Wave Dragon

The Wave Dragon™ Reality

The Wave Dragon™ prototype (above) has been tested in real sea since March 2003. The white container is for test purposes.

The Wave Dragon™ floating wave energy converter is developed for large scale power production using well-proven technology. The Wave Dragon™ prototype produced its first power to the grid in May 2003.

Fact sheet

	Prototype	*Full size*
Yearly average wave climate	*0.4 kW/m*	*36 kW/m*
Weight, concrete, steel and ballast (tonnes)	*237 t*	*33,000 t*
Total width and length (meters)	*58 x 33 m*	*300 x 170 m*
Height	*3.6 m**	*19 m*
Height above sea level	*<1.5 m**	*3 –7 m*
Water reservoir	*55 m^3*	*8,000 m^3*
Number of propeller hydro turbines	*7*	*16 – 20*
Generators	*PMG*	*PMG*
Rated power	*0.02 MW*	*7 MW*
Annual power production/unit	*-*	*20 GWh/y*

** Control container not included.*

Wave Dragon™ is a clean power generation technology even compared to other renewables: very low visibility, modest “footprint” on seabed, no noise and no risk of spill.

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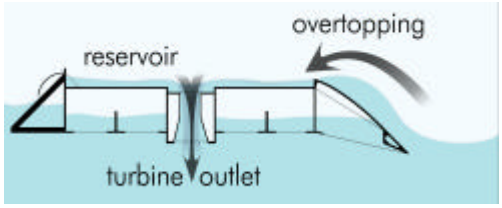
Simple construction - complex design
The basic idea of the Wave Dragon™ wave energy converter is to use well-known and well-proven principles from traditional hydropower plants in an offshore floating platform.

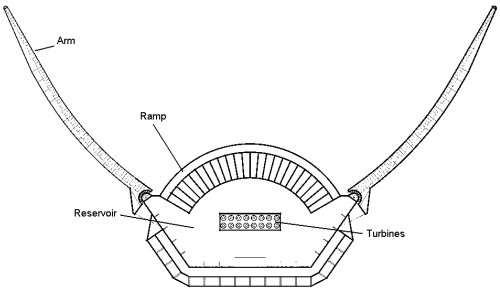


It is very simple: The Wave Dragon™ overtopping device elevates ocean waves, and the water overtopping Wave Dragon™ is stored temporarily in a large reservoir creating a head, i.e. the difference between the "normal" level of the water surface and the water surface in the reservoir. This water is let out of the Wave Dragon™ reservoir through several turbines, thus generating electricity like in hydro power plants.

The construction is equally simple and has only one kind of moving parts: the turbines. This is essential for any device bound for operating offshore where the extreme forces and fouling etc seriously affect any moving parts. One has to imagine the Wave Dragon™ moored (like a ship) on relatively deep water (>25 meters) to take advantage of the ocean waves before they lose energy as they reach the coastal area. Wave Dragon™ is a floating device designed to be very stable in storm waves. The roll and pitch movements are much smaller than seen for ships of comparable size. It doesn't convert waves to energy by popping up and down or by some parts being moved by the motion of the waves. It simply utilizes the potential energy in the water that overtops it.

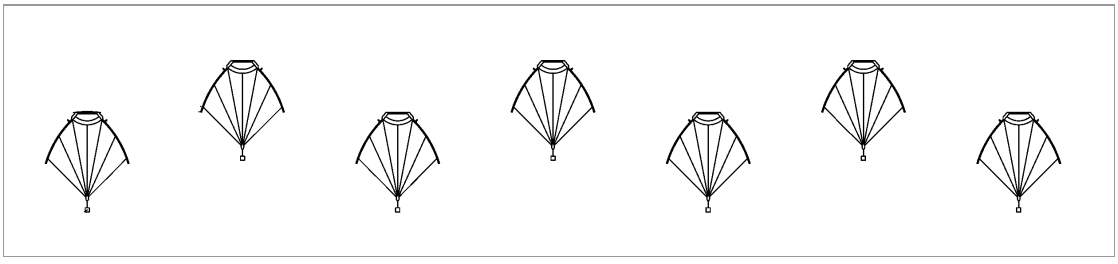
But yet Wave Dragon™ represents a very complex design where large efforts have been spent on design, modelling and testing in order to produce as much electricity as possible at the lowest possible costs - and in an environmental friendly and reliable way.

Overtopping
To most offshore and breakwater devices extensive effort is done to avoid overtopping. With its doubly curved ramp and wave reflectors Wave Dragon™ is in contrast to that designed to maximize the amount of overtopping water.



The wave reflectors (arms) concentrate the wave energy and thereby the water flow overtopping the ramp. The Wave Dragon™ ramp can be compared to a beach. When a wave reaches a beach it looses energy by friction against the bottom and by wave breaking. The Wave Dragon™ ramp is very short and relative steep in order to minimise the energy losses. The wave changes its geometry, too, and elevates. The special elliptical shape of the ramp optimizes this effect, and model testing has shown that overtopping increases significantly.

Wave Dragon™ Farms
Offshore wave energy converters will most profitably be - as it is the case with wind turbines - arranged in farms. Wave energy farms will typically provide more power pr. km^2 than wind farms. A typical 7 unit (~50-70 MW) Wave Dragon™ farm is illustrated below.



Such a farm will have a length toward the wave front of 3.9 km and will occupy 3.2 km^2. The rated power relative to the use of sea will thus be 15.3 MW/km^2.

At the present wind farms being deployed off the UK coast occupy between 11 and 13 MW/km^2.

Wave Dragon™ Environmental Impact Assessment – Generic Scoping Study

Wave Dragon™ prototype from a distance of 350 meters with 2MW wind turbines 8.5 km away.

Potential Environmental Impacts and Mitigating Measures

Below are listed construction, operating and decommissioning activities associated with the Wave Dragon™ technology. For each activity potential environmental impacts are stated as well as the associated mitigation measures.

Various studies and guides for offshore wind farms have been used in compiling this list for a Wave Dragon™ farm.

Construction and Installation Activities

Activities	***Potential Impacts***	***Mitigation Measures***
Subsea cables	Temporarily affect the nature of sub tidal habitats in the cable duct. Comparable to effect known from e.g. offshore wind projects.	Identification of important habitats for fisheries, benthos etc. and avoiding laying cables in these areas.
	Damage to archaeology sites.	Identify potential sites and avoid these.
Onshore cables	Will temporarily affect the nature of shore habitats. Comparable to effect known from e.g. offshore wind.	Identification of important habitant or scenic places and avoid going onshore at these locations.
Installation of mooring system	Temporarily affect the nature of sub tidal habitats. Effects are known from mooring of ships.	Identification of important habitats for fisheries, benthos etc. and avoiding deployment of mooring blocks in these areas.
Construction of Wave Dragon™	Wave Dragon™ will not be constructed on site but towed to the site from the dry dock where it is constructed.	A separate EIA will be made if a purpose build dry-dock is established. Sensitive areas will be avoided and the area re-establish after use.
Vessels traffic during installation	Installation of the mooring arrangement and deployment of the Wave Dragon™ units will cause an increased amount of traffic. Can affect sea birds • Moulting • Breeding, and • Resting Comparable to the effect known from existing vessel traffic.	Installation will be carried out with respect to the breeding, resting and moulting periods of sea birds species.

Operation and Maintenance

Activities	***Potential Impacts***	***Mitigation Measures***
Physical presence of moored structures at sea	Will have some impact on landscape and be visible.	The colour and design of the Wave Dragon™ structure will – to the extend possible with regard to marking requirements and to the operation of the Wave Dragon™ - be adjusted to minimise visual impact. Compared to wind turbines the visual impact will be low.
	Effects on sea birds in periods of breeding, moulting and resting.	Due to the non-motional nature of the Wave Dragon™ negative effects are not likely. Impacts are studied in the present prototype project situated in a RAMSAR and EU bird protection area.
	Positive effects on fish resources • Will create a fishery exclusion zones • Artificial reef effect will attract fish	No mitigating measures needed. See below.

Operation and Maintenance (continued)

Activities	*Potential Impacts*	*Mitigation Measures*
(continued)	Negative effect on fisheries	Locations have to be chosen with respect to commercial and recreational fisheries.
	Effects on mammals • Both the back side of the arms, mooring buoys, the ramp and horizontal trash rag covering the reservoir will attract resting seals	Design will be adapted to the optimal solution for the seals.
	Effect on navigation: Will affect the navigational use by commercial ships, fishing vessels and recreational boating.	Standard marking of the structures and the area: lights, colours, radar reflection. Wave Dragon™ farms will be located out of traffic zones.
	Reduce marine debris and spill of oil from ships washed on shore. A substantial part of this debris will end in the reservoir.	No environmental mitigating measures needed.
	Changes in the hydro physical regime due to extraction of energy from the waves may cause: • Impact on coastal processes as erosion and sediment transport. • Changes in the marine habitats • Reduced recreational value, i.e. regarding surfing due to smaller waves.	Wave Dragon™ farms will extract energy from waves and to some extend changes the hydrodynamics behind a farm. Wave heights are initially estimated to be between 37 % to 22 % lower 1 km behind a Wave Dragon™ farm. Effect will be subject to generic and site specific hydrodynamic studies and the results from these will act as guidance in the site selection process.
Presence of subsea cables in seabed	Electromagnetism	The subsea cables will be buried in the sea bed.
Operation of the turbines	Fish and mammals will to some extend travel with the overtopping sea water into the reservoir. This may cause physical damages on fish and mammals from passage through hydro turbines. Impact level: Permanent – low.	Establishing of a trash rag covering the total reservoir preventing fish and mammal access to the reservoir and turbine system (as known from traditional hydro power stations). Fish smaller than the openings in the trash rag will pass through the operating turbines. A turbine with a slow turning (300 rpm) propeller has been chosen.
	Increased level of noise and vibrations may affects mammals dependent on sound for navigation.	Noise and vibration impact level will be low. If necessary measures to dampen these effect will be taken. Areas with abundance of cetaceans will be avoided.
	Leaking of hydraulic fluids	Water hydraulic has been chosen to eliminate any possibility for leaks of oil to sea water. No other potential polluting fluids etc. onboard.
Presence of mooring arrangements	Mooring blocks on sea bed will locally affect the nature of sub tidal habitats	Identification of important habitats for fisheries, benthos etc. and avoiding deployment of mooring blocks in these areas.
	Mooring chains moving on the seabed may damage the nature of sub tidal habitats	Design mooring arrangement I a way so chains are kept free of the sea bed.
	Mooring arrangement – blocks, chains and buoys – may have an artificial reef effect with locally increased wildlife in quantity and diversity.	No mitigating measures needed.
Overhead-lines and substations onshore	Can reduce the aesthetic value of the landscape.	Landscape and visual assessment to identify route and location of infrastructure.
Maintenance	Offshore installations and machinery require regular maintenance. Wave Dragon™ is modularly built and it is expected that components as turbines will be replaced on a regular basis for maintenance onshore. This will generate vessel traffic.	Maintenance will be carried out with highest possible respect to the breeding, resting and moulting period of sea birds species.
	Maintenance on mooring arrangements, marking equipment and the Wave Dragon™ structure will be performed on site. This will generate vessel traffic.	Maintenance will be carried out with highest possible respect to the breeding, resting and moulting period of sea birds species.
Anti fouling	There will be emission from any toxic antifouling.	Toxic antifouling is not used, as the weight from fouling is not a problem. A non-toxic silicone based slippery coating is tested in the turbine system (turbine outlet) in the present prototype project.

Decommissioning

Activities	*Potential Impacts*	*Mitigation Measures*
Removal and decommissioning of WEC from site	No impact near the deployment site.	The structure will be towed to an appropriate site for re-cycle and decommissioning. Wave Dragon™ is designed and constructed in a way to ease recycling.
Removal of mooring arrangements	Will temporarily affect the nature of sub tidal habitats.	Available low impact techniques will be used.
Removal of subsea cables	Will temporarily affect the nature of sub tidal habitats.	Available low impact techniques will be used.

October 2003