Offshore wind innovation competition - launch event

14/05/2018

CATAPULT Offshore Renewable Energy

Agenda

- Background
- Stephen Wyatt, ORE Catapult
- Andy Macdonald, ORE Catapult
- Andrew Tipping, ORE Catapult
- Taylor Mackenzie, Scottish Power Renewables
- Nick Lyth, Green Angel Syndicate

- Lunch & networking

- Innovation Challenges
- Ross Main, Scottish Power Engineering Team
- Andy Kay, ORE Catapult
- Alberto Armella Avila, Scottish Power Engineering Team
- Javier Rodriguez Ruiz, Scottish Power Engineering Team
- Wrap up and networking

Introduction

Steve Wyatt, Director of Research and Innovation

14/05/2018

Catapult Offshore Renewable Energy

ORE Catapult

Our Mission:

Accelerate the creation and growth of UK companies in the ORE sector

- Engineering and research experts with deep sector knowledge
- Independent and trusted partner
- Work with industry and academia to commercialise new technologies
- Reduce the cost of offshore renewable energy
- Deliver UK economic benefit

80+ technical experts

We de-risk technologies with representative testing




Dual axis blade testing, Bearing testing, Novel cables,
Real data for simulations…..

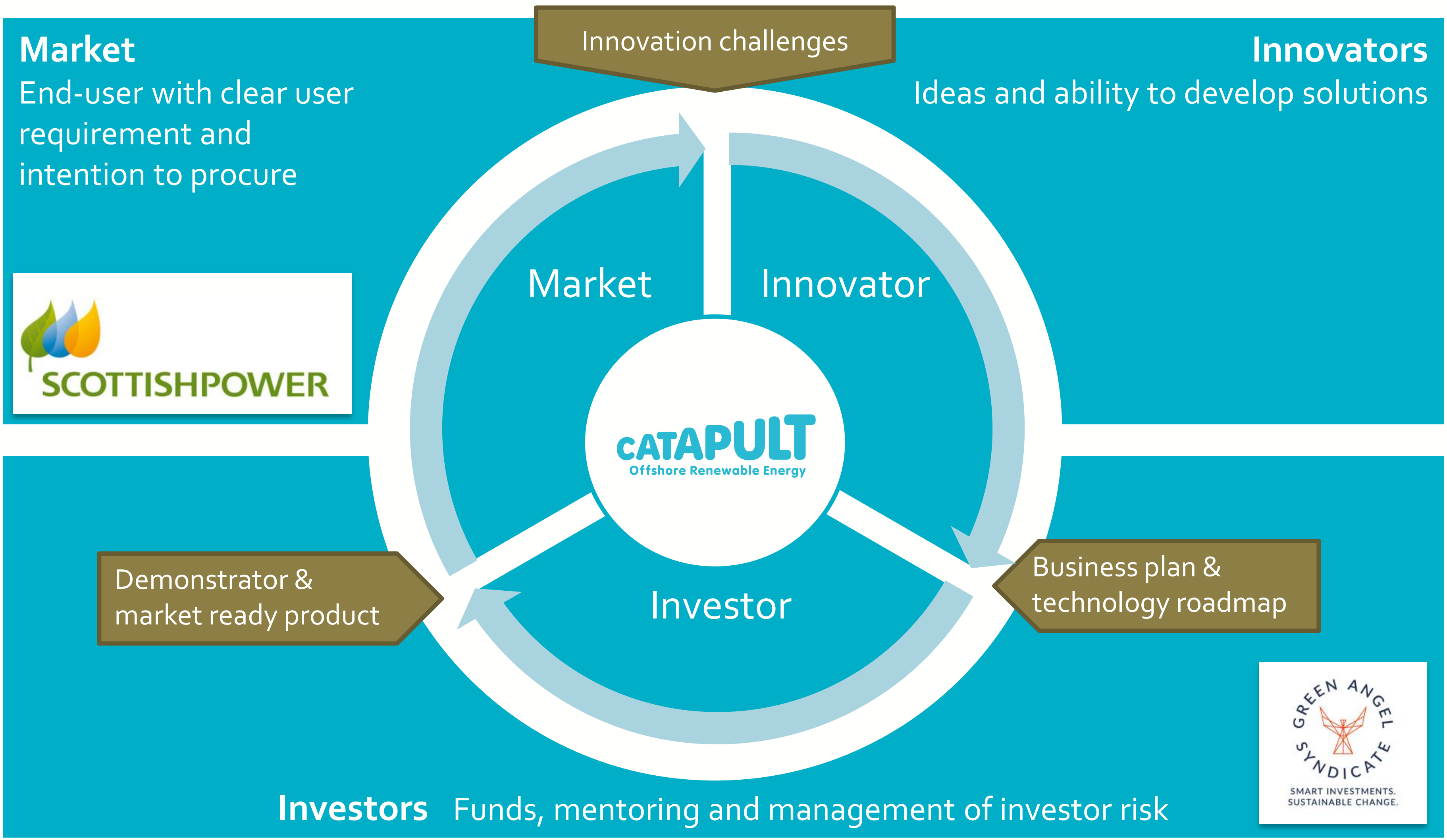
Creating the innovation ecosystem

How Catapult can help

10/08/2017 | Andy Macdonald

Catapult Offshore Renewable Energy

Innovation cycle



How we can help

ORE Catapult SME support services

Innovation challenges
- Providing SMEs with industry-led market opportunities

Technology assessment
- Benchmarking SME innovations and providing confidence to investors

Funding identification
- Supporting product development as partners in public R&D programmes

Engineering and test services
- Delivery of engineering and test capabilities to reduce development risk

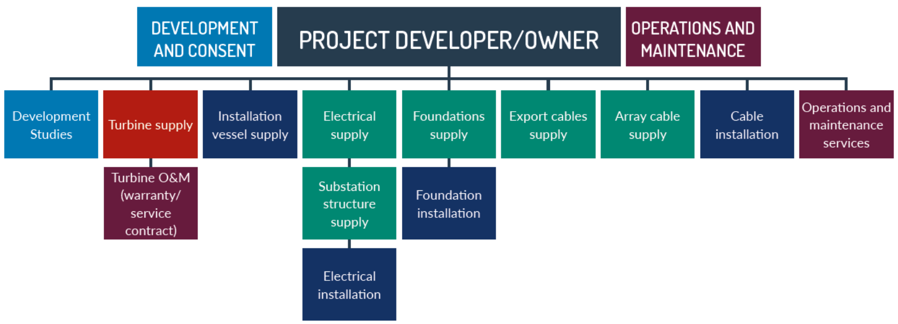
Commercialisation
- Market intelligence, business modelling and commercialisation support

An innovator's guide to the offshore wind market

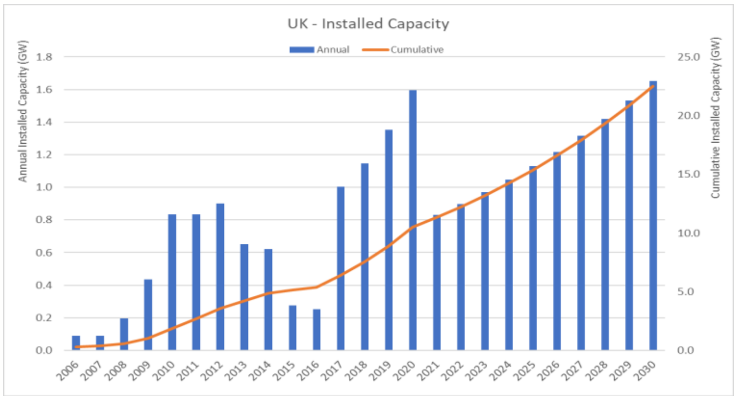
An innovator's guide to finance and funding

An innovator's guide to commercialisation

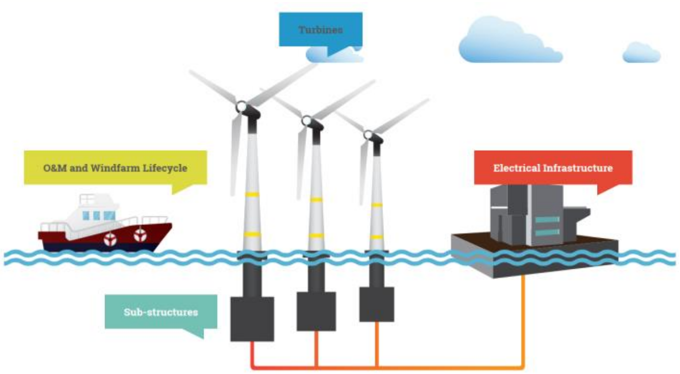
The offshore wind market



Market structure



Market size



Technology trends

PROJECT					
Development and consent	Turbine manufacture	Balance of plant manufacture	Installation and commissioning	Operations and maintenance	Decomissioning
3% of LCoE	25% of LCoE	17% of LCoE	11% of LCoE	40% of LCoE	4% of LCoE
5+ Years CAPEX				up to 25 years OPEX	Up to 3 years DECEX

Project procurement

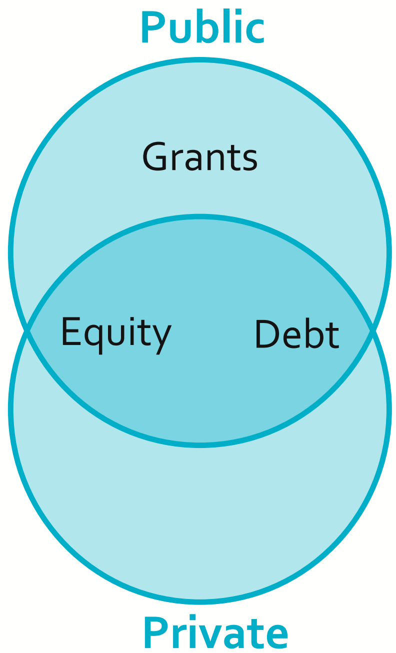
Finance and funding

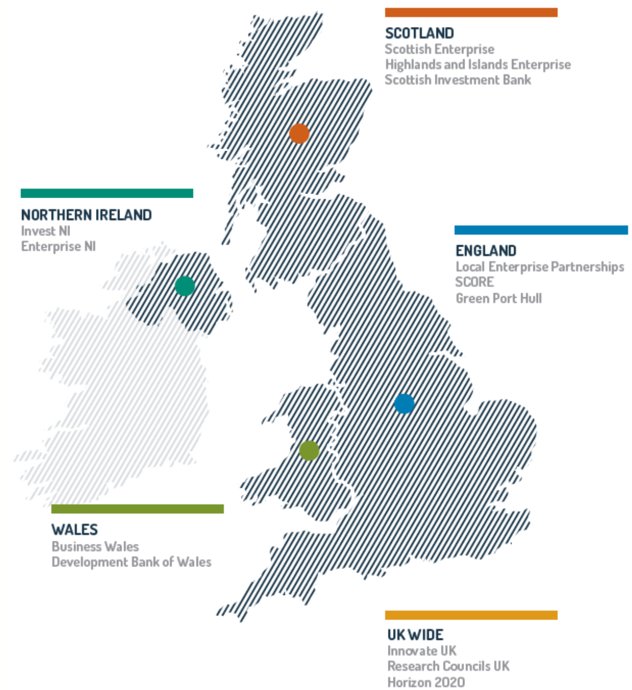
Key considerations

- Investor readiness
- Amount required
- Purpose

Other considerations

- Timeframe
- Flexibility
- Location
- Collaboration
- Specialist support



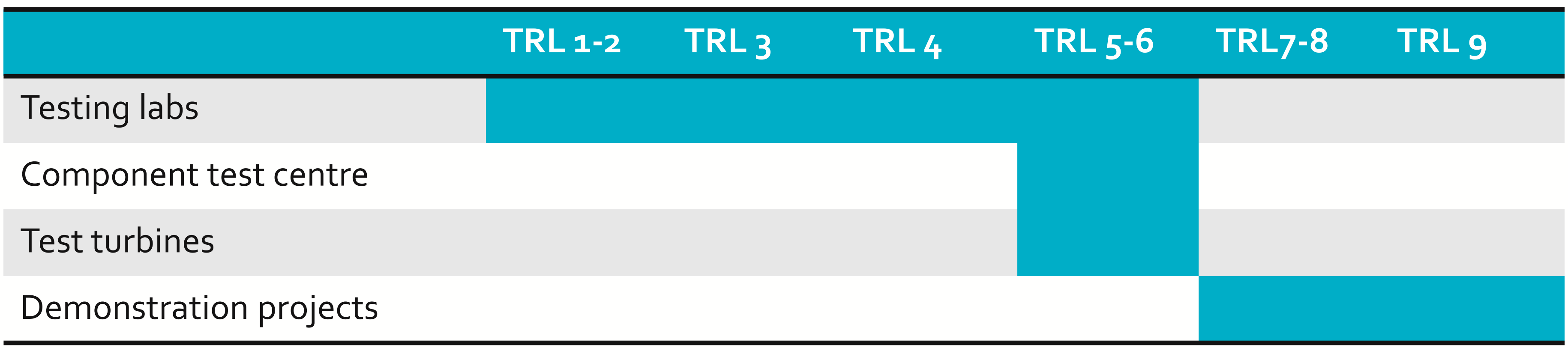


Funding types

Funding sources

Commercialisation

Technology development	Technical steps needed to develop and prove the performance of a technology
Commercial preparation	Steps needed to understand the commercial proposition and successfully position the product within the market
Market readiness	Steps required to ensure the market is ready to receive the technology; this may require operational changes or regulatory change



Case Studies

Limpet Technology

Limpet Technology
Pioneering Total Height Safety

Limpet Offshore Personnel Transfer System

- Turbine access solution using inbuilt lasers to track the motion of a vessel's deck, adjusting the height of a hoist in real time

Benefits

- Lowering O&M costs
- Improving safety & access to far-offshore wind farms

ORE Catapult Support

- Access to full scale operational turbine
- Supported demonstration of a range of technologies
- Building investor and customer confidence

Technicians inspect blade controlling position with Limpet

Limpet's award-winning height safety solution

Wideblue Ltd

wideblue
making technology happen

- Optical condition monitoring system for blades
- System of lasers to monitor the blade's health
- First ever to be installed INSIDE the blade

Benefits

- Capture structural & blade shape info from whole span, not just root

ORE Catapult support

- Test system on 88m blade + possibly Levenmouth
- Sector knowledge (new sector for WB)

View of the inside of a blade

ACT Blade

ACT Blade Ltd

Novel blade technology from sailing sector to renewables

- Two genuinely groundbreaking ideas:
    - a **textile** blade and a **modular** blade

Benefits

- Cost reduction
- Increased efficiency of energy production,
- More eco-friendly materials

ORE Catapult Support

- SMAR AZURE responded to Blade Innovation Challenge
- Identified funding avenues & co-developed bid
- Secured 3 rounds of Energy Catalyst funding (IUK)
- ACT Blade Ltd set up to exploit technology

Innovate UK

SMAR AZURE design and manufacture sails

Tekmar

tekmar® Control Systems

ORE Catapult's Support

Replicated a full scale cable pull in trial in our shallow water test facility, to simulate the offshore operation of the Tekmar's cable protection system to key customers

Result

Tekmar secured an order for 92 TekTube systems for the Westermeerwind offshore wind project

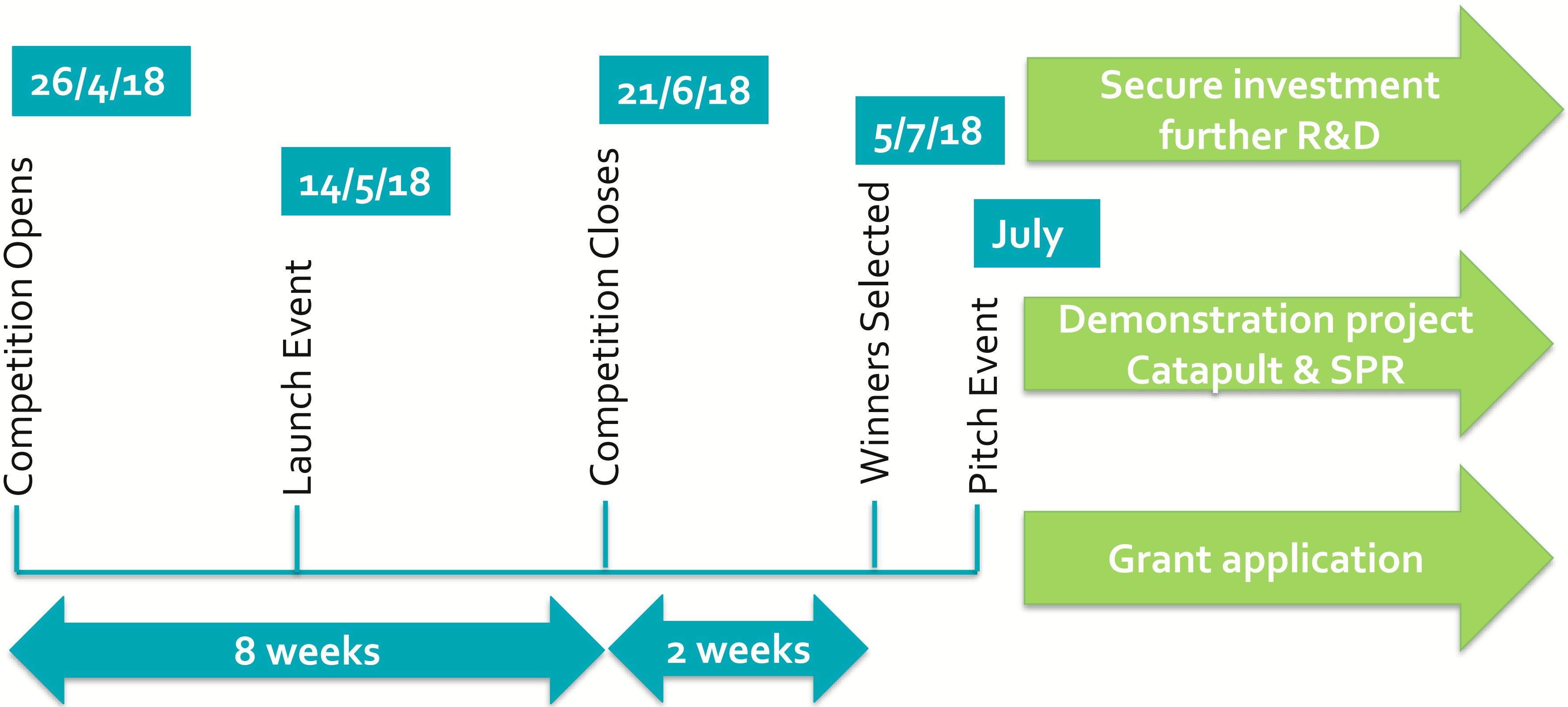
Pull in trial at ORE Catapult

Offshore wind innovation competition
How it works

14/05/2018

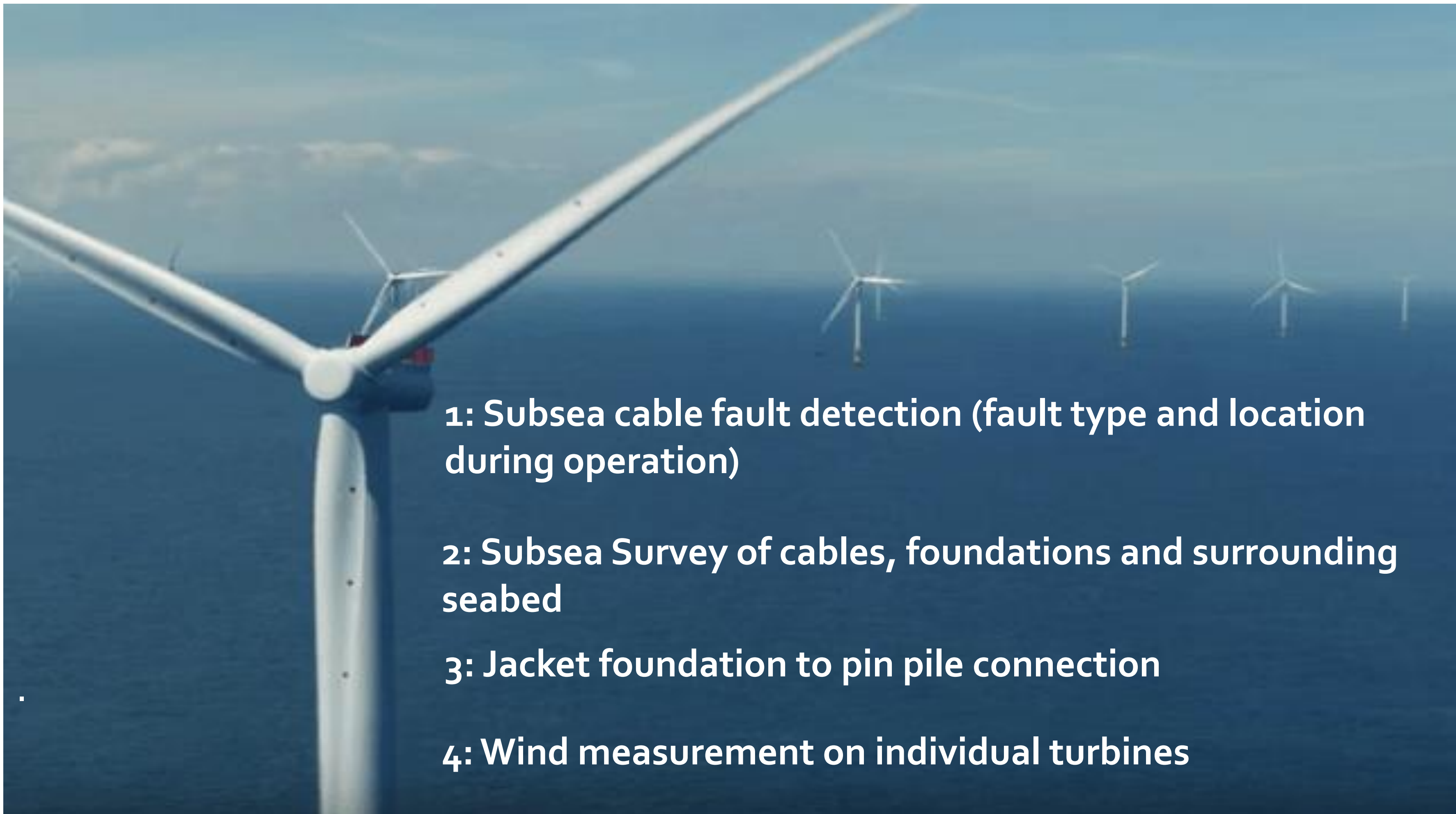
Catapult Offshore Renewable Energy

Competition Timeline



Four Industry Challenges:

SCOTTISHPOWER



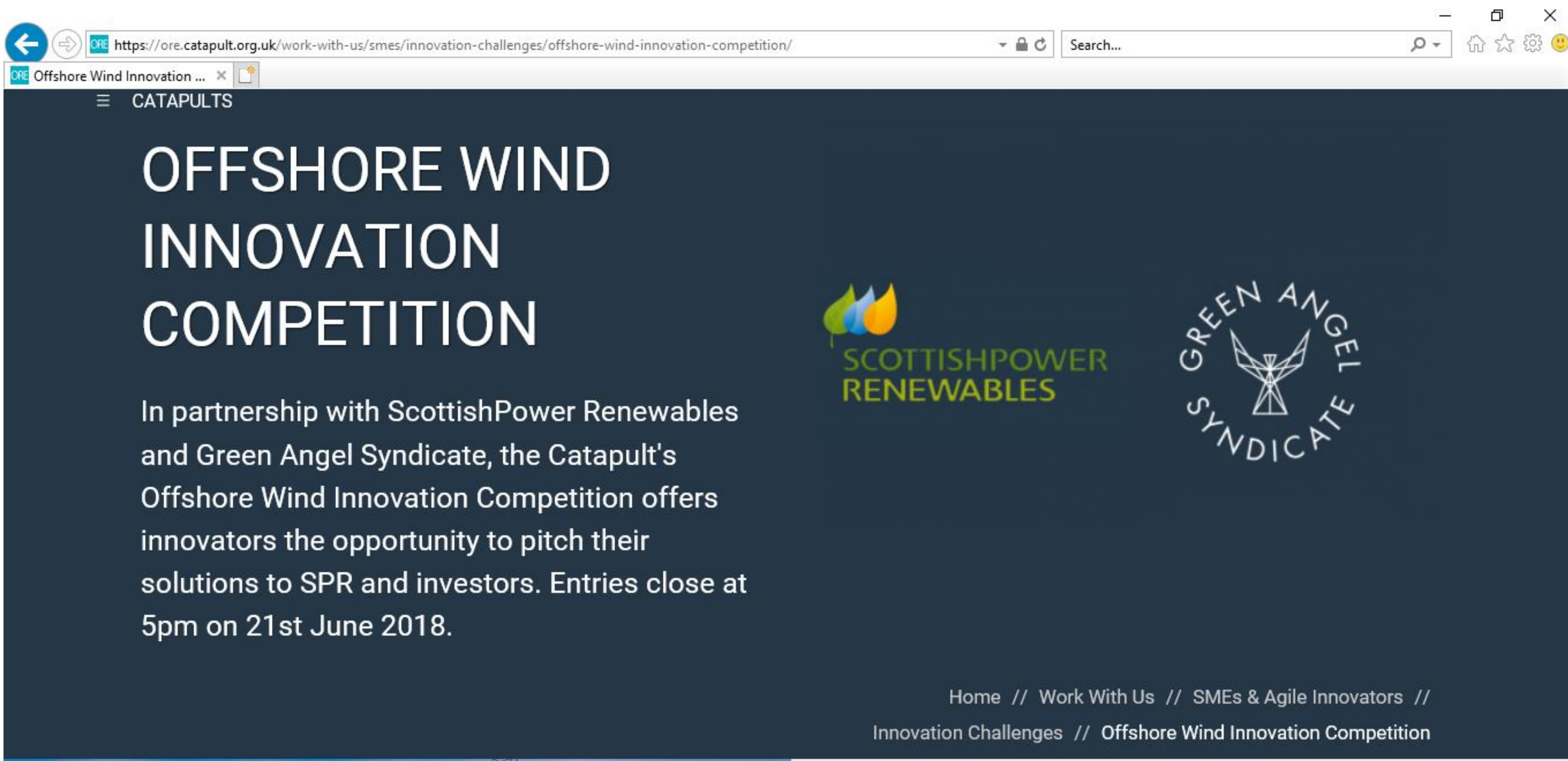
1: Subsea cable fault detection (fault type and location during operation)

2: Subsea Survey of cables, foundations and surrounding seabed

3: Jacket foundation to pin pile connection

4: Wind measurement on individual turbines

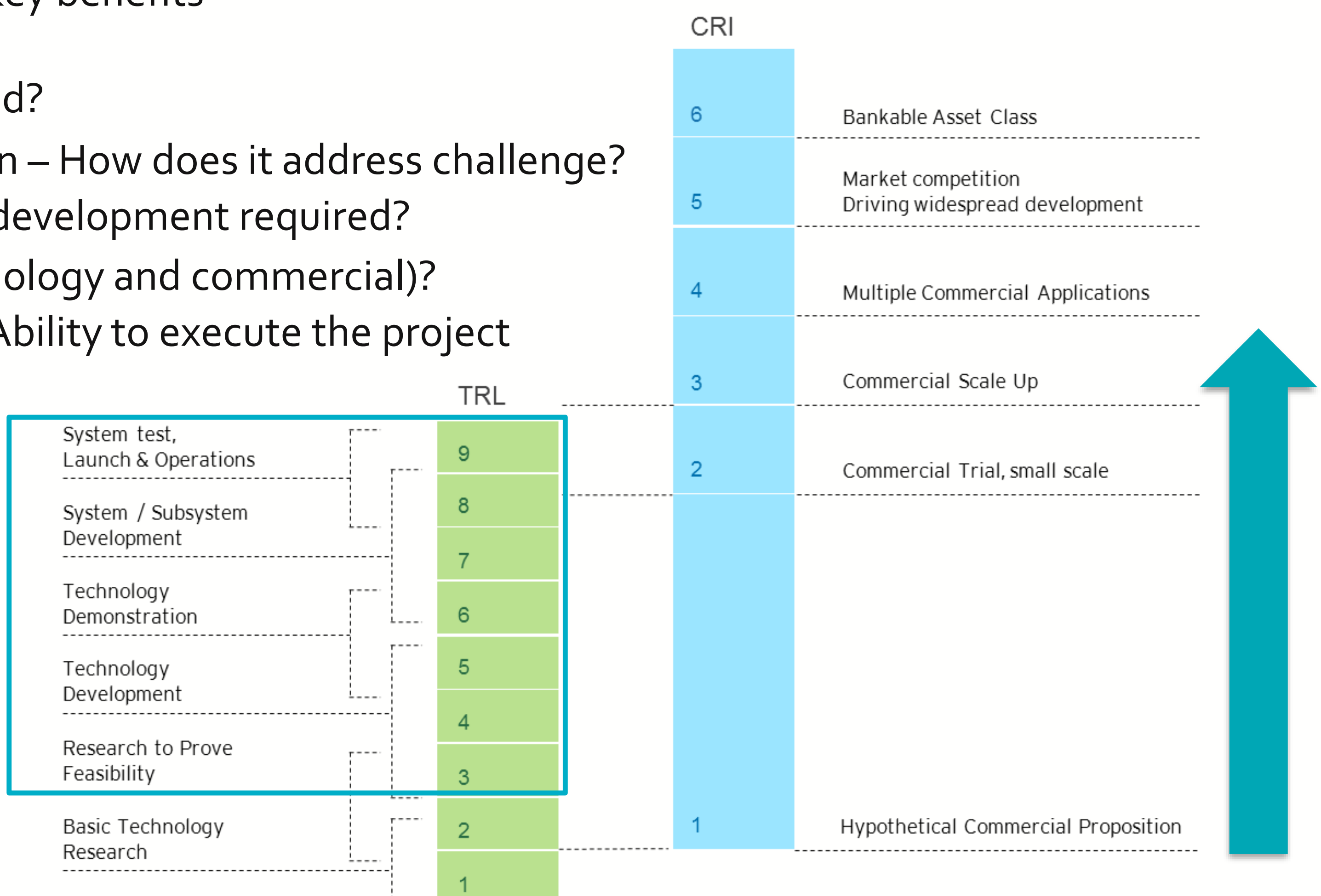
Competition Portal



Challenge areas launched on website with Expressions Of Interest (EOI) process **https://ore.catapult.org.uk/work-with-us/smes/innovation-challenges/offshore-wind-innovation-competition/**

Application

Q3: What is it? Key benefits
Q4: TRL
Q5: IP – Patented?
Q6: Your solution – How does it address challenge?
Q7: Additional development required?
Q8: Risks (technology and commercial)?
Q9: Company? Ability to execute the project



Source: https://arena.gov.au/assets/2014/02/Commercial-Readiness-Index.pdf

Selection process

SCOTTISHPOWER

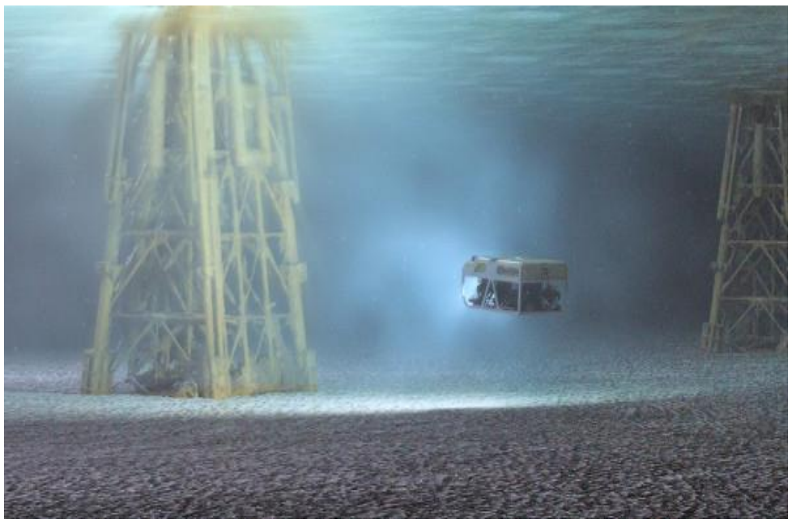
CATAPULT Offshore Renewable Energy

GREEN ANGEL SYNDICATE
SMART INVESTMENTS. SUSTAINABLE CHANGE.

2 x concepts / challenge taken forward

Case study: Mobilising investment

ROVCO
The Future Of Subsea Technology - Today



£200k Grant

Innovate UK

£1.3m Private Investment

Green Angel Syndicate
SMART INVESTMENTS. SUSTAINABLE CHANGE.

sustainable ventures

Commercialisation of 3D subsea survey visualisation technology

ScottishPower Renewables Innovation

Taylor McKenzie

Innovation Analyst

Leader in clean energies

Iberdrola, **leader in renewable energies** with an installed capacity of **29,100 MW[2] and 1st wind energy producer worldwide…**

1st investor worldwide in renewable energies: £27 billion renewable investment till 2016 and close to additional £8.1 billion planned to 2020[1]

1.2017-2020 investment

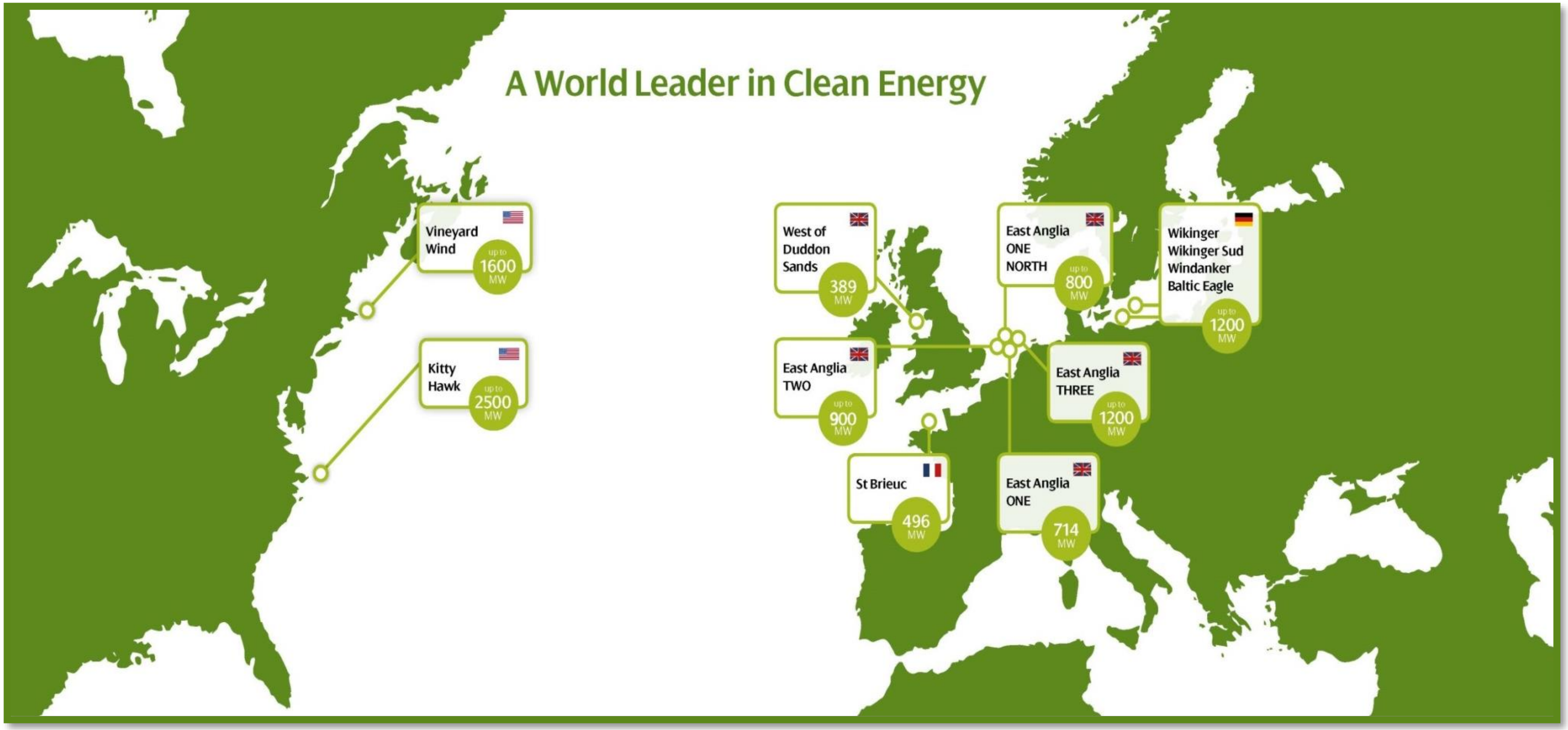
2. Includes hydro capacity

Wind energy Ranking

- **… # 1 Worldwide**
- **… # 1 Europe**
- **… # 1 United Kingdom**
- **… # 1 Spain**
- **… # 3 US**

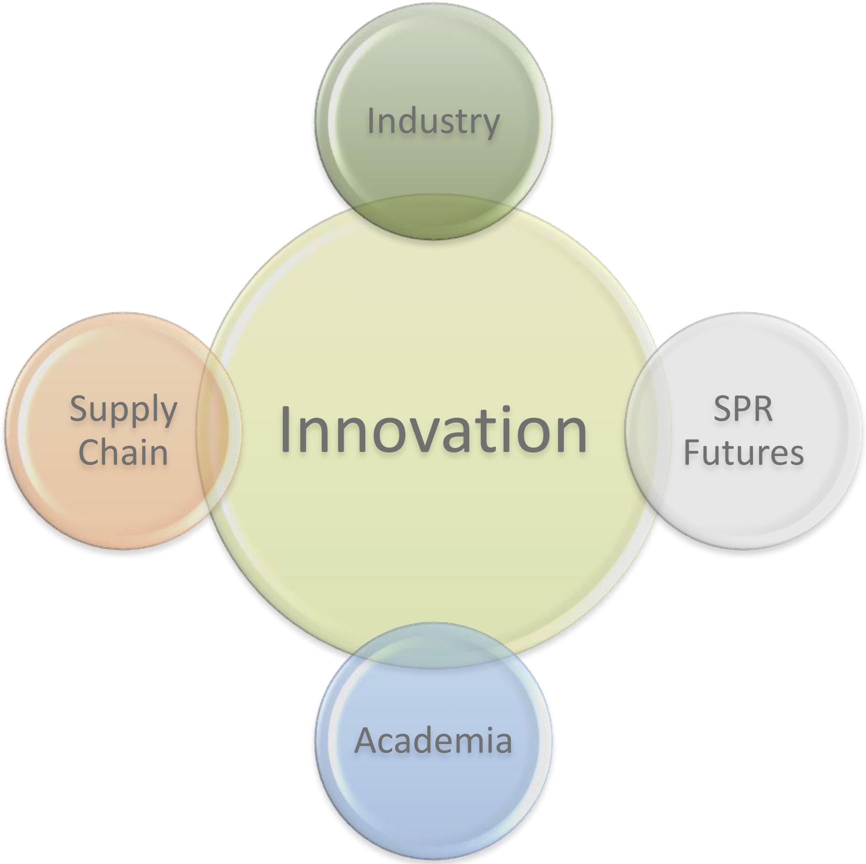
…and leveraging **solar solutions for** our **domestic** and **industrial clients**

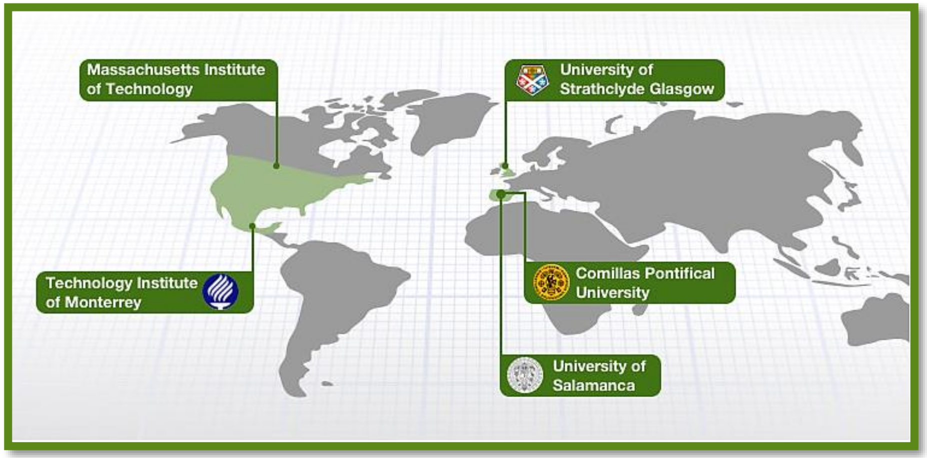
Iberdrola World Wide Offshore Projects



Iberdrola, "utility of the future"

SPR Innovation



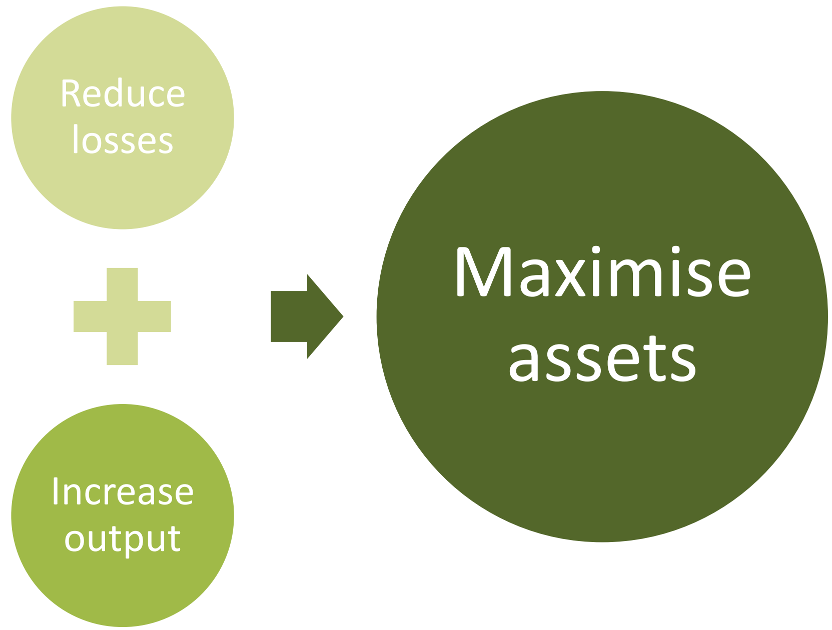


Optimisation

What <u>more</u> can we do with our existing portfolio?

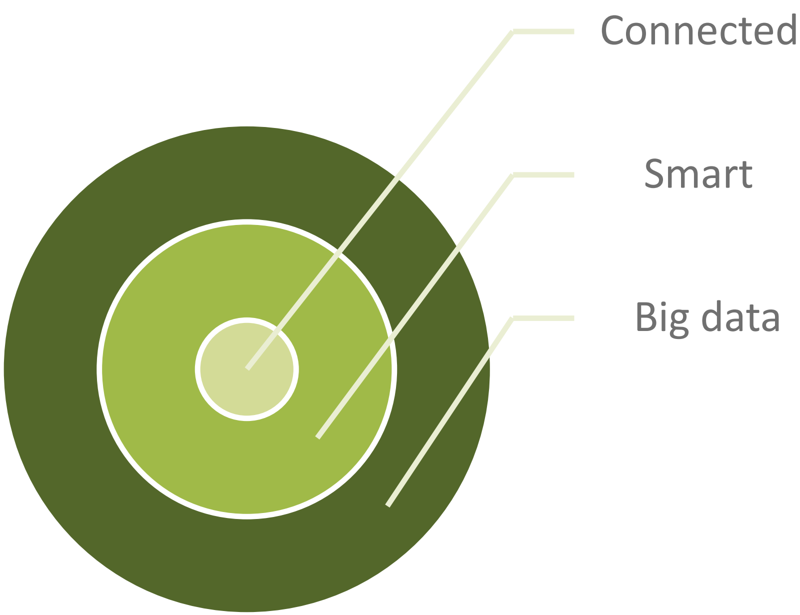
- Maximise efficiencies in our technology
- Availability vs profitability?
- In-depth knowledge of operational assets

http://ora-system.com/index.php/features/header-footer



Digitalisation

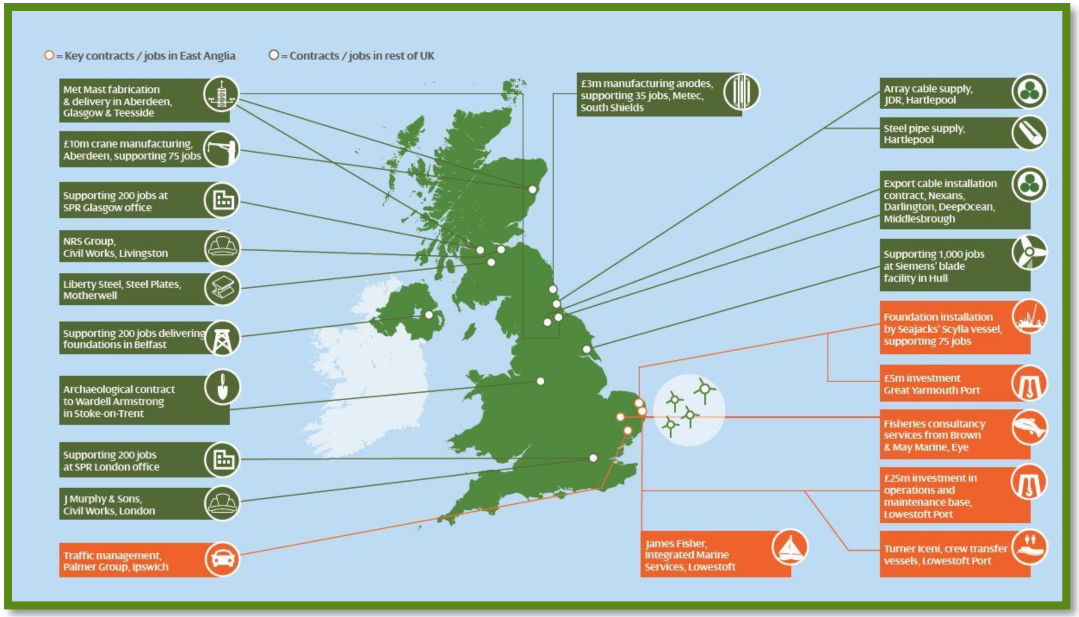
- Using digital solutions to streamline business processes
- Informed decisions ➔ machine learning
- Combining technology suppliers with service providers



http://www.iotl.com/engineering-and-development/avnet-iot-communities-evolving-iot-community-grows

Collaboration

Committed to supporting the UK content through our EA1 Supply Chain Plan



EA1 UK contracts

Economic impact over the lifetime of the projects

£1.2bn gross value-added in the UK	31,118 UK FTE years	£814 million UK earnings

"Economic benefits from onshore wind farms" - BVG associates

Contact us

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ScottishPower

Securing investment:

Nick Lyth
Green Angel Syndicate

Lunch and networking

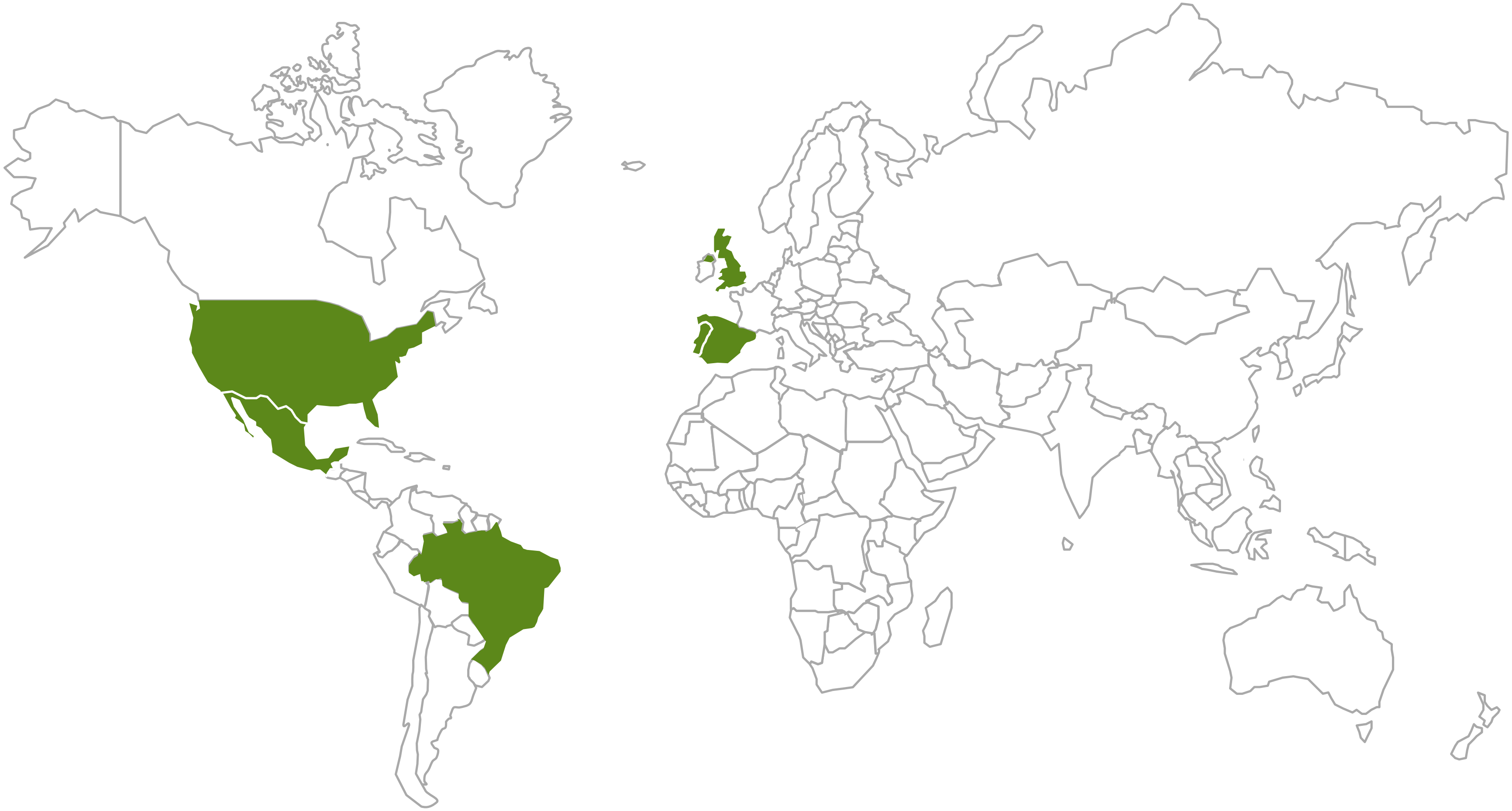
Ross Main
Senior Electrical Engineer
EA1 Electrical Design Manager
May 2018

Condition Monitoring & Fault Detection in Subsea Cables

Strong expansion in offshore wind, including excellent progress with Wikinger windfarm in Germany

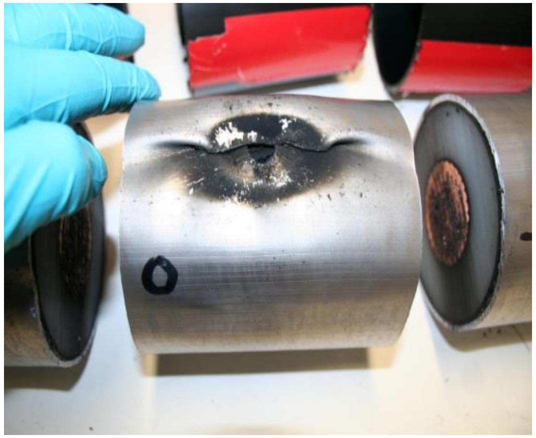
Group's Global Offshore Business managed from Glasgow
West of Duddon Sands windfarm fully operational (389 MW)
East Anglia ONE (714 MW) under construction
Wikinger (350 MW, Germany) under construction: Turbine installation complete
Saint Brieuc (500 MW, France) under development
USA Development Projects in North Carolina and Massachusetts (3000 MW)

Iberdrola Around The World



The Issue

- Subsea cables only account for a fraction of the development cost of offshore wind generation
- Around 80% of insurance claims are attributed to cable failures
- Claims in the region of EUR 60 million per year (often excluding loss of generation)
- Subsea cable repairs are expensive and time consuming
- Weather as well as vessel and spare component availability can delay repairs




The Challenge (Condition Monitoring)

- Subsea cable faults can result from issues during the design, manufacture, installation or operation phase
- Continuous monitoring of cables during each project phase may help to prevent or pre-empt such failures and allow for better planning of offshore remedial works (scheduling & availability of vessels, personnel and spare parts)
- The vast majority of subsea cables in offshore wind generation feature an integral (or local) fiber optic cable which is seen as a primary starting point for the development of such a monitoring system
- Parameters such as strain, temperature, insulation resistance and electrical loading are key to condition monitoring of subsea cables
- Monitoring systems would ideally be:

Low Cost (CAPEX / OPEX)

Real Time

Utilise Existing Infrastructure

Applicable Across Lifespan of Cable

Low Maintenance

The Challenge (Fault Detection)

- IAC fault detection in offshore wind farms can take several forms ranging from **manual switching** to **active systems** utilising voltage detectors and directional fault indicators (plus associated CT / VTs)

	Manual Detection	Active Detection Systems
Pros	• No added costs • No additional equipment required	• Faster than Manual Detection • Accurate • Minimises switching duty on equipment
Cons	• Exposes equipment to further switching duty following initial fault • Time consuming • Requires SAP availability	• Incurs additional costs upwards of EUR 1 million • Requires additional equipment • Consequential maintenance of additional equipment

- The LCoE can be reduced considerably by minimising fault location times
- A system which utilises the associated fibre optic infrastructure and combines **condition monitoring** and **fault detection** may further reduce the LCoE

Thank you for your attention

SPR Innovation Challenge #2
Subsea Survey and Inspection

14/05/18

Andy Kay – O&M Strategy Manager
andrew.kay@ore.catapult.org.uk

CATAPULT Offshore Renewable Energy

Subsea survey and inspection

Why survey and inspect?

Pre – installation phase

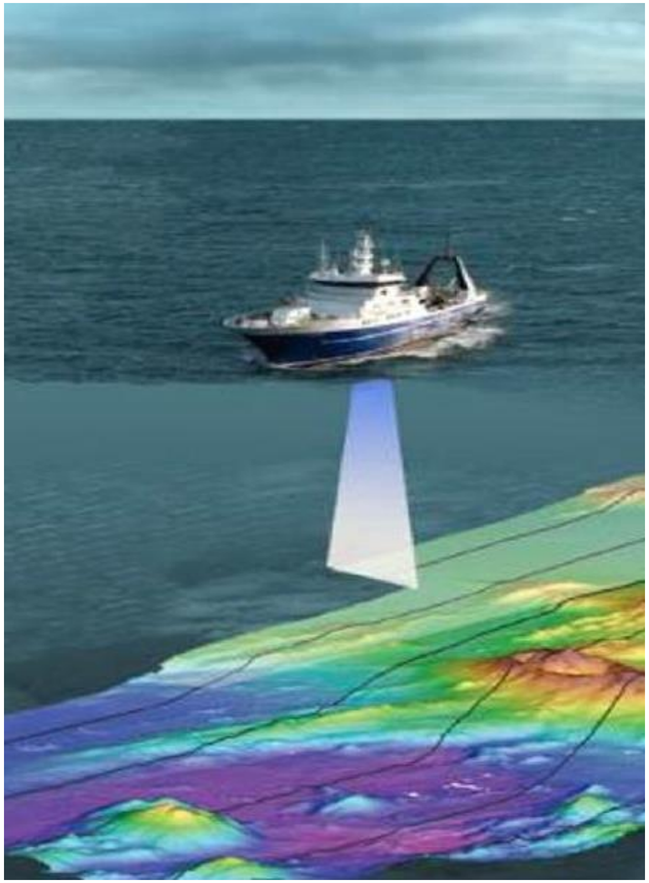
- Site investigation (36 months):
  - Geotech survey (seabed properties/morphology);
  - Geophysical survey (seabed seismic activity);
  - UXO surveys;
  - Cable/foundation placement and cable burial.

Installation phase

- Installation verification (18 - 22 months):
  - 'As-laid' survey (verify position - cables/foundations);
  - 'As-built' survey (verify cable burial).

Post – installation phase

- Monitoring and maintenance planning (ongoing):
  - Consent - marine authority surveys (first 3-5 years);
  - Cable condition and burial status;
  - Foundation condition and scour;
  - Sediment movement and level;
  - Areas of archaeological interest



Offshore wind subsea survey

Current approach and limitations

How it's done and limitations

Vessel mounted and/or towed sensors

- Acoustic inspection:
    - Side-scan sonar (seabed properties data)
    - Swathe bathymetry (seabed depth);
    - Sub-bottom profiler (properties and depth).

ROV deployed from a vessel

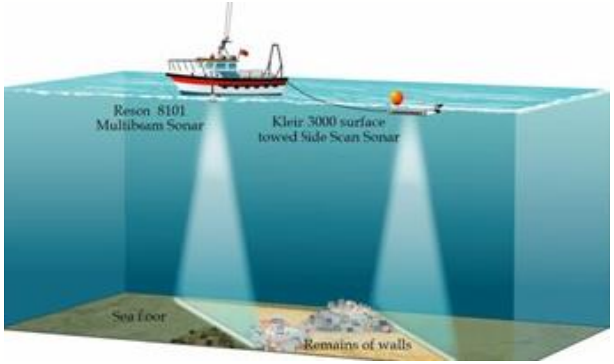
- Sonars, magnetometers and still cameras;
- NDT equipment (for foundations)

Diver inspection

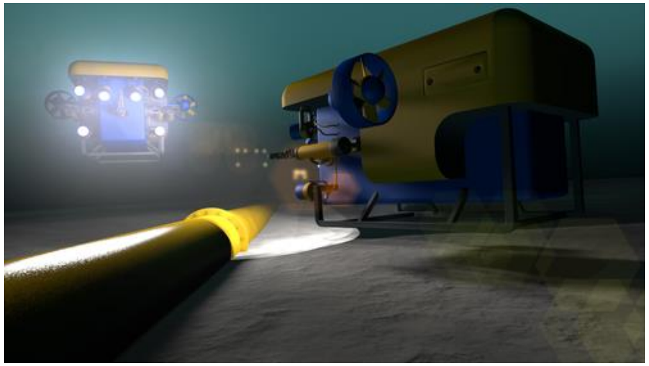
- Uses probes to detect cable depth and burial
- NDT equipment (for foundations)

Limitations

- Methods require personnel and vessels (~ £800K/year)
- Weather dependent
- Can be high risk using divers



Acoustic inspection using towed and/or vessel mounted sensors



ROV with electromagnetic and/or imaging equipment

Innovation challenge

The challenge

- Cost-effective subsea survey methodology for cables, substructures and surrounding seabed surveys:
    - *Gather equivalent or improved data for significantly less than £800K/year (site specific).*
- Reduce the vessel requirement through the utilisation of autonomous technologies:
    - *Autonomous underwater technologies that can reliably and safely navigate themselves around a wind farm with no risk to asset integrity and gather equivalent or improved data.*

Solution requirements

The test

Operating conditions

- Water depths up to 60m for fixed bottom;
- Up to 600m cabling;
- Wind farm 50 km from shore and area of 700 km2.

Data requirements

- Seabed morphology (slopes, hollows, sand waves/banks etc.) and properties;
- UXO location and size;
- Cable depth, burial and exposure;
- Foundation scour, weld integrity and corrosion protection condition.

Communications and navigation

- Ability to locate and track cable routes
- Ability to locate and inspect foundation scour and structural properties
- Collision avoidance for subsea infrastructure
- Ability to communicate data and receive commands with minimal vessel requirement
- Ability to charge vehicle with minimal vessel requirement
- Power and comms connections may be possible from existing wind farm infrastructure

SCOTTISHPOWER RENEWABLES

May 2018

Alternative Pile-Jacket Connection Systems

Alberto Avila
Principal Installation and Logistics Manager

Connection pile-jackets, during construction

- Increasingly deeper waters, North Sea-type conditions.
  → More lateral loading.
- Grouted connections need time for execution and curing
  → Scarce weather windows

⇨ Challenging on-bottom stability

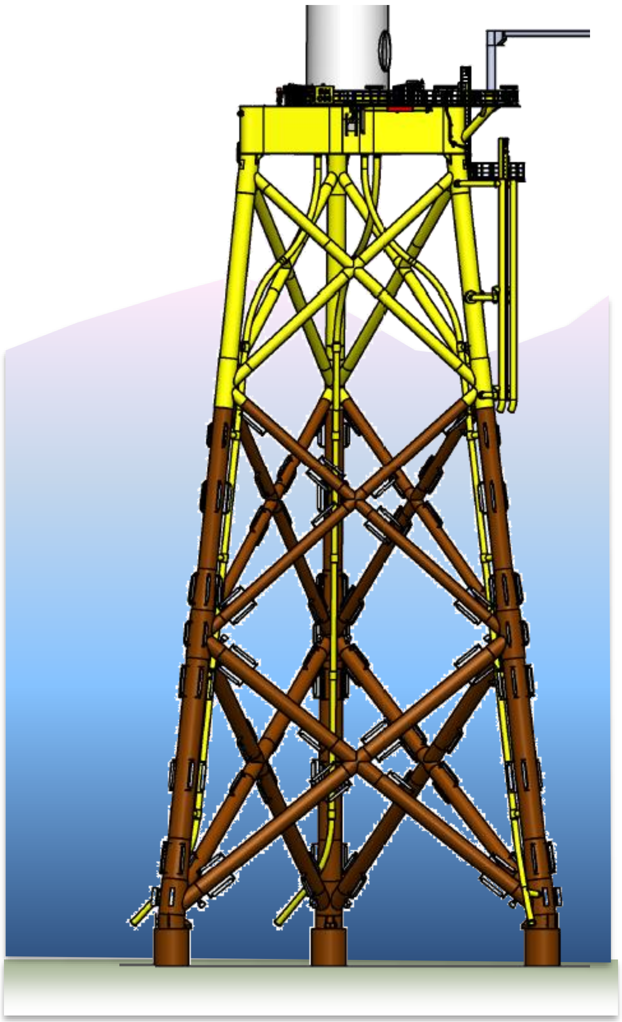
Connection pile-jackets, On-bottom Stability

DNVGL-ST-N001 Marine operations and marine warranty (2016-06), 13.10.1.2:

In any event, the structure shall be capable of withstanding the following minimum wave heights (and associated range of wave periods) within 48 hours of the Point of No Return (typically the decision to start cutting seafastenings); the seasonal 1 year return waves may be used when they are smaller:

- *Benign areas* $H_s = 2.5$ *m*
- *Non benign areas* $H_s = 5.0$ *m.*

Wave/current forces shall be calculated from the maximum wave (H_{max}*) in a 3 hour exposure period. Wind forces shall be included, using a wind speed compatible with the sea state considered in each case. The 1-minute averaging period should be used for computation of wind forces.*



Connection pile-jackets – Other issues with grouted connections

- Precedents of several issues.
- Cyclic loading.
- Costly QAQC.
- Cost of high strength grout-materials.
- Risky subsea operations.

Connection pile-jackets – R&D requirements:

Objective:

To develop improved and/or new systems to:

- Improve on bottom stability
- Reduce vessel utilization
- Reduce weather window requirements

Expectations (based on existing concepts):

- Mechanical connection (e.g. grippers, clamps)
- Remotely activated, from the surface; no ROV.
- Time:
  - Temporary (while grout is installed and cured), or
  - Definitive (instead of grout)
- Stabilization:
  - Partial (to work in conjunction with other systems, e.g. grout).
  - Total (no to rely on other stabilizing means).

Javier Rodríguez
Senior Wind Measurements Engineer
Iberdrola Offshore Operations
May 2018

Wind measurement methods on individual turbines

The Issue

- Pre-Construction Energy Yield Estimates and therefore Project Feasibility depends strongly on the accuracy of the ‘guaranteed’ theoretical power curves provided by the wind turbine OEMs in early phases of the Projects.

- In same way, Project Performance during the Operational phase is directly linked, among other things, with the turbines power curve performance across time.

- Therefore, is essential to have very accurate methods to test and monitor the power curve performance across the project lifetime.

- In offshore wind projects, the usual contractual power curve measurement procedures accepted by OEMs are based on the IEC 61400-12-1 (abandoned by developers due to the cost of the required fixed offshore met masts) or recently through nacelle LiDAR technology.

The Issue

Iberdrola-SPR offshore wind farm West of Duddon Sands (UK): power curve performance testing through Floating LiDAR and fixed met mast (IEC 61400-12-1)

Iberdrola-SPR offshore wind farm Wikinger (Germany): power curve performance testing through nacelle LiDAR

The Issue

- LiDAR technology have significantly evolve in the last years becoming an efficient and reliable alternative for offshore power curve verification to the IEC 61400-12-1 normative.

- Nacelle LiDAR technology has already become to one widely used alternative to conduct power curve measurements offshore, accepted by most of the offshore wind turbine OEMs, and even with one IEC normative under development during next 3 years.

WindIris 4-beam nacelle LiDAR set up

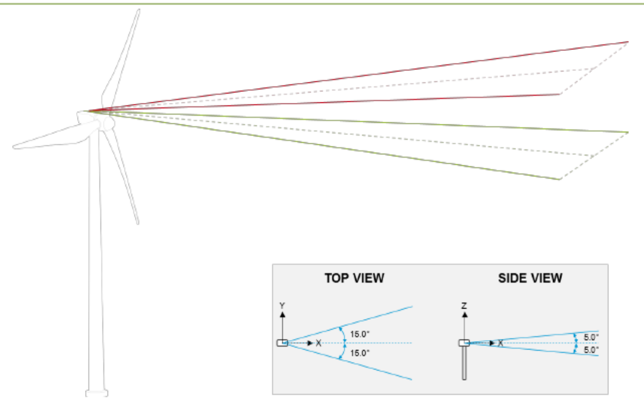
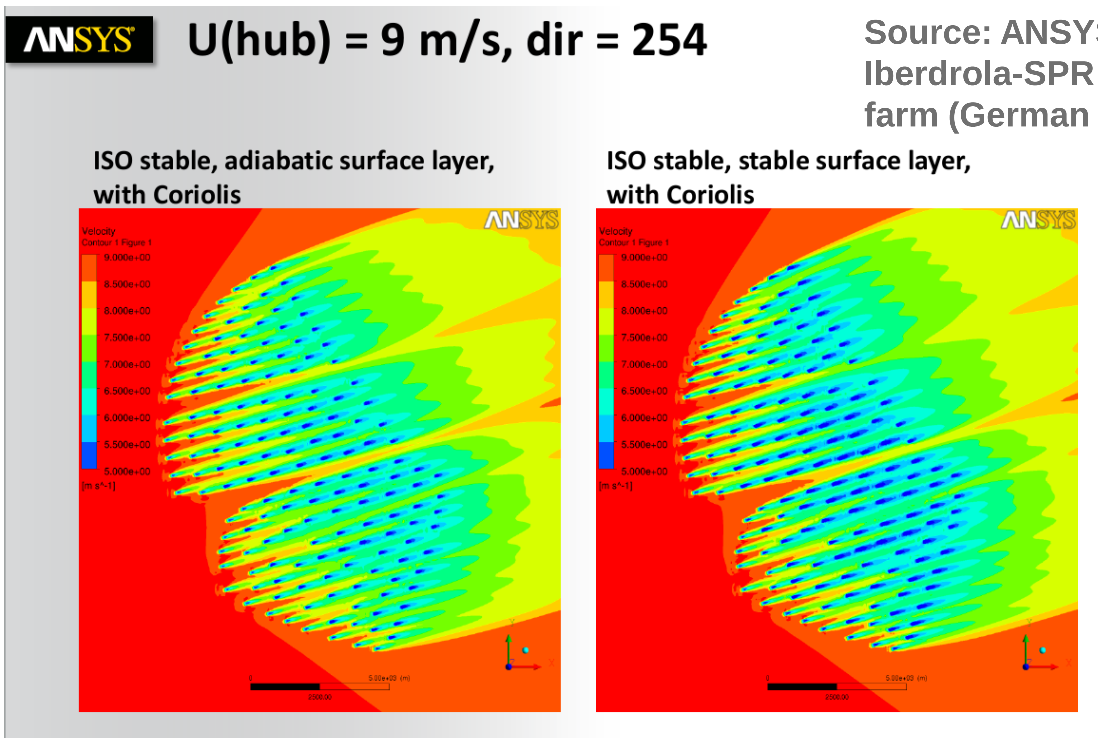


Figure 6 Wind Iris 4-beams configuration in operation

- 2 beams are measuring upward (+) and 2 beams measuring downward (-).
- The horizontal opening angle is 30°, like the 2-beam Wind iris
- The vertical opening angle is 10°, for shear measurements

The Issue

- However, new generation of offshore turbines with rotor diameters bigger than 200m will difficult the application of nacelle LiDAR technology, currently only suitable to measure wind conditions forward to the turbine up to around 400-440m, well shorter than 2.5D => compression zone/blockage effect issue



Source: ANSYS – Modelling in the Iberdrola-SPR Wikinger Offshore Wind farm (German Baltic Sea)

The Challenge

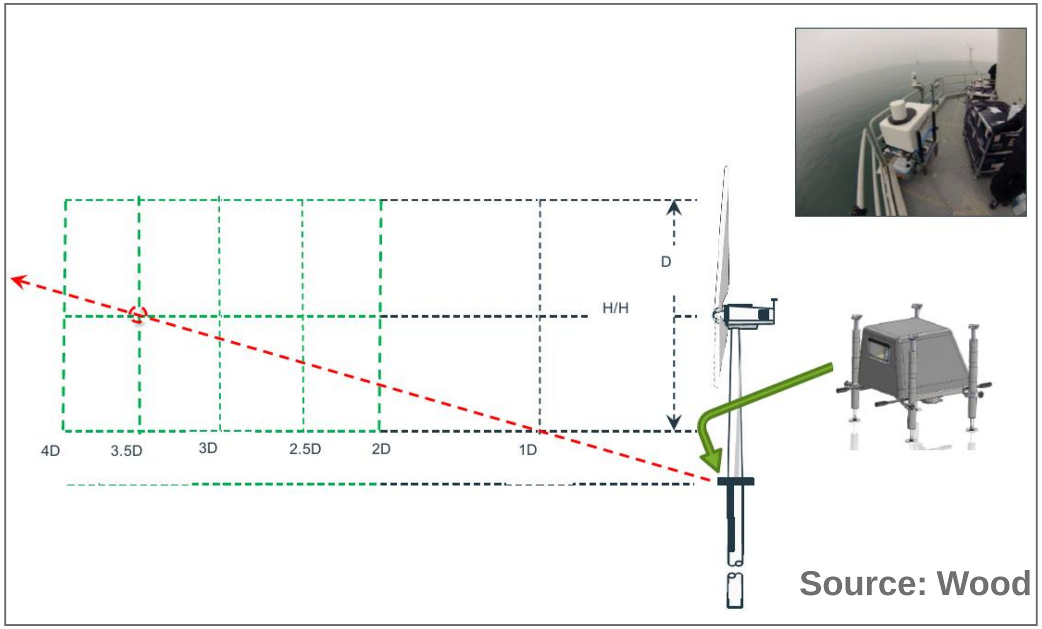
- Other alternatives needs to be explored and developed. Accurate performance validation presents challenge.

- Ideally these alternatives should fulfil with as much as possible of:
  - Compliance (as accurate) as IEC 61400-12-1.
  - Low Cost.
  - Easy & rapid deployment ('simple' devices), no turbine downtime.
  - Able to monitor all turbines in turn (re-deployability)
  - Accurate and comprehensive long-term monitoring

- These alternatives must be demonstrated through a set of track record complete power PPT validations and in the future **must secure OEC acceptance (very challenging).**

The Challenge

- Transition-Piece (TP) mounted LiDAR can be considered currently as the most promising cost-effective alternative to the nacelle mounted LiDAR technique for power curve verification offshore.



Source: Wood (Galion TP Scanning LiDAR)

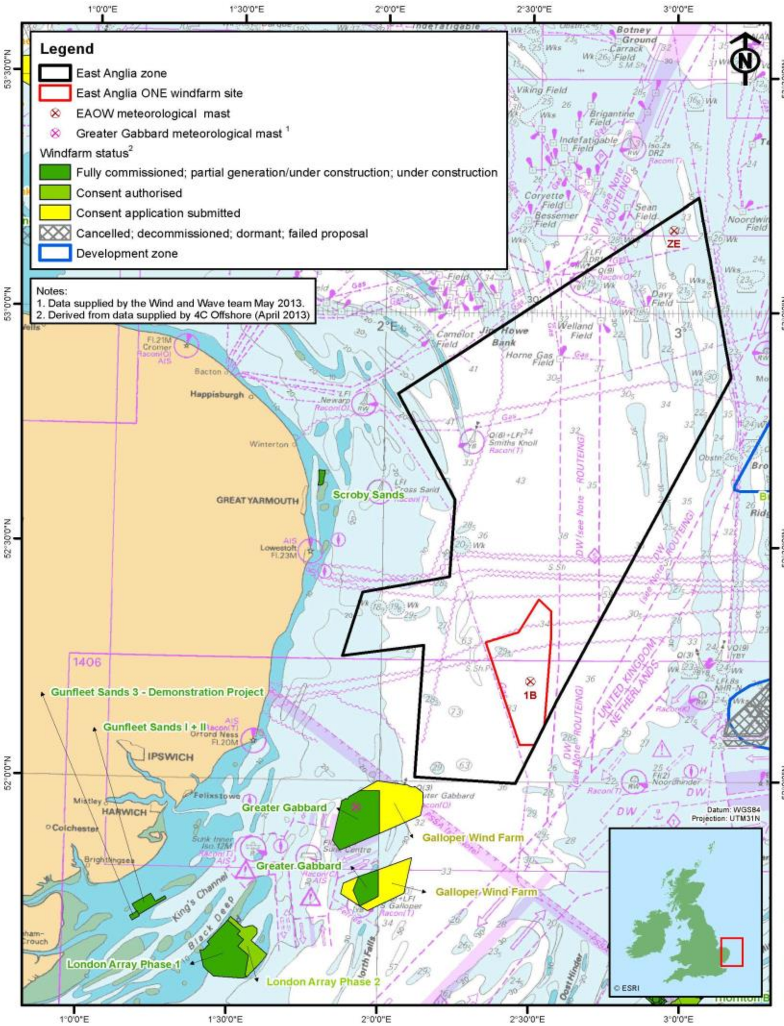
- **But other alternatives based on other wind measurement techniques, even combined with wind modelling, needs to be explored in order to develop detailed procedures for PPT, including uncertainty.**

Opportunity – East Anglia ONE Project

- SPR Offshore wind farm East Anglia ONE (UK) is to consist of 108 turbines Siemens Gamesa SWT154-7.0MW, currently under construction. EA1 will be commissioned by Q1-Q2 2020.

- The EA1 Project will be used as 'Test Site' in order to implement there a number of innovative ideas. On-site measurements, data analysis and detailed research activities might be conducted there from Q2 2020 to Q4 2021.

- Projects scoping and selection, during Q3-Q4 2018 and 2019.



Thank you for your attention

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