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**an overview of
the WECwakes project**

**PHYSICAL MODELING OF AN ARRAY
OF 25 WAVE ENERGY CONVERTERS**

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introducing the problem

▪ wave energy

- rising contribution to renewable energy supply
- Wave Energy Converters “WECs” under development

▪ a farm of WECS

- power production of a single WEC is limited
- arrangement of several WECs in a geometric configuration
- power production of a farm of WECs depends on optimisation of farm lay-out

▪ study of wake effects behind

- a single WEC
- multiple WECs in a farm

a wake based lay-out seen from another perspective ...



fwo 

**a wake based lay-out
seen from another perspective ...**


avoid wake !



Risoe (Denmark) wind farm

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overview

1. Introduction and problem statement
2. Research objectives and methodology
3. Main experiment results and deliverables
4. Conclusions

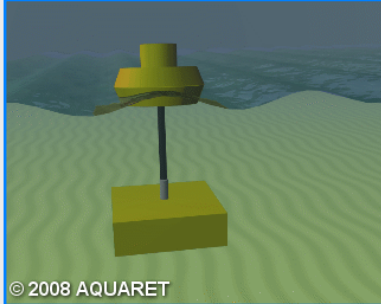
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harvesting energy from sea waves: Wave Energy Converters (WECs)

- The energy from waves can be captured and converted into electricity by wave energy converter (WEC) devices
- Classification:
 - Conversion technology
 - Floating/anchored/integrated in coastal structures



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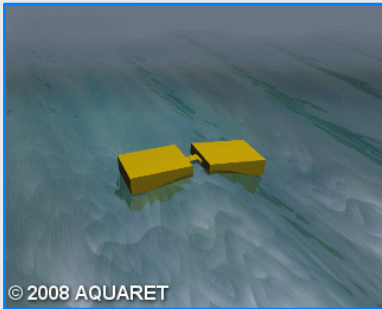
examples of WEC types: how do they work?

Attenuator:

- floating device operating parallel to the wave direction, riding the waves
- captures energy from the relative motion of its parts as waves pass them



Pelamis
Pelamis Wave Power Ltd



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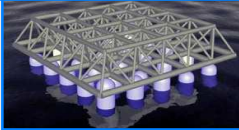
examples of WEC types: how do they work?

Point absorber:


- floating device absorbing energy from all directions through its motions.
- converts motion of the buoyant top relative to the base, into electrical power




Wave Star



Manchester Bobber



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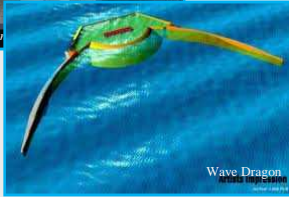
examples of WEC types: how do they work?

Overtopping/Terminator device:

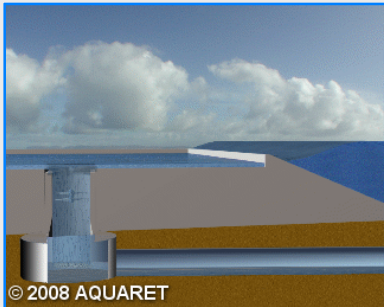
- captures overtopping water volume into a storage reservoir
- water returns to the sea passing through a conventional low-head turbine which generates power




SOG Seawave Slot-Com



Wave Dragon



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about Wave Energy Converter farms

Capture energy from waves and convert it into electricity
several concepts; 2 types of devices

oscillating principle

overtopping principle

WEC 'farm' or 'array'

Wavebob

SSG

Wave Dragon

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MILDwave simulation result

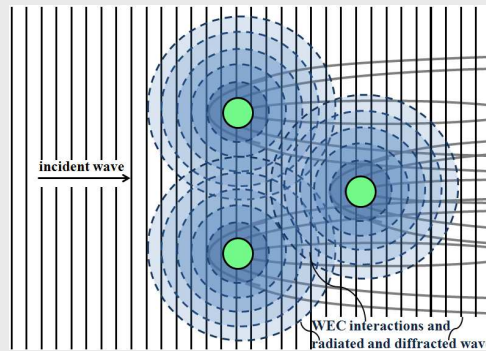
LCW

SCW

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WEC array effects!

INTRA-ARRAY INTERACTIONS between the WECs within an array:
power production (**P**) smaller or larger than expected



Influenced by:

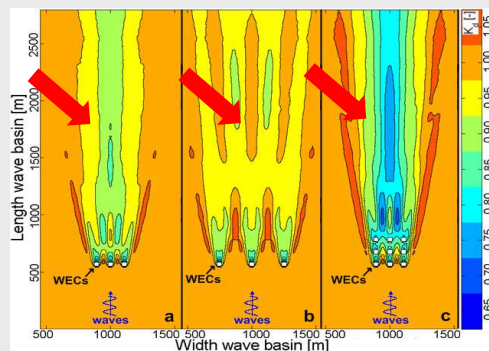
the WEC array lay-out, WEC spacing, number of the WECs, wave conditions

WEC array effects!

EXTRA-ARRAY EFFECTS: wave height attenuation due to wave energy extraction

They may influence:

- other activities in the sea or (marine energy) projects
 - coastal eco-systems
 - coastline morphology
 - or even the coastal defence conditions and parameters
- **possible environmental impact!**



Influenced by:

the WEC array lay-out, WEC spacing, number of the WECs, wave conditions

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necessity for experiments with large WEC arrays

Numerical modelling (e.g. MILDwave, WAMIT) ☒
 Experimental research with one or two WECs ☒
 Experimental research with large WEC farms ☐

HYDRALAB IV
 ↓
 WEC array experiments
 “WECwakes”
 ↓
 Large scale wave basin DHI,
 Denmark

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objectives of large scale experiments

(1) Understanding of the WEC array effects by:

- investigate the **intra-array interactions** between WECs of a farm
- measure extents and impact of **extra-array effects** behind the wave farm
- quantify **the effect on wave power absorption** by:
 - (i) changing the **spacing** between the WECs in a farm,
 - (ii) changing the **number** of the WECs in a farm and
 - (iii) modifying the farm **geometrical layout**

(2) compare data with results from the established point absorber theory

(3) provide experimental data for validation of numerical models:

- (i) i.e. **phase resolving** models (e.g. MILDwave, ARTEMIS),
- (ii) **phase averaging** models (e.g. SWAN, TOMAWAC) and
- (iii) Boundary Element Methods based on **potential flow** (e.g. Aquaplan, WAMIT)

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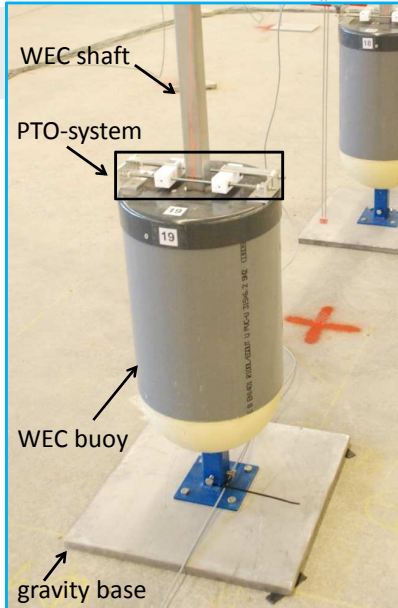
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a set of 25 WEC units

REQUIREMENTS:

- no new WEC concept
- appropriate for numerical treatment
- robust and simple to use in basin

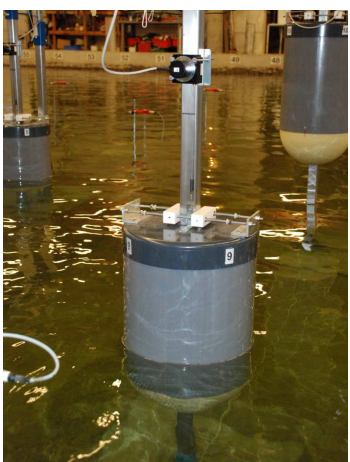
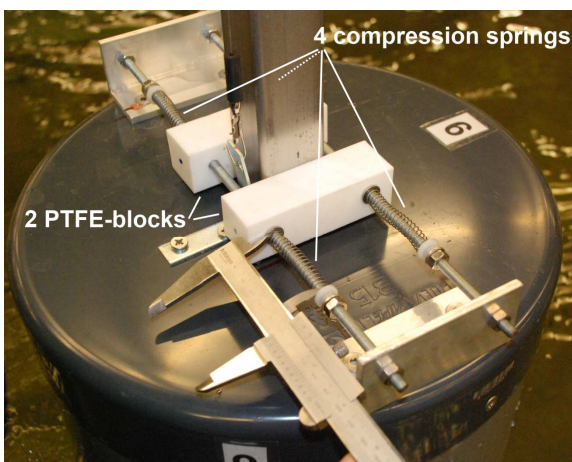
- point absorber with a **simple** generic **geometry** and 1 DOF motion (**heave only**)
- low cost** for construction and reproduction in large numbers
- easy **repositioning** within an array and easy to **operate**
- measurable** buoy response and energy extraction



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illustrations of the WEC model and its PTO-system

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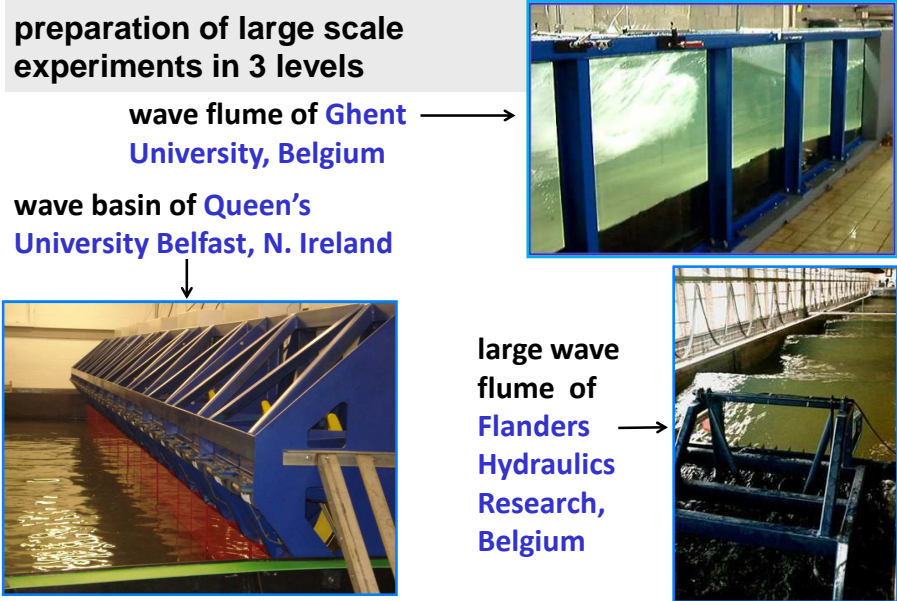
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preparation of large scale experiments in 3 levels

→ wave flume of Ghent University, Belgium

↓ wave basin of Queen's University Belfast, N. Ireland

→ large wave flume of Flanders Hydraulics Research, Belgium



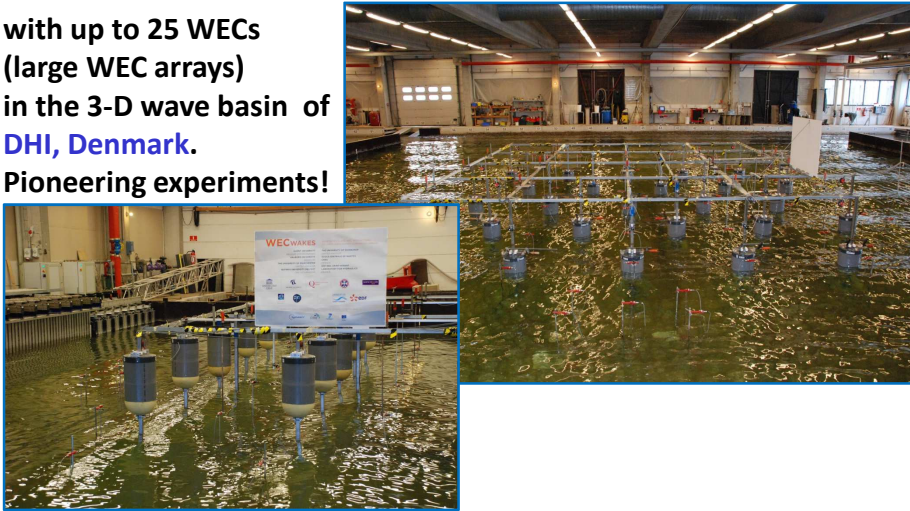
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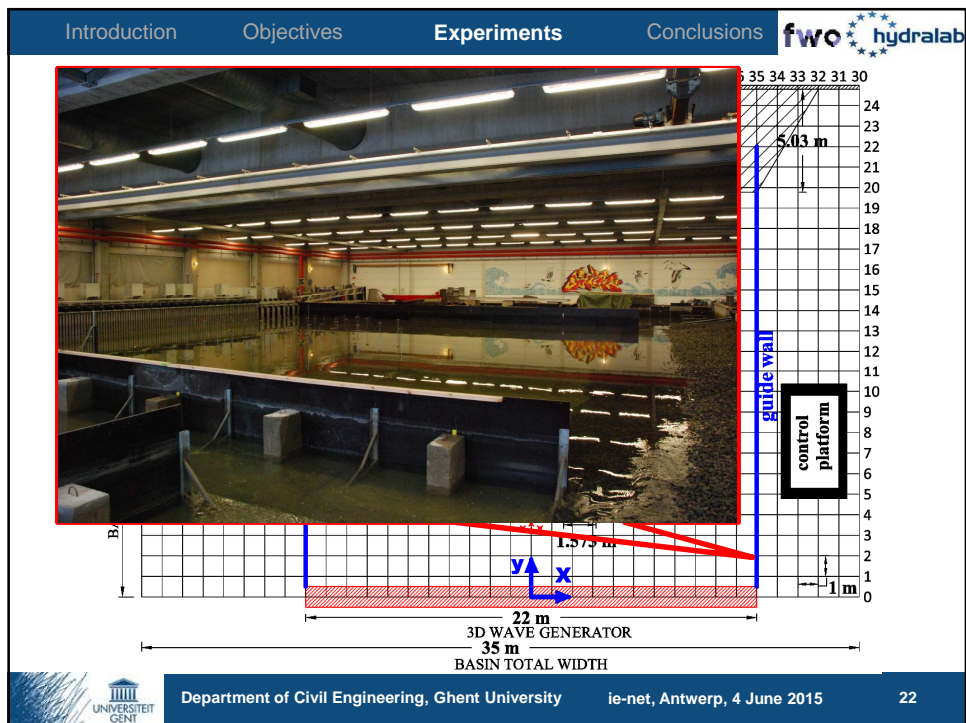
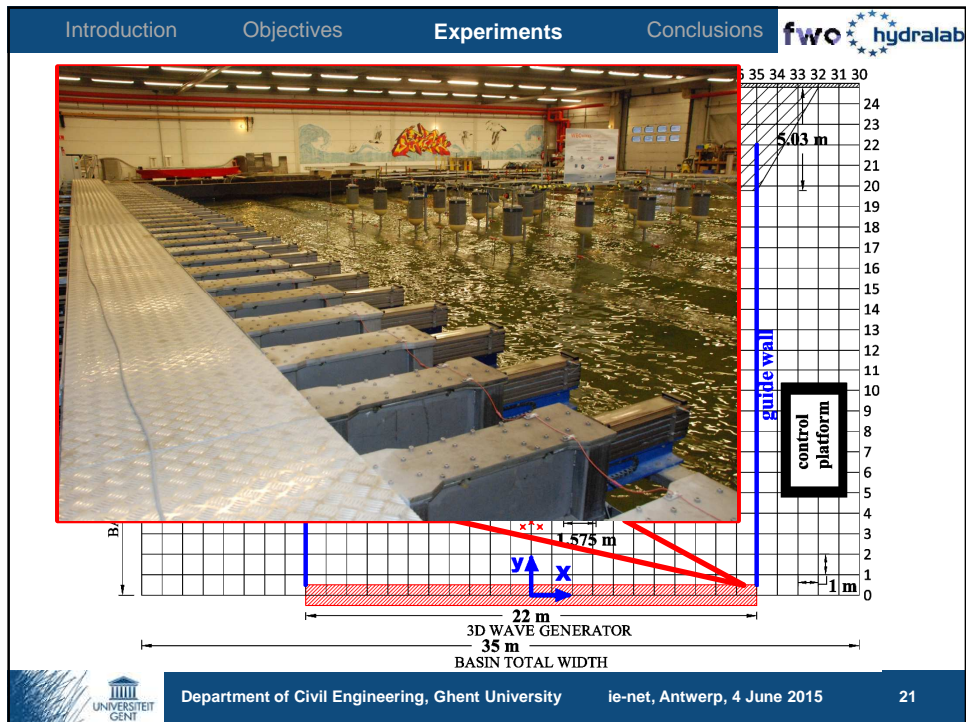
'WECwakes' experiments - HYDRALAB IV

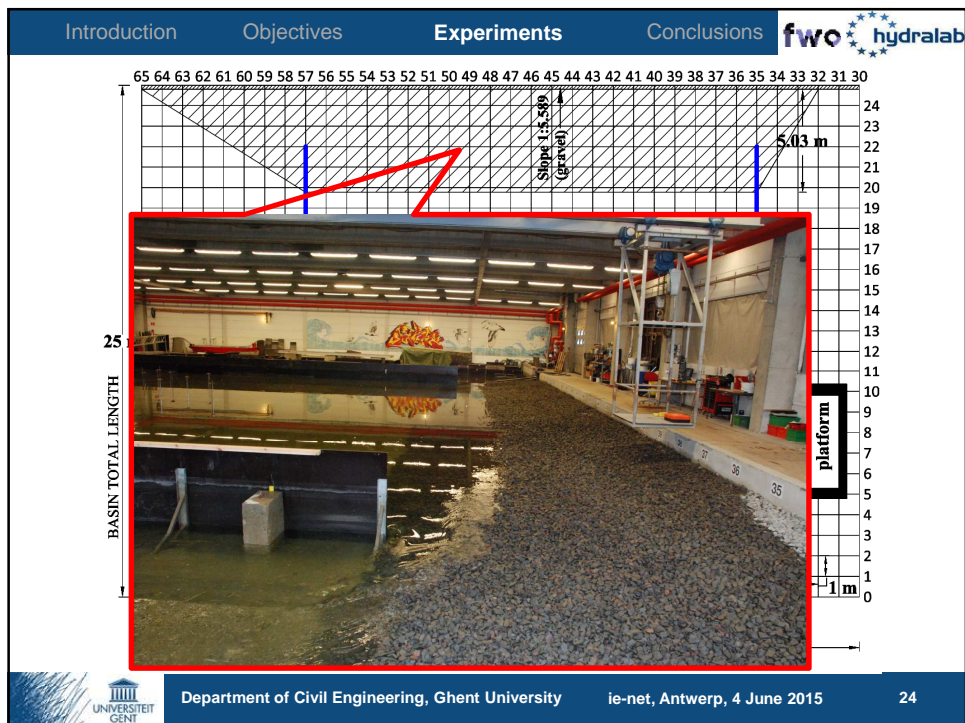
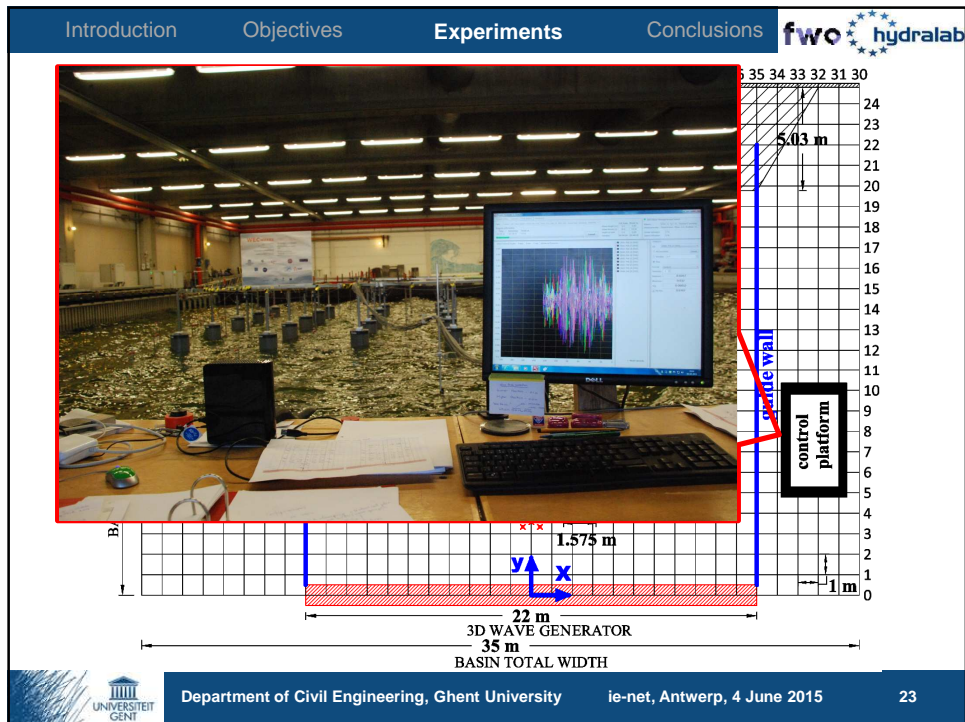
with up to 25 WECs (large WEC arrays) in the 3-D wave basin of DHI, Denmark. Pioneering experiments!



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65 64 63 62 61 60 59 58 57 56 55 54 53 52 51 50 49 48 47 46 45 44 43 42 41 40 39 38 37 36 35 34 33 32 31 30

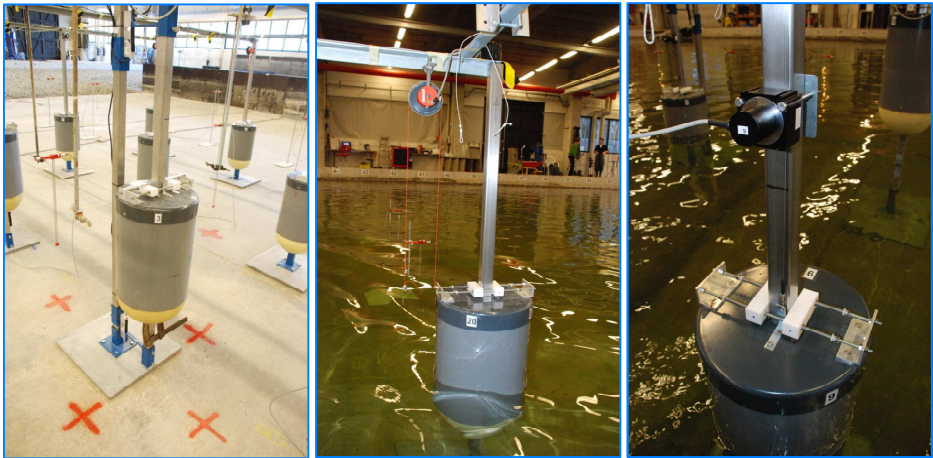


3D WAVE GENERATOR
35 m
BASIN TOTAL WIDTH

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instrumentation: force on buoy F_{surge} , vertical displacement of the buoy, surface elevations



Simultaneous measurements of time series


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overview of the database and test parameters












water depth d is constant at 0.70 m

parameter	range
wave period, $T = T_p$ [s]	0.87 - 1.51
wave height, $H(Hm0)$ [m]	0.018 - 0.104
Inter-WEC distance ($D=0.315$ m) [m]	5D, 10D (pairs: up to 20D)
WEC number within a configuration [-]	0 - 25
WEC motion	free decay, fixed, damped response, free response
PTO: spring compression, dx [mm]	0, 50.5, 45.5, 40.5, 35.5, 30.5, 20.5, 10.5
wave type [-]	regular, irregular long- & short-crested
angle of incident waves [°]	0, 10, 20
short-crestedness, s_{max} [-]	0, 10, 75



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a unique database



Configuration	Layout sketch	Configuration	Layout sketch
Waves (no WECs)	N/A	10-WEC column	
Individual WEC		5x5-WEC aligned	
2-WEC column		5x5 WEC staggered	
2-WEC row		3x3-WEC aligned 10D	
5-WEC column		3x3-WEC aligned 5D	
5-WEC row		13-WEC staggered	

- **Simultaneous measurements of: WEC response, forces on WECs, wave field.**
- Wide range of parameter variations
→ large number of combinations
→ hundreds of tests:
 - **array lay-out,**
 - **WEC motion,**
 - **wave conditions**
 - **wave types**
- Database **applicability**:
 - WEC arrays,
 - floating structures/platforms,
 - stationary cylinders,
 - wind turbine monopiles...


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setting up the WECs in the DHI wave basin

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working with the WECs in the DHI basin: set-up changes and test control





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data analysis of WEC array experiments

effect of **intra-array interactions** on the array overall power absorption

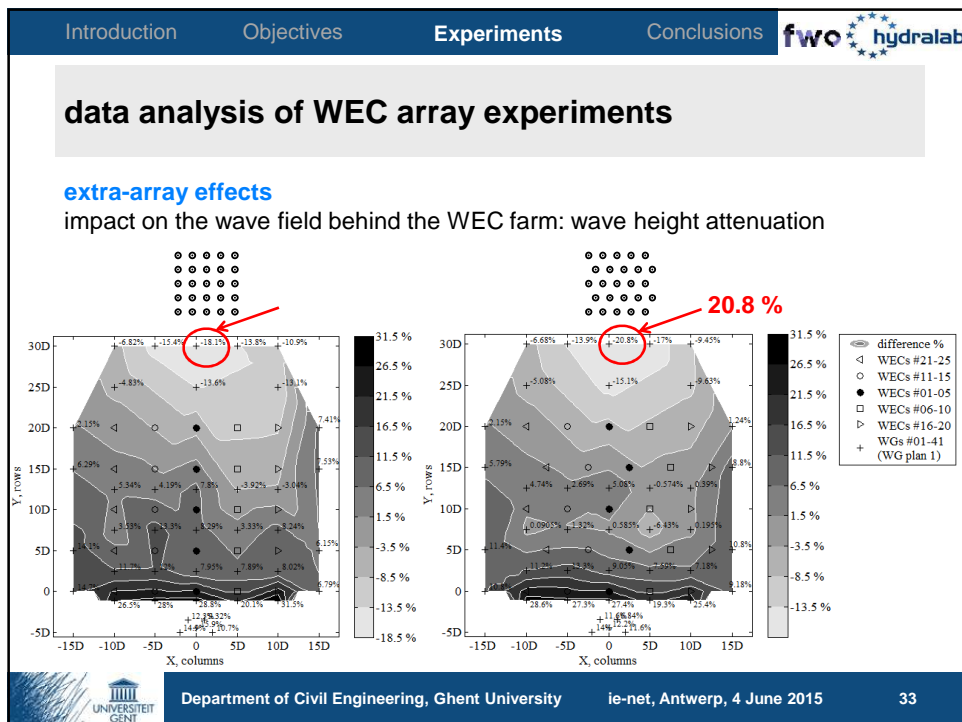
$$\bar{q} = \frac{\sum_{i=1}^N P_{i,tot}}{N \cdot P_{0,tot}}$$

$\bar{q} > 1.0$

$\bar{q} < 1.0$

wave type	5x5-WEC aligned array	5x5-WEC staggered array	3x3-WEC aligned 5D array	3x3-WEC aligned 10D array
long-crested irregular waves	constructive by 3 %	constructive by 16 %	destructive by 20 %	highly constructive by 68.4 %
\bar{q} interaction factor	1.03	1.16	0.80	1.68

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Home » Research units » Coastal Engineering, Bridges and Roads » News and Events » News bulletin » Wave energy research by Ghent University in Danish educational video

Wave energy research by Ghent University in Danish educational video

(03-11-2014)

The Danish Hydraulic Institute (DHI) assisted in producing an educational video, designed to teach secondary school students about the impact of climate change on Denmark. The video was funded by the Danish Ministry of Education and has been produced by AlphaFilm.

The UGent EU FP7 project "WECwakes" is also presented. Take a look at the video part between 16:15 and 17:30, to see the tests with heaving wave energy converters performed by the UGent research group at the Shallow Water Wave basin of DHI.

Video

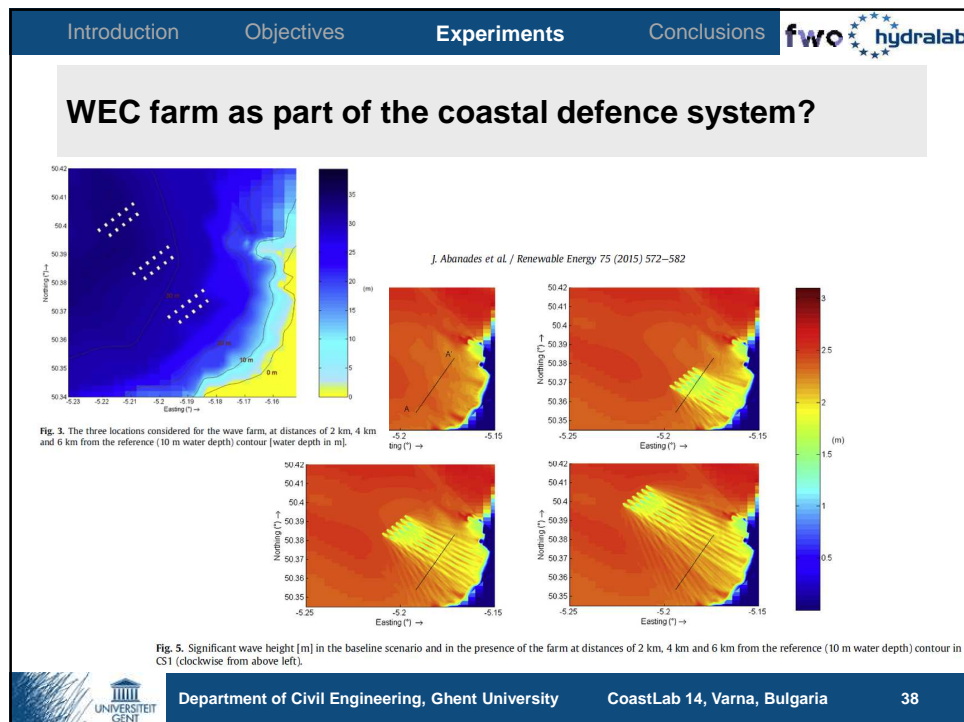
Future impact of climate change - part 2

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visit: <http://awwww.ugent.be>

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morphological effects of WEC farms on coastline


- *Coastal defence through wave farms* (Stratigaki V., 2015; PIANC-DPWA Int'l Award winning paper; ICCE2014):
wave height attenuation downwave of WEC farms is used for estimating the coastline evolution by using morphological models or by applying traditional formulae predicting the long-shore sediment transport and erosion or accretion, based on wave height parameters.
- Littoral transport in the lee of the farm decreases due to attenuated waves and longshore currents in the area sheltered by the farm
- Littoral transport of sediments is deposited in the lower wave energy region
- A wave farm traps sand under all circumstances

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WECs as multi-purpose devices


- The wave field findings from WECwakes prove the ability to **satisfy energy demand in coastal areas** by, simultaneously, providing **coastal protection**, securing local sea activities and navigation, and reducing the costs by using WECs as multi-purpose devices.


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Overview of main research deliverables / conclusions


- **WEC array database for array effects**
 - extensive and unique database is established (590 tests; up to 25 WECs)
 - WEC response, wave induced forces, wave field modifications measured
 - WEC farm power output
 - large parameter variation
 - database is useful for numerical model validations
- **Database analysis:** significant effect of *intra-array interactions* and *extra-array effects* on power production & wave field modification
- **Guidelines for design of the geometrical lay-out of WEC arrays**
 - to optimize power absorption
 - to limit environmental impact



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take home messages

- An array of 25 WECs is tested experimentally in a wave basin for the study of intra-array and extra-array effects (wake effects).
- The test matrix includes geometric lay-out and wave conditions.
- An extensive database is available.
- Results include measurements of WEC response, surge forces on WECs and wave field modifications, and power absorption calculations.
- Database is useful for numerical model validations.
- Significant effects of intra-array and extra-array effects on power production and wake formation have been illustrated.
- Morphological effects have been illustrated


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Physical modelling of wave energy converter arrays in a large-scale wave basin: the WECwakes project



Thank you for your attention!

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