WAVE ENERGY SCOTLAND

SIDE EVENT – Contractor speed updates

EWTEC 2017

28th August 2017

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WES Contractor - Speed Update

Materials - Hybrid Stage 1	**RotoHybrid -The use of rotationally moulded polymers in hybrid WEC structures**	Donald Naylor - Pelagic Innovation Ltd (on behalf of University of Edinburgh)
Materials - Elastomer Stage 1	**Polyshell**	Dr. Paul Mc Evoy - Technology From Ideas
Materials - Concrete Stage 1	**Advanced Concrete Engineering-WEC**	Leah Barker Ewart – IDCORE (on behalf of Quoceant)
NWEC Stage 2	**Mocean Wave Energy Converter**	Cameron McNatt - Mocean Energy Ltd
PTO Stage 2	**Gator - a compliant seal free hydraulic PTO**	Annicka Wann - Exceedence
PTO Stage 2	**Power Electronic Controlled Magnet Gear (PECMAG)**	Paul Brewster - Pure Marine (on behalf of Ecosse Subsea Systems)
PTO Stage 3	**Quantor hybrid hydraulic PTO**	Richard Yemm - Quoceant (on behalf of Artimus Intelligent Power)
PTO Stage 3	**EMERGE Overview**	Luca Castellini - Umbra Group
	Multi Project Overview	Wave Venture
NWEC Stage 2	**Attenuator Cost of Energy Reduction (ACER)**	Cian Murtagh - Seapower Ltd (on behalf of 4cEngineering)

ROTOHYBRID Project

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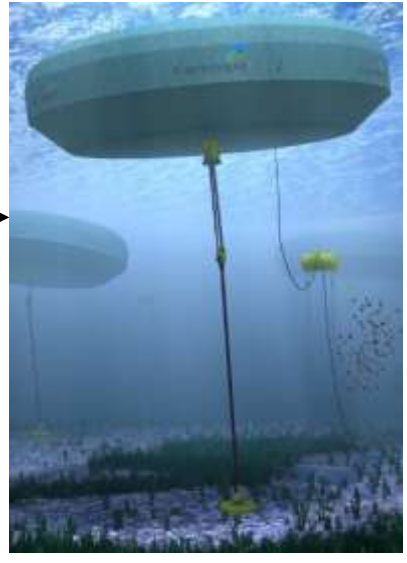
Can we apply
This

To this?



THE UNIVERSITY of EDINBURGH

Queen's University Belfast

Pelagic Innovation

Carnegie CLEAN ENERGY

Kingspan

ÉIRECOMPOSITES

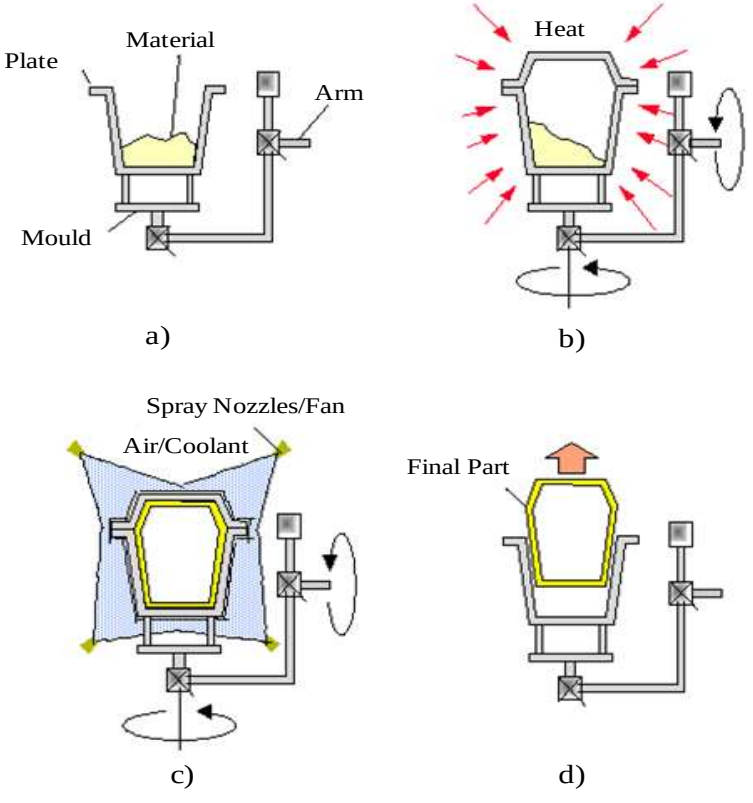
Hybrid Technology

Rotational Moulding
Large, cheap, hollow structures

+

Steel / Composite
Strength and stiffness

Reduced CAPEX
Improved LCOE



Project Methodology

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Inputs

Materials / process (QUB / UoE)

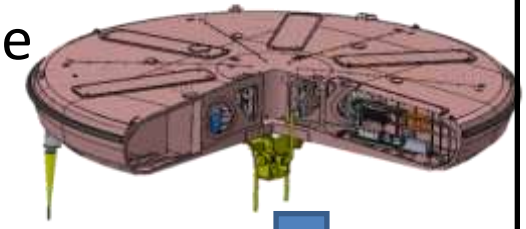
Manufacturing (Kingspan)

Specific testing (UoE)

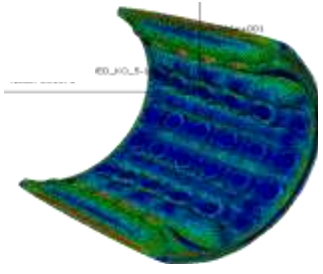
Knowledge Transfer

Case Study

CETO 6 Baseline (Carnegie)



Analysis and design (UoE / PI)



LCOE (PI)

WES Polyshell

A thermoplastic-Elastomer Hull for WEC devices

Paul Mc Evoy

WES EWTEC Event

28th August 2017

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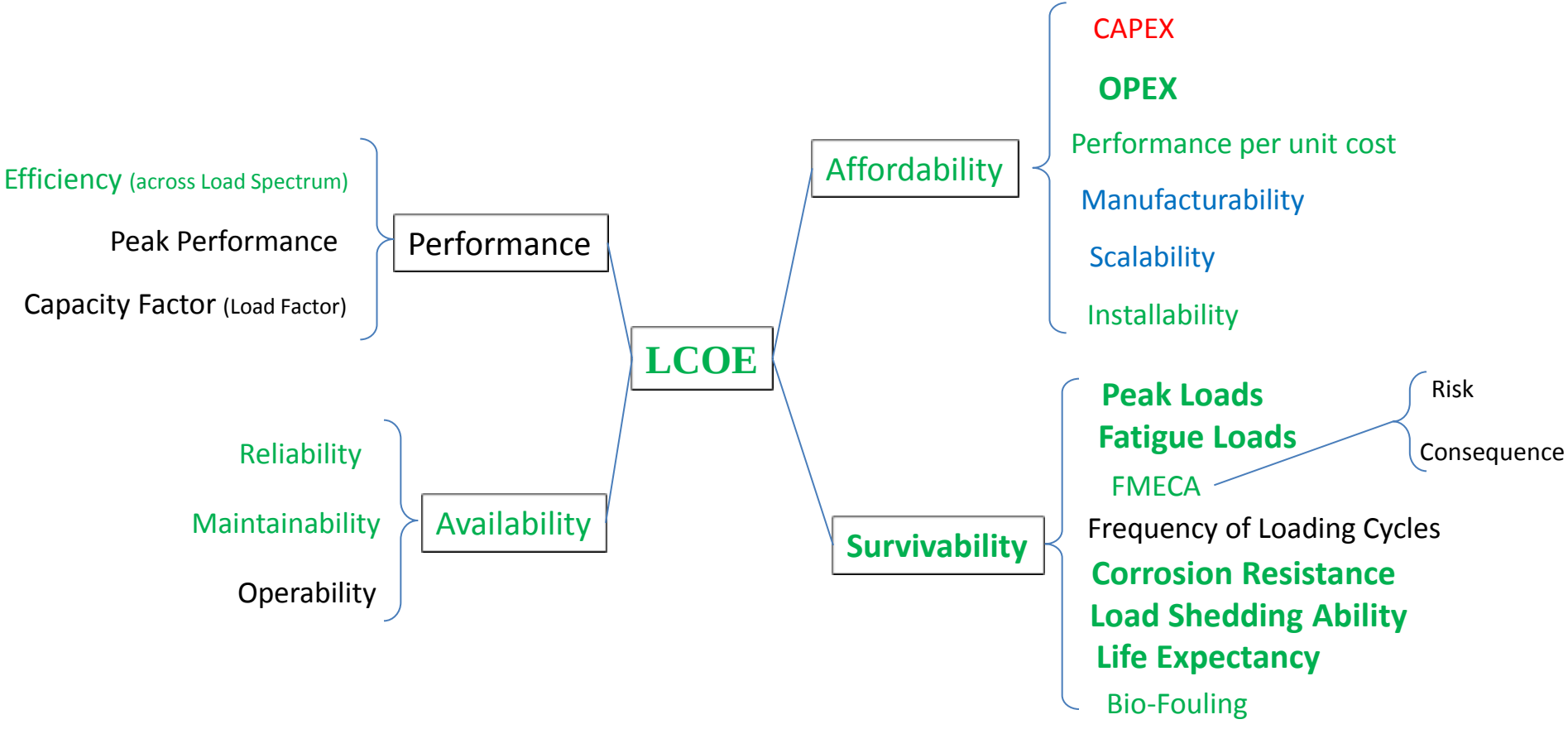
Concept Summary

- This study will assess the potential of using high performance thermoplastic elastomers as the outer shell of wave energy devices to
  - Enhance Performance
  - Dissipate Loads
  - Reduce LCOE
- With the right design these materials could dramatically reduce peak and shock loads on WEC structures, while naturally having a lower cost of maintenance
  - These materials could revolutionise wave energy in a similar manner to how composite materials revolutionised the aircraft industry
- With many years experience developing Hytrel for mooring components (designed to bend in complex ways under applied loads of up to 3MN) the team have the experience and expertise to develop these features into WEC structures

WES Metrics impacted by concept



Polyshell Project Summary

Materials

- Review of DNV Standards to identify material parameters and base case comparators
- Review of DuPont material to identify known material parameters
- Additional analytical and experimental testing to identify missing parameters
- Assessment of potential material impact on Affordability, Availability, Survivability and Performance

Engineering

- Manufacturing studies on fabrication of large polymer structures
- Investigations on attachment of polymer components to other hull materials (polymer, steel, composites)
- Assessment of the limitations and opportunities
- Assessment of Failure Modes and impact of failure of other components on the material
- Detailed engineering risk register

Design

- Hull designs which flex under extreme loads to change hull surface area and/or drag coefficient
- Hull contact point designs which flex to dampen loads
- Hull surface designs which contain localised load absorption and load transfer pathways
- Environmental Load modelling of new hull designs compared to base case designs

Commercial

- Impact of material, design and engineering on Affordability, Availability, Survivability and Performance
- LCOE calculations compared against a base case structure
- Commercial assessment of the material as a hull structure
- ‘Voice of the Customer’ feedback from WEC developers
- ‘Go / no Go’ recommendation with Stage 2 plan

Current Project Status Snapshot

- Material Work Complete
  - Materials well understood with excellent properties for what we are trying to achieve
- Design Work
  - Have changed our design approach based on the modelling
  - New approach is so far showing 40%+ reductions in loads
  - New approach focusses use of material where it is needed rather than everywhere
  - Completed initial review of impact on Affordability, Availability, Survivability and Performance
- Current Status
  - Progressing well
  - Engineering and commercial analysis starting

Summary

Project summary

- Stage 1 engineering studies to determine feasibility of Hytrel as a WEC material
- Strong partners
- Material, design, engineering and commercial activities

Challenges

- Delivering the desired design performance to shed loads
- Managing the unshed loads
- Manufacture of very large polymer structures

Technical product or integration offering

- Hull Superstructure material requiring minimal steel core skeleton with integrated shape changing, attachment point and localised surface features
- Hull components containing any of the individual features (e.g. polymer joints)
- Solutions to manufacture and engineering challenges of using large scale polymers

Skills, expertise and technology required

- Voice of the Customer – WEC developer feedback
- Real data on loads -> refine models
- Potential to combine with stronger materials for load pathways

Pelagic Innovation

Quoceant Innovation Offshore

University of Dundee
Scottish University of the Year

Advanced Concrete Engineering ACE-WEC

Wave Energy Scotland Structural Materials Project

28th August 2017

Leah Barker-Ewart

IDCORE Post-graduate, Quoceant Ltd

INNOSEA

BLACK & VEATCH

David Kerr Consultancy

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ACE-WEC Project Objectives

- **Remove / Reduce primary manufacturing cost centres**

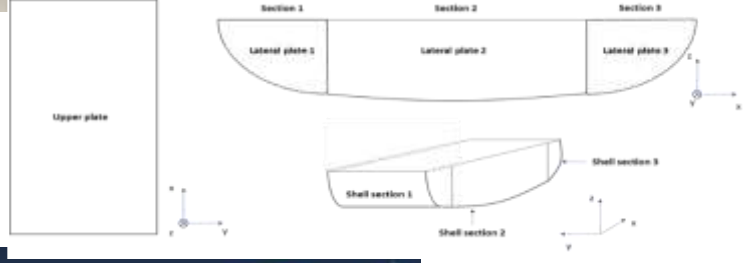
- **Novel High-fibre concrete mixes, carbon fibre wrapping and additive manufacture**



ACE-WEC Project Progress

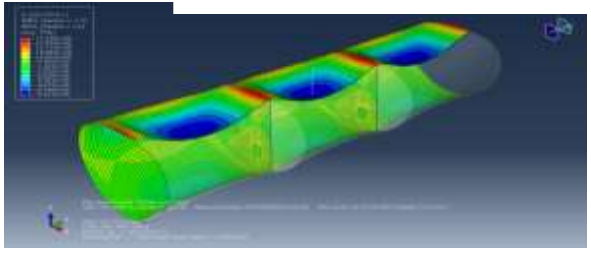
State of the Art materials and techniques review

- Materials review complete
  - High % content fibre concretes provide large gains in ULS loading
  - Combined with high-strength (C100) concretes could provide large material savings
- Additive manufacturing (3D printing) advanced centre visit completed (Skanska / Loughborough University)



WEC applications and engineering

- 5 WEC examples selected
  - Used to evaluate advanced concretes as primary structural material
  - Preliminary calculations complete
- Failure Modes and Criticality analysis complete for selected WEC types



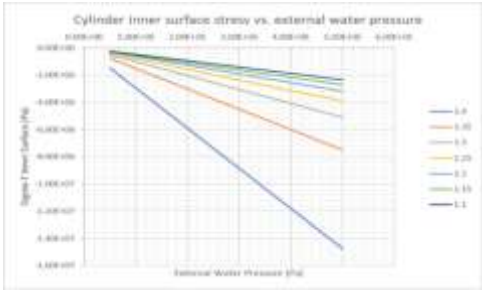
ACE-WEC Next Steps

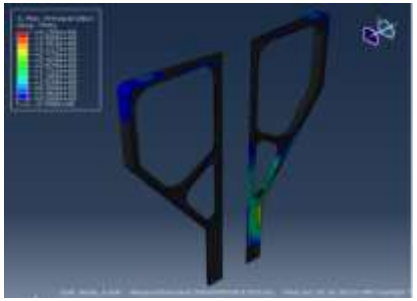
Technical Risk Register Review

- Further review of technical risks and define methods of mitigation (i.e. testing)
- To be updated to include cost risks to support CAPEX assumptions for LCOE calculations

WEC applications and engineering

- Advancement of designs to find appropriate solutions to meet defined load conditions
- Assessment of material requirements to support CAPEX assumptions for LCOE calculations

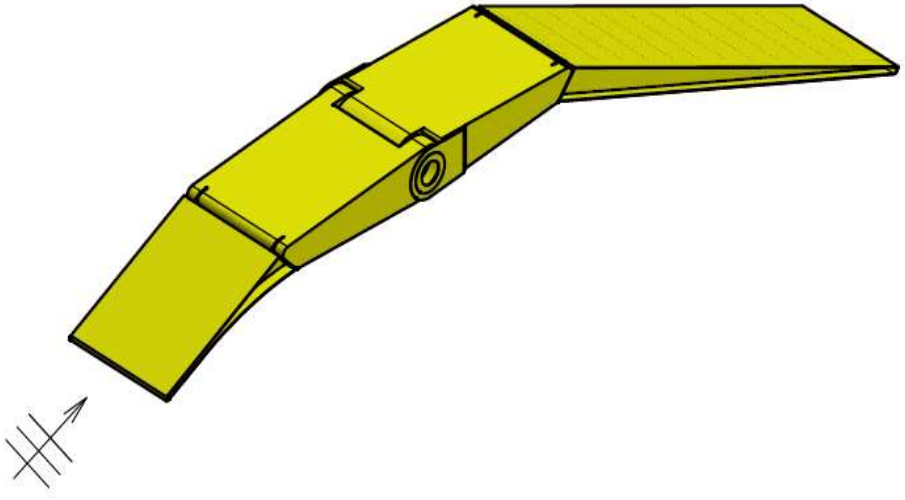




Manufacturing Study and LCOE assessment

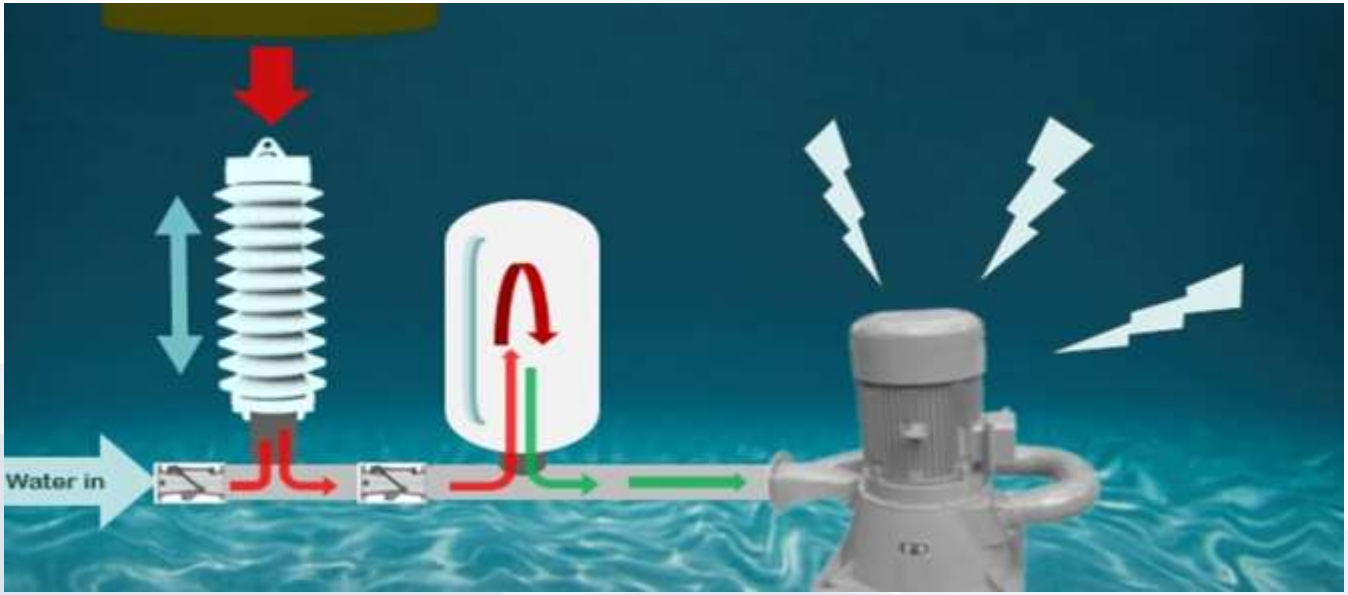
- Further engagement with the supply chain to assess additional options & potential problems
- Assessment of CAPEX costs for finalised WEC designs to produce comparable LCOE calculations for assessment

The Mocean WEC



www.moceanenergy.com/technology

The Gator – The Hydraulic PTO



annicka.wann@exceedence.com

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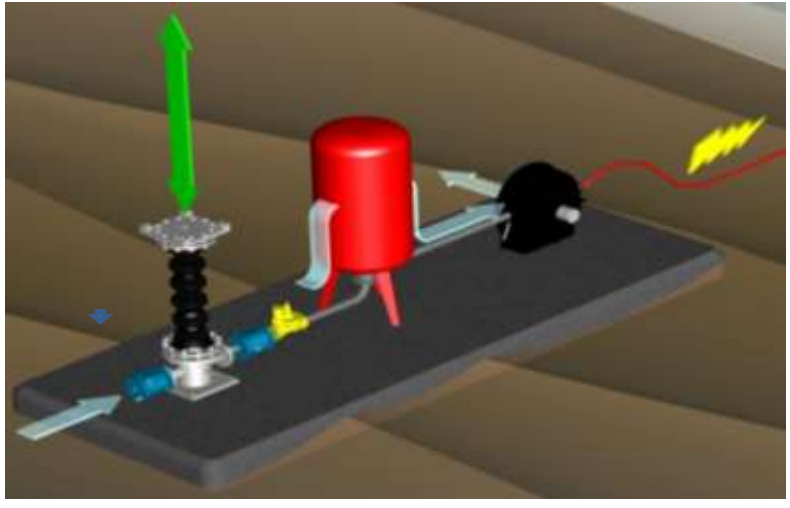
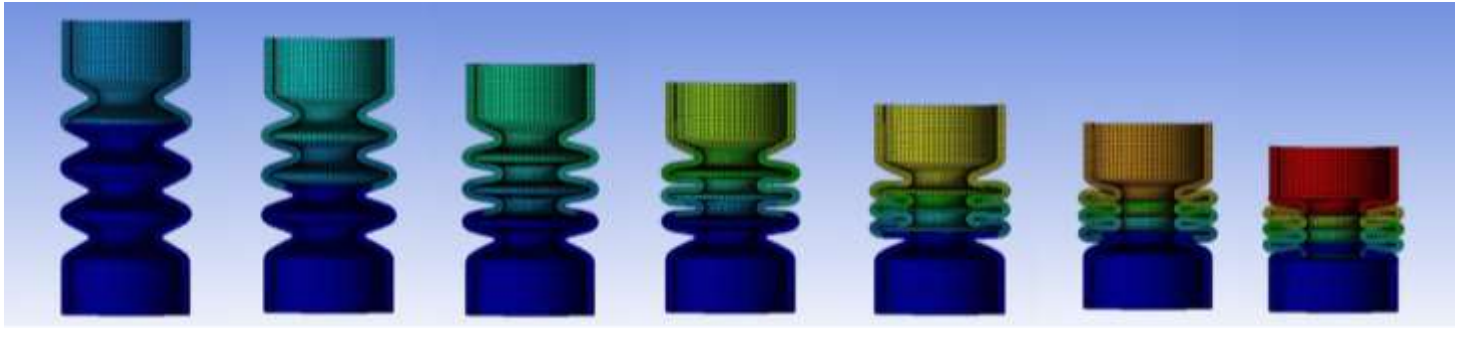
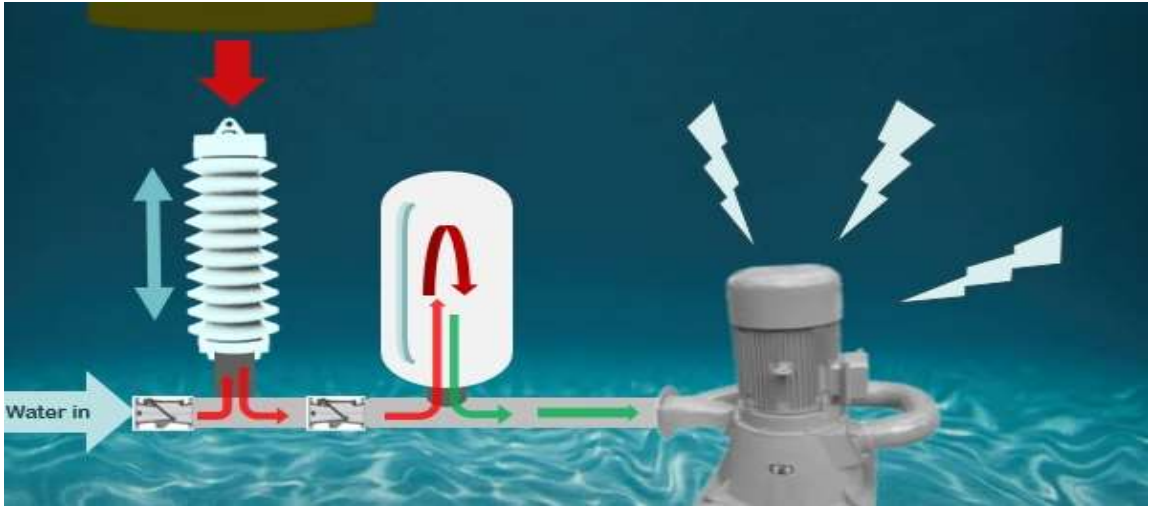
Gator – standard components



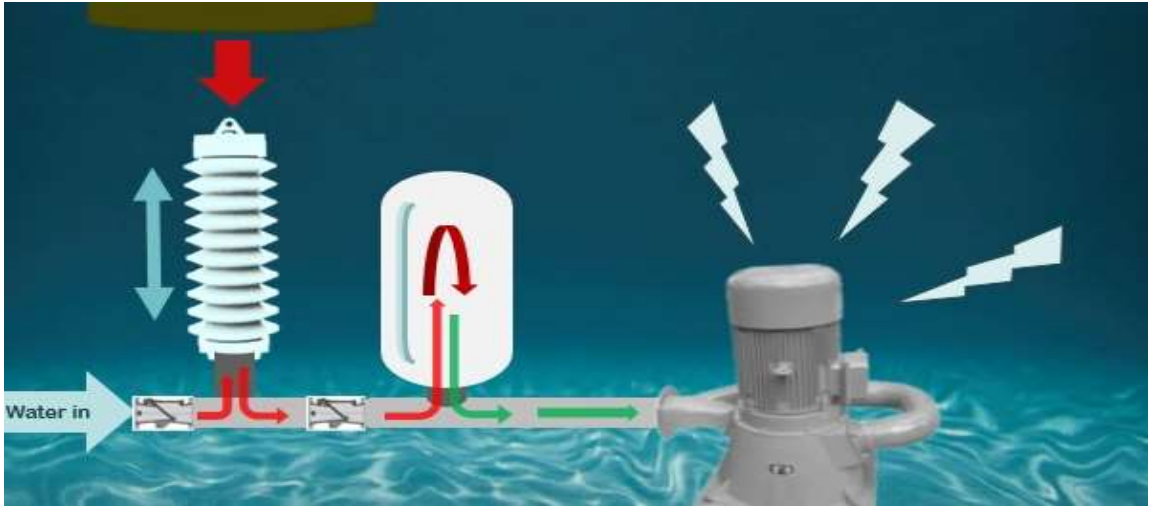


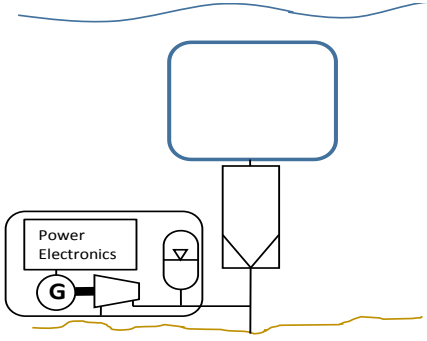
Gator – the Advantages



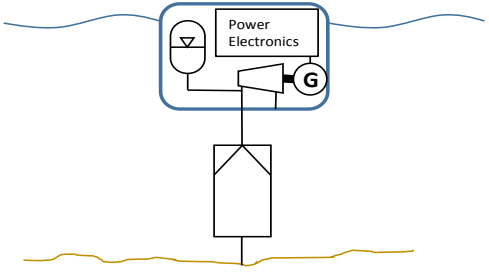
- The Gator PTO offers
  - LCOE reductions on current systems
  - Scalable solutions – 1kW, 10kW, 100kW, 1MW
  - Built in end-stop – due to non-linear stiffness response
    - Reduces failure risk
    - Increases survivability!

Gator – Suits most WECs!

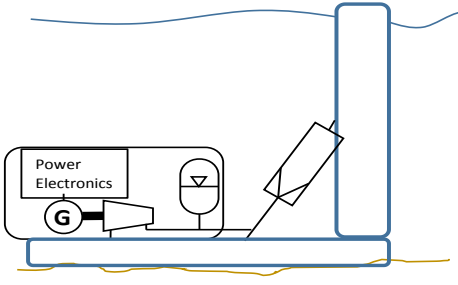




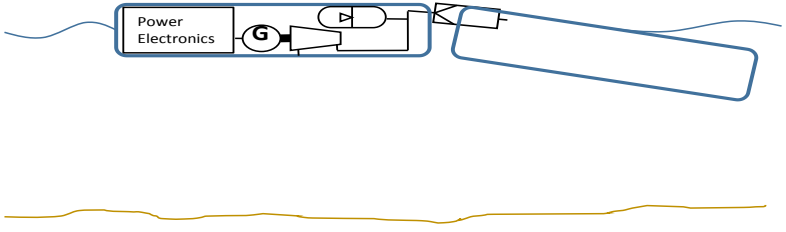
GATOR PTO adjacent to Point Absorber or Submerged Pressure Differential device



GATOR PTO located in Point Absorber or Submerged Pressure Differential device

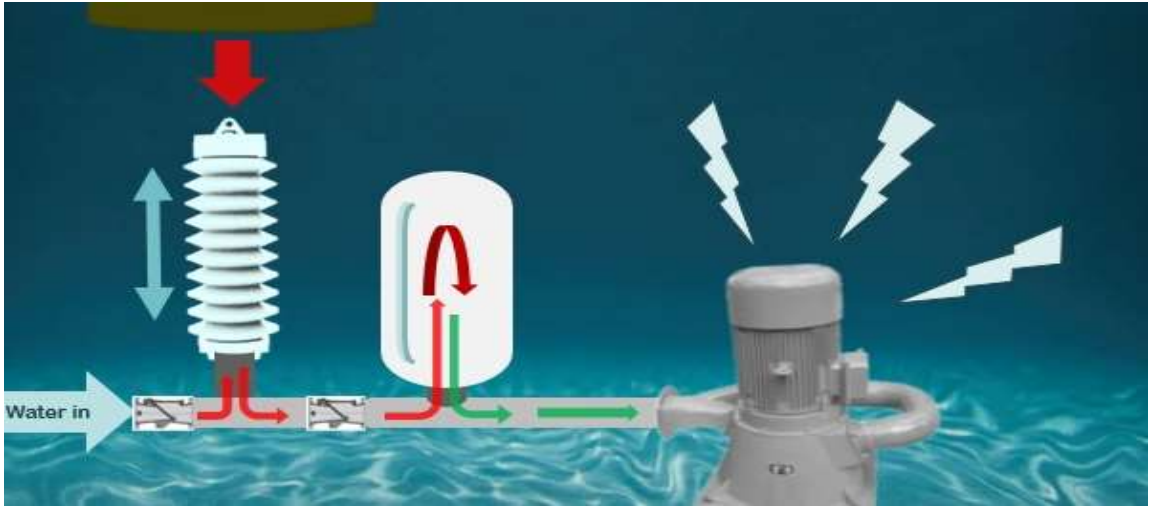


GATOR PTO with Oscillating Wave Surge Converter



GATOR PTO with attenuator WEC

Gator – early commercialisation



- Early commercialisation opportunities
  - Aquaculture
  - Aid to navigation buoys
  - Other marine industries

Gator – Team members

- Talk to us this week!

Noel

Ray

Paul

Donald

Annicka

Conor

Gator – other presentations

- Development of a Polymer Spring Pump based PTO
  - Date: Tuesday 29th
  - Time:14:00-15:20
  - Location: *West Wing Building, WW6*
- Preview Combined Software Exceedence/WoodGroup
  - Date: Tuesday 29th
  - Time: 15:20 sharp
  - Location: *O'Rahilly Building, Room 132*
- Mooring Load Management for SR2000 Floating Tidal Device Using Non-Linear Polymer Components
  - Date: Wednesday 30th
  - Time: 08:45 – 10:05
  - Location: *Kane Building, Room G01*

Power Electronic Controlled Magnet Gear PECMAG

Ecosse Subsea systems
Supply Design
Bathwick Electrical Design
Pure Marine Gen

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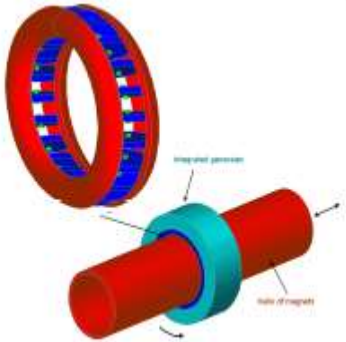
Power Electronic Controlled Magnet Gear PECMAG

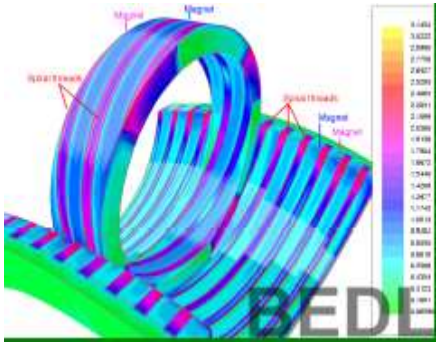
Project summary

- *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*

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ARTEMIS INTELLIGENT POWER

Quoceant
Specialists in Marine Energy & Technology

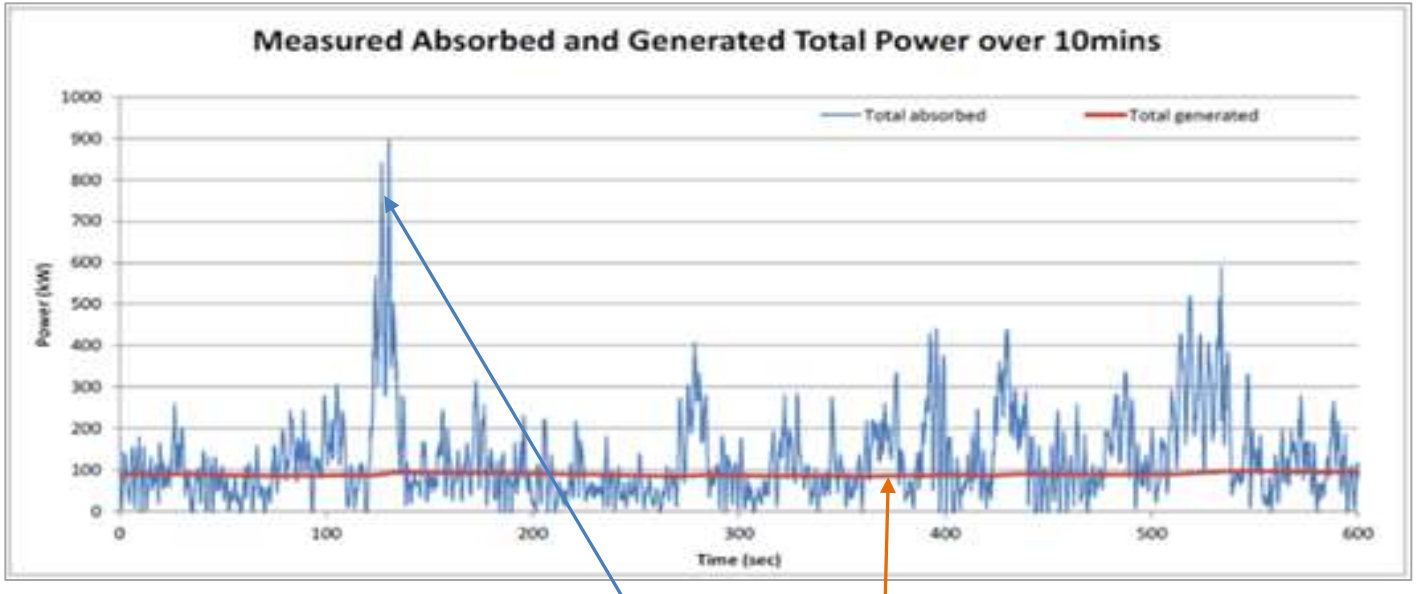
QUANTOR

advanced digital hydraulic power-take-off

Richard Yemm
Director
Quoceant Ltd

Major challenge

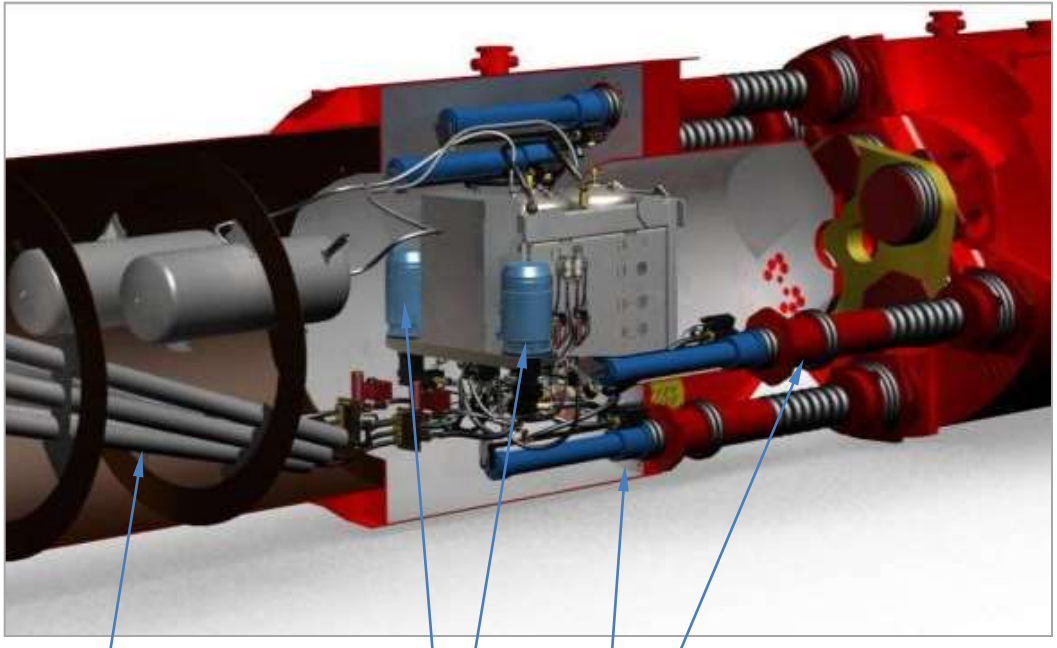
- ~~Need accurate control of force to maximise absorption~~
- Input power is extremely variable, over 20:1 instantaneous : average normal
- The output must only vary slowly
- High instantaneous power capacity & part load efficiency are absolutely critical



Power from WEC to PTO

Power from PTO to grid

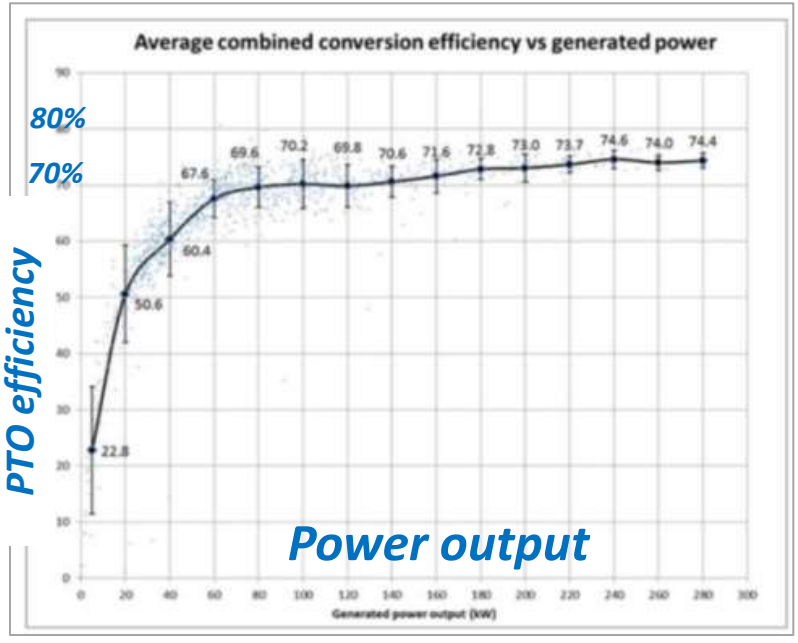
Pelamis quantised PTO



Hydraulic accumulators

Induction generators

Multi-chamber rams



- *Extremely high instantaneous power capacity*
- *High wave to wire PTO efficiency*
- *Stepped load application a limiting factor for optimising control response & absorption*

Digital Displacement® hydraulics

Electronic commutation by individual solenoid valves on each cylinder

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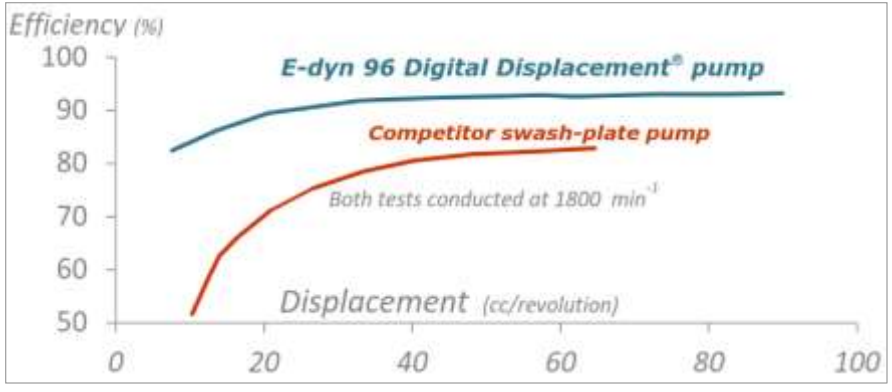
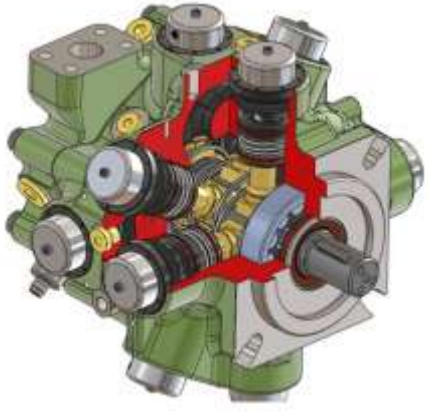
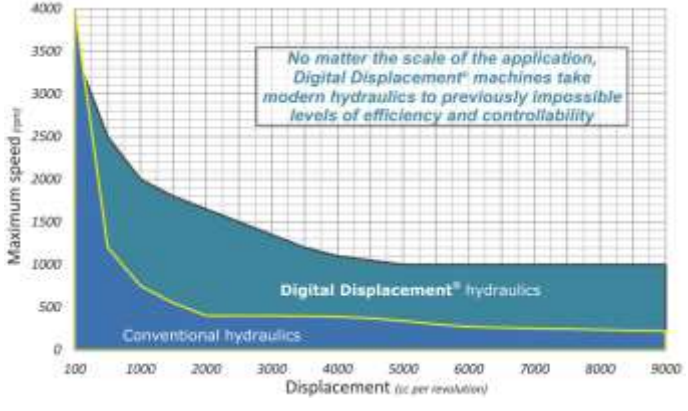




Very high-efficiency including at part load

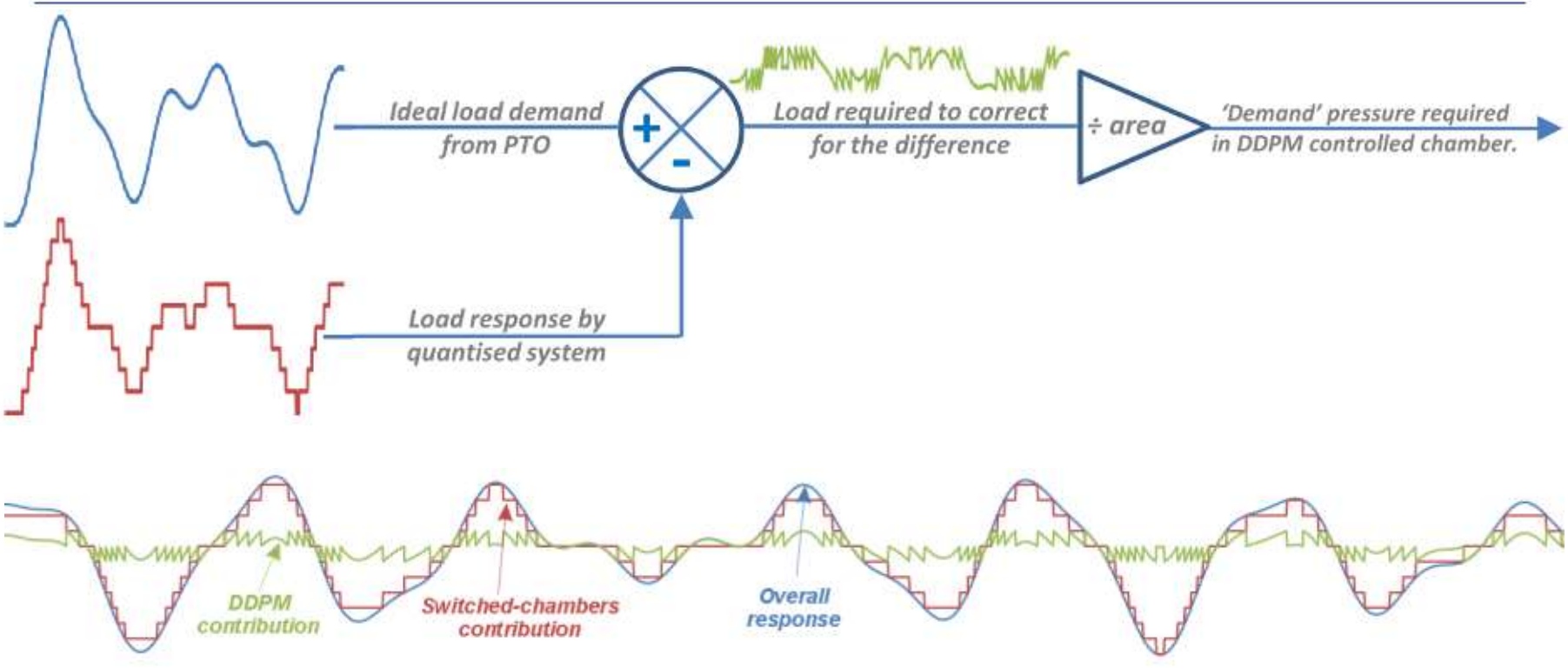


Scales well to high speeds and high power

'E-dyn 96', 140 kW, 3000 rpm

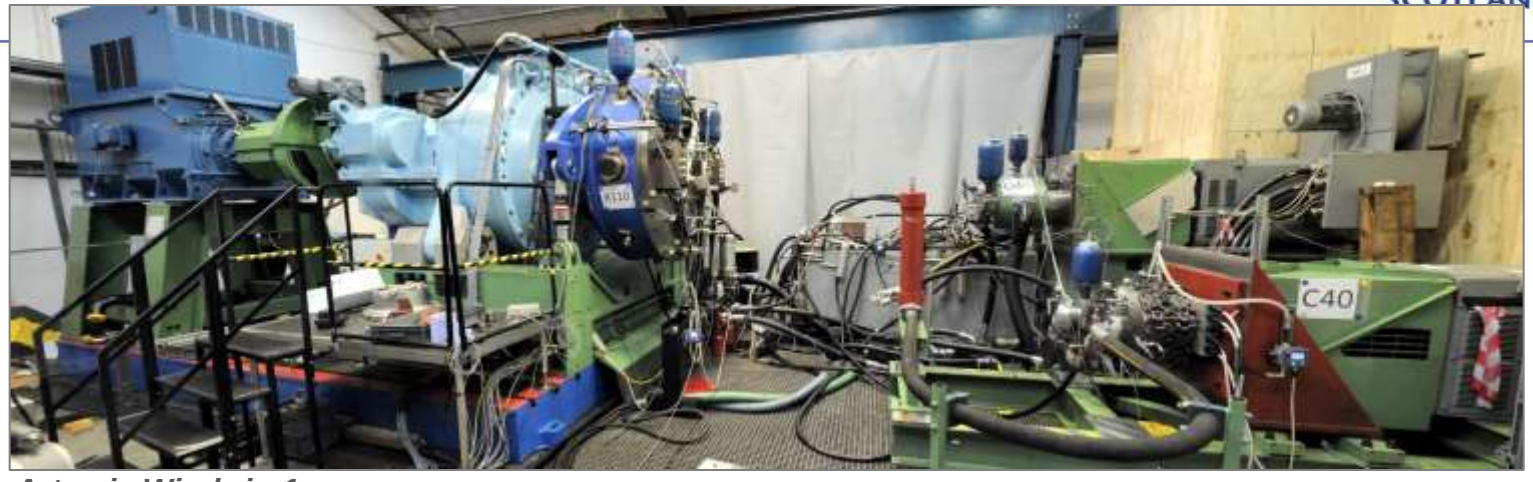
'H201': 3.5 MW, 1000 rpm

Quantor concept



Quantor = Quantised chamber-switching + step-softening by DD pump-motor

WES Stage 2 – Quantor demonstration



Artemis Wind-rig 1

Dual service pump-motor

Control cabin

Quantor Stage 3 project

- *Market & application development*
- *WEC-emulation test-rig*
- *Quantor PTO system & controller*
- *Advances in required core digital hydraulic technology*

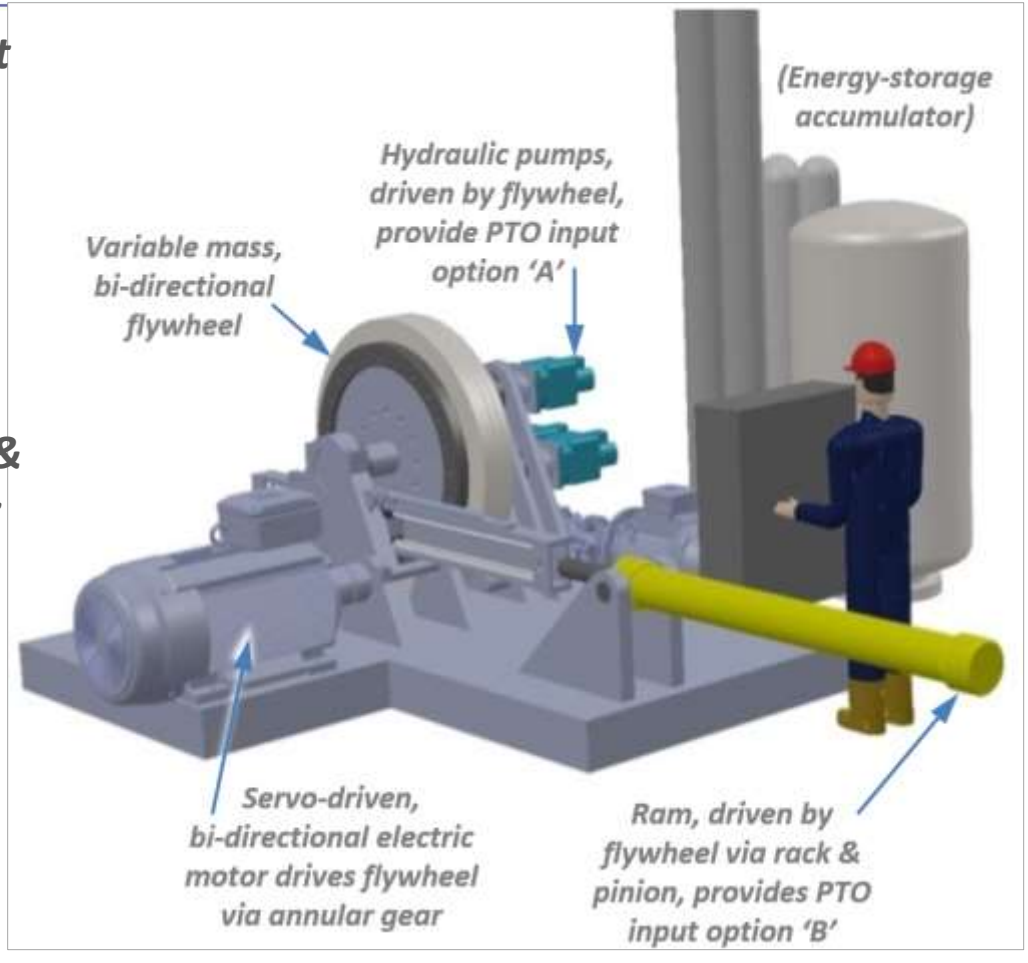
Currently engaging to ensure test rig & PTO as broadly applicable as possible:

Please contact us:

j.taylor@artemisip.com

richard.yemm@quoceant.com

THANK YOU!



EMERGE

Electro-MEchanical Reciprocating GEnerator

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Overview on PTO Stage 3 project EMERGE

Cork, Ireland, August 28th
2017

COMPANY INTRODUCTION

The Umbra Group

UMBRA CUSCINETTI S.p.A.

Foligno *- more than* ***29,000 m²***

Ballscrews, actuators, bearings, electrospindles and milling heads

UMBRA CUSCINETTI S.p.A.

Albanella

Research Centre

KUHN PRÄZISIONSSPINDELN und GEWINDETECHNIK GmbH

Freiberg *- more than* ***2,500 m²***

Ballscrews

PRÄZISIONSKUGELN ELTMANN GmbH

Eltmann *- more than* ***12,000 m²***

Balls

UMBRA CUSCINETTI Inc.

Everett *- more than* ***5,000 m²***

Gears, torque tubes

Processes and activities:

- *Metal cutting*
- *Turning*
- *Grinding*
- *Heat treatments*
- *Thermo-chamical treatments*
- *Galvanic treatments*
- *Non-destructive tests*
- *Assembly*
- *Test laboratory*
- *Industrial repair*

COMPANY INTRODUCTION

Sectors of interest and products

AEROSPACE

ENERGY

INDUSTRY

STEEL BALLS

ACME SCREWS

BEARINGS

SHAFTS

BALLSCREWS

ELECTRO-MECHANICAL ACTUATORS

ELECTRO-MECHANICAL GENERATORS

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SEAPOWER scrl
Consortium with University of Naples Federico II

UMBRAGROUP HMS

PTO - STAGE 2

ReBaS Project

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Project summary:

Nov. 2015
Project Kick-off

Dec. 2015
Start of performance dry tests

MS3

MS2

Jan. 2016
Start of WEC float design

WP2 - Dry testing

WP3 - Detailed design of WEC

Wave tank testing:

WP4 - Wave tank testing of the PTO with a WEC

Results:

Nov. 2016 MS8

Affordability

- Project CAPEX: 2500 €/kW
- Industrial target for CAPEX (similar size): 1600 €/kW
- Industrial target for CAPEX (200-300 kW rating): 600-700 €/kW

Performance

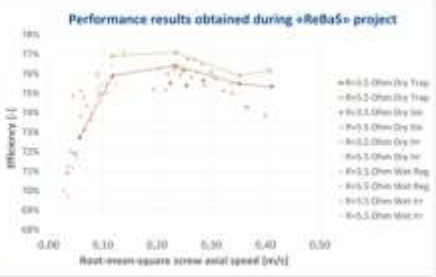
- A maximum efficiency of 67% was reached
- Efficiency is stably above 70% for most of the tests (both dry and wet)
- Efficiency is independent on the wave conditions

Availability

- The generator run 2,000,000 cycles at maximum speed and load
- ≈ 185 days operation at max. load and speed if wave period is 8 s
- No wear, damage or malfunction of any component was registered.

Survivability

- High load ratios (4 reached in wave tank, up to 15 allowable)
- Life expectancy is 20 years (if working under design conditions and ordinary maintenance is performed)

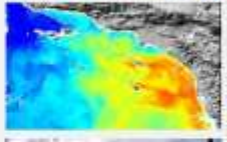


WP5 - Reporting and Stage 3 planning

Next developments:

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

STAGE 3

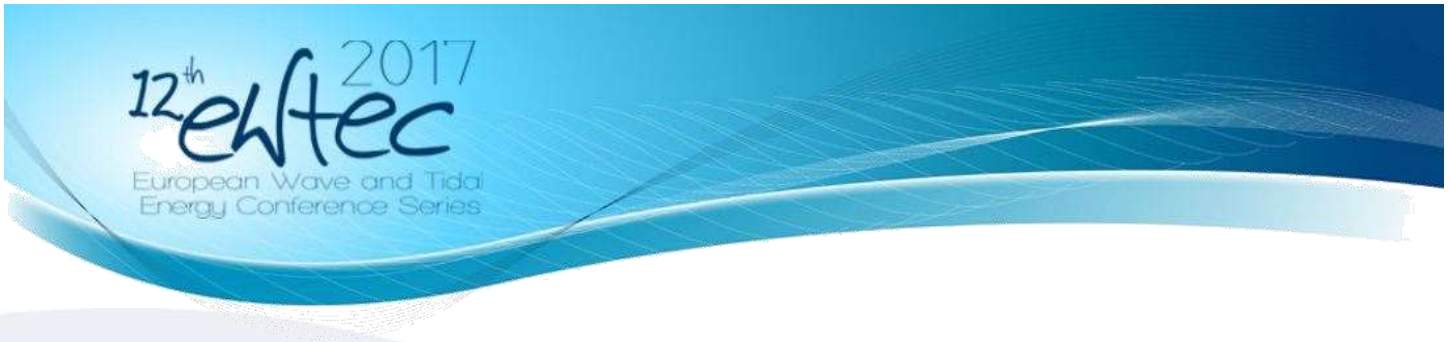


UMBRAGROUP

www.umbragroup.it

Wednesday the 30th session:

Grid Integration, Power Take-Off & Control 10 (WW6)



Development and Testing of a Ballscrew Electro-Mechanical Generator (EMG) for Wave Energy Conversion

Castellini, L., Martini, M., Alessandri, G.

Presented by

Michele Martini, Ph.D. - R&D Engineer

wave energy SCOTLAND

wave energy SCOTLAND

GREEN MARINE

JGC

UMBRAGROUP

SUPPLYDESIGN

BUREAU VERITAS

HMS

DOOSAN

SEAPOWER scrl
Consortium with University of Naples Federico II

THE UNIVERSITY OF EDINBURGH

PTO - STAGE 3

STAGE 3 PROJECT TIMELINE

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TRL 5 — TRL evolution for a 100 kW PTO — TRL 6 — TRL 7

July 2017
MS2: System Specification Control Document

December 2017
MS3: Finalization of the WEC, PTO & CS Design

May 2018
MS4: Finalization of the WEC, PTO & CS Fabrication

July 2018
MS5: Laboratory Tests Completed

October 2018
MS6: Sea Tests Completed

December 2018
MS7: Techno-economical Evaluation

March 2019
MS8: Technology and Test Qualification

June 2017
Project kick-off

May 2019
End of project

EMERGE

UMBRAGROUP
www.umbragroup.it

«EMERGE» PROJECT *Scope of work/1*

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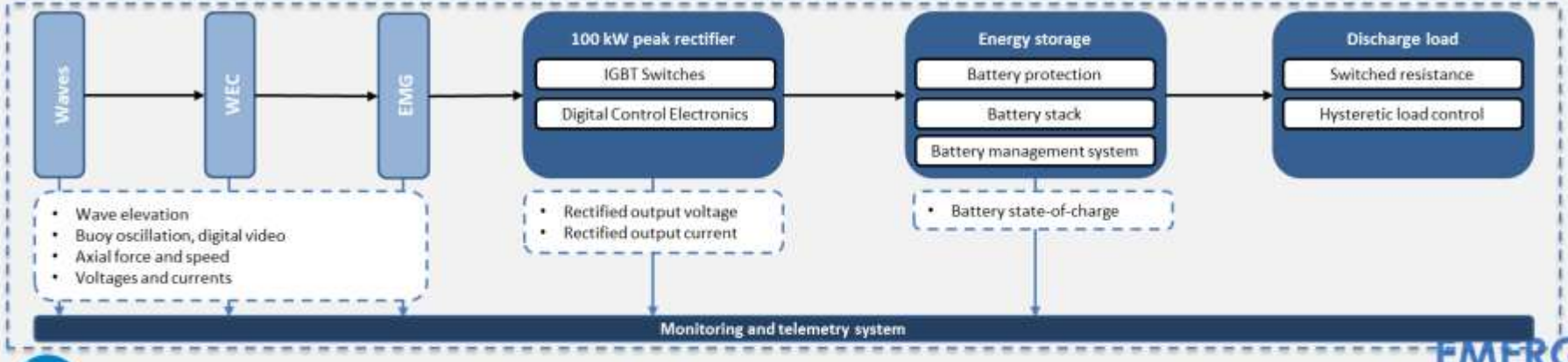
EMG prototype (WPs 2,4-6)

- **Tailored for connection to point-pivoted buoy**
  - Electrical power: 100 kW (IEC 60034-1 S6 duty 15%)
  - Axial stroke: 500 mm
  - Axial peak force: 120 kN
- **Protected against marine environment**
  - Coating or painting
  - Bellow or telescopic cylinder
- **Integrates monitoring and control system (variable damping)**



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EMERGE

«EMERGE» PROJECT *Scope of work/2*

Laboratory tests – TRL 5 to 6 (WP 7)

- Doosan Babcock facilities in Renfrew (Scotland)
- Fit-for-purpose test bench
- Hardware-in-the-loop configuration
- Tests in submerged conditions

Sea trials at Orkney Islands – TRL 6 to 7 (WPs 6,8)

- WEC fabrication
- Installation on GM700
- Sea trials

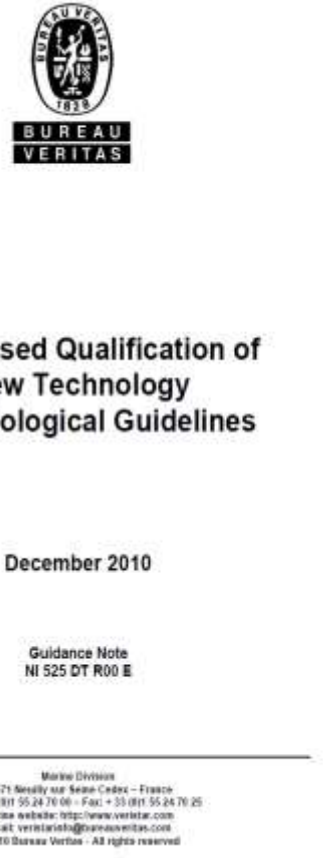
«EMERGE» PROJECT *Scope of work/3*

Techno-economical analysis (WP9)

- **Techno-economic analysis**
  - Techno-economic model for LCOE calculation
  - Techno-economic report for impact on wave energy sector
- **Roadmap for technology development**
  - Business cases
  - Commercialisation strategy

Technology qualification (WP10)

- **Technology assessment**
  - Identification of system novelty
  - FMECA workshop
  - Issue of «Statement of feasibility»
- **Review of Technology Qualification Plan**
  - Issue of «Endorsmenet of Qualification Plan»
- **Review of qualification tests**
  - Attendance of BV surveyor to tests
  - Issue of «Endorsement of Qualification Tests»



EMERGE Project

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Project summary:

GREEN MARINE · JGC · SUPPLYDESIGN · HMS · DOOSAN · SEAPOWER scrl

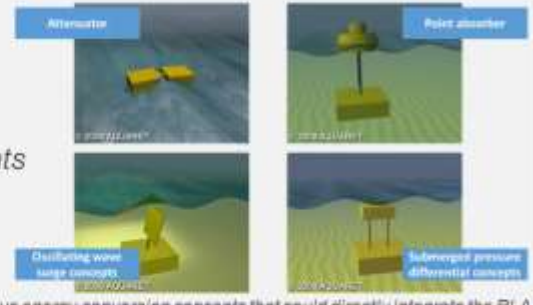
Reliable sub-contractors

Project goals:

- *Test validation and design certification for TRL7*
- *Market analysis and technology assessment*
- *High efficiency 80% avg*
- *Reliability: 20 y lifetime*


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

Future:

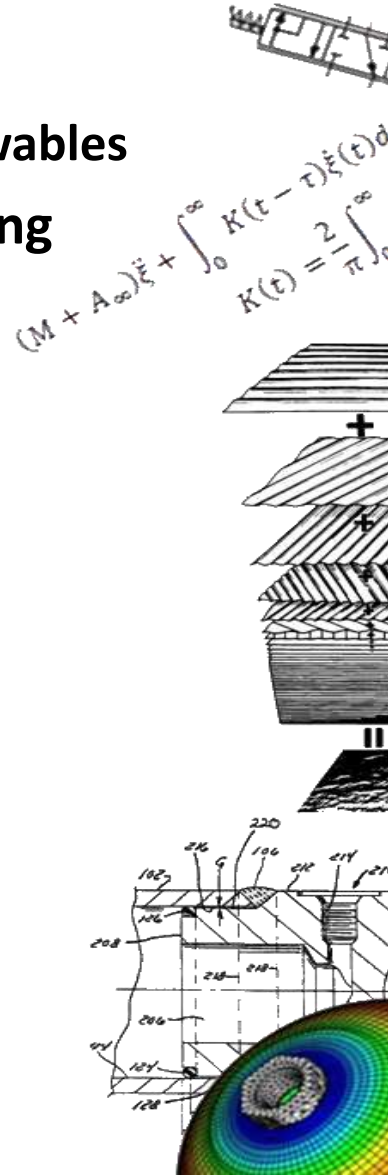

- *Ready to plug into applications*
- *Seeking WEC dev. collaboration*
- *Cooperation in Control System dev.*
- *Testing in open sea*

EMERGE

THANK YOU FOR THE ATTENTION

ARMOR – Advanced Rotational Moulding for Ocean Renewables

Wave Energy Scotland: Structural Materials and Manufacturing Process - Stage 1.



Presenters
Ronan Costello, Wave Venture Ltd

haydale
Composite Solutions

Materials and composites

WaveVenture

Hydrodynamics and simulation

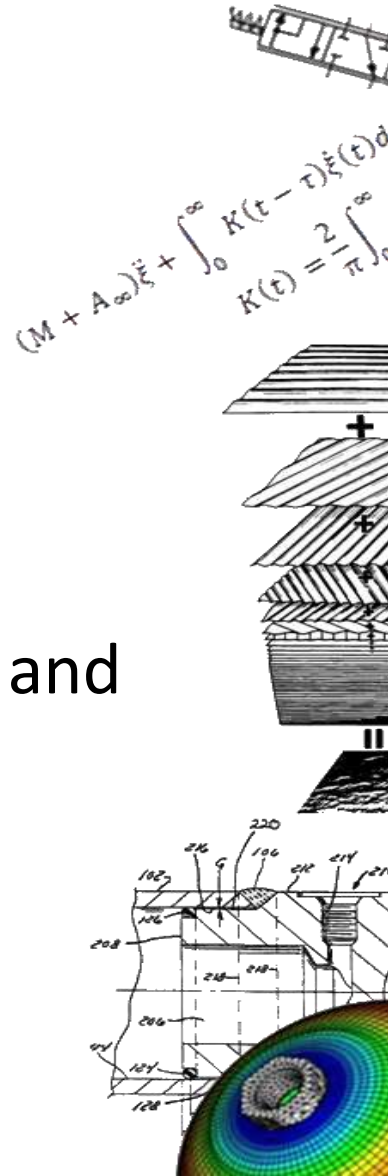
CARBON TRUST

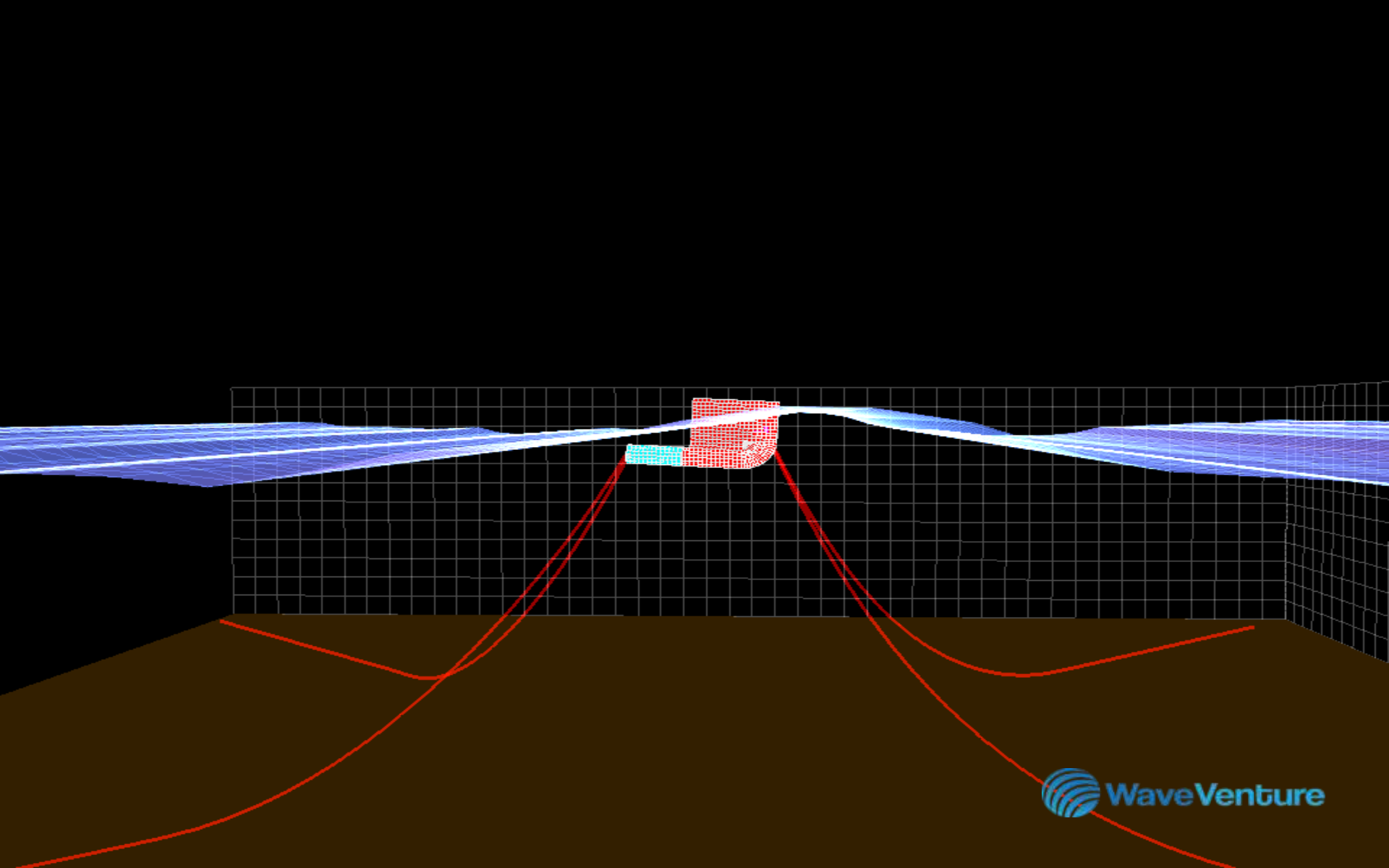
Project management and LCOE model

Crompton mouldings ltd

Manufacturing

Wave Venture




WaveVenture

HydroComp

Wave Energy Scotland: Structural Materials and Manufacturing Process - Stage 1.

CORPOWER OCEAN

WaveVenture

BALMORAL

wave energy SCOTLAND

Presenters
Ronan Costello, Wave Venture Ltd

Wave Venture

CORPOWER OCEAN

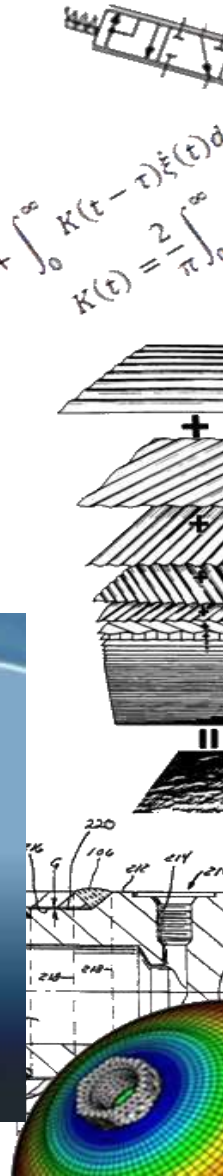
- Device design and numerical modelling

WaveVenture

- Integrated hydrodynamic and structural solver
- LCOE

BALMORAL

- Materials
- Manufacturing



Wave Venture

ARMWET – *Advanced Rotational Moulding for Wave Energy Technologies*

Wave Energy Scotland: Structural Materials and Manufacturing Process - Stage 1.

Presenters
Ben Kennedy, Wave Venture Ltd

PolyGen

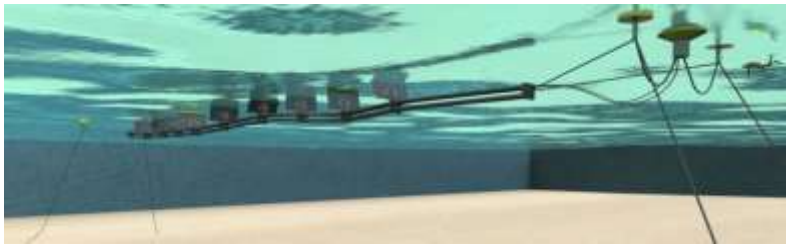
Polyethylene experts and device developer

WaveVenture

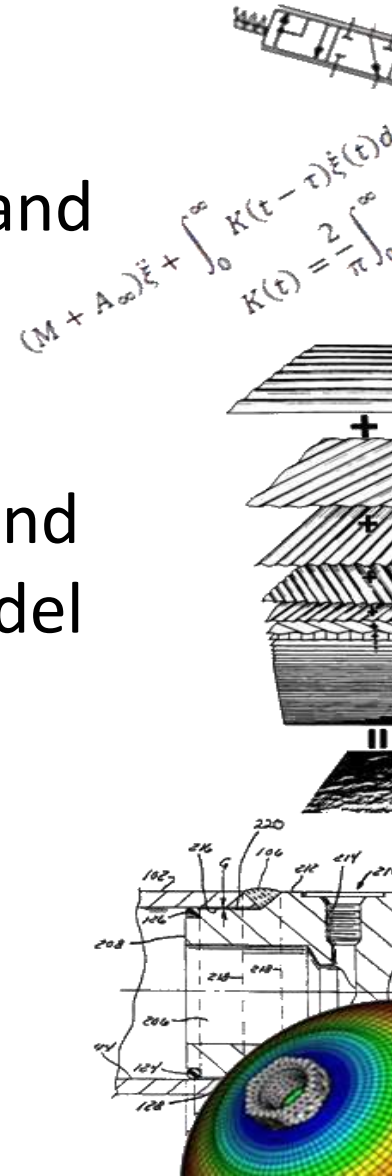
Design optimisation and techno-economic model

ROTOTEK

Manufacturing



Wave Venture



Full Sessions

Main Session Title	Presenter	Main Session	Time	Session title	Location
WES Gator PTO - Development of a Polymer Spring Pump based PTO	Conor Casey	Tuesday	14:00 - 15:20	Grid Integration, Power Take-Off & Control 5	West Wing Building, WW6
H2020 Flotec paper - Mooring Load Management for SR2000 Floating Tidal Device Using Non-Linear Polymer Components	Paul McEvoy	Wednesday	08:45 – 10:05	Station-Keeping, Moorings and Foundations 2	Kane Building, Room G01).
Development and Testing of a Ballscrew Electro-Mechanical Generator (EMG) for Wave Energy Conversion [WES PTO Stage 2 Project]	Luca Castellini, Michele Martini	Wednesday	16:00 - 17:20	Grid Integration, Power Take-Off & Control 10	West Wing Building, WW6