

1st Annual WES Conference

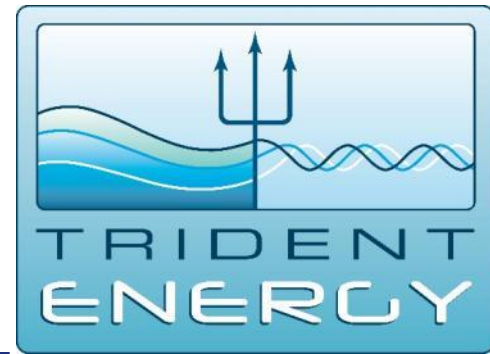
3 minute elevator pitches

Power Take-Off call participants (PTO)

Running Order

1. Trident Energy
2. Scuola Superiore Sant'Anna
3. Romax Technology
4. Oscilla Power
5. University of Edinburgh
6. Ecosse Subsea
7. BluePower Energy
8. Artemis Intelligent Power
9. CorPower Ocean
10. Umbra Cuscinetti
11. Exceedence

WaveDrive



Steve Packard

WES Annual Conference

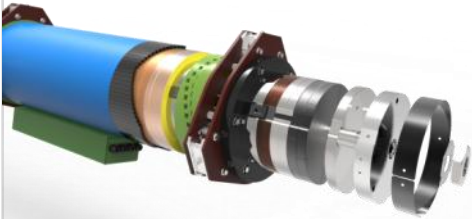
2nd December 2016



WaveDrive

Project summary

- **Optimisation of Linear Generator (LG) PTO:**
 - *Improve performance*
 - *Design for manufacture*
 - *Ease of maintenance*
 - *Generic and Modular*
 - *Marinisation*



Challenges

- **Multiple WEC types and designs**
- **Sea trials to test PTO and validate control system innovation..**

Technical product or integration offering

- **100% electro-magnetic Direct Drive PTO**
- **Scalable: PowerPod range: 30kW ~ 350kW**
- **4-Quadrant generator control**
 - *Dynamic force control*
 - *Impedance matching*
 - *MPC – >100% power conversion*
 - *API to access control system “smarts”*

Skills, expertise and technology required

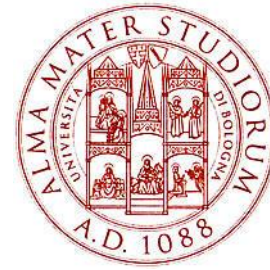
- *WEC device developers*
- *Offshore energy systems integrators*
- *Manufacturing partners/suppliers*
- *Technology licensees*

Dielectric Elastomer Generator PTO

Giacomo Moretti

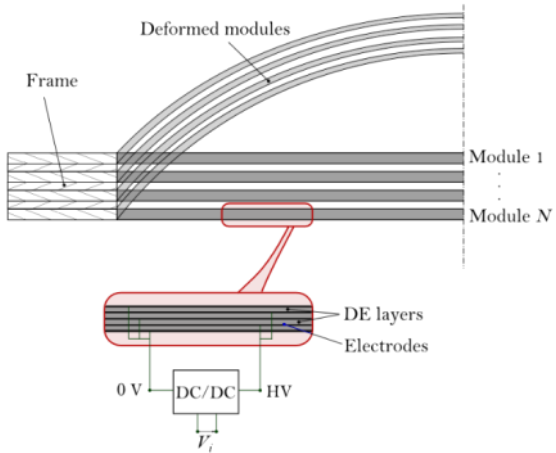
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Dielectric Elastomer Generator PTO

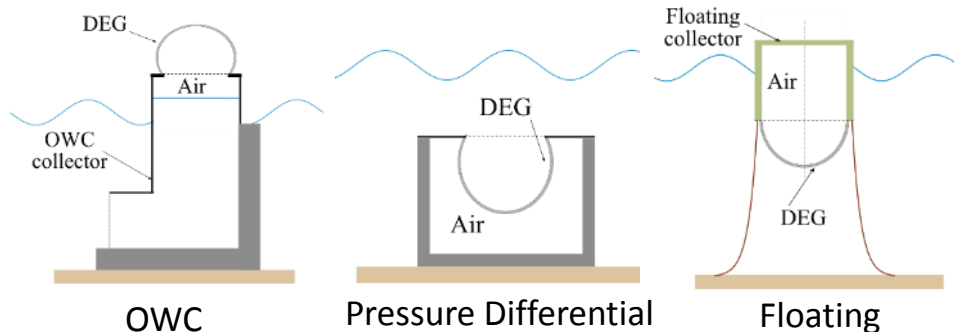
Objective: developing a fully-functional prototype of electrostatic deformable **PTO** based on **Dielectric Elastomers**



Dielectric Elastomer Generator (DEG) PTO

- Low-cost polymeric material
- High-Voltage Direct-Current operation
- Modular architecture

Application & Integration

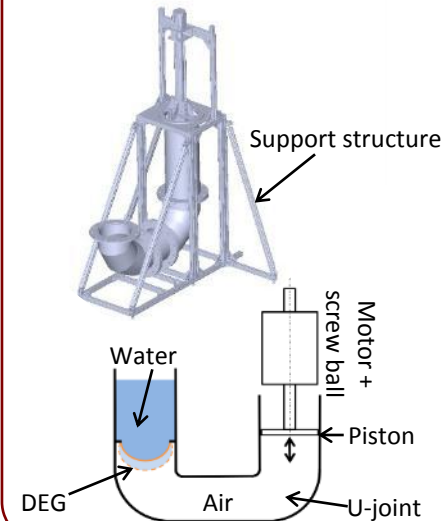


Challenges

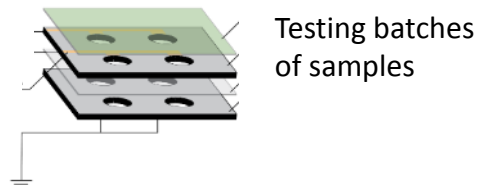
- Scale-up. Target: 1:15-1:20
- Improving fatigue lifetime
- Self-priming electronics
- Techno-economic assessment

Activities

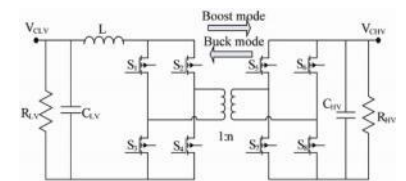
- PTO Lab test-bench



- Electromechanical fatigue



- Power electronics



- Numerical modelling & techno-economic assessment

Dielectric Elastomer Generator PTO

Work Packages

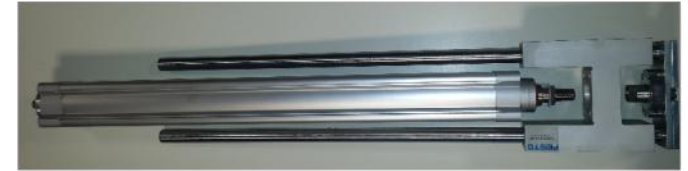
- WP1: Project management
- WP2: Concept and Control
- WP3: Implementation and Hardware-in-Loop testing
- WP4: Reliability testing
- WP5: Techno-economic assessing and road-mapping

Milestones

- M1: Architecture, models and experimental setups (month 3)
- M2: Setups and evaluation strategy (month 6)
- M3: Testing results and preliminary evaluation (month 9)
- M4: Final results and evaluation (month 12)

Start: 2 Oct. 2016

Progress



Ball screw



U-joint



Piston



Rotary motor

**Procurement completed
Setups in construction!**

Wave Energy Transmission Module

Romax Technology Ltd



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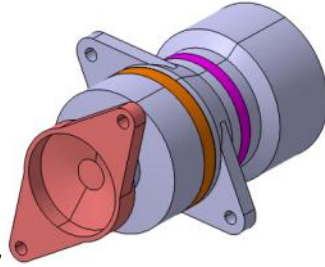
Limerick Wave



Wave Energy Transmission Module

Project summary

A WEC PTO module comprising a speed-increasing gearbox and rotary generator, which is **efficient**, **robust**, works across **multiple WEC types and scales**, and uses **mature technology** from other industries.



Challenges

- **We can:** capture and convert a lot of energy, keep a large WEC producing power through extreme conditions.
- **We want to:** see if we can capture even more energy, improve output quality/smoothing, enhance controllability.

Technical product or integration offering

- Any WEC where rotation (through any angle) around an axis may be produced.
- Self-contained, sealed and protected gearbox and generator unit.
- Feasible across all likely device sizes, including sub-scale prototypes.

Skills, expertise and technology required

- Opportunity to demonstrate cross-platform applicability.
- Collaboration on what 'enhanced controllability' might mean.
- Practicality/economics of in-PTO power smoothing vs alternatives.

Development of a Variable Damping Linear Power Take-Off

Oscilla Power

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OSCILLA
power™

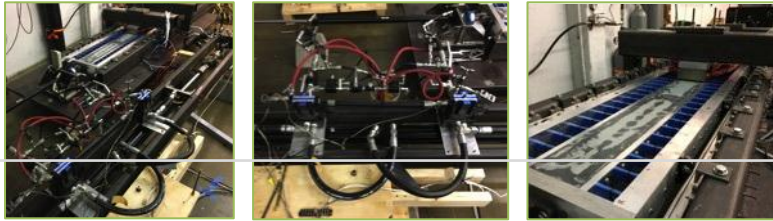
EMEC  **ORKNEY**
THE EUROPEAN MARINE ENERGY CENTRE LTD


wave energy
SCOTLAND

Development of a Variable Damping Linear Power Take-Off

Project summary

- *Hydraulic/direct drive hybrid drivetrain*
- *Hydrostatic hydraulic gearbox provides velocity increase and allows mech. power management*
- *Double-sided Vernier PM generator provides high efficiency and elec. frequency at low velocity*

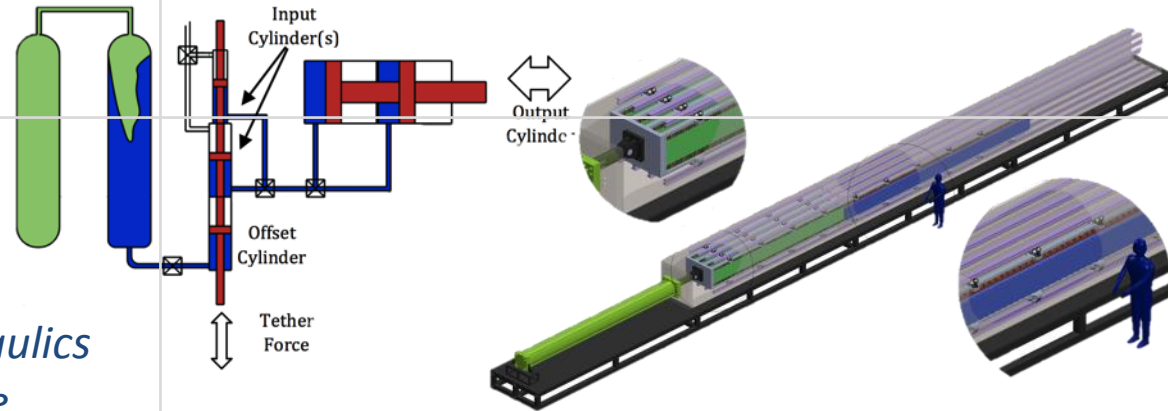


Technical product or integration offering

- *Controllability of direct-drive systems with power management of conventional hydraulics*
- *Highly efficient drivetrain with controllable damping for maximum WEC control/efficiency*
- *Hydraulic power dissipation increases survivability and average to peak power ratio*

Challenges

- *In double-sided generator topology, matching small air gaps on both sides is challenging*
 - *Single sided topology an option*
- *PTO performance/reliability highly dependent on bearing and hydraulic seal solutions.*
 - *Working with Trelleborg and Schaeffler*



Skills, expertise and technology required

- *Other WEC developers interested in collaboration*

C-GEN Direct Drive

University of Edinburgh

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THE UNIVERSITY of EDINBURGH
School of Engineering

Institute for Energy
Systems



C-GEN Direct Drive

Project summary

- *Fully flooded generator design*
- *CFD modelling of thermal*
- *Wet coil operation to improve cooling.*
- *High performance reliable bearings*
- *Experimental validation*



Challenges

- *Integration of power conversion into generator modules.*
- *Offshore structural design for survivability.*
- *Commercialisation of a disruptive technology.*

Technical product or integration offering

- *Modular design increases availability and reduces OPEX.*
- *Manufacture using standard components, reduces CAPEX.*
- *Integrate as linear or rotary machine.*
- *Applicable to a wide range of wave devices, and other offshore renewables.*

Skills, expertise and technology required

- *Power electronic conversion for control and grid interface.*
- *Condition monitoring and predictive maintenance strategies.*
- *Manufacture and production engineering*

Power Electronic Controlled Magnet Gear PECMAG

Ecosse Subsea systems
Supply Design
Bathwick Electrical Design
Pure Marine Gen

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ECOSSE
Subsea Systems

SUPPLYDESIGN
BESPOKE ELECTRONICS

BEDL
Bathwick Electrical Design Ltd

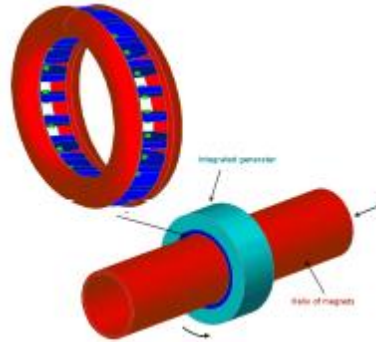
P Pure
Marine


wave energy
SCOTLAND

Power Electronic Controlled Magnet Gear PECMAG

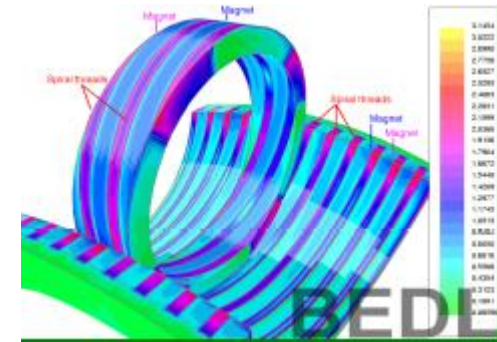
Project summary

- *Non-contact magnetic gear*
- *Enables all-electric / high conversion efficiency*



Challenges

- *Clear & Standardised benchmarking*
- *Integration with scaled WEC prototype*



Technical product or integration offering

- *Design, supply, install & maintain a linear or Rotary PTO for WEC developers*

Skills, expertise and technology required

- *WEC developers to provide specifications*
- *Manufacturing partner for Gear system ??*

Direct drive ball screw PTO

Blue Power Energy

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Direct drive ball screw PTO

Project summary:



Design, built and tested 5 kW PTO with control system and kinematics model

Technical product or integration offering:

Wave energy convertors compatible with:

- Attenuator.
- Point absorber.
- Oscillating wave surge convertors.
- Wave star like devices.

Challenges:

Future development:

Have teamed up with a WEC developer to apply for stage 3 WES project and deploy 1/10th scale model at EMEC.

Technical Challenges:

- To marinize PTO.
- Fit torque limiter/damper.
- Deploy at sea to prove survivability.

Skills, expertise and technology required:

We would be delighted to speak with any WEC developers who would like to trial our PTO.

Hybrid Digital Displacement[®] hydraulic PTO for wave energy

Jamie Taylor

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ARTEMIS 
INTELLIGENT POWER

Quoceant

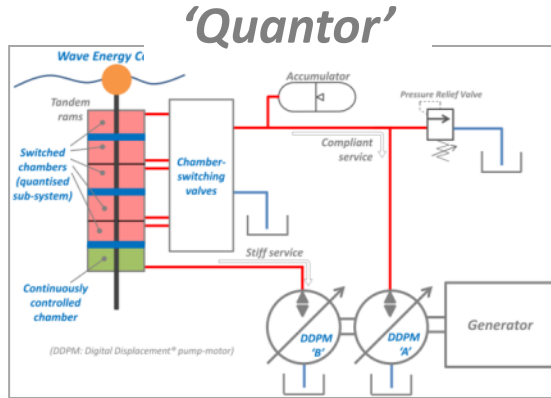
Specialists in Marine Energy & Technology


wave energy
SCOTLAND

Hybrid Digital Displacement® hydraulic PTO for wave energy

Project summary

- Marriage of quantised and Digital Displacement® hydraulic technologies.
- Linear and rotary versions are possible.
- The key requirements of pressure-control & transforming have been lab verified in this Stage 2 project.
- LCoE reductions of up to 15% (compared with quantised-only PTO) have been modelled.



Challenges

- Build lab test system with representative inertia.
- Test and demonstrate 100kW scale PTO.
- Develop core component technology for '100kW' & '1MW'.
- Form partnership(s) for future sea-going trials.
- Create WEC-Sim module for third party use.

Technical product or integration offering

- Advanced PTO system.
- Multiple configurations possible.
- WEC and non-WEC applications.

Skills, expertise and technology required

- Seeking end-users.

HiDrive

Nicolas Meyer

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IBERDROLA



Project summary

- *Development of a ½ scale WEC*
 - *Phase control (Energy density > 8MWh/ton)*
 - *Leightweight units*
 - *Effective install and O&M scheme*
- *Dry testing with HIL-rig*
- *Ocean testing at EMEC*



Challenges

- *Upcoming development 1:1 scale WEC*
- *Management of design evolution*
- *Developing supply chain*



Technical product or integration offering

- *WaveSpring*
- *Pneu-mechanical PTO*

Skills, expertise and technology required

- *Offshore operation*
- *Mooring and anchoring*
- *Electrical systems*

ReBaS [Reciprocating Ball Screw] Generator

Umbra Cuscinetti SpA

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2nd December 2016



UMBRA GROUP

SEAPOWER srl
Consortium with University of Naples Federico II



HMS
Hebrides Marine Services Ltd


wave energy
SCOTLAND

ReBaS Generator



Project summary:

- WP2 - Dry testing
- WP3 - WEC Detailed engineering design
- WP4 - Wave tank testing
- WP5 - Reporting and Stage 3 planning



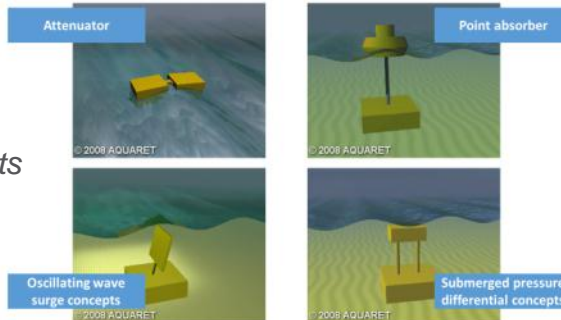
Future developments:

- ➔ Real sea environment testing
- ➔ Test validation with different control laws
- ➔ Integration on other WEC concepts
- ➔ Product sizes standardization



Integration in existing WECs can bring the following benefits:

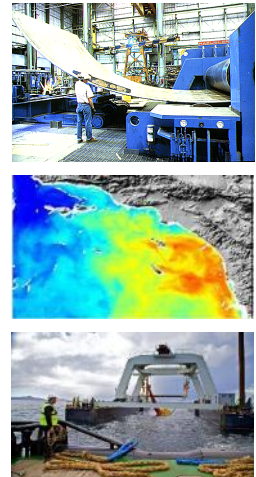
- ➔ Higher efficiencies
- ➔ Higher reliability
- ➔ Lower space requirements
- ➔ Weight saving
- ➔ Costs reduction



Wave energy conversion concepts that could directly integrate the RLA

Required skills, expertise and technology:

- ➔ Collaboration with test sites and deployment services
- ➔ Construction of buoy and structures
- ➔ Certification and third-party evaluation.
- ➔ Maintenance support and environmental monitoring



GRAZIE PER L'ATTENZIONE
THANK YOU FOR YOUR ATTENTION

Gator – a compliant seal free hydraulic PTO

Annicka Wänn

WES Annual Conference

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Pelagic Innovation



Gator – a compliant seal free hydraulic PTO



Project summary

- Stage 2 WES PTO project
- Polymer spring pump to drive pressurised water at around 10 bar
- Eliminates major failure mechanism in similar systems
- Stage 1 identified significant LCOE gains
- Stage 2 will optimise concept and validate LCOE assumptions
- Validate concept at small scale of interest to potential non-WEC customers (1kW scale) and design large scale system prototyping for Stage 3

Challenges

- Control algorithms for non-linear responses
- System integration of the pump/valve/turbine
- Polymer valve solutions
- Hydro turbine selection

Technical product or integration offering

- 1kW size product at the end of Stage 2
- Polymer pump with polymer valves driving hydro turbine
- Large scale system suitable for up to 80% of WEC
- Suitable for integration into non-WEC applications (mooring lines)

Skills, expertise and technology required

- System engineering partners
- Control system engineering
- Control strategy experience
- Mechanical engineer
- Hydro electric Turbine
- Accumulation systems

1st Annual WES Conference

3 minute elevator pitches

Novel Wave Energy Converter call participants (NWECC)

Running Order

1. Zyba
2. Joules E. E. S.
3. Mocean Energy
4. AWS
5. 4c Engineering
6. Anaconda (Checkmate)
7. Quoceant

CCell – Curved WEC Optimisation

Zyba Ltd

WES Annual Conference

2nd December 2016

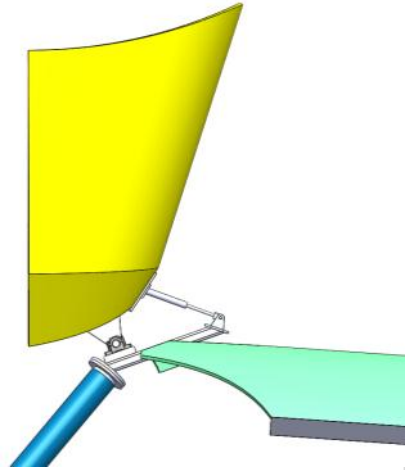


CCell – Curved WEC Optimisation

Project summary

•Optimise:

- *Power to weight*
- *Manufacturing*
- *Operations*
- *Implicit extreme protection*
- *Validate performance in lab*
- *Validate numerical tools*
- *LCOE modelling*



Challenges

- *Operational unknowns*
- *Long term performance of composites*
- *Design of joints between materials*
- *Flexible couplings / hoses*
- *Efficient power conversion to electricity*
- *Shore connections*

Technical product or integration offering

- *1:3 scale system (4m height; RMS: 2 to 6 kW)*
- *High energy capture (up to 80%)*
- *Lightweight (paddle < 350 Kg at 1:3 scale)*
- *Rapid deployment (target 90 minutes at site)*

Skills, expertise and technology required

- *Marine operators*
- *Fabricators (Composites and Steel)*
- *Coatings / Galvanising*



Joules E. E. S. Ltd. - WaveTrain

Dr Nick Wells

WES Annual Conference

2nd December 2016



Project Summary

- Attenuator array
- Three linked buoys in a row
- Integral inclined water columns
- Efficient hydrodynamic capture
- Air turbine & generator PTO
- Modular System
- Simple catenary mooring



Opportunities for Collaboration

- Inflatable membrane tuning/de-tuning though change of the water plane area
- Alternative PTO systems to air turbine/generator
- Reinforced lightweight concrete construction expertise
- Control strategies for ultimate performance

Mocean Wave Energy Converter

Cameron McNatt

WES Annual Conference

2nd December 2016



Mocean Wave Energy Converter

Project summary



Challenges

- *Nonlinear wave effects*
- *Structural costs*
- *PTO costs*
- *Controls*

Technical product or integration offering

- *Hinged raft prime mover*
- *Rotational PTO*
- *High power to mass ratio*
- *Good reliability and survivability characteristics*

Skills, expertise and technology required

- *Higher-order numerical modelling*
- *Alternative materials (concrete)*
- *Inexpensive PTO*
- *Control algorithms*

Advanced Archimedes Waveswing

AWS Ocean Energy

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Advanced Archimedes Waveswing

Project summary

- *Hydrodynamic study*
- *Numerical modelling*
- *Tank testing & model validation*
- *FEED study*
- *Parametric cost optimisation*

Challenges

- *PTO integration / optimisation*
- *Excess power dissipation*
- *Rolling seal*
- *Electrical system*
- *Deployment & maintenance*

Technical product or integration offering

- *High-efficiency, lower cost subsea point absorber*
- *Advanced control techniques to maximise energy conversion*

Skills, expertise and technology required

- *PTO with high force-density*
- *Rolling seal with long fatigue life*
- *End-stops capable of significant power dissipation*
- *Low cost anchoring and deployment*

ACER

Attenuator Cost of Energy Reduction

4c Engineering

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ACER (Attenuator Cost of Energy Reduction)

Project summary

- *Verified tank testing campaign*
- *Validated numerical model (DNV GL)*
- *Concept engineering of full scale device*
- *Enhanced understanding of Sea Power Platform*



Challenges

- *Future development needs:*
 - *Length scaling/site matching*
 - *Control strategy*
- *Technical challenges to overcome:*
 - *Pontoon costs*
 - *Hinge bearings*

Technical product or integration offering

- *Stable platform for further development of:*
 - *PTO and control systems*
 - *Structural materials*

Skills, expertise and technology required

- *Hydrodynamics expertise – slam loads*
- *Floating concrete hulls – optimisation*
- *Electrical concept engineering – WEC array*

Anaconda Novel Wave Energy Converter

John Fitzgerald

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2nd December 2016



BLACK & VEATCH



University of
Strathclyde



INNOSEA
Marine Energy Engineering

The logo for wave energy SCOTLAND, featuring a stylized blue wave above the words "wave energy" in green and "SCOTLAND" in blue capital letters below it.

Anaconda Novel Wave Energy Converter

Project summary



Challenges

- *Complex Physics / Numerical Modelling*
- *Full Lifecycle Rubber Engineering*
- *PTO coupling and Optimisation*

Technical product or integration offering

- *Utility scale bulk electricity generation*

Skills, expertise and technology required

- *Deformable body numerical modelling*
- *Materials Engineering / Manufacturing*
- *PTO*

Ectacti-Hull

Quoceant

WES Annual Conference

2nd December 2016

The logo for Quoceant is contained within a dark blue rectangular box. The word "Quoceant" is written in a large, white, sans-serif font. Below it, a thin white horizontal line separates the name from the tagline. The tagline "Specialists in Marine Energy & Technology" is written in a smaller, white, italicized sans-serif font.

Quoceant

Specialists in Marine Energy & Technology

Ectacti-Hull

Project summary

“Making a survivable machine economic or an economic machine survivable”



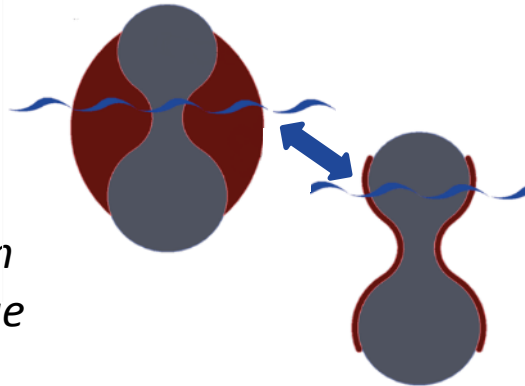
Challenges

*Concept feasibility investigated, refined, & proven
→ Now to detailed engineering using available technology*



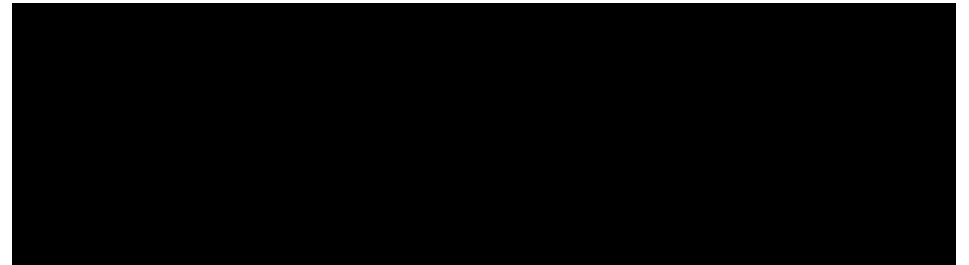
Technical product or integration offering

- *Modular, inflatable units to provide gross change of hull volume*
- *Technology applicable to multiple WECs - from point absorbers to surge devices to attenuators*



Skills, expertise and technology required

- *WEC device developers interested in investigating benefits of system to their device.*



Ectacti-Hull

Project summary

“Making a survivable machine economic or an economic machine survivable”



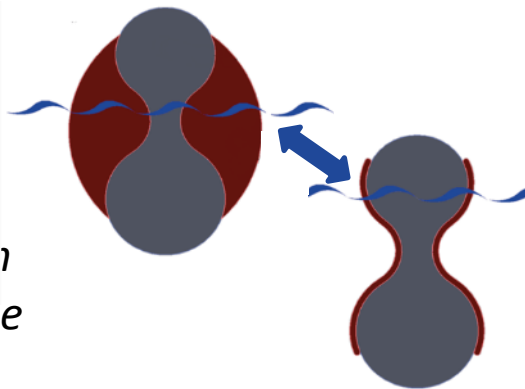
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