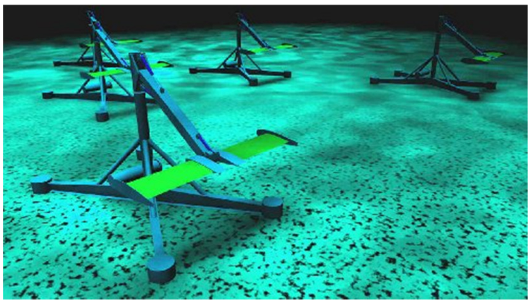
Energy Resources and Policy
Handout:
Tidal current turbines

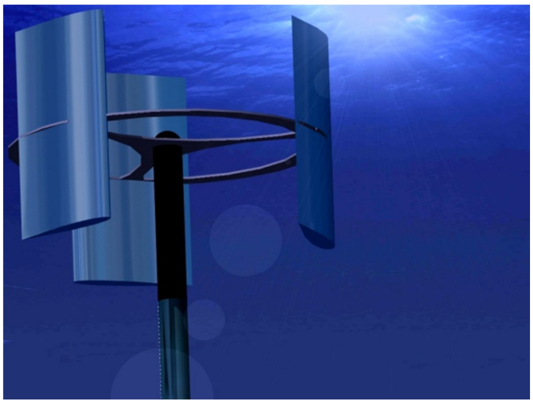
1. Exploitation

In certain parts of the world, tidal effects produce large local velocities as water forces its way through narrow passages between land masses. The energy in these tidal streams could be extracted by free turbines immersed in the water. In the UK, it has been estimated that 15% of electricity demand could be met from this source. Even in the Mediterranean there are possibilities: the Straits of Messina appear to be a very promising site.



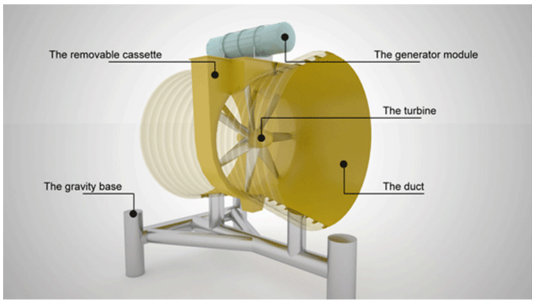
Stingray oscillating hydrofoil

The technology is not well developed, but can draw on experience in other areas. The fluid dynamic behaviour is similar to that for wind turbines, although the presence of a free surface and adjacent land masses will tend to confine the flow. Existing expertise in the offshore oil and gas industries will assist in choice of materials, and techniques for deployment and recovery. Velocity shear, turbulence, cavitation and the presence of surface waves must all be considered in predicting turbine performance.

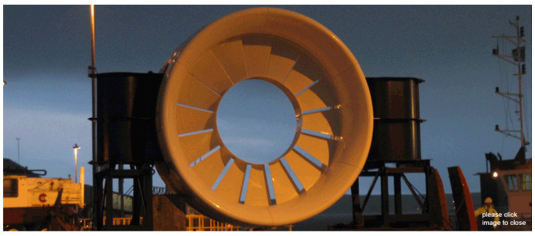


Generic vertical-axis turbine

The horizontal-axis wind turbine is the model for most designs proposed so far. This of course dominates the wind turbine market, but in tidal stream technology no such superiority yet exists: a variety of alternative designs are under active development, including oscillating hydrofoils and vertical-axis turbines. Horizontal-axis machines with open-centred, ducted and contra-rotating rotors have been devised, in addition to more conventional designs. Mooring arrangements proposed so far have included rigid piles, gravity bases, floating platforms and tensioned flexible arrangements.



Lunar Energy ducted turbine



Open Hydro turbine rotor

2.5 m diameter contra-rotating horizontal-axis turbine

300 kW horizontal-axis turbine

1.2 MW twin-rotor turbine, now installed in Strangford Lough, N Ireland

Marine current turbines are essentially modular in nature, and like wind turbines can be built into arrays or ‘farms’.

The initial investment required is fairly moderate and although energy costs are at first expected to be high (up to 10 pence/kWh), they should fall steadily as the technology matures.

Environmentally, there are a number of concerns:

- Impact on marine eco-systems during construction and deployment;
- Damage to large marine creatures from collision with rotors (although the low velocity of the current implies very low rotational speeds);
- Interference with shipping and fishing activities;
- Visual impact of transmission lines: unfortunately many of the most promising sites are far from centres of electricity demand.

2. Estimation of energy capture

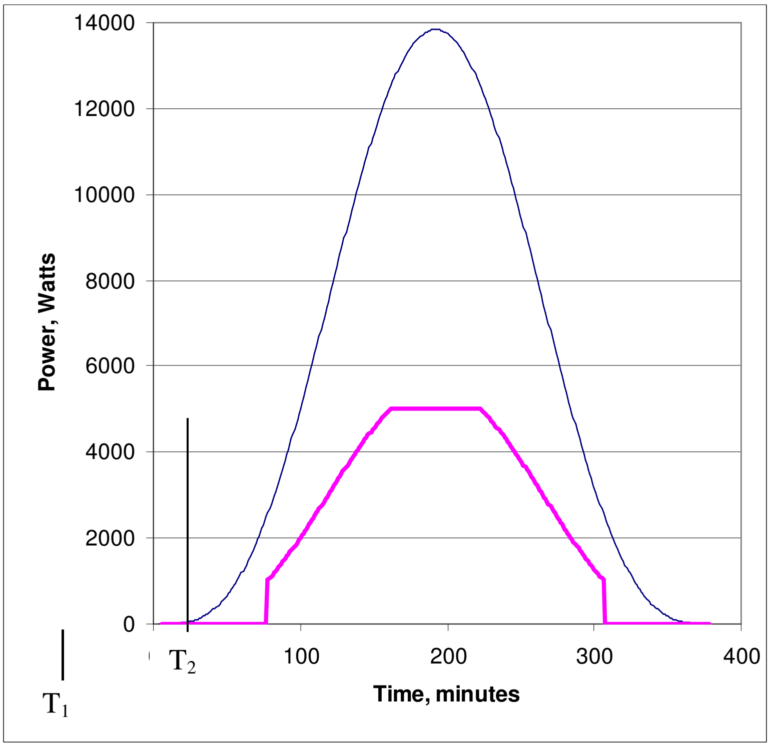
In some locations, marine turbines might receive energy from a combination of quasi-steady marine currents and flows induced by the tides. Estimation of energy capture is then a fairly complex procedure. But for most sites the flows are purely tidal, and calculation is relatively simple. Current velocity V follows a cyclic pattern:

$$V = V_{\max} \sin \omega t$$

where $\omega = \frac{2\pi}{T}$ and T is the period of the cycle.

For tides, T is typically 12 h 25 min or 745 minutes. A tidal current turbine will normally generate power for both flow directions, so its power characteristic (as a function of time) will be similar for each half of the cycle. The value of V_{max} is not necessarily the same for the two halves of the cycle; each site has its own peculiarities.

The graph shows the power available (faint line) and the predicted power output (heavy line) for a small turbine over a typical half-cycle.



Here the turbine power coefficient is assumed to be 0.4, a cut-in power level of 1 kW is imposed, and power is limited to a maximum (rated) value of 5 kW. Given the predictable nature of tidal flows, it should not be necessary to set a cut-out condition for the turbine during normal operation.

The times at which cut-in and rated power occur (relative to the start of the cycle) are indicated by T_1 and T_2 in the Figure.

The energy captured is given by the area under the power curve. In general the power produced by the turbine is

$$P = 0.5\, C_p\, \rho\, \pi R^2\, V^3$$

where R is the radius of the rotor, ρ is the water density and C_p is the power coefficient.

So the energy captured during one quarter of a full tidal cycle is $\int P\,dt$, or

$$\int_{T_1}^{T_2} 0.5 C_p \rho \pi R^2 V_{max}{}^3 \sin^3 \omega t + P_{rated}\,[186.25 - T_2]$$

working in units of minutes for time; *t* = 186.25 represents the mid-point of the half-cycle shown in the Figure. Mean power output and capacity coefficient (same definition as for wind turbines) may easily be calculated.

Note that the turbine produces no power for a period equal to $2T_1$, spanning the end of one half-cycle and the beginning of the next.