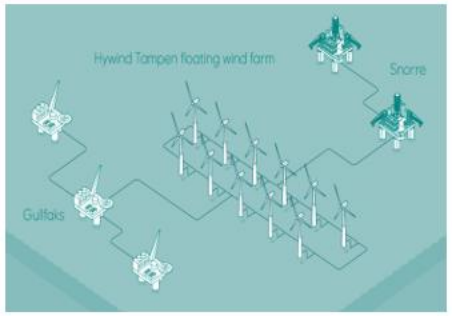
Arkona - first turbine installed in 2018

Batwind
start up 2018

Empire Wind
bid round 2018

Dogger Bank
auction 2019

Hywind Tampen
FID 2019

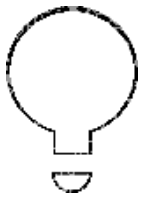


What is Hywind?

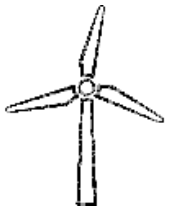
A standard offshore wind turbine placed on a ballasted substructure and anchored to the seabed

- Conventional technology used in a new way
- Simple substructure construction that enables mass production
- Inshore assembly reduces time and risk of offshore operations
- Equinor's floating motion controller uses blade pitch control to dampen out motions

2001
The idea

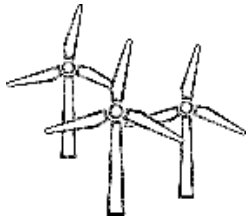


2009
Hywind demo,
Karmøy, Norway



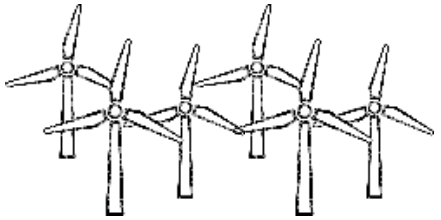
1 turbine@2.3 MW
85 m rotor

2017
Hywind Scotland:
The world's first
floating wind park



5 turbines@6 MW
154 m rotor

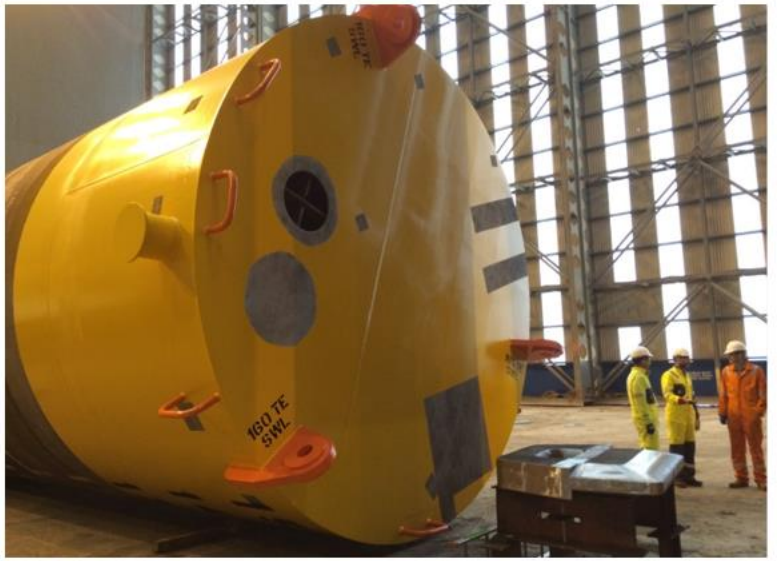
2022
Hywind Tampen:
Wind powered offshore
electrification



11 turbines@8 MW
167 m rotor

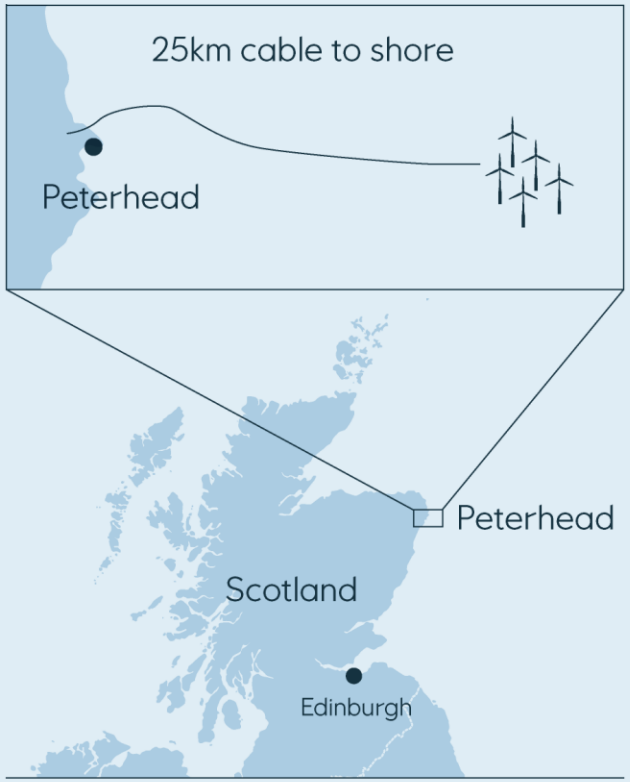
Hywind Scotland Project

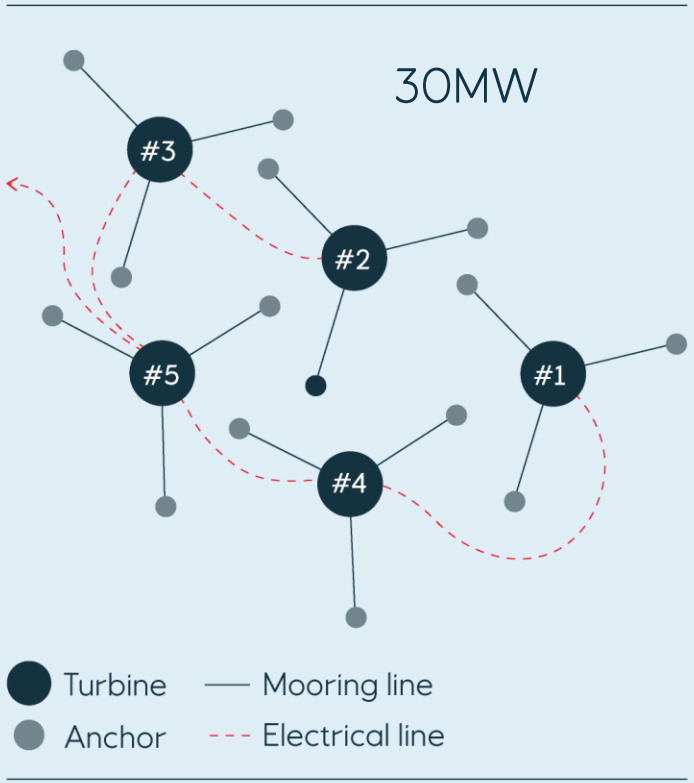
- **Investing around NOK 2 billion**
- **60-70% cost reduction** from the Hywind Demo project in Norway
- **Powering ~20,000 UK homes**
- **Installed capacity**: 30 MW
- **Water depth**: 95-120 m
- **Avg. wind speed**: 10.1 m/s
- **Area**: ~4 km^2
- **Average wave height**: 1.8 m
- **Export cable length**: Ca. 30 km
- **Operational base**: Peterhead
- **Start power production**: Q4 2017

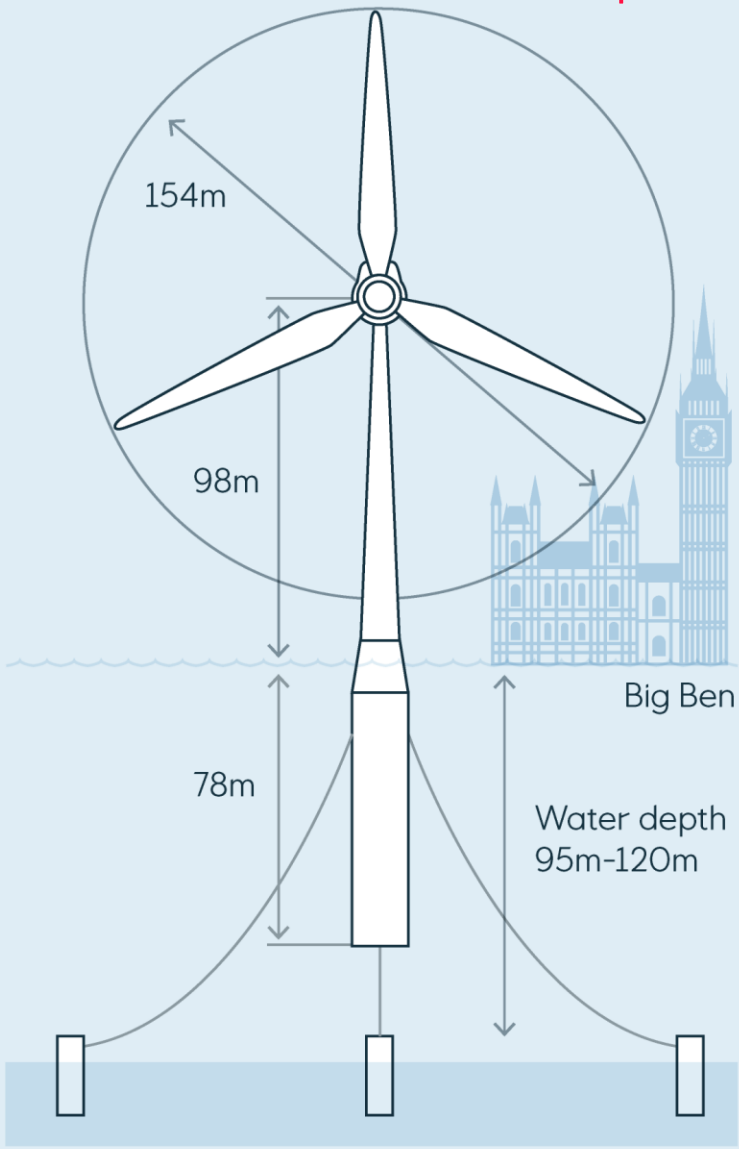


Hywind Scotland – Main Objectives

- Demonstrate cost-efficient and low risk solutions for commercial scale floating wind
- Test, verify and further develop the Hywind motion controller (EMC) for a larger turbine
- Verify up-scaled design
- Verify reliability and availability of optimized multi-turbine concept
- Develop, test and verify a developed motion controller using individual pitch to control yaw motions

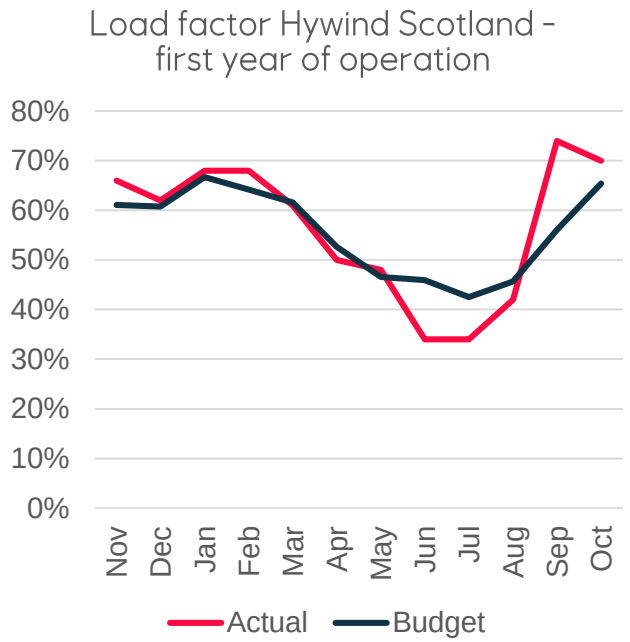






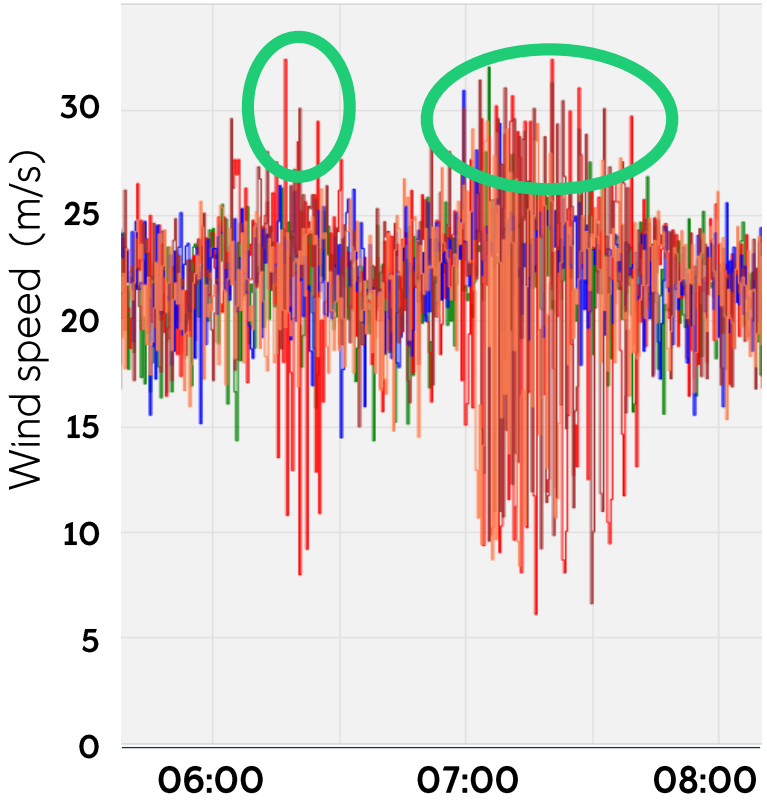
Hywind Scotland – first year of operation

- Successful commissioning and start-up
  - Project delivered on time and without serious incidents
  - Opening in Scotland 18/10 2017
  - Handover to operations 15/11 2017
- First year - performance
  - Production and performance significantly exceeding expectations
  - Average availability: 95%
  - Average capacity factor: 56%
- Next steps
  - Optimize operations, production, costs
  - Test, qualify and develop the technology
  - Input to ongoing and new projects

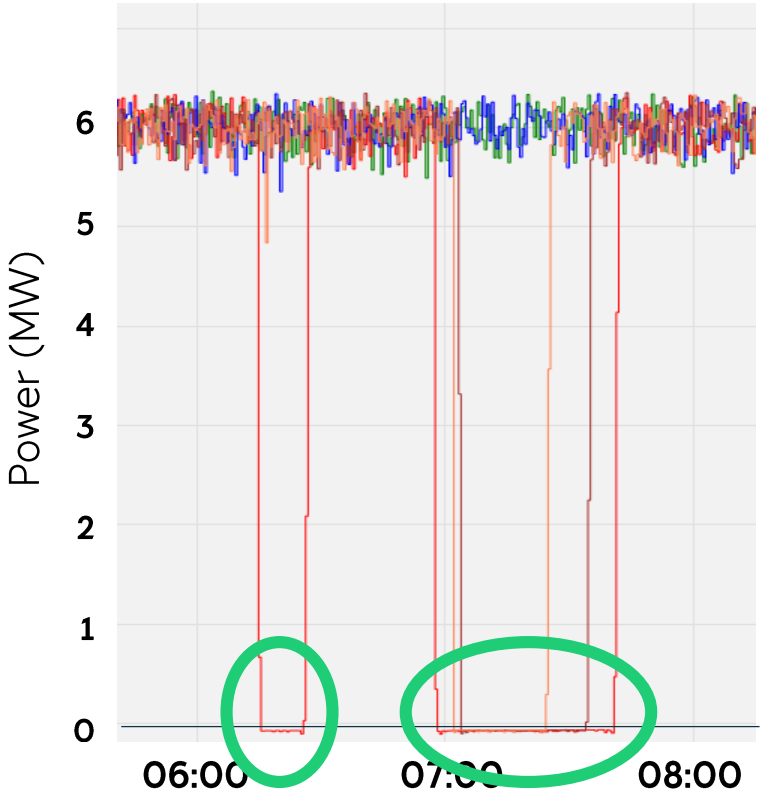


Hurricane Ophelia 17/10 -2017 – Structure Pitch Motion Confirms Design

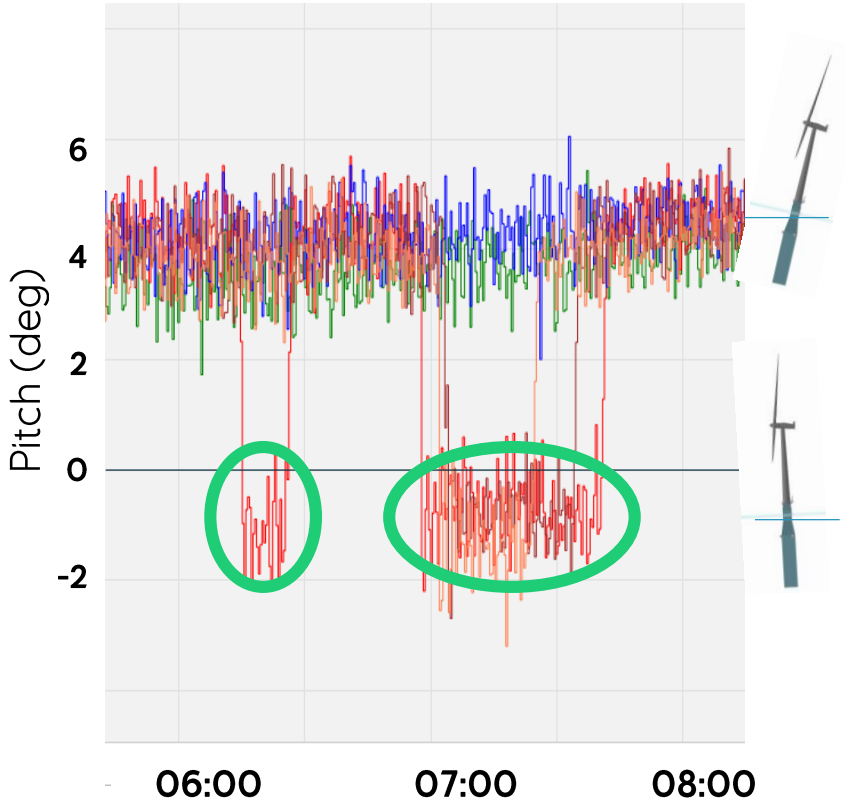
Wind speed – all turbines



Power generation – all turbines



Pitch motion – all turbines



During the hurricane, wind speed exceeds the cut-off level

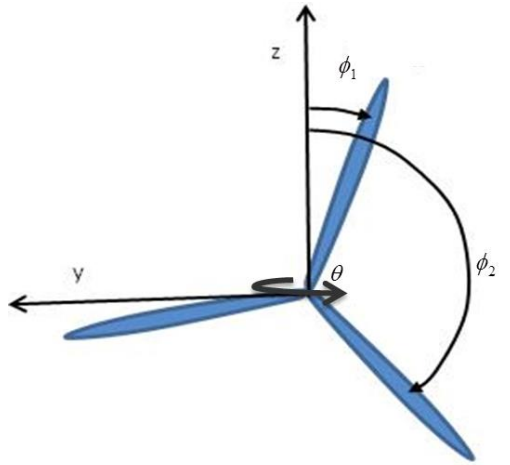
As a consequence, some turbines neutralise their blades and shut down generation

With no thrust force, these turbines pitch back to their neutral position

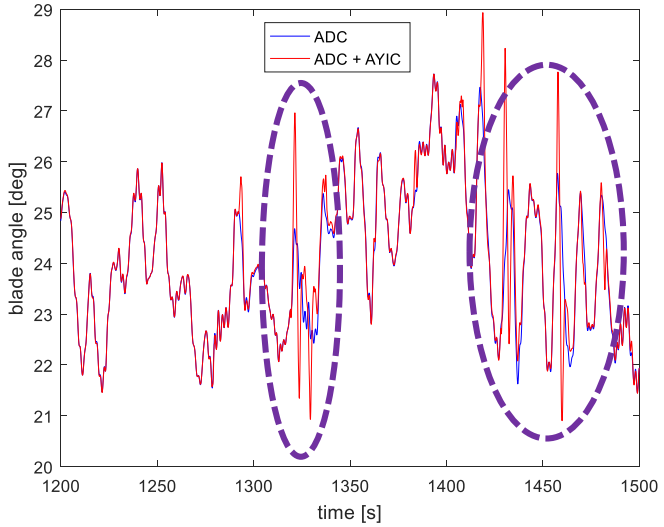
Testing of Advanced Motion Controller Functionality

AYIC Testing:

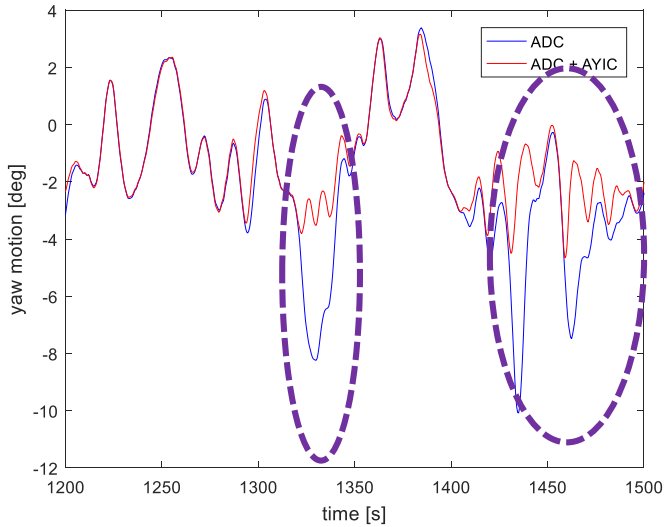
- Active Yaw Individual Pitch Control
- Yaw control in combination with individual pitch is used to reduce the fatigue on the mooring system



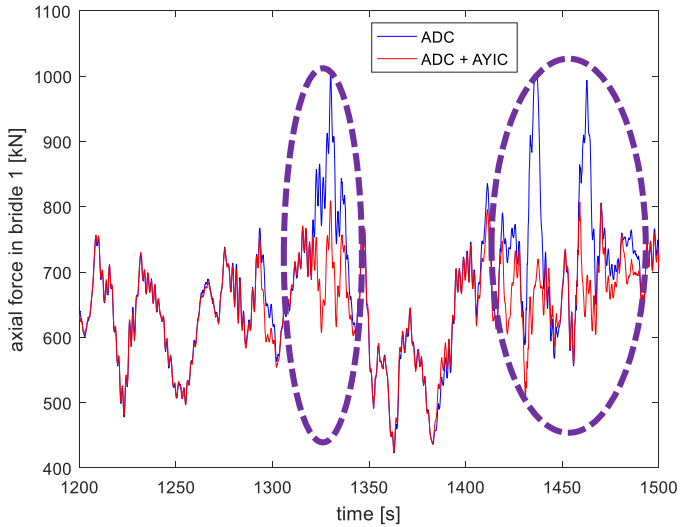
Blade angle



Yaw motion

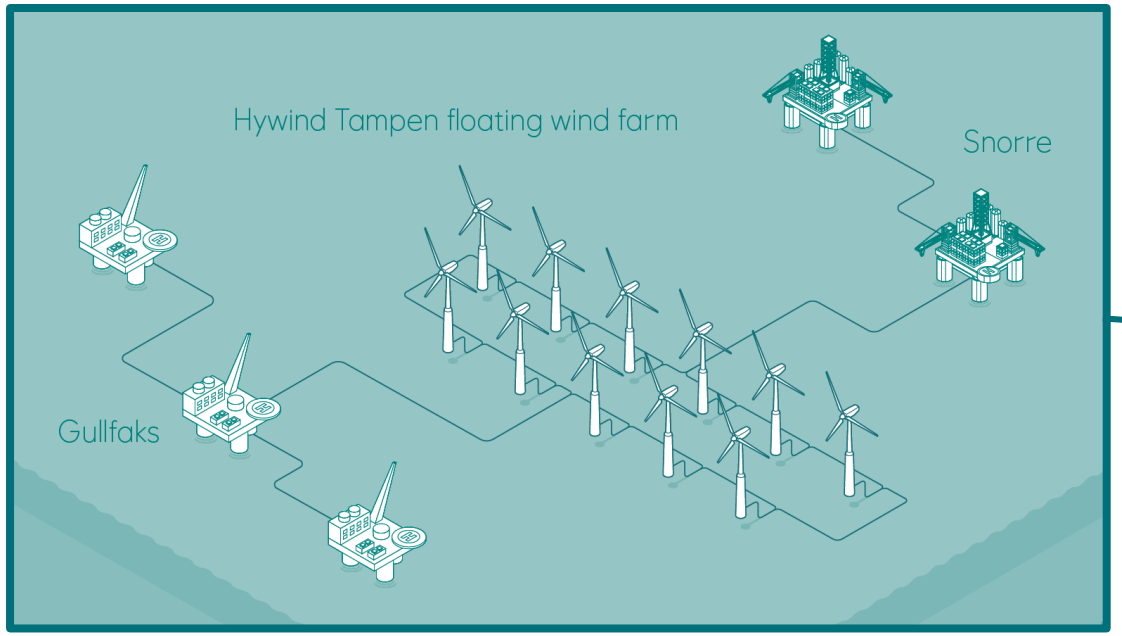


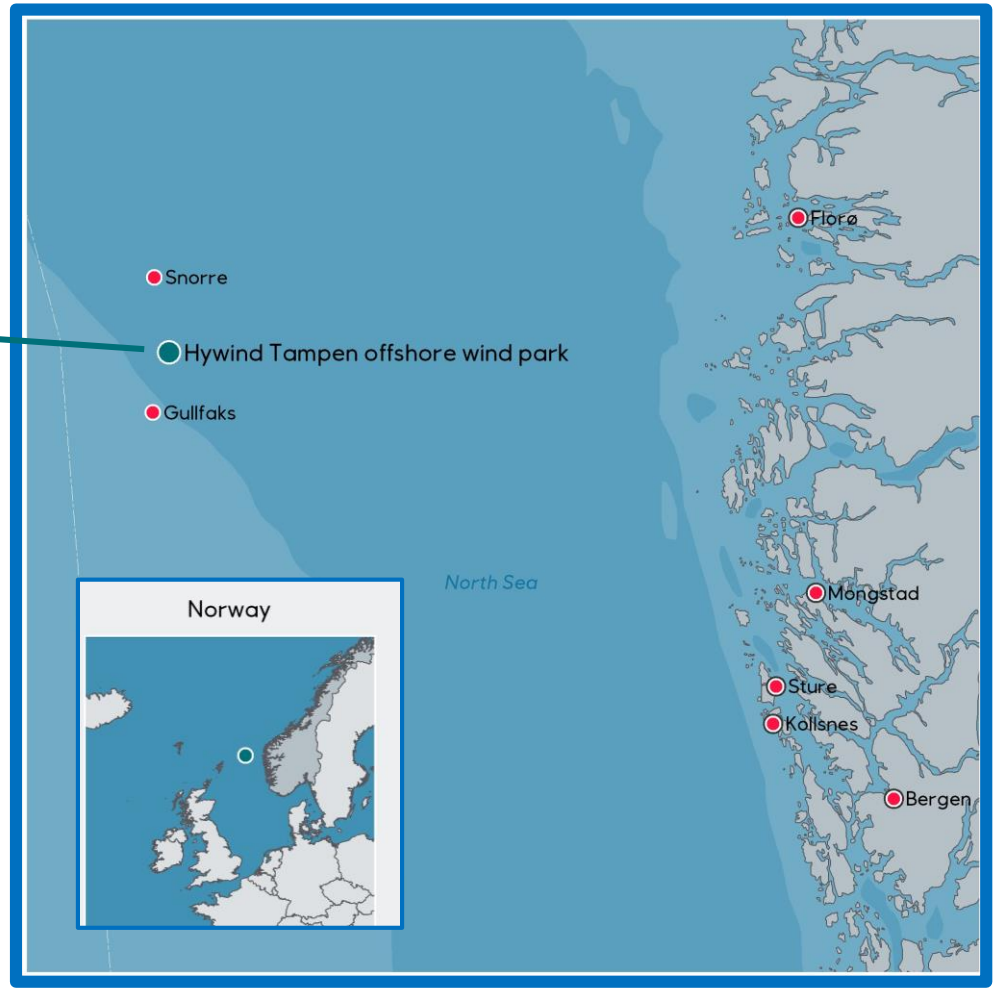
Bridle force



Modified blade angle → Reduced yaw motion → Reduced bridle force

Hywind Tampen – offshore wind farm in the North Sea





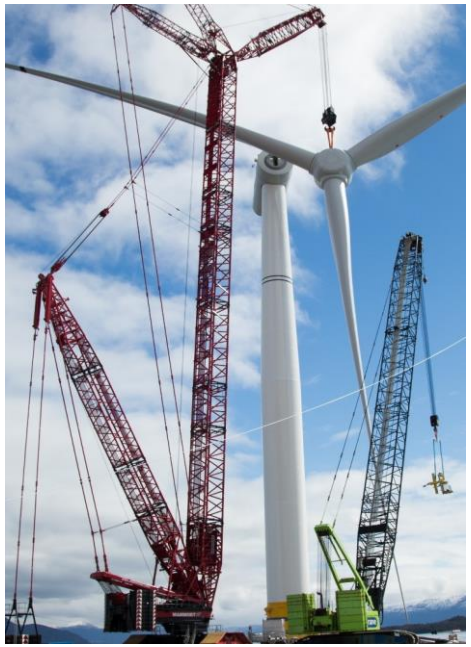
11 wind turbines between Snorre and Gullfaks

Combined capacity of 88MW

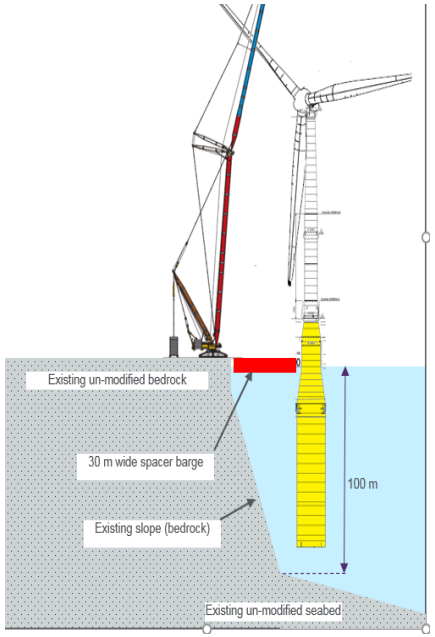
Concrete substructures and shared anchors

Considerable CO2 emission reductions

Technology development at Hywind Tampen



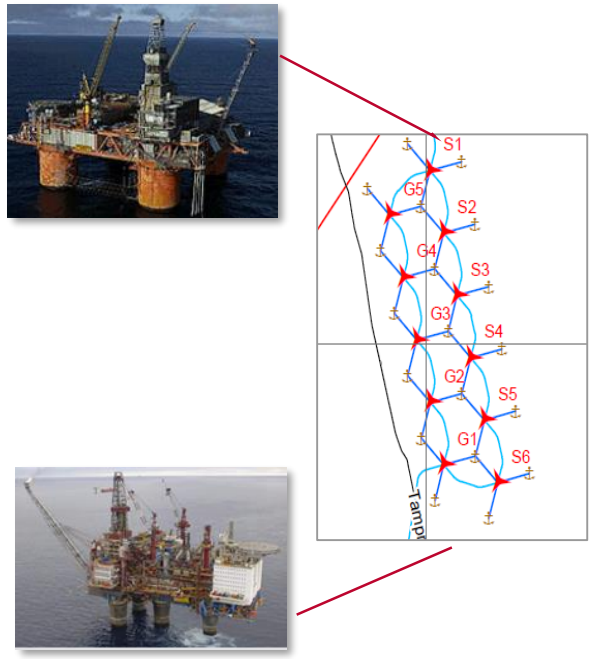
Larger turbines



Installation method

Simplified mooring

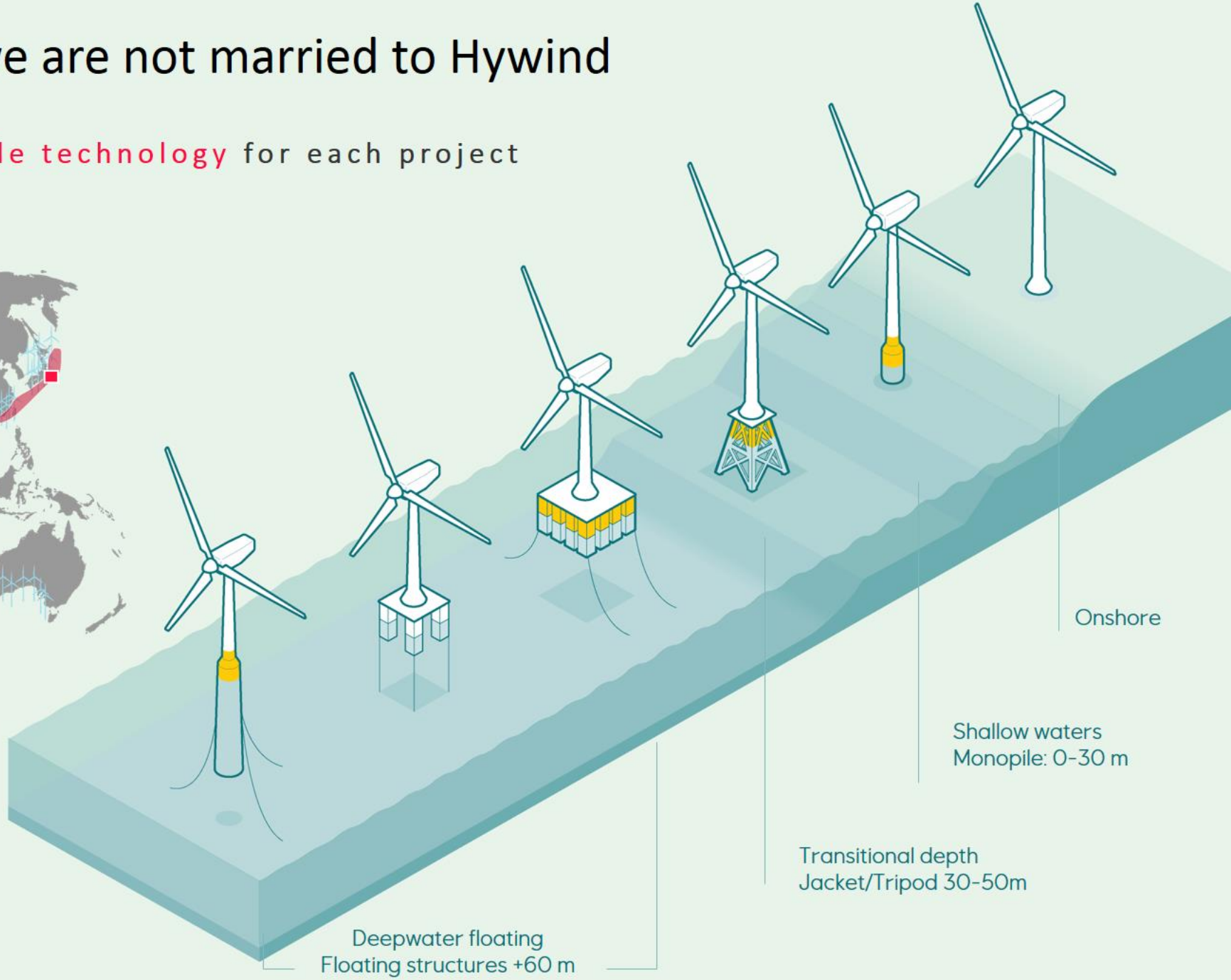
Concrete substructure



Gas and wind power generation system integration

Great potential globally, we are not married to Hywind

We will deploy the best available technology for each project

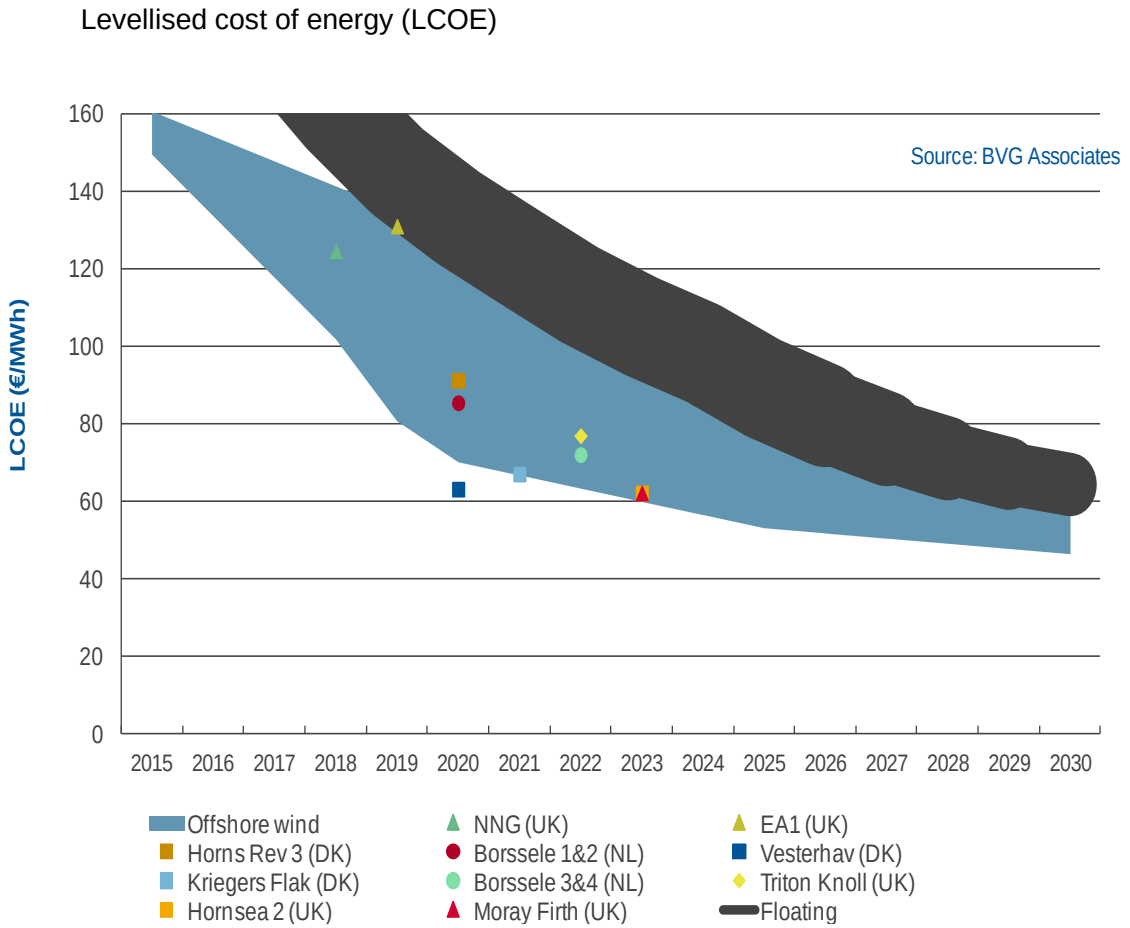


Floating offshore wind – how to reduce costs

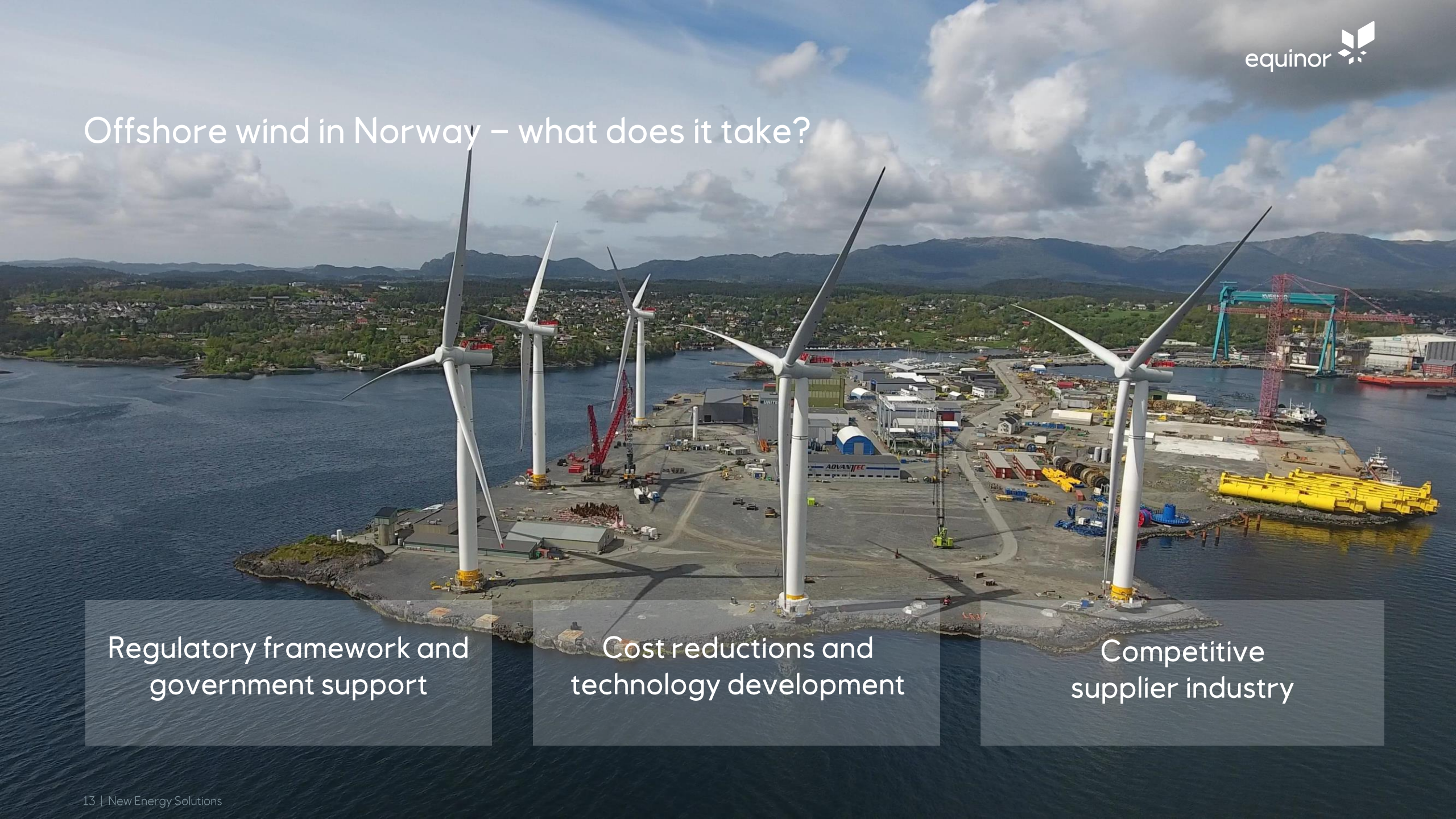
The cost reductions in the floating offshore wind industry can be accomplished through the following key areas:

- Industrialisation: Optimise design of substructure and mooring and reduce the cost per ton towards mass production levels,
- Economies of scale: Larger parks will drive down costs for infrastructure and logistics,
- Upscaling: Follow the bottom-fixed industry towards turbine sizes of 10-15 MW,
- Technology development: Establish new and more efficient methods for installation, operation and maintenance

BVG Associates LCOE trajectory for floating vs bottom fixed offshore wind



Offshore wind in Norway – what does it take?



Regulatory framework and government support

Cost reductions and technology development

Competitive supplier industry

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