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TIDAL ENERGY RESOURCES

The gravitational pull of the moon and sun upon the earths oceans causes the surface of the oceans to be periodically raised and lowered resulting in tides. Tidal energy can be harnessed using two main types of tidal technology: Barrages and Tide mills. Though barrages are the more advanced technology, the UK has yet to install any such devices. There have however been several studies to assess the feasibility of barrage projects at various locations around the UK shoreline (ETSU, 1994).

Tidal energy captured in the form of barrages is possible due to the increased amplitude of the tidal range towards an estuary, caused by a shelving of the sea bed and funnelling of water by the narrowing estuary. The amplitude of the tides can be further increased by a reflection of the tidal wave by the coastline. The available energy depends both upon the location and time of the tides, but is highly predictable; it is approximately proportional to the square of the tidal range. However, the extraction of energy from tides is only worthwhile at sites where the estuary is geographically suitable for the construction of both barrages and power plants, and the tidal amplitude is sufficiently large (ETSU, 1994).

Barrages are constructed across the mouth an estuary using caissons (concrete or steel blocks), which are towed to the barrage site and sunk into prepared foundations. Each caisson would hold a group of turbine generators or sluices, or be blank to make up remainder of barrage. Other possibilities include the construction of a barrage behind a temporary dam (as was done at La Rance), or the construction of diaphragm walls of reinforced concrete within temporary sand island. However there are no cost advantages to these methods; they are usually riskier and take longer construction time (ETSU, 1994).

The usual and simplest method of energy generation for barrages is Ebb generation (Figure 1). Sluicing occurs on flood tide to fill up the basin; the water is then held until the tide recedes creating a head; water passes through the turbines back to sea generating electricity. At the next tide, the process is repeated.

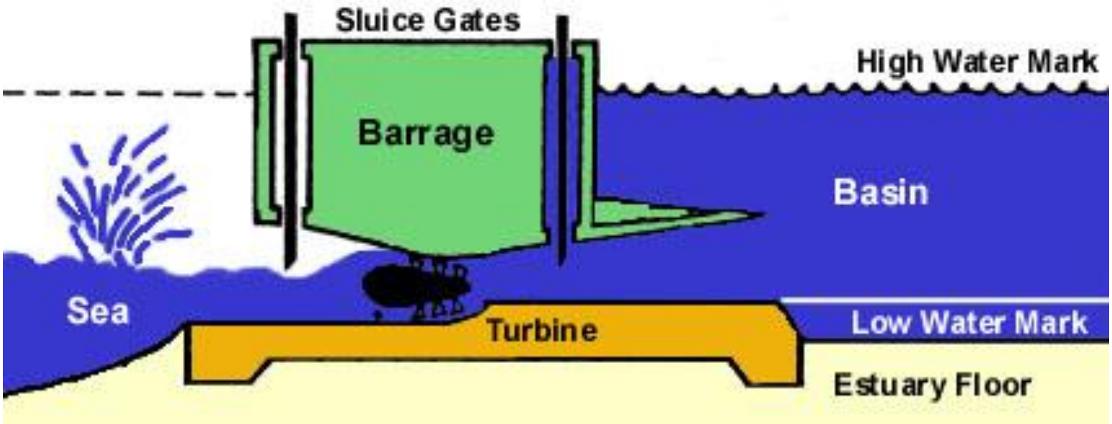

Figure 1: Ebb generation (http://reslab.com.au/resfiles/tidal/text.html)

Though tidal barrages only produce energy for approximately 10 hours per day, when the tide is moving in or out, this can be accommodated for if an element of storage is incorporated into the barrage schemes. Peak generation varies though day with the tidal maxima and as the time of the peak tide is known in advance, barrages at different geographical locations have tidal maxima at different times during any 24-hour period; therefore energy can be available throughout the day when needed (http://www.darvill.clara.net/altenerg/tidal.htm).

There are several advantages to tidal energy, the most apparent being that this is a renewable source of energy; it is non-polluting i.e. emission free. Another key advantage of tidal energy is that it can provide reliable energy production and is totally predictable in terms of the amount and timing of production. Tidal barrages have a design life of around 120 years, but with maintenance, the lifetime is effectively limitless, as long as the turbines are replaced every 40 years (ETSU, 1994). Once built and the capital cost paid off, future energy production is technically free. However, the high capital cost in relation to output may be reflected in the generation costs. Barrages can also provide protection against coastal flooding acting as storm surge barriers. This may be of particular use with the predicted sea level rise, and increase in storm surges as a result of climate change. Another advantage is the ability of larger barrage schemes to directly connect into the national transmission system, with smaller schemes connecting into local distribution systems. In terms on non-energy benefits, the construction of a barrage would inevitably create employment opportunities, as well as the possibility of marina and water sports development (ETSU, 1994).

There are, as with any technology, various disadvantages to tidal energy production in the form of barrages. The building of barrages across estuaries and inlets would cause severe disruption to the local ecology, the hydrodynamics of the estuary, water turbidity and as a result, the water quality. These affects would be seen over a wide ranging area. Barrages also have long construction times, for example, the planned Severn barrage has an estimated 9 year construction period, plus a 5 year environmental monitoring, leaving a total 14 year lead time before full scale production. Prospective financers may find this long lead time unattractive from an investment viewpoint. This is compounded by the fact that although the tides and consequentially the energy output can be predicted, operation has a relatively low load factor of 23%. This is due to the fact that it is intermittent – only producing ebb generation energy once per tide. The cost of energy production is highly sensitive to discount rates and the method of financing; doubling the discount rate would double the cost of energy for the Severn (ETSU, 1994).

The World Offshore Renewable Energy Report 2002-2007 states that 3000GW tidal energy is available in the UK. The UK has favourable conditions for generating electricity due to the high tidal range across the west coast where there are multiple estuaries and inlets (ETSU, 1994) (Figure 2). However, due to site specific nature of tidal barrages, only 3% of areas are suitable for power generation.

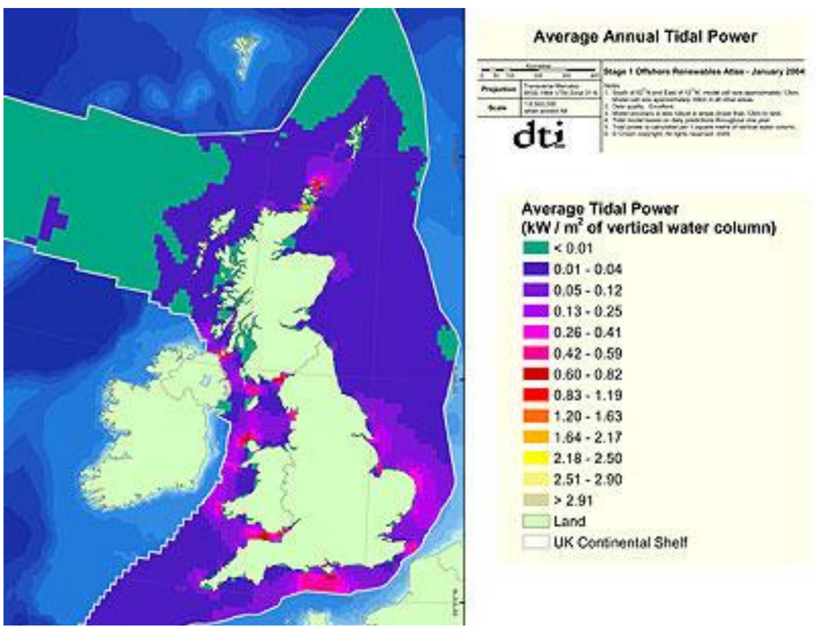

Figure 2: Availability of tidal power in the UK

Table 3 shows some of the proposed tidal energy schemes in the UK. The main proposed scheme is the Severn Barrage, which could provide up to 7% of total UK energy demand. A £4.2 million development study was completed in 1989. The proposed 16km barrage would cost £15.1 billion at 2004 prices, and would produce 8640 MW of energy. The Severn estuary is a particularly suitable location because it has a maximum tidal amplitude of 11m. Once the initial capital cost has been paid off it is estimated that electricity would cost 0.5p/kWh to produce (ETSU, 1994).

Tidal energy scheme	**Build time yrs**	**Capacity MW**	**Load factor %**	**Cost £/kW (1992)**	**Cost £/kW (2004)**	**Generation cost p/kWh**	
						8% DR (2004)	**15% DR (2004)**
Severn barrage	10	8640	23	1250	1750	10.1	22.7
Mersey barrage	5	700	23	1280	1792	9.9	20.0
Wyre barrage	2	63.6	24	1470	2058	9.5	17.4
Conway barrage	2	33.4	21	1610	2254	12.2	22.0

Table 3: Tidal Energy schemes in the UK (ETSU, 1994)

Under the Renewables Obligation Certificate, tidal energy would qualify for the proposed buyout cost of 3.0p/kWh. This would significantly reduce the cost of production, and increase the viability of tidal energy in the UK.

Tidal streams are caused by tides, where natural constrictions in shallow seas cause the flow of water to speed up. There are two main methods to gain energy from tidal streams: tidal fences and turbines. Tidal Fences are effectively barrages, with the advantage of having the generators and transformers above water. Water has a slower flow rate than air, and so, though tidal turbine technology is similar to that of wind turbines, the diameter of the turbines must be smaller (Figure 4). This technology does not have the disruption issues that barrages have on an estuary, however, the installation and maintenance of turbines does pose problems (www.esru.strath.ac.uk/EandE/Web_sites/01-02/RE_info/Tidal%20Power.htm).

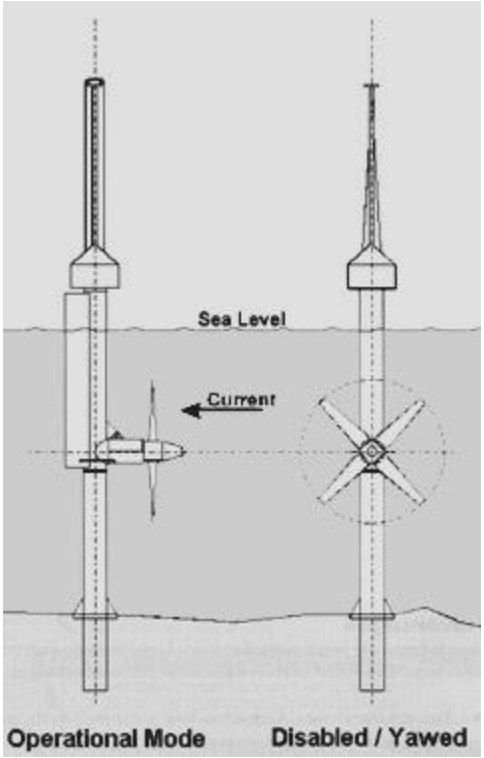

Figure 4: Tidal Turbine (http://reslab.com.au/resfiles/tidal/text.html)

There are around 30 tidal stream locations around the UK that have been identified as suitable for energy generation. The Seaflow project based in Lynmouth, Devon is a tidal turbine development project, which aims to be totally completed in 2010, when it will generate 300MW of electricity. There are three main phases to its development. Phase 1: 1999-2003 – installation of an 11m rotor, which only operates in one direction – cost £3.3million. Phase 2: 2003-2005 – installation of grid connected twin rotor system, operating in both directions – cost £4.5 million. Phase 3: 2004-2005 – installation of 3 to 4 tidal turbine units. It is hoped that this project will be self financed through the sale of electricity (http://www.dti.gov.uk/renewables/renew_1.5.2.htm).

The UK currently has very little installed capacity for Tidal energy production (only very small schemes like the Seaflow project are already in use). It is unlikely that this will increase significantly until 2020, when perhaps a few of the smaller tidal barrage schemes could be producing energy and possibly a few more tide turbines. For this to happen, the construction of barrages must begin in the coming few years, and energy production would probably not exceed 5 PJ. By 2025, with perhaps the Mersey barrage scheme adding to the total production and again more tide turbines, production could increase to 10 PJ. By 2030, the Severn barrage could be contributing to the UK energy supply, and if tide turbines take off on a similar rate as wind turbines have, energy production could be of the order of 50 PJ. However, again, for this to be achieved construction of the Severn barrage must begin in the next 5 years, due to the extensive lead time. The Energy Technology Support Unit states that the UK has a potential of 180 PJ, if all potential sites are developed, including Solway Firth, Dee, Thames, Wash and Humber barrages.

References:

- Energy Technology Support Unit, Atomic Energy Research Establishment, (1994), *An assessment of renewable energy for the UK*, London: HMSO
- http://www.darvill.clara.net/altenerg/tidal.htm
- http://www.esru.strath.ac.uk/EandE/Web_sites/01-02/RE_info/tidal1.htm
- http://reslab.com.au/resfiles/tidal/text.html
- http://www.dti.gov.uk/renewables/renew_1.5.2.htm
- www.dti.gov.uk/energy/renewables / publications/pdfs/technologies/tech8.pdf
- www.econ.cam.ac.uk/dae/Supergen-workshop/ Presentations/Session%202/Thorpe%20-%20Wave%20tidal%20energy.pdf

Bibliography:

- Great Britain. Department of Energy, (1977), *Energy paper ; no.23: Tidal power barrages in the Severn Estuary: recent evidence on their feasibility*, London: H.M.S.O
- Great Britain. Department of Energy, (1989), *Energy paper ; no.57: The Severn Barrage Project: general report*, London: H.M.S.O
- Great Britain. Department of Energy, (1987), *Energy paper ; no.54: Energy technologies for the United Kingdom: 1986 appraisal of research, development and demonstration*, London: H.M.S.O