WAVE ENERGY CENTRE

Potential and Strategy for the Development of **Wave Energy in Portugal**

Version 0.1

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1. The Energetic Resource

The waves are a result of the continued action of the wind on large surfaces of the ocean. They propagate thousands of kilometres of distance in the sea without considerable dissipation of energy. As a result of being an integrated form of wind energy, wave energy is more stable, predictable and concentrated than wind energy.

Wave energy spreads in the direction of the propagation of the crests. The energy flux per metre of wave crest is proportional to the double of the amplitude and the wave period.

The waves are an important energy resource at a world-wide level, as well as at a European and National level. The gross global resource along shore (annual average) is estimated to be approximately 2TW, which is in the range of the annual average of world-wide electricity consumption. In Europe the resource is ca. 300 GW, and in Portugal around 15 GW on the continent and around 6 GW on the Islands.

Fig. 1 presents the distribution of the average annual flux of wave energy offshore, in kW per metre of wave crest. With its 40 kW/m Portugal is considered to be a region with medium-high resource.

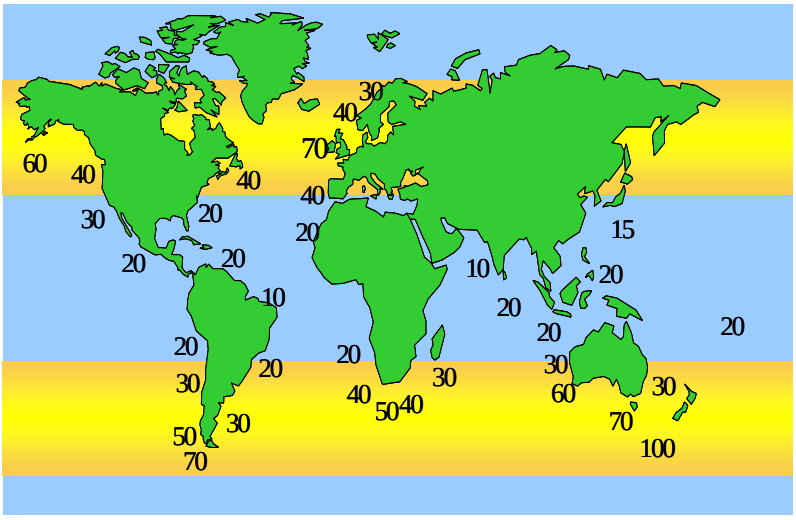
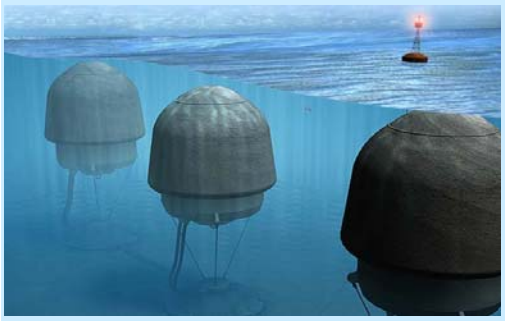


Fig.1 – Distribution of the annual average of wave energy at planetary scale in kW per metre wave crest. It is estimated that the energy can be exploited economically viable when levels are superior to 15~20 kW/m.

2. Actual wave energy prototypes

Currently 4 different types of wave energy technology (AWS, Pelamis, OWC, Wave Dragon) have been / are being tested in the sea (in Portugal, Scotland and Denmark). At the moment it is not possible to identify what or which systems can first become economically competitive; another 4 systems are in an earlier stage of development.

Oscillating Water Column Plant on the Pico Island (400 kW). The production of energy is created with the help of an ar turbine connected to a electrical generator.



Future vision of the AWS. The 2 MW submersed Pilot plant was tested in the sea off the coast of Póvoa do Varzim in 2004. The producion of electrical energy is created by a linear generator. The pilot plant was mounted on a pontoon, leading to a different appearance.

Prototype of the 750 kW Pelamis being tested in Scotland. The conversion of energy is made by hydraulic systems connected to electrical generators.

Wave Dragon pilot plant (scale 1:4,5) being tested in the Baltic Sea. The production of energy is created by hydaulic low-head turbines.

3. The present context

Currently we acknowledge an increasing interest in wave energy at a world level with a rapidly rise of enterprises willing to invest in this field.

The United Kingdom and particularly Scotland define a strategy to become a world leader of this technology aiming to achieve a production of 700 MW systems of wave energy (waves and maritime currents) in 2010, of which 100 MW for internal use and the remaining for exportation, with which it is estimated to create 7000 new jobs.

Iberdrola (Spain) announced the installation of a wave energy farm at the Basque Sea in 2005 of the American company Ocean Power Technology.

In Portugal

Recently the following measures have been taken:

- Constitution of the Wave Energy Centre in March 2003, a private non-profit association formed by 8 companies and 3 R&D institutions;
- Acquisition of Oceanenergia by Enersis, owner company of the submersed AWS pilot plant with 2 MW rated power and tested off the coast of Póvoa do Varzim in 2004;
- Start of the renewal and exploitation of the Pico Plant by the association of companies in the scope of the Wave Energy Centre in 2004;
- Project for the construction of a plant similar to the Pico Plant on the new north breakwater at the Foz do Douro in 2005;
- Preliminary contract between Enersis and OPD (Scotland) for the construction and sea trails of 4 units of the Pelamis (of 750 kW each) in Portugal in 2005.
- Three applications for financing submitted to PRIME in 2003 for the support of the renewal of the Pico Plant, the trails with the AWS and the basic engineering of the Foz do Douro plant, without final decision until the moment.

Comparative Advantages of Portugal

- **Good natural conditions** for the development and exploitation (deep water near the coast, medium-high resources, good weather conditions);
- **Well developed infra-structures** close to potential deployment sites (ports, shipbuilding infrastructures and grid connection points);
- **Technological and scientific background** (More than 25 years of R&D activities at the IST and INETI and involvement of 3 European pilot plants – Pico, Limpet (Scotland) and AWS – have made Portugal to one of the world leaders in this area);
- **High buy-back tariff** for electricity produced from ocean waves.

4. Environmental impact and the conflict of utilisation

Possible configuration of wave energy farms

It is expected that the intensive use of wave energy will be located in a water depth between 50 and 80 metres.

Depending on the technology, the potential of each system to be installed in Portugal shall reach between 0,5 and 4 MW.

20 MW shall be installed per kilometre parallel to the coast with systems sufficiently spaced in the order of 200 metres in one single line parallel to the coast for more potential systems. For less powerful systems this distance shall be of 100 metres between the plants and formed in several lines parallel to the coastline.

In order to reduce the impact on navigation and fishery, **the farms should not have a length superior than 5 km in the direction parallel to the coast. The width of the farms will depend on the type of technology used, reaching between 15 m (AWS) and 1 km (Pelamis). A corridor for navigation of 1 km will be necessary between each pair of farms with 5 km of length.**

Environmental impact and conflict of utilisation utilisation of wave energy farms

It is estimated that the environmental impact of the utilisation of wave energy at water depths between 50 and 80 metres shall be low in accordance to studies and sea trials with pilot plants (AWS, Pelamis and Wave Dragon).

There might be positive impacts on fishery activity associated to the installation of structures that may act as an artificial reef and creation of interdiction zones (the wave energy farms should be interdicted to navigation and fishery for security reasons).

The utilisation of the maritime zone by wave energy exploitation will affect the fishery with little significance, due to the fact that craft work fishery is made at water depths between 20~30 m, sometimes 40 m and trawl fishery is made, by law, beyond 6 miles where the water depth is deeper, except for the Aveiro zone. The surround net fishery could be especially affected, due to the shoal that can be localised temporary in the wave energy farms.

The long-haul navigation of is made far beyond the potential areas for installation of wave energy farms, therefore it is only necessary to reserve access channels to the main ports.

5. Potential for the installation of wave energy farms

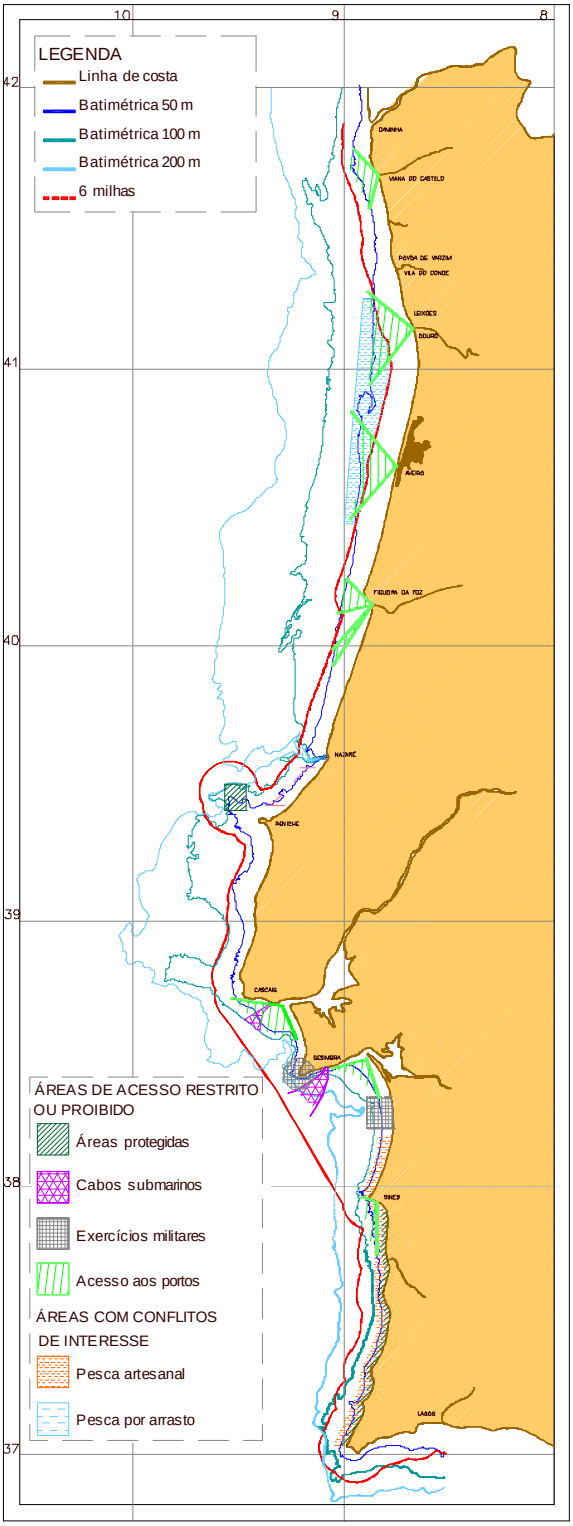
As a result of the study on any conflicts between wave energy farms and fishery, navigation, environment or military zones, the areas have been identified and presented in table 1 and map 1. This study has however no consideration with more specific technical issues linked to the subsoil (important for the installation of submarine cables and anchor systems) and availability of grid connections. **The marked zones sum a total area of around 335 km**, of which at least 20% is reserved to local navigation corridors.

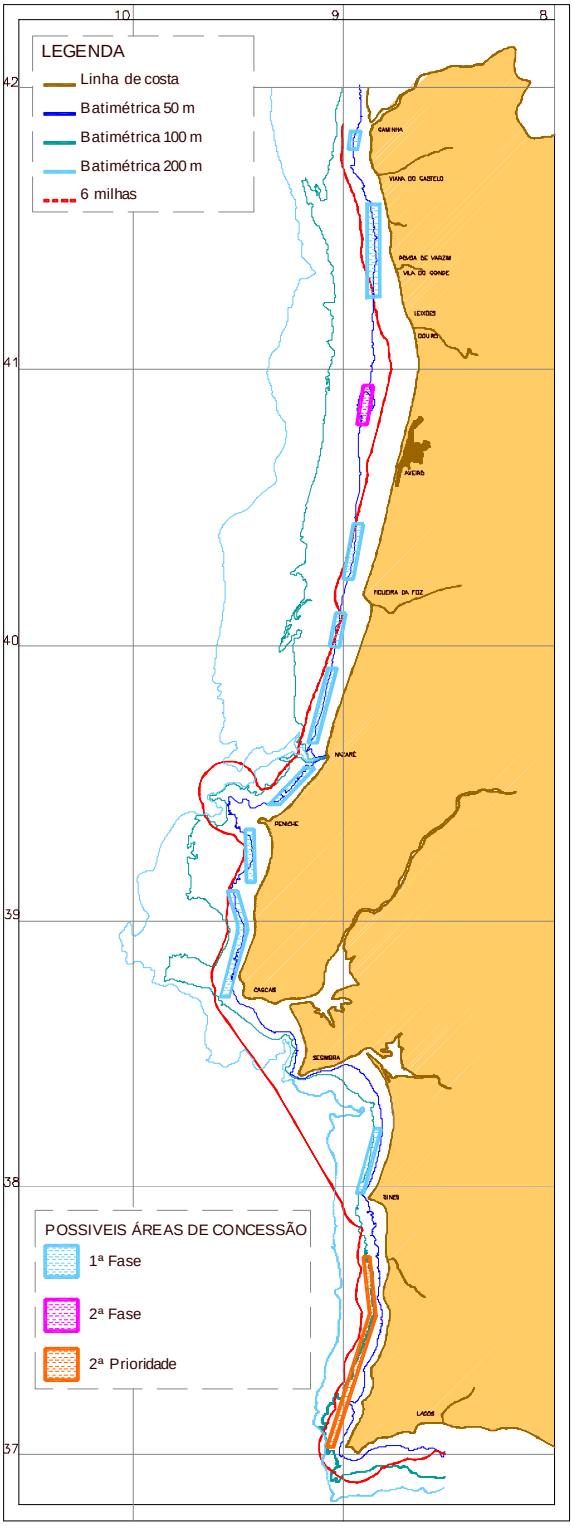
Table 1 – Potential zones for utilisation and possible concession areas for wave energy farms at the Western coast of Portugal.

ZONE	LOCALIZATION	LENGHT	DEPTH
1. PRIORITY ZONES *Without significant interference with other applications*			
1	between Caminha and Viana do Castelo	8 km	50 m
2	between Viana and Póvoa de Varzim	38 km	50 m
3	between Aveiro and Figueira da Foz	24 km	50 m
4	between Figueira da Foz and Nazaré	46 km	50 m
5	between Nazaré and Peniche	22 km	50 m
6	between Peniche and Cascais	71 km	50 m
7	between Sesimbra and Sines	28 km	60 – 80 m
2. SECOND PRIORITY ZONES *Possible conflict with trawl fishery*			
8	between Douro and Aveiro	16 km	50 m
3. SECOND FASE ZONES *Without conflict, nevertheless with difficulties of grid connections*			
9	between Sines and Sagres	82 km	60 – 80 m

Conflict zones

Proposed concession areas





Map 1 – Potential zones for utilisation and possible concession areas for wave energy farms at the western coast of Portugal.

Legend of the previous maps

Conflict zones	Possible concession areas
Legend Coast Line Water depth 50 m Water depth 100 m Water depth 200 m 6 miles RESTRICTED OR FORBIDDEN AREAS Protected areas Submarine cables Military exercises Access to the ports CONFLICT AREAS Craft fishery Trawl fishery	Legend Coast Line Water depth 50 m Water depth 100 m Water depth 200 m 6 miles POSSIBLE CONCESSION AREAS 1st Phase 2nd Pahse 2nd Priority

6. National stategy

The utilisation of wave energy may have a significant socio-economic impact on Portugal, namely regarding production of energy through renewables, creation of job opportunities, opportunity of exportation of equipment and services, innovation and development of technology, as well ascompanies dedicated to the exploitation of other oceanic resources. The level of this impact depends on the development that goes beyond the National scale, as well as the National organisation capacity. The objective is to attract foreign investors by presenting Portugal as an appropriate region for the industrial and commercial development of wave energy utilisation of and to reinforce its technical, scientific and business related capacity to assure a active and intelligent participation of companies and national R&D institutions from the start of the development.

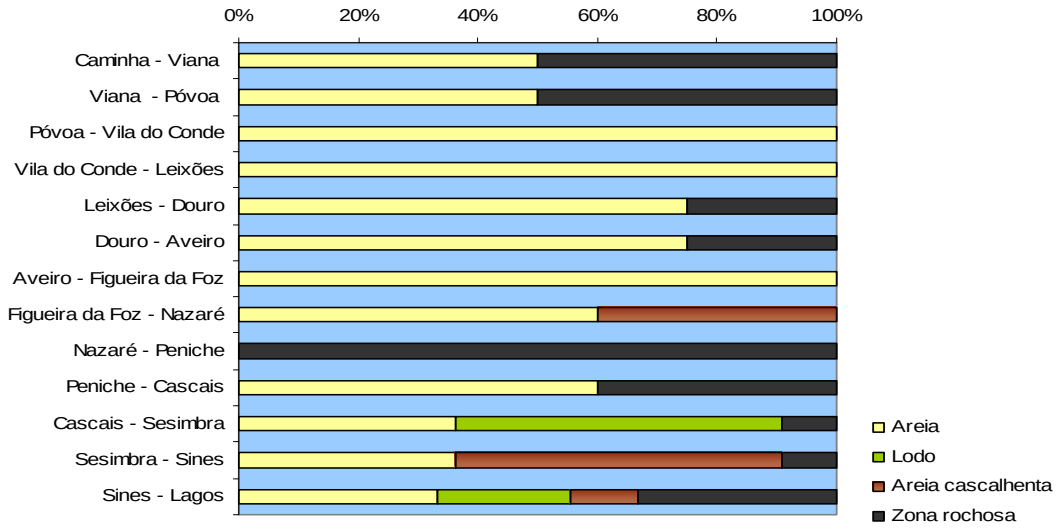
The strategy with the following aims is proposed:

- **Attract foreign projects and investment to this area, if possible involving companies with financial, technological and commercial capacity in association to National companies;**
- **Promote the appearance of a credible National supply chain of equipments, components and services;**
- **Endow the country with legal instruments and clear and agile administrative processes regarding licensing, request of grid connection points, fiscal and financial supports;**
- **Define a licensing and tariff policy for the present phase that promotes the constitution of strong consortia to develop the technology with a significant involvement of National industry and services;**
- **Promote the identification and characterisation of coast areas appropriate to the installation of wave energy farms, regarding waves, wind conditions, currents, water depths, subsoil and supporting infrastructures (ports, shipbuilding yard and grid connection points);**
- **Provide in due time the necessary information to the promoters of wave energy farms;**
- **Create a reflexion group regarding the definition of the National strategy for this area.**

Some figures regarding wave energy in Portugal

Annual average power per wave front	30 MW/km	Power to install until achieving 1M€/MW[1]	1250 MW
Extension of usable coast (at 50 m water depth).....	250 km	Potential of installation in Portugal.....	4500 MW
Average conversion rate into electric energy (from wave to wire) ...	15 %	Necessary investment to achieve 1M€/MW..... ..	1600 M€
Potential of electrical energy production	10 TWh/year	Investment for installation of 250 km in Portugal.....	4500 M€
Annual National production of electrical energy .....[2]	50 TWh/ year	Potential of creation of new direct job opportunities[3].....	7000
Annual cost of installation.....	5 M€/MW	Potential of annual exportation.....	600 M€
Cost to become economically viable.....	1 M€/MW	Potential of annual installation.....	100 MW

Figures relating the subsoil of the water depht of 50 m of the portuguese coast



Legend: "Areia": **sand; "Lodo": mud; "Areia cascalhenta":grit, "Zona rochosa": rocky zone**

Note: the placement of submarine cables is expensive and not recommended in rocky areas

[1] Admitting that the costs are reduced to 15% each time the installed power is duplicated. These numbers do not refer only to Portugal.

[2] Indicative value presented by the responsible of the Scottish Energy and Environmental Foundation at the European Wave Energy Conference in 2003. The real values might be lower.

[3] This number and the next are taken from a study for Scotland.

Appendix

Figures regarding fishery activity at the Portuguese coast

REGION	PORTS	QUANTITY [tons]	VALUE [Mil Esc.]
North	Póvoa de Varzim	6 599	1 373
	Matosinhos	42 771	6 006
Centre	Aveiro	8 023	1 838
	Figueira da Foz	15 969	2 471
L.V.Tejo	Nazaré	4 896	1 813
	Peniche	26 728	5 679
	Sesimbra	18 796	5 913
Alentejo	Sines	9 457	1 857
TOTAL		133 239	26 950

Table 1 – Average between 1990-1998 of the main fishery ports *(MARE Programa Operacional Pesca 2000-2006)*