OPIN Workshop: Energy Policy and Offshore Renewables State of the Nation

23/10/2019

Simon Cheeseman

CATAPULT Offshore Renewable Energy

Todays Agenda

10:00 Welcome and coffee

10:30 Intro to ORE Catapult and OPIN – Simon Cheeseman and Lesley Doyle (Scottish Enterprise)

10:45 Marine Energy Policy in UK and ROTW developments include technology innovation requirements – Simon Cheeseman

11:15 OPERA – Paul Goodwin (Global Marine)

11:45 Coffee

12:00 David Young (Predicting failure of dynamic cables)

12:20 eGrid (Michael Smailes)

12:45 Robbie Brady – TIGER (Tidal Project)

13:00 Lunch

13:45 PPE for site tour

14:00 Site Tour – BT2, BT1, Nautilus, Docks, Charles Parsons

15:30 Depart

OPIN Project Introduction

Lesley Doyle, Scottish Enterprise

Wednesday 23 October, Blyth

Interreg North-West Europe

EUROPEAN UNION

OPIN

European Regional Development Fund

OPIN Project Partners

seai SUSTAINABLE ENERGY AUTHORITY OF IRELAND

Scottish Enterprise

CATAPULT Offshore Renewable Energy

sirris driving industry by technology

WEAMEC Research, Education & Innovation in Pays de la Loire FOR MARINE ENERGY

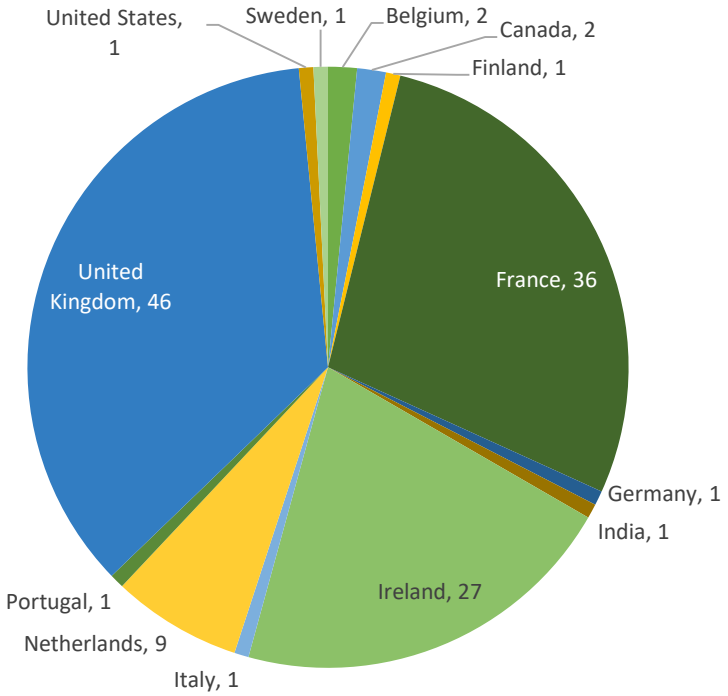
DMEC Dutch Marine Energy Centre

Fraunhofer IEE

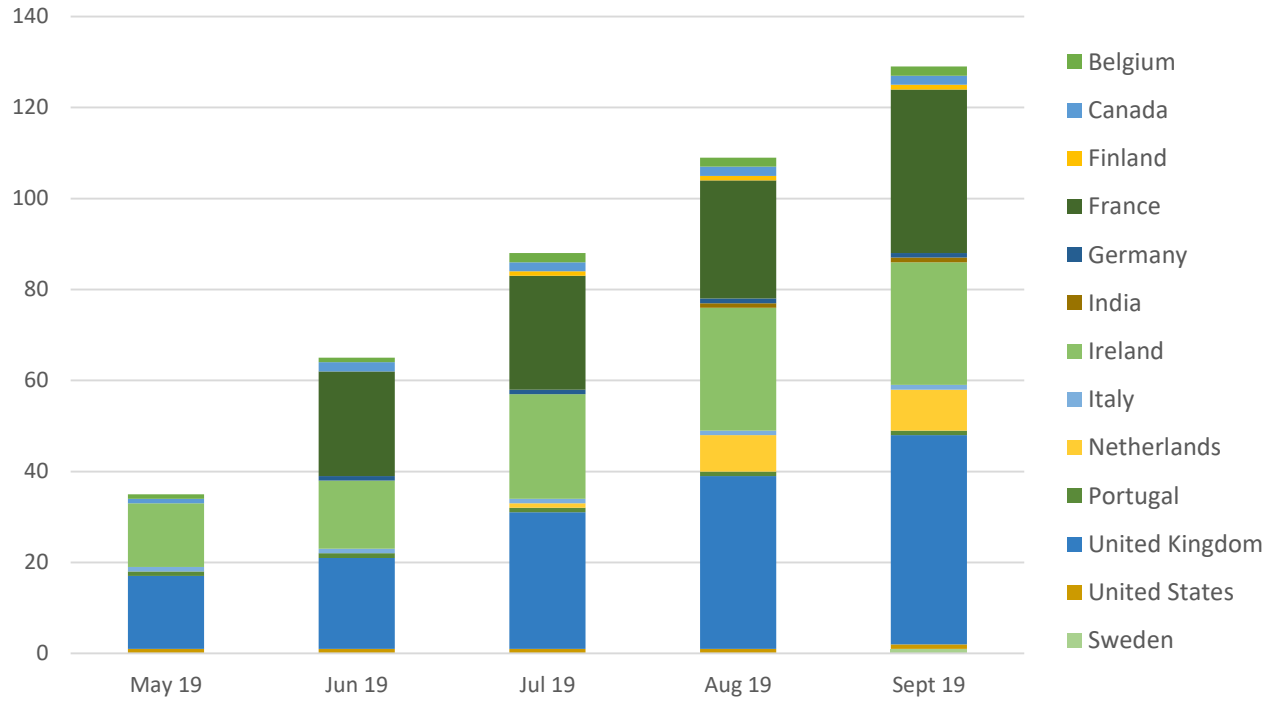
Interreg North-West Europe OPIN European Regional Development Fund

EUROPEAN UNION

OPIN Membership



Country of Origin



129 members from
13 countries

Interreg
North-West Europe
OPIN
European Regional Development Fund

EUROPEAN UNION

OPIN Premise

To encourage both **cross-sectoral** and **cross-regional** collaboration for Offshore Renewable Energy SMEs

Interreg North-West Europe OPIN
EUROPEAN UNION
European Regional Development Fund

OPIN Aims

- Support over 100 companies

- Develop a self-sustaining network providing a mechanism for the transfer of expertise between sectors in North West Europe

OPIN Supports

- Annual Symposiums, workshops and masterclasses
- Travel Support
- Technology Assessment Processes (TAPs)
- Collaborative Innovation Groups (CIGs)

Interreg North-West Europe OPIN
EUROPEAN UNION
European Regional Development Fund

OPIN Events

- Masterclass: Maritime solutions for offshore renewable energy,

  6 November, Rotterdam, Netherlands

- Workshop: Advanced Materials and Manufacturing,

  12 November, Nantes, France

- Masterclass: Installation and Mooring,

  February 2020, Nantes, France

OPIN Innovation Support Scheme

Technology Assessment Process (TAP) Support

A high-level technology assessment allowing companies to benchmark their technologies, map structured development paths and identify potential collaborators

Collaborative Innovations Group (CIG) Support

Support for clusters of SMEs, working with research entities/large companies, solving issues identified as barriers to the ocean energy sector

Travel Support

Enabling SMEs to travel abroad either to take part in an OPIN workshop, masterclass or a CIG meeting or activity

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EUROPEAN UNION
European Regional Development Fund

Q&A

Any Questions?

Interreg

EUROPEAN UNION

North-West Europe

OPIN

European Regional Development Fund

Thank you!

Agenda

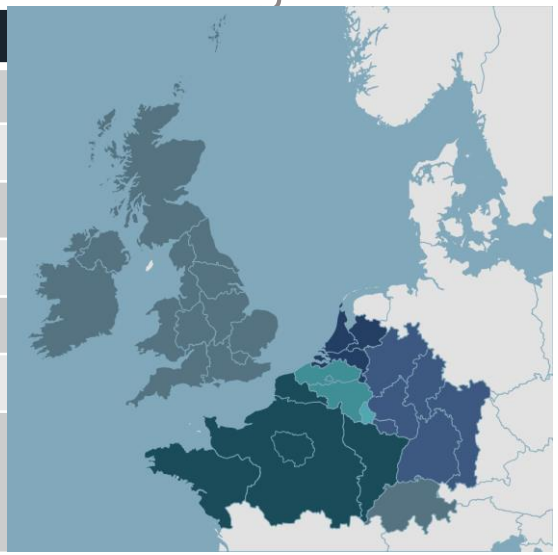
- OPIN
- Introduction to ORE Catapult
- Introduction to wave energy
  - Devices and types of converter
  - Notable examples
- Introduction to tidal energy
  - Devices and in-stream vs range
  - Notable projects
- State of Marine Industry
- ORE Catapult Projects

Ocean Power Innovation Network (OPIN)

OPIN Interreg North West Europe funding total budget € 2.57 m from 2018 to 2021. Free to join:

- Will deliver supports to encourage both cross-sectoral and cross-regional collaboration.
- Annual Symposiums: providing networking opportunities for OPIN members
- Workshops and Masterclasses: to facilitate knowledge transfer between the project partner regions and to simulate the growth of the network.
- Technology Assessment Processes (TAPs): assessments allowing

OPIN Partners	Country
Sustainable Energy Authority of Ireland	IE
Scottish Enterprise	UK
Offshore Renewable Energy Catapult	UK
Sirris, het collectief centrum van de technologische industrie	BE
Ecole Centrale de Nantes	FR
Dutch Marine Energy Centre	NL
raunhofer-Gesellschaft zur Förderung der angewandten Forschung e.V.	FDE



http://www.nweurope.eu/projects/project-search/opin-ocean-power-innovation-network/

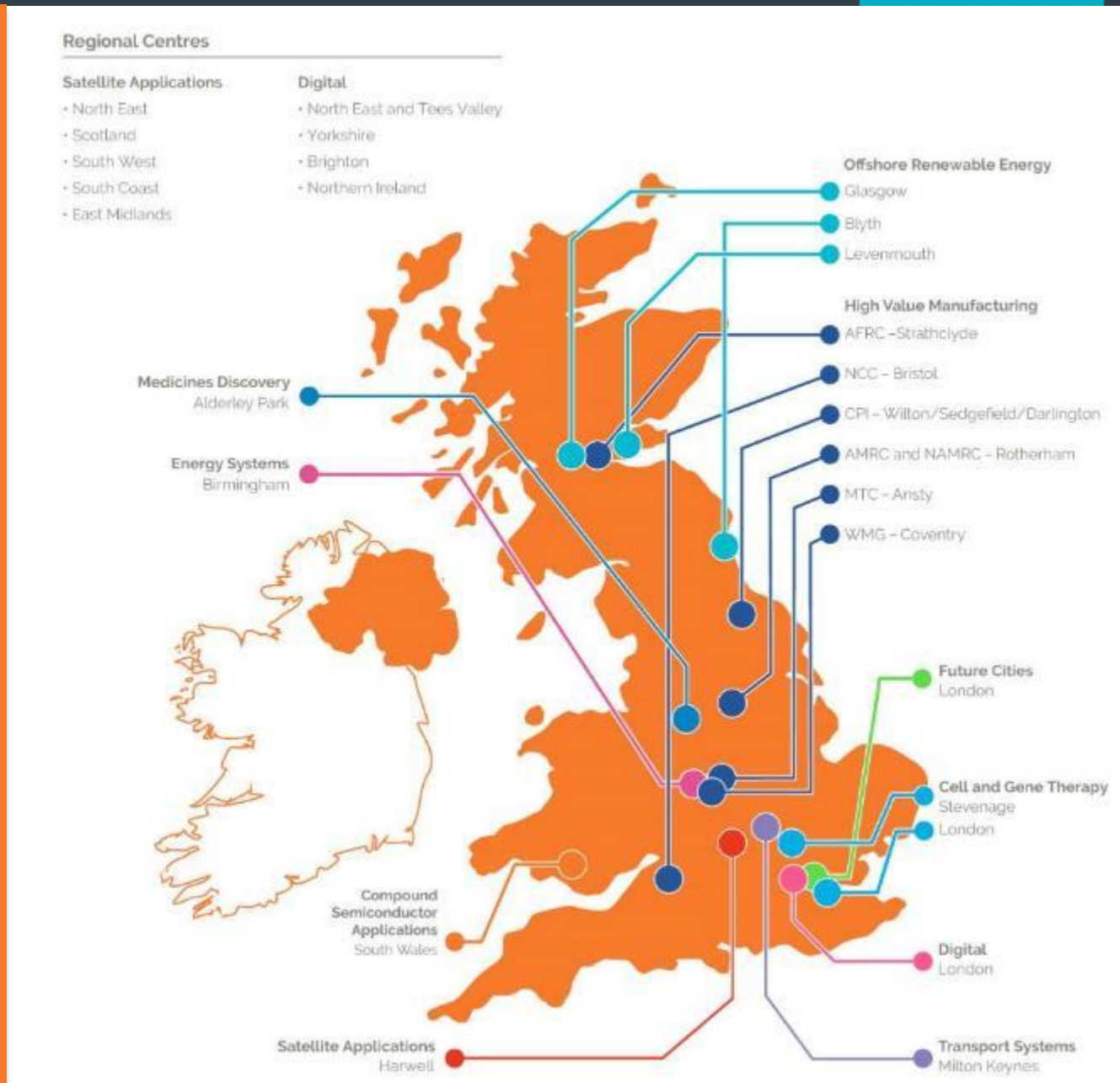
ORE Catapult

The Catapult Network

10

Innovate UK

- Designed to transform the UK's capability for innovation
- Core grant leveraged with industry and other public funding



Our Mission and Vision

Our mission

To accelerate the creation and growth of UK companies in the ORE sector

Our vision

By 2023, ORE Catapult will be the world's leading offshore renewable energy technology centre

- **Centres of Excellence**
- **Academic Research Hubs**
  in partnership with leading universities
- **Expanding our assets in Blyth and Levenmouth**
  the world's foremost open-access facilities

Risk (and its perception) drives the cost of borrowing money…

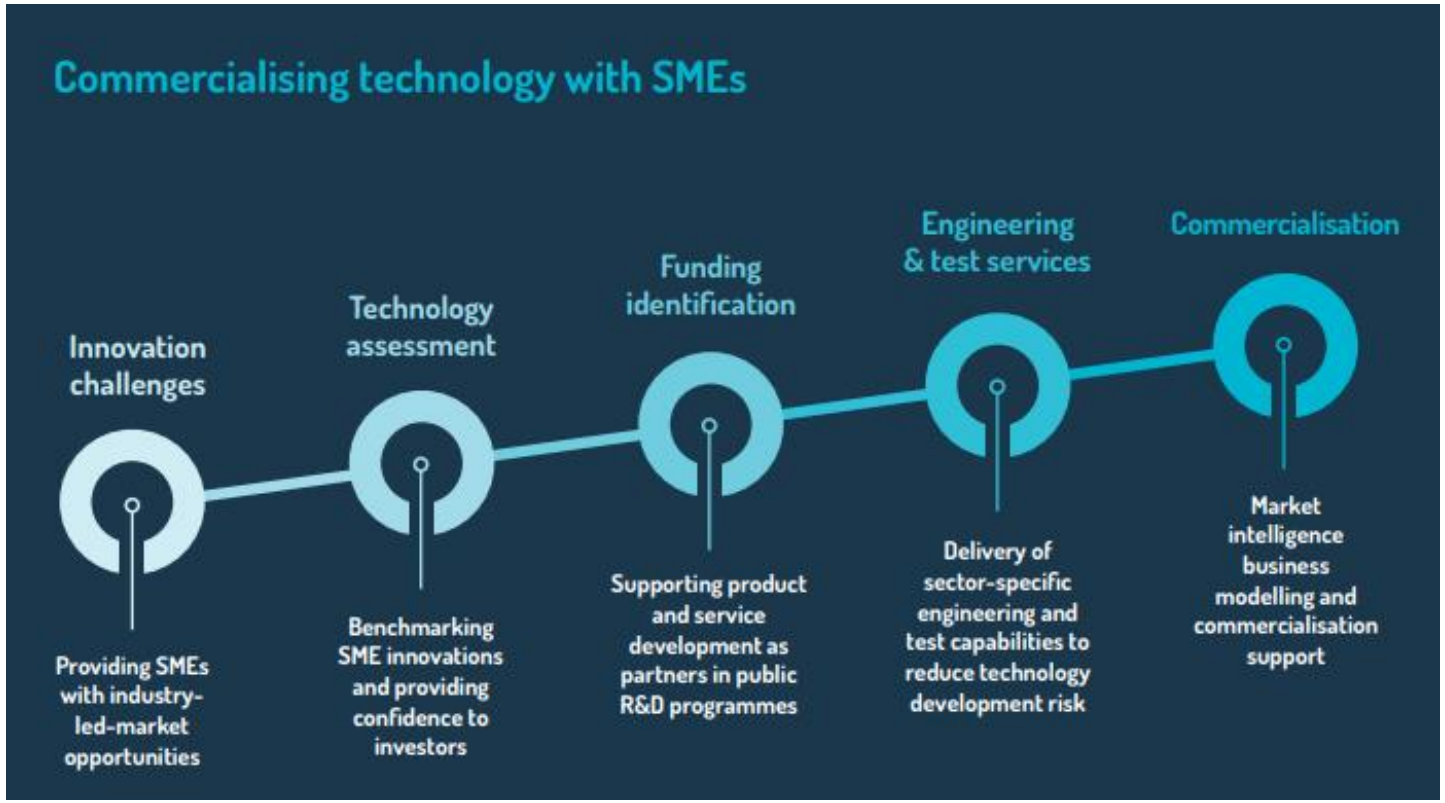
Reduce risk through:

- Sound design principles
- Testing and validation
- Track record

Commercialising Technology

164 SMEs supported in 2017/18

410 SMEs supported since 2013



Testing, Operational Performance, Research Development & Innovation

Our structure

Test & Validation

- Next generation technology
- Design validation and component testing

56
technical experts

Operational Performance

- Better intervention techniques
- Developer/owner solutions
- SMEs developing solutions
- Test & validate solutions
- O&M

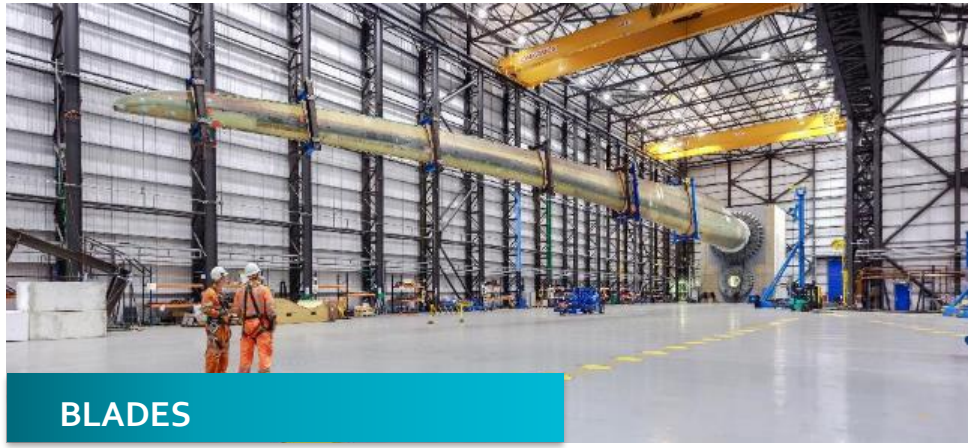
34
technical experts

Research & Disruptive Innovation

- Evaluation and support for future technologies
- Floating wind, Wave & Tidal
- Under pinning research
- Gateway to UK academia

37
technical experts

① Test & Validation



BLADES

- Test & validate next generation 100m+ offshore wind turbine blades
- Develop and test innovative solutions for rain erosion (e.g. composite materials)
- Accelerate innovative blade designs and materials

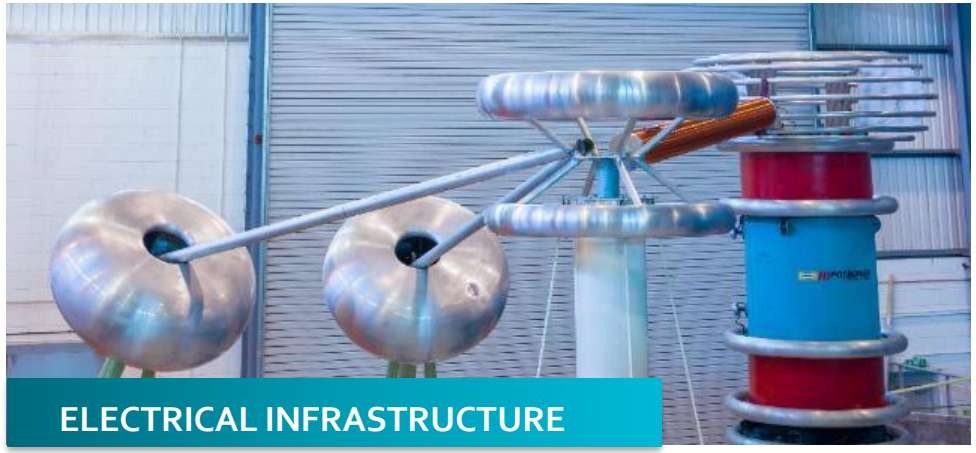
FACILITIES: 100m and 50m Blade Test Halls
Blade Erosion Test Rig
Wind Turbine Blade Test Facility

POWERTRAINS

- Test & validate next generation 10MW+ offshore wind turbine powertrains
- Accelerate innovative powertrain technology, from Sub-1MW to 3MW
- Support development of critical powertrain components: bearings, gearbox, generator

FACILITIES: 1MW, 3MW, 15MW Powertrain Facilities
Wind Turbine Bearing Test Facility

① Test & Validation



ELECTRICAL INFRASTRUCTURE

- Test & validate the market's largest cables - 66kV - through ageing, insulation breakdown and failure analysis
- Dynamic cable fatigue testing - for the future development of floating wind

FACILITIES: HV and Materials Labs
Pre-qualification bays
Dynamic cable rig

O&M TECHNOLOGY TEST & VALIDATION

- Test robotics & autonomous systems (RAS) using controlled subsea dock environment, training tower (drones) and blades (blade inspection)
- Wet and dry controlled dock environment testing:
  - Cable inspection, protection and connection systems
  - Subsea & topside balance of plant

FACILITIES: Subsea docks
Training tower
Blade sections

② Operational Performance

ORE Catapult's role

- Help position the UK as an internationally recognised centre of excellence for operating offshore renewable plant
- Assist UK innovators to develop products and services to build and maintain a UK based supply chain
- Boost productivity of UK businesses and create an exportable commodity

Collaboration and Partnerships

- Owner/operators and OEMs – to understand common engineering and operational challenges
- Supply chain and cross sector - to develop solutions to challenges
- Develop offshore wind supply chains

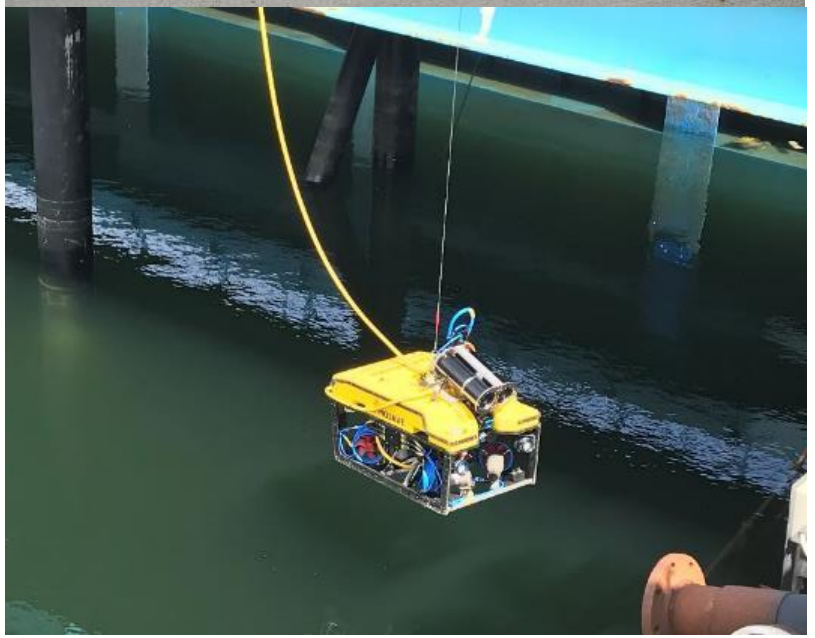
③ Research & Disruptive Innovation

Challenges for offshore wind

- Next generation offshore wind turbines, to + 8MW+ machines will substantially reduce the levelised cost of energy.
- OEMs must access new technologies from all corners of industry
- Opportunities for innovative UK companies to enter the supply chain

ORE Catapult's role

- De-risk emerging technologies
- Link supply chain new entrants with those developing the next generation of wind turbines
- Fill the knowledge gaps through our strategic research programmes in Blades, Drive trains and Electrical Systems
- Bring forward disruptive UK innovations to the global turbine market
- Drive down cost and drive up UK value



Test and validation for business models

Analysis & Insights

- **Generating insights from detailed analysis**
  - Flagship reports for policy-makers and industry
  - Economic impact from developing new technologies
  - Current and future cost reduction trends

- **Robust financial modelling**
  - Bottom-up LCoE analysis
  - Project economics
  - Cost-benefit analysis

High growth SME support

- **Business planning and market analysis**
  - Maintaining basic market overview material
  - Preparing investor-ready business plan documents
  - Guiding SME's on investor requirements

SME Growth Platform Reports – Finance & Funding

Outline of key funding types

- Public funding
- Equity
- Debt

Outline of UK public funding bodies

- National funding bodies
- Regional sources of public funding

Key considerations to consider when deciding finance plan

- Business canvas
- Funding required
- Being investor ready

SME Growth Platform Reports – Technology Commercialisation

Steps to technology development in offshore wind

- Detailed assessment of areas of technology development such as concept feasibility and refinement, design specification, and component system design

Commercial Preparation

- Steps required in areas such as business planning, IP protection, manufacturing supply chain and marketing

Market Readiness

- Steps required to address regulatory barriers, build supply chain, develop skill base and ensure stakeholder acceptance

Commercialisation Considerations

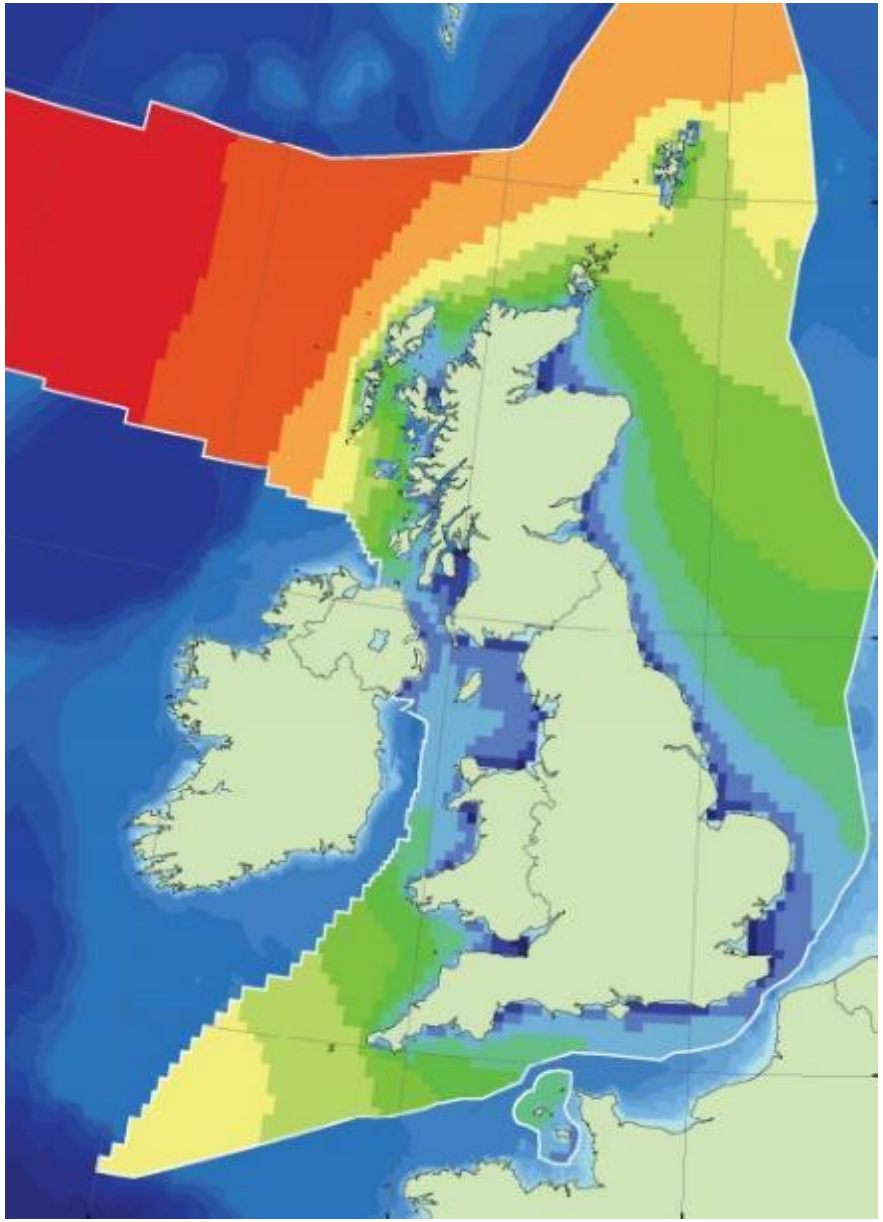
- Tips and hints on testing and demonstrating technology
- IP strategy
- HS&E considerations

Wave Energy

The Basics

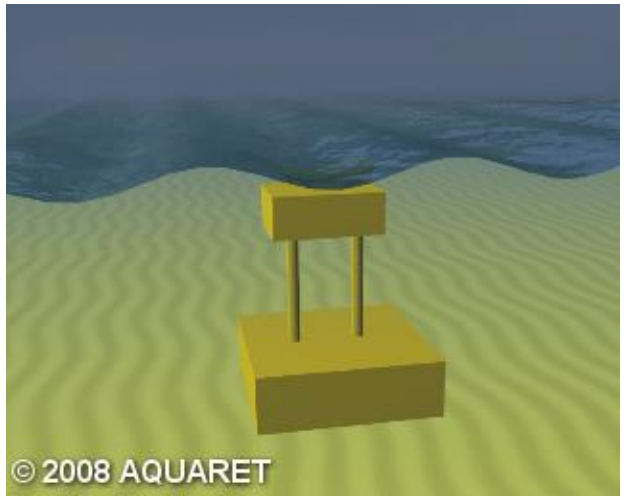
- Waves driven by the wind
- Size and energy dependent on:
  - Wind Speed & duration
  - Fetch
  - Seabed bathymetry
- UK well-placed to make use of this resource

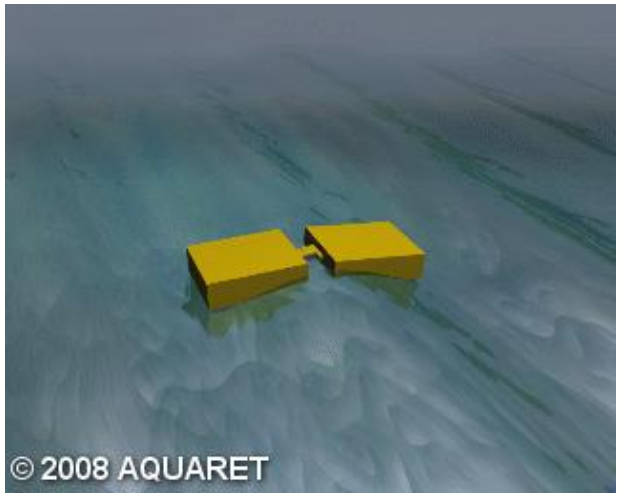
EMEC: Billia Croo Wave Test Site

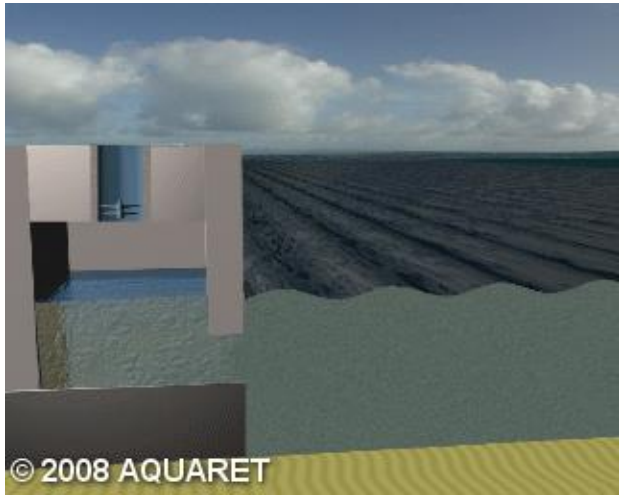


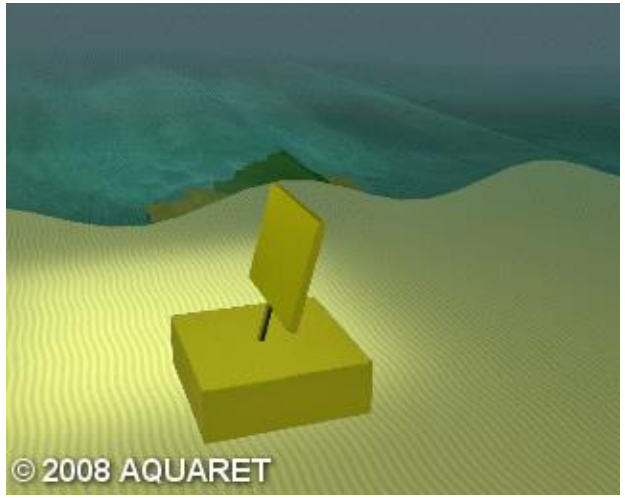
Types of device…

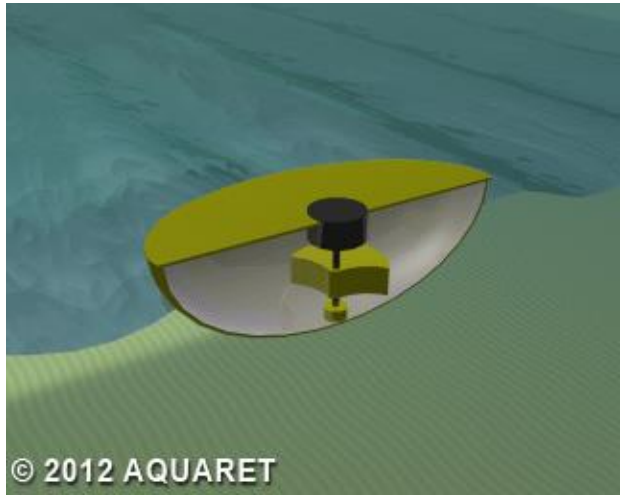
- Many ways of capturing energy from waves
- No signs of design consolidation

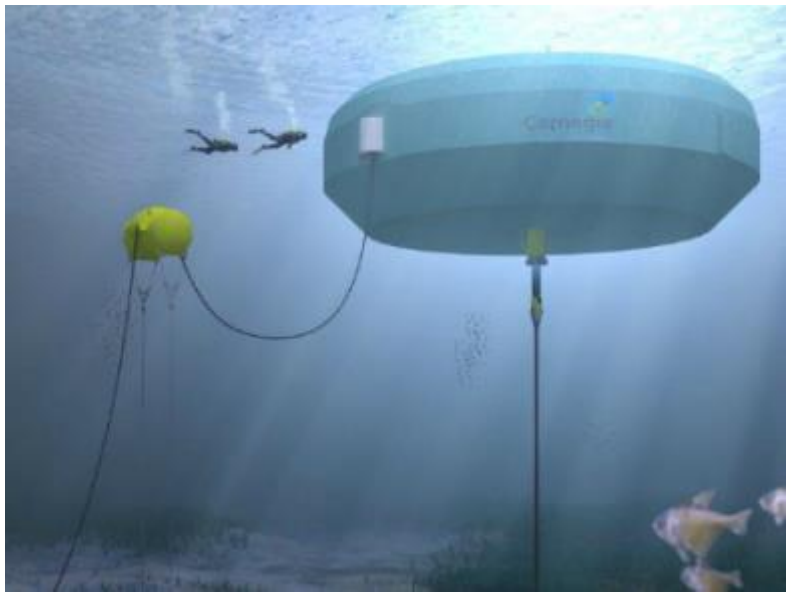






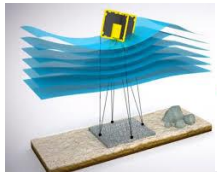






MARINE POWER SYSTEMS

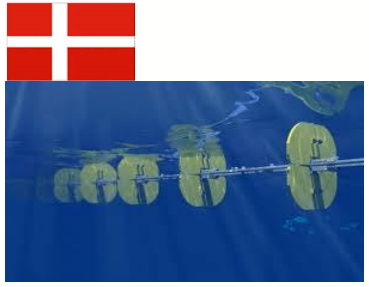
ALBATERN
Wave Energy



LAMINARIA

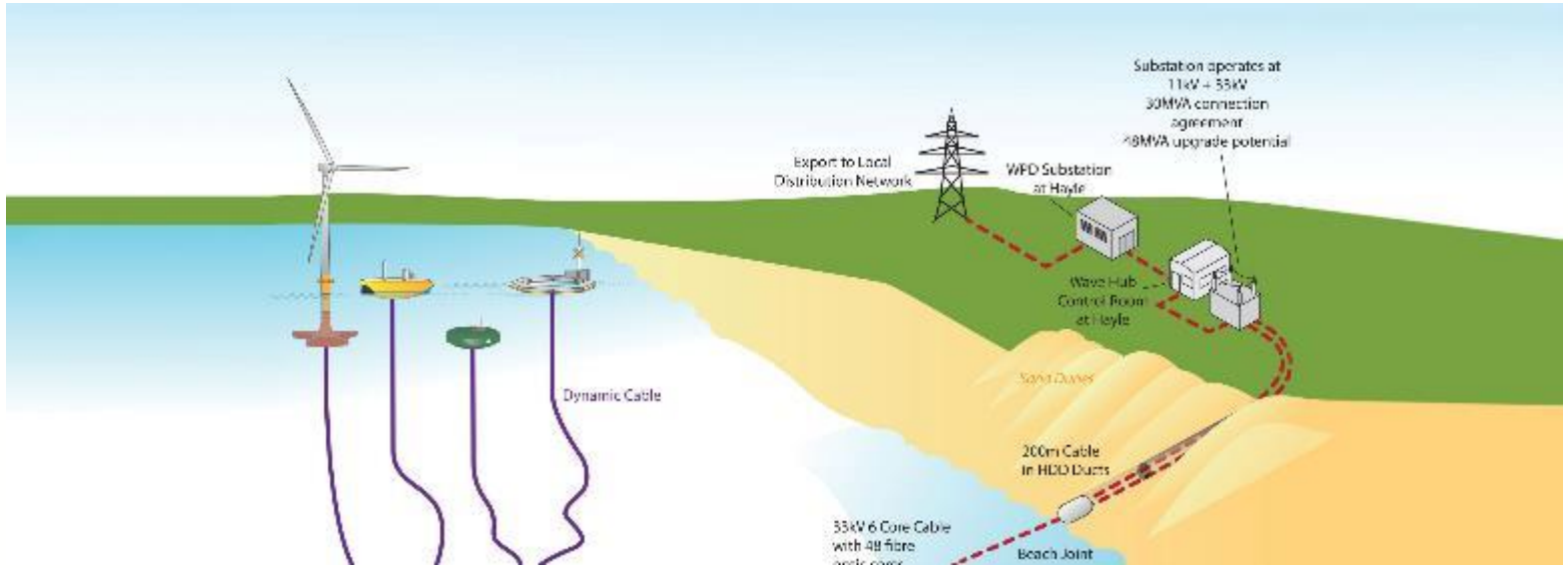
CORPOWER
OCEAN

bombora
wavepower

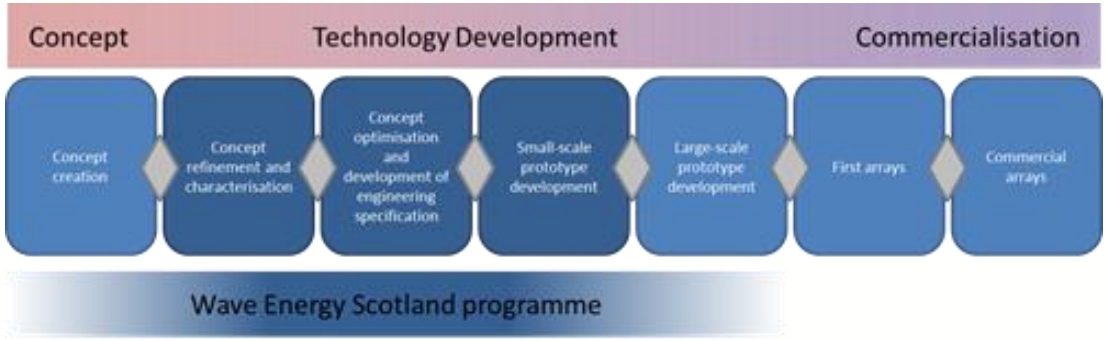


Innovation Landscape

Fabtest

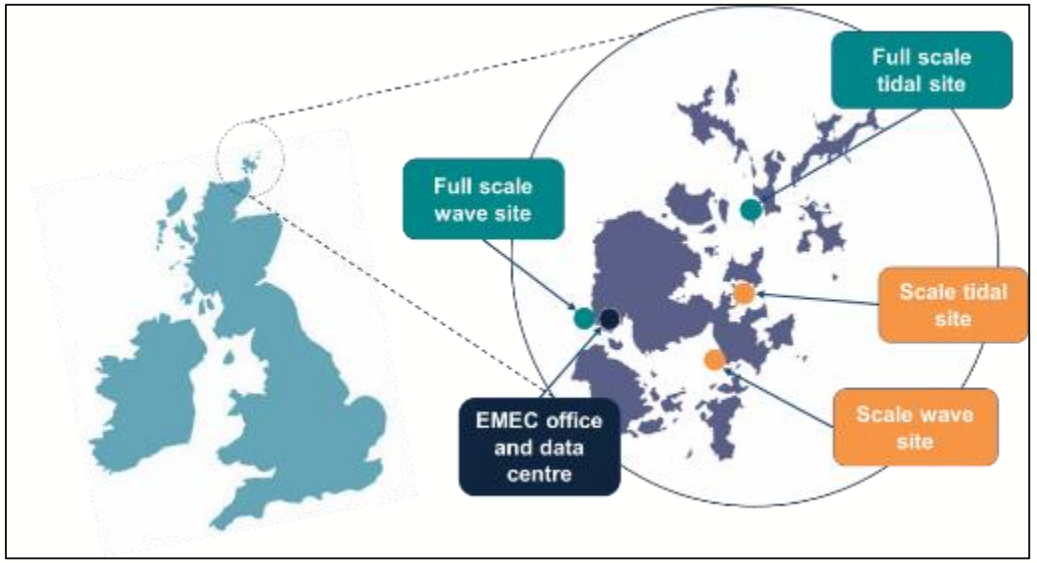


Wavehub



Wave Energy Scotland

European Marine Energy Centre

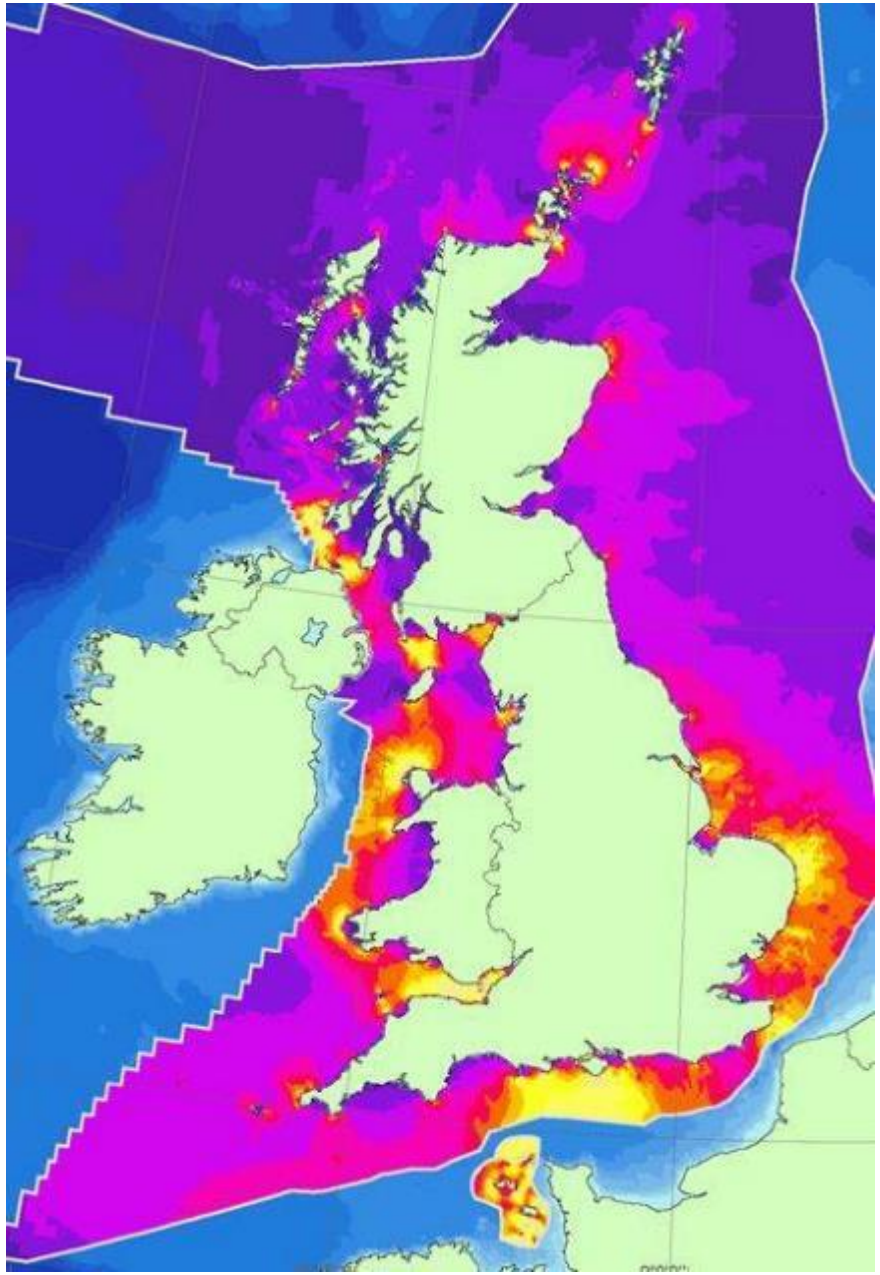


Tidal Energy

Tidal Energy

- Driven by the moon's gravitational pull
  - Can simplistically think of it as a large wave being dragged slowly round the earth by the moon's gravity
- Further developed than wave energy
- Predictable energy
  - Can be used as baseload/firm power
- 50% of Europe's tidal resource is in UK

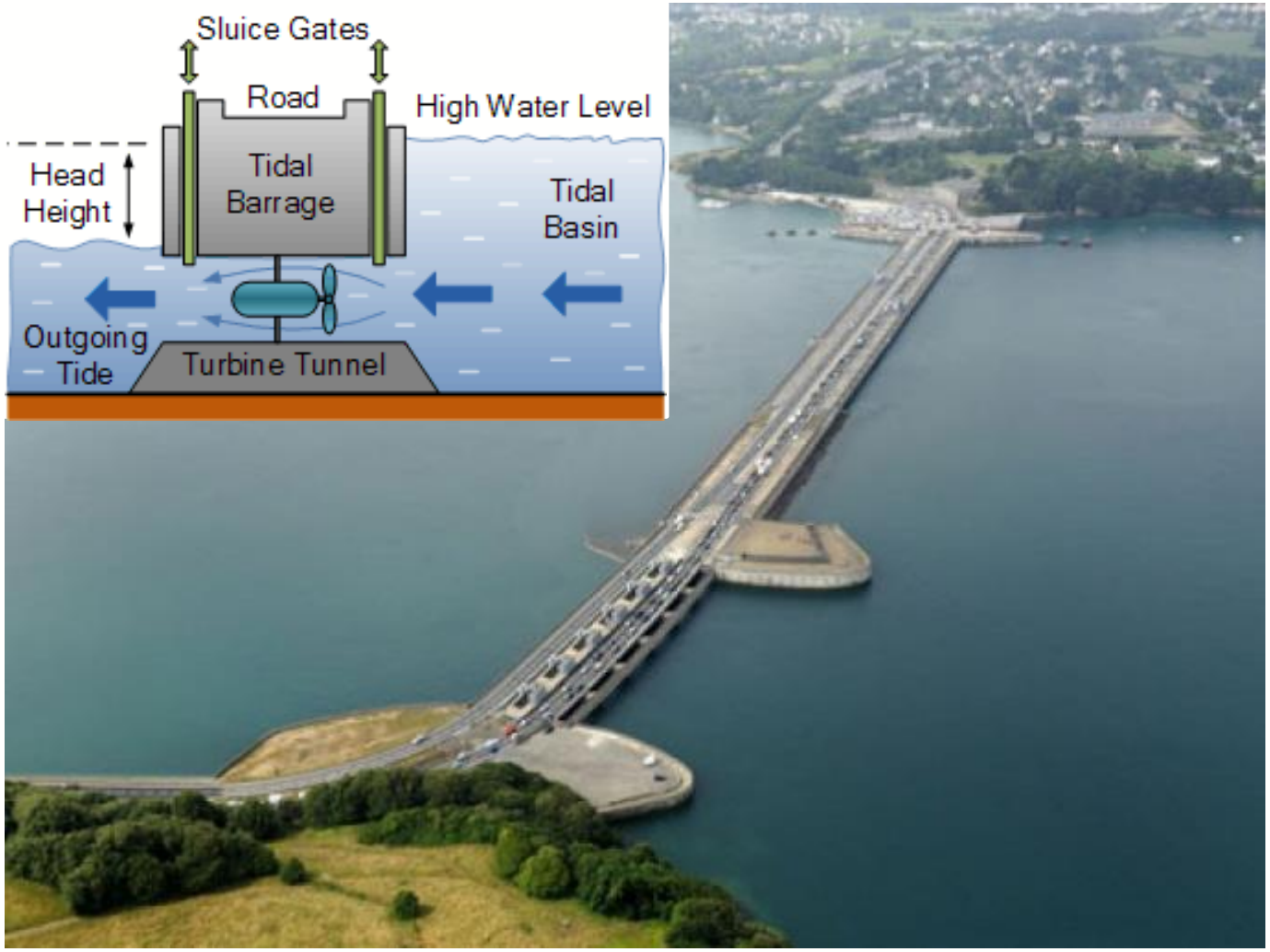
EMEC: Falls of Warness Tidal Test Site



Tidal Barrages

- Used in estuaries to capture high tides
- Water is then released during low-tide to generate electricity
    - Generate approximately 30% of time

- Severn Barrage
    - 10-mile barrage could meet ~5-9 % of the domestic energy generation needs



Rance Tidal Barrage 240MW - France

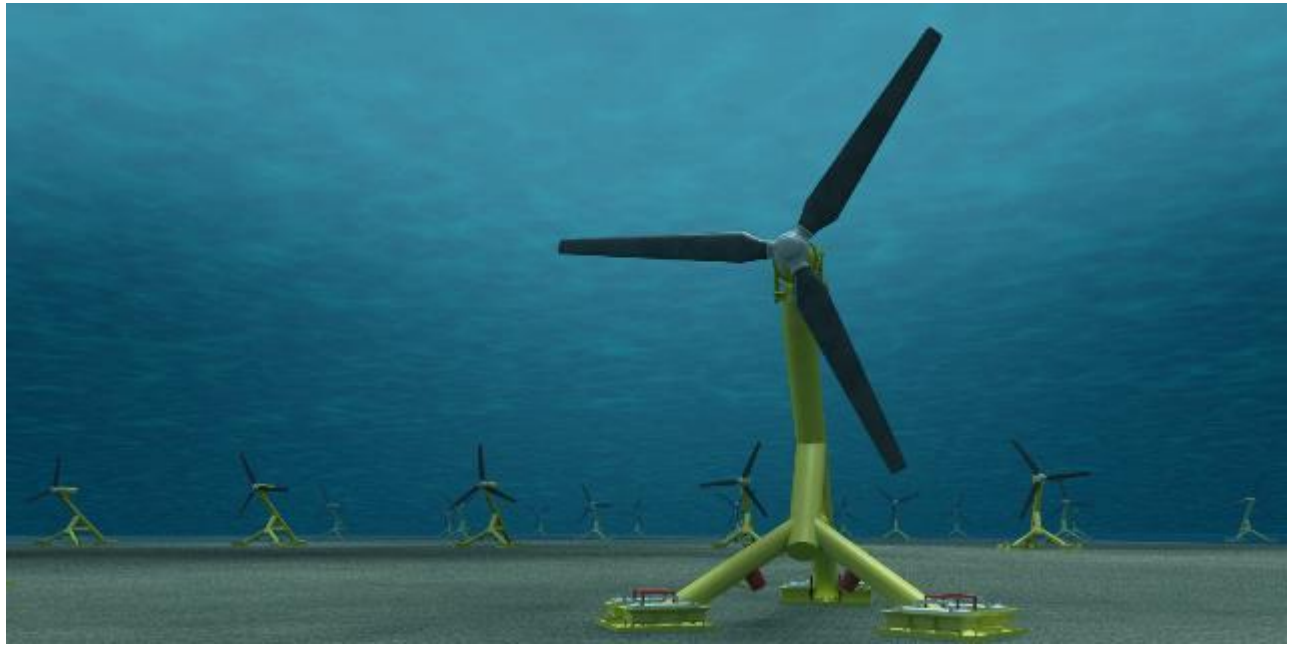
Tidal Lagoons

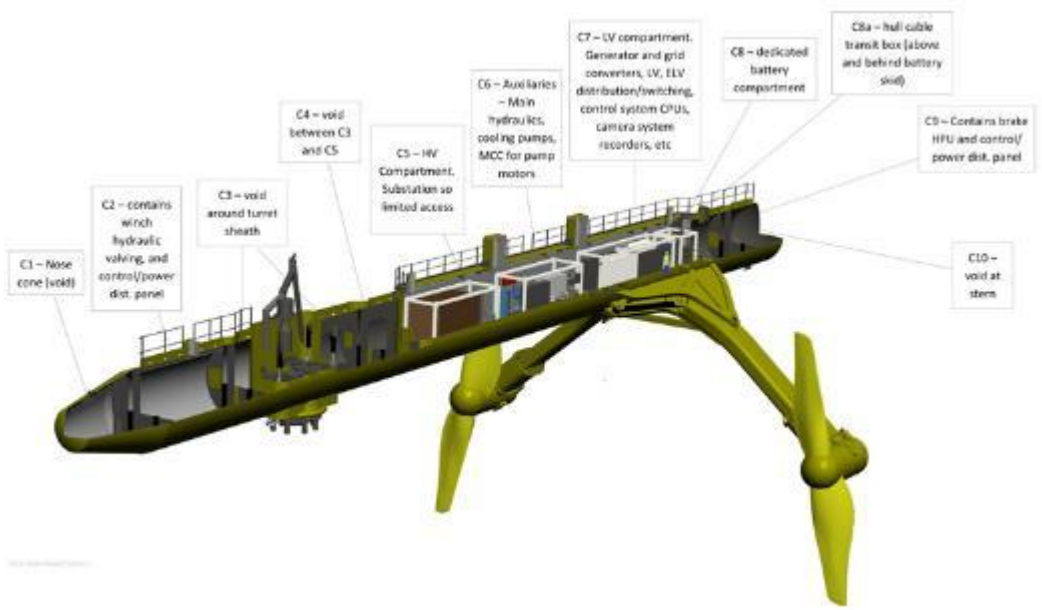
- Breakwater built out from coast to capture high tides
  - Same generating principle as barrages
- Charles Hendry Review (2017)
  - Review of tidal lagoon projects in UK context
  - Recommended a <500 MW pathfinder project to pave the way
- Swansea Tidal Lagoon
  - Was asking for 90-year strike price of £89.90
    - £92.50 Hinkley Point C
    - £43 latest offshore wind CFD
  - Had £200m backing from Welsh assembly
  - Controversially? cancelled by UK government in mid-2018.

Artist's impression of Swansea Tidal Lagoon

Tidal Stream Technology

- Captures tidal currents
- Resource particularly strong in areas where the tidal flow is narrowed/shallowed
- UK has world's first 2 tidal arrays:
  - Nova Innovation – Bluemull Sound (Early 2016) – 3 x 100 kW devices
  - Simec Atlantis Energy – MeyGen Pentland Firth (Late 2016) – 4 x 1.5 MW devices
- Relatively unobtrusive technology (compared to barrage/lagoon)
- Operations and maintenance can be challenging
- Most developed of the tidal energy technologies in the UK.





Fixed-bottom vs Floating

Small (kW Scale) → Large (MW Scale)

Floating

Fixed-bottom

Notable UK Developers

Nova Innovation

- Small (100 kW) turbines
- Bottom-fixed
- 1st Tidal array
- Incremental de-risking of technology to demonstrate cost reduction (ENFAIT project)

Simec Atlantis

- Large (1.5 MW) turbines
- Bottom-fixed
- Array with largest installed capacity
- > 8GWh exported to grid

Scotrenewables

- Large (2 MW) turbines
- Floating platform for easier O&M
- 3 GWh generated in 12 months (more than entire Scottish W&T industry in prior 12 years)

State of the Industry

UK and Global Market

Tidal:

UK present – 10MW, UK future – 6GW

(Hinkly Point C Nuclear Power Station 3.2GW £20bn)

Wave:

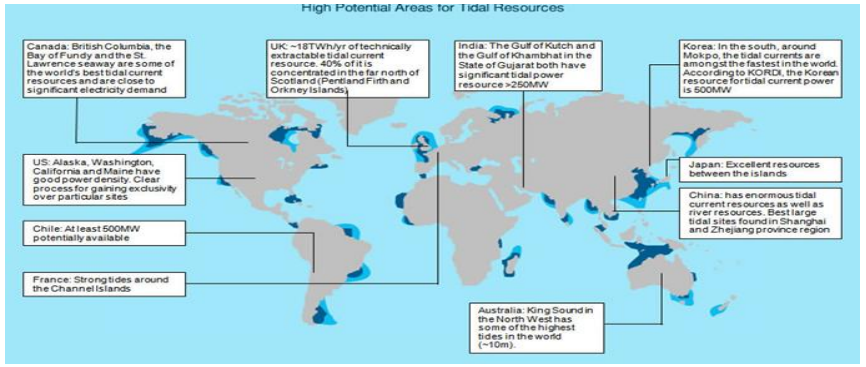
UK present – 1MW, UK future – 27GW

Worldwide:

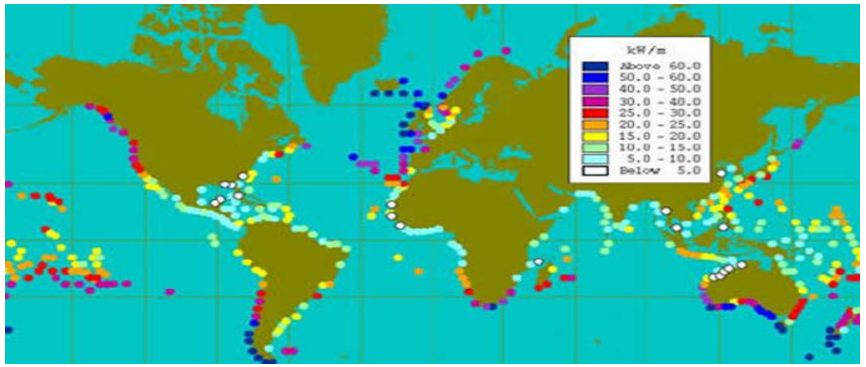
Tidal – 60GW; Wave – 180GW

Global market potential for wave & tidal £8 billion

Other countries actively building marine energy industries - Australia, Canada, Chile, Indonesia, Japan, USA.



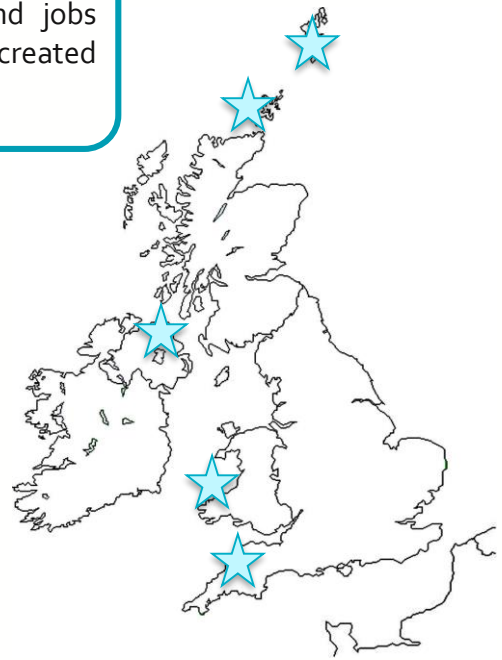
Global market tidal - 60GW



Global market wave – 180GW

The UK is a global leader in marine energy technology with a deployment problem

- Hubs of activity in South West, Scottish Highlands and Islands, Wales and Northern Ireland
- 50-60% of GVA and jobs are expected to be created in coastal areas



20+ tidal stream & 20+ wave technology developers in the UK

850 supply chain companies

However: Lack of revenue support means no progress on UK installed capacity or cost reduction

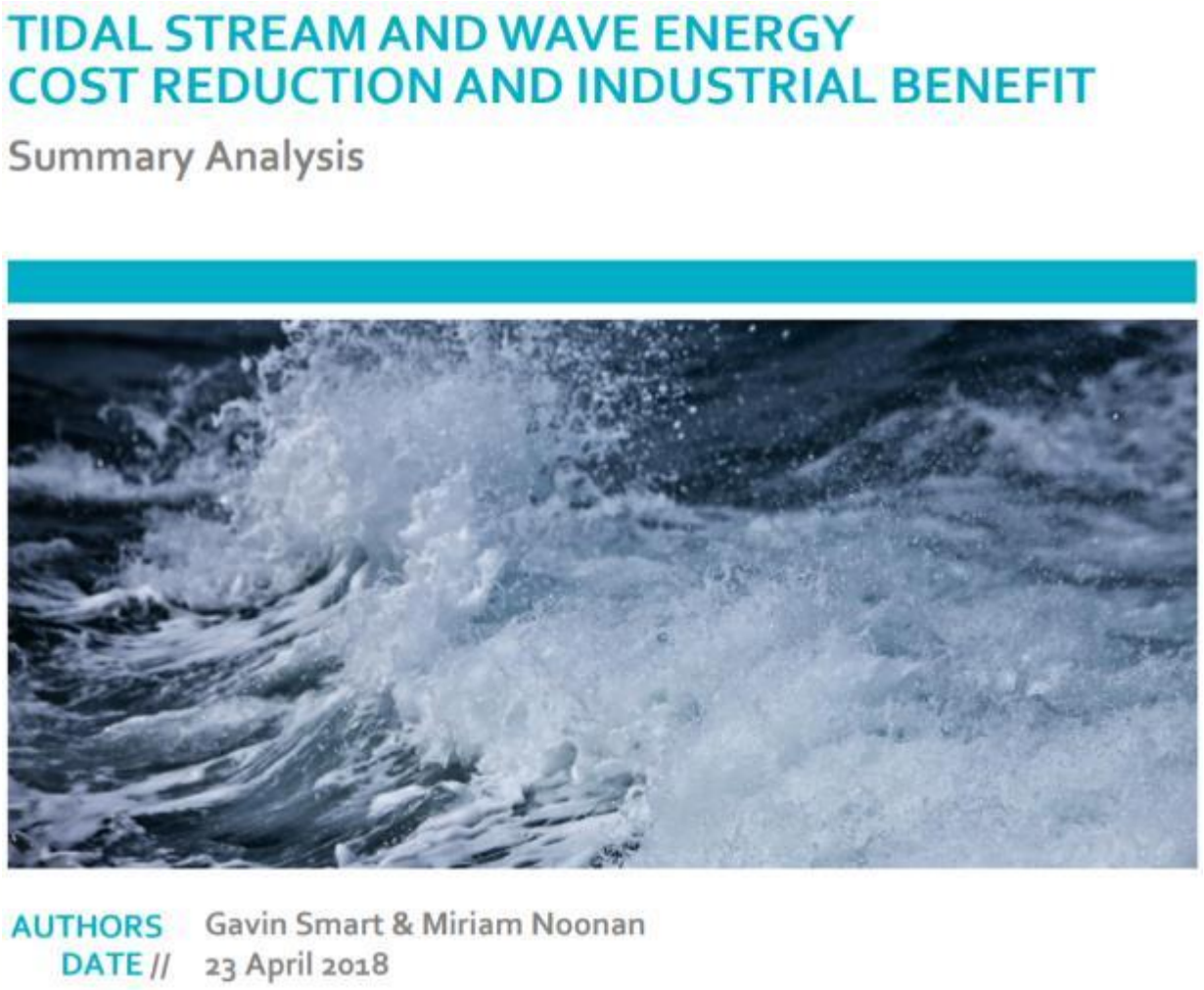
Therefore: we must look to leverage oversea sites, while maintaining out technology leadership position

1,700 jobs today growing to 28,000 by 2040*

*Direct and indirect jobs supported

Industry in need of support

- UK is currently the world leader in wave and tidal technologies
    - Approximately 2 years ahead of other nations
- There is currently no support available for these technologies however
    - No revenue or capital support
    - (Although innovation funding is available)
- ORE Catapult has undertaken work on behalf of the industry in order to lobby for this to change



Marine energy has been assessed against 3 key tests

- The UK government's clean growth strategy has set out three tests.

1 Can we see a clear cost reduction pathway for this technology, so we can deliver low cost solutions?*

2 Can the UK develop world-leading technology in a sizeable global market?

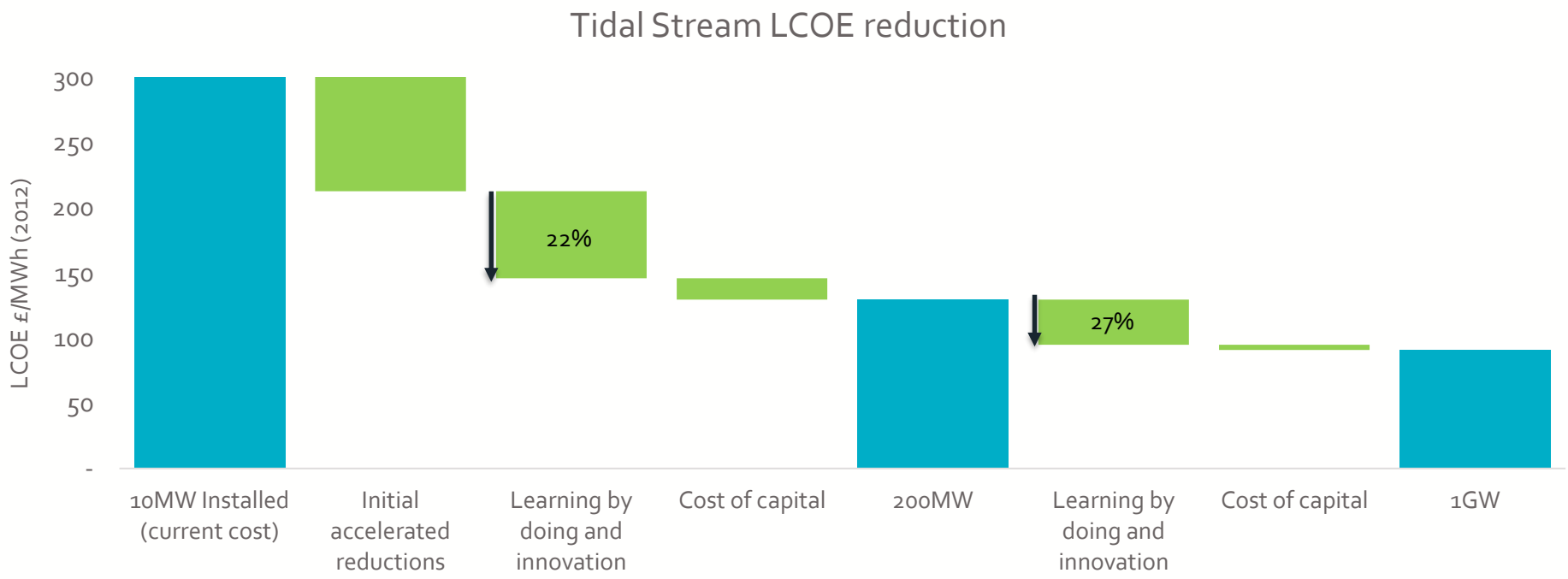
3 Does this deliver maximum carbon emission reduction?

- This study is assessing how the UK's Tidal Stream and Wave Energy industries can perform against these tests.

- *Tidal stream has been assessed against all three test and wave energy against tests 2 and 3.

Link to report:
https://s3-eu-west-1.amazonaws.com/media.newore.catapult/app/uploads/2018/05/04120736/Tidal-Stream-and-Wave-Energy-Cost-Reduction-and-Ind-Benefit-FINAL-v03.02.pdf

Test 1: Cost Reduction Pathway



Initial Accelerated Reductions

- Economies of Volume
- Economies of Scale
- Accelerated Learning

Learning by Doing & Innovation

- Optimised processes & manufacturing
- Real life operational & weather data
- Collaborative shared learning

Cost of Capital

- Increase project debt
- Reduce equity risk

LCOE expressed in pre-tax real, 2012

Link to report:
https://s3-eu-west-1.amazonaws.com/media.newore.catapult/app/uploads/2018/05/04120736/Tidal-Stream-and-Wave-Energy-Cost-Reduction-and-Ind-Benefit-FINAL-v03.02.pdf

We will only reach £150/MWh with extensive commonalty across the installed capacity

Our role is to drive as much collaboration as possible across all technology variants as we move to into array stage.

Blades

- Instrument blades to feed better understand performance
- Fatigue life testing
- Identify manufacturing facilities that can expand with industry

Pitch Control

- Record and share data on failures
- Work with key suppliers to share learnings and secure continuous improvement

Subsea Hubs

- Subsea cabling is expensive to lay and prone to damage
- Hubs are being deployed by Atlantis and NOVA. Combine learnings to accelerate development

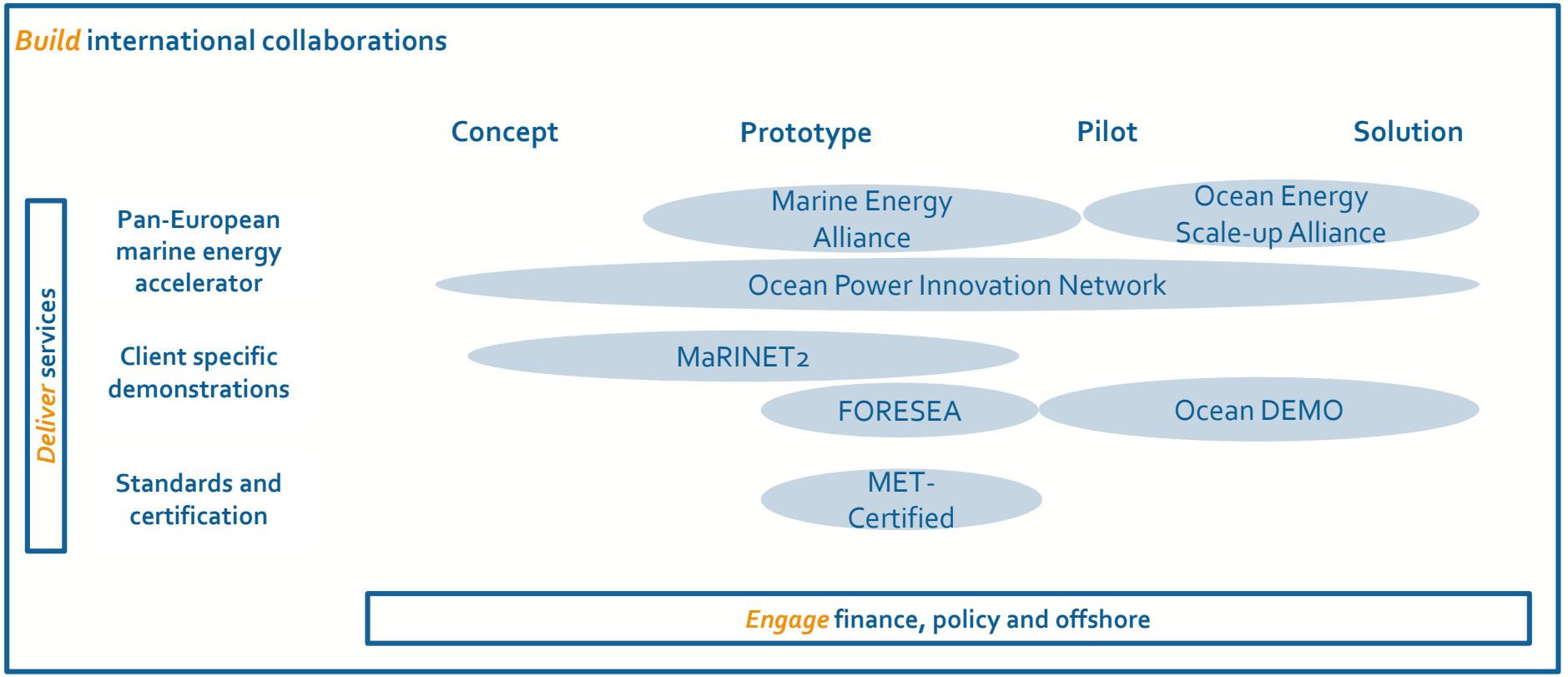
Wetmate Connectors

- Not currently designed for voltage required and harsh environment
- Collaborate with industries experienced using the technology, such as oil and gas

Nacelle Deployment & Recovery

- Limited operating windows
- Assess requirements against capabilities of Scottish vessels
- Explore opportunities to develop harbour infrastructure in the North of Scotland.

DMEC – European project portfolio 2019



Funding

Research

- UK Research Innovate UK – SMART; Energy Entrepreneur;
  - Wales – Welsh European Funding Organisation; Scotland – Scottish Enterprise; Regional – SME Innovation
  - Wave Energy Scotland
- Interreg
- EU Eurostars
- EU H2020 SME Instrument
- Marinet 2 – access to EU test facilities
- H2020 JA-3 call - Wave Energy Europe (proposal being prepared)
  - http://ec.europa.eu/research/participants/portal/desktop/en/opportunities/h2020/topics/lc-sc3-ja-3-2019.html

Pre-Commercial Deployment

- H2020
- Interreg

ORE Catapult Ocean Energy Projects

Reliability in a Sea of Risk (RiaSoR 2)

OceanERANET-funded RiaSoR 2 builds on reliability assessment guideline for wave and tidal energy converters (WEC/TEC) developed in RiaSoR1.

Objective of the RiaSoR 2 project is to offer a **comprehensive suite of testing methodologies to wave and tidal developers** providing a systematic approach to achieve optimal reliability and performance, while minimising cost and time-to-market.

Enables WEC/TEC developers to **validate findings, establish practical condition based monitoring platform** to prepare for future arrays where big data handling and processing will be vital to drive down operational expenditures (OPEX).

RiaSoR 2 proven on CorPower system equipped with several sensors to collect the required data, which was be fed into the reliability process to reduce uncertainties. Sea tests act as case studies to feed the methodologies and **training**. Findings will be trialled with the other developers.

Project partners

RI.SE Research Institutes of Sweden

Synective Labs

cruz atcheson CONSULTING ENGINEERS

CORPOWER OCEAN

Ocean Harvesting TECHNOLOGIES

EMEC ORKNEY THE EUROPEAN MARINE ENERGY CENTRE LTD

CATAPULT Offshore Renewable Energy

Funders

HIE Highlands and Islands Enterprise Iomairt na Gàidhealtachd 's nan Eilean

Swedish Energy Agency

MaRINET2

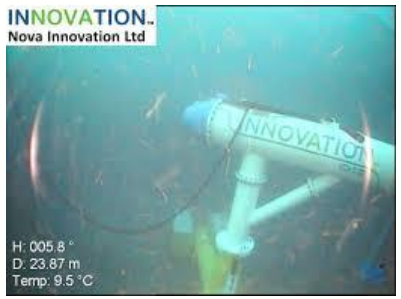
MaRINET 2 follows on from the successful first phase of the Marine Renewables Infrastructure Network (MaRINET), which provided periods of 'free-of-charge' access to world-class R&D facilities for marine renewable energy technologies.

With secured funding from the recent Horizon 2020 – INFRAIA call, 39 project partners from across Europe continue to accelerate the development and testing of offshore renewable energy systems, providing access to around 57 research and testing facilities. ORE Catapult will again participate in the project, hosting European partners and providing its world-leading capabilities to all interested applicants that successfully access the available funding.

Find out more on the MaRINET2 website or download the MaRINET2 information brochure.

Tidal Stream: En FAIT - Nova Innovation – Shetlands

Rotor diameter of 10 m
Hub height of 9 m
Total height 14 m
Water depths > 30 m
Footprint 13.5m x 12.2 m
Weight in water 80 tonnes
Maximum sustained tidal speed of 2.6 m/s



Tidal stream Industry enerGisEr pRoject (TIGER)

Interreg Channel region promotes European Territorial Cooperation funding economic development projects in border regions between different European countries, to find common solutions to common problems which exist in multiple countries.

TIGER is a 46M€ , 4 year project, with 19 partners, approved 2 Jul 2019.

Led by ORE Catapult it will:

- consent new sites and deploy turbines in UK and France;
- develop a UK/FR supply cluster across the Channel region supported by FCO and DIT;
- collect tangible evidence of cost reduction; and
- persuade UK/FR policy makers to introduce a preferential support mechanism for tidal stream.

Contact

CORNWALL

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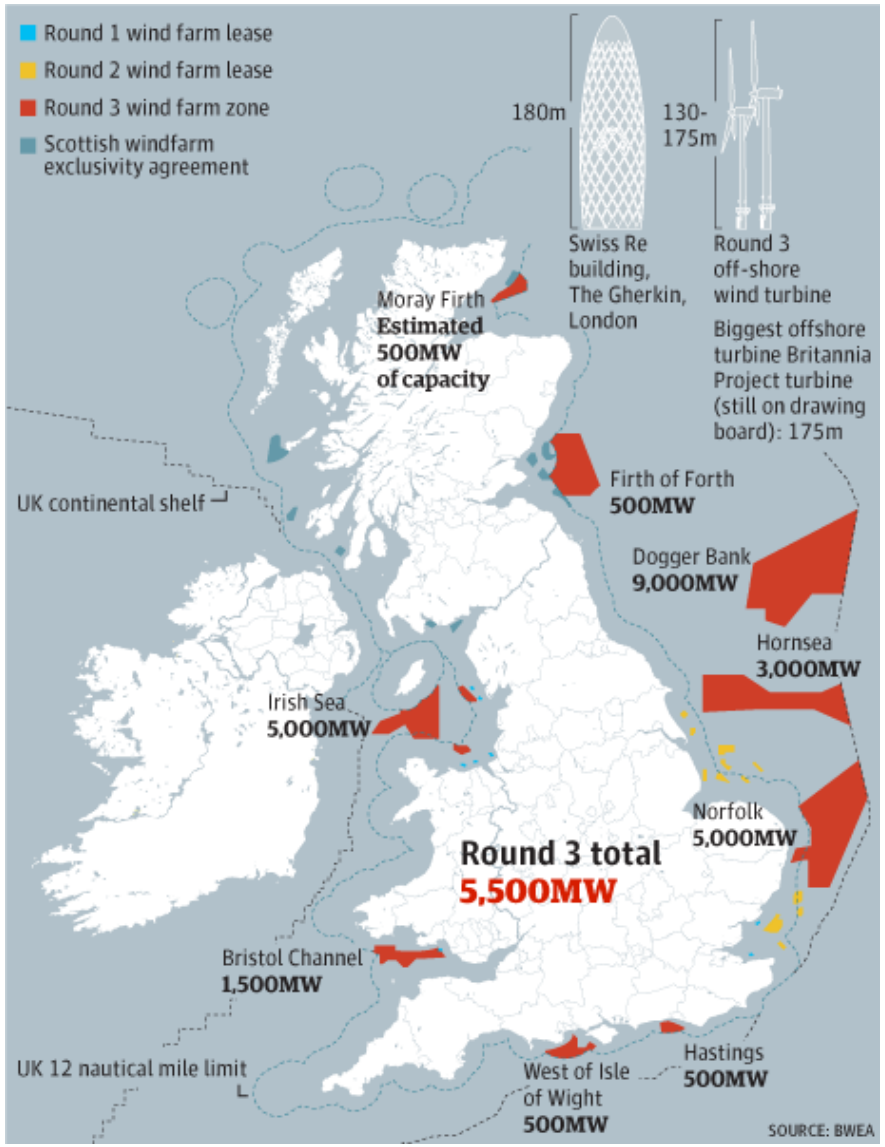
Offshore Wind in 5 Minutes

Offshore Wind in UK
June 2016

Offshore Wind in UK*	
Operating	5.10GW
Under construction	1.06GW
With planning permission	12.27GW
In planning	3.90GW
In development	11.95GW

*Renewable UK, June 2016

1GW powers 701,301 homes per annum



Offshore Wind is Growing…

United Kingdom

- 2020 Operational Turbines
- 8.53 GW

Rest of Europe

- 2470 Operational Turbines

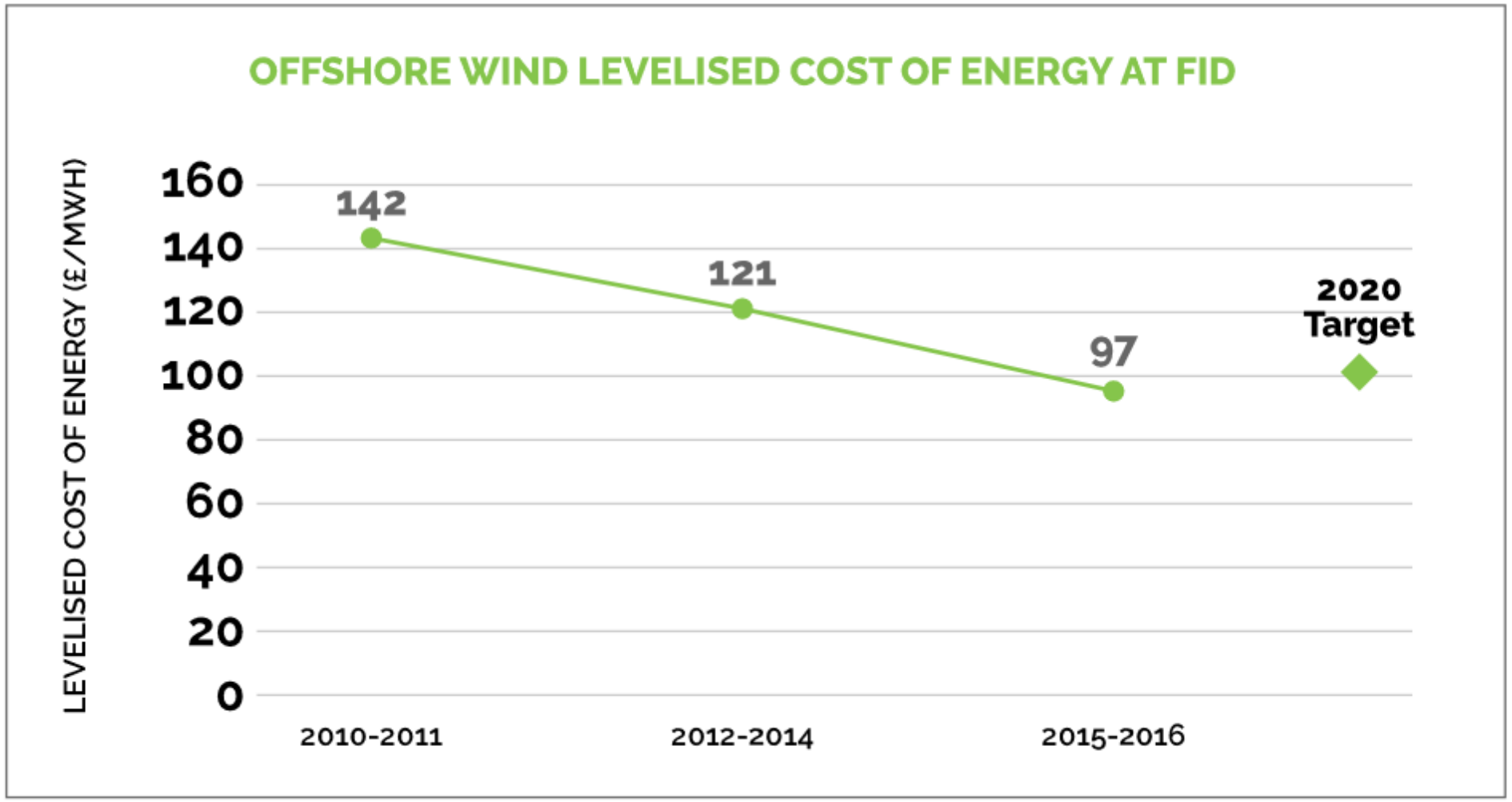
Globally

- 5046 Operational Turbines

http://electricinsights.co.uk/#/dashboard?_k=q8az3x

Cheapest form of large scale electricity generation…

- Offshore wind is now cheaper than new-build gas power stations, coal and nuclear.



Latest UK CFD Auctions:

- Triton Knoll: £74.80/MWh (2021)
- Hornsea One & Moray East: £57.50/MWh (2022)

Germany/Netherlands latest auction rounds were subside free

OPEN SEA OPERATING EXPERIENCE TO REDUCE WAVE ENERGY COSTS

Ocean Power Innovation Network

OPERA - Update

Paul Goodwin, Global Maritime

Blyth, 23-10-2019

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 654444

Consortium

- 11 partners / 5 Countries
- Multidisciplinary team
- Covers value chain

Validated cost models	Promotors	EVE
Validated operational procedures	Service companies	Global Maritime
Contribution to standards & de-risking	Certification bodies	DNV GL
Floating WEC & shared mooring	WEC & farm designers	OCEANTEC
Components & sub-systems	Suppliers	Kymaner
Open-sea test data	Field Test facilities	EVE BiMEP
Advanced control algorithms	Researchers	TECNALIA Univ. Edinburgh Univ. Exeter UCC IST

Key Challenges of Wave Energy

- Reduce COST of energy
- Improve overall PERFORMANCE
- Lower RISKS to attract investors

→ **Very limited EXPERIENCE of real open-sea operation**

Project Aims

Collect, analyse and share for the first time high-quality **open-sea operating data and experience**

Validate & de-risk **4 industrial innovations** for wave energy

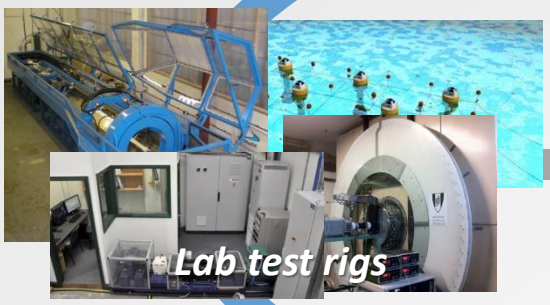
Innovation	Target	LCOE impact
Novel biradial air turbine	50% higher annual efficiency compared to Wells turbine	33%
Advanced control strategies	30% increase in energy production	23%
Elastomeric mooring tether	Reduce peak loads by 70%	7-10%
Shared mooring configuration	50% reduction in overall mooring costs in arrays	5-8%

Reduce the **cost of wave energy** by 50% in the long term

Methodology

1 Baseline configuration
Nationally funded prototype (2.5 M€)

3 Benchmarking of new configuration
Global assessment



DATA COLLECTION
2 years

2 De-risking path
Innovations and procedures

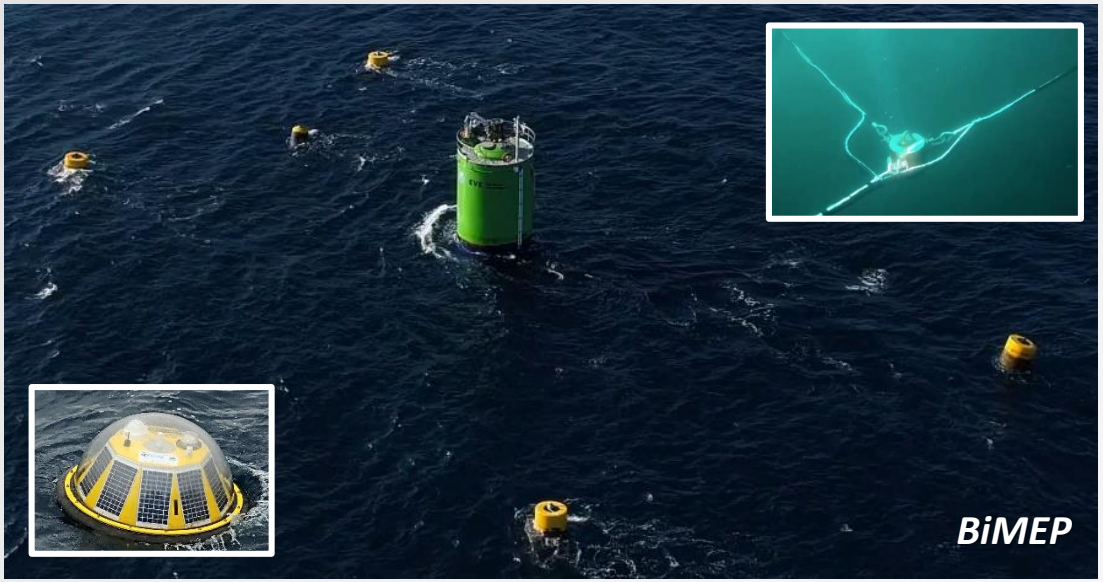
Feb 2016 • Jul 2019

https://www.youtube.com/watch?v=Px26idK701c

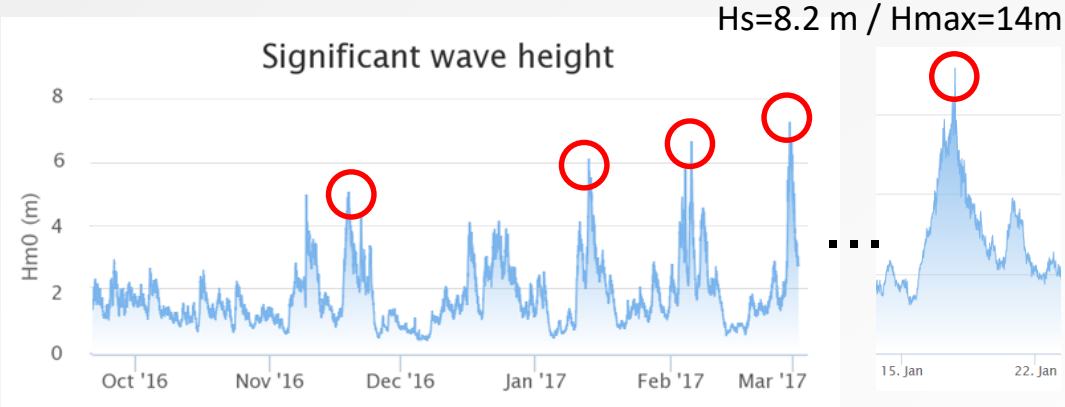
Highlight of technical results (I)

ALL

Successful testing of MARMOK-A-5 baseline configuration and biradial turbine



Hs=8.2 m / Hmax=14m



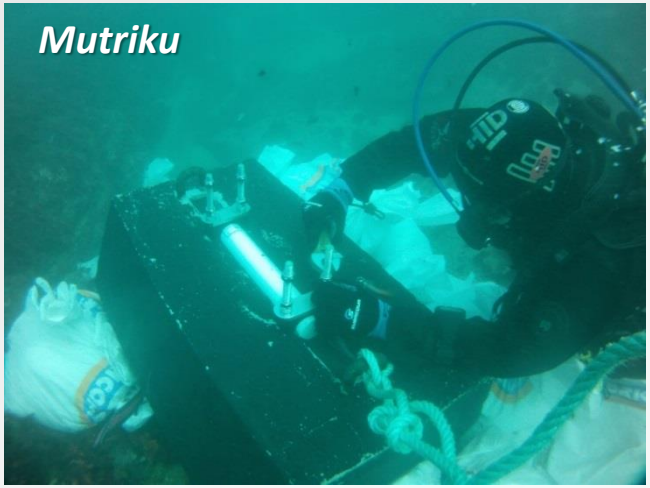
Highlight of technical results (II)

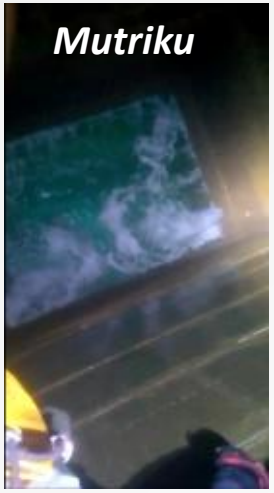
WP1

Collection of state of the art operating data and publication of extended datasets in ZENODO:

- Mooring loads monitoring system at BiMEP — 12 months → **155 GB** (582M rows)
- Power quality monitoring at Mutriku — 2 x 10 min/day → **150 GB** (1.6Bn rows)

Periodic inspection, maintenance and data recovery

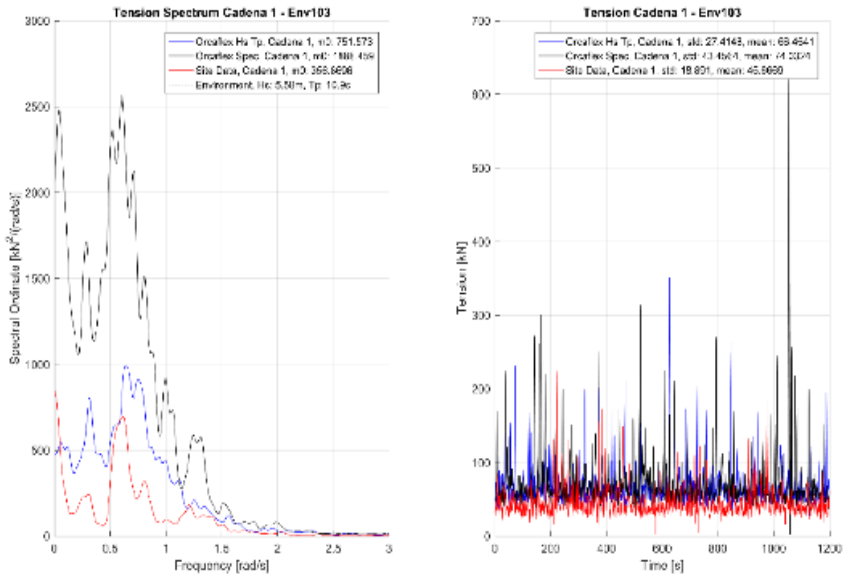




Highlight of technical results (III)

WP2

Validation of numerical model and Evaluation of conventional mooring



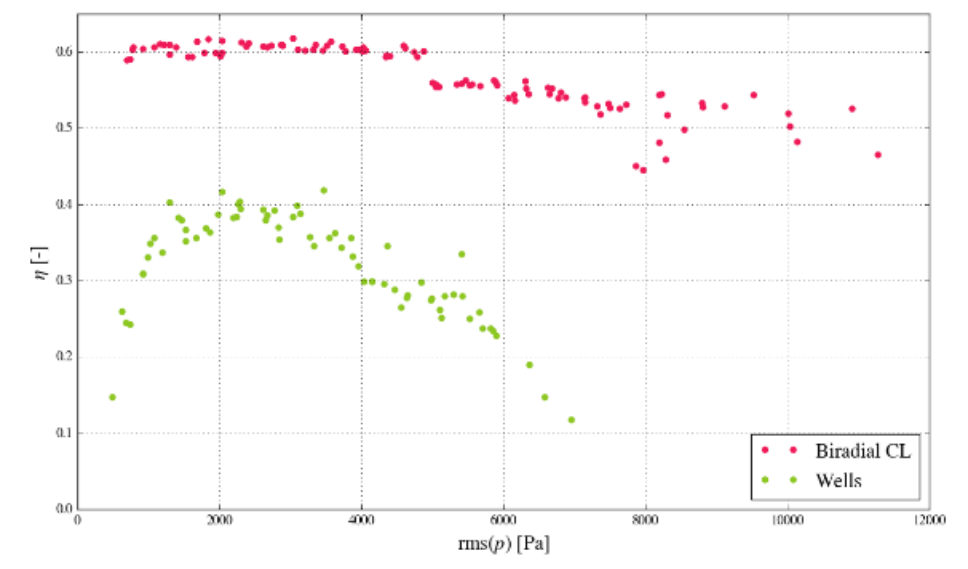
Deployment of two elastomeric tethers at BiMEP

Improvements to LSCS design

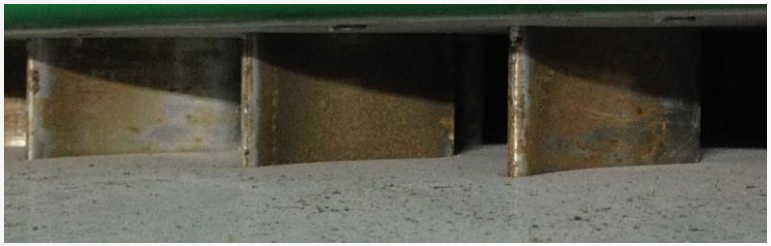
Highlight of technical results (IV)

WP3

Performance assessment of biradial turbine in Mutriku (efficiency +55%)



Identification of PTO fatigue drivers, risks and maintenance requirements

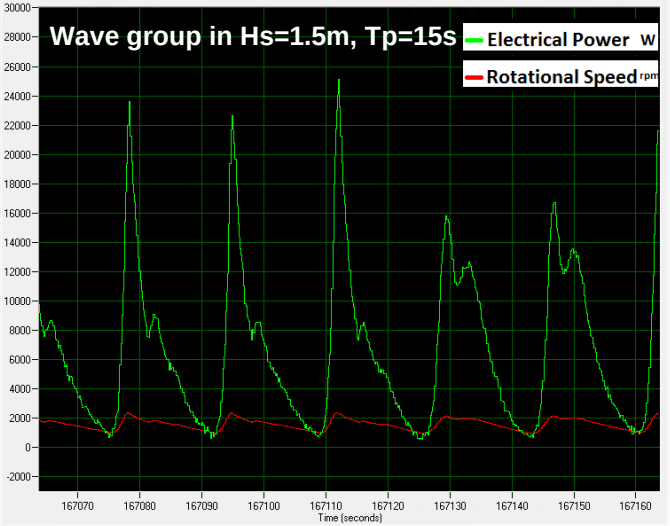


Highlight of technical results (VI)

WP4

Open-sea testing of 6 control laws at Mutriku

Generator peak load reduction (25%)



Increase in power production for the best adaptive controller (20%) and predictive controller (30%)

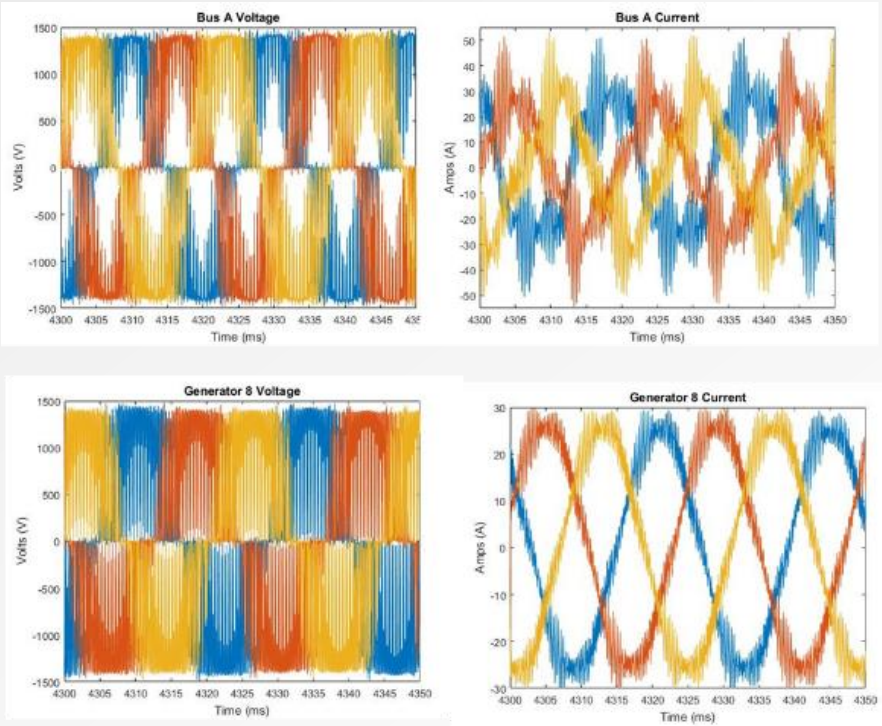
SUMMARY OF POWER PRODUCTION PERFORMANCE BY CL

SS	CL1	CL2	CL3	CL4	CL5	CL6
Weighted total avg	1	1.22	0.63	0.85	1.1	1.31

Highlight of technical results (VII)

WP5

Application of Technical Specifications and standards (mooring design, performance, power performance, power quality).



Initial recommendations based on the analysis of the operating data gathered

Highlight of technical results (VIII)

WP6

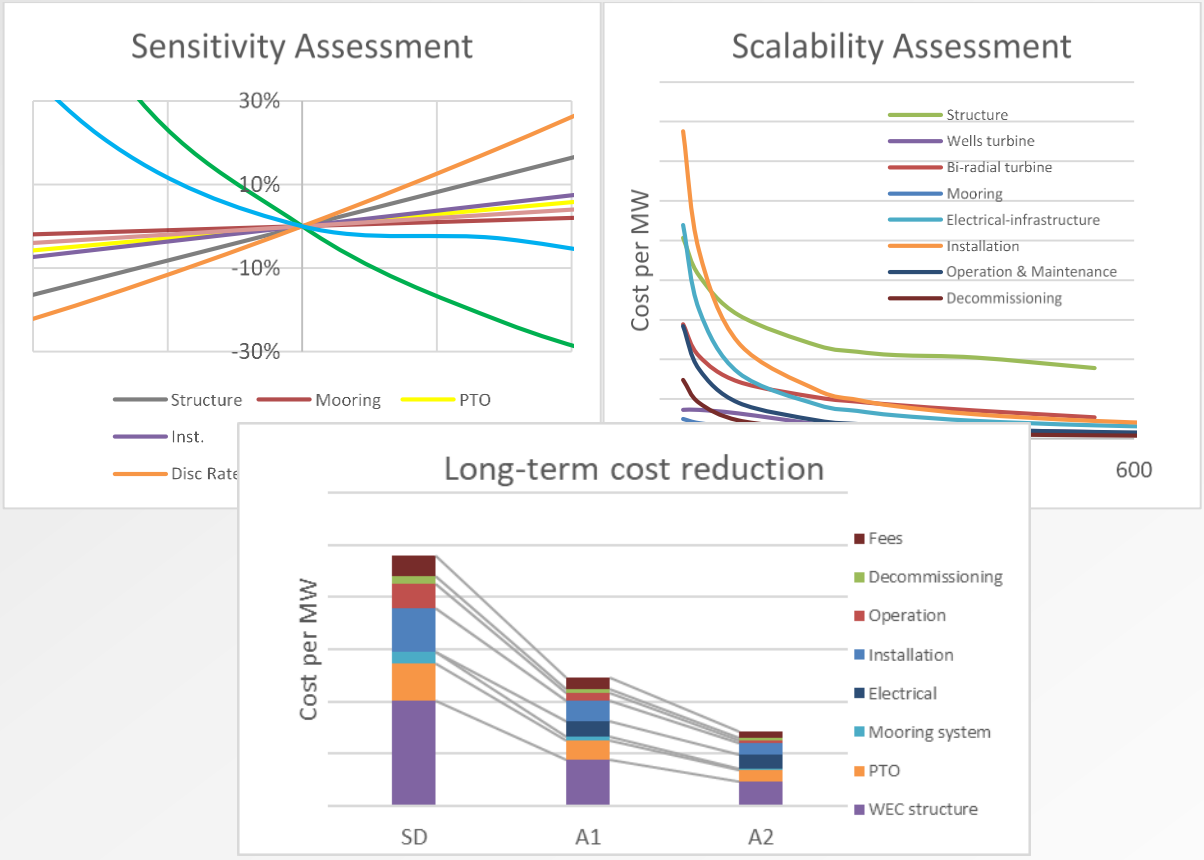
Definition, engineering and execution of towing-in of MARMOK-A-5

Coordination of elastomeric tethers deployment

Highlight of technical results (IX)

WP7

Development of economic, life-cycle and social impact assessment studies



Periodic update of technical risks (min. every 6 months)

Thank you for your attention!

Paul Goodwin
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Disclaimer

This Presentation reflects only the author's views and the Agency is not responsible for any use that may be made of the information contained therein

OPIN Workshop
Predicting failure of dynamic cables

23/10/2019 | David Young

CATAPULT
Offshore Renewable Energy

Agenda

- Overview of subsea cables
- Future cable industry trends
- Cable failure rates
- Cable failure cost
- Cable failure causes
- ORE Catapult Cable failure research

Static Cables / Dynamic Cables

Static Applications

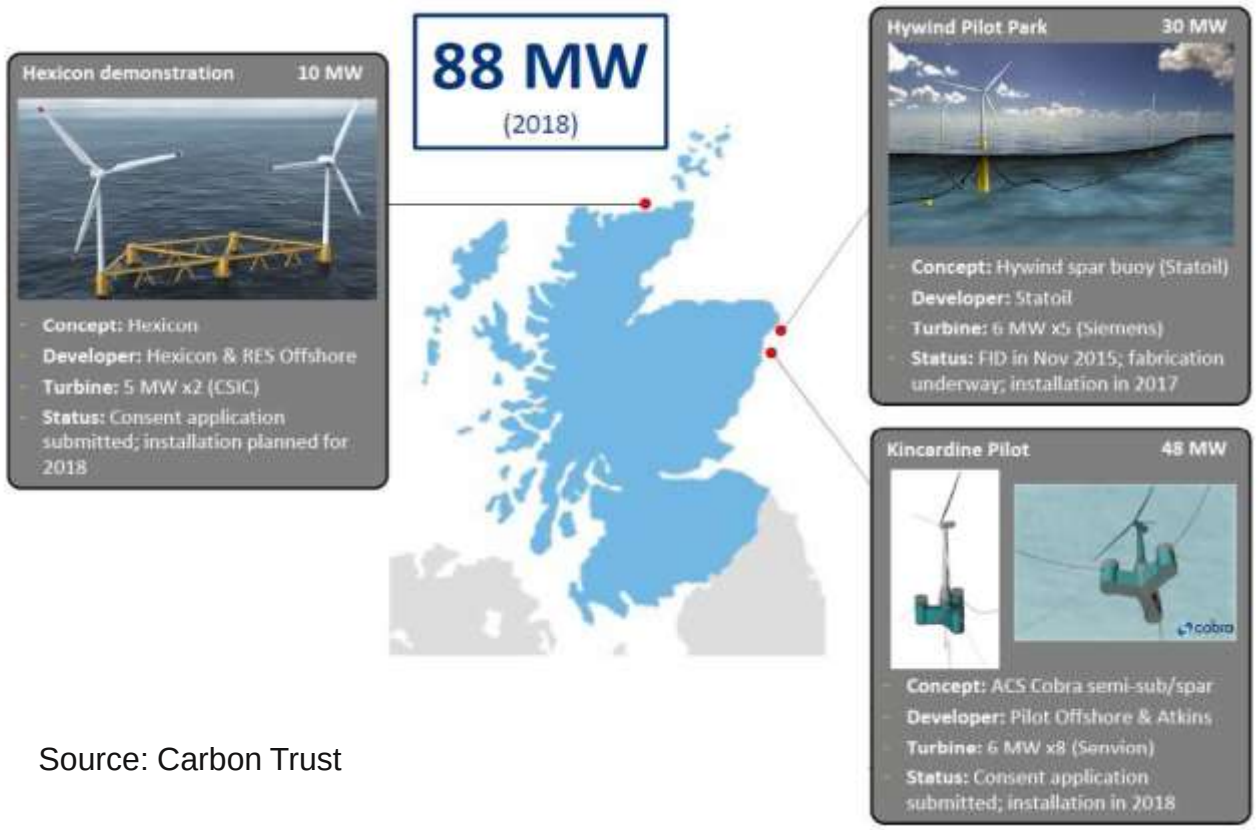
- Single Armour Layer
- Metallic Sheath/Screen
- Weight designed for Stability

Dynamic Applications

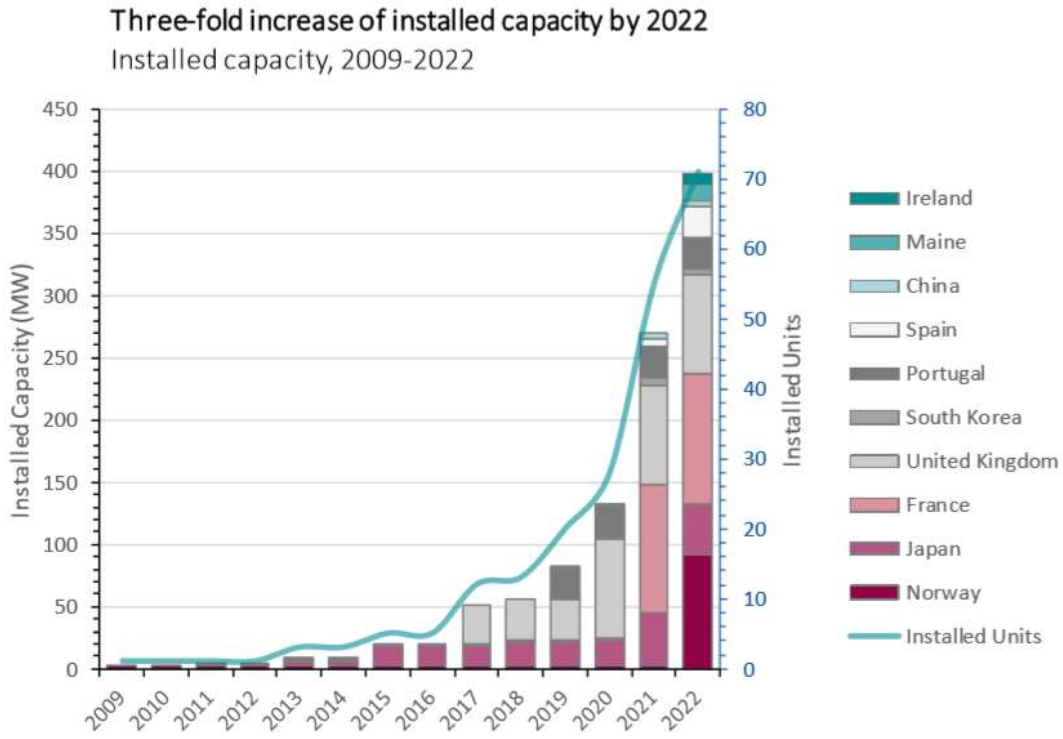
- Double Armour Layer
- Polyethylene Sheath/Screen
- Weight & Stiffness designed for dynamic applications

Source: JDR Cables

The Future, UK Floating Wind Industry



Source: Carbon Trust



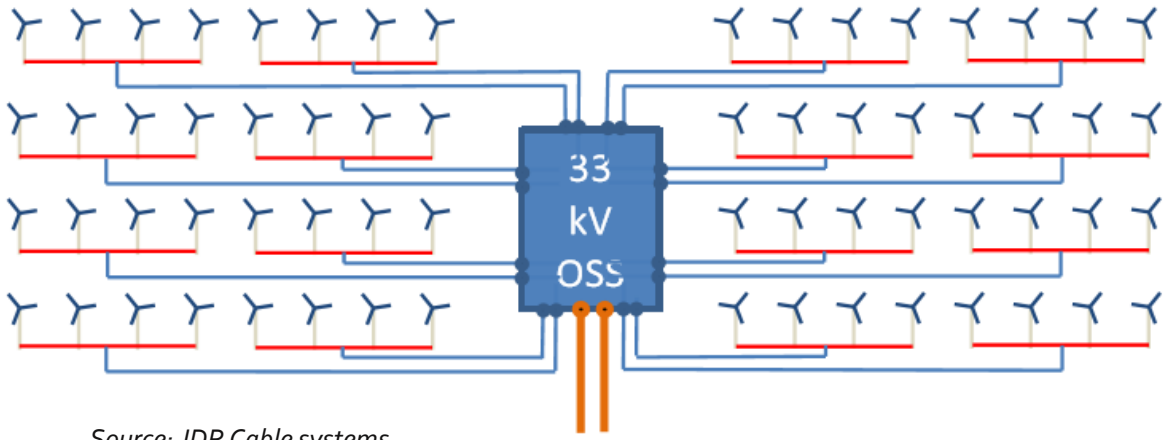
Estimated installed floating wind capacity to 2022

Source: 4C Offshore

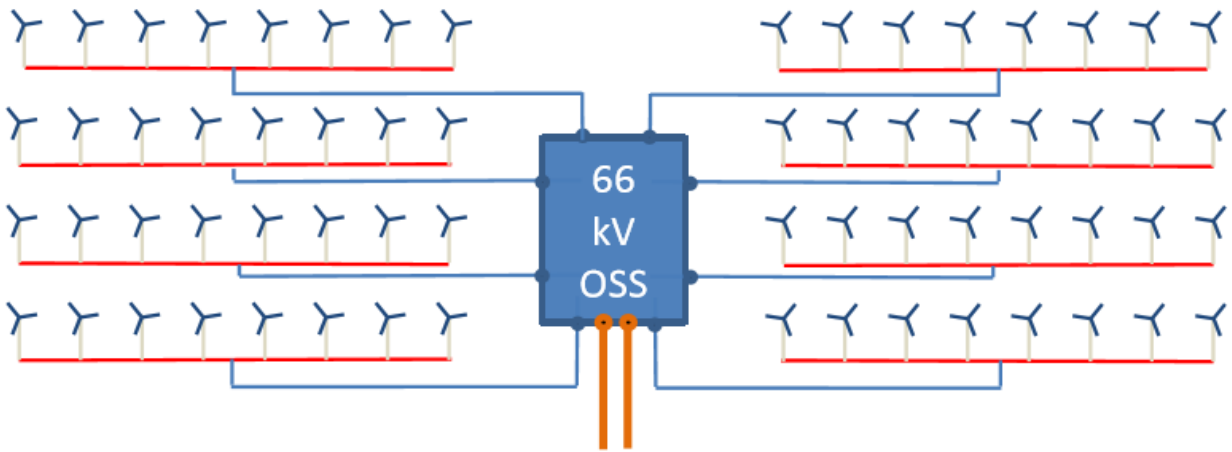
- End of 2019, UK Global leader with 32MW installed capacity.
- If offshore wind market expanding, so too must the subsea cable market to meet this demand. Currently 17,000km of offshore wind array and export cables installed globally. This is expected to increase to 53,000km by 2027.
- Tugce estimates that within Europe, 0.96km/day of array cables and 1.19km/day of export cables need to be installed to meet this demand.
- Is supply chain ready?

The Future, why move to 66kV?

- Historically MV 33kV array cables used
- Industry move to 66kV cables
- Mirrors trend in turbine capacity (3,4 MW → 7 to 8, even 12MW!)
- Double the voltage doubles the power



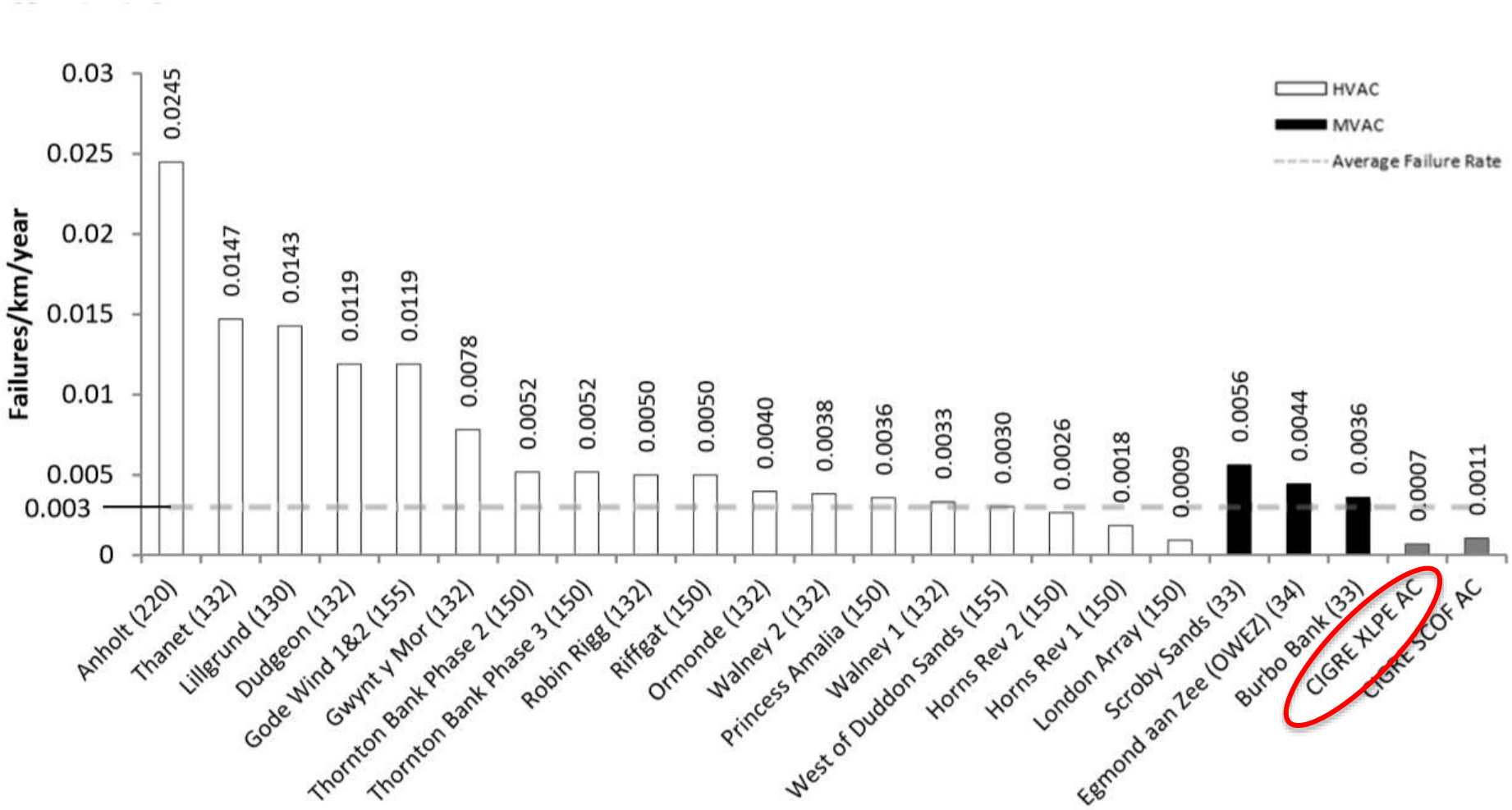
Source: JDR Cable systems



- Moving to 66kV layout reduces array cable lengths by 20-30%
- Simplifies offshore substation layout

Cable Failure Rates

- Cable failure rate for static wind farms: **0.003 failures/km/year**
- ORE Catapult has in house cable failure rate database, verifies Warnock's values.
- Much larger than currently used CIGRE failure figures.
- 1,681km of export cable in UK waters
- 1806km of array cable in UK waters



Failure rate of alternating current (AC) European offshore wind farm transmission connections until March 2018 (Source: Warnock et al. 2019)

Cost of Cable Failure

- Cables cost ~10% of a wind farm initial investment.
- Approximately 80% of insurance claims in the offshore wind industry are linked to cable failures.
- Average cost of a single cable repair **£12.5 million**.
- Average cable repair time **3-5 months** for an unexpected failure.
- When lost revenue accounted for total cost rises to **<£21 million**
- Insurers seeing trend **cables failing 2-5 years in service.**
- **With move to floating offshore wind, dynamic cables exposed to both mechanical and electrical stress.**
- Cables are found to be the most costly cause of financial losses in offshore wind industry.
- Cable failures have been named as the greatest risk to the continued lowering of the LCOE of offshore wind.

Table 1: Publicly disclosed cable repair costs

Repair	Cost	Source
Guernsey-Jersey (2012)	£8m	BBC News
Guernsey-Jersey (2015, pre-emptive)	£5.3m	Owners' annual reports
Moyle (2011-12), 2 repairs	£15.5m average per repair	Owner's annual report
Gwynt y Mor (summer 2015)	£10.2m	Ofgem (income adjustment claim)
Gwynt y Mor (2015-16)	£14.2m	Ofgem (income adjustment claim)
Thanet (2015)	£11.7m	Ofgem (income adjustment claim)

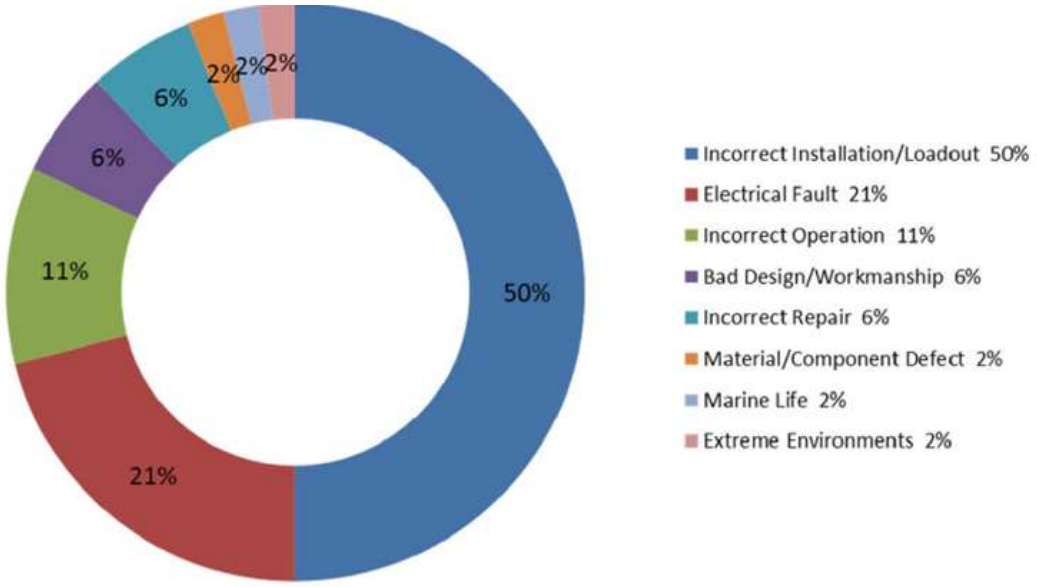
Cost of failures so far recorded have totaled over £1,150,000,000 of generation costs (UK).

Cause of Cable Failure

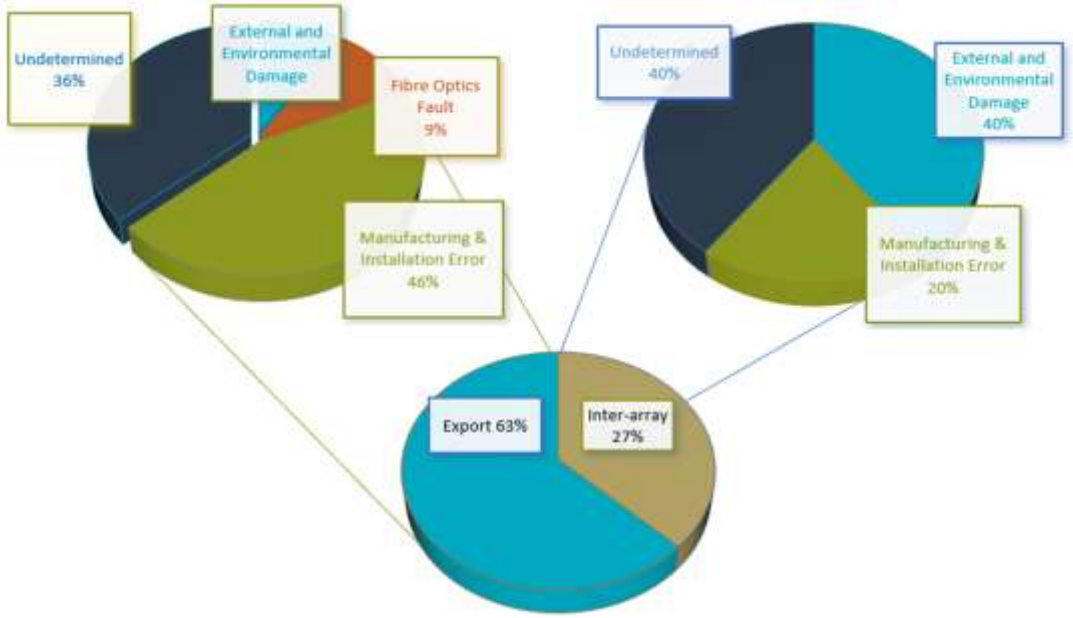
- Incidents taking place during operation of subsea power cables

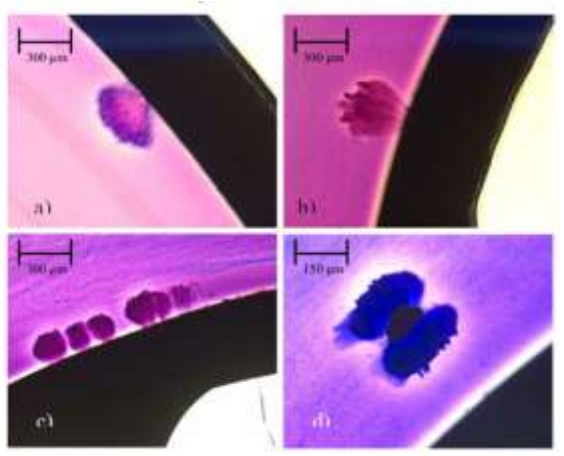
- Faults caused during various processes:
  - Design
  - Manufacturing
  - Installation
  - Operation

- Issues associated with these failures vary in nature.



Breakdown of cable failure causes (GCube)





Water trees across XLPE cable insulation

- During normal operation, excluding third part interference, cable failures can be grouped into three mechanisms:

1. Mechanical damage
2. Water ingress
3. Overheating

Global Model

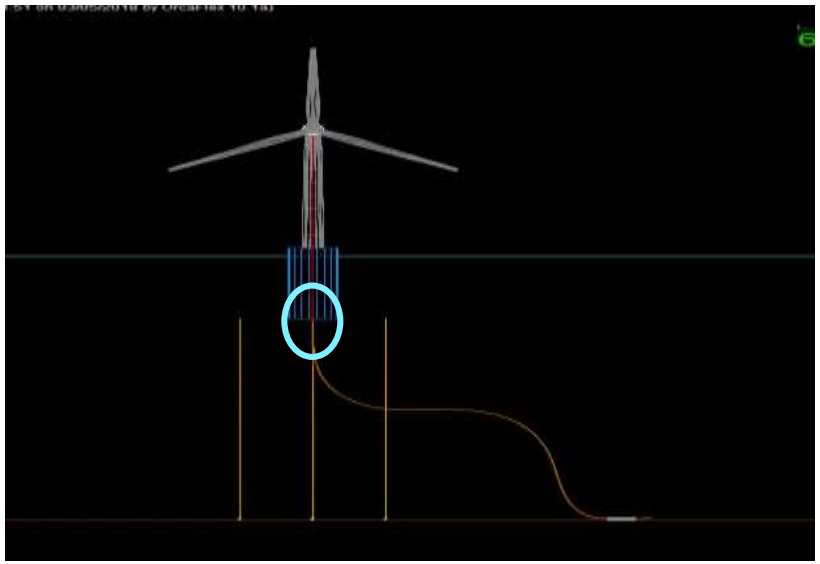


Fig. 3 Global Model Hs 4.75m, Tz 7.75s

- Can choose any location of interest along the length of the dynamic cable.
- At that point can extract force time histories.
- This allows for capture of the marine hydrodynamics, and the aerodynamics on the turbine and tower.

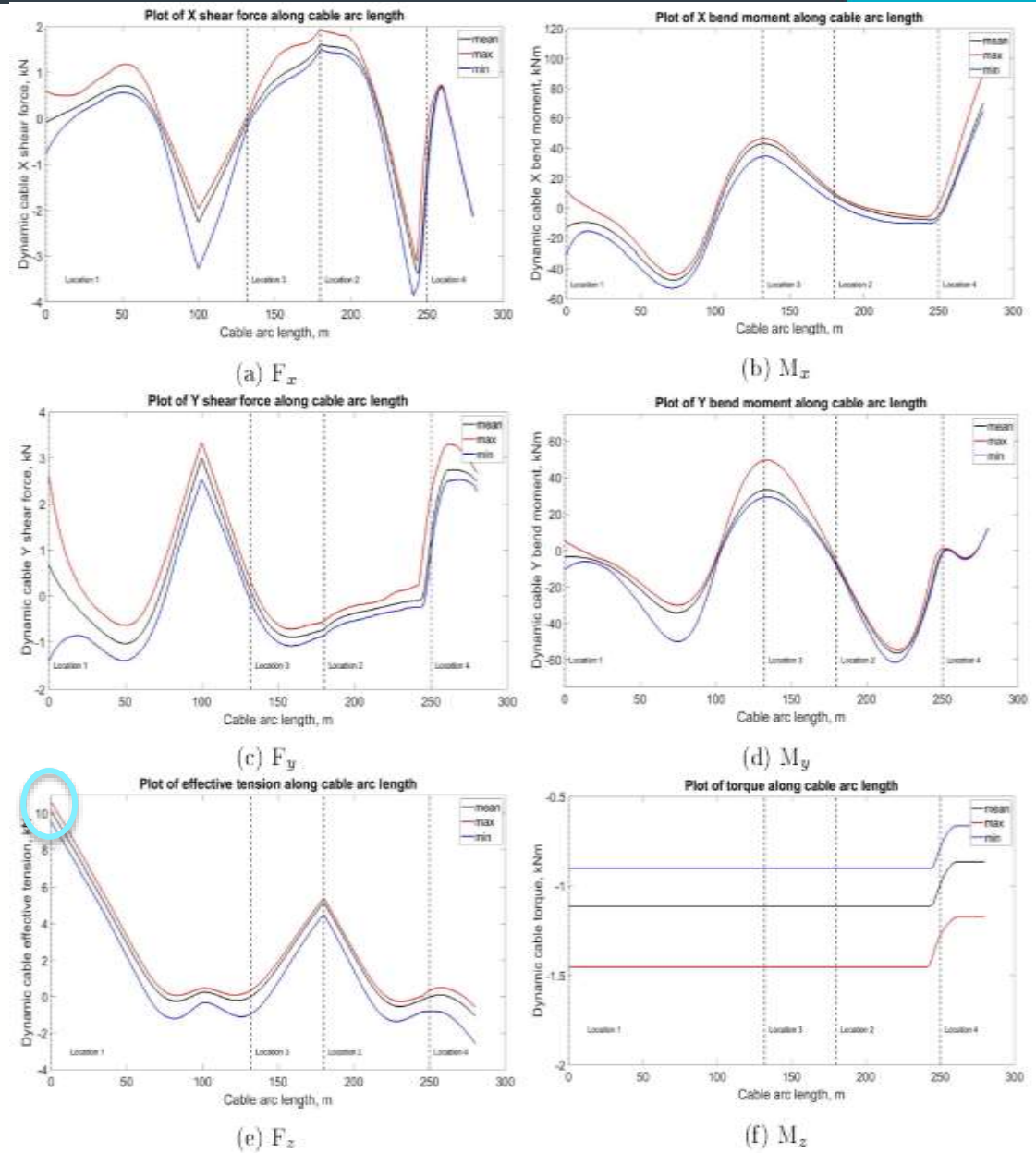
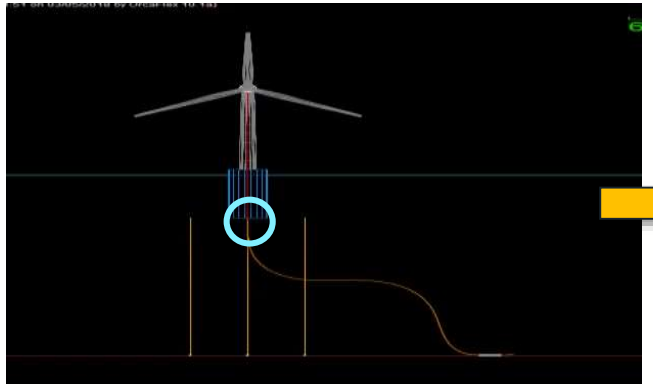
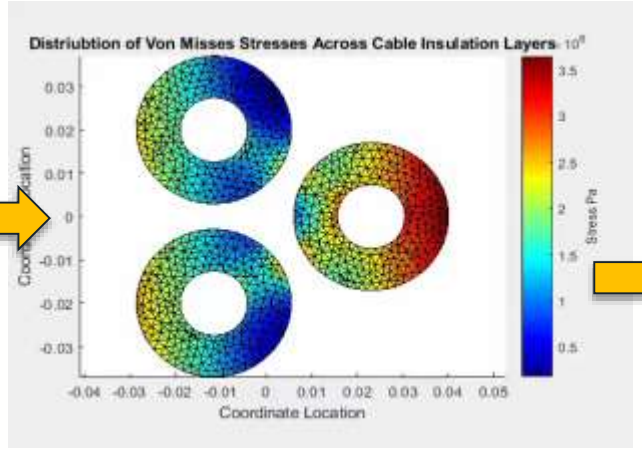


Fig. 4 Force results for load case 1, Hs 4.75m, Tz 7.75s

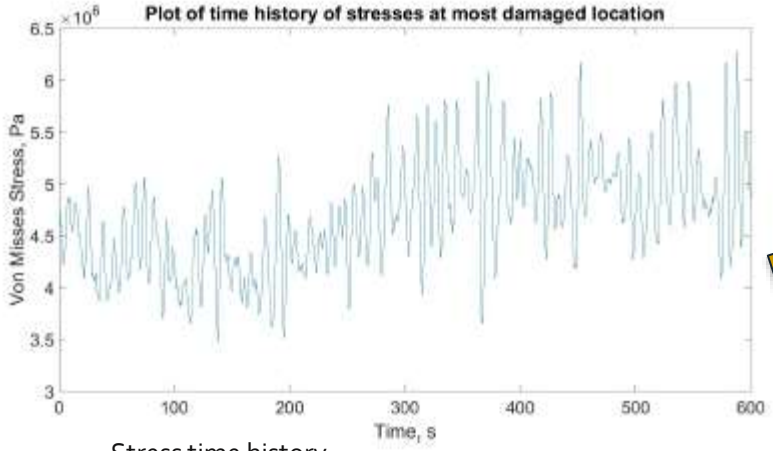
Local Model



Global Model



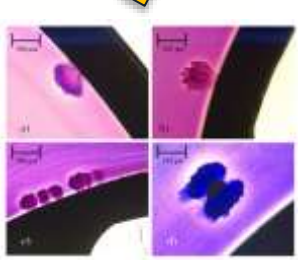
Local Model



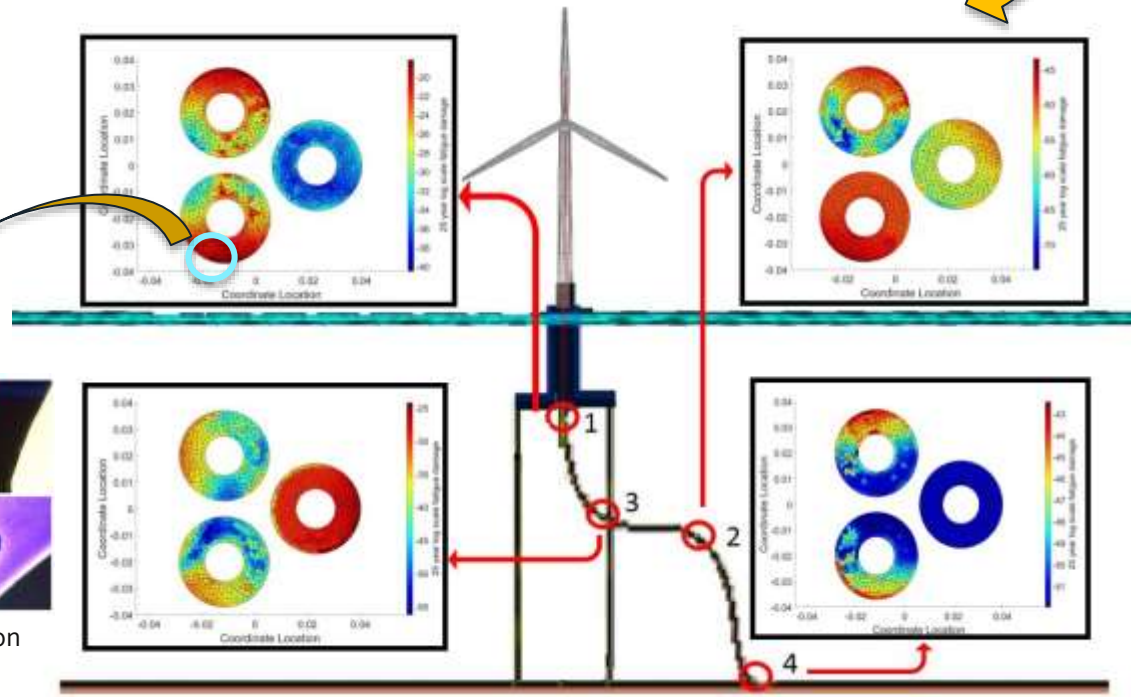
$$D = \sum_{i=1}^{k} \frac{n_i}{N_i}$$

Stress time history

- Can visualise stress distributions across the cable cross section
- Can chose particular cross section component
- Allows combining of the global model with local model.
- Figure 8 shows how fatigue damage is distributed across the insulation layers of the cable at different locations. Identifying water treeing initiation points.

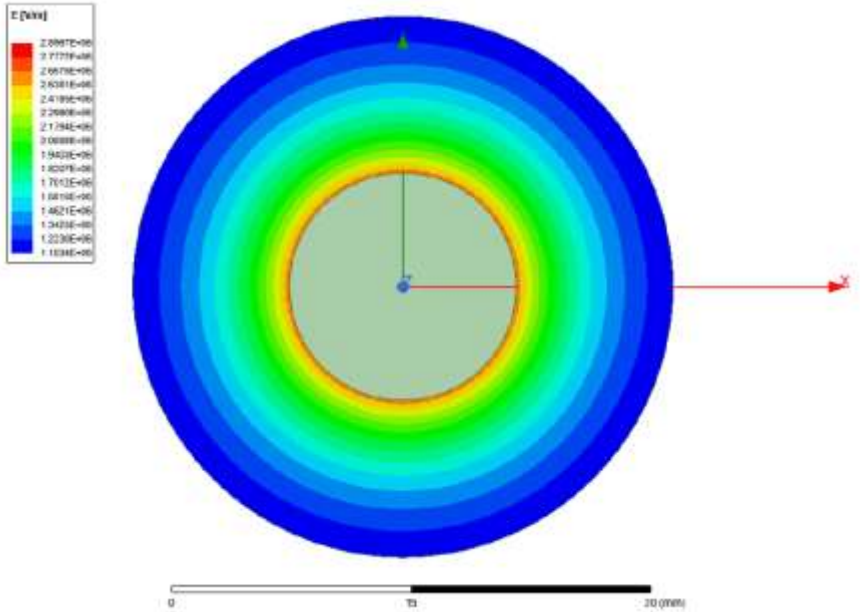


Water tree initiation

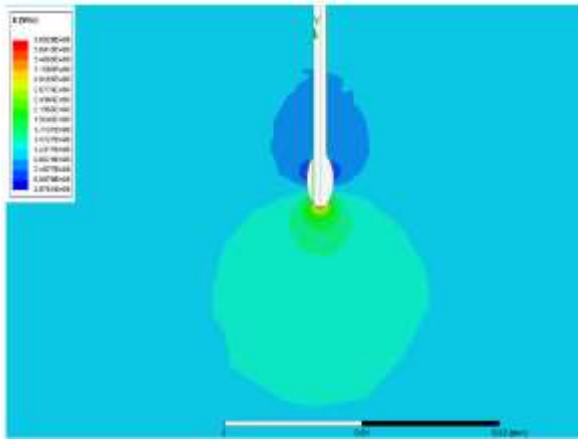


Insulation damage at various cable locations

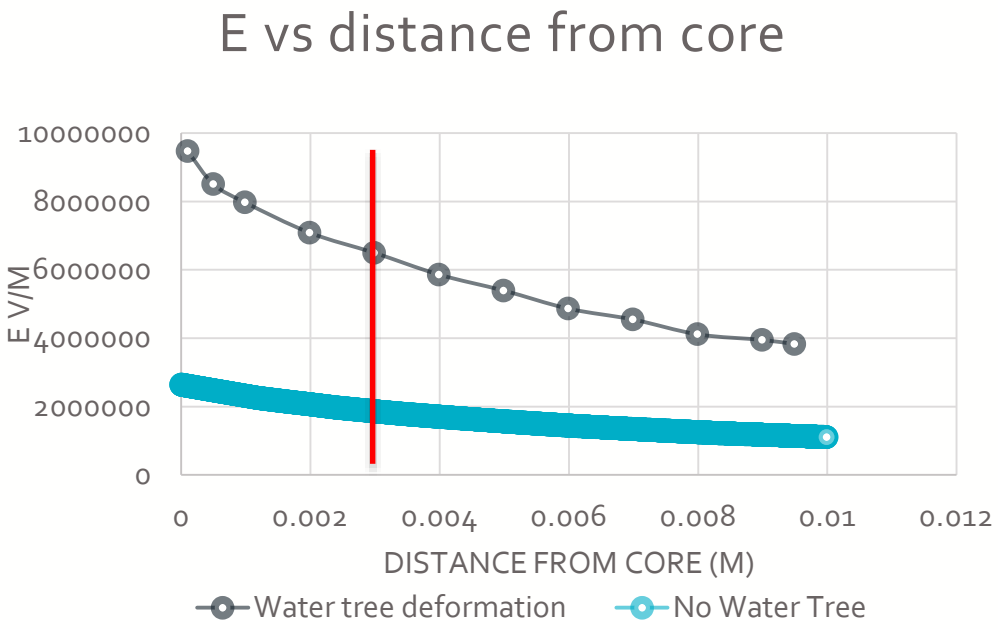
Electrical field distortion



Undisturbed electrical field model across the insulation



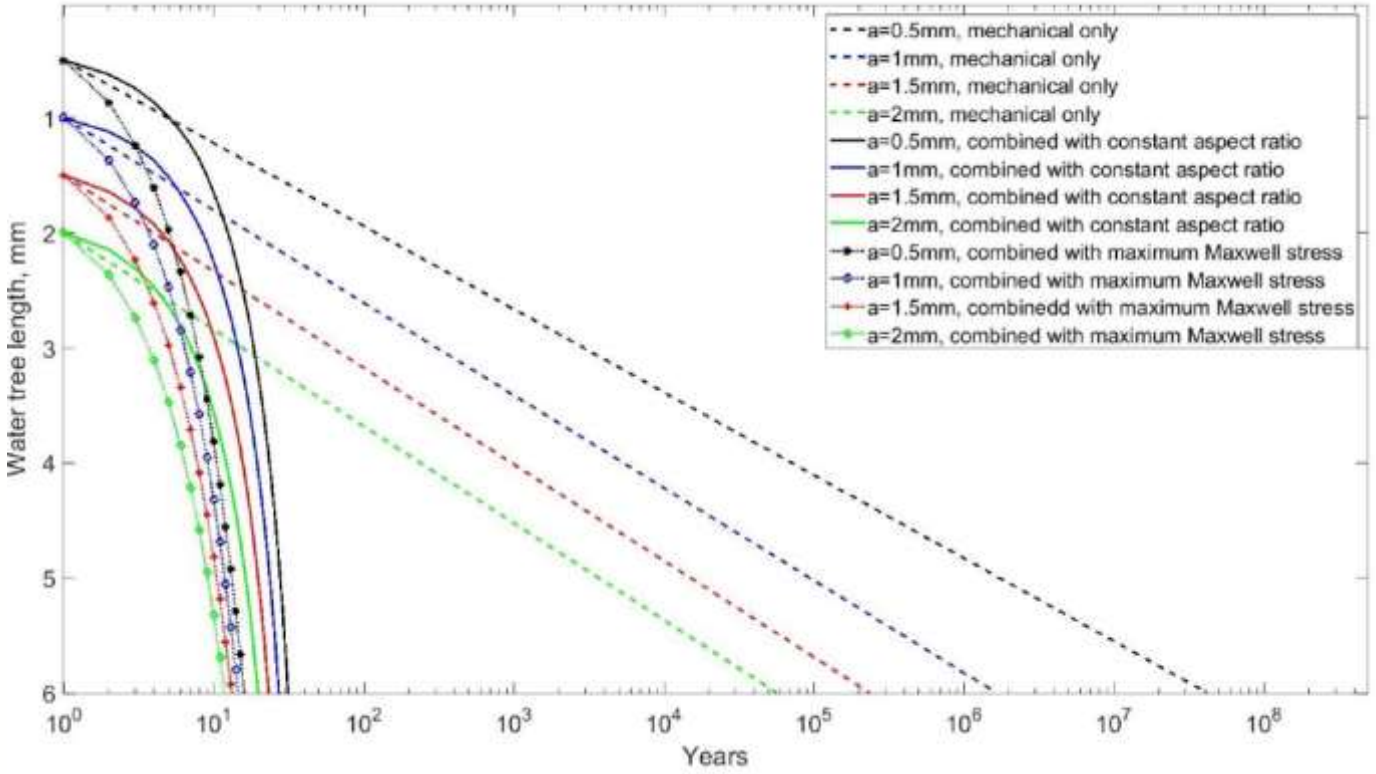
Electric field distortion due to water tree



Electric field strength at tip of water tree

- Electrical field is greatly distorted and concentrated at the tip of the water tree.
- Concentration happens over very small areas ~3 **µm**
- Water tress only need to propagate 60% across the insulation to cause failure.
- Electrical field concentrations generate stress on the XLPE polymer chains.
- This electrical stress is coupled with the previously calculated mechanical stress

Conclusions & Future work



Comparison of fatigue lifetimes for varying conditions. Clearly seen that coupled mechanical and electrical drastically reduces fatigue lifetime of dynamic cable

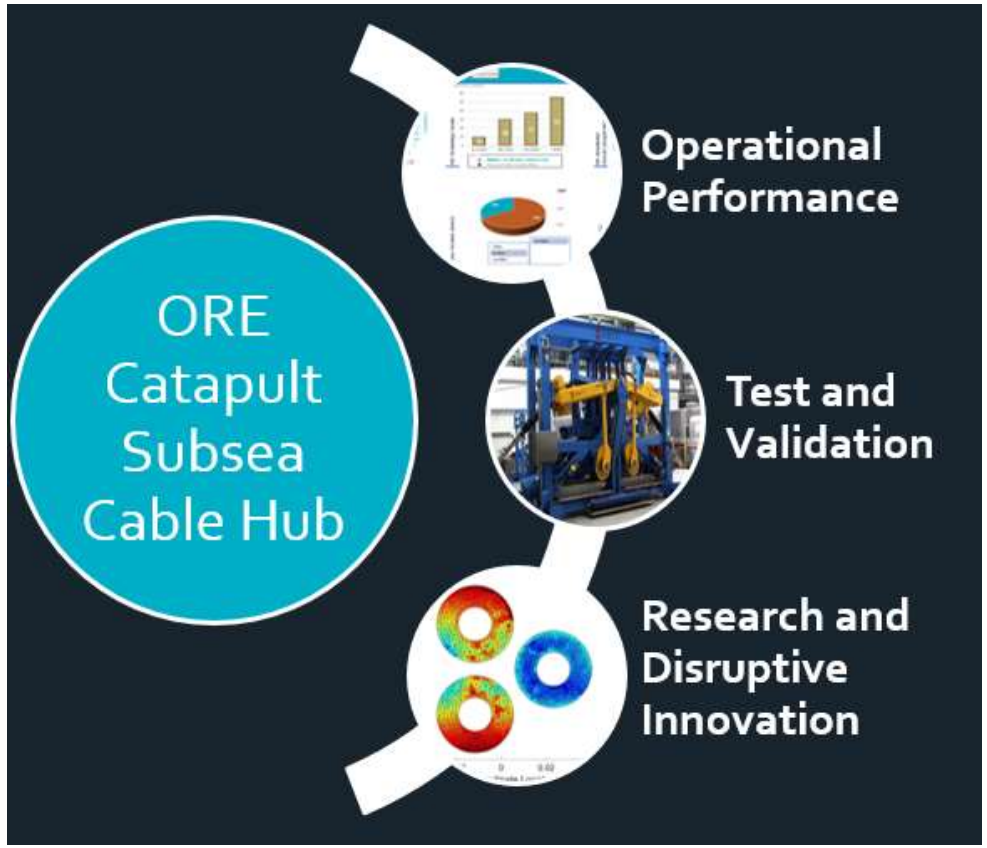
Future work is envisioned to validate models using the new dynamic cable test rig

Benefits:

1. **Considers dynamic mechanical stresses**. This is especially important for as industry moves to floating wind turbine.
2. **Coupled mechanical and electrical**. More comprehensive fatigue life assessment.
3. **Early warning of failure.** Currently cables health is assessment of its partial discharge (PD). Water trees cause failure but do not PD. Therefore this method allows for prediction of failure before PD.
4. **Allows for preventative maintenance.** Shown in initial table if a cable repair can be pre-emptive, drastically reduces costs.

Conclusions

- Dynamic cables are not the same as traditional static cables
- Subsea cable failure rate 0.003 failures/km/year
- Cable failures so far have totalled over £1,150,000,000 of lost generation costs
- "Mechanical damage" (incorrect installation, external & environmental interactions) greatest cause of cable failure
- Coupling mechanical and electrical stresses drastically reduces cable fatigue lifetimes
- New testing capabilities with new cable rig for simultaneous wet, energised and bending cable testing.



Critical factors and impacts on failures

- Support with the development of the failure and cause root database
- Leveraging technical and commercial knowledge from its internal database of UK' operating offshore wind farms
- Support improvements in the testing requirements, offering expert opinion on new testing methods and updates to the specification and guidelines that may reduce the failure rates
- Research and collaborate with academia and industry to research new disruptive technologies.

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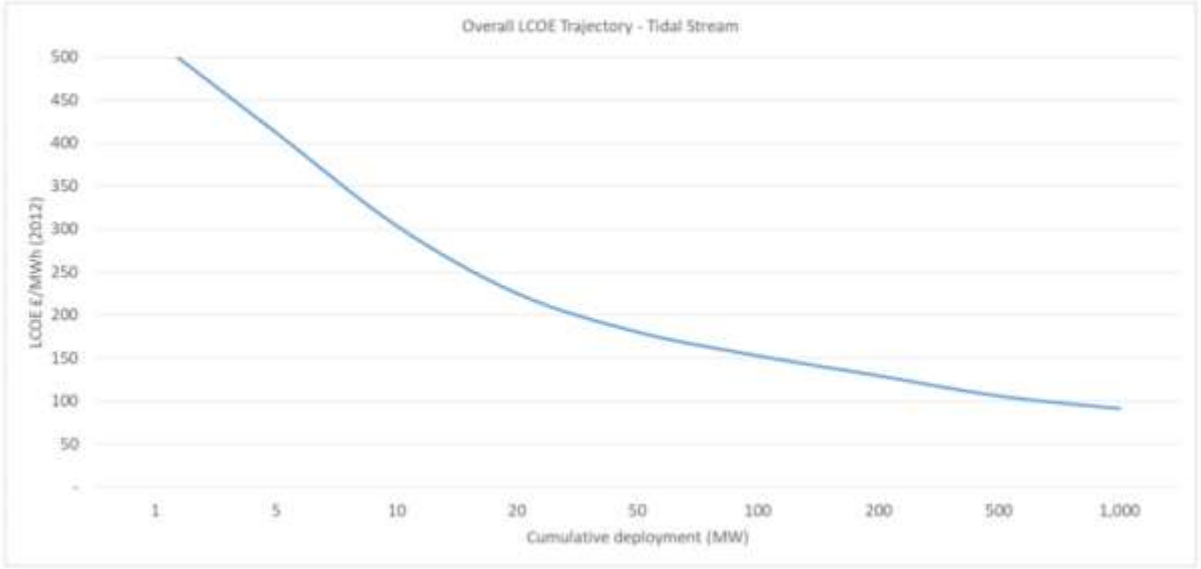
Tidal stream Industry enerGisEr pRoject (TIGER)

22/10/19 | Robbie Brady

CATAPULT Offshore Renewable Energy

Project Justification

- Momentum created by significant UK public support between c.2004 and 2014 has now visibly slowed, with a knock-on impact on private sector investor confidence.
- the UK government's clean growth strategy has set out three tests:
    1. Can we see a **clear cost reduction pathway** for this technology, so we can deliver low cost solutions?
    2. Can the UK develop world-leading technology in a sizeable global market?
    3. Does this deliver maximum carbon emission reduction?
- Commonality across technology is essential to achieve the cost savings the industry needs: pitch control systems, deployment/retrieval, blades etc
    - TIGER aims to support commonality through cross border collaboration and shared learning



Tidal stream Industry enerGisEr pRoject (TIGER)

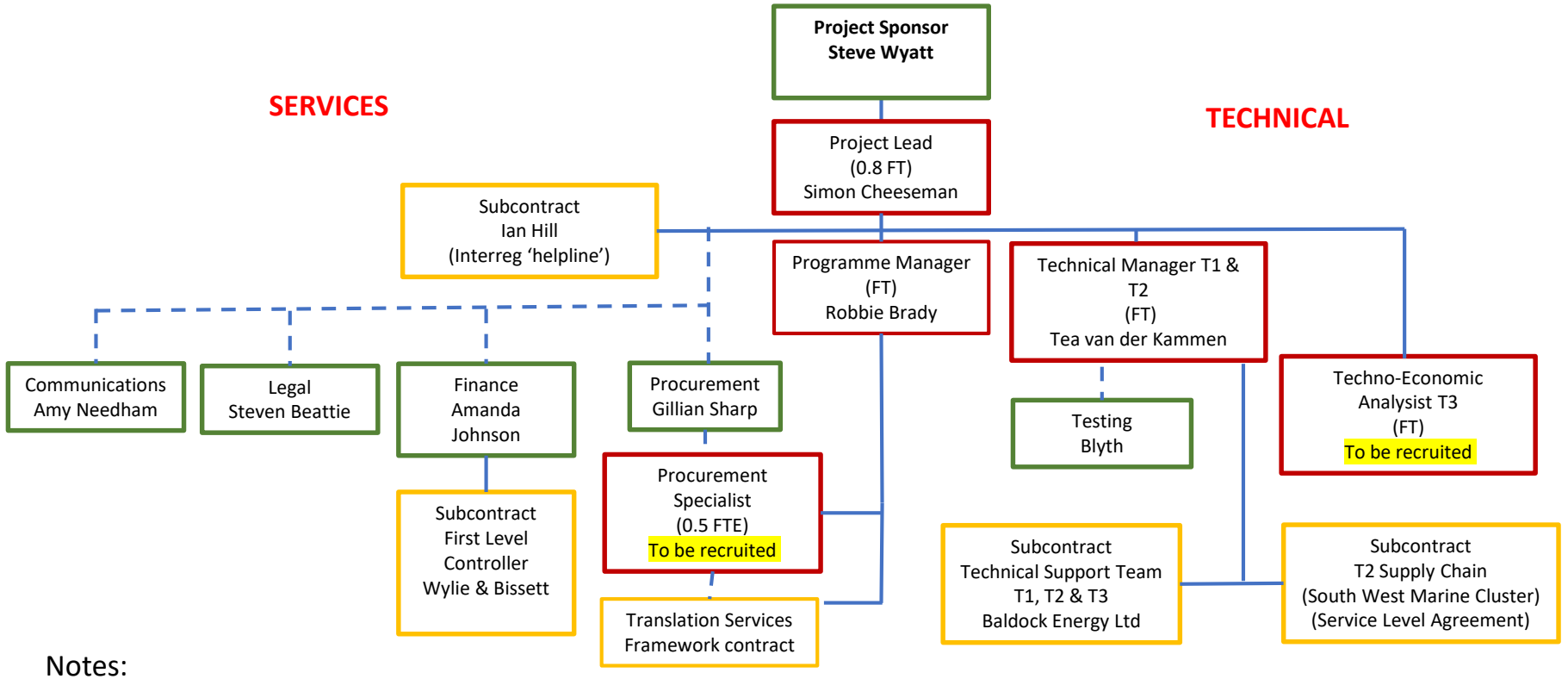
Interreg Channel region promotes European Territorial Cooperation funding economic development projects in border regions between different European countries, to find common solutions to common problems which exist in multiple countries.

TIGER is a 46M€ , 4 year project, with 19 partners, approved 2 Jul 2019.

Led by ORE Catapult it will:

- Consent new sites and deploy turbines in UK and France;
- Develop a UK/FR supply cluster across the Channel region supported by FCO and DIT;
- Collect tangible evidence of cost reduction; and
- Persuade UK/FR policy makers to introduce a preferential support mechanism for tidal stream.

TIGER - Catapult Project Team

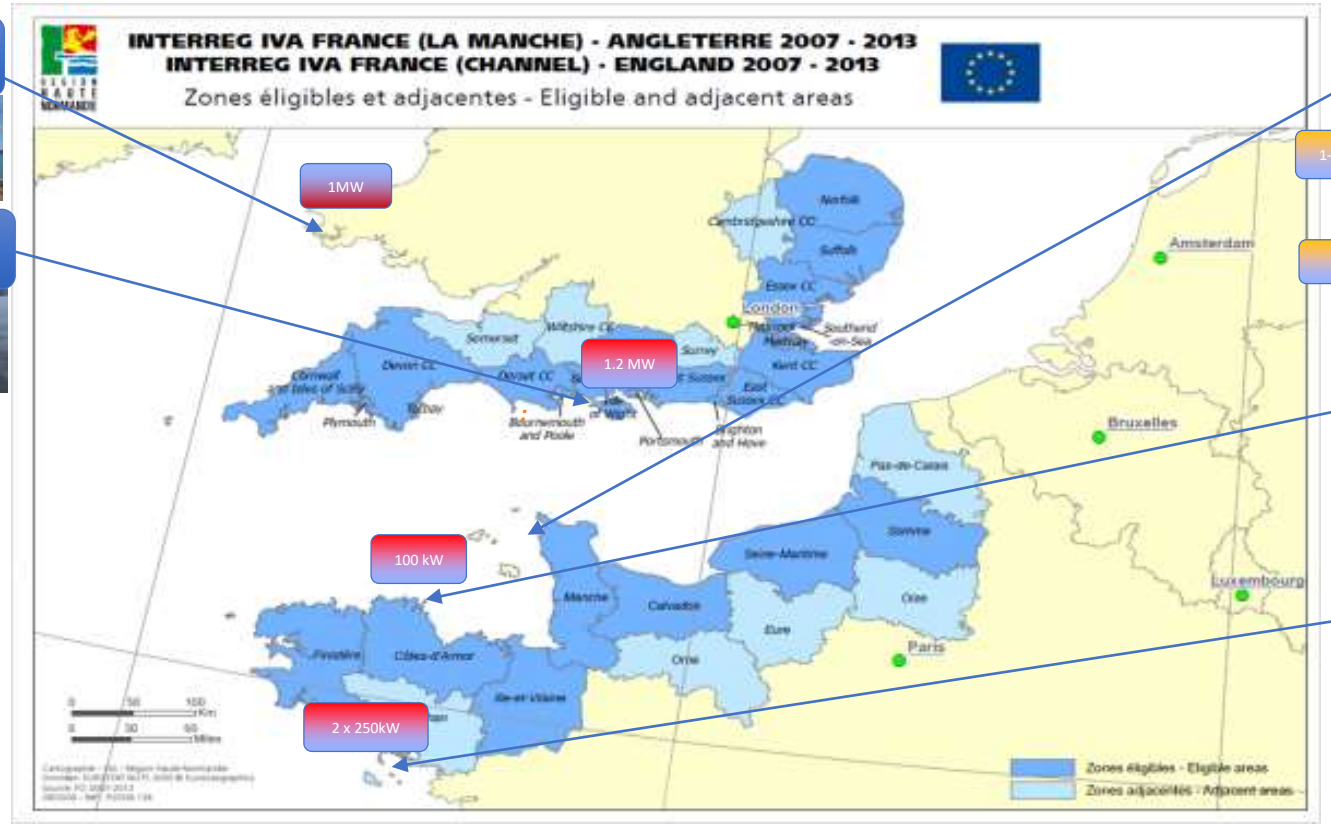


Notes:

- Based in Catapult's Cornwall Office x5
- Subcontract x5
- Reach back to Blyth/Glasgow x6

Programme Area and Project Sites

Project = A joint investment to demonstrate commercial potential through shared problem solving and economic modelling



TIGER will deliver:

2 sites re-purposed
4 new consented sites

2.8MW (+ 5MW) installed

12 New designs
8 New Products (inc turbines)

New networks - MEC; Supply Chain
Training – Tidal, Low Carbon

Cost reduction reports, data base, environmental data

Project Summary

Project Title: Tidal stream Industry enerGisEr pRoject (TIGER)

Project timeframe: July 2019 ⟶ March 2023

Description: Multi partner collaborative project to:

1. Complete consent on three new tidal sites:
   - Le Raz Blanchard – (1) SIMEC Atlantis (initially 20MW); (2) CMN (up to 10MW)
   - Morbihan – Sabella (up to 10MW)
2. Sites re-purposed:
   - Paimpol-Bréhat – DC to AC outputs, infrastructure for generic fixed bottom turbines
   - Ramsey Sound – Remove 400kW Delta Stream turbine, refurbish infrastructure, install new turbine
3. New tidal turbines installed (c 2.5MW):
   - Minesto - DG100, 100-kW power plant at the Paimpol-Bréhat test site
   - Ramsey Sound – 1 x 1MW generic turbine design
   - Sabella – 2 x 250kW at Morbihan
   - Trident – Phase 1 - 1 x 12kW demonstrator; Phase 2 – 10 x 120kW at Yarmouth
4. New UK/FR Networks – Marine Energy Council; Supply Chain; Awareness; Training
5. New Training – Supply Chain; Societal

WP T1, T2

WP T3

Catapult role: Proj Man, technical coordination, cost reduction assessment.

Questions?

ORE Catapult eGrid Presentation

23/10/2019

Dr. Michael Smailes

EUROPEAN UNION
European Regional Development Fund

CATAPULT
Offshore Renewable Energy

Agenda

- Test Facility Motivation
- eGrid Introduction
- eGrid Next Steps
- Grid Connection Support Series

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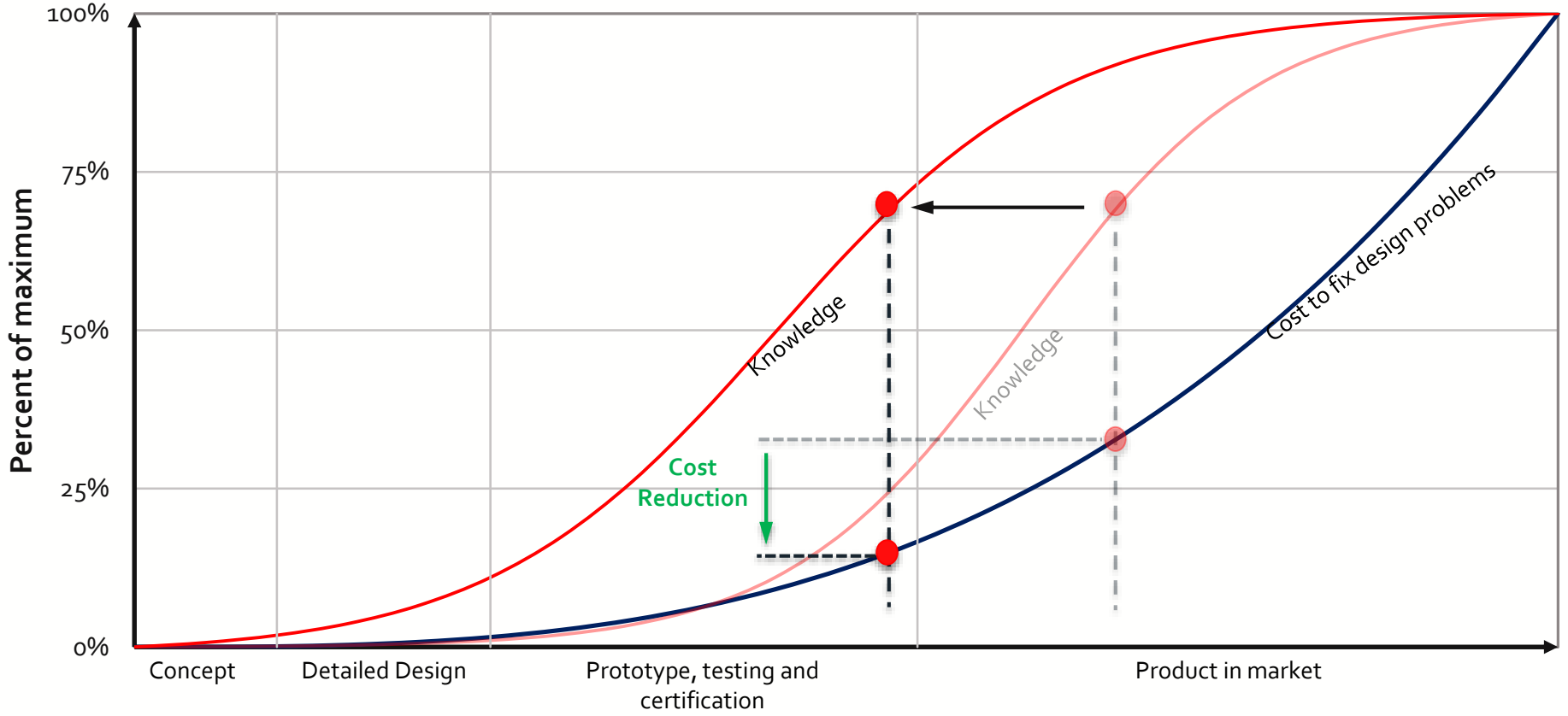
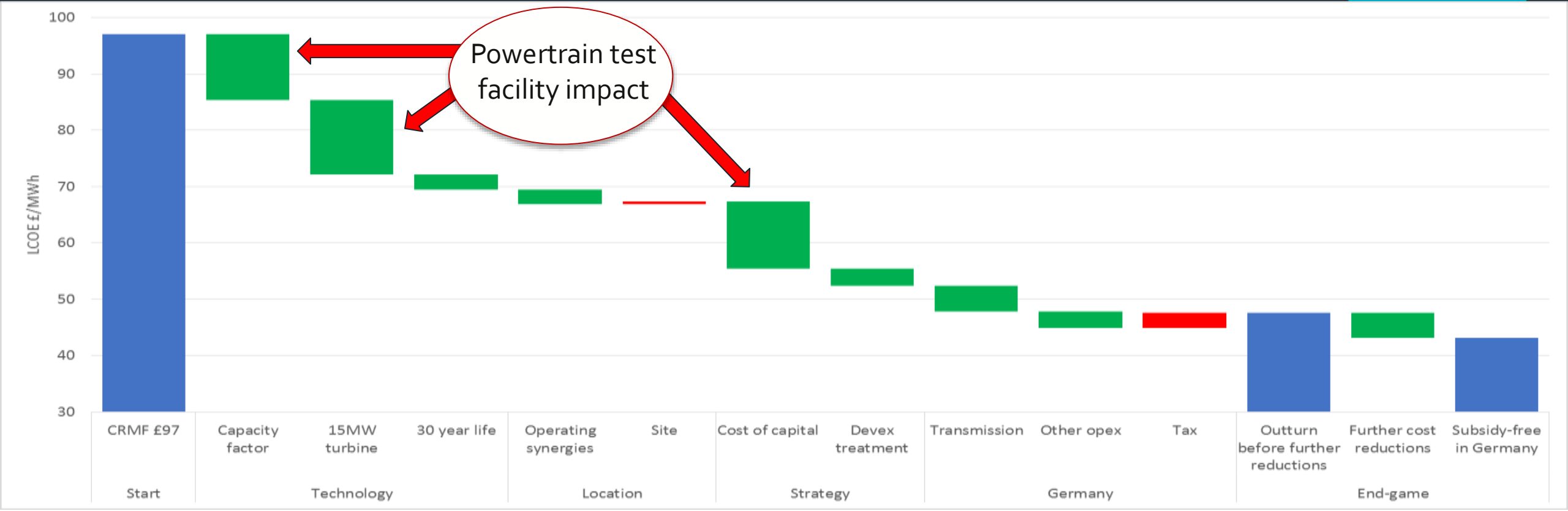
Test Facility Motivation



- Cost to rectify problems increases exponentially through the design phases and into how long the product has been on the market (how many devices have been sold)
- This is coupled with knowledge of the turbine only increasing with time…
- To reduce costs and increase confidence, knowledge of the device's performance must be realised earlier on

eGrid Motivation: Offshore Wind – towards subsidy-free



3 key required cost reductions to move from £97/MWh to subsidy-free in Germany can be aided significantly by a Powertrain Test Facility as follows:

Capacity Factor Increase

- Accelerated life testing
- Failure analysis
- Digitalisation validation

15MW Turbine

- Faster, controlled testing
- Accelerated learning

Cost of Capital

- Increased confidence
- Higher reliability

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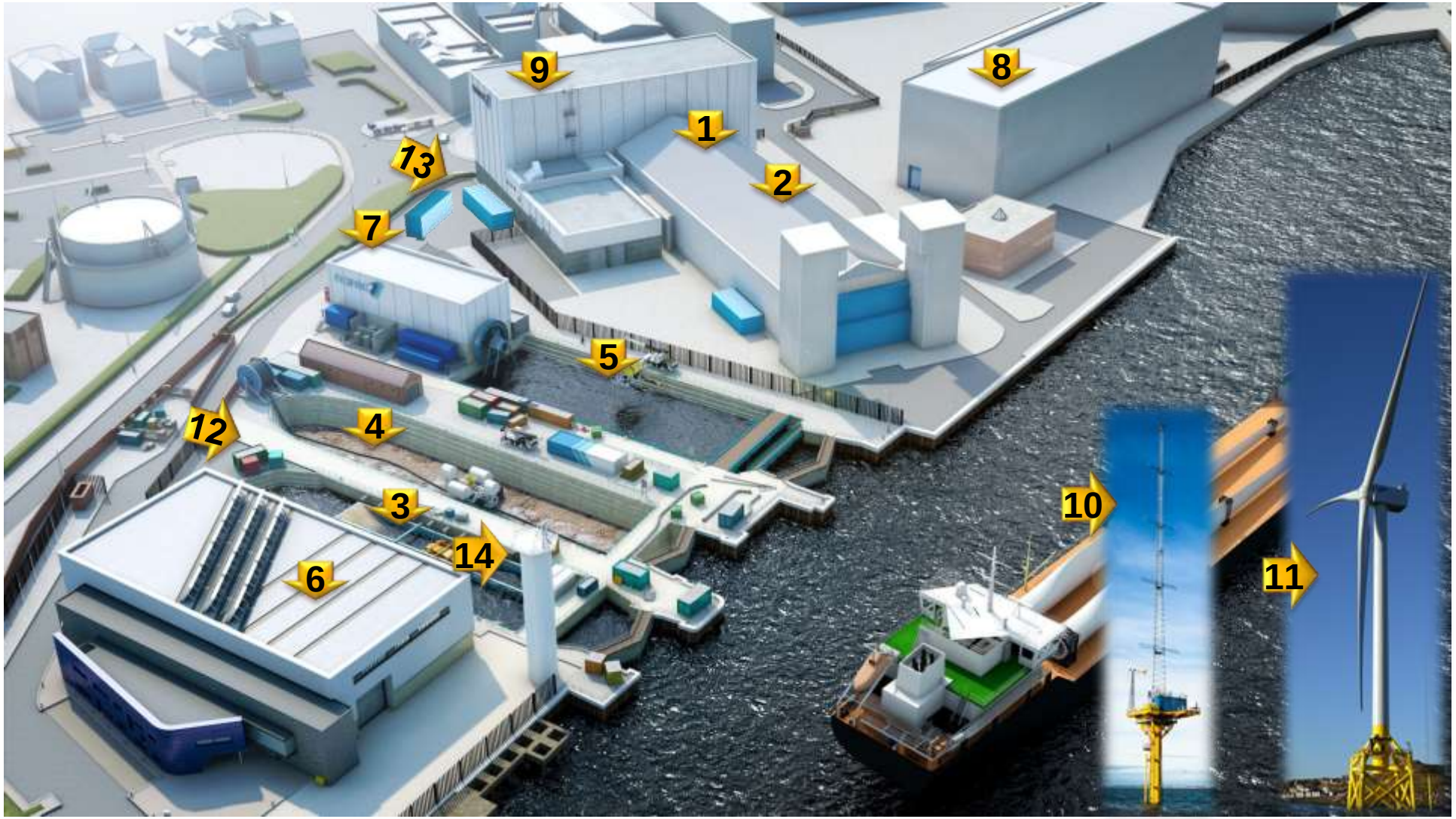
Blyth Site



Test Facilities

1. 50m blade test
2. 1 MW Drivetrain Test Rig
3. Wave flume
4. Simulated seabed
5. Dry Dock
6. Electrical and materials laboratories
7. 3 MW Powertrain test facility
8. 100m Blade test facility
9. 15 MW Powertrain test facility
10. Offshore anemometry hub
11. 7 MW Wind Turbine
12. Blade Erosion Test Rig
13. 18 MVA Grid Emulation System
14. Wind turbine training tower

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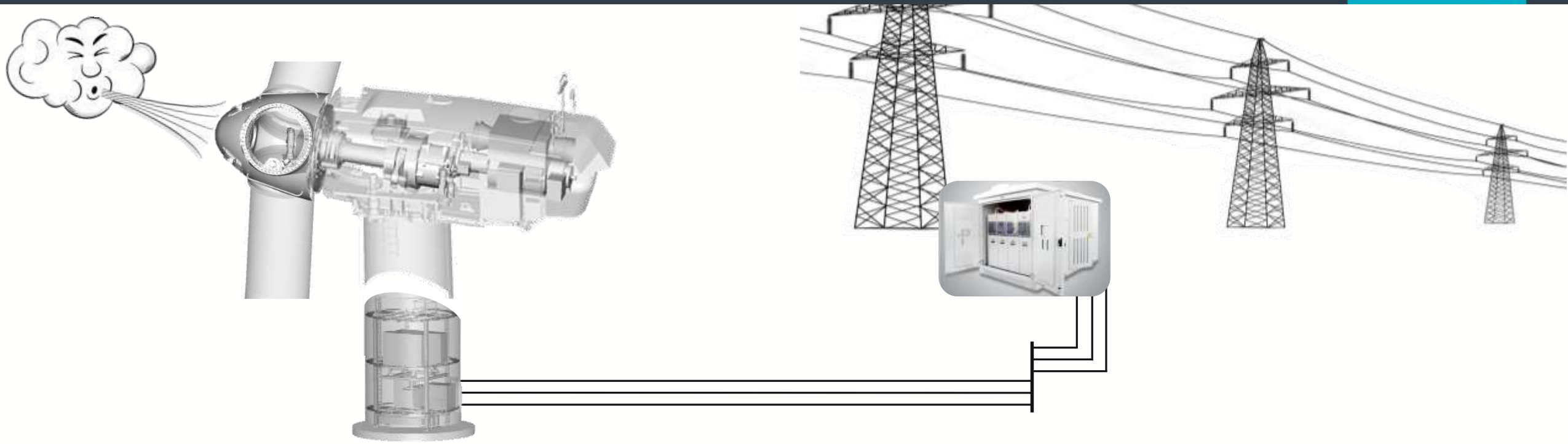
eGrid: Motivation and Configuration



Traditionally full scale tests are run in the field which has several disadvantages:

- **Time Consuming** - planning permission required, standards tests take years to finish
- **Costly** - replacing broken parts and updating designs is difficult
- **Weather Dependent** - have to rely on wind conditions at site ⇒ limited repeatability

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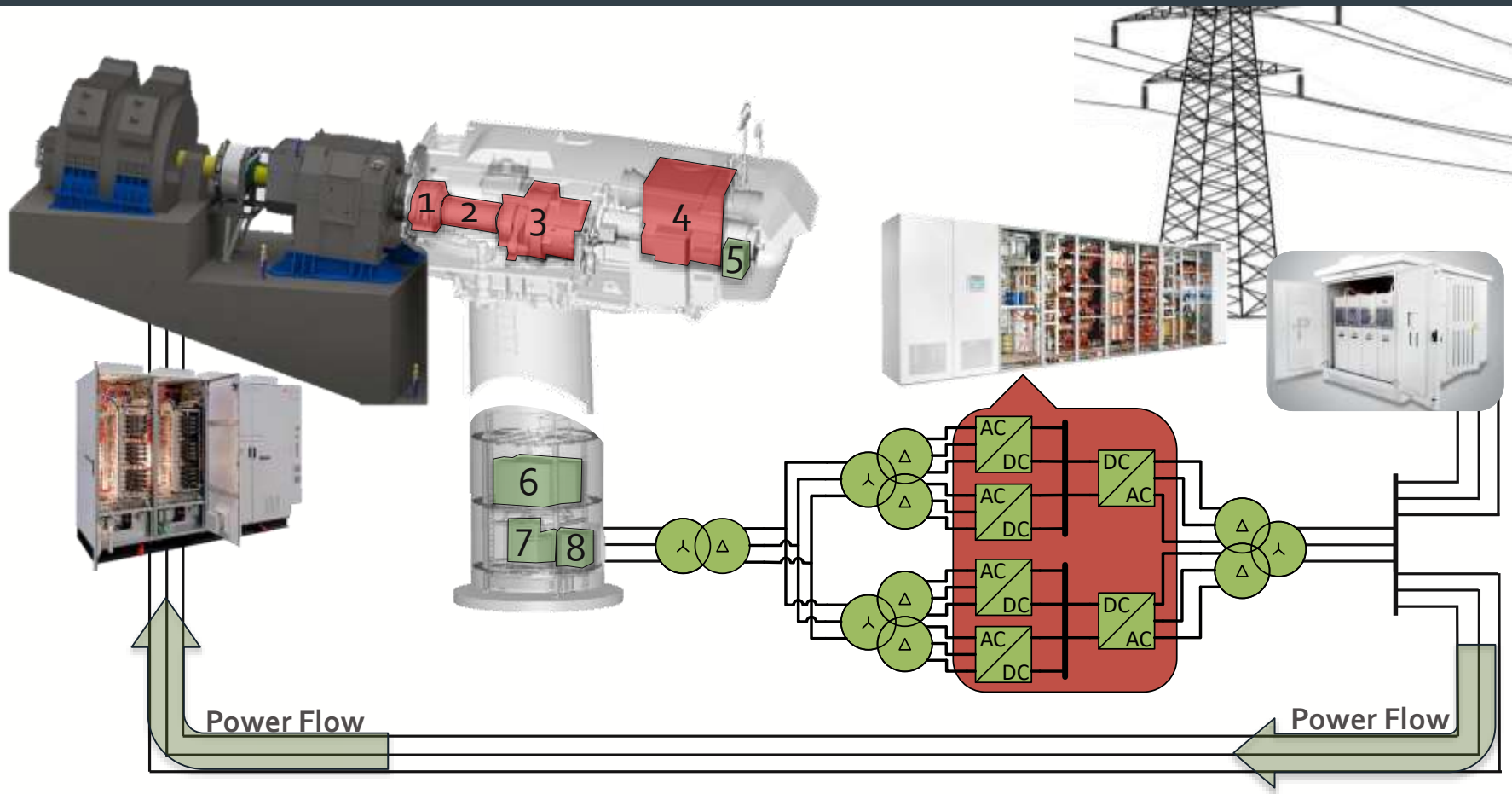
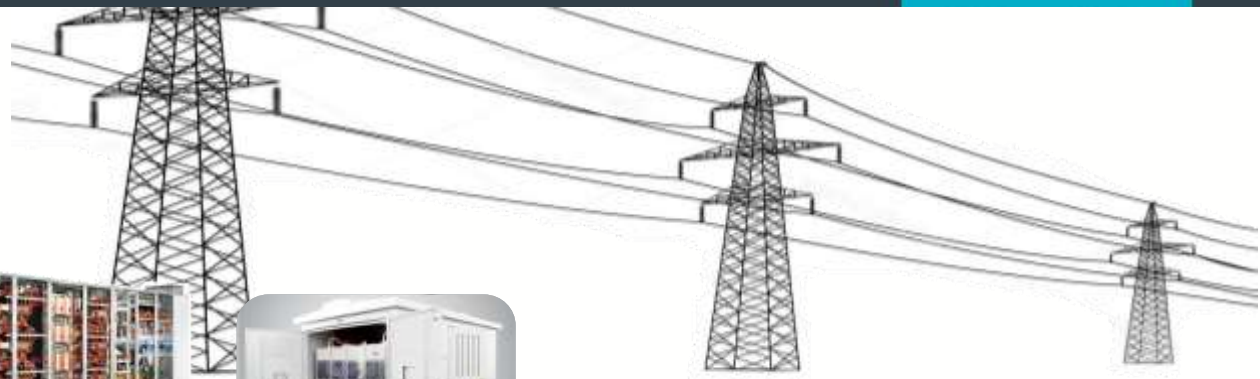
eGrid: Motivation and Configuration





Existing Elements Tested

1. Main Bearing
2. Drive Shaft
3. Gearbox
4. Generator

Further Elements Tested

5. Central Controller
6. Power Converters
7. Transformer
8. Switch Gear

Traditionally full scale tests are run in the field which has several disadvantages:

- **Time Consuming** - planning permission required, standards tests take years to finish
- **Costly** - replacing broken parts and updating designs is difficult
- **Weather Dependent** - have to rely on wind conditions at site ⇒ limited repeatability

Replacing the wind and blades by a 6 axis prime mover and non torque loading and grid by a grid emulator:

- **Reduces time** – no planning permission, any conditions can be created, repeatable
- **Reduces cost** – Repairs are easy to complete

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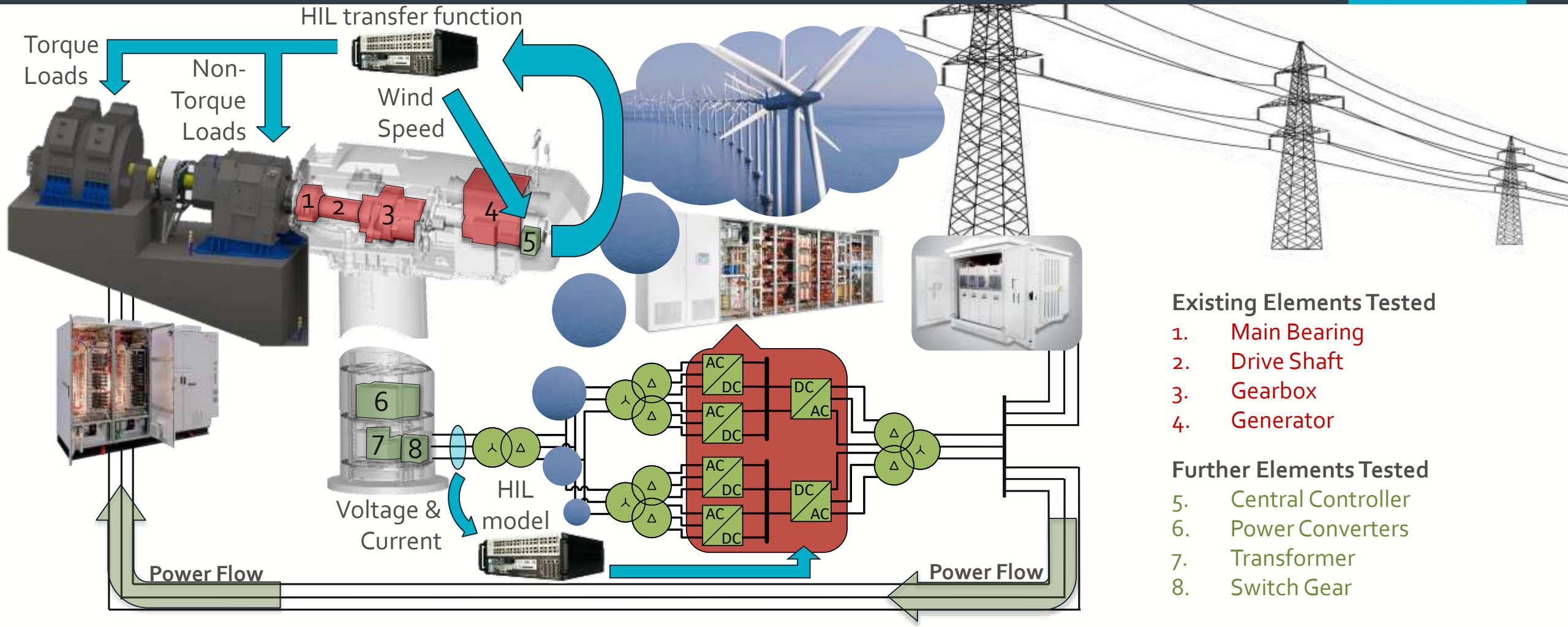
eGrid Next Steps



Existing Elements Tested

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Further Elements Tested

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Next Steps:

Electrical Hardware in the Loop

- Provides opportunity for MS-HIL
- Allows combination of physical and simulation tests

Mechanical Hardware in the Loop

- Pitch system also tested
- Fully immersive experience for turbine control

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European Union
European Regional Development Fund

GRID CONNECTION SUPPORT SERIES

Business support and advisory services for UK SMEs

1. Masterclass Series

Free to attend training, seminars and workshops organised or delivered by ORE Catapult

2. Innovation Challenge

Support to develop innovative services and products in response to needs and gaps identified by industry

3. Direct Business Support

One-to-one support for businesses either with ORE Catapult's specialists or relevant industry partners

1. Masterclass Series

Free to attend training, seminars and workshops organised or delivered by ORE Catapult

1. eGrid Introduction
2. Grid Connection for Connecting Renewables and Storage
3. Future Energy Systems - How to test new energy system innovations in a highly regulated industry
4. Future of Energy Systems Masterclass - The Rise of Energy Storage: Growth and Diversification Opportunities
5. Future of Energy Systems Masterclass - Digitalisation in Energy Sector
6. Get Into Renewables – Future of Energy System

Access 12 hours free-of-charge support and advisory services

Each participating company can access 12 hours free-of-charge support time with ORE Catapult. This includes the following services:

> Technical Advice and Assessment

Access specialist advice to support technology development, such as testing and validation, R&D, design and demonstration

> Business Support

Facilitating introductions to academic and industry partners, as well as market insights and business plan support

> Funding and Investment Support

Receive advice on the range of funding available, relevant funding bodies and how to apply to receive funding

> Regulatory and Compliance Guidance

Learn about the latest industry guidance directly from a range of grid connection experts

Contact us

Email us: info@ore.catapult.org.uk
Visit us: ore.catapult.org.uk

Engage with us:

GLASGOW | BLYTH | LEVENMOUTH | HULL | ABERDEEN | CORNWALL | PEMBROKESHIRE | CHINA

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