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Coastlab

Technology Readiness Level approach for the development of WECs

	Phase 1 Validation model (lab.)			Phase 2 Design model (lab.)	Phase 3 Process model	Phase 4 Prototype	Phase 5 Demonstration
	Concept	Performance	Optimization		Sea trials		
Primary scale (λ)	λ = 1 : 25 – 100 (∴ $λ_t$ = 1 : 5–10)			λ = 1 : 10–25	λ = 1 : 3–10	λ = 1 : 1–2	λ = Full size
Tank	2D flume and 3D basin			3D basin	Benign site	Exposed site	Open location
Duration (inc. analysis)	1–3 weeks	1–3 months	1–3 months	6–12 months	6–18 months	12–36 months	1–5 years
Typical no. tests	50–500	250–500	100–250	100–250	50–250	Continuous	Statistical sample
Budget (€,000)	1–5	25–75	25–50	50–250	1,000–2,500	5,000–10,000	2,500–7,500
Excitation/Waves	Monochromatic linear waves (10–25 Δf) Panchromatic 5 reference	Panchromatic waves (20 min full scale) +15 classical spectra long crested head seas		Deployment: pilot site sea spectra Long & short crested classical seas Select mean wave approach angle	Extended test period to ensure all seaways included	Full scatter diagram for initial evaluation, continuous thereafter	

Dr Valentin Heller

Fluid Mechanics Section, Department of Civil and Environmental Engineering

4th CoastLab Teaching School, Wave and Tidal Energy, Porto, 17-20th January 2012

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Content

- Introduction
- Overview TRL approach
- Funding
- Phases 1-3 in laboratory
- Phases 3-5 at sea
- Conclusions

Lecture gives overview of TRL approach and covers some selected to-pics of wave energy conversion at various levels following Heller (2012)

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Introduction

What is a Technology Readiness Level TRL?

The *TRL approach* was established by the US space agency NASA and is now widely used by many engineering research establishments to describe the advancement in the development of a technology

The TRL approach was proposed to provide a structured 5 main test phase programme to develop buoyant type wave energy converters by HMRC (2003) with the aim to mitigate technical and fiscal risk

This 5 phase structured programme is now adopted in many publications (e.g. Holmes 2009, IEE 2009, Heller 2012)

Even though the TRL approach is restricted to buoyant type WECs, it may provide a good base to classify the advancement of all WEC devices

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Overview TRL approach

Overview 5 test phases of TRL for WECs

	Phase 1 *Validation model (lab.)*			Phase 2 *Design model (lab.)*	Phase 3 *Process model*	Phase 4 *Prototype*	Phase 5 *Demonstration*
	Concept	*Performance*	*Optimization*		*Sea trials*		
Primary scale (λ)	$\lambda = 1:25 - 100$ ($\therefore \lambda_f = 1:5$–$10$)			$\lambda = 1:10$–25	$\lambda = 1:3$–10	$\lambda = 1:1$–2	λ = Full size
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Short version from Holmes (2009), for long version see HMRC (2003)

- Some devices may be able to exclude a phase
- Some devices had to go back to a lower phase (expensive and time consuming)
- It addresses technical aspects and excludes others such as resource investigation etc.

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Overview TRL approach

Phase 1

	Phase 1 Validation model (lab.)			Phase 2 Design model (lab.)	Phase 3 Process model	Phase 4 Prototype	Phase 5 Demonstration
	Concept	*Performance*	*Optimization*		*Sea trials*		
Primary scale (λ)	$\lambda = 1:25 - 100$ ($\therefore \lambda_t = 1:5–10$)			$\lambda = 1:10–25$	$\lambda = 1:3–10$	$\lambda = 1:1–2$	λ = Full size
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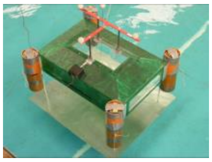

Oceanlinx, Laboratory HMRC, Ireland

Validation model

- Initial proof of concept at scale 1:25-100
- Simple idealised models with model PTO tested in regular waves (*concept*)
- Performance and response are then tested in irregular waves (generic spectra, *performance*) and optimised with parameter variations (*optimisation*)
- Development of mathematical models

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Overview TRL approach

Phase 2

	Phase 1 Validation model (lab.)			Phase 2 Design model (lab.)	Phase 3 Process model	Phase 4 Prototype	Phase 5 Demonstration
	Concept	*Performance*	*Optimization*		*Sea trials*		
Primary scale (λ)	$\lambda = 1:25 - 100$ ($\therefore \lambda_t = 1:5–10$)			$\lambda = 1:10–25$	$\lambda = 1:3–10$	$\lambda = 1:1–2$	λ = Full size
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Manchester Bobber Laboratory, Manchester

Design model

- New/modified model at 1:10-25 with extended measurement array
- Larger set of physical parameters measured with more realistic PTO
- Tests in short-crested seas and different wave propagation directions (validate moorings) and early survival tests (extreme motions and loadings)
- Bench testing of PTO system can also begin

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Overview TRL approach

Phase 3

	Phase 1 *Validation model (lab.)*			Phase 2 *Design model (lab.)*	Phase 3 *Process model*	Phase 4 *Prototype*	Phase 5 *Demonstration*
	Concept	*Performance*	*Optimization*		*Sea trials*		
Primary scale (λ)	$\lambda = 1:25 - 100$ ($\therefore \lambda_t = 1:5\text{–}10$)			$\lambda = 1:10\text{–}25$	$\lambda = 1:3\text{–}10$	$\lambda = 1:1\text{–}2$	λ = Full size
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WaveBob, benign site
Galway Bay, Ireland

Process model

- Bridges end of laboratory tests and beginning of sea trials at a benign site
- Tests either in large wave basin or at benign site
- Scale 1:3-10 enables actual components (PTO, mooring) to be included
- Tests in specific seasons at outdoor site (scaled wave conditions, safety)
- Extended PTO bench testing should be considered
- Mathematical predictions should move from frequency into time domain modelling

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Overview TRL approach

Phase 4

	Phase 1 *Validation model (lab.)*			Phase 2 *Design model (lab.)*	Phase 3 *Process model*	Phase 4 *Prototype*	Phase 5 *Demonstration*
	Concept	*Performance*	*Optimization*		*Sea trials*		
Primary scale (λ)	$\lambda = 1:25 - 100$ ($\therefore \lambda_t = 1:5\text{–}10$)			$\lambda = 1:10\text{–}25$	$\lambda = 1:3\text{–}10$	$\lambda = 1:1\text{–}2$	λ = Full size
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Archimedes Wave Swing
Aguçadoura, Portugal

Prototype device

- By now, realistic performance data should be available, together with accurate manufacturing and construction costs
- Scale 1:1-2
- All operation components must be (scaled) units of final components
- Tests do not have to take place in the actual array site
- Grid connection not essential at beginning, but should be considered towards the end

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Overview TRL approach

Phase 5

	Phase 1 Validation model (lab.)			Phase 2 Design model (lab.)	Phase 3 Process model	Phase 4 Prototype	Phase 5 Demonstration
	Concept	Performance	Optimization		Sea trials		
Primary scale (λ)	$\lambda = 1:25 - 100$ ($\therefore \lambda_t = 1:5\text{–}10$)			λ = 1 : 10–25	λ = 1 : 3–10	λ = 1 : 1–2	λ = Full size
Tank	2D flume and 3D basin			3D basin	Benign site	Exposed site	Open location
Duration (inc. analysis)	1–3 weeks	1–3 months	1–3 months	6–12 months	6–18 months	12–36 months	1–5 years
Typical no. tests	50–500	250–500	100–250	100–250	50–250	Continuous	Statistical sample
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Pelamis array
Aguçadoura, Portugal

Demonstration device

- Full-size WEC is built or relocated to projected WEC park
- Grid connection and electricity sale must be part of the package
- Tests with isolated device possible, but better a small array configuration (economic reasons)

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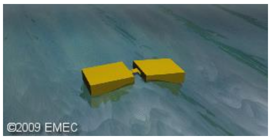
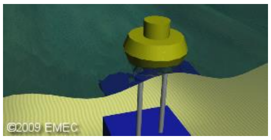
Overview TRL approach

WEC classification of European Marine Energy Centre EMEC, Scotland

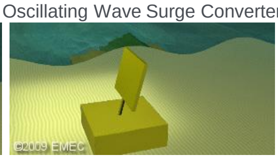
Attenuator



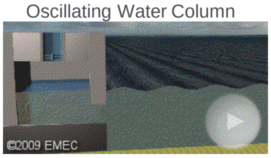
Point Absorber



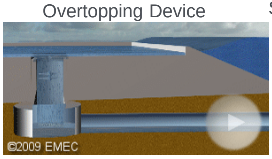
Oscillating Wave Surge Converter



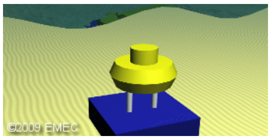
Oscillating Water Column



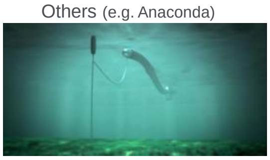
Overtopping Device



Submerged Pressure Differential



Others (e.g. Anaconda)



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Overview TRL approach

Some WECs as a function of classification of EMEC and highest reached TRL by early 2010 (some devices moved to other phase by now)

	Attenuator	Point absorber	Osc. wave surge conv.	Osc. water column	Overtopping device	Sub. pressure differential	Other
Phase 5	Pelamis						
Phase 4		Direct Drive Linear Generator	Oyster WaveRoller	LIMPET/Pico Oceanlinx*	WavePlane	AWS*	
Phase 3	Oceantec Energy Converter	AquaBuOY Ceto DECM FO^3/B1 PowerBuoy SeaDog Pump Waveberg* Wavebob Wave Star WET EnGen	Poseidon	MRC OE Buoy Sperboy*	SSG Wave Dragon		Wave Rotor
Phase 2		Manchester Bobber					Grampus*
Phase 1	Ocean Treader	Multi Cell Platform	Langlee System BioWave			WECA	Anaconda

- Only Pelamis (and Mutriku by now) in phase 5
- Large variety of device concepts in phase 4
- Many point absorbers are in phase 3
- Some devices (*) are at lower phase than shown

Heller (2010)

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Overview TRL approach

Some WECs as a function of the developers country and their highest reached TRL by early 2010 (some devices moved to other phase by now)

	UK	Denmark	Australia	USA	Norway	Canada	Ireland	Spain	Others
Phase 5	Pelamis								
Phase 4	AWS* LIMPET Oyster	WavePlane	Oceanlinx*						Direct Drive Linear Gen. Pico WaveRoller
Phase 3	DECM MRC Sperboy*	Poseidon Wave Dragon Wave Star	Ceto	PowerBuoy SeaDog Pump Waveberg*	FO^3/B1 SSG	AquaBuOY WET EnGen	OE Buoy Wavebob	Oceantec Energy Con.	Wave Rotor
Phase 2	Grampus* Manchester Bobber								
Phase 1	Anaconda Ocean Treader		BioWave		Langlee System			Multi Cell Platform	WECA

Heller (2010)

- Others includes Sweden, Portugal, Finland, The Netherlands and Greece
- UK is leading WEC developer followed by Denmark
- Developer's reaching phase 3 originate from many countries (global activity)

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Funding

Funding opportunities with focus on the UK

<table>
<tr><th></th><th>Phase 1</th><th>Phase 2</th><th>Phase 3</th><th>Phase 4</th><th>Phase 5</th></tr>
<tr><td>Duration (months)</td><td>2¼-7[1]
3-9[2]</td><td>6-12[1,2]</td><td>6-18[1]
6-36[2]</td><td>12-36[1]
24-36[2]</td><td>12-60[1]
24-60[2]</td></tr>
<tr><td>Cost (€,000)</td><td>51-130[1]
5-125[2]</td><td>50-250[1,2]</td><td>1,000-2,500[1]
500-2,500[2]</td><td>5,000-10,000[1]
5,000-15,000[2]</td><td>2,500-7,500[1]</td></tr>
<tr><td>Funding (%)</td><td>100-50[2]</td><td>100-50[2]</td><td>75-50[2]</td><td>75-25[2]</td><td>0[2]</td></tr>
<tr><td>Grant type</td><td>Capital[2]</td><td>Capital[2]</td><td>Capital[2]</td><td>Capital and feed-in tariff[2]</td><td>Investment and feed-in tariff[2]</td></tr>
<tr><td rowspan="6">Public sector support</td><td colspan="4">EPSRC</td><td></td></tr>
<tr><td colspan="3">Carbon Trust (Marine Energy Accelerator, £3.5m)</td><td>MRPF (£22m)</td><td>MRDF (£42m)</td></tr>
<tr><td colspan="3">Technology Strategy Board (historically, × £100K)</td><td colspan="2">Technology Strategy Board (£2.5m)</td></tr>
<tr><td colspan="3"></td><td colspan="2">Energy Technology Institute (× £10m)</td></tr>
<tr><td></td><td colspan="4">European Commission</td></tr>
<tr><td colspan="3"></td><td colspan="2">The Saltire Price (£10m)</td></tr>
<tr><td>Private sector support</td><td></td><td></td><td></td><td>Strategic investors</td><td>Strategic investors & project finance</td></tr>
</table>

[1] Holmes (2009) [2] IEE (2009)

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Funding

Funding sources

- **EPSRC (Engineering and Physical Sciences Research Council)**: EPSRC with partners fund research into marine energy mainly through the SuperGen Marine consortium and is an important funding source for academia
- **Carbon Trust**: It seeks to accelerate the move to a low-carbon economy (reduction of emissions, development of low-carbon technologies) and is running a £3.5m Marine Energy Accelerator investing in marine energy projects
- **Technology Strategy Board (TSB)**: It invests in projects and in sharing knowledge. Historically, it invested in the order of £100K per early-stage marine energy project. It funded in 2011 three marine energy device developers with over £2.5m for R&D of their full-scale devices
- **European Commission (EC)**: The EC has been supporting projects such as FO/P1, SSG, WaveBob, Wave Dragon or WaveRoller
- **Marine Renewables Proving Fund (MRPF)**: It aims to accelerate leading marine devices to qualify for the UK government's existing Marine Renewables Deployment Fund (MRDF) scheme with a £22m initiative (up to 60% of project costs with maximum of £6m per device)

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Funding

Funding sources

- **Environmental Transformation Fund (ETF)**: Provides funds for low-carbon energy and energy-efficiency technologies; £50m of this fund is in MRDF including a £42m wave and tidal energy demonstration scheme (up to 25% of capital cost, maximum £5m per project); devices must be grid-connected and tested at sea for 3 months continuously or for 6 months within 12 months
- **Energy Technologies Institute (ETI)**: Both the private (EdF, Shell, BP, E.On, Rolls-Royce and Caterpillar) and the public (UK government) sector spend £300m each to accelerate the deployment of low-carbon energy systems, including a marine energy program of about £10m each to a small number of projects
- **The Saltier Price**: Announced in April 2008, it offers £10m for an advance in clean energy; open globally for WECs and TECs, but winner must deliver an advance relevant to Scotland and device can be deployed within 2-5 years
- **Wave and Tidal Energy Scheme (WATES)**: Supports nine Scottish WEC and TEC developers since 2006 with £13.5m (currently no more funding available)

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Funding

Further (non-fiscal) support

Include training, knowledge exchange, networking, generic research, establishment of protocols and guidelines, infrastructure etc.

SuperGen Marine (EPSRC): Research, doctorates and training courses

European Commission:

- **WaveTrain2** (2008-12): Training for 16-20 students
- **CORES** (2008-11): 13 partners worked on critical components required for OWCs
- **EquiMar** (2008-11): 24 partners worked on guidelines and recommendations for development of WECs/TECs in all phases
- **Waveplam** (2007-10): 8 partners worked on nontechnical barriers influencing the growth of a wave energy industry with cross-border information and the establishment of networking links

Test centres:

- **NaREC** (National centre for the advancement of renewable energies), UK: Large scale facilities
- **EMEC** (European Marine Energy Centre), Orkney, Scotland: Sea berths and infrastructure to grid-connect and test devices in ocean at test phase 4
- **Wave Hub**, Southwest England, and Biscay Marine Energy Platform (**BIMEP**), Spain: Infrastructure and subsea connections to plug in devices in phase 5 offshore

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Phases 1-3 in laboratory

Phases 1, 2 and 3 (if taking place in laboratory); *controllable*

	Phase 1 *Validation model (lab.)*			Phase 2 *Design model (lab.)*	Phase 3 *Process model*	Phase 4 *Prototype*	Phase 5 *Demonstration*
	Concept	*Performance*	*Optimization*		*Sea trials*		
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Phases 1-3 in laboratory

Some important points to consider in Phases 1-3

Model-prototype similarity (scale effects)

Test facilities
- Towing tank (2D)
- Wave flume (2D)
- Wave basin (3D)

Wave generation
- Flap-type wavemaker
- Piston-type wavemaker
- Absorbing or non-absorbing

Wave absorption
- Reflections
- Active beach
- Passive beach

Model design
- Model material (scaling)
- Mooring
- Power take-off (**model PTO**)

Measurements
- **What to measure**
- **Sensor in water (waterproof)**
- **Intrusive or non-intrusive**

Device testing
- Regular waves (linear or non-linear)
- Irregular waves (which spectra)
- Extreme waves

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Phases 1-3 in laboratory

Model design: model PTO

The PTO needs to be included in the model not only to measure power, but also to correctly model the effect of the PTO on a WEC (it behaves differently without PTO).

Definitions of power

Linear mechanical system:	**Mechanical power** (W) = force (N) × velocity (m/s)
Hydraulic PTO:	**Fluid power** (W) = flow rate (m^3/s) × pressure (N/m^2)
OWC system:	**Air power** (W) = flow rate (m^3/s) × pressure drop (N/m^2)
Overtopping system:	**Water power** (W) = fluid density (kg/m^3) × gravitational acceleration (m/s^2) × flow rate (m^3/s) × head difference (m)
Rotary mechanical system:	**Shaft power** (W) = shaft torque (Nm) × angular velocity (1/s)

→ Model can, or often has to (scale effects), apply other PTO than full-scale device

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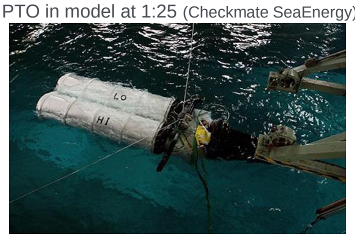
Phases 1-3 in laboratory

Model design: selection of model PTOs of Anaconda

Artists impression full-scale PTO (water power)

PTO in model at 1:25 (Checkmate SeaEnergy)



Model PTOs at University of Southampton

Actuator (mechanical power)

Piston with pressure transducer

Linear, tuneable (air power)

2400 capillary tubes

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Phases 1-3 in laboratory

Measurement systems

Water surface elevation:

- Incident, reflected, radiated, transmitted waves
- Overtopping basin
- Velocity of an Oscillating Water Column OWC

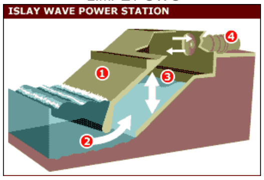
Fluid velocity:

- OWC
- Large-scale turbulent structures
- Cavitation

Coherent turbulent structures:

- Reduction of losses (improve streamlines)

LIMPET OWC



Water vortex

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Phases 1-3 in laboratory

Measurement systems

Flow rate:

- Overtopping device
- Flow between high to low pressure tank

Force/pressure:

- Power
- Hull or mooring
- Dimensioning structure in which WEC is integrated

Movement analysis (body motion):

- Optimisation of performance
- Investigation of radiation problem

Wave Dragon (overtopping device)

WECA (submerged pressure differential)

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Phases 1-3 in laboratory

Measurement systems

Measurement category	Measurement system	Spatial resolution	Effect on flow field
Water surface elevation	Capacitance wave gauge	Point measurement	Intrusive
	Resistance wave gauge	Point measurement	Intrusive
	Acoustic wave gauge	Point measurement	Non-intrusive
	Ultrasound gauge	Point measurement	Non-intrusive
	Pressure reading	Point measurement	Non-intrusive at measurement point but elsewhere in the flow field
	Drop-depth gauge	Point measurement	Intrusive
	Camera system	Measurement over an area	Non-intrusive
Fluid velocity	Pitot-static (or 'pitot') probe	Point measurement	Intrusive
	Doppler system (laser or acoustic)	Point measurement	Non-intrusive at measurement point but elsewhere in the flow field
	Hot wire/film anemometers	Point measurement	Intrusive
	Cross flow/propeller turbine wheel	Point measurement	Intrusive
	Particle image velocimetry PIV	Measurement over an area	Non-intrusive
	Particle tracking velocimetry PTV	Visualisation/ measurement over an area	Non-intrusive
Coherent turbulent structures	Tracer particles/dye	Visualisation of an area	Non-intrusive
Flow rate	Electromagnetic meter	Measurement at a cross section	Non-intrusive
	Propeller or orifice meter	Point measurement	Intrusive
Force	Strain gauge	Point measurement	Intrusive
	Force transducer	Point measurement	Intrusive
Pressure	Pressure transducer	Point measurement (small area)	Non-intrusive if fixed flush to a surface
Movement analysis (body motion)	Liquid metal strain gauge	Point measurement	Intrusive
	Camera system	Visualisation of an area	Non-intrusive
	Video motion tracking device	Several points	Non-intrusive
	Accelerometer	Point measurement	Practically non-intrusive
	Potentiometer	Point measurement	Intrusive
	Laser distance sensor	Point measurement	Non-intrusive at measurement point but elsewhere in the flow field
	Electromagnetic actuator	-	Intrusive

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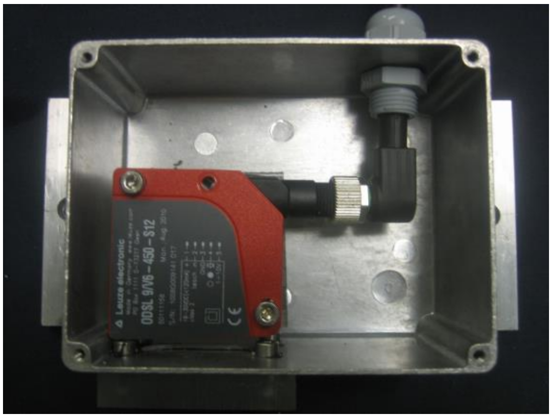
Phases 1-3 in laboratory

Sensors have to be submerged (waterproof)



Laser distance sensor in an IP68 rated enclosure with an IP68 cable gland for power supply (top) and a window covered with perplex for the laser (bottom)

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Phases 3-5 at sea

Phases 3 (if taking place at sea), 4 and 5; *not controllable*

	Phase 1 Validation model (lab.)			Phase 2 Design model (lab.)	Phase 3 Process model	Phase 4 Prototype	Phase 5 Demonstration
	Concept	Performance	Optimization		Sea trials		
Primary scale (λ)	$\lambda = 1:25 - 100$ ($\therefore \lambda_t = 1:5$–$10$)			$\lambda = 1:10$–25	$\lambda = 1:3$–10	$\lambda = 1:1$–2	λ = Full size
Tank	2D flume and 3D basin			3D basin	Benign site	Exposed site	Open location
Duration (inc. analysis)	1–3 weeks	1–3 months	1–3 months	6–12 months	6–18 months	12–36 months	1–5 years
Typical no. tests	50–500	250–500	100–250	100–250	50–250	Continuous	Statistical sample
Budget (€,000)	1–5	25–75	25–50	50–250	1,000–2,500	5,000–10,000	2,500–7,500
Excitation/Waves	Monochromatic linear waves (10–25 Δf) Panchromatic 5 reference	Panchromatic waves (20 min full scale) +15 classical spectra long crested head seas		Deployment: pilot site sea spectra Long & short crested classical seas Select mean wave approach angle	Extended test period to ensure all seaways included	Full scatter diagram for initial evaluation, continuous thereafter	

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Phases 3-5 at sea

Some important points to consider in phases 3-5

Location

Wave energy resource

- **Significant wave height, period and directionality**
- Extreme waves (survivability, storm protection mode)

Environmental impact

Measurement system (redundancy)

Cost efficiency

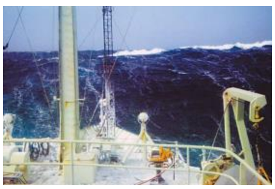
Operation and maintenance (on device or in harbour)

Reliability (redundancy)

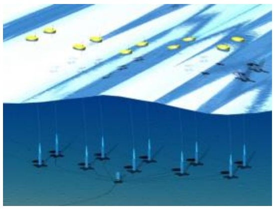
Grid Connection

Interaction effects in arrays

- A device in an array may generated more power then isolated
- Different incident power on devices in array



Planned 10 MW wave farm in Sweden with 420 Direct Drive Linear Generators



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Phases 3-5 at sea

Requirements for test location

- Favourable energy resource (scaled in TRL 3)
- Known wave resource and environmental data (wind, bathymetry, seabed properties) and pre-deployed wave measurement instruments
- Proximity between shore and national grid
- Small distance between the 50 m contour and the shoreline (avoid long cables)
- Access to harbours and shipyards (O&M, safety)
- Simplified regulations and licensing procedures
- One or more offshore connection points
- Monitoring facilities related to the device itself and the environment
- Potential to be extended to test site for small array
- Good accessibility
- Out of the region of major shipping lanes, fishing areas and military training sites

→ Most problems solved if tests take place at a test centre (EMEC, Wave Hub, BIMEP) 27

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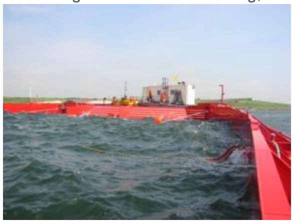
Phases 3-5 at sea

Some WECs tested in phase 3 at benign sea sites

Wavestart at Nissum Bredning, Denmark

Wave Dragon at Nissum Bredning, DM



Ceto at Fremantle, Australia

OE Buoy at Galway Bay, Ireland

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Phases 3-5 at sea

Some WECs in phase 4

Pelamis at EMEC, Scotland

Oyster at EMEC, Scotland

PowerBuoy, Hawaii, USA

Device	Year of tests	Location	Rated power
LIMPET OWC	2000-2007	Islay, Scotland	500 kW
Ceto	2011	Garden Island, Australia	200 kW
Mighty Whale	1998	Nansei Town, Japan	120 kW
EU Pilot Plant	1999	Pico Island, Azores	400 kW
AWS	2004	Agućadoura, Portugal	2 MW
Pelamis	2004-2007; 2010-2011	EMEC, Scotland	750 kW
Direct Drive Linear Generator	2005	Lysekil, Sweden	10 × 10 kW
OWES	2005-2006	Port Kembla, Australia	500 kW
WavePlane	2008	Hanstholm, Denmark	100 kW
Oyster	2009-2011	EMEC, Scotland	300 kW
PowerBuoy	2009-2010	Hawaii, USA	40 kW
	2011	Invergordon, Scotland	150 kW
WaveRoller	2007-2008	Peniche, Portugal	2 × 15 kW

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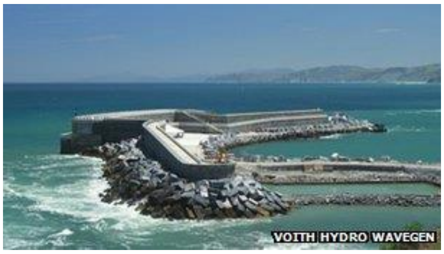
Phases 3-5 at sea

First WEC arrays



3 Pelamis devices
Agućadoura, Portugal in 2008
First wave farm
Total rated power 2.25 MW

16 oscillating water columns
Mutriku, Spain in 2011, integrated in breakwater
First commercial project
Total rated power 296 kW

→ Many further farms are under development or planned

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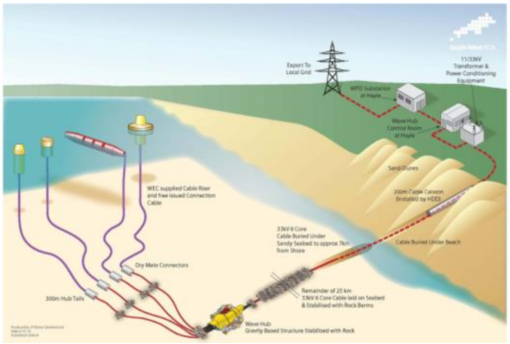
Phases 3-5 at sea: Multi MW test sites

Wave Hub in Cornwall, England

- Provides infrastructure for up to four wave farms with simplified licensing procedure
- Subsea connections available
- Produce up to 20 MW in total
- 8 km^2 area of sea
- 25-years lease

Confirmed devices:

- Fred Olsen Ltd (B1)
- Ocean Power Technologies Ltd (PB150)
- WestWave (Pelamis)



Artists impression of Wave Hub

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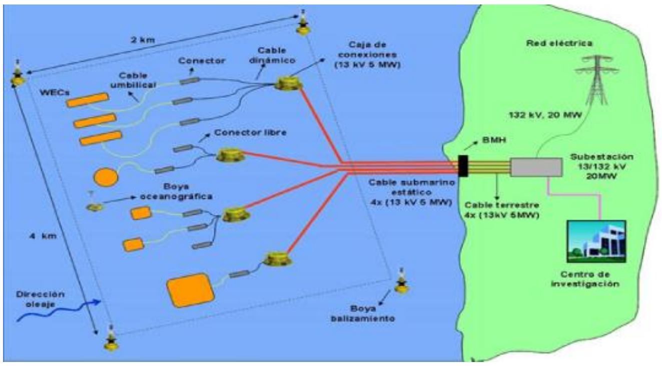
Phases 3-5 at sea: Multi MW test sites

Biscay Marine Energy Platform BIMEP, North Spain

- Provides infrastructure for four wave farms
- Subsea connections are provided and it should produce up to 20 MW
- 2 × 4 km^2 area of sea in 50 - 90 m deep water



Artists impression of BIMEP

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Conclusions

- The technology readiness level TRL approach concentrates on technical aspects and helps to mitigate technical and fiscal risk
- The TRL approach is also a convenient way to assess the advancement of WECs
- Many devices are under investigation at full scale and first arrays are being tested or planned and seem commercially feasible
- The support for wave energy conversion from Governmental Agencies, Research Councils and the European Commission is substantial despite the economic problems
- An overview about the current state of wave energy conversion was given

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