ETIPOCEAN

European Technology & Innovation Platform for Ocean Energy

Technology Theme Webinar

Investigating novel devices before moving towards convergence of design

23 March 2018

Agenda

Moderator	Speakers	
Shona Pennock	**Marco Fontana**	**Matthew Holland**
The University of Edinburgh	University of Trento	Wave Energy Scotland

Questions and comments from the audience

WEC Based on Dielectric Elastomers Generators Status and Future Perspectives

Marco Fontana

University of Trento, Italy

ETIPOCEAN

Investigating novel devices before moving towards convergence of design

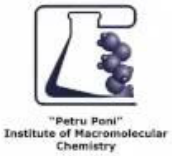
Overview

- Dielectric Elastomer Generators: how do they work?
- Research on DEG for WEC
- Main achievements
- Techno-economic considerations
- Future perspective

DEG: How do they work?

PolyWEC

polymeric wave energy converter



Why DEGs for WECs?

Motivation

- High energy density: 2-3 kJ/kg (theoretical) 0.8kJ/kg (experim.)
- Low cost: few dollars per kg (row materials)
- Cyclical operation
- High efficiency tolerant to low speed and frequencies
- Tolerant to marine environment
- Resilient/reliable
- Light weight easy to assemble

Potentially match requirements for PTO for Wave Energy Harvesting

Projects

- **PolyWEC:** Future Emerging Technology FP7, EU Project. New mechanisms and concepts for exploiting electroactive Polymers for Wave Energy Conversion.

- **WETFEET:** H2020 Energy Project, Wave Energy Transition to Future by Evolution of Engineering and Technology

- **WES St1&St2:** Wave Energy Scotland funded project on direct contact dielectric elastomer wave energy converters.

Collaborations:

WavEC Offshore Renewables (Pt) , IST Lisboa, University of Edinburgh (UK), ENEA (IT), University of Reggio Calabria (IT), Selmar (IT), Sendekia (Spain), Trellerborg (DK), INNOSEA (Fr), Teamwork Technology (DK), Plymouth University (UK), Wave Energy Scotland (UK).

Starting point

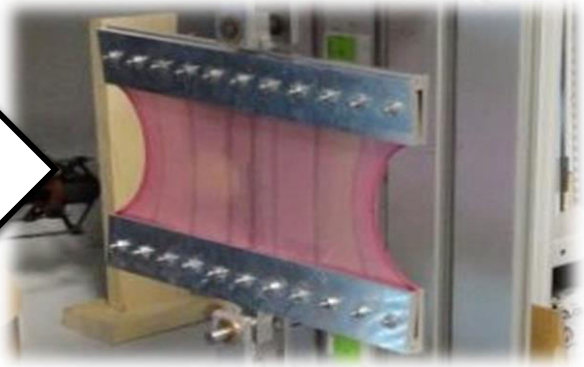
General problem

Conceive possible mechanisms to convey oscillating energy of waves into large deformation of dielectric elastomer membranes.

Wave Energy

Mechanism

Dielectric Elastomer Membrane



PolyWEC
polymeric wave energy converter

WEC Concepts

Motivation:

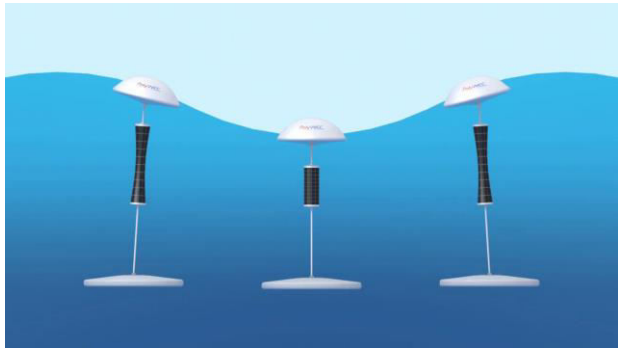
Strategies to convey oscillating energy of waves into large deformations of DE

How to model/evaluate them?

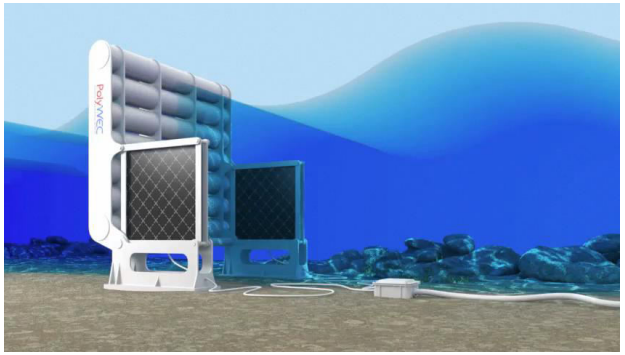
Wave-to-wire models

Hydrodynamic models borrowed from the wave-energy sector

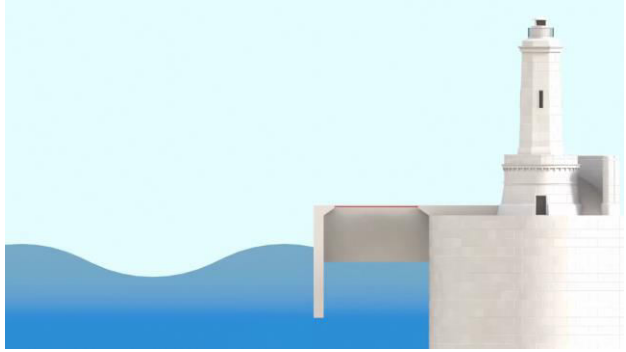
Poly-Buoy



Poly-Surge



Poly-OWC



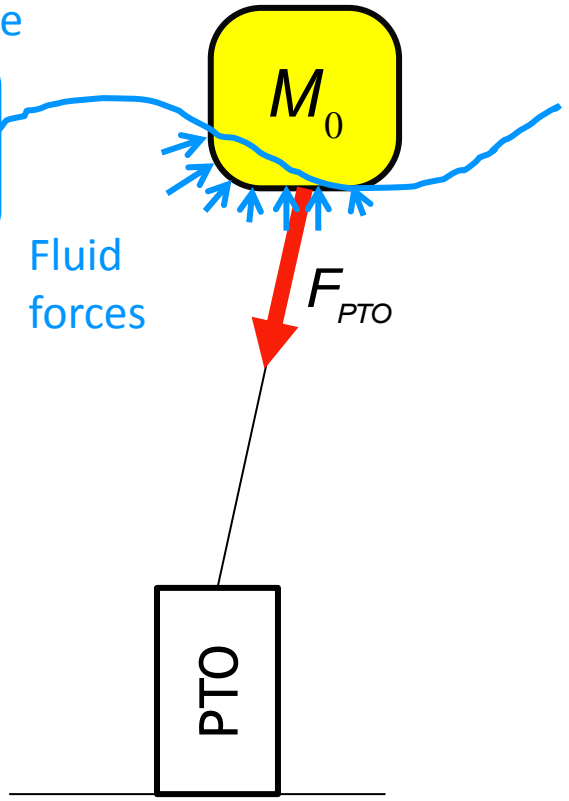
Vertechy R., **Fontana M.**, Dielectric elastomers for wave energy harvesting, *SPIE Newsletter*, May 2015. DOI: 10.1117/2.1201505.005954.

Wave Energy Converters Numerical Models

Linear Hydrodynamic model

Inertia | Radiation | Buoyancy | Generator | Wave Force

$$M_0\ddot{z} + M_\infty\ddot{z} + \int_0^t \dot{z}(\tau)K(t-\tau)d\tau + k_b z + F_{PTO}(t) = F_w(t)$$



Evaluation of energy production

P[Hs_vs_Te](%)	=<0.5 m	0.5-1 m	1-1.5 m	1.5-2 m	2-2.5 m	2.5-3 m	3-3.5 m	3.5-4 m	4-4.5 m	4.5-5 m	5-6 m	6-7 m	7-8 m	8-9 m	9-10 m	10-12 m	P[Te]
=< 4 s	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4 - 5 s	0	3	7	0	0	0	0	0	0	0	0	0	0	0	0	0	9
5 - 6 s	0	6	15	29	47	0	0	0	0	0	0	0	0	0	0	0	97
6 - 7 s	0	10	25	46	73	86	0	0	0	0	0	0	0	0	0	0	241
7 - 8 s	0	9	24	44	68	97	142	182	0	0	0	0	0	0	0	0	568
8 - 9 s	0	11	28	52	80	113	165	210	261	0	0	0	0	0	0	0	921
9 - 10 s	0	12	30	53	82	115	147	188	233	284	370	0	0	0	0	0	1513
10 - 11 s	0	11	29	52	78	110	145	171	215	266	345	345	0	0	0	0	1766
11 - 12 s	0	0	26	47	72	100	132	161	207	261	315	315	315	0	0	0	1950
12 - 13 s	0	0	22	39	60	84	110	139	175	218	290	290	290	290	0	0	2005
13 - 14 s	0	0	0	38	58	80	105	139	176	222	268	268	268	268	268	0	2157
14 - 15 s	0	0	0	0	0	78	101	126	166	205	250	250	250	250	250	0	1923
15 - 16 s	0	0	0	0	0	0	0	122	147	188	233	233	233	233	0	0	1391
16 - 17 s	0	0	0	0	0	0	0	0	0	0	0	0	219	219	0	0	439
17 - 18 s	0	0	0	0	0	0	0	0	0	0	0	0	0	0	207	0	207
18 - 19 s	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
19 - 20 s	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
20 - 21 s	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
21 - 22 s	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
> 22 s	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
P[Hs] (%)	0	61	206	399	618	863	1047	1438	1579	1644	2070	1700	1575	1260	724	0	15185

[1] Moretti G., **Fontana M.**, Vertechy R., Model-Based Design and Optimization of a Dielectric Elastomer Power Take-Off for Oscillating Wave Surge Energy Converters. Meccanica, 50 (11), 2015.

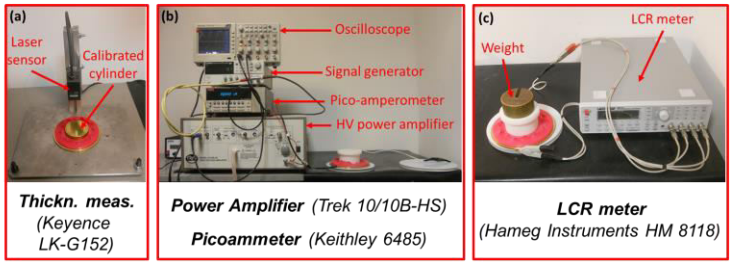
Materials Characterization

Motivation

- Identify optimal materials
- Characterize material response (analysis and design)

Methodology

- Develop a procedure for comprehensive characterization of DE

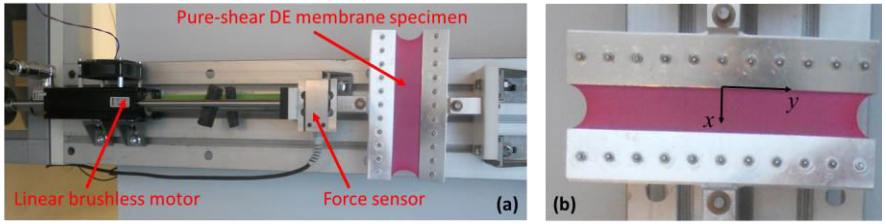


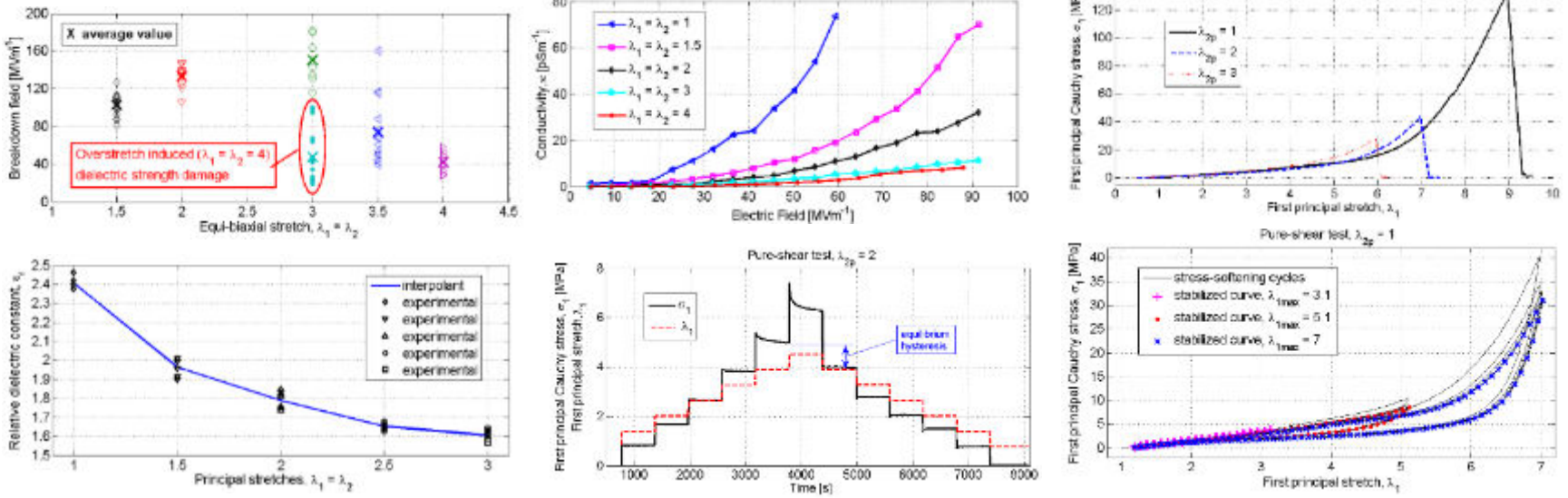
Thickn. meas. *(Keyence LK-G152)*

Power Amplifier *(Trek 10/10B-HS)*

Picoammeter *(Keithley 6485)*

LCR meter *(Hameg Instruments HM 8118)*





Vertechy R., **Fontana M.** *Proc. SPIE 9056, Electroactive Polymer Actuators and Devices (EAPAD) 2015*, (March 9, 2015).

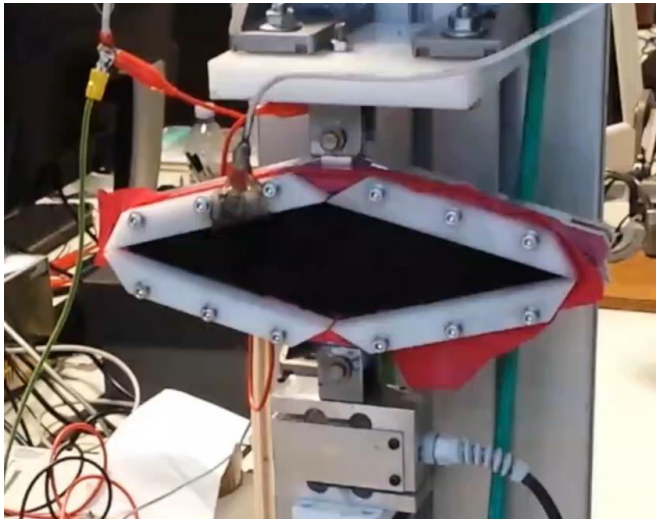
Berselli, G., Vertechy, R., **Fontana, M.**, Pellicciari, M. In *SMASIS 2014*. ASME.

Vertechy R., **Fontana M.**, Stiubianu G., Cazacu M *Proc. SPIE 9056, (EAPAD) 2014*, 90561R (March 8, 2014).

Test-bench experiments (Dry-run tests)

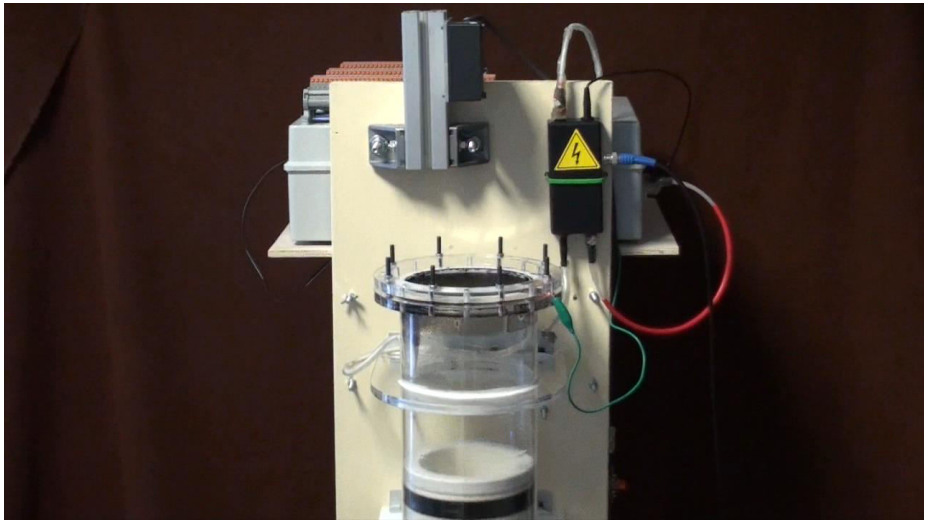
Motivation:

1. Verify the simplified (reduced) models assumed for the DEG against experimental measures;
2. Implement in laboratory set-up simulation of the controller through Hardware in the loop (HIL) simulations;



Poly-Surge test bench:

- DE: OPPO Band Red 8012 (NR)
- Electrodes: Carbon grease



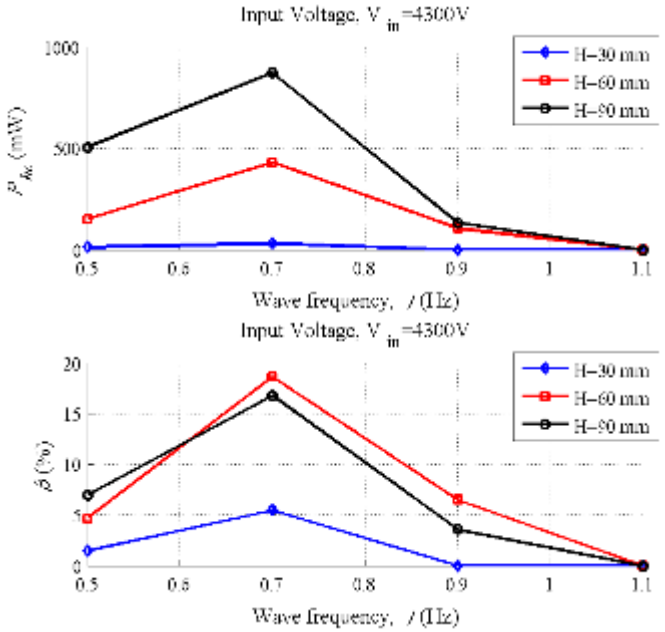
Poly-OWC test bench:

- DE: VHB Acrylic (NR)
- Electrodes: Carbon grease

[1] Moretti G., Vertechy R., **Fontana M.**, Parallelogram-shaped dielectric elastomer generators: analytical model and experimental validation Journal of Intelligent Material Systems and Structures, 26, 2015.

[2] Moretti G., Papini Rosati G.P., Vertechy R. , **Fontana M.**; Hardware in the loop simulation of a dielectric elastomer generator for oscillating water column wave energy converters, in Proceedings of OCEANS 2015 - Genova, 18-21 May 2015

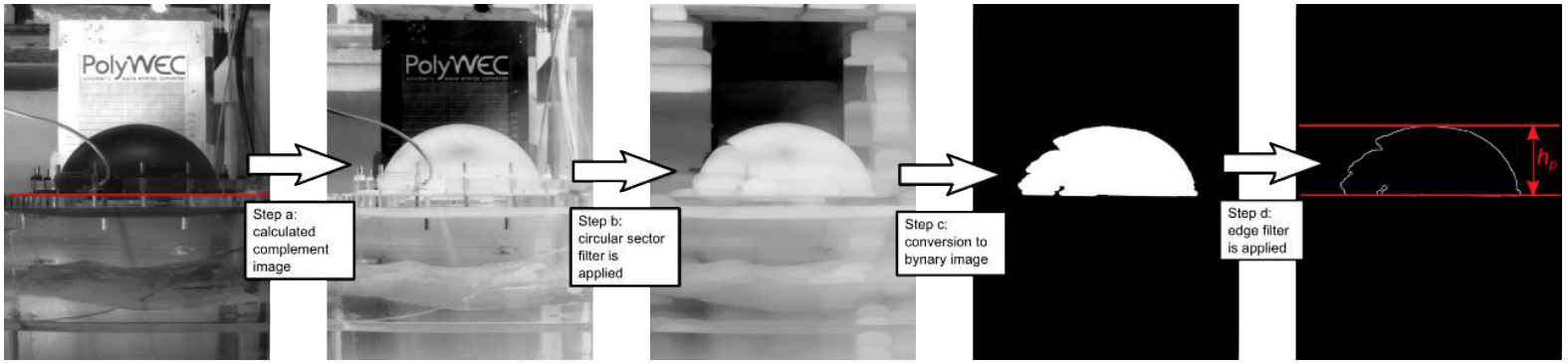
Poly-OWC Wave-flume



Max Power: 0.9W (*H*=4.5cm *f*=0.7Hz)

Energy density: 110J/kg (w-t-w eff.: 20%)

full-scale equiv: >300kW (*H*=1.8m *T*=9s)



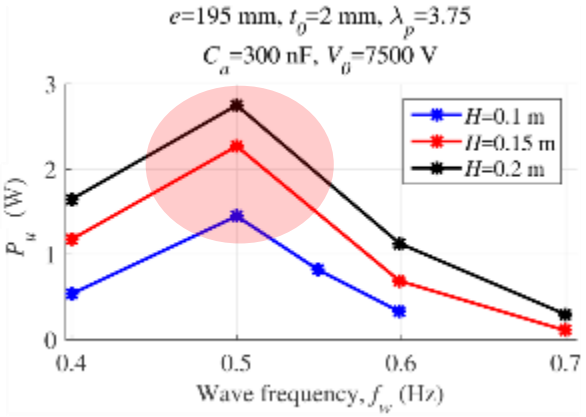
[1 Moretti, G., M.Righi, Forehand D. **Fontana M.** Wave tank tests of a wave energy converter based on dielectric elastomer generators (submitted).

Poly-OWC Flowave Tank

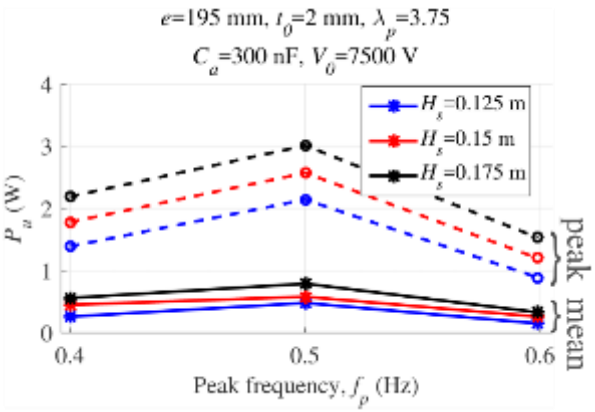
Scale 1:15 / 1:25

- 2 W average
- 3.7W peak ouput (300-600kW in real scale)

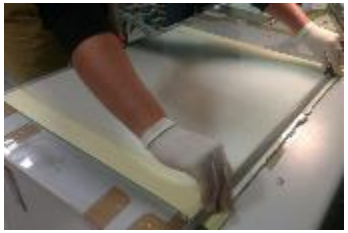
Regular Wvaes

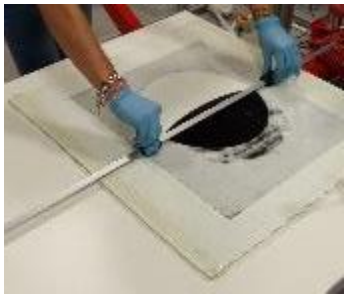


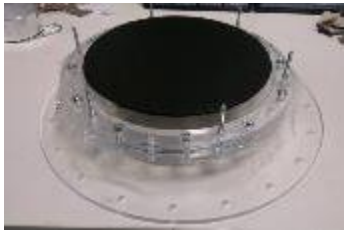
Irregular Waves

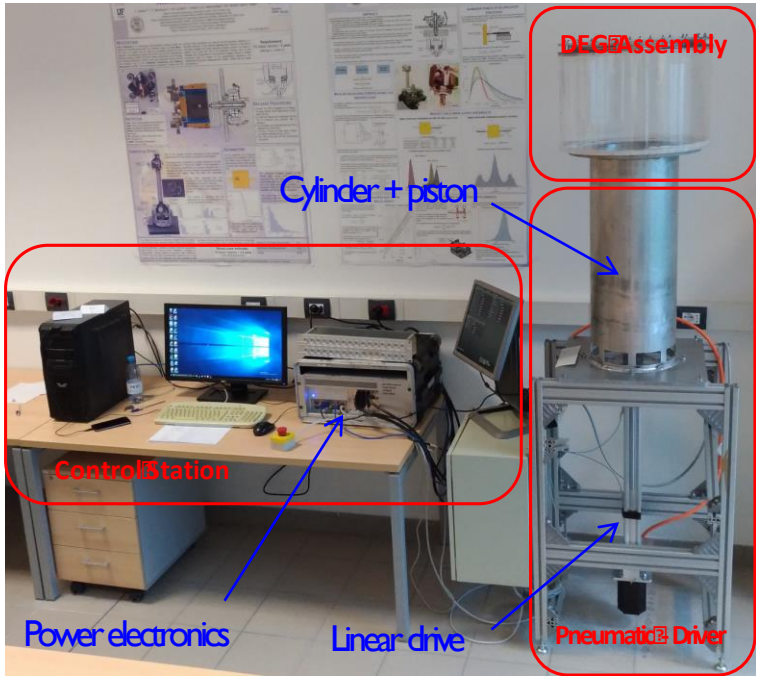


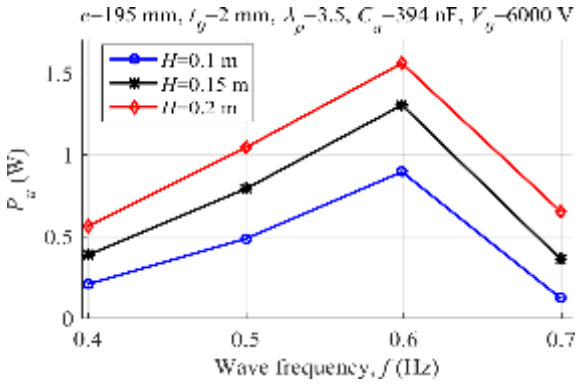
Manufacturing and HIL tests



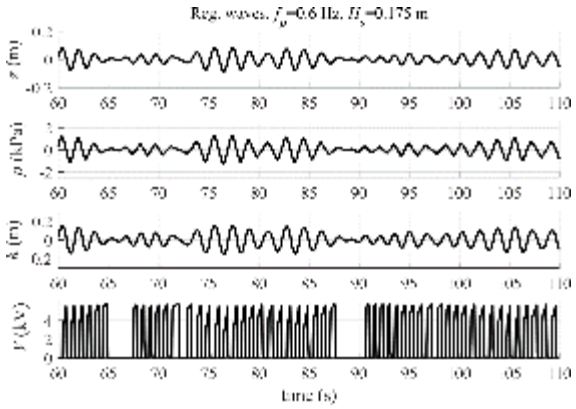




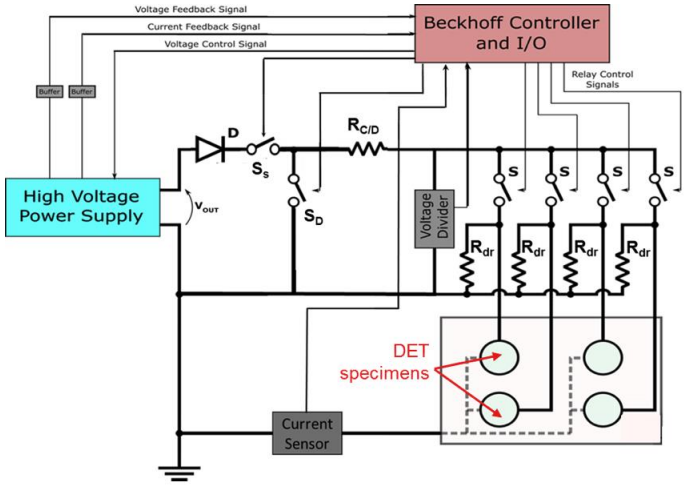


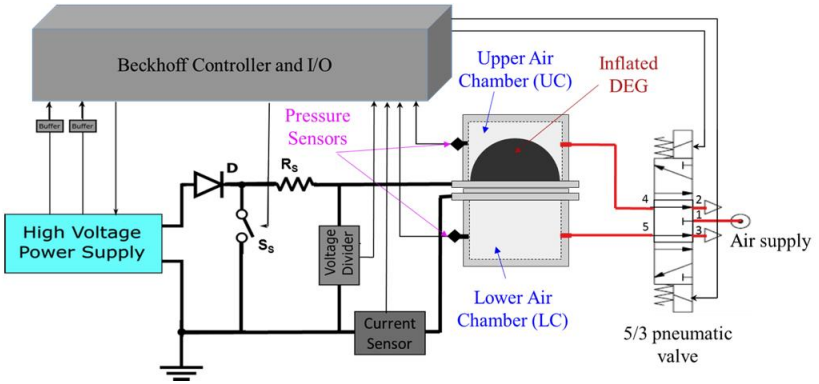


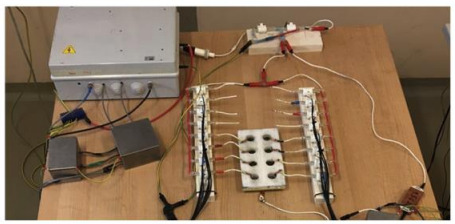
Irregular

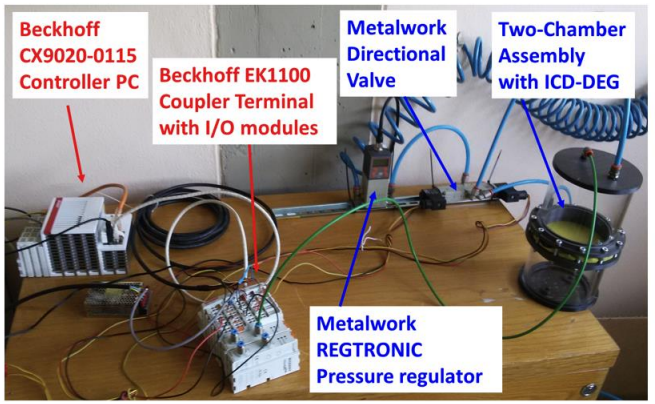


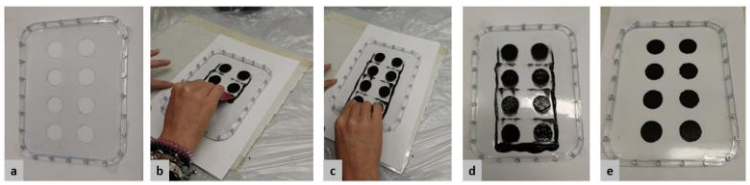
Long term characterization



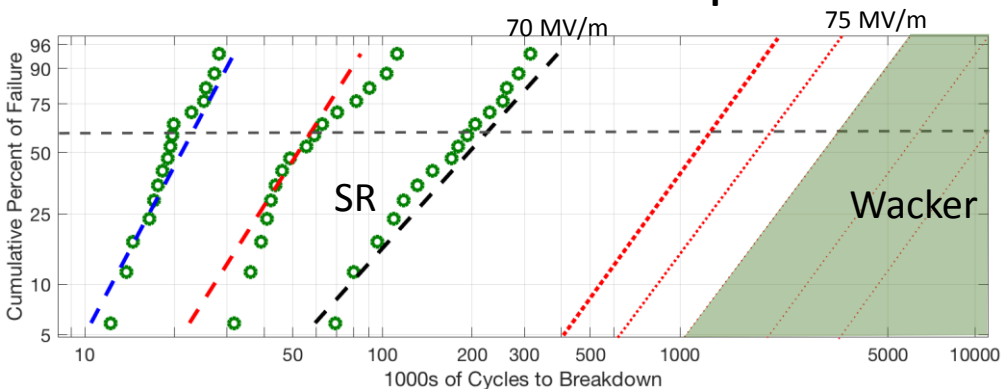






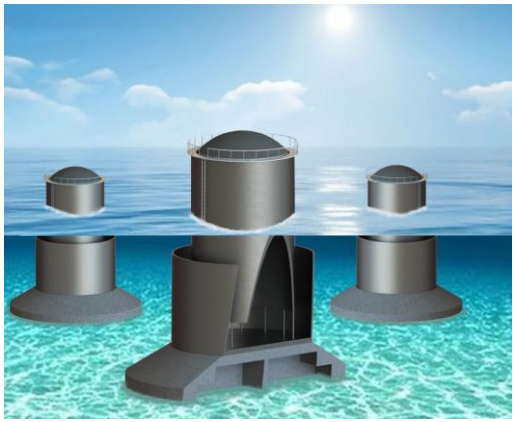


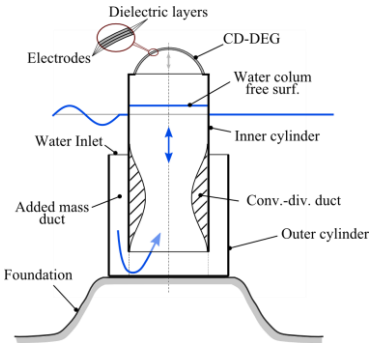
Different materials comparison

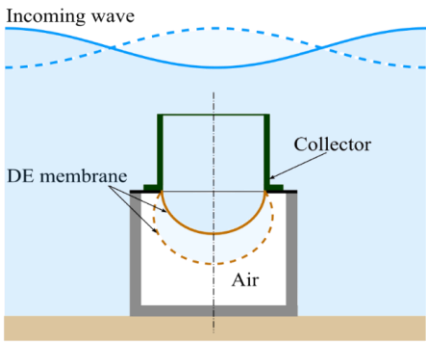


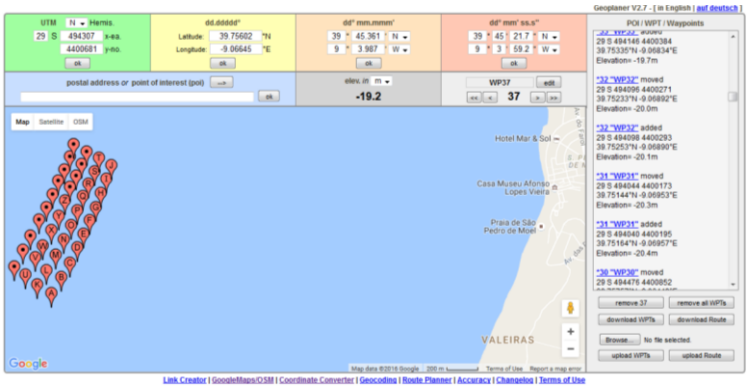
Techno Economic Analysis

- **Analysis**
  - Devices: different type and arrangements
  - Scales: form 150-500kW per unit
  - Wave climate
- **Main outcomes:**
  - Huge reduction in the PTO costs;
  - Capex costs reduced
  - Promising LCOE
- **Uncertainties:**
  - Long term duration (preliminary promising results)
  - Manufacturing process







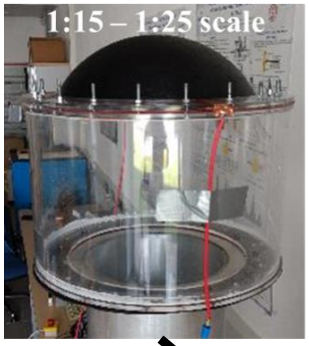


Future perspective

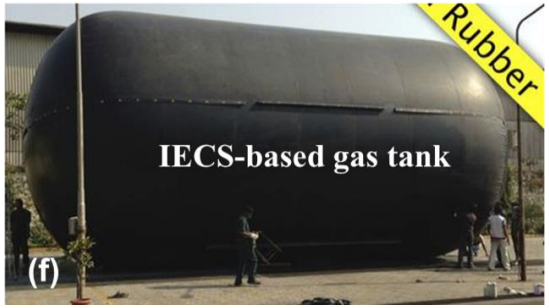
Fully elastomeric WEC

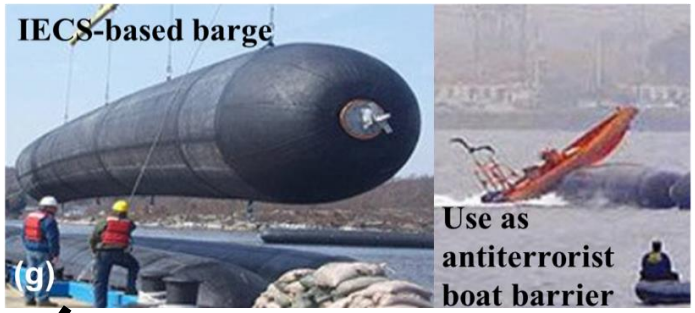
Combination of DEG-PTO with collectors made of low-cost elastomeric composite components.

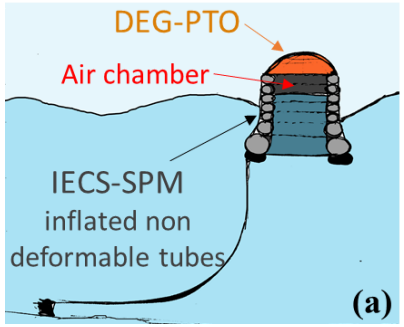
DEG PTO

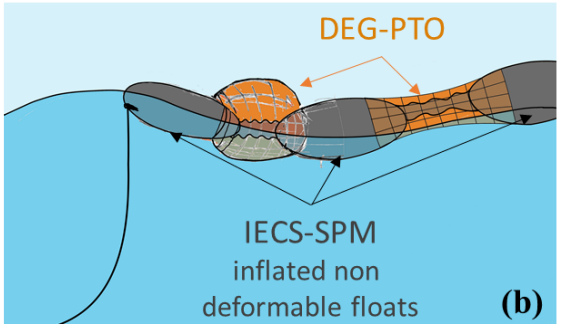


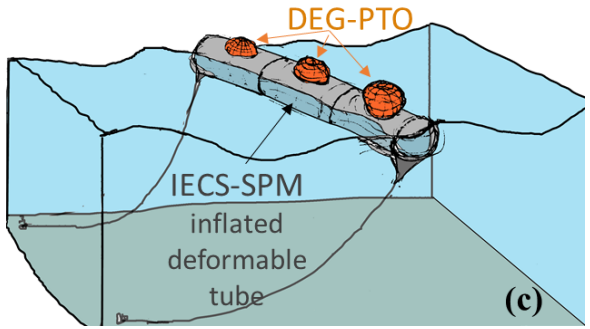
Composite Elastomeric Collectors











Conclusions

- DEG based WEC investigation
- Validation of the feasibility
- Summary of results
- Convergence toward a new device
- Future
  - Fully elastomeric WEC
  - Spin-out company
  - Investments on smaller scale application

Acknowledgement:

Univ. of Bologna, Unv. Of Edinburgh, WavEC, PPIMC, Scuola Superiore Sant'Anna, Univ. of Reggio Calabria

Thank you! Questions ?

More info

e-mail: marco.fontana-2@unitn.it

Preliminary sea-trials at University of Reggio Calabria

Novel Wave Energy Converter Programme

Matthew Holland

ETIP Webinar
23rd March 2018

Overview

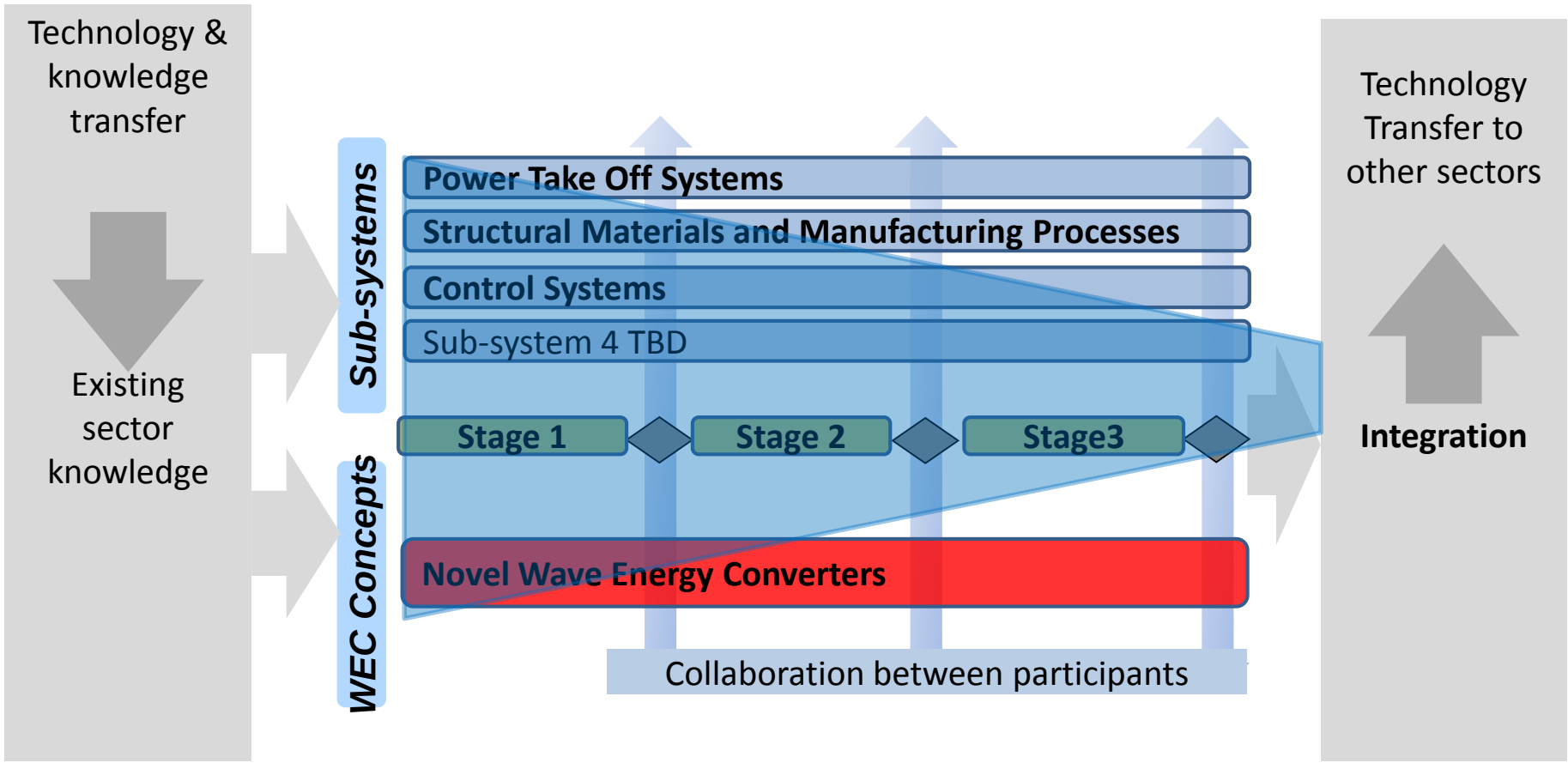
- WES development programmes
- Novel WEC objectives
- Case Study – Novel WEC convergence
- Next steps

WES Programme

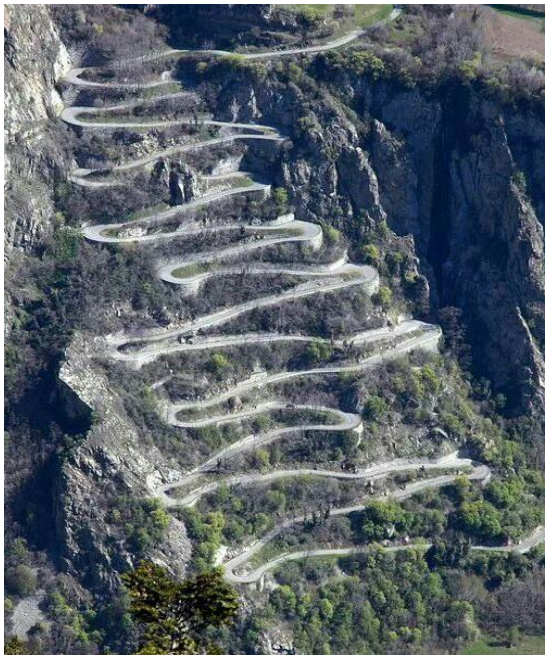
- How is WES encouraging technical convergence?

- Structured development programme based on sector experience and learning
  - Programme entry open to all
  - Awards to only most techno-economically promising
  - 100% funding
  - Most promising technologies successful at stage gates
  - Promote use of industry best practice – IEC, commercial guidelines/standards, etc

WES Activities



Novel WEC Programme



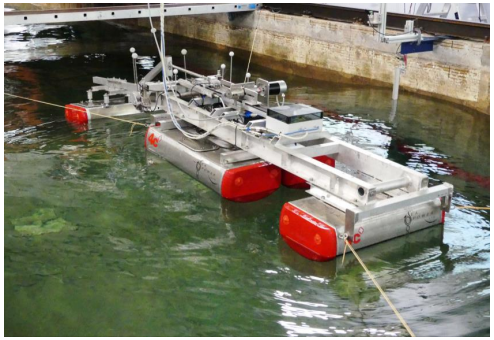
- Objectives:
  - Support the development of prime mover technologies which will have significant impact
  - Address technical risks and challenges
  - Understand device "–ilities"
  - Build on industry learning to date
  - Integrate representative subsystems
  - Testing at an appropriate scale in representative environment in 3-5 years

…leading to…

  - Step change in Levelised Cost of Energy (LCOE) – goal <£150/MWh
  - Affordable, targeted de-risking prior to FOAK full-scale

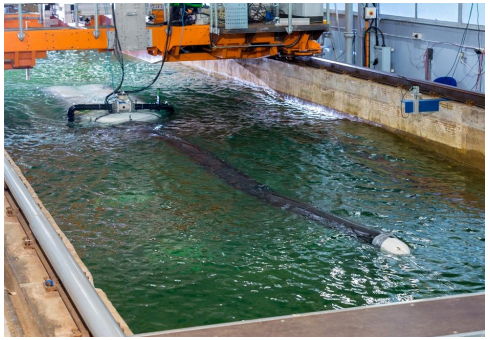
Novel WEC Stage 1 Participants

4CE - Attenuator

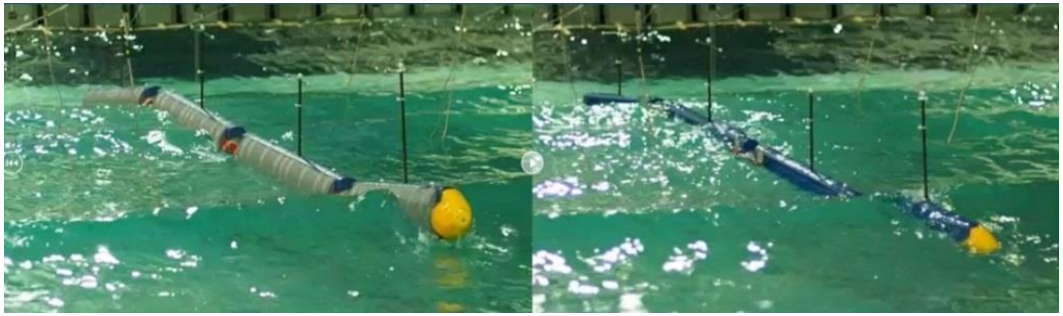


Albatern – Point Absorber/Attenuator

Checkmate – Bulge Wave

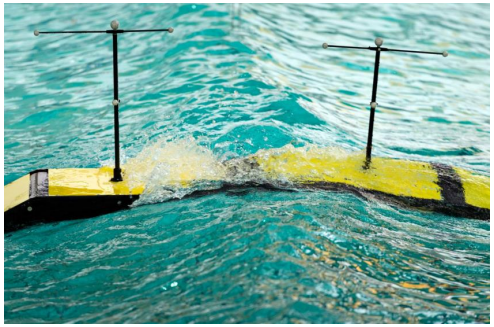


Quoceant – Multi-body Attenuator with Inflatable Volume



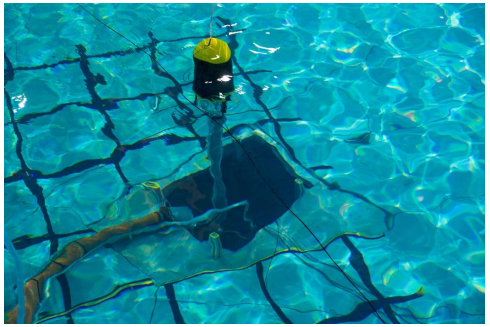
Zyba – Floating Surge Converter

Mocean - Attenuator



Joules – Floating OWC

AWS – Submerged Pressure Differential



Novel WEC Programme Pathway

wave energy SCOTLAND

Research Needs

Engineering Needs

Commercial Needs

TRL 1-2	TRL 1-3	TRL 4	TRL 5-6	TRL 7-8
Concept Creation & Feasibility Work	**Stage 1** Concept Characterisation & Refinement	**Stage 2** Concept Optimisation & Demonstration of Engineering Specification	**Stage 3** Small Prototype Development	Large Prototype Demonstration
	• Idea and design development • Analytical studies and numerical modelling • Small scale tank testing • System simulation and optimisation • Concept engineering • Costing and LCOE/related metrics	• Concept refinement • Technology optimisation • Control system design • FEED study • Large scale tank testing • Numerical model validation • LCOE calculation • Subsystem testing • Small prototype design	• Refined system • Design and fabrication understood • Large open water model developed • Fully operational system with integrated sub-systems • Performance proven for full system • Certification of system • Full scale system design	

Stage Gate / Technical Milestone / Defined Performance

Novel WEC Testing

- Evolution of testing objectives:
  - Stage 1 – Performance baseline
  - Stage 2 – Optimisation/comparison
  - Stage 3 – Validation of modelling

- Why do mandatory testing?
  - Standardised conditions give comparable results
  - Compliant with best practice
  - Appropriate for stage of device development
  - Representative of generic Scottish wave climate
  - High % of power matrix covered
  - Comparative conditions to US Wave Energy Prize

- Testing validated and observed

Stage Gates

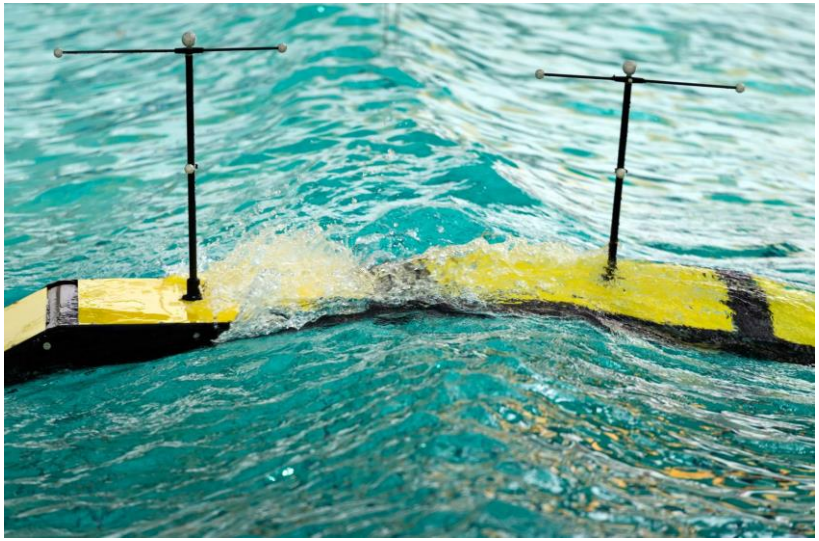
- Process of selecting which technologies continue in the programme
  - Consistent technical assessment
  - Engineering design reviews
    - Stage 1 – 3rd Party Verification of testing
    - Stage 2 – Third Party Appraisals
    - Stage 3 – Third Party Appraisals and Certification
  - Application form – proposed scope for next stage
- *"Survival of the fittest"*

Novel WEC Stage 2 Participants

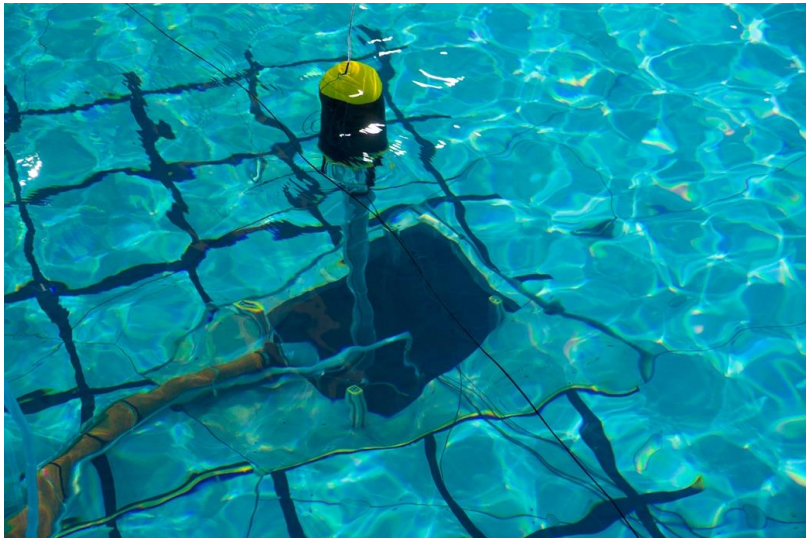
4CE - Attenuator

Checkmate – Bulge Wave

Mocean - Attenuator



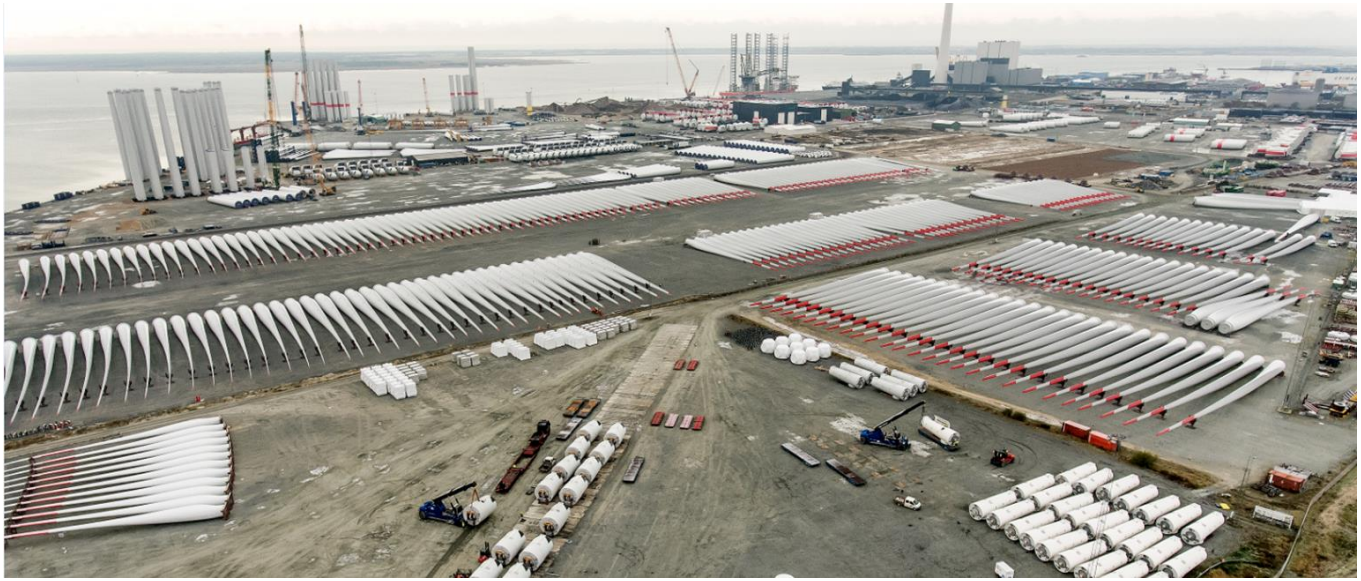
AWS – Submerged Pressure Differential



What happens now?

- NWEC Stage 3 transition – Q4 2018
  - Programme convergence
  - Systems integration
  - Recognition of system/subsystem requirements

- Long term goal – commercial-scale markets



https://www.offshorewind.biz/wp-content/uploads/2016/11/photo-of-the-day-port-of-esbjerg-displays-offshore-wind-bounty-768x326.jpg

Questions?

matthew.holland@hient.co.uk

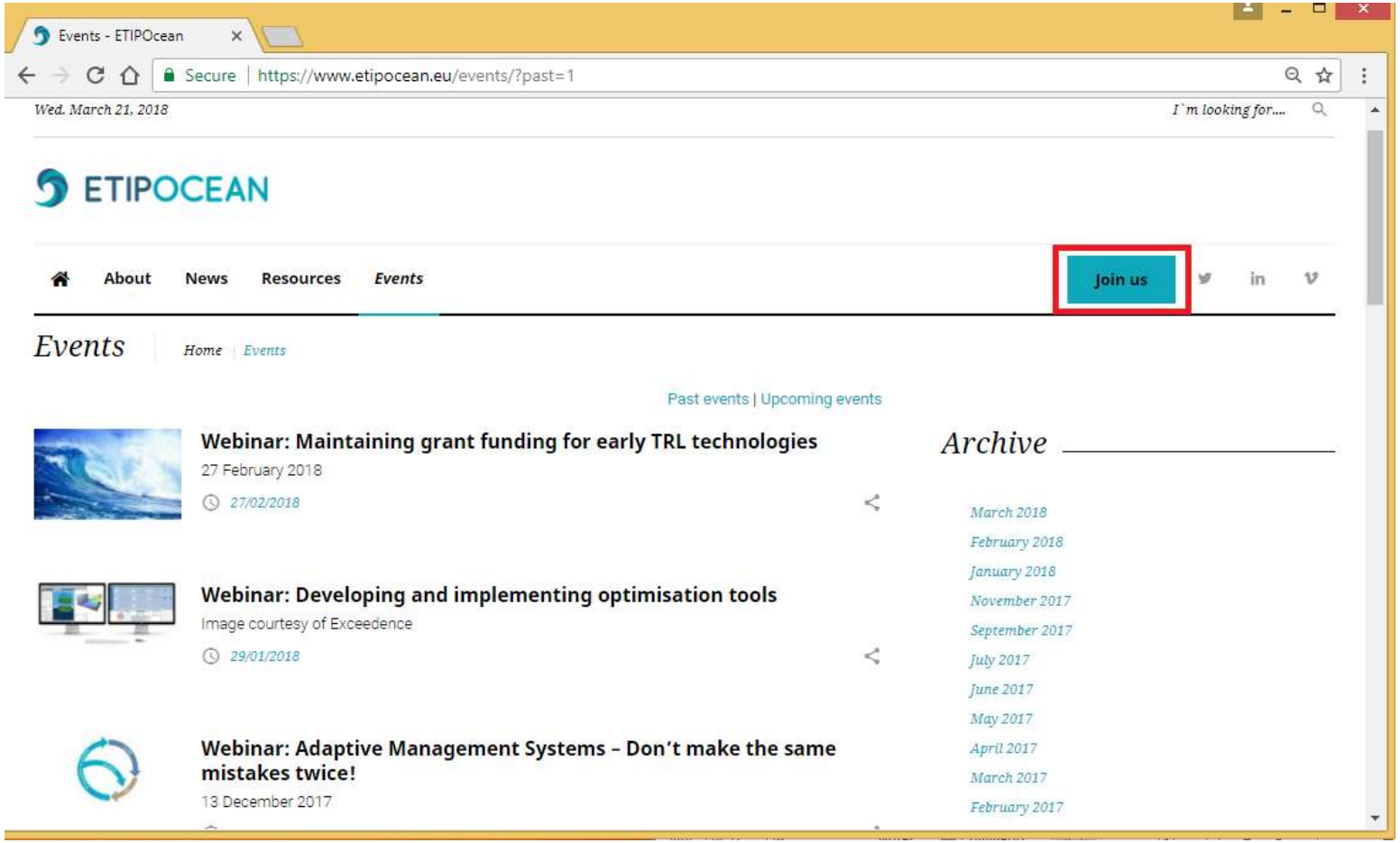
library.waveenergyscotland.co.uk

Technology Theme Webinar

Investigating novel devices before moving towards convergence of design

23 March 2018

ETIP mailing list



Staying in Touch

www.etipocean.eu

info@etipocean.eu

@etipocean

https://www.linkedin.com/in/etip-ocean-316262133/

https://vimeo.com/channels/1210250