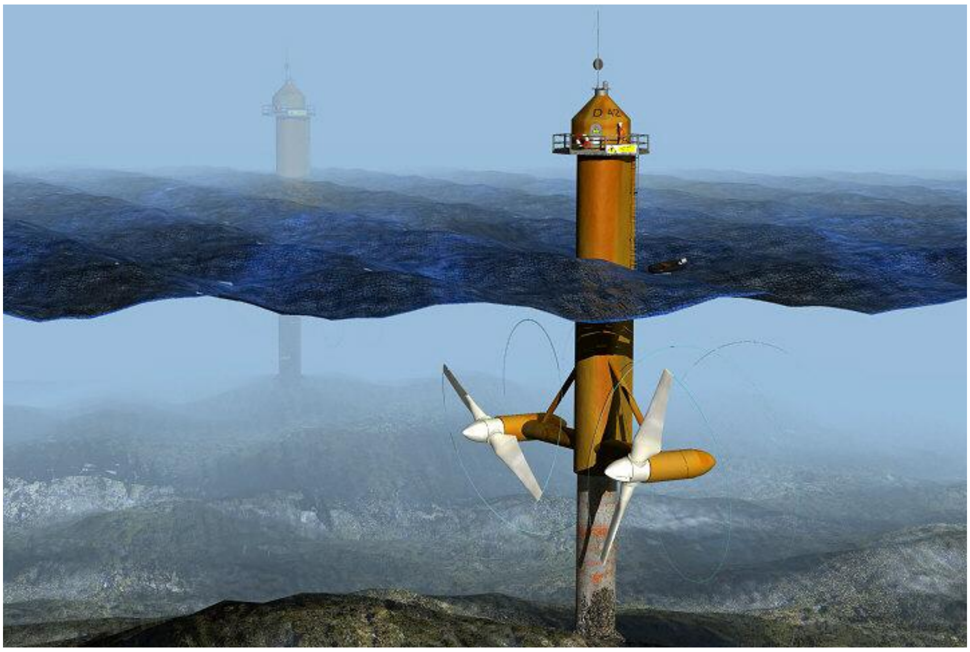
Energy Resources

ENV-2E02 2005

Predictions for the UK tidal energy sector

2010 - 2030



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Introduction

The UK is fortunate enough to have a large proportion of the world's tidal power resource in its waters. This is extractable using two leading methods, tidal barrage and tidal stream technology. Tidal barrage involves blocking off tidal basins (estuaries and bays) from the sea with a man-made concrete barrier. When the tide is at its peak difference on each side, sluice gates in the barrage are opened allowing water through at high pressure to turn turbines contained in the structure, and generate electricity. This process is represented in figure 1.

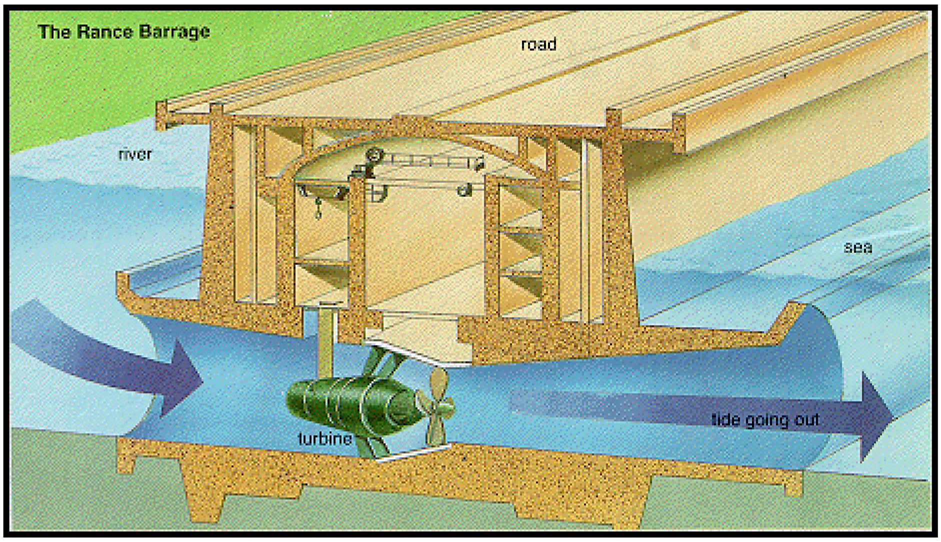

Figure 1: Diagram of La Rance tidal barrage in France
Source: Clapper 1997

A tidal barrage can only be effective in a tidal basin with a difference of at least 5m between high and low tide and a sufficient volume of water to turn several turbines. There are few sites in the UK where this is practicable. The Severn is the largest of these with the potential of generating 8640 MW, the Mersey is also a possible site for a barrage, capable of generating 700MW (World Energy Council, 2005).

Tidal stream is the other means of extracting tidal energy. Unlike barrage, tidal stream involves the point extraction of energy by placing a device in one of the several strong tidal streams around the UK's coastline. There are several different types of tidal stream devices. Figure 2 shows a picture of 'Seaflow', a 300 KW tidal stream prototype currently being tested in the Bristol Channel 1.1km off Lynmouth, North Devon (Fraenkel 2003). This is the first phase of a project by Marine Current Turbines Ltd. The second phase will result in the construction and testing of the 'Seagen' baseline project (due 2005/06), a double vertical axis turbine capable of generating electricity in excess of 1MW. Seagen is currently the most efficient tidal stream design, an artist's impression of the design is shown in figure 3.

Figure 2: The existing Seaflow tidal stream device in the Bristol Channel
Source: Fraenkel, 2003

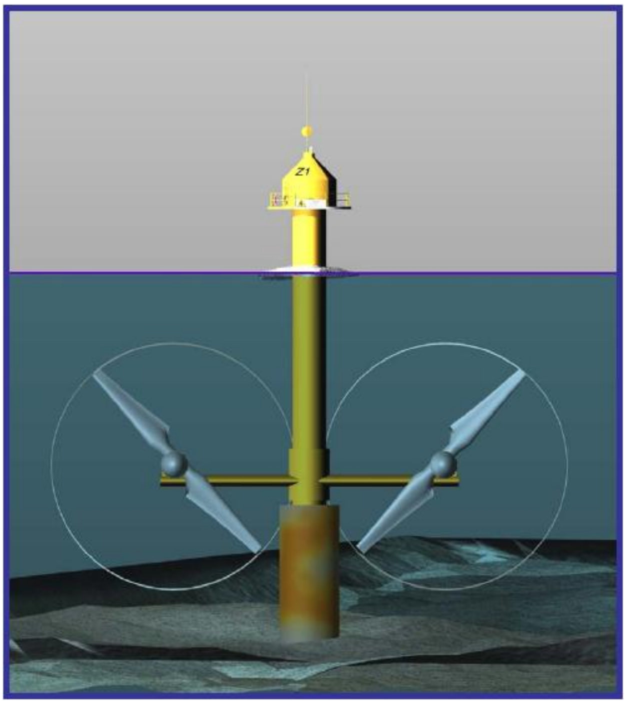

Figure 3: Artist's impression of the 1 MW Seagen double turbine design
Source: Fraenkel, 2003

Other tidal stream generation devices include the Stingray (figure 4), constructed by The Engineering Business ltd. and capable of generating 150 KW of electricity. The hydrofoils on the device move up and down in a tidal stream causing the arms to pump hydraulic fluid and turn generators. Another design, the Venturi effect devices, work on a different principle. In these, the tidal flow is directed through a duct which concentrates the flow and produces a pressure difference. This causes a secondary fluid flow through a turbine (University of Strathclyde 2005).

Figure 4: A computer representation of the 'Stingray' tidal stream device
Source: The Engineering Business Ltd., 2003

The aim of this paper is to analyse the potential of tidal power in the UK from a technical and economic perspective. Projections will be made in petajoules for the energy tidal power is likely to generate for the years 2010, 2015, 2020, 2025 and 2030.

The Potential of tidal Barrage

Tidal barrage is an attractive option for power generation for a number of reasons. It is a predictable and continuous energy source so it will always be available as long as the barrage is in place, it produces no pollution, including carbon dioxide, in operation and it is cheap to run after completion

Currently there is only one large-scale tidal barrage scheme in the world. This is located at La Rance in Brittany, France and has a generation potential of 240MW (figure 5).

Figure 5: A photograph of the LA Rance 240 MW tidal barrage in Brittany, France
Source: The Open University: Faculty of Technology 2005

There are several locations in the UK that are potentially suitable for a tidal barrage but only the most viable ones have been analysed in any detail. Table 1 shows the location and potential output of the potential schemes under consideration.

Location	Possible Output (MW)
Severn	8640
Mersey	700
Duddon Estuary (Cumbria)	100
Orkney Churchill Barriers	100
Wyre Estuary (Lancashire)	63.6
Conwy (North Wales)	33.4
Loughor (Swansea)	5

Table 1: The locations and potential output (in descending order) of possible UK tidal barrage schemes
Source: Original, Data: World energy Council 2005, Orkney Renewable Energy Forum 2005

The potential Severn barrage has been extensively researched in a project costing £8 million and lasting from 1978 to 1994 (House of Lords 2004) and also again in the last few years. Both times the proposed scheme was found to be “not attractive compared with other energy options” (House of Lords 2004). In fact, none of the schemes in table 1 have been given the go-ahead for a variety of reasons:

Firstly and most importantly the capital cost of tidal barrage schemes are very high due to their size and technical requirements, the Severn barrage would cost an estimated £10-15 billion to construct (University of Strathclyde 2005). The high cost of construction will result in a high cost per unit of electricity, in 2001, tidal electricity would cost 4 - 8 p/KWH whilst fossil fuels cost only 2 – 3 p/KWH (The UK Parliament 2001). This factor could make a project economically inefficient.

Secondly there are several environmental impacts from obstructing an estuary’s flow with a tidal barrage. These include extra mixing of water which stimulates growth of new organisms, blocking of species and sediment migration and changes in the distribution of nutrients (DTI 2005)

Another impact is the visual impact caused by a large man-made structure blocking an estuary, this could damage views and possibly reduce tourism to an area.

Navigation will also be affected, ships will need to pass through locks to cross a barrage and this could reduce trade and other boat traffic.

There is a problem concerning when electricity can be generated by barrages. The time of generation is dictated by the tides and does not necessarily coincide with peak energy demand. Large surpluses of energy could exist that would have a knock on effect on other generators elsewhere on the national grid.

Finally investors are starting to acknowledge tidal stream as a suitable alternative to tidal barrage due to its smaller number of environmental and economic impacts. As a result the emphasis is being taken off tidal barrage as the major method of tidal electricity generation.

The Future for Tidal Barrage

With these factors in mind, does tidal barrage have a contribution to electricity generation in the future?

It is unlikely with the economic and environmental risks involved that there will be any sizeable tidal barrage schemes between now and 2030. The only possibility is the Orkney Churchill Barriers proposal in the Orkney islands north of Scotland. The Churchill Barriers were constructed under order of Winston Churchill in 1940 to restrict German U-boat passage (Orkney Renewable Energy Forum 2005). It is thought that these barriers could now be used to harness the strong tidal power between islands and generate between 20 and 100MW of electricity. According to the Orkney Renewable Energy Forum, the Churchill barriers present the only realistic tidal barrage proposal. This is because the existing barrage will result in a lower than normal capital cost, the barriers provide shelter for construction work, there will be no large environmental impacts, fishing may improve due to increased tidal flows, public are supportive because there will be little visual change. As a result of these existing benefits the Orkney barrage minimises the drawbacks that would prevent all other tidal barrage schemes from taking place.

Projections

These are the projections of future energy generation from tidal barrages in the UK:

2010 – 0 MW, **0 PJ**

2015 – 0 MW, **0 PJ**

2020 – 0 MW, **0 PJ**

2025 – Orkney tidal barrage is implemented and operational (OREF estimate) producing its maximum 100 MW due to technological improvements.

100 MW x 0.25 (25% load factor) x 8760 hours = 219000 MWh = **0.79 PJ**

2030 – 100 MW, **0.79 PJ**

The Potential of Tidal Stream

Tidal stream power generation shares some of the same benefits of tidal barrage: it releases no pollution (including greenhouse gases) in operation and it provides a continuous and reliable energy source. The benefits of tidal stream not shared by tidal barrage are its minimal visual impact; only a small proportion of a device is visible from the surface (Stingray is completely submerged). The environmental impacts are also much less as the devices, which are slow moving, do not affect species and sediment movement.

Tidal stream does also have shared disadvantages with tidal barrage. The cost of construction is high due to the fairly new technology required. This will result in high electricity costs. The peak generation time is also controlled by the tides and doesn't necessarily coincide with peak demand. Tidal stream's unique disadvantages include transmission of electricity. Large populations are a long way from the main tidal streams, the locations of which are shown in figure 6. Also, maintenance will be costly and require boats and possibly divers to access devices.

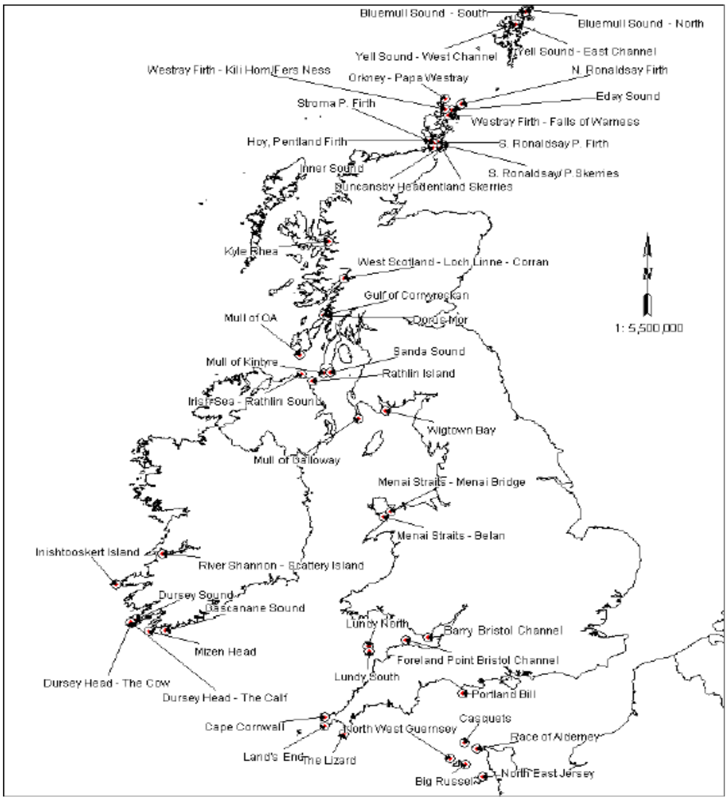

Figure 6: The location of suitable tidal stream energy extraction sites
Source: The Carbon Trust 2004

According to the Carbon Trust (2004), the total extractable tidal energy for the UK is 22 TWH/year. To work out how many devices will be needed to generate this, the type of device must first be established. Currently the Seagen double turbine design (figure 3) is the most efficient device design, capable of generating 1 MW where as the stingray can only generate 150 KW. Also, the Seagen device can have its turbines raised to the surface for maintenance, solving a problem that the Stingray has because it is mounted on the sea floor. Due to its superiority, the Seagen design will be the basis for tidal stream energy projections.

So how many turbines will be needed to extract this maximum 22 TWH/year? This is calculated using the following process:
First the figure is converted into GW:
22 TWH / 8760 (number of hours in a year) = 0.000251 TW
0.000251 TW = 2.51 GW

Then this figure is divided by the generating capacity of 1 device. The load factor is 39% on average (Carbon Trust 2004), therefore each Seagen device is capable of 39% of 1 MW: 0.39 MW or 0.00039 GW. So:
2.51GW / 0.00039 GW (one device) = 6435 devices needed.

In order to build this many turbines by 2030, 257 would have to be made each year between now and 2030. That means 0.7 turbines must be made each day. This doesn't seem possible given that no Seagen devices have yet been built and tidal stream still faces many challenges.

So what can be realistically expected?

Currently the development of a Seagen prototype is being held back by a funding gap. It is extremely expensive to build a tidal stream device because the technology is fairly new. A study conducted by the Department of Trade and Industry (2001) suggests a cost of over £3m to create a single device. Investors are therefore sceptical to experiment with this new technology as

£3m is a large and risky investment. To solve this problem the DTI have set up a 'Marine Renewables Development Fund' in October 2004, offering grants of up to £5m for suitable wave and tidal prototypes (DTI 2005). This fund could very well speed up tidal stream development programs.

The Marine Current Turbines Ltd (MCT) program mentioned in the introduction should now be able to construct and test a Seagen prototype and further tidal stream development.

Tidal Stream Projections

According to MCT, the plan of implementation is to install a grid connected farm of 3 to 5 Seagen devices and test it, expand the farm and test it more then install farms in other areas. The aim is to have over 500 MW installed capacity by 2012 (Fraenkel 2003). However this seems like an unlikely timescale due to the late start and financial problems of the project. The alternative projections are described below:

2010 – With the availability of the new Marine Renewables Development Fund it is likely that the Seagen prototype can be constructed and grid connected by this time. The capacity will be 1 MW. 1 MW x 0.39 (39% load factor) x 8760 hours = 3416.4 MWh = **0.01 PJ**

2015 – Provided the tests give positive feedback (this is likely because the existing Seaflow turbine, figure 2, is out performing expectations by 27%, (Fraenkel 2003) one farm of around 25 Seagen turbines could be set up between 2010 and 2015. 25 turbines = 25 MW, 25 MW x 0.39 x 8760 hours = 85410 MWh = **0.31 PJ**

2020 – The tidal stream farm will be expanded to several different sites (say 4) to provide an installed capacity of 100 MW (4 farms x 25 turbines). 100 turbines = 341640 MWh = **1.23 PJ**

With four tidal farms successfully installed, the potential of tidal stream power will be recognised by the government and businesses. By this time technology will have improved and all devices will be capable of generating 1.5 MW. With these assumptions in mind:

2025 – Around 50 devices will be constructed each year as the capital cost becomes cheaper resulting in 350 operational 1.5 MW devices. 1795800 MWh = **6.46 PJ**

2030 – As capital costs continue to fall, devices will be constructed at an average of 80 per year. By 2030 there will be 750 operational 1.5 MW devices. 3845640 MWh = **13.8 PJ**

Figure 7 The projected tidal energy generated from 2010 - 2030

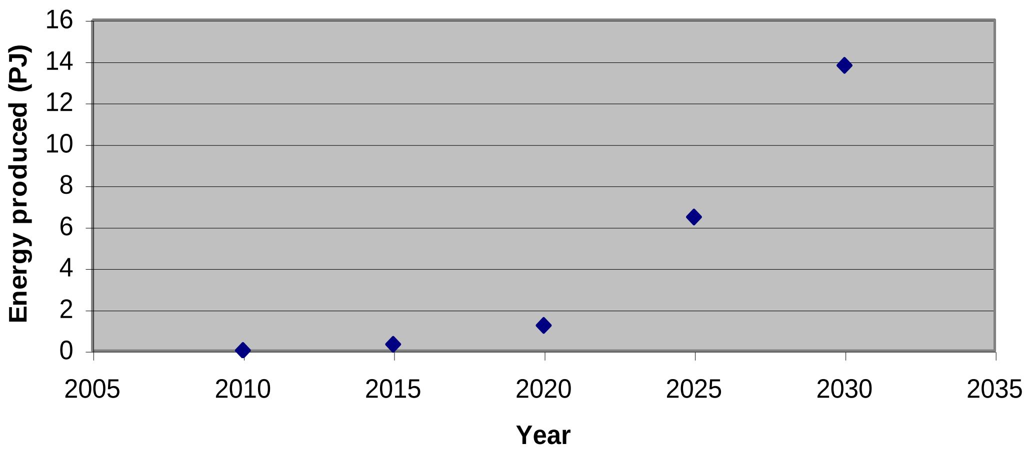

Figure 7 shows how the energy produced increases exponentially with time due to lowering of capital costs and increases of investment as tidal stream technology becomes more popular.

Conclusion

This papers projections for tidal energy can be summarised in table 2 below.

	Year				
	2010	**2015**	**2020**	**2025**	**2030**
Barrage Only (PJ)	0	0	0	0.79	0.79
Stream Only (PJ)	0.01	0.31	1.23	6.46	13.8
Total (PJ)	0.01	0.31	1.23	7.25	14.59

Table 2: Energy projections for tidal barrage and tidal stream power 2010 – 2030

Source: Original

Limitations of Projections

There is a large margin of error associated with these projections. They rely on the Orkney barrage being constructed even though it hasn't been officially approved yet. It is also assumed that the tests of the Seagen device will be successful and result in a continuing development program. The actual figures will also depend heavily on the government and its decisions. If it is struggling to reach renewable targets, the government may spend money subsidising tidal power, on the other hand it may see tidal as insignificant compared to other renewable options. Government could also subsidise suppliers that buy tidal electricity, this would make the previously expensive tidal electricity comparable with other forms and possibly encourage development of tidal stream devices and barrages at a faster rate than predicted.

The projections assume that only MCT's Seagen device will be constructed. If the company restricts other businesses from building this design, there will be investment by other companies in different designs such as Stingray and Venturi devices.

This paper has overlooked a new form of tidal generation known as tidal lagoon. This involves dividing up an estuary into a series of small lakes with walls that are submerged at high tide. Turbines in the walls generate electricity in a similar way to tidal barrage. This scheme can generate comparable energy to barrage with less environmental damage, capital cost and hindrance to navigation. If this principle works, much more energy could come from tidal power than has been projected.

To conclude, tidal power has many drawbacks but it is still a viable means of electricity generation. The technology is still under development, but its prospects are promising (Boyle 2003) and difficult to predict!

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