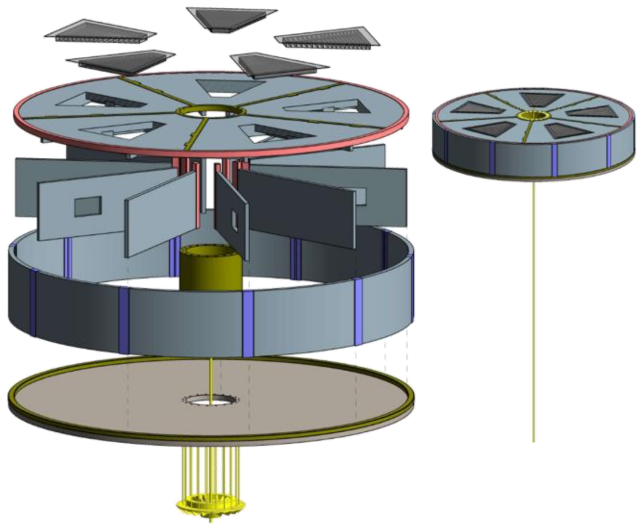
WES TECHNOLOGY PROGRAMME

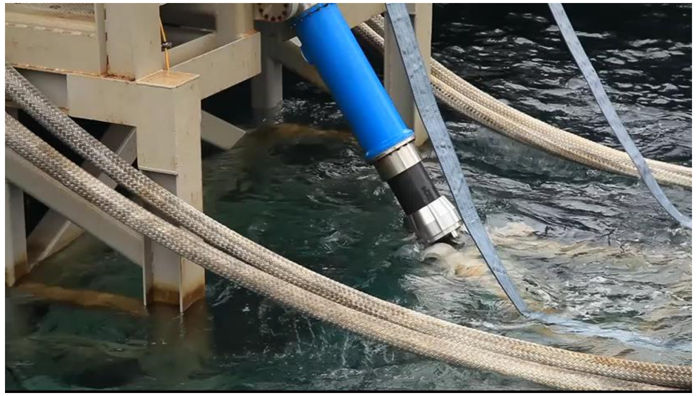
Peter Dennis

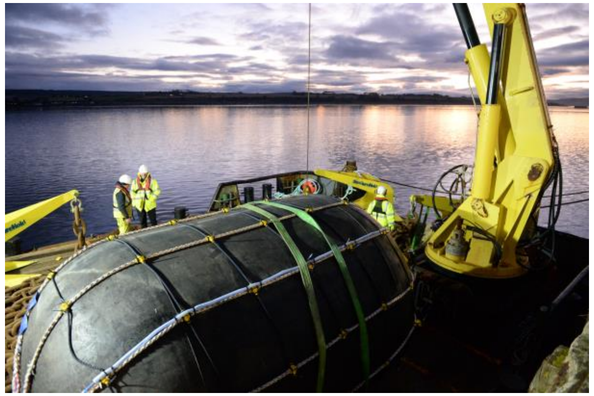
wave energy SCOTLAND

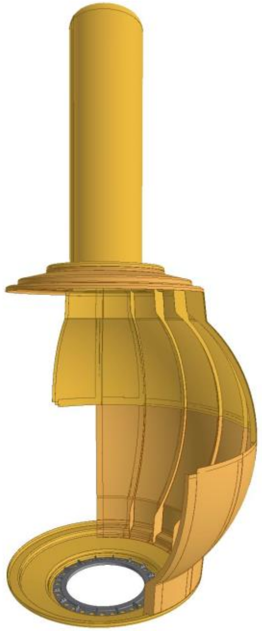
Programme Overview: NWEC

Programme Overview: PTOs, Materials, Controls

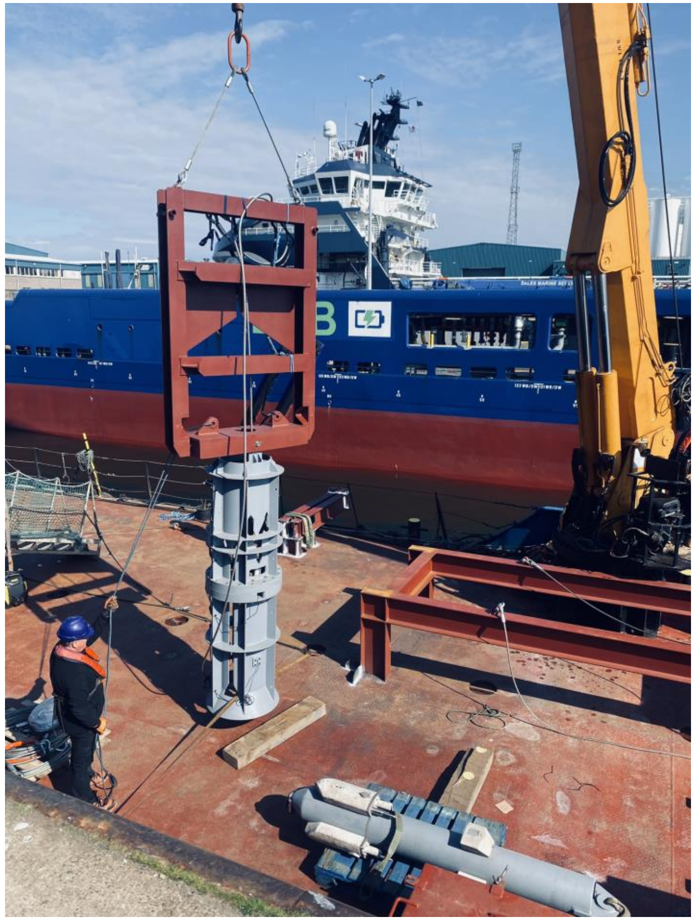




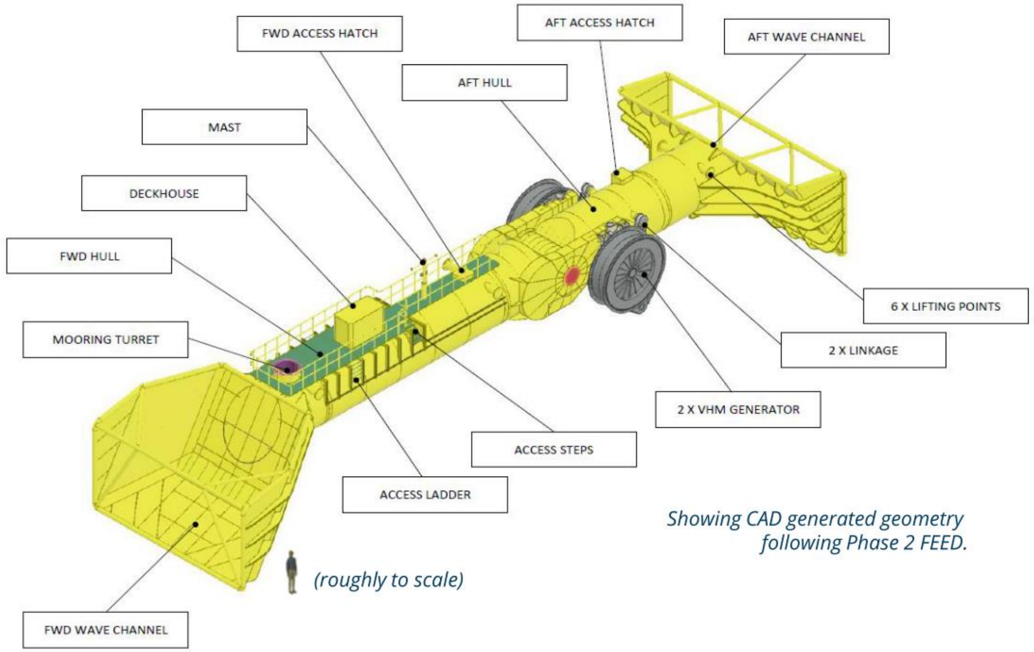




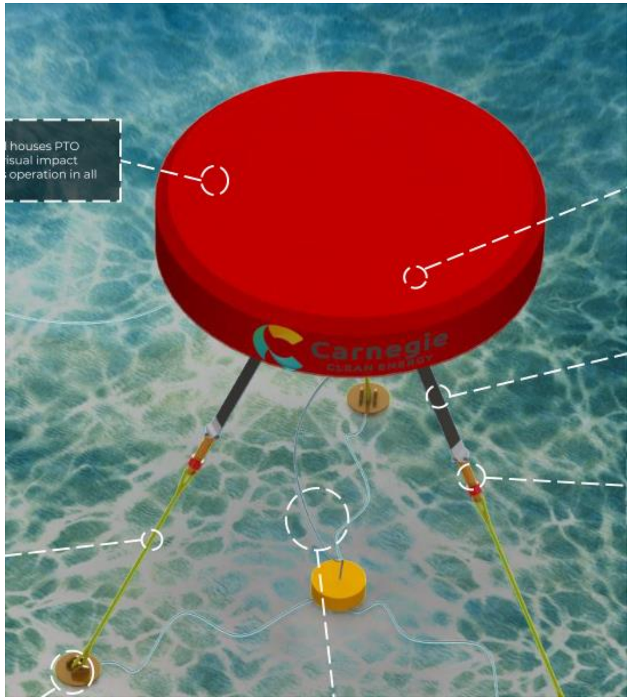
Quick Connection Systems



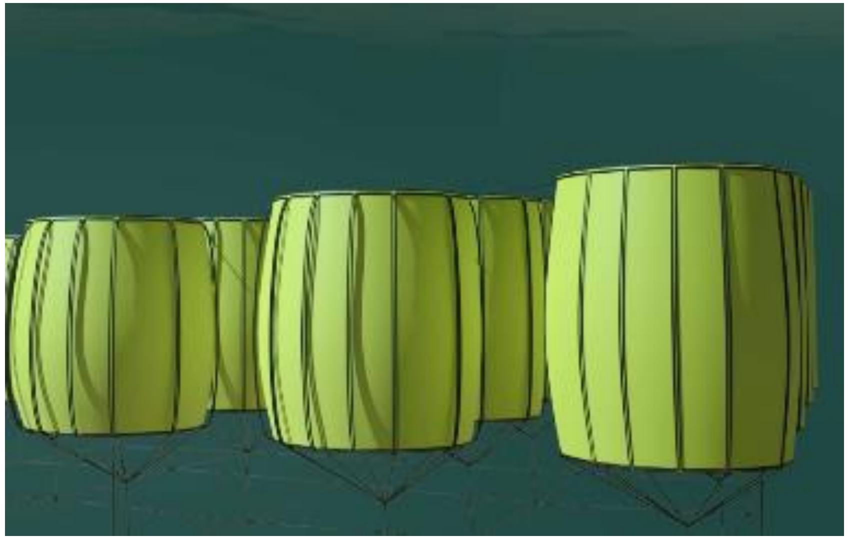
EUROPEWAVE

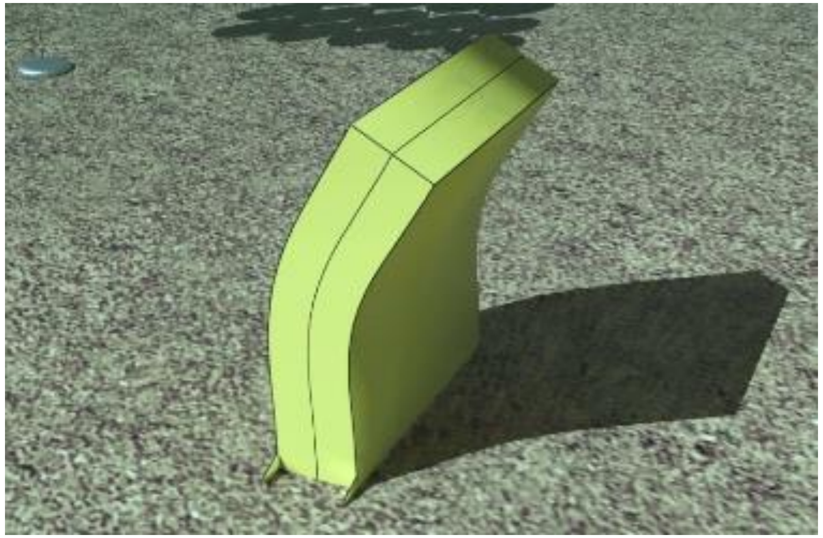


Showing CAD generated geometry following Phase 2 FEED.

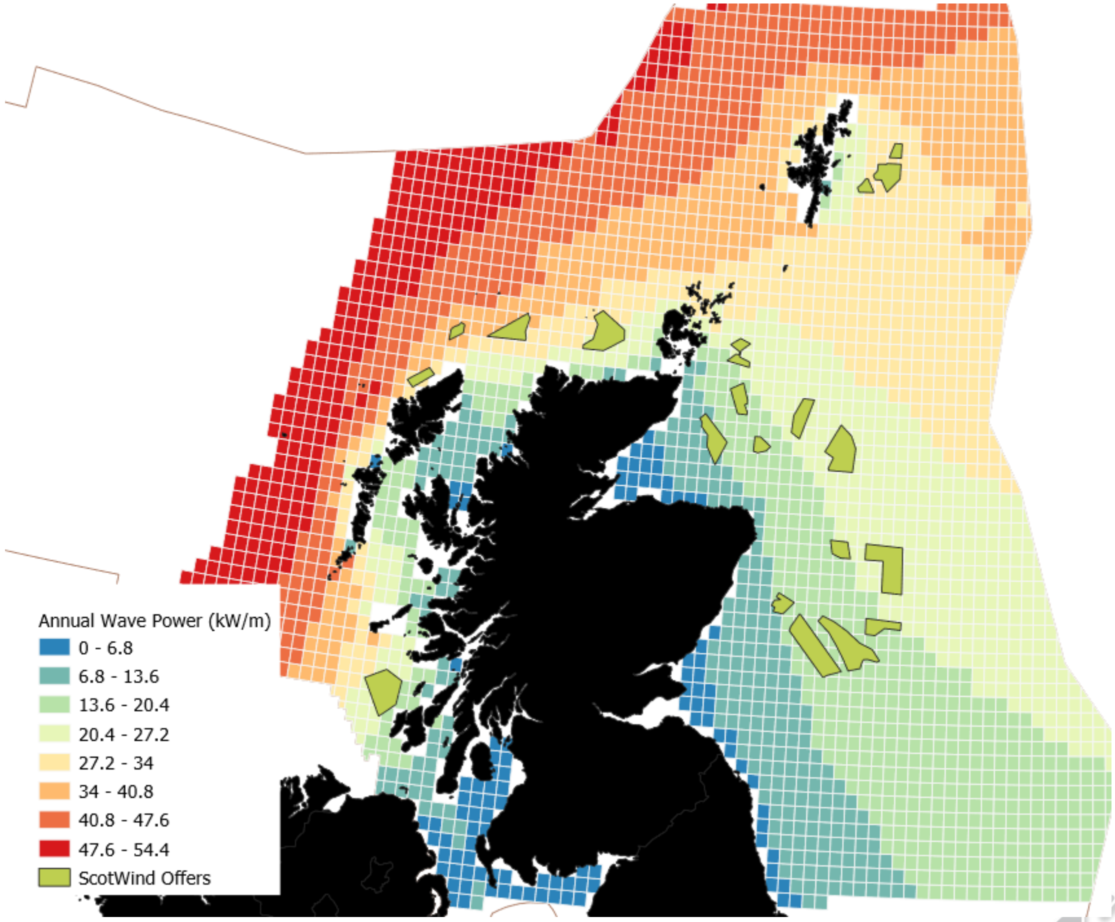


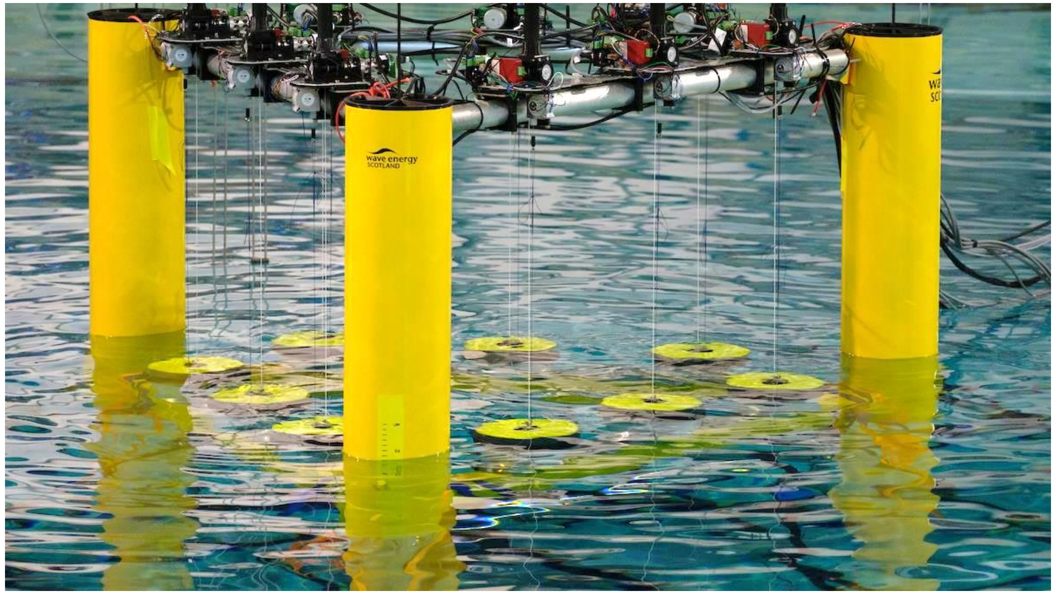
Next Generation Wave Energy





Co-location with Floating Offshore Wind





Peter Dennis
Project Manager
Wave Energy Scotland

wave energy
SCOTLAND

AWS Ocean Energy

Simon Grey – CEO

Perspectives on wave power

Edinburgh Wave Power Group 1980

Where has 50 years of wave power R&D got us?

- Yes, it is 50 years since the 1973 energy crisis when Stephen Salter first started his pioneering wave energy research
  - And 50 years since the wind and solar power started too
- Where has 50 years of R&D in wave got us?
  - Over 100 projects and start-ups, and to date not one single commercially successful company
  - The closest near-miss was Pelamis and we are still trying to get back to where they were 10 years ago
- Where has 50 years of wind power development got it?
  - 900 GW of installed capacity (2022)
  - Multiple multi-national companies active in supply, operation and project development – a multi-billion dollar industry delivering carbon-free energy

Progress?

1981

2019

Why is wave power failing to deliver?

- We fail to learn from the past
- We fail to recognize the BIG issues and hence focus on the wrong problems
  - Maintenance feasibility and cost
  - Scale
- The funding model is wrong (WES excepted)
  - Solving large challenges requires large amounts of money and a long-term stable framework
  - Private equity drives counter-productive behaviours

No-one has yet got past the valley of death, because when they actually face the realities of operating plant in the ocean, everything changes!

If you want to push ever-increasing amounts of renewable energy onto the grid at above market prices, there is only one group who pays for it and that is the tax-payer

So how do we fix this?

- Governments must take a decision that society wants wave power and is prepared to pay for it
- Then establish a long-term strategic plan for delivery, backed by a solid funding plan, and in conjunction with other stakeholders, particularly licensing, sea-bed leasing and grid
- Funding must be 100% with delivery contracted to competent companies, at least until pre-commercial demonstration stage (BOOT)
- IP should be publicly owned until it is shown to be worth something and then licensed to provide a return for the public purse
- Finally, we have to stop the hype, face the real challenges and get on with solving them!

100% development funding

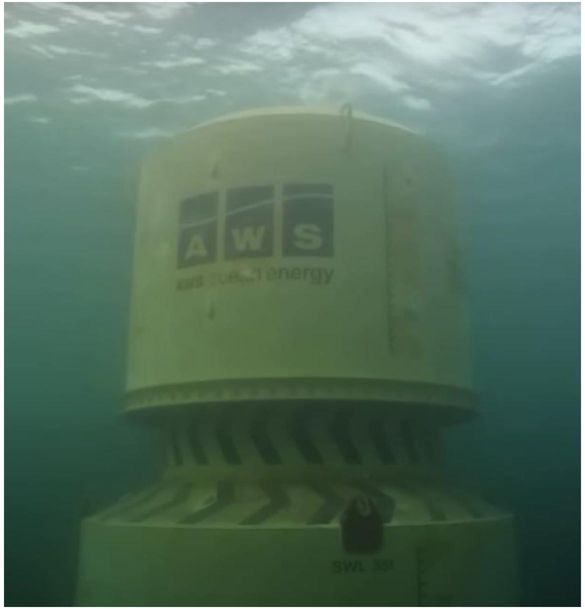
Public IP ownership

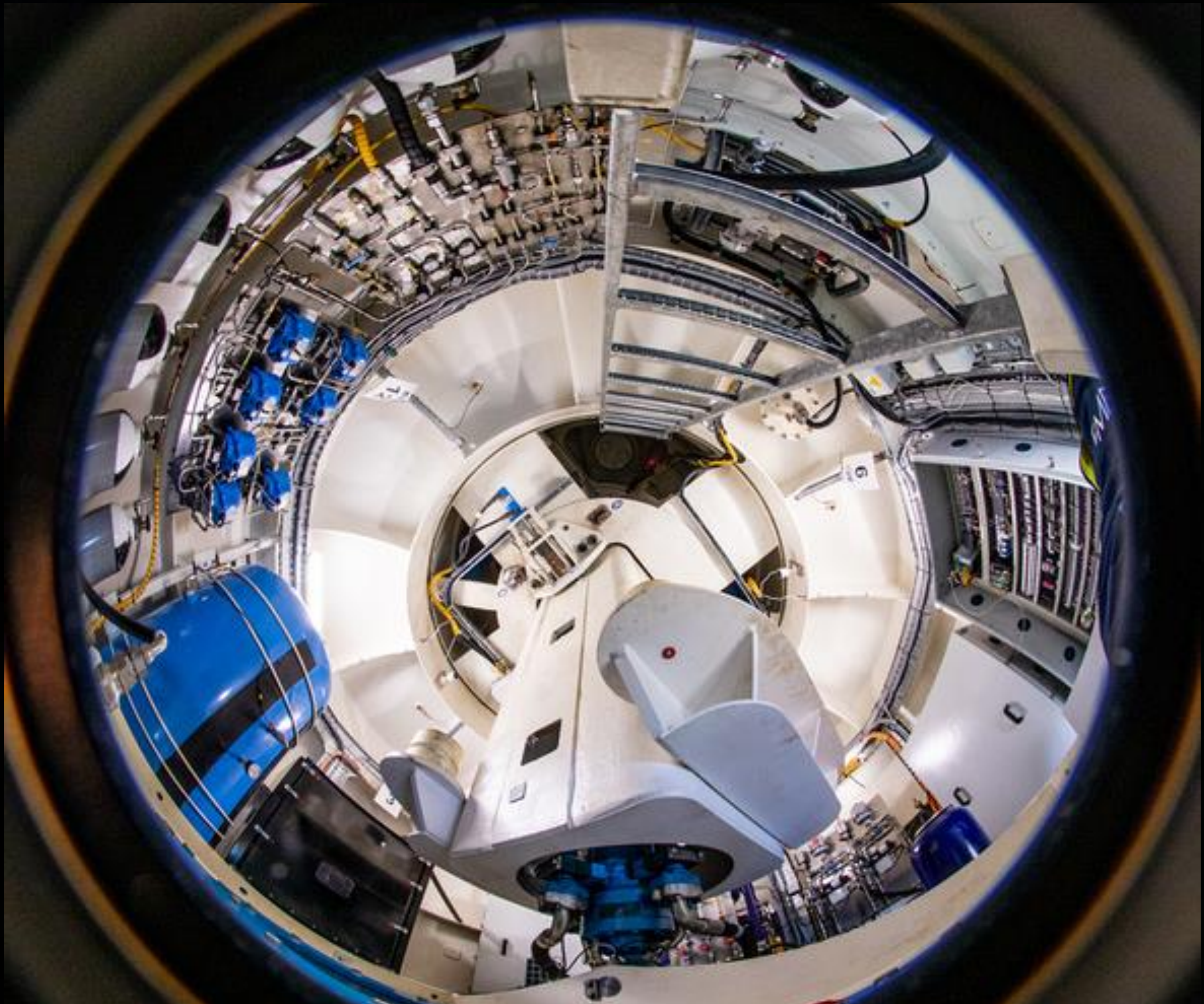
BOOT for pre-commercial demonstration

Transparency and integrity

And the AWS update?

- We have taken the first successful steps to prove a modular and efficient WEC technology
  - But this needs more hours on the clock in realistic conditions, and this means money
- By combining generating modules into multi-absorber structures we believe that we have a solution for both the maintenance and scale challenges
  - We are ready to develop these solutions if and when a suitable funding model is put in place
- Meantime, we offer our 20+ years of experience in wave power development to support any other teams to whom we can add value





Practical affordable wave energy

www.awsocean.com

Session Two: Technology Development

Wave energy technology development milestones

Chris Retzler
Technical Director
chris.retzler@mocean.energy

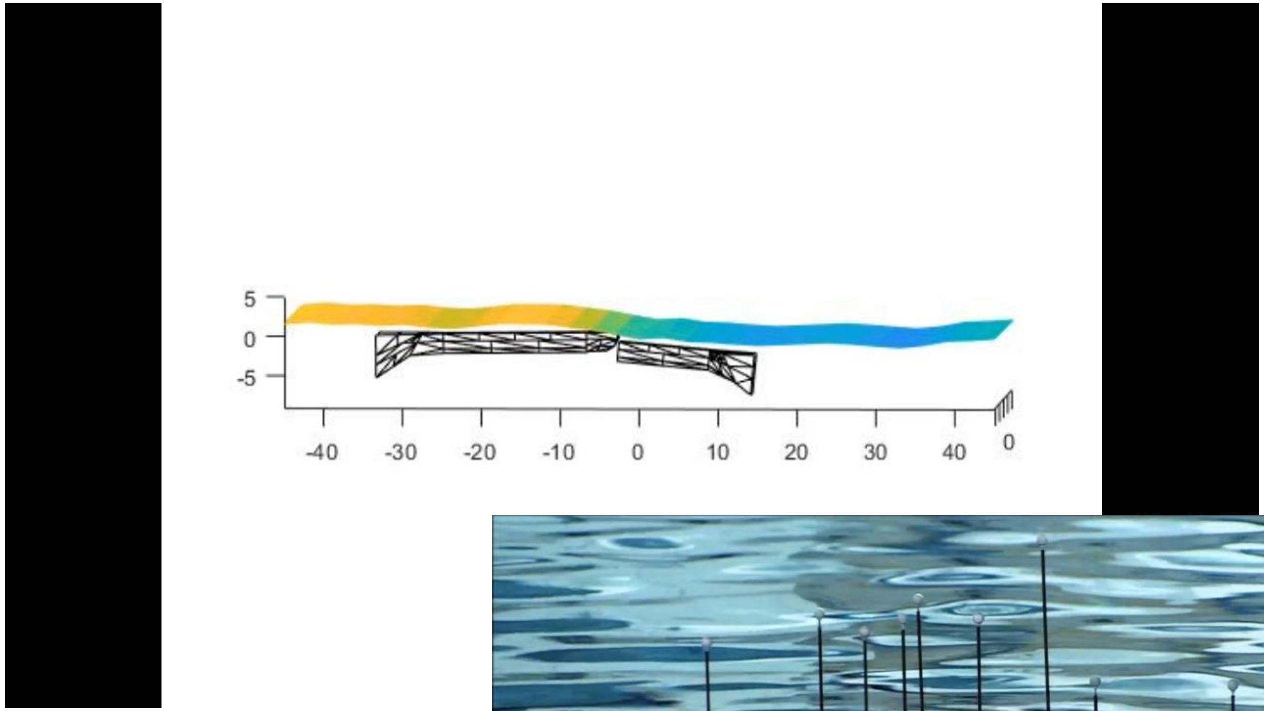
Wave Energy Scotland Conference – Edinburgh
16th November 2023

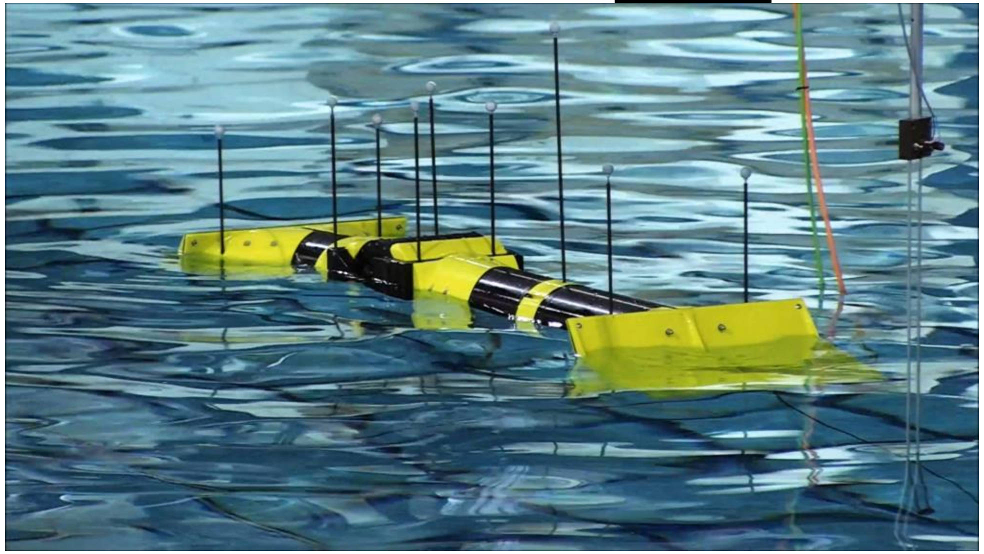
www.mocean.energy

Milestones

- Robust validated numerical models
- Demonstration at sea
- Technical track record
- Markets to serve
- Commercial traction
- Scaling up
- Technical to regulatory shift (RSP)

Robust validated numerical models





- Experimental and numerical modelling of WEC geometry, body dynamics and hydrodynamics.
- WEC geometry numerically optimised for performance and cost
- Modelling integrated interactively with the engineering design process.
- Extensive exploration before any steel cut.
- Optimisations and sensitivity studies used to evaluate componentry such as batteries, solar and other innovation.

Demonstration at sea

BLACKFISH
SUPPLYDESIGN
The University of Edinburgh
sequentec
industrial systems and control
FLD
AJS Production Ltd
LEASK MARINE
TADEK Ocean Engineering
EMEC The European Marine Energy Centre Ltd
aquatera environmental services and products
Orcades Marine Management Consultants Ltd
MAESTRO Global Structural Analysis

Technical Track Record

Mocean's credibility has been bolstered by robust demonstration of each of the IEA-OES metrics

Blue X was deployed first at the EMEC 'nursery site' of Scapa Flow for 5 months, then for 8 months and ongoing at Copinsay, east Orkney from March 2023 with 4 months more to run.

It has demonstrated power capture, conversion, automated controllability and storage.

Encounters with extreme waves in seas of Hs up to 7.2m have confirmed its survival capacity.

Site visits in small craft have been utilized for maintenance. The machine is steadily accumulating reliability data.

Areas included in the IEA-OES Evaluation and Guidance Framework

Markets – adapt by scale

Small scale
>10 kW

Off-grid & demand markets
Reliable, integrated renewable power and comms in situ

Mid
>100 kW

Power to islands, remote locations, larger off-grid

Grid
>1000 kW

Wave arrays & combined wind-wave farms
Adding balance and grid efficiency

Traction – enabling upscaling

Competitive Funding awards. Success in 6 consecutive Pre-Commercial Procurement contracts (WES & EuropeWave)

Extensive engagement with supply chain – fabrication, balance of plant, operations

Successful record of partner and customer engagement in the marine engineering sector

Scaling up

Exciting emerging shifts for wave energy:

- Growing recognition as a ready, reliable source of off-grid power & communications
- Cross-industry collaboration - emerging ocean energy sector combining with traditional big energy players
    - Attracting international investment
    - Integrators with aligned visions
- Larger scale decarbonisation opportunities
    - Awarded ~€3.7m to deliver next size up machine (EuropeWave)
    - Carbon Capture & Storage, aquaculture, islanded and national grids
    - Co-location with wind farms

mocean energy

10 years

- 200 ocean technology projects enabled
- 20 communities empowered by ocean energy
- Flagship wind wave farms
- Mitigate 200,000 TCO2 per year

Chris Retzler

Technical Director

chris.retzler@mocean.energy

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www.mocean.energy

EuropeWave Programme

EUROPEWAVE

EuropeWave – Update
16 November 2023

This project has received funding from the European Union's Horizon 2020 research and Innovation programme under grant agreement 883751.

EUROPEWAVE

www.europewave.eu

Bridging the gap to commercialisation of wave energy technology using pre-commercial procurement

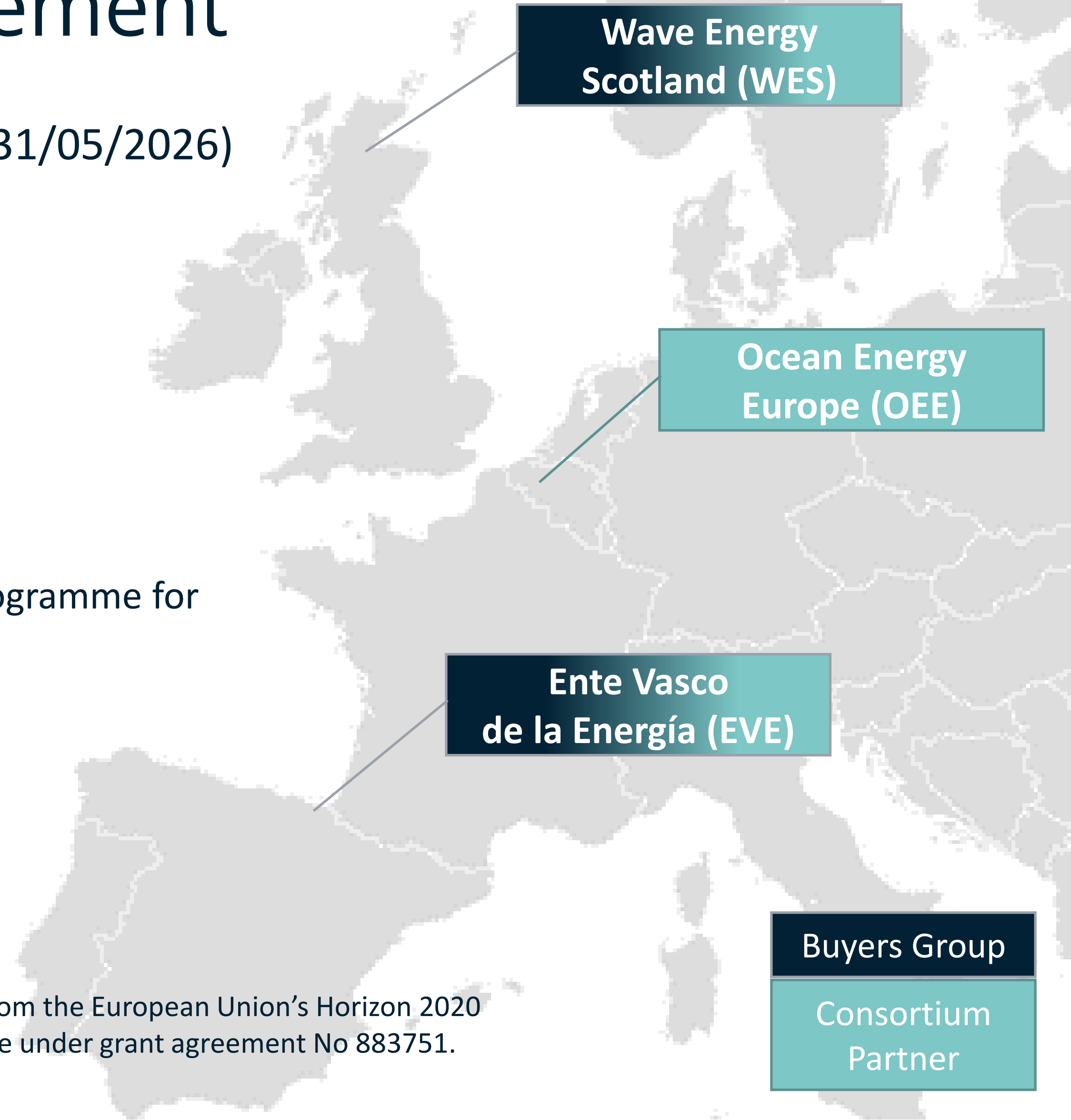
Duration: 65 months (01/01/2021 to 31/05/2026)

PCP Budget: €19,600,000

Total Budget: €22,702,112

Programme: H2020-EU.3.3.2.
[Low-cost, low-carbon energy supply]

Topic: LC-SC3-JA-3-2019
[European Pre-Commercial Procurement Programme for Wave Energy Research & Development]



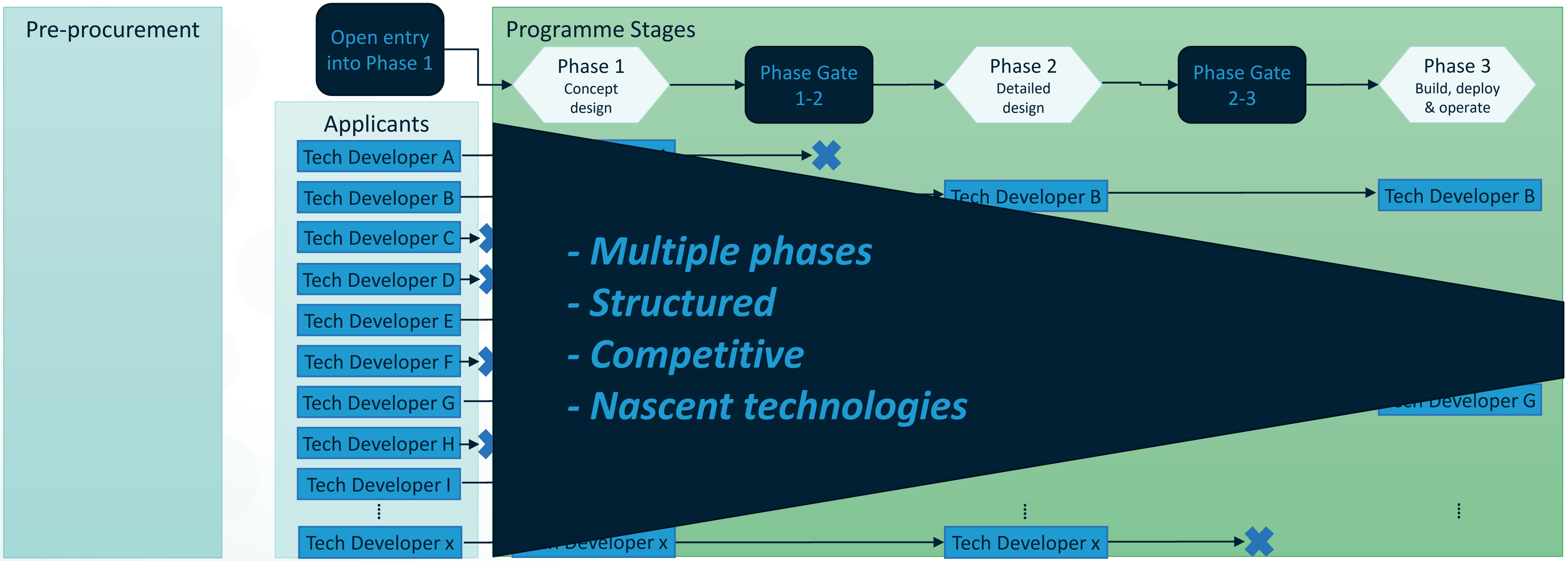
wave energy SCOTLAND

ENERGIAREN EUSKAL ERAKUNDEA
ENTE VASCO DE LA ENERGÍA

Ocean Energy Europe

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 883751.

Pre-Commercial Procurement Approach



EuropeWave PCP

PCP budget: **€19,600,000 (inc. VAT†)**
Duration: 53 months

Phase 1
Concept Development

Phase budget:
€2,450,000 (inc. VAT†)

Call-off contracts:
Awarded 7

Contract budget:
up to €350,000 (inc. VAT†)

Duration: 7 months

Phase 2
Design / modelling

Phase budget:
€3,650,000 (inc. VAT†)

Call-off contracts:
Awarded 5

Contract budget:
up to €730,000 (inc. VAT†)

Duration: 9 months

Phase 3
Open-sea deployment & testing programme

Phase budget:
€13,500,000 (inc. VAT†)

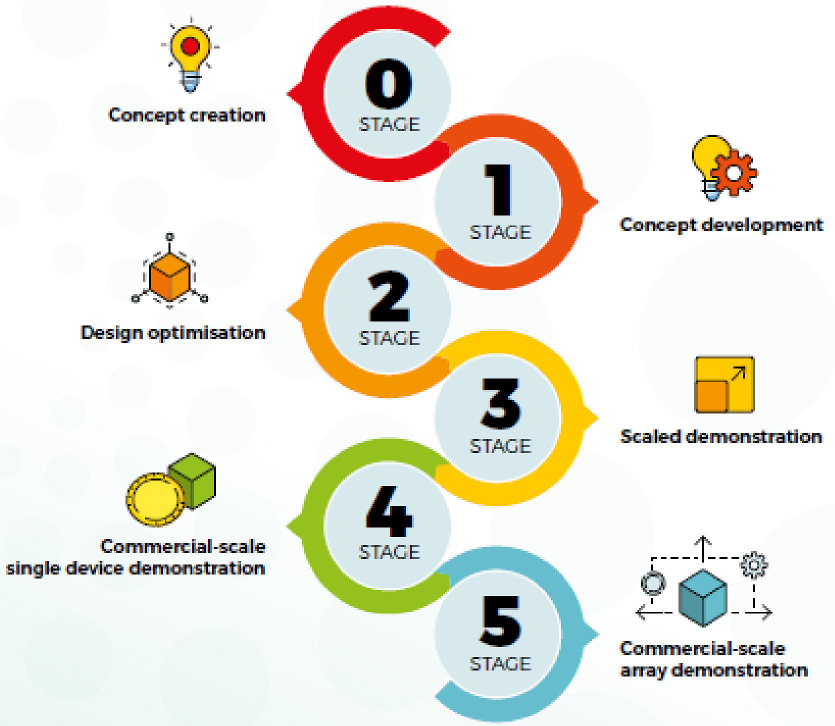
Call-off contracts: 3

Contract budget:
up to €4,500,000 (inc. VAT†)

Duration: 33 months

† the applicable VAT rate is that in the country of the Lead Procurer

IEA-OES Framework



Evaluation Criteria	Units	Format
Mean Time to Failure (MTTF)	Hours	Numerical value
Failure Rate (probability of failure per unit time)	Non-dimensional	Numerical value

Table 13 Evaluation Criteria for Reliability (wave and tidal stream)

3.4.3 STAGE ACTIVITIES

Stage	Stage Activities
Stage 0 Concept creation	• Definition of technology and market requirements and challenges associated with Reliability (the problem statement) • Selection of high-level reliability targets, appropriate to the technology • Evaluation of the reliability of comparable technologies and applications. This evaluation should be based on the conceptual understanding of the technology and identification of physical and functional characteristics that impact reliability or the requirement for a specific level of reliability, including: • near/ far from shore • deep/ shallow water • floating/ surface piercing/ bottom mounted • suitability for implementation of supervisory monitoring and control systems • proposed structural material considered, with respect to scale and loading scenarios and suitability for expected environmental conditions • concept mode of operation, moving parts, potential exposure, perceived susceptibility to damage
Stage 1 Concept development	• Development of a numerical model or structural calculations to estimate commercial-scale loads in subsystems and devices (see section 3.1.4.1 for discussion on device scale and size) • Identification of likely design limit states • Identification of structural strength of proposed structural materials and high-level evaluation of safety factors of key structural components • Use of experience from similar technology in a comparable environment and application to identify key failure modes and to estimate failure rates. High-level evaluation of the sufficiency of the identified failure modes and rate. • Evaluation of the potential for control system actions to be implemented and consideration of: • potential benefits to Reliability • level of reliance on control to maintain Reliability
Stage 2 Design optimisation	• Physical, laboratory or bench testing of key components at appropriate scale to evaluate life (or cycles) capability and failure rate • Development of numerical model to estimate structural loads on a commercial-scale device, validated to the extent possible using physical testing • Quantitative assessment of likely loads (including fatigue) on a commercial-scale device in representative conditions (see section 3.1.4.2 for a set of recommended wave energy sea-states) from tank test, rig test and validated numerical modelling • Development of an FMEA based on FEED (Front End Engineering Design) activity for Stage 3 open-water test device, tank-test & modelling data, and Reliability experience from similar technology in a comparable environment and application

The Vision – Bringing wave energy to commercial-scale with innovative procurement

Stage	TRL	
Stage 0	1	**Early (1-3)** Analytical and numerical models
Stage 1	2 3	
Stage 2	4	**Mid (3-6)** Experimental tests in controlled environment
Stage 3	5 6	
Stage 4	7 8	**Late (6-9)** Experimental tests in representative environment
Stage 5	9	

EUROPEWAVE — *2021 -2026*

Future development – First of a Kind commercial system — *Post 2026*

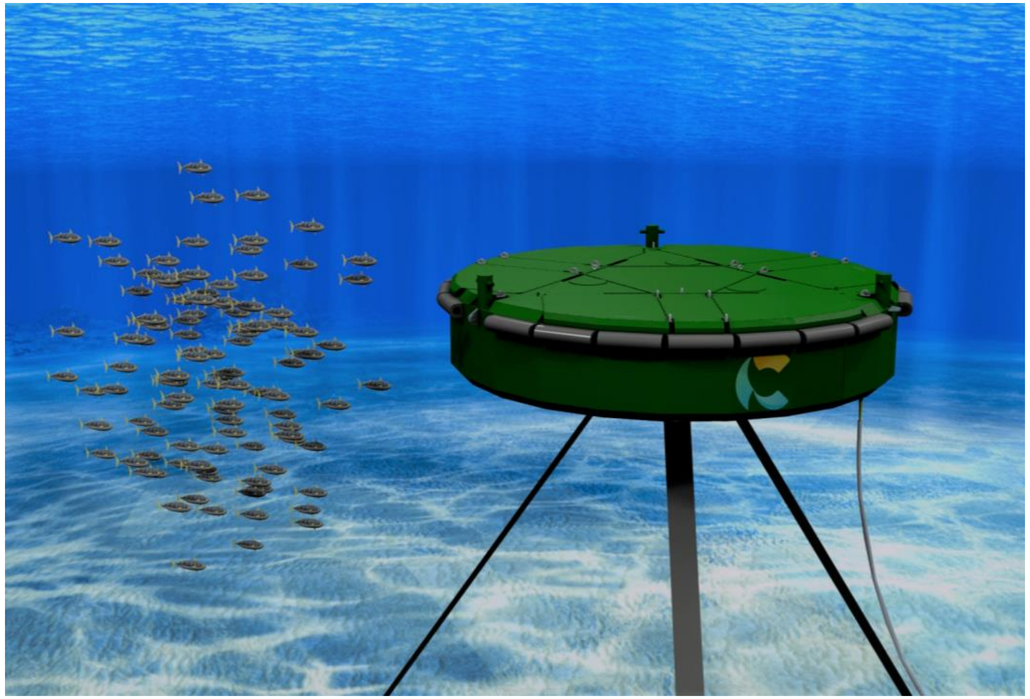
Commercial deployment

Image taken from:
An International Evaluation and Guidance Framework for Ocean Energy Technology, IEA-OES, 2021

CETO Wave Energy Ireland

- Submerged point absorber
- Deployment of the CETO 6 at BiMEP for 12 months
- Demonstrate operational and survival strategies
- Complete IEA Stage 3
- Build confidence for commercial roll-out

- Innovations…
  - Advanced controller
  - Rotary electric PTO
  - Continued operation through all conditions
  - QCS to allow rapid connection/disconnection



CETO Wave Energy Ireland

saitec offshore technologies

LR

HUTCHINSON

Hewlett Packard Enterprise

VGA

JULIA F. CHOZAS CONSULTING ENGINEER

ACS AUSTRALIA

Quoceant Innovation Offshore

IDOM Consulting

- Floating OWC
- Redeployment of the MARMOK A-5 at BiMEP for 12 months
- Testing with an improved PTO and control system
- Focus on improving installability, performance, operational experience and survival/reliability

- Innovations…
  - Air turbine PTO with variable pitch mechanism
  - Machine learning based control strategy, with reinforcement learning algorithm
  - Operational improvements to avoid use of divers wherever possible
  - Array design configuration developed

IDOM

Mondragon Unibertsitatea Faculty of Engineering

tecnalia MEMBER OF BASQUE RESEARCH & TECHNOLOGY ALLIANCE

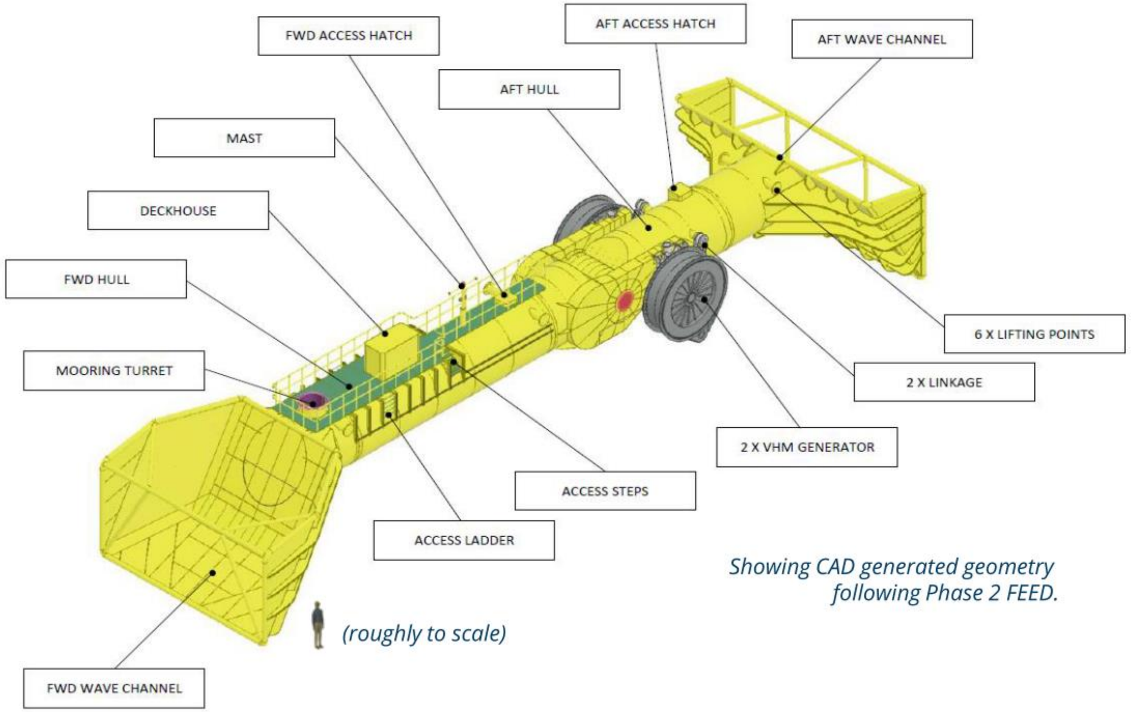
CoreMarine SMART OCEAN SOLUTIONS

DNV

Mocean Energy

- Attenuator type WEC
- Full scale, first-of-a-kind, 250kW WEC
- Minimum 12 months of at-sea trials at EMEC, Billa Croo
- TRL7 by end of 2026
- Healthy pipeline of commercial projects

- Innovations…
  - AI-based design to optimise geometry
  - Direct-drive PTO - Vernier Hybrid Machine
  - PTO linkage gearing = more power delivered
  - QCS to streamline operations
  - Installability for future array deployments



Showing CAD generated geometry following Phase 2 FEED.

EUROPEWAVE

Thank you!

matthew.holland@waveenegyscotland.co.uk

This project has received funding from the European Union's Horizon 2020
research and Innovation programme under grant agreement 883751.

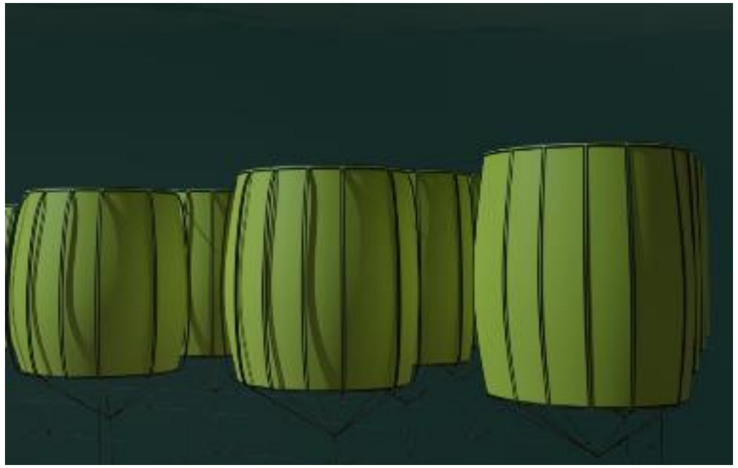
Next Generation Wave Energy: Direct | Distributed | Flexible

Jonathan Hodges

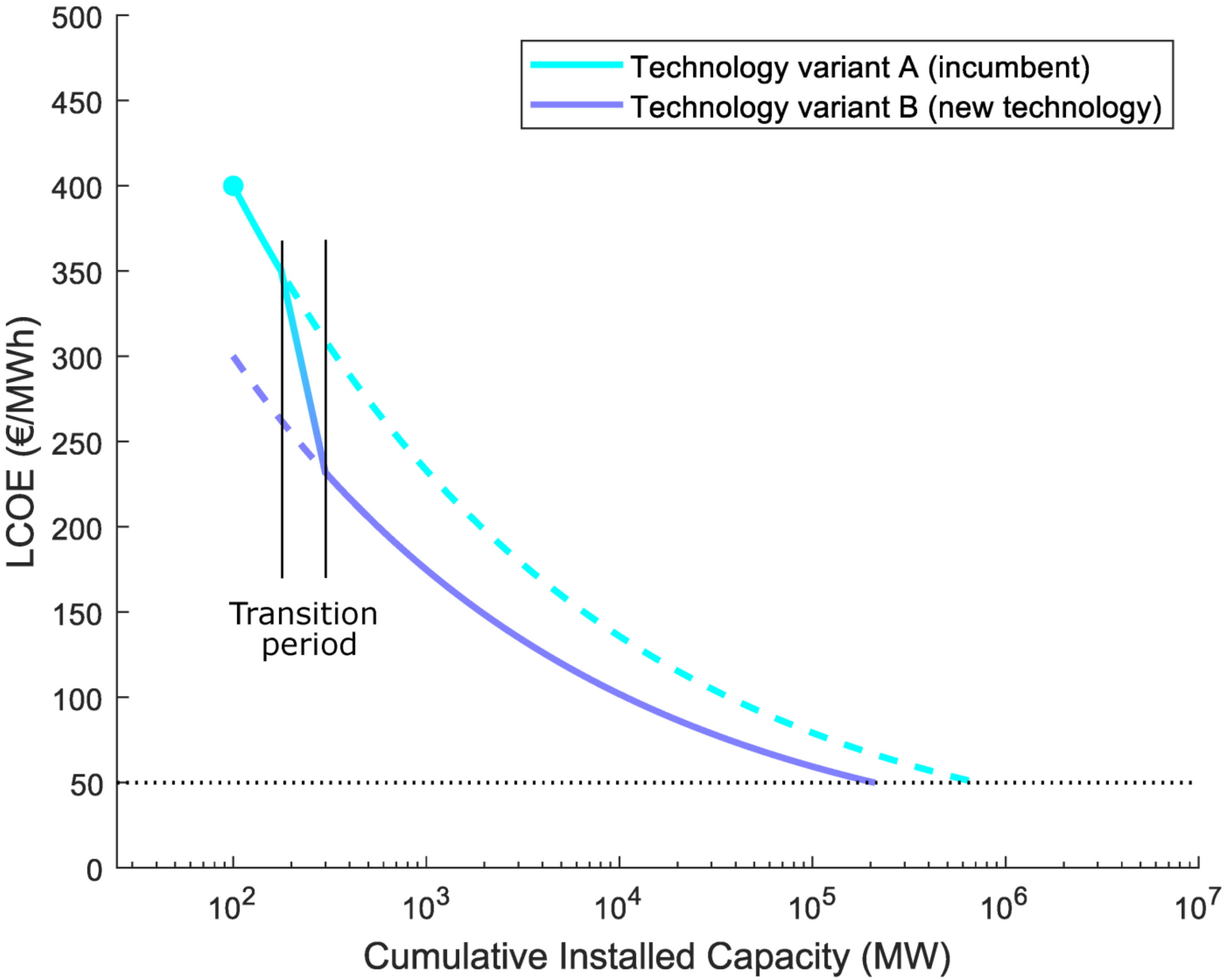
wave energy SCOTLAND

Next Generation Wave Energy
Direct | Distributed | Flexible

- Radical innovation
- Direct | Distributed | Flexible
- Potential benefits
- Collaborative innovation strategy
- Building a collaborative R&D programme



Seeking (balanced) radical innovation



- Enables
  - Step change LCOE
  - Higher learning rates
  - Reduced learning investment
- Longer-term cost reduction potential

Kerr, P.; Noble, D.R.; Hodges, J.; Jeffrey, H. Implementing Radical Innovation in Renewable Energy Experience Curves. *Energies* **2021**, *14*, 2364. https://doi.org/10.3390/en14092364

Radical innovation – next generation technology

- Direct, distributed, flexible generation
- Electrostatic generation technologies
  - Flexible properties of polymers, elastomers, and dielectric fluids
  - Dielectric Elastomer Generators (DEG) and Dielectric Fluid Generators (DFG)
- Waves → stretching, twisting, bending → electrical energy
  - A new class of wave energy converters

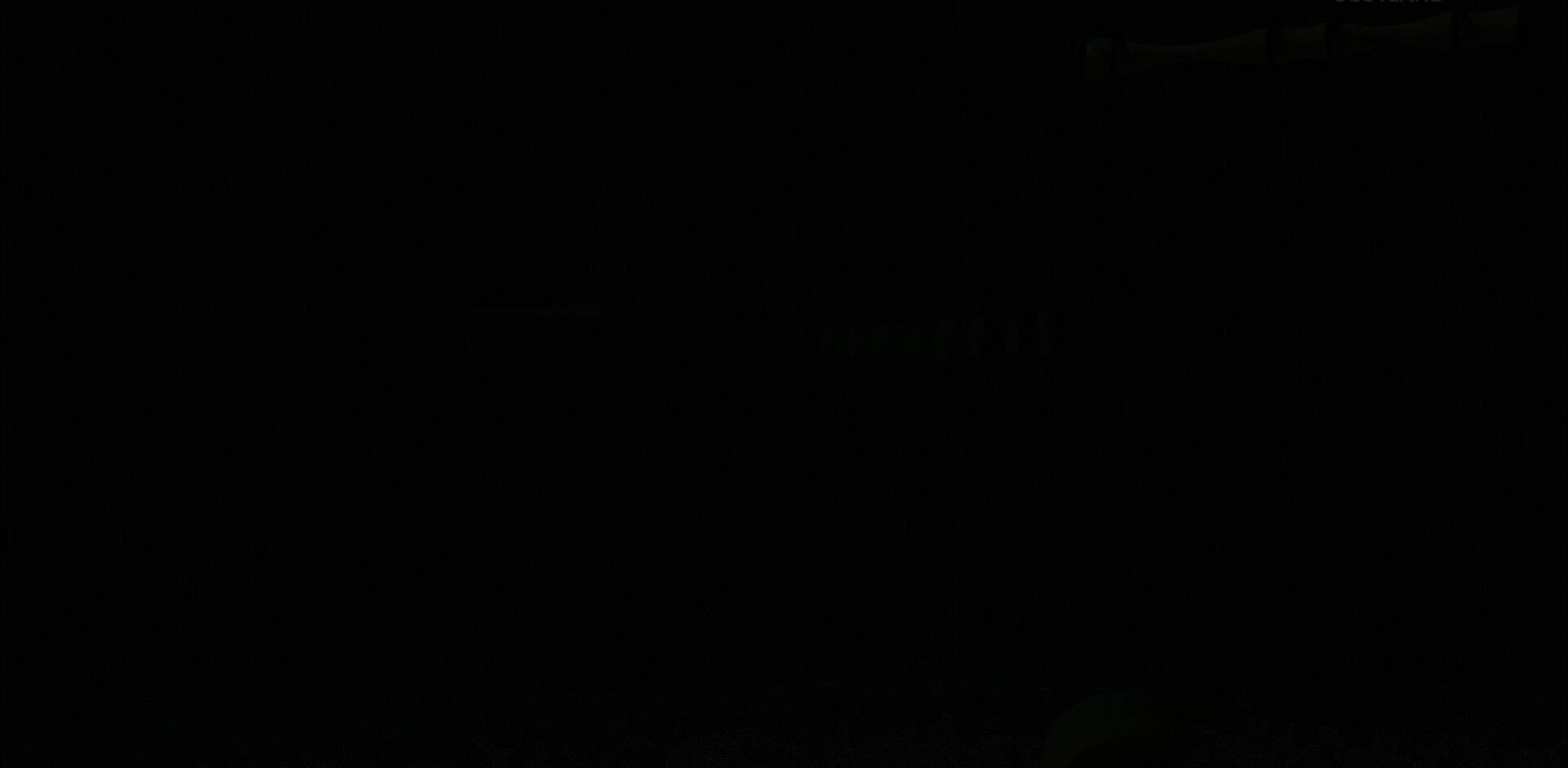
wave energy SCOTLAND

FRAZER-NASH CONSULTANCY A KBR COMPANY

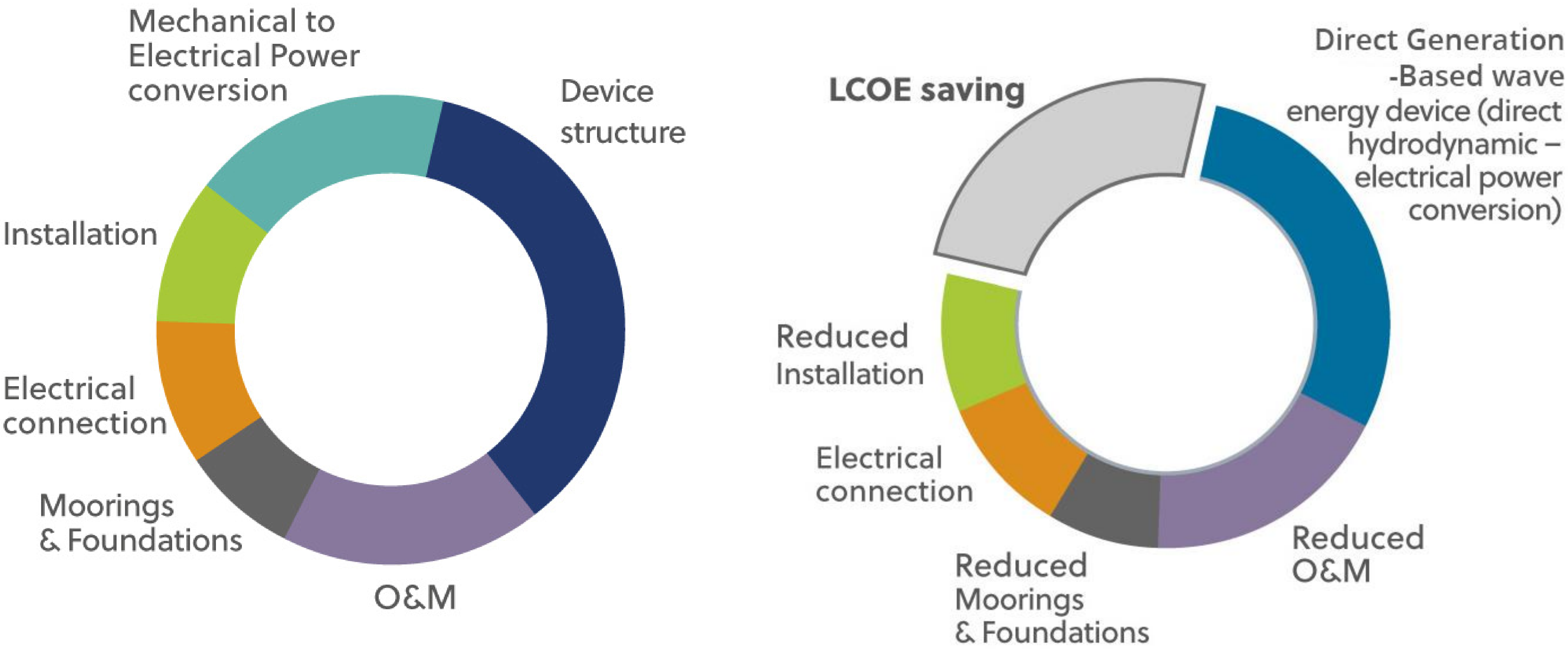
THE UNIVERSITY of EDINBURGH

WES

A new class of wave energy converters



Potential benefits

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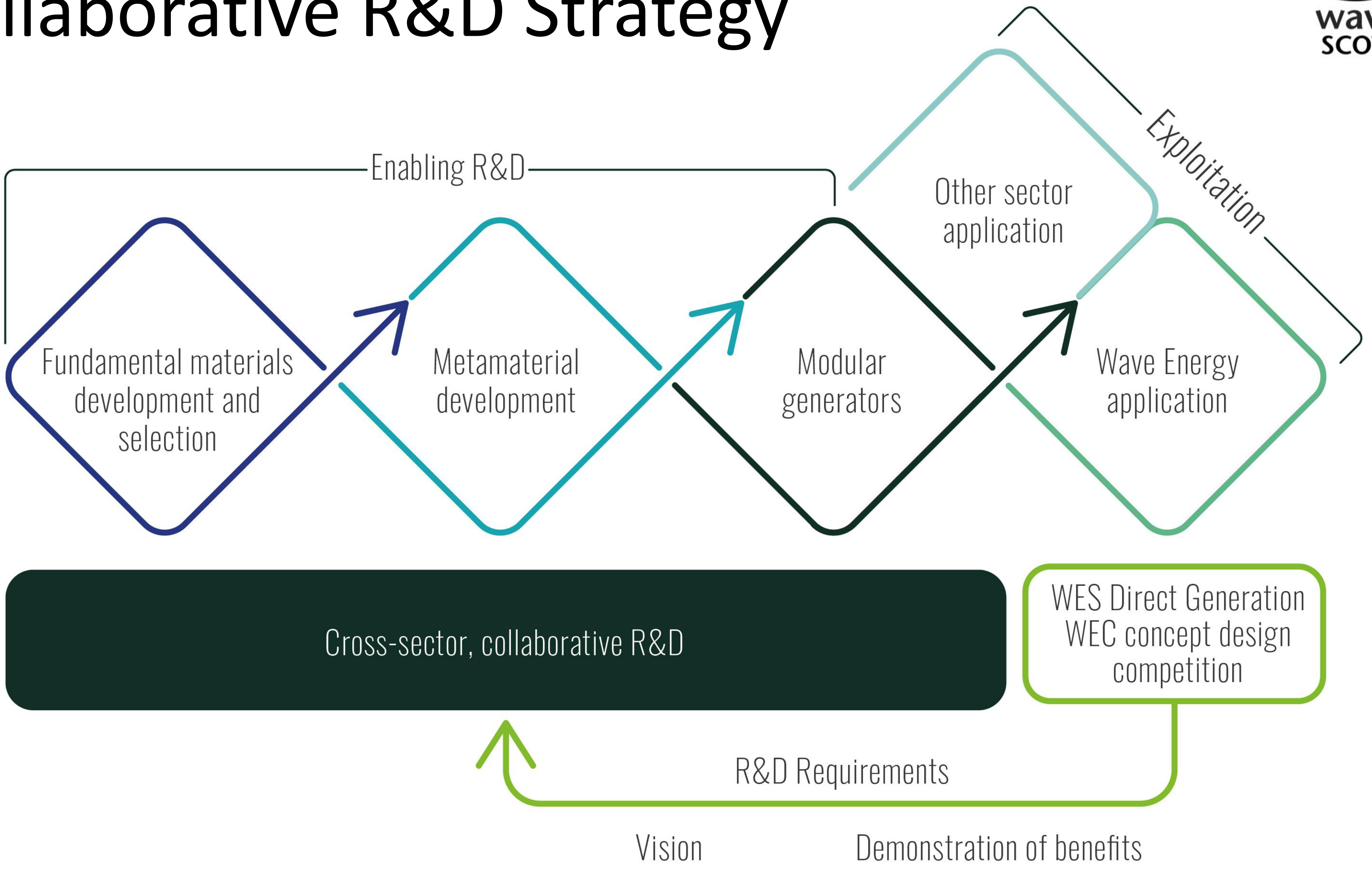
Collaborative R&D Strategy



Building a collaborative R&D programme

- Strategic concept design
  - 5 x concept design projects
    - Concept
    - Benefits and feasibility
    - R&D direction
    - Vision
- Enabling R&D
  - Materials
  - Metamaterials
  - Generation modules

Thank you!

16th November 2023

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