Marine Energy

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Abstract

New technologies and strategies are often available but have not been implemented in the framework of sustainability practice. The information classified through the SPICOSA SSAs experiences and modelling scenarios can provide a pool of information out of which it is possible to trace a baseline for existing technologies. This article reports a brief review of the Marine Energy technologies that can be considered such as Alternative Strategies to explore some simulation scenarios.

Contents

1 Introduction

The sea is an aquatic environment and a rich source of energy that can be harnessed in a number of different ways. Coastal zones can now benefit from the first technologies developed to capture marine energy, which have now almost reached the commercial operation stage.

The Alternative Strategies in the framework of the SPICOSA Project evaluates technical options for management and monitoring to reduce damaging practices in human activities and is constructing an information base concerning the effectiveness of various ICZM policy strategies.

Coastal zones can also benefit from political initiatives at national and European levels, which can be a source of financial incentives, but before reaching this stage the energy potential of each individual site must be defined (cf. WT10.1 SPICOSA project policy instruments).

It is hence a matter of tapping into these natural, renewable energy sources and drawing up concrete proposals for mobilising this potential, while managing the deployment of this energy across the territory and among the categories of stakeholders concerned.

2 European context

*The European legislative context includes a number of key directives relating to European energy policy. This summary is drawn from the analysis performed in the framework of SPICOSA project (**Policy Instruments).***

This WT reviews the different types of policy instruments and policy implementation schemes and focuses on identifying published and unpublished policy research or policy review papers in the area of CZM but also theoretical material on the institutional analysis of public policies in the broad areas of environment and local development.

Developing renewable energy is one response to the challenges of climate change and fossil fuel resource depletion.

In its meeting of 8 and 9 March 2007 in Brussels, the Council of the European Union proposed an integrated climate and energy policy.

http://www.consilium.europa.eu/uedocs/cms_data/docs/pressdata/en/ec/93135.pdf

Demonstrating the European Union's determination to set precise, legally binding targets, the Council:

- *made a unilateral commitment to reduce greenhouse gas emissions by at least 20% by 2020 compared to 1990,*
- *stressed the need to increase energy efficiency in order to achieve the target of saving 20% of the EU's energy consumption compared to projections for 2020,*

- *approved the target of a 20% share of renewable energies in overall EU energy consumption by 2020.*

The Climate and Energy Package presented by the European Commission on 23 January 2008 proposes solutions to enable the European Union to achieve these targets.

http://register.consilium.europa.eu/pdf/en/08/st06/st06683.en08.pdf

http://www.consilium.europa.eu/uedocs/cms_Data/docs/pressdata/en/envir/100984.pdf

In this package the target of a 20% share of renewable energies in overall EU energy consumption is broken down in the form of binding national targets: all member states must reach a fixed minimum share of + 5,5%, and a variable share modulated according to the GDP of each member state, in accordance with the principle of solidarity.

For France, this represents a renewable target of 23%, since Brussels considers nuclear energy to be non-renewable, even though it means France's greenhouse gas emissions are lower than those of other European countries.

The renewable energy directive was eventually adopted on 17 December 2008, after a compromise between the Parliament and the Council was reached at first reading.

http://www.europarl.europa.eu/sides/getDoc.do?pubRef=-//EP//TEXT+TA+P6-TA-2008-0609+0+DOC+XML+V0//EN

It constitutes one of the key components of the Climate and Energy Package. In addition to confirming the target of a 20% share of renewable energies in overall EU energy consumption by 2020, this directive stipulates that each member state must draw up a national renewable energy plan by 30 June 2010, setting national targets and describing the steps to be taken to achieve them.

3 Presentation of the existing technologies

The SPICOSA Project investigates those advances in available technology (e.g. remediation, ***pollution reduction****, aquaculture, geological risks, etc.) that could provide policy options to reduce damaging practices in human activities. The aim of Alternative Strategies is to evaluate technical alternatives that can be inserted and evaluated as policy options for enhanced sustainability. These would include* ***a large set of new alternatives*** *that may not yet have been introduced as options in any given CZM situation that could reduce the impact of damaging practices in human activities or* ***reduce the cost of implementing sustainable strategies****.*

In many cases, new technologies and strategies are available but have not been implemented. The information classified through the SPICOSA SSAs experiences and modelling scenarios will provide a pool of information out of which it is possible to trace a baseline for existing technologies.

In the following paragraphs a general review on existing technology is provided and in relationship with their advantages and constraints in the framework of sustainability.

4 Reminders and orders of magnitude

The electrical power of a device is expressed in Watts (W). Power represents the maximum quantity of electricity that a facility can produce or consume instantaneously. The most frequently used unit is the MW, i.e. 1 000 kW, or 1 million W. The orders of magnitude of electricity generation facilities are as follows:

- *a prototype marine turbine: 0.5 to 1 MW*
- *a recent offshore wind turbine: 5 MW*
- *the Rance tidal power plant: 240 MW*
- *a nuclear reactor at Flamanville: 1300 MW*

Electrical energy represents the quantity of electricity that this installation produces or consumes over a precise period, expressed in hours. Energy is hence expressed in watt-hours (Wh and not W/h). Thus, a 5 MW wind turbine operating at full power for 3 000 hours produces 5x3 000 = 15 000 MWh = 15 GWh of energy.

The orders of magnitude of energy generation facilities are as follows:

- *a 1 MW prototype marine turbine: 3 GWh*
- *a 5 MW offshore wind turbine: 16 GWh*
- *the 240 MW Rance tidal power plant: 550 GWh*
- *a nuclear reactor at Flamanville: 9 600 GWh*

By way of a comparison, annual electricity consumption in France amounts to approx. 450 000 GWh.

5 Offshore wind power

Winds are generated over vast, obstacle-free expanses of ocean, giving a higher wind potential than on land.

The technologies currently in use are based on wind generators anchored offshore. A new generation of wind generators mounted on floating structures is currently entering commercial operation. This technology will allow the turbine to operate in water depths where bottom-mounted towers are not feasible.

Advantages

- *Better machine utilisation (equivalent full-load hours of operation)*
- *Higher power from the resource*

- *Fewer environmental impacts and nuisances (visual, noise).*

Constraints

- *Difficult marine environment*
- *Possible sea-use conflict*
- *High cost of transmitting the energy produced to shore*
- *Difficult servicing and maintenance conditions*
- *Interference with radar signals*

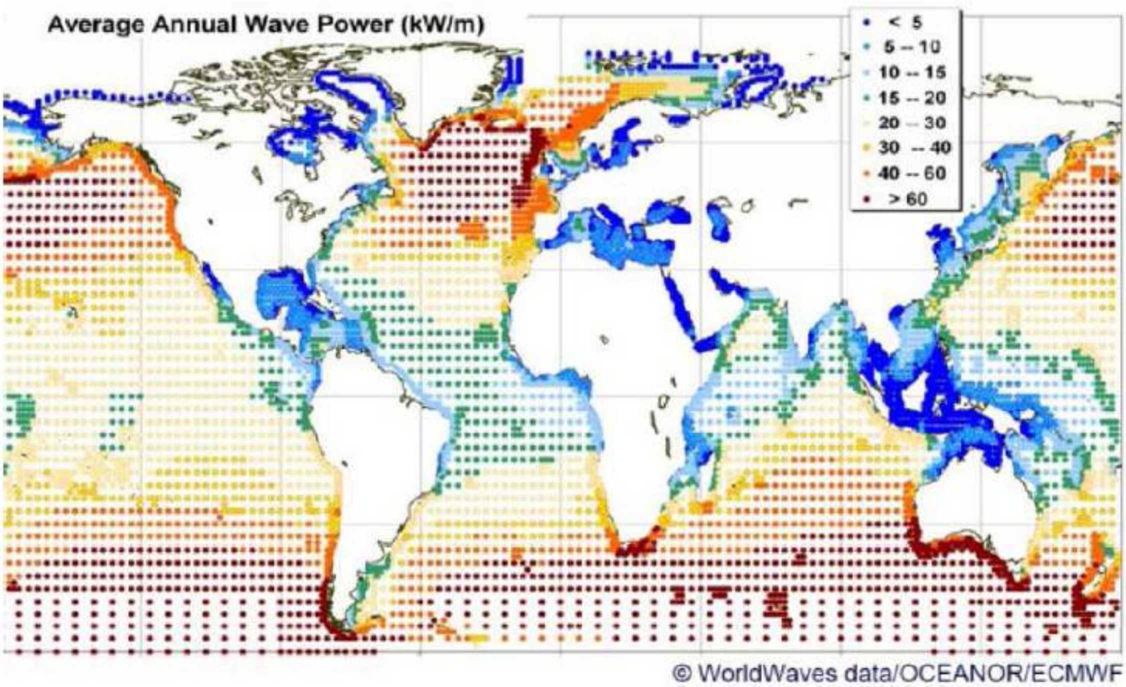
See also:

http://en.wikipedia.org/wiki/Wind_power

http://en.wikipedia.org/wiki/List_of_offshore_wind_farms

6 Wave power

Wind blowing on large expanses of ocean generates an oscillatory motion on the water surface, thus concentrating wind energy. Waves can cover very long distances and transfer the energy collected offshore to the coast. Wave power is approximately proportionate to wind speed to a power of five. According to the WEC (World Energy Council), wave power represents a net available capacity of 140 to 700 TWh/yr, i.e. between 1 and 5% of total global annual demand for electricity. The harnessable energy could even be as high as 2 000 TWh/yr with more efficient conversion systems.



The energy density of a wave farm is approx. 20 to 30 MW/km². The machines are capable of operating for up to 4000 equivalent full-load hours per year. Waves are a random phenomenon that depends on the sea state and, hence, on meteorological conditions. They are 10 times stronger in the winter than in the summer, corresponding to the higher demand for electricity during the winter months. Wave power resources can be predicted on a scale of 3 or 4 days.

The technologies fall within one of the following categories:

- *oscillating water column systems: the water surface acts like a piston that pushes air into a cylinder and drives an air turbine,*
- *overtopping systems: waves break over a slope and into a raised tank. As the water flows out of the tank back into the sea, it drives hydraulic turbines,*
- *attenuator-type floating systems: these are floating devices placed parallel to the direction of wave propagation,*

Source: Ocean Power Delivery Ltd - www.pelamiswave.com

- *point absorber systems: these are floating devices capable of absorbing energy in all directions,*
- *oscillator-type submerged systems: a flap mounted on an articulated arm oscillates with the waves,*
- *pump-type submerged systems: the difference in sea level creates a pressure difference in a piston,*
- *shoreline wave energy conversion devices: these harness breaking waves or use the oscillating water column principle.*

The latest generations of these systems are installed offshore, whereas the older generations had to be close to the coast. Wave power is no doubt the marine energy field with the widest range of available concepts.

Advantages

- *The resource is predictable even though it varies over time.*
- *A wide variety of technologies are available to harness this resource and can be adapted to suit the conditions of each specific area.*

Constraints

- *Systems must be able to survive extreme maritime conditions.*
- *With the exception of systems mounted to bridge piers, wave power is not compatible with fishing and fauna are likely to be disturbed by noise.*

See also:

http://en.wikipedia.org/wiki/Wave_power

http://en.wikipedia.org/wiki/Wave_farm

7 Tidal power

Tides generate powerful currents that are concentrated under the effect of variations in bathymetry and coastline at certain places. Locally, areas at estuary outlets and in arms of the sea may also constitute potential sites.

The greater the current velocity, the greater the potential for electricity generation, which proves that it is economically advantageous to set up power plants in areas with strong currents. Taking into account the hydrodynamic efficiency of the rotors, the average power obtained is in the order of 1,2 kW/m² with a 2 m/s current and 4 kW/m² with a 3 m/s current. Since the strongest currents are exceptional (spring tides), the machines are sized electrically for a current velocity that occurs frequently.

The predictability of tidal currents makes them suitable for base-load but intermittent production. The energy density of an offshore tidal power plant is in the order of 20 to 30 MW per km² at favourable sites, compared with the 8 to 10 MW/km² obtained at offshore wind farms. Marine turbines are capable of operating for 2 500 to 3 000 equivalent full-load hours per year.

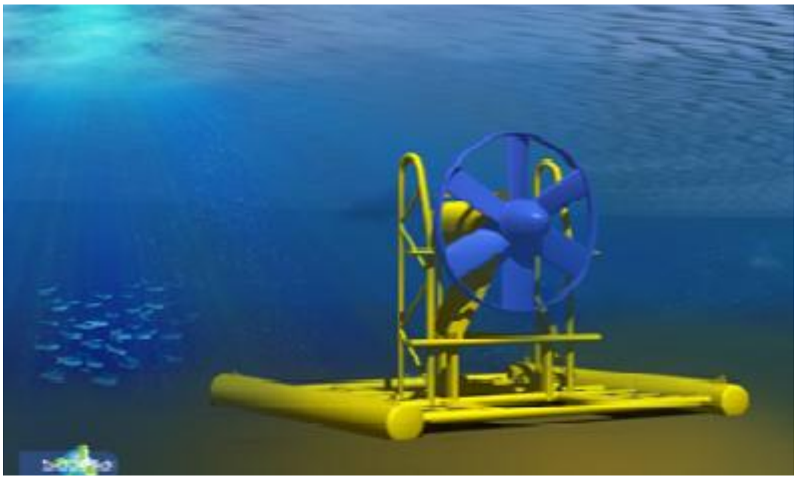
300 kW prototype marine turbine (here the cradle is shown before being submerged in the current)

(source: Des énergies marines en Bretagne: à nous de jouer, Région Bretagne !, Région Bretagne, 2009)

Installation and maintenance are carried out using maritime equipment.

The technologies fall within the following categories:

- *horizontal-axis crossflow turbine: this system captures energy from the moving seawater in a similar manner to wind turbines driven by wind action.*



Source: Hydrohelix - www.sabella.fr

- *vertical-axis crossflow turbine,*

- *oscillating hydrofoil: energy is produced by an oscillating device driven by the currents on either side of the "wing". This movement then drives a fluid in a hydraulic system in order to generate electricity.*

- *Venturi effect: this turbine-based system exploits the increasing current velocity in a shroud with a decreasing diameter (venturi effect).*

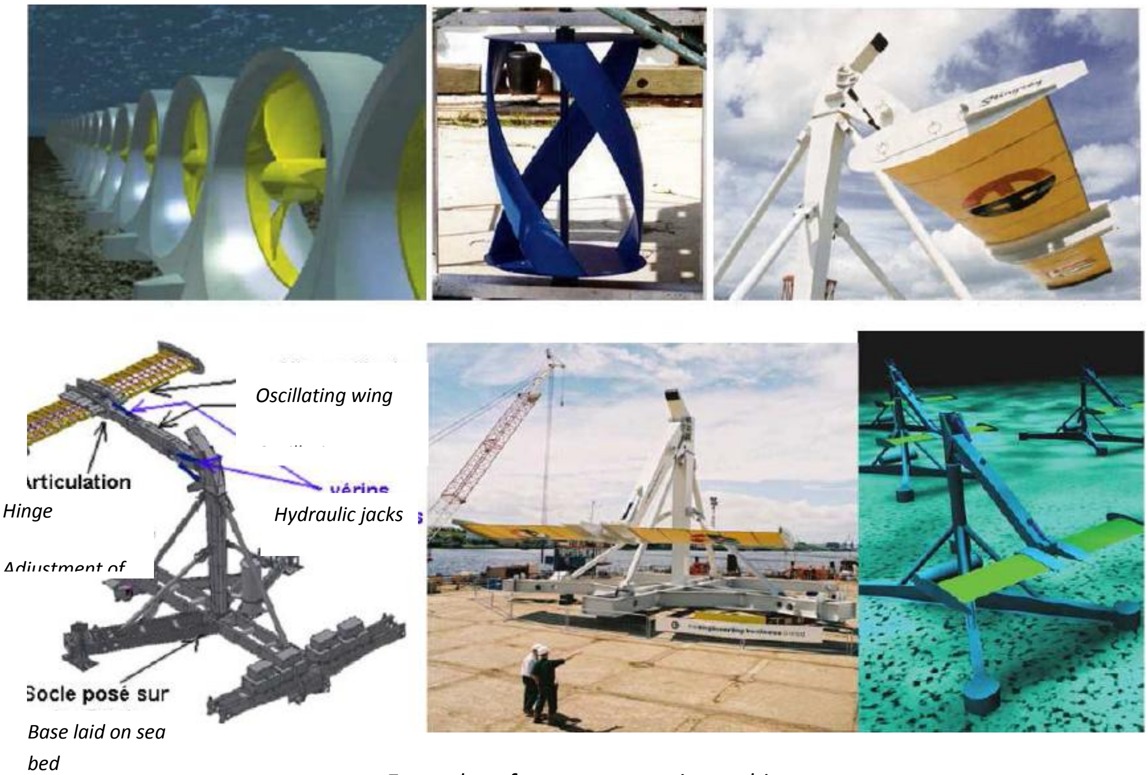
The technologies may be also be defined in terms of their capacity:

- *Capacity of about 1 MW, installed in the open sea: these machines measure 10 to 20 meters and require current velocities greater than 2 m/s.*

- *Capacity of 10 to 50 kW, installed in stream currents, estuaries, or on bridge piers: these machines can operate in currents with very low velocities.*

The fixing systems may be gravity-based (placed on the sea bed), floating, or attached to a bridge pier or other existing structure. Each technology has its own specific advantages. It should be noted that, in addition to the characteristics of the resource, the nature of the sea bed is a key criterion when selecting a technology.

Installation and maintenance are carried out using light maritime equipment. The visual and environmental impacts are limited. The first prototypes are already operational in Norway and the United Kingdom.



Examples of prototype marine turbines

Advantages

- *Highly predictable yet intermittent resource: good for base load operation.*
- *Not highly dependent on the weather.*
- *A wide variety of technologies are available to harness this resource and can be adapted to suit the conditions of each specific area.*

Constraints

- *Systems must be able to survive extreme maritime conditions.*
- *With the exception of systems mounted to bridge piers, tidal power is not compatible with fishing and fauna are likely to be disturbed by noise and vibrations.*

See also:

http://en.wikipedia.org/wiki/Tidal_power

http://en.wikipedia.org/wiki/List_of_tidal_power_stations

8 Osmotic power

A semi-permeable membrane placed in contact with fresh water on one side and sea water on the other side is placed under osmotic pressure. This phenomenon can be harnessed to capture energy.

Two technologies exist:

- *pressure-retarded osmosis*
- *reverse electro-dialysis*

Although a prototype of the first technology was recently inaugurated (in Norway), the second is progressing more slowly. The main difficulty lies in manufacturing the membrane.

Advantages

- *Stable and controllable production: good for base load operation.*
- *Independent of the weather.*
- *Installed on-shore.*

Constraints

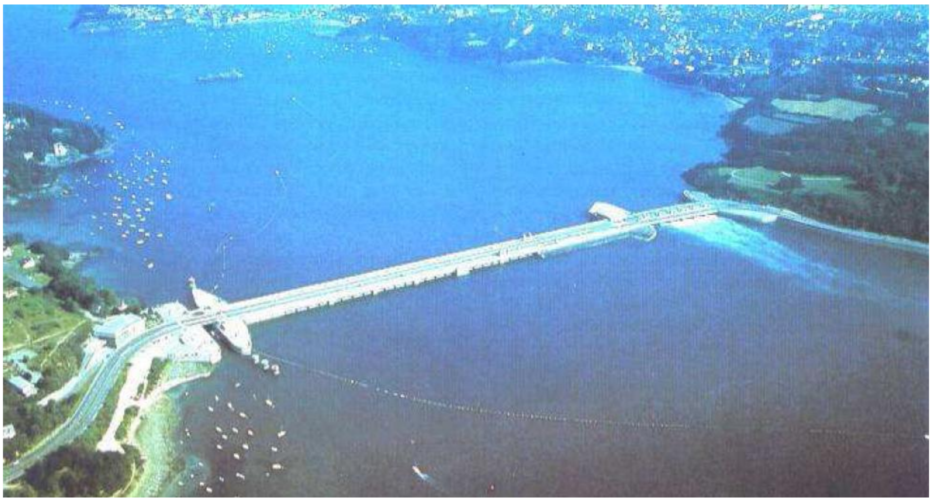
- *Presence of large quantities of fresh and sea water on-site.*

See also: http://en.wikipedia.org/wiki/Osmotic_power

9 Barrage tidal power

The ebb and flow of the tide is used to alternately fill and empty a basin while operating turbines built into the barrage forming the basin.

This technology can only be implemented in highly specific conditions and it is practically impossible to create new large-scale facilities because of the environmental impact. One alternative exists, involving creating a man-made lagoon.



Source: EDF – Rance tidal power plant

Advantages

- *Highly predictable yet intermittent resource: good for base load operation.*
- *Independent of the weather.*
-

Constraints

- *High environmental impact.*
- *Few suitable sites.*

See also:

http://en.wikipedia.org/wiki/Tidal_barrage

http://en.wikipedia.org/wiki/List_of_tidal_barrages

10 Algae biofuel

The principle consists in using or cultivating macro- or microalgae in order to extract sugar and oil respectively to produce algae fuel or biogas.

Algae fuels, which have already been classed as third-generation biofuels, offer the major advantage of not competing with food crops or fresh water resources. The best photosynthetic yield is obtained from microalgae, which reproduce quickly and continuously, producing vegetable matter yields that are much higher than those obtained from terrestrial plants. The yield from rape and sunflower is 1 g/m²/day.

The Innovalg company, in the Vendée department of France, claims to have achieved 13 g/m²/day from an open-air facility, while Ifremer has obtained 30 g/m²/day in a controlled photobioreactor. Whereas the best palm trees yield 6 000 litres of oil per hectare, microalgae could produce 24 000 l.

There are several "technologies" in existence:

- *Production in "raceway" ponds (open ponds with an average depth of 0.3 m),*
- *Photobioreactors,*
- *Controlled cultivation in enclosed ponds.*

Advantages

- *Higher yields than from terrestrial biofuel crops.*
- *Form of energy storage that can be used as a substitute for conventional fuel applications.*
- *Algaculture does not compete with food cultivation.*

Constraints

- *Requires large expanses of land by the sea*
- *Fairly recent (experimental) technologies*

See also:

http://en.wikipedia.org/wiki/Algae_biofuel

http://en.wikipedia.org/wiki/List_of_algal_fuel_producers

11 Feasibility study of facilities

Assessing the feasibility of marine power facilities involves listing and conducting a comparative analysis of a large quantity of basic data:

- *oceanographic constraints,*
- *environmental constraints,*
- *human constraints,*
- *administrative constraints.*

Potentially suitable areas for building a marine power plant can be determined by juxtaposing all these data and factoring in all the relevant constraints.

The adaptability of the various technologies to the coastal area being studied depends on a combination of their technical characteristics (dimensions, foundations, etc.) and the constraints of the site(s) being studied (water depth, nature of bed, etc.).

Other SOGREAH expert involved: Bernard Yon