January 2004

Friends of the Earth Cymru

Cyfeillion y Ddaear Cymru

Briefing

A Severn barrage or tidal lagoons?

A comparison

Friends of the Earth Cymru, 33 Castle Arcade Balcony, Cardiff CF10 1BY
Tel 029 2022 9577 Fax 029 2022 8775 Email cymru@foe.co.uk Website www.foecymru.co.uk

Summary

Electricity-generating tidal lagoons located in the Severn Estuary could provide an economically attractive and environmentally acceptable way of supplying up to 7% of England and Wales's electricity consumption with low-cost, low-carbon electricity.

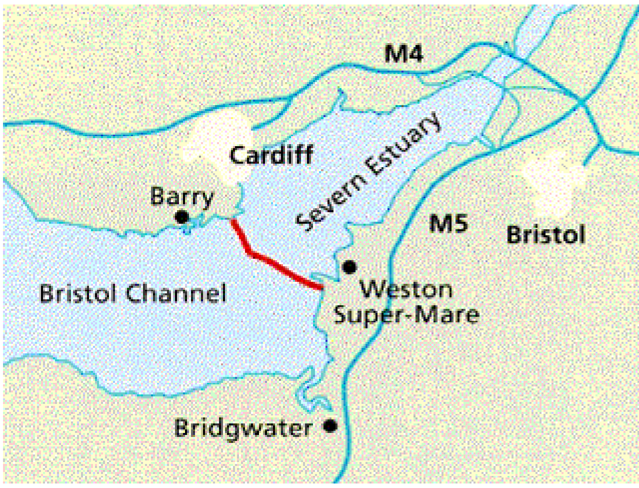
There are a large range of potential environmental and economic benefits and disbenefits associated with siting lagoons or the proposed Severn Barrage in the Estuary. However, initial comparisons strongly suggest that lagoons could be significantly less extensive and environmentally damaging and more cost effective and powerful than the Barrage. Lagoons would not directly impound the ecologically highly valuable inter-tidal areas of the Estuary. Indeed, lagoons may offer potentially significant wildlife habitat. Yet, lagoons would generate twice as much power per square mile impounded than the Barrage and could extract about 25 - 40% more energy from two thirds of the impounded area.

Considering the wider environmental and economic issues, the sourcing of large volumes of aggregates for the lagoons would be critical because this could result in substantial adverse impacts. Yet, every tonne of aggregate used in lagoon construction would enable the generation of about three times more electricity than a tonne of coal burnt in a power station, and there would be no greenhouse gas or acid gas emissions.

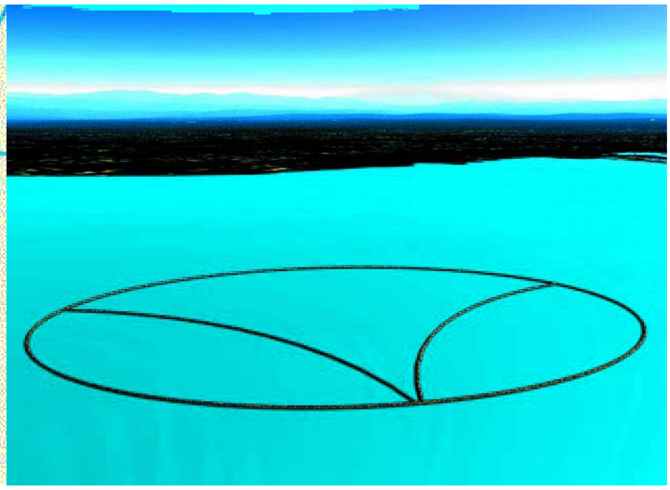
Lagoons would not impede shipping but the Barrage could provide a novel transport link. Both technologies would generate significant quantities of low-carbon electricity close to large populations. However, the Unit generation cost, output timings, storage capability and smaller capital costs of lagoons are likely to be far more attractive to private investors and consumers.

The table below summarises the main details of the schemes:

	Barrage	**Lagoons (largest scenario)**
Power Generated	17-19 TW hours/year	24 TW hours/year
Average output	1.95 -2.17 GW	2.75 GW
Capacity	8.64 GW	4.50 GW
Capacity Factor	26%	61%
Emissions avoided	4.6-5.1 mtC per year	6.5 mtC per year
Impounded area	185 square miles	115 square miles
Overall wall length	9.8 miles	95 miles (approx)
Aggregates required	13 m tonnes	200 m tonnes (approx)
Design life	Min 120 years	Min 120 years
Generation cost	5.5 pence/kWhour	2.0-2.5 pence/kWhour



Location of the proposed Barrage across the Severn Estuary



Computer generated image of a tidal lagoon in Swansea Bay

Introduction

The Severn Estuary is an environmentally protected area currently being proposed for Special Area for Conservation (SAC) designation in recognition of the European importance of its ecology. The vast inter-tidal area over 77 square miles (200 square km) provides food for over 50,000 waterfowl on major migration routes. The shifting sediments and muddy water severely limit the growth of small waterborne plants but other parts of the Estuary are very rich. Beneath the surface, billions of shrimps and millions of fish live on worms and other tiny creatures. The Severn and its 10 sub-estuaries represent 7% of the UK's total estuary resource.

The tidal range in the Severn Estuary is the second highest in the world, averaging about 13 metres. For this reason, taking advantage of the Severn's high tidal range for energy generation has long been talked about by the public and energy specialists alike. Indeed, detailed barrage designs were drawn up in the 1980s yet the schemes were economically unattractive and also gave rise to environmental concerns.

Recently there has been renewed debate as the urgent need to address global warming by reducing fossil fuel use has become more widely recognised. Yet, at a time when the perceived need for a Severn barrage may be at a historical high a new type of tidal energy generation scheme has entered the debate.

The new type of scheme is called a tidal lagoon. It is basically a rock-walled impoundment, which would look like an oval or similar shaped breakwater enclosing an area of shallow coastal sea forming a 'lagoon'. Tidal water is trapped and released from the lagoon through electricity generating water turbines built within the impoundment walls. The lagoon concept has been peer reviewed and considered technically feasible and economically attractive.

So, a question arises, how tidal lagoons in the Severn Estuary would compare to a Severn

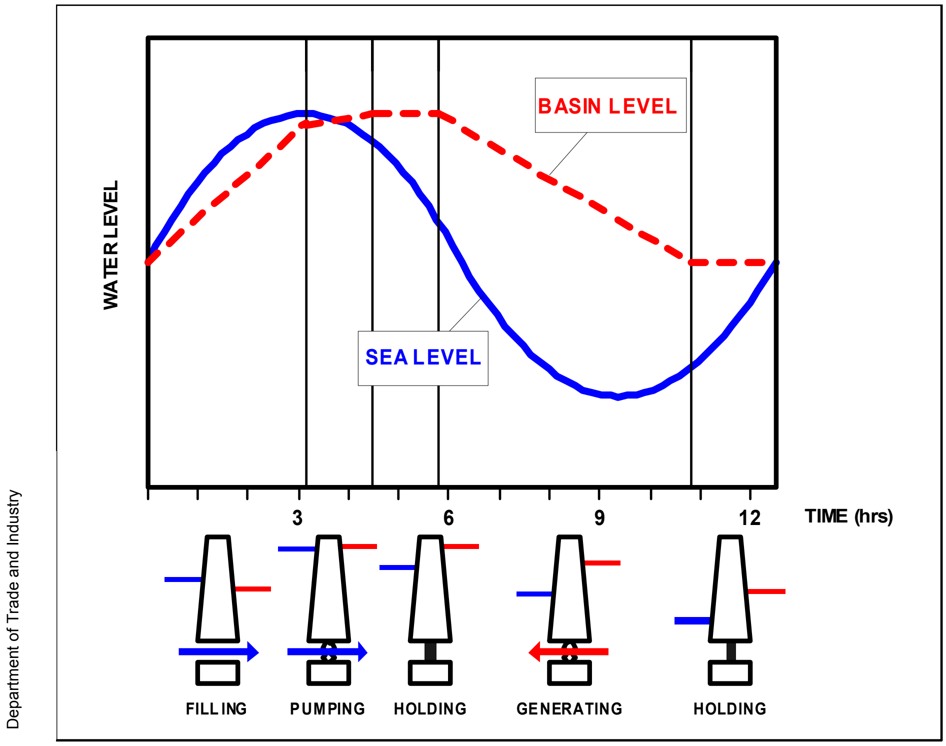
Barrage. This briefing makes an initial comparison in terms of cost, energy output, environmental and wildlife effects, construction issues and other considerations.

The Severn Barrage

A range of barrage studies were made between 1974 and 1987 at a cost of £65 million out of which a specific Severn Barrage scheme was drawn up by the Severn Tidal Power Group (STPG). A revised report was published in 2002 and is on the DTI's website.

The Barrage proposed would stretch 10 miles from Lavernock Point west of Cardiff to near Brean Down in Somerset, impounding an area of 185 square miles. The scheme wall would pass close to and just east of Steep Holm Island and two miles west of Flat Holm Island. The Barrage would incorporate lock gates to allow shipping and smaller craft to access the port at Bristol, other docks and the River Severn. The installed capacity, or maximum output, of the proposal would be 8,640 megawatts (MW) or 8.64 gigawatts (GW).

The proposed Barrage would generate about 5.4 % of current England and Wales electricity demand of 350 tera-watt hours per year (TW hours per year) and cut 18 million tonnes of greenhouse gases per year. A STPG spokesperson recently stated that the annual Barrage output could be 17-19 TW hours per year though the recent review confirms 17 TW hours per year. Assuming an average annual Barrage output of 17 - 19 TW hours per year, the average output would be 1.95 - 2.17 GW. This output is broadly equivalent to a large coal-fired power station or two to three nuclear power stations. At UK level, electricity demand in 2002 was 395 TW hours per year requiring an average UK power station output of 45 GW. Electricity demand in Wales was about 19.5 TW hours per year.



Basic operation of a Severn barrage showing changes in water levels

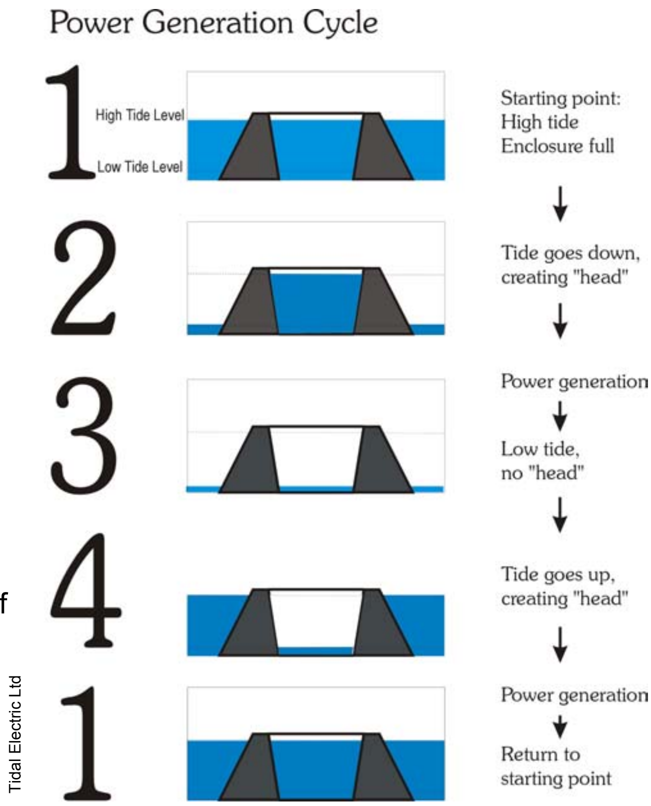
Tidal Lagoons

The company and patent holder of the tidal lagoon concept is Tidal Electric Limited. It is proposing to build the world's first tidal lagoon in Swansea Bay which would impound just over two square miles of sea near Port Talbot. The 30 MW scheme (installed capacity) would have an average output of about 15 MW. The Swansea Bay scheme and the lagoon concept in general has been reviewed favourably by independent energy consultants AEA Technology. The review described the lagoon concept as "mechanically mature, environmentally acceptable, and economically self-sustaining".

Visually, at lower states of the tide, a tidal lagoon would look like a typical rubble mound breakwater as seen around many marinas or harbour approaches. At high tides the structure would be more or less submerged. The nearest walls of a lagoon would have a exterior slope of about 30 degrees and would be located at the low-water mark typically up to a mile out from firm ground. The lagoons would be internally subdivided, by less substantial walls, for optimising power output to supply variations in demand and provide storage.

Tidal Electric Ltd currently has no specific plans for the Severn Estuary other than the Swansea Bay scheme. Yet the Severn Estuary is a globally prime site because of its very high tidal range. This is because power output is proportional to the square of the tidal range. Twice as much energy can be extracted from a 13 metre tide compared to a 9 metre tide.

The company estimates that large schemes in the most optimum sites could impound up to 115 square miles and generate as much as 24 TW hours per year. Such schemes would have an installed capacity of about 4.5 GW and an average output of about 2.75 GW which is equivalent to just less than 7% of England and Wales electricity demand. The near-zero carbon output would correspondingly save about 23 megatonnes of greenhouse gas emissions per year or 6.5 mega tonnes of carbon (mtC).



Basic operation of a tidal lagoon showing changes in water levels

Tidal Electric also says that there are additional tidal energy resources around the UK such as Liverpool Bay (up to 8 TW hours per year) and some in progressively less optimum areas such as navigable areas and shipping lanes.

Comparisons between barrage and lagoons

Scale of schemes

Several large lagoons could be built over time to impound as much as 115 square miles of the Estuary (roughly an area 11 miles by 11 miles). Even then the lagoons would cover 70 square miles less than the 185 square miles the Barrage would impound. Yet this area of lagoons would capture about 26 - 41% more of the Estuary's tidal energy than the Barrage (2.75 GW average from lagoons, 1.95-2.15 GW average from Barrage). This is because the lagoons can generate electricity on both the ebb and flood tides while the Barrage is limited to generating mostly on the ebb tide to reduce silting. Both types of scheme would enhance their output by innovative pumping techniques. Overall, lagoons would generate just over twice as much electricity per square mile impounded than the Barrage.

Technically speaking, the capacity factor of a multi-pool lagoon is about 61%, compared to about 26% for the Barrage. For comparison, the nominal capacity factors for other electricity generation technologies are 30% for onshore windfarms, 35% for offshore windfarms, and 33% for marine current turbines. The capacity factor of the Wylfa nuclear power station has been about 56% to date, and the now closed Trawsfynydd station was 60%.

Costs

The cost of electricity from tidal lagoons in the Severn Estuary is estimated at about 2.0-2.5 pence per kW hour (or £20/MWh) by Tidal Electric. Generation at prices anywhere between 2.0-2.5 pence would be highly cost-competitive rivalling the forecast price of onshore windfarms and the cost of gas generated electricity. Indeed, gas prices are now rising due to increasing global demand and the UK is likely to be a net importer by 2006. Unit costs for the Barrage are estimated to be possibly less than £60/MWh in the Severn Tidal Barrage Group 2002 report (calculated to within +/- 15%). The Barrage's unit costs would be dependent on major public-private finance contracts. Lagoons would be privately funded according to the developer whose financial advisors are NM Rothschild & Sons Ltd.

Construction of the Barrage was estimated at 10-12 billion pounds until recently when a reduction of several billions of pounds was put forward on the basis of new cost-saving engineering techniques. Tidal Electric says that lagoon schemes would produce power at about 2 pence per Unit (kW hour) much cheaper than the Barrage. Capital outlays would also be lower because each lagoon scheme could be financed sequentially. The STPG says that the Barrage may also offer flood protection for the low-lying areas in Gloucestershire which would be of large economic benefit. They state that flooding costs in the area could rise to as much as £200 million per year. Yet, much smaller and far cheaper flood-protection schemes up river may be able to offer better flood defence at a fraction of differential cost between lagoons and the Barrage.

So, not only may the electricity generation costs of lagoons be significantly less than the Barrage but lagoons would also offer the prospect of much smaller capital outlays rather than the one-off, multibillion pound sum for the Barrage. Indeed, the possibility of sequential deployment of smaller lagoon schemes may also reduce any technical, planning or political uncertainty about large schemes of either kind.

Tidal Electric Ltd says that the uncertainties of the consent process are making private investors cautious. However, once consent for an initial lagoon project has been secured then private funding would be available. A detailed environmental study required to apply for consent of the Swansea Bay proposal may cost about £2.5 million.

Regional Effects

Both technologies would produce electricity close to major demand centres in south Wales and the south west of England. This geographical proximity is highly valuable because of grid security and transmission losses. The major electricity flows along the UK grid are from power stations in the north to demand centres in the south. Also, by around 2010 it is likely that the two remaining nuclear power stations in the region, namely Oldbury (440 MW capacity) and Hinkley Point B (1,325 MW capacity) will be near to closure or closed. Hinkley Point A (475 MW capacity) has recently closed.

The combined power of all these three nuclear stations when operating at maximum output would have been 2,240 MW but they would probably have averaged about 1600 MW due to maintenance and fault outages (assuming a 70% capacity factor). So, the average output of the nuclear stations would be roughly 75% of the average Barrage output, and only 60% of the average output of lagoons covering an area of 115 square miles. In population terms the lagoons could supply over 3.5 million people at current demand levels.

Both schemes would require Grid strengthening. However, the maximum output of the lagoons would be 4.5 GW so requiring less expensive reinforcement than the 8.64 GW Barrage.

Because tides are predictable, the electrical output of both lagoons and Barrage would be predictable. However, both technologies might also provide significant and cost-effective, demand-responsive and energy storage capabilities. This would depend on pumping losses and the market value of electricity as traded under the New Electricity Trading Arrangements (NETA). Such capabilities may well reduce the need for ‘spinning reserve’ as a back-up for the existing unpredictable power generating technologies and facilitate the integration of the more intermittent renewable energy technologies particularly wind and solar energy.

Transport Considerations

Lagoons in the Severn would not be a significant impediment to shipping unlike the Barrage which would have a lock-gate system for access to ports such as Bristol, Cardiff and

Newport. However, the Barrage, unlike lagoon schemes, would offer the potential for a road or rail scheme to link Devon with south Wales. Yet the strategic need for such a link is not great.

Environmental Effects

In terms of ecological and wildlife effects, detailed environmental studies would have to be undertaken for any large scheme be it lagoon or Barrage. Specific coastal processes and effects would have to be assessed for various sizes and shapes of lagoons to identify optimum proposals. Helpfully, the range of effects that need to be studied, such as salinity, oxygen levels, sewage dispersion, fish migration, sediment transport, erosion and deposition have already been identified in the Severn Barrage Report.

Generally speaking, minimising the impoundment of the particularly rich inter-tidal areas and tributary rivers, is better. In this respect the lagoons appear to be far preferable to the Barrage. The nearest coast-facing lagoon walls would be located around the low water mark, typically up to one mile from the coast, and would avoid the inter tidal areas. Also, a large area which may be suitable for lagoons is Bridgewater Bay which covers over 20 square miles and lies outside the area which would be impounded by the Barrage.

So, lagoons generating 2.75 GW would not only impound about 70 square miles less than the Barrage, they would avoid the inter-tidal areas and could be located over a wider area of the Estuary. Consequently, it could be that much of the existing 77 square mile inter tidal area would not be directly impounded or affected even by the largest capacity of lagoons. However, any indirect effects would require site specific studies. The lagoons could also form isolated rocky islands which could provide significant additional habitat for birds and other species.

In terms of waves, currents and sedimentation effects, both lagoons and Barrage would remove energy from the water column which would increase sedimentation of mud and or sand. However, this would directly reduce the high turbidity of the water which itself is the main factor inhibiting primary food production which forms part of the estuarine food chain. The Barrage studies indicated that there may be environmental benefits in reducing turbidity.

Both Barrage and lagoon schemes would generally provide shelter to sensitive coastlines from increasing wave action, more severe storms and sea-level rise resulting from global warming. A lagoon scheme in Bridgewater Bay may reduce the existing erosion problems in the Bay. Specific comparisons are difficult to make without knowing the location and shape of lagoon schemes.

Construction Effects

Lagoons would require considerably more construction aggregate than the Barrage and there could be significant environmental and social implications in sourcing the tonnages required. The actual tonnage will very much depend on the size and shapes of the lagoons but may well be in the order of 200 million tonnes of rock, sand and gravel (25% rock/75% infill). This amount would be 91 million cubic metres in volume or an area of one square mile by 115 feet high. Sourcing anything like this amount of material from quarries in south Wales and the south west of England would be bound to have knock-on effects for future aggregate procurement.

Tidal Electric Ltd says sources could include dredged material from the Bristol Channel away from sites which may be affecting the Gower beaches. However, it may prove beneficial to import aggregates say from Norway or Spain. Indeed, coal is imported to Aberthaw power station from more distant locations yet aggregates used in lagoon construction may have more than three times the energy value by weight (See Coal Comparison). In any event, the location of required land and marine aggregate sources and the extraction impacts would be a significant issue and would require a detailed study in itself.

There is scope to use inert waste materials called secondary aggregates as infill between the larger rocks. Tidal Electric Ltd has indicated that slate waste, of which there is well over 200 million tonnes in north Wales, would be suitable. However, there would be capacity constraints associated with transporting the slate along rail links and conveyor belts where such facilities exist or could be built. Output by rail from the Blaenau Ffestiniog area would probably be limited to about 2 million tonnes per year and any lagoon construction in Liverpool Bay might draw all available capacity.

Coal Comparison

A revealing comparison can be made between the large tonnage of aggregates required for lagoons and the tonnage of coal required for the same electrical output.

The most detailed figures produced by Tidal Electric for a large lagoon scheme are those for a possible 430 MW scheme in Liverpool Bay. This scheme would generate an average of 260 MW producing about 2.2 TW hours per year and would require 23.6 million tonnes of aggregate for construction.

To generate 1 TW hour of electricity in a coal-fired power station requires about 228,000 tonnes of coal depending on the technology (DTI figure for 2002). So, to generate the same 2.2 TW hour per year output of this Liverpool Bay lagoon scheme would require 500,000 tonnes of coal per year. Assuming a lagoon design life of 120 years shows that only about two fifths of the tonnage of aggregates may need to be quarried or dredged compared to the tonnage of coal mined or worse, open-casted, to generate the same amount of electricity.

The higher tidal range of the Severn, compared to Liverpool Bay, may provide an even higher saving. Lagoons in the Severn capable of generating 24 TW hours per year would supply 2,880 TW hours in 120 years and would require 200 million tonnes of aggregate. Yet 200 million tonnes of coal would generate only 880 TW hours. This suggests a ratio of 3.3 in favour of aggregates. Hence, it would take about 37 years for the tonnage of coal burnt to exceed the tonnage of aggregates needed to build the lagoon.

In other words, primary or secondary aggregates may be worth over three times their weight in coal for the purpose of electricity generation if used in lagoon construction. Primary aggregates are currently priced at around £5.50 per tonne, slate waste would be cheaper and forecast coal costs prices are about £25 to £30 per tonne. The implications of this are diverse and considerable.

Design Life and Decommissioning

Both Barrage and lagoon schemes, given normal maintenance, could last well over one hundred years with little change. The low-head turbines which would be used by either scheme are a well proven, long-lasting technology and aggregates have an unlimited life span. Indeed, the lagoon aggregates, which are for the most part loose, could be reclaimed for further uses as part of any decommissioning process at some point in the future.

Conclusions

The high tidal range of the sensitive Severn Estuary may yet be harnessed for electricity generation, possibly sooner rather than later, and not in a way previously envisaged. On the basis of this preliminary analysis and comparison tidal lagoons could provide a major source of safe, clean, regionally generated renewable electricity. Lagoons also appear to offer numerous significant economic and environmental advantages over a Severn Barrage. Yet only a few years ago the Royal Commission on Environmental Pollution included the Severn Barrage in three out of four of its 2050 energy scenarios to reduce UK greenhouse gas emissions.

For the reasons stated in the Summary Friends of the Earth Cymru continues to call on the Welsh Assembly Government to investigate the potential of tidal lagoons, to help fund specific lagoon studies and to support acceptable proposals.

Recommendations

The appearance of tidal lagoons off the Welsh coast could be a ‘world first’ for Wales as would befit a country with a world-leading sustainable development remit. Observable from space, large lagoons would be a spectacular symbol of a species harnessing natural planetary forces for the protection of the Earth’s biosphere and all the diverse species it supports.

Friends of the Earth Cymru recommends that the National Assembly for Wales and all other relevant agencies provide the necessary support to assist in detailed studies to identify if the construction of tidal lagoon schemes in the Severn Estuary, and elsewhere, is viable and sustainable.

Written by Neil Crumpton

Campaigner and Energy Spokesperson