EUSUSTEL

European Sustainable Electricity
Comprehensive Analysis of Future European Demand and
Generation of European Electricity and its Security of Supply

WP3: Electricity generation technology and integration system

Energy from the Sea

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Contents

The oceans cover about 70% of the terrestrial area. They contain a lot of energy. A small part of it can be used. Maritime energies which are technically available are the following:

- Offshore wind power
- Wave power
- Tidal power
- Tidal power
- Thermal energy conversion
- Osmotic power from salinity gradients

Studies have already started in several countries in all these domains. We shall focus our attention on the four first kinds of energies.

Off shore wind power:

It is not really a maritime energy, but its exploitation on sea presents some particularities. The wind intensity is stronger and wind blows more regularly than on the land, therefore the yield is better. Seas are larges spaces without obstacles, where implantation is in principle ideal. But there are lots of technical constraints to build offshore windmills, which favor the construction of large power machines to decrease electricity cost.

Offshore windmill have nowadays a power ranging from 2 to 5 MW. An offshore farm corresponds to about 6MW/km^2 and could produce about 20 GWh of electricity per km^2 and per year. The average investment is between 1500 and 2500 €/kW, 3000 €/kW for hard building conditions. The cost of the electricity produced ranges from 70 to 100 €/MWh. It is expected to decrease down to 40-60 € /MWh with the development of larges farms. These costs are including all expenditures during the life of the farm, from construction to dismantling.

Wave power

Wave energy is a concentrated form of wind energy issued from the sun. The 20 first meters of water of Atlantic Ocean are sweep over by a swell energy of about 2,5kW/m^2. Most part of the European coasts is concerned.

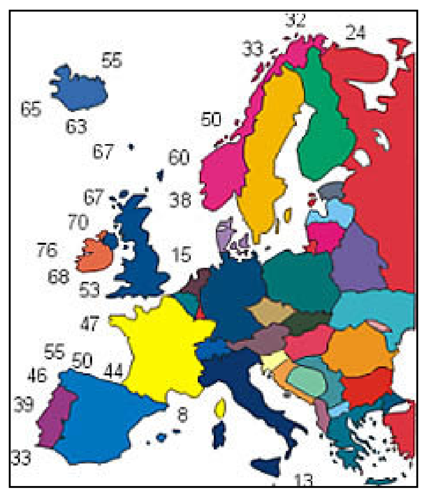

Figure 1 Average wave power on European coasts (kW/meter of coast)

From the economical point of view, costs have strongly decreased. The investment is about 1000-3000 €/kW, depending on local conditions, for an annual operation of about 4000 hours. Current electricity costs range between 50 and 100 €/MWh.

Ocean waves can produce electricity using an Oscillating Water Column (OWC). This system consists in a large column open in the sea at the bottom and a turbine at the top. When a wave hits the OWC, the water inside the column rises, and the air inside is compressed and moves upwards. When the wave falls the air is sucked back down. A two-way turbine spins when the air is forced upwards by a wave, and continues to spin in the same direction when the wave drops and the air is drawn back down again. The air turbine at the top of the column is connected to an alternator generating electricity.

The first successful OWC device was produced in Japan to power light for navigation. Most OWC’s are experimental. An OWC used in Norway is one of the most advanced wave-to-energy generators in the world, developing an electric power of 500 kW. This had a 19.6 meter steel chimney pipe that went 7 meters into the ocean. This device, along with most others, suffered from the unpredictability of the ocean waves and damage to the plant may occur when gale or storm are raging.

Other devices, such as “Salter Ducks”, use the bobbing motion of waves. When they were tested, rough seas damaged them.

The Tapered Channel Station, or TAPCHAN, directs waves into an ever-narrowing channel in which the water is forced to climb 10 to 15 meters into a dam. Water from this dam then flows back down to the sea through a hydro turbine to produce electricity.

Trials have been conducted on various types of wave electricity-generation equipment since the early 1970's, but Oscillating Water Column (OWC) systems have been the most successful.

OWC's have been built and tested in Japan, Norway, India, China, Scotland and Portugal. Portugal and Scotland use this technology to produce small amounts of electricity. The Islay Oscillating Water Column, In the west coast of Scotland, has been running for 10 years and produces a power of 75 kW.

These units are designed to generate up to 2 MW, for short periods, but have not been operated during extended periods.

Wave electricity generation is a source of clean, renewable energy and does not produce any greenhouse gases. The unpredictable characteristics of the sea waves remain a problem with wave electricity generation.

Facilities need to be built to withstand the effects of waves under exceptional circumstances. Indeed, waves can exert forces 10 times stronger than normal waves.

Electricity generating facilities using waves may cause changes to coast lines and local ecosystems.

Current power

There are ocean currents and some of them are quite important close to European coasts. Their carry a lot of kinetic energy and part of it can be transformed to electricity using submarine windmills. Those are most compact than windmills used on the land just because the water density is much larger than the air density. The physical characteristics of sea currents are well known. The power is about 1,2W/m^2 for a current of 2m/s, and 4kW/m^2 for a current of 3m/s.

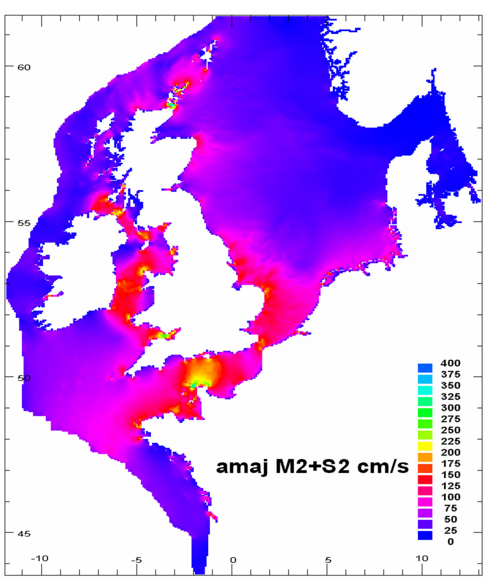

Figure 2 : current tidal resource in Europe

The potential sites for exploiting current power are those where the current speed is faster than 175 centimeters per second in the map. This concerns mainly France and United Kingdom. In the Channel, the time difference of the tides theoretically permits to obtain a continuous power by installing submarine windmills all along the coast.

Researches and experimental projects are made, in particular in France, to develop installations up to 1 MW. Prototypes with a power about 300kW are already running in Norway and United Kingdom.

Tidal energy

Tides are the daily rise and fall of ocean level caused by the gravitational forces of the moon and the sun. The exploitation of tidal energy is a known technology for a long time. It consists in a system of dams and storage basins, like at La Rance, the French tidal power plant (240 MW, 91% of world capacity). The periodic nature (12h) of the resource implies that plants are generating only 4 or 5 hours per cycle and one cannot generate electricity continuously. However, since the use of this energy is predictable, the reversibility of the plant permits to pump the water during slacks periods and store energy. It has not the flexibility of hydraulic plants and the cost is about two to three times more expansive than conventional hydraulics.

Tidal power stations need to be set up in places like estuaries and along beaches that have very high and low tides. A wall is built across a beach or river. As the tide comes in, and the sea level rises, the water flows through a turbine in the wall to produce electricity. A slide gate is lowered to hold back the water behind the wall. When the tide goes out and the sea level falls the slide gate is raised and the water flows out through the turbine. The turbine is connected to the alternator, which produces electricity. It is a two-way turbine and can produce electricity on incoming and outgoing tides.

Tidal mills were invented in the early 1900's. They only used the energy of outgoing tides. When the tide came in a floodgate was lowered trapping the water behind it. When the tide was low the gate was lifted up and, as the water flowed out, it rotated a water wheel.

Tidal power stations are already being used in France, Russia and China. The station that generates the largest quantity of electricity is on the Rance River in France. It has a power of 240 megawatts. This tidal plant was built in the 1960's and is the only long-term operational tidal electricity plant. The tidal head difference there is approximately 15 meters.

Figure 3: aerial photography of the La Rance plant

Australia has large tidal differences in northern parts of the country but many of these occur in relatively remote areas where there is a limited demand of electricity. Several other tidal plants in China, India, Canada and Russia have been build with some smaller generating capacity plants still operating.

Tidal electricity generation does not produce greenhouse gases. Electricity produced in this way could replace electricity that is generated from fossil fuels. This would contribute to the reduction of CO_2 being released into the atmosphere. Operation and maintenance costs for tidal generation plants are low. The development of electricity generation plants using the energy of tides involves high initial building costs.

The plants change existing environmental systems by controlling tidal waters in coastal inlets. The process of trapping water in inlets for extended periods of time interferes with fish spawning and breeding cycles in that area. Fish could be injured attempting to pass through water turbines to reach spawning grounds. Tidal dams could contribute to environmental harm by trapping pollutants that have been released into the rivers upstream from the dam.

For tidal electricity generation to be viable tidal variations greater than 15 meters are required. These large variations occur in a limited number of countries in the world.

Conclusion and synthesis

There are several possibilities to exploit energies from the sea. The four technologies discussed here have a large potential of development although they are still not economically competitive. Anyway, environmental impacts should be systematically studied.

Energy	**Offshore wind power**	**Wave power**	**Tidal currents**	**Tidal power**
Development in UE	612 MW in 2004 2000MW in development			
Availability	Intermittent	Intermittent	Intermittent	Intermittent
Predictability	In progress	Good	Excellent	Excellent
Predicted costs	50-100 €/MWh since 2015	50-70€/MWh since 2015	50-70€/MWh since 2015	

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