Wave energy converter: a brief review of WECs technology and some aspects of oscillating wave column converter design

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- Wave energy converters classification
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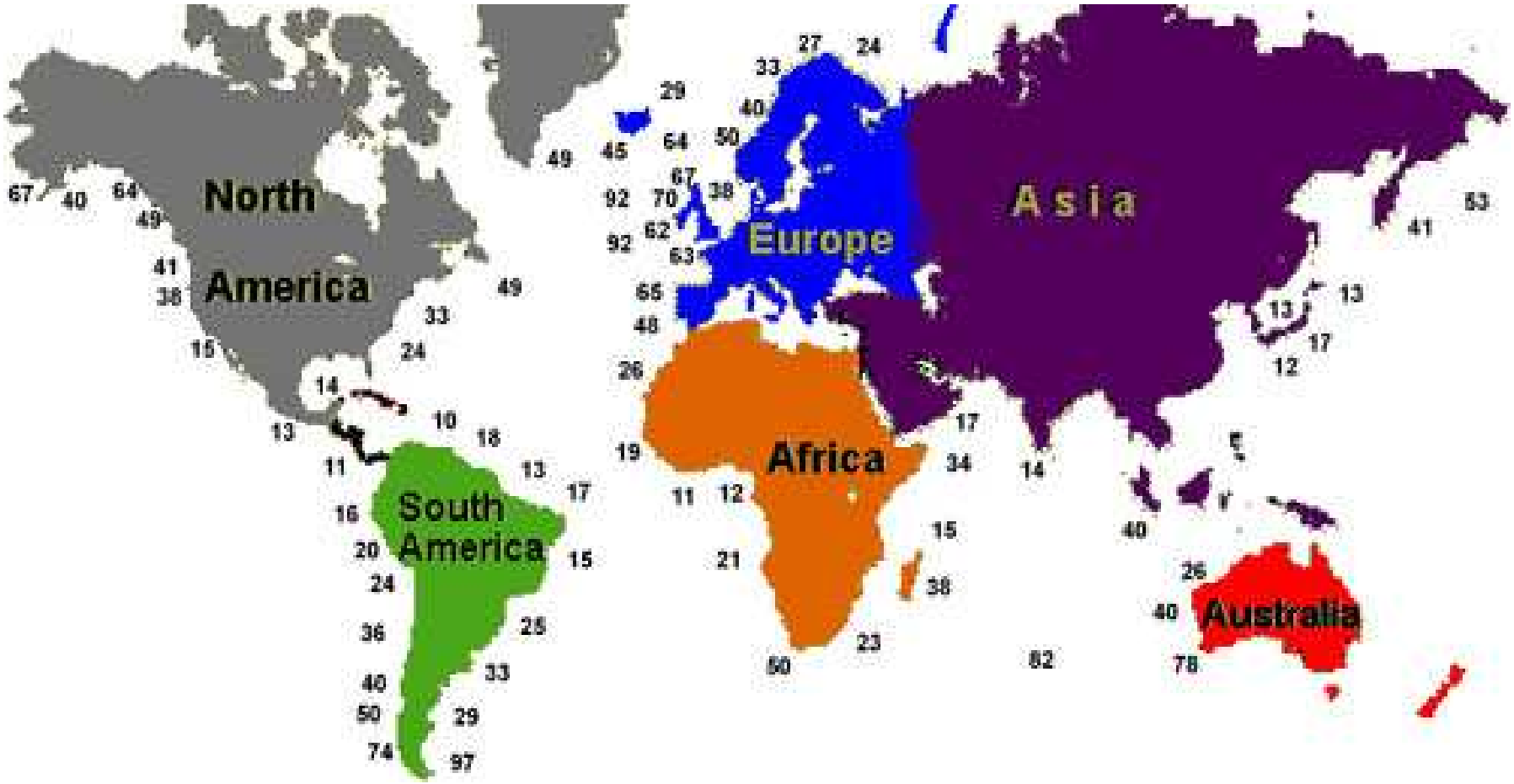
Energy extraction from the seas

Energy can be extracted from the seas using a range of procedures depending on how it has been stored:

- tides
- temperature gradients
- ocean currents
- waves

Apart from the tidal energy, the other kinds of sea energies have also being tested obtaining different results, some of them closed to the the oretical calculations and other ones rather different.

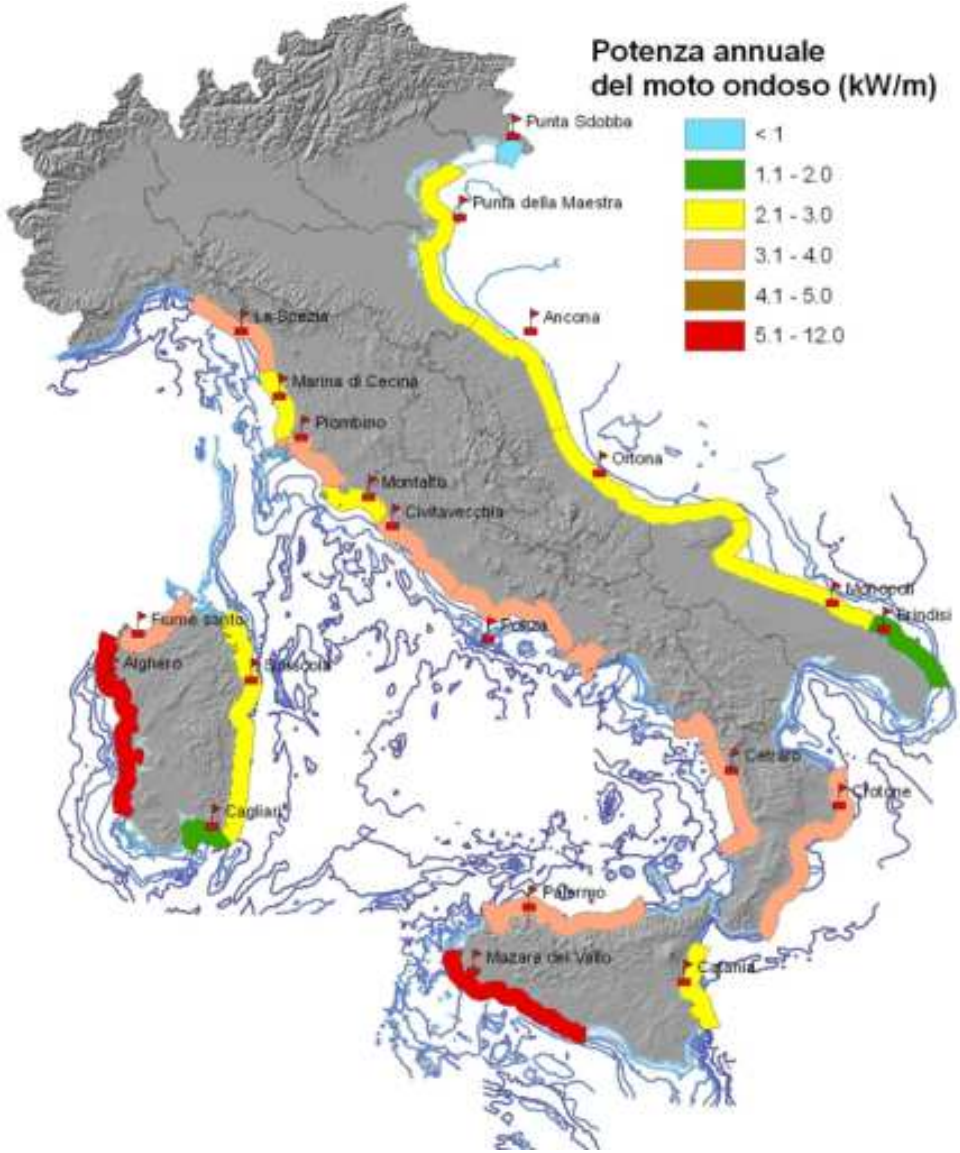
Global wave resources



Average annual wave resource kW/m deep water

It is estimated that the potential worldwide wave power resource is 2 TW.

… in Italy



Near shore average annual wave resource

Wave Energy Converters (WECs) classification

Although the large variation in designs and concepts, WECs can be classified into three main types:

- Attenuator
- point absorber
- terminator

Within the categories identified above, there is a further level of classification of devices, determined by their mode of operation, e.g:

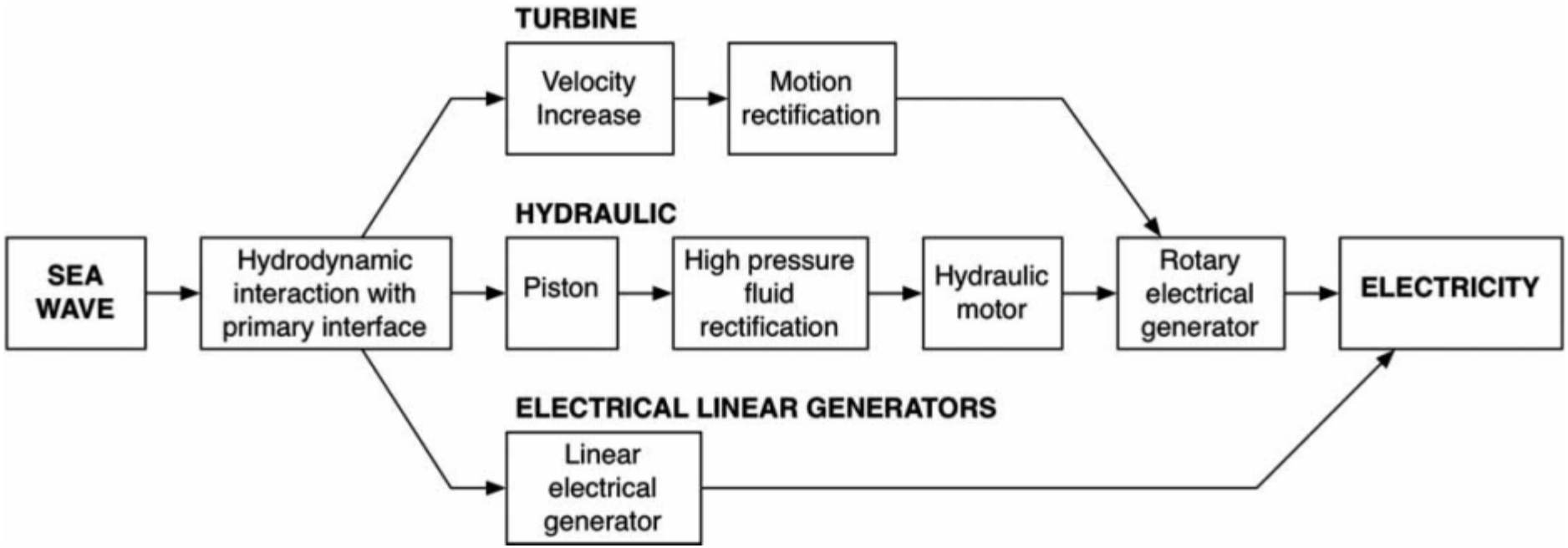
- *Submerged pressure differential*
- *Oscillating wave surge converter*
- *Overtopping device*
- *Oscillating water column (OWC)*

Design challenges in wave energy

- Convert energy in waves to useable form
  - Elliptic fluid particle motion – large cyclic forces
  - Irregular frequency, amplitude, direction
  - Extreme loads can be > 100 × average working

- Wave power converters must
  - Survive extremes
  - Produce a predictable defined output
  - Compete with other forms of generators
  - Have a substantial positive energy balance

Alternative power take off (PTO) mechanisms

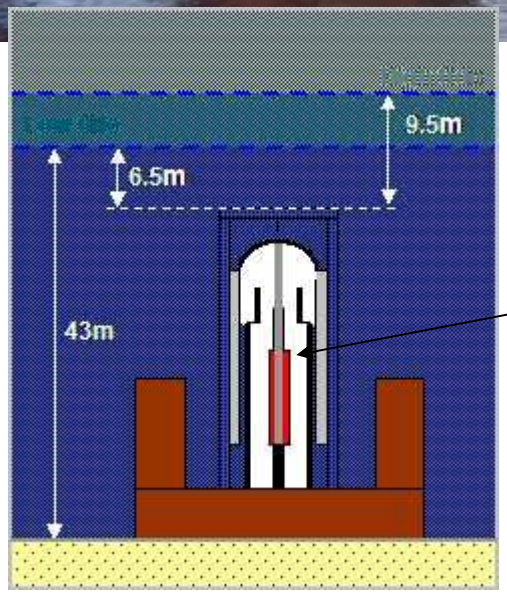


Pelamis - raft, array, attenuator

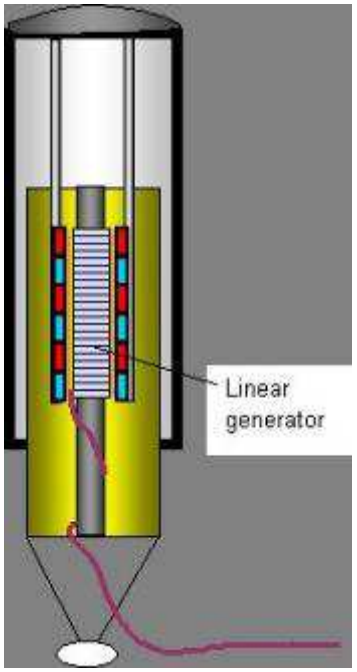
- Relative motion between floats
- attenuator line array
- high pressure hydraulics
- active stiffness control

120m long, and contains three power modules, each rated at 250kW.
It is designed to operate in water depths of ~50 m

Archimedes Wave Swing

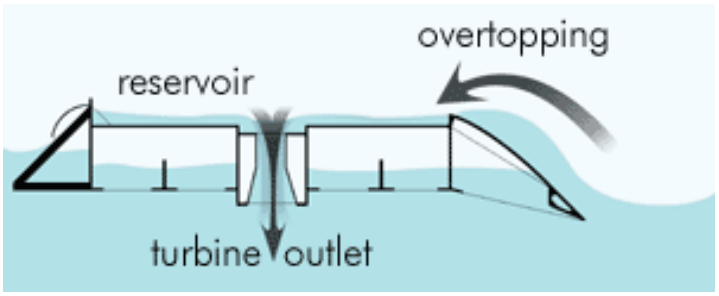


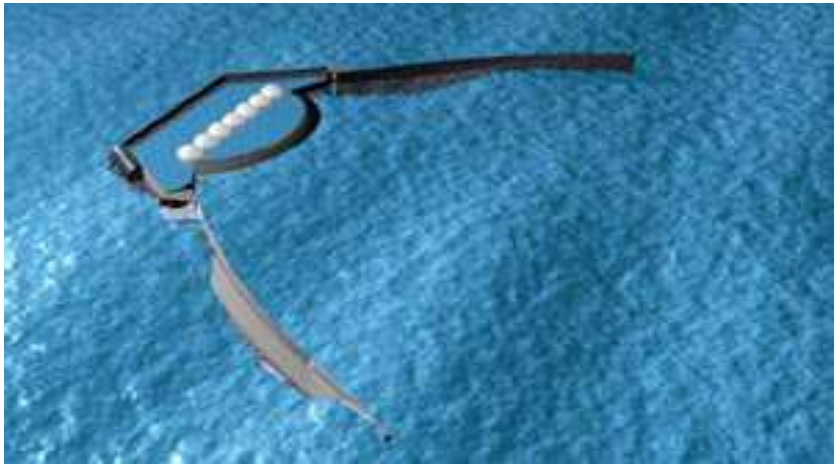
- Sea bed mounted
- Point absorber
- Linear generator



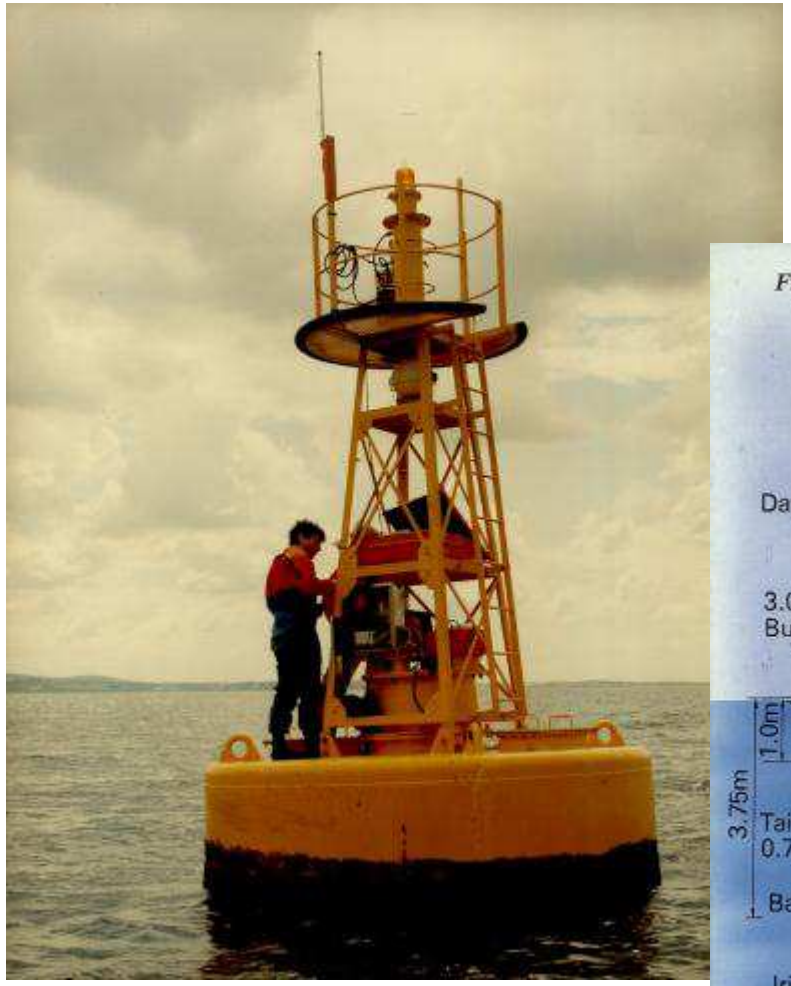
Wave Dragon

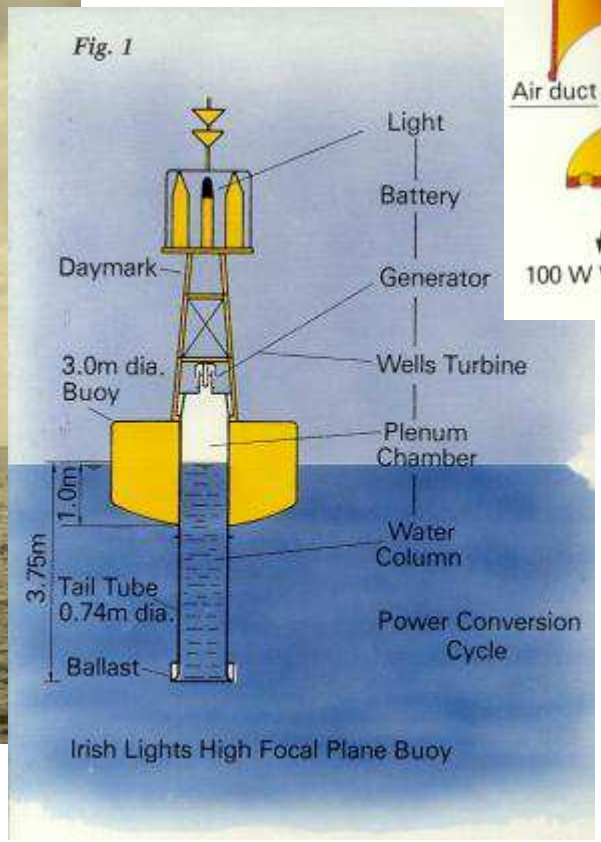
- Overtopping system
- Low head hydro PTO
- Energy storage

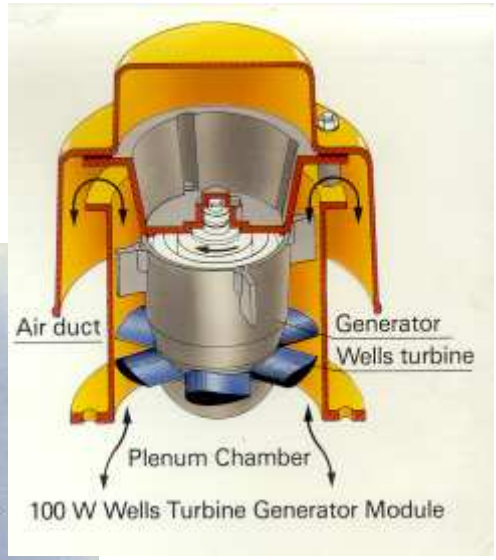




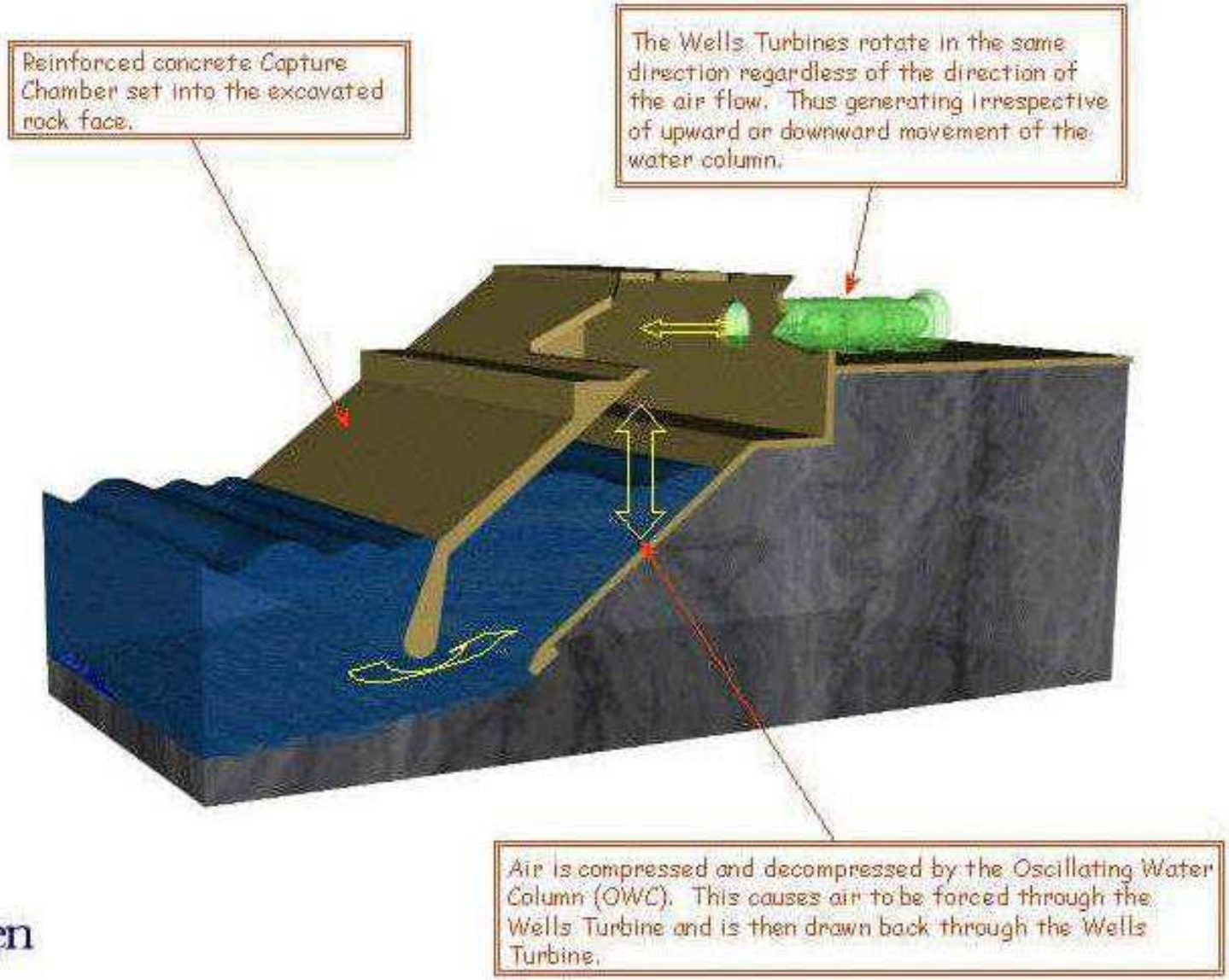
Wave Powered Navigation Buoys







Schematic of LIMPET



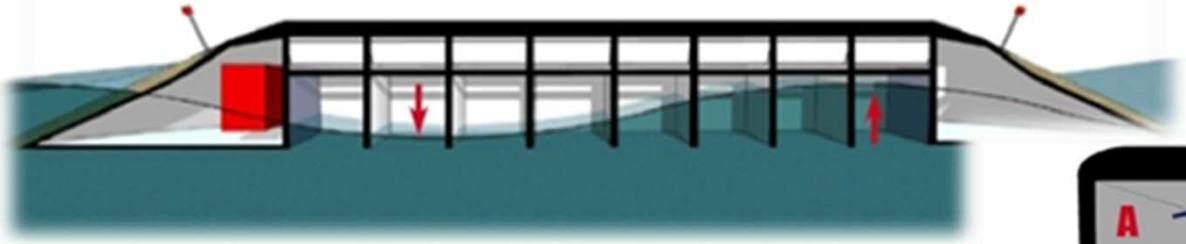
Wavegen

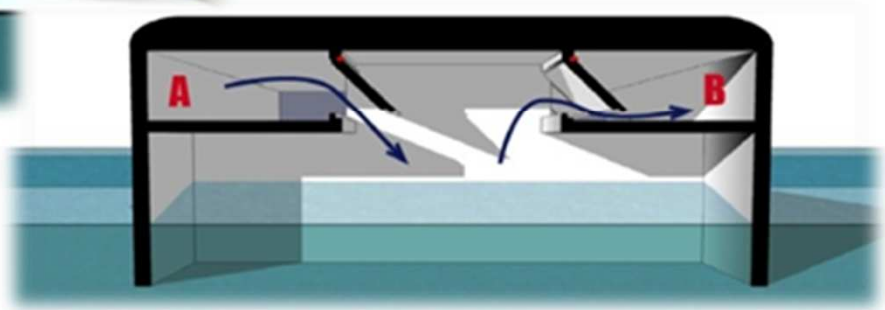
LIMPET shoreline OWC

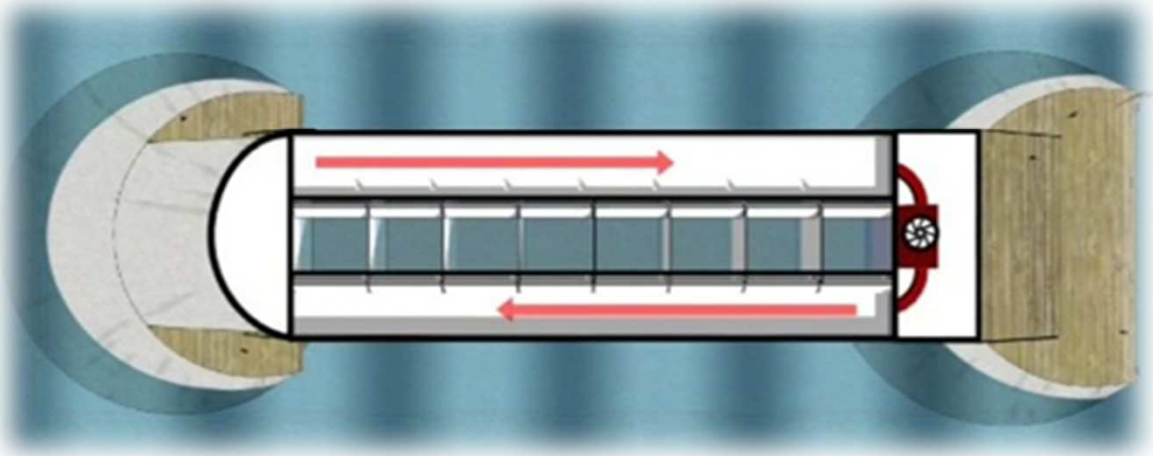
Maximum power 750 kW

Multi-chamber OWC

Nautilus AdvancedWavePower and *Seabreath* WECs

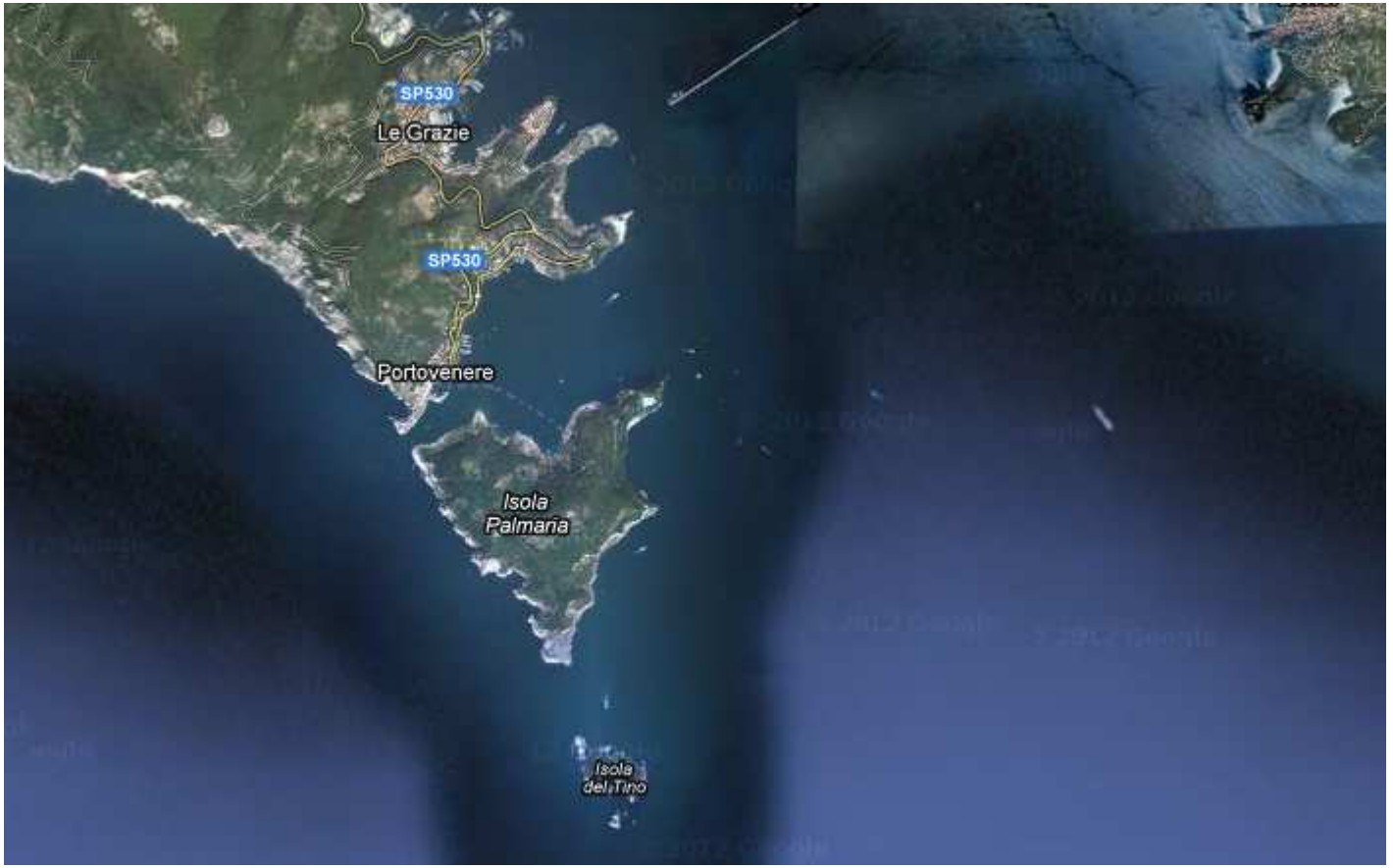






An example of multi-chamber OWC: the e-pier

The site



Cala del Pozzale – Palmaria Island
Porto Venere Regional Park

An example of multi-chamber OWC: the e-pier

The piers

Cala del Pozzale – Palmaria Island
Porto Venere Regional Park

The e-pier design

- Two piers: each with one embedded multi-chamber oscillating wave column converter, replacing the existing languishing in a state of decay
- Features:
  - boats mooring
  - Pedestrian crossing
  - Coastline erosion reduction
  - **Electric energy production (WEC)**

The e-pier design

- Users: houses, restaurants, others touristic facilities and public lights
- by the buoy for wave measurement of La Spezia and some calculations considering the sea bed profile at the coastline:

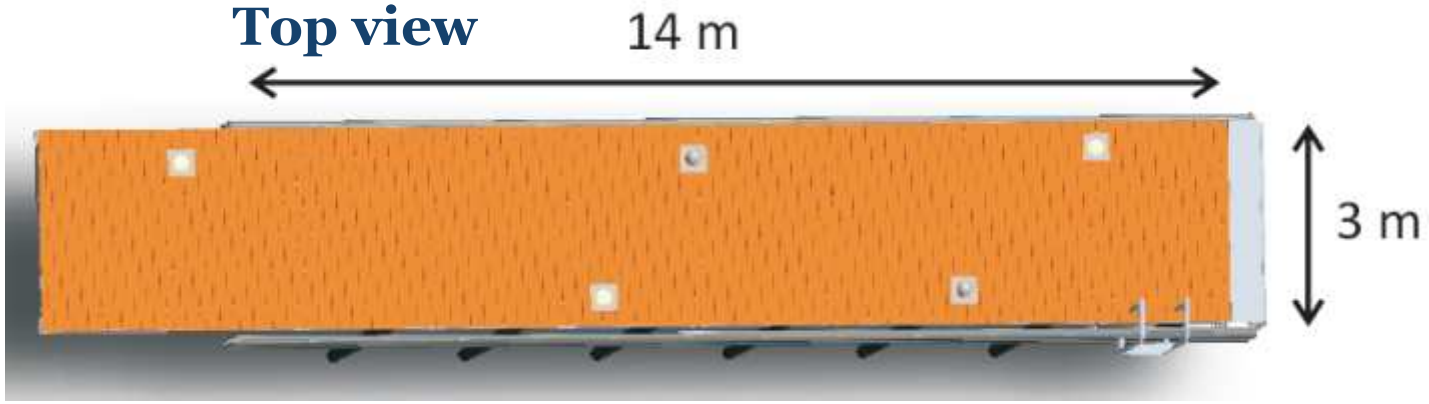
Direzione / T_s	2.0 s	3.5 s	4.5 s	5.3 s	6.0 s	6.6 s	7.2 s	7.7 s	8.2 s
30°N	1.14	13.42	11.99	5.14	2.99	4.39	4.16	2.38	4.89
45°N	0.74	7.97	7.41	3.37	2.66	3.29	4.16	5.95	1.63
60°N	0.54	7.24	7.41	5.32	3.32	3.84	4.16	2.38	1.63
75°N	0.58	6.56	6.26	3.37	2.32	4.39	3.33	4.76	4.89
90°N	0.52	6.39	6.57	4.43	2.99	2.74	4.16	3.57	6.51
105°N	0.55	6.65	6.72	5.85	6.31	3.84	4.16	4.76	4.89
120°N	0.54	7.75	10.62	7.44	6.64	8.23	5.00	7.15	11.40
135°N	0.67	12.23	12.99	8.50	7.97	9.87	12.49	11.91	14.66
150°N	0.97	18.13	17.95	10.99	9.96	20.29	15.82	10.72	11.40
165°N	1.29	22.07	33.54	23.03	14.28	13.16	22.48	33.35	14.66
Somma	8.00	108.00	121.00	77.00	59.00	74.00	80.00	87.00	77.00

TOTALE: 692 W/m/y (incidente la spiaggia)

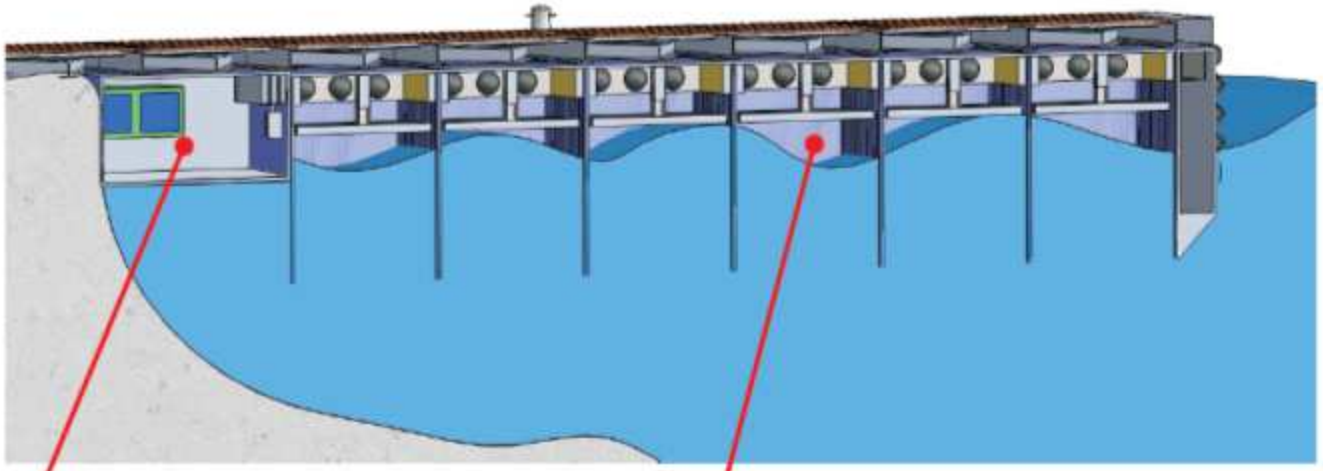
- Energy production (2 WEC): 18 MWh/y

The e-pier design

Top view



Longitudinal vertical section

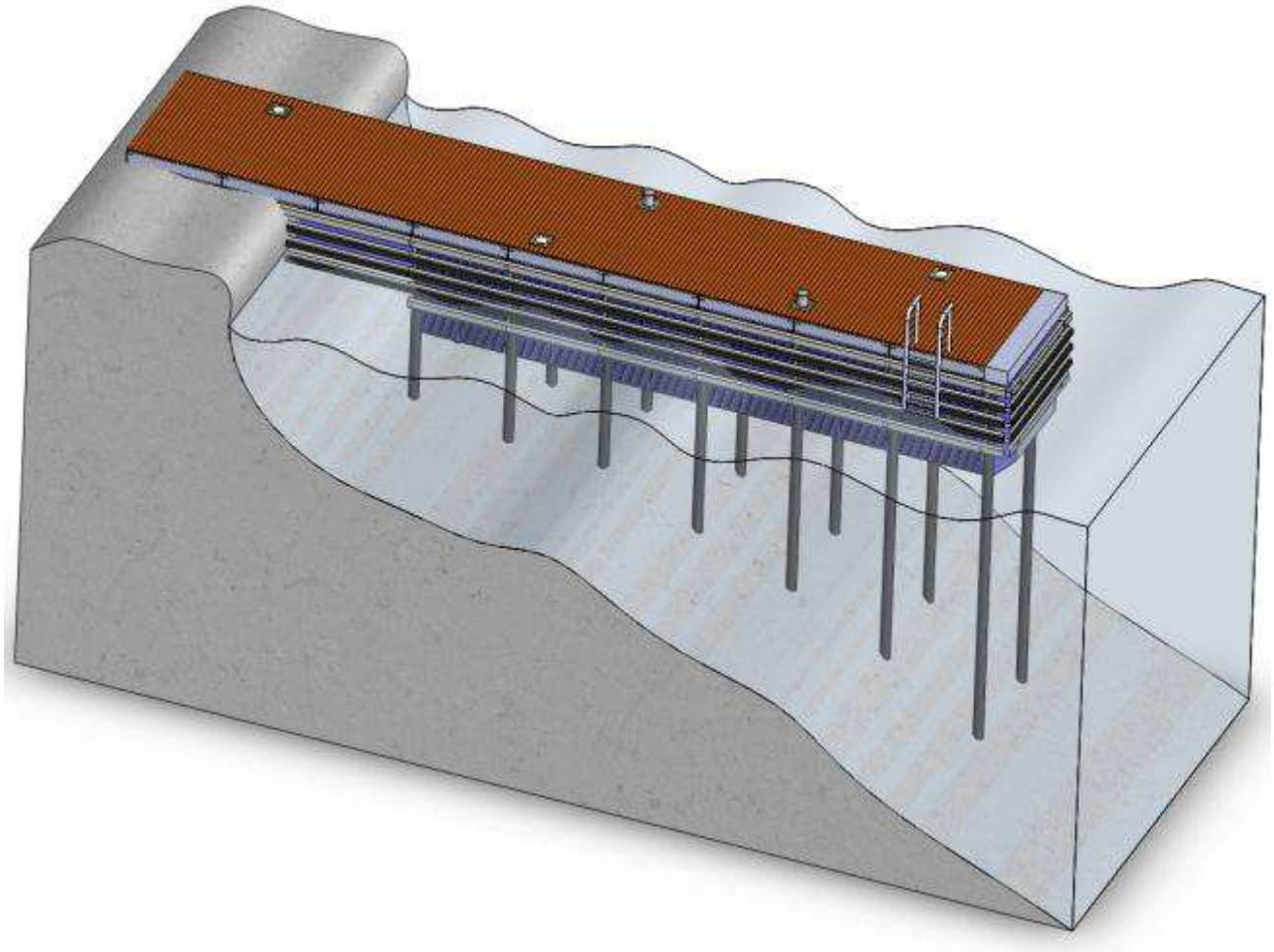


Cabinet for wind turbine and power electronics

OWC chamber

The e-pier design

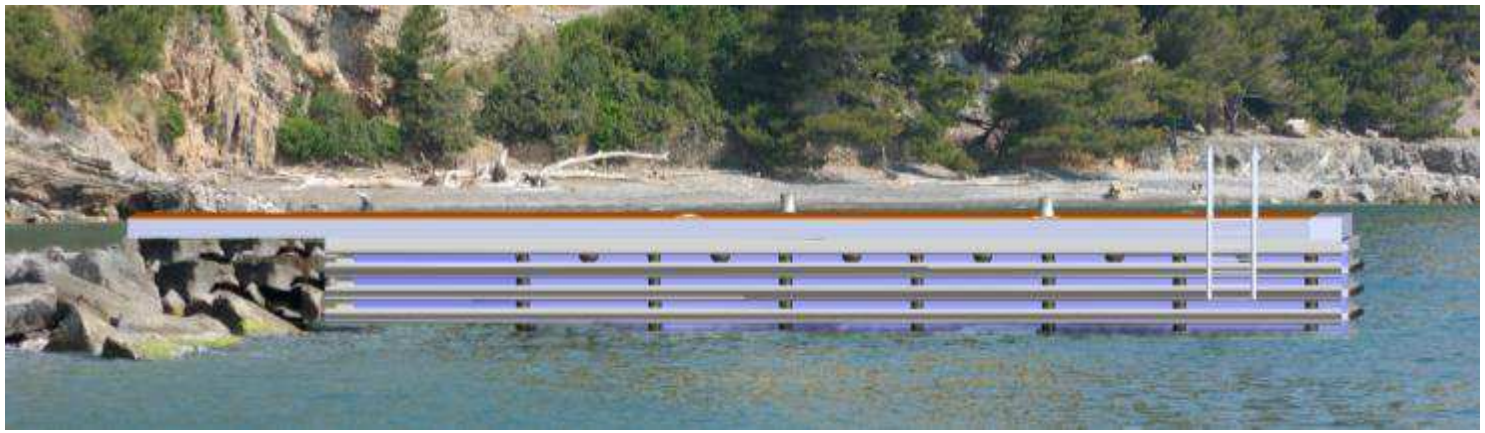
Perspective

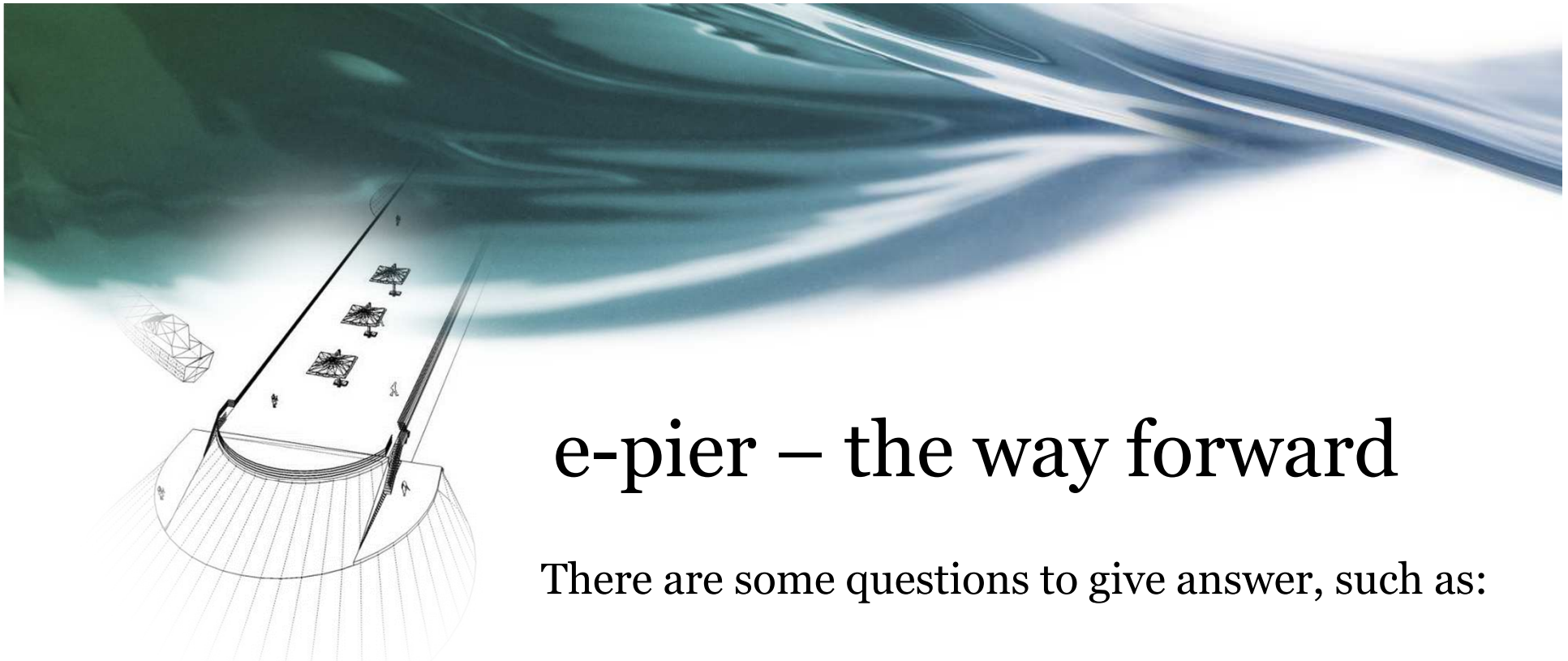


The e-pier design

As it is

After refurbishment





e-pier – the way forward

There are some questions to give answer, such as:

- Which kind of inverter? Current or voltage source?
- Which control features are needed?
- Is it necessary to implement a control for irregular waves and/or for throttle valves to regulate air flow?
- Can be useful an MPPT?
- Which smart control and remote monitoring can be applied?

Many investigations on power electronics have to be done to complete the e-pier design.