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# The Severn Barrage

This report sets out why Friends of the Earth Cymru maintains its opposition to the construction of a Severn Barrage after reviewing recent calls for a new appraisal of the scheme.

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## Summary

Friends of the Earth Cymru has revisited the case put forward for the construction of the Severn Barrage project (Cardiff-Weston barrage) and remain unconvinced about its claimed benefits.

We consider that there are various other cost-effective and less ecologically damaging ways to generate possibly as much, if not considerably more, renewable or low carbon power in the timescales in which the barrage may operate. Indeed, such technologies potentially include tidal lagoons in the basin area of the Severn estuary, which the presence of the Cardiff-Weston barrage would preclude. Consequently, there is no overriding national need for the barrage and the legally protected bird and other species, together with their rare habitats, should continue to be given protection under EU law.

We consider that there are far less environmentally damaging ways to minimise existing and forecast future climate related flood risks around Severnside. New coastal defence techniques, which include managed retreat, forward building, retractable barriers, and the construction of bunds using silt filled geo-textile bags might also actually enhance the Severn's protected biodiversity. A much smaller Shoots barrage located just downstream of the Second Severn Crossing may also be an option, and one which could carry a strategic (south Wales-London) rail link and generate tidal power.

We are concerned that the Cardiff-Weston barrage would impede navigation of larger ships and so significantly reduce freight trade entering the UK via the Severn ports, particularly Avonmouth and Portbury. This would have adverse knock-on effects on the economy around Bristol, and strain port capacity at, and transport links to, other UK ports.

We are concerned that the barrage would draw investment away from other renewable energy technologies in which the UK has commercial leads and export potential. We also point out that the huge twice daily pulses of barrage power to the National Grid would be costly and difficult to balance.

In our view the issues above combine to make a powerful case against the building of the Severn (Cardiff - Weston) barrage project. However, the possibility of building a significant capacity of 'high output' tidal lagoons in the Severn estuary, generating possibly well in excess of 10 % of UK electricity demand and with a storage potential of several Dinorwic pumped storage schemes, deserves serious investigation.

For these reasons, Friends of the Earth Cymru recommends that an environmentally benign tidal lagoon demonstration scheme is given strong political support at the very least, and built as soon as possible, be it Swansea Bay or other location.

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## Introduction

The tidal range in the Severn Estuary is one of the highest in the world, reaching over 13 metres. So ideas for taking advantage of the Severn's high tidal range for energy generation have long been talked about by the public and energy specialists alike.

Numerous studies focussed around an electricity generating barrage were carried out between 1974 and 1988 following which a scheme was drawn up. It was called the Severn Barrage project and is essentially the design which has been proposed since. Yet the scheme was then and has since been widely considered as economically unattractive and also gave rise to environmental concerns.

The Government's recent energy review sparked renewed public debate about the construction of this Severn barrage scheme following further publicity by barrage supporters. This was perhaps unsurprising as the urgent need to address global climate change by reducing fossil fuel use is becoming widely understood.

Barrage supporters have cited new reasons for a re-examination of the barrage: rising world energy prices, 'low carbon' energy security, global warming related flood defence and coastal protection benefits, the potential for new habitat creation and the inevitable habitat changes due to sea-level rise, improved waterfront amenity, and a road and possible rail link between south Wales and the west of England.

Perhaps more surprisingly, the Welsh Assembly Government in its 'memorandum' response to the energy review said that it supported a new feasibility study into the barrage scheme. This call flew in the face of widespread calls over a number of years for a strategic comparative assessment of all potential large scale tidal energy generating technologies, or combinations thereof in the Severn Estuary (i.e. tidal lagoons, tidal fences, barrages, and underwater turbines in the deeper waters to the west).

In July the Government announced its review findings in a document called 'The Energy Challenge'. It stated that the government will work with 'key interested parties to explore the issues arising on the tidal resource in the UK, including the Severn Estuary, including

potential costs and benefits of developments using the range of tidal technologies and their public acceptability' (1).

Friends of the Earth Cymru welcomed the decision for an inclusive study of the range of tidal technologies, particularly as tidal lagoons appear to have the potential to extract tidal energy from the eastern part of the Severn estuary in a cost-effective and environmentally friendly way.

## Section 1 The estuary and the barrage

### 1.1 The Severn Estuary

The Severn Estuary is an ecologically rich and rare environment of international importance for birds and wildlife habitats. The extremely high hyper-tidal range caused by the funnelled shape of the estuary, globally one of the highest, has created niche and unique habitats in an environment which changes greatly by the hour.

In recognition of its international importance the estuary is currently being proposed for designation as a Special Area of Conservation (SAC) the highest protection in European Union law.

The fast flowing tides cause major sediments movements daily in the main heavily scoured channels. The resulting muddy waters severely limit the growth of small waterborne life in some areas. Yet adjacent areas of the Estuary are very biologically rich. Beneath the surface, there are around 10 billion shrimps and millions of fish living on worms and other tiny creatures within the mud.

Inter-tidal mudflats and sandflats, totalling around 77 square miles, have been created by the huge, twice daily tides. These flats provide a source of food and undisturbed refuge for thousands of water birds, some resident, many more over-wintering on major migration routes. Most bird species feed on the inter-tidal mudflats. The Severn is in the top 20 of the most important estuaries in the UK for wintering wildfowl and waders. It is one of the vital food refuelling stations for species breeding at high latitudes and spending winter in southern or western Europe, the Mediterranean and Africa. This is especially so when severe weather affects other UK sites further north and on the east coast.

The Estuary regularly supports over 20,000 birds and the over-wintering peaks have reached about 65,000 in the last 5 year, down from around 80,000 in the 1990's. Around 100,000 birds were recorded in the winter season of 1994 - 95. This includes several species whose numbers currently reach levels of international importance (1 % or more of that species): shelduck, teal, pintail, dunlin, redshank, and in recent years, Beswick's swan



and gadwall. Other species include European white-fronted goose, pochard, curlew, tufted duck, lapwing, wigeon, shoveler and grey and ringed plover.

The Bewick's Swan, found in important populations on the upper reaches of the Estuary, is listed as a species in danger of extinction. It feeds on the saltmarsh and nearby meadow grasses and uses the mudflats as a refuge when disturbed.

The huge tidal range has created extensive areas of saltmarsh, around 350 hectares in Gloucestershire. The saltmarshes are a roosting area for birds and some species feed on the seeds of saltmarsh plants. Areas called Atlantic salt meadows are of international significance.

Within the fast moving, turbid waters 110 species of fish have been recorded, more than any other UK estuary including 7 species of migratory fish, also more than any other in UK. Stocks include tens of millions of young sea bass which form a basis of the Irish Sea fisheries.

The migratory species, which move between salt and fresh water to complete their breeding cycle, are salmon, sea trout, allis shad, twaite shad, river lamprey, sea lamprey and eel. The rivers Wye and Usk are important migratory destinations. Elvers and eels migrate 2,000 miles from and to the mid Atlantic.

Other species, such as the abundant shrimp which are the basis of a complex food web, migrate within the estuary on a seasonal basis. Over the course of a year shrimp and their predators range from the mouths of the sub-estuaries seawards to Bridgwater Bay. They use the whole estuary system as a breeding area, nursery and food resource.

Several habitats have been prioritised in the UK Biodiversity Action Plan. The Severn and its ten sub-estuaries represent 7 % of the UK's total estuary resource.

The estuary's narrowing coast and upward sloping bed forms a funnel shape which generates a pronounced wave called the Severn Bore as spring flood tides travel the 20 miles upriver towards Gloucester. The largest bores occur on about 25 days per year, can reach 2.5 metres high or more, and can travel at over 12 miles per hour.

The Severn has always been a highly dynamic estuary and the position of the shoreline has changed markedly in prehistoric and historic times. This process explains the extraordinary richness of the archaeology of the Severn and the surrounding wetlands.

## 1.2 The Severn Barrage

A range of 'tripartite' barrage studies were made between 1974 and 1988 which cost millions of pounds of public and private finance (2). From these studies a Severn Barrage Project was drawn up by the Severn Tidal Power Group (STPG) in 1989 (3). A revised 'New Appraisal' report was published in 2002 by the STPG calling for a re-examination of the Barrage Project (4).

The barrage scheme proposed would stretch nearly 10 miles from Lavernock Point west of Cardiff to near Brean Down in Somerset (hence called the Cardiff-Weston barrage). 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 impound an area, called a 'basin', of around 185 square miles of the estuary. A 140 mile stretch of coastline would border the basin. 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 Project proposal would be 8,640 megawatts (MW) or 8.64 gigawatts (GW) and would have a load factor of about 23 %. Generation would occur on the ebb tide. Output may be augmented by pumping additional water from sea to basin when the flood tide is near its peak (known as 'flood' pumping). The proposed barrage would generate about 17 tera-watt hours per year (TWh/y) in an average year or about 4.3 % of current UK electricity demand which was close to 400 TWh/y in 2005.

Some over-estimation in the public mind of the actual scale of the barrage output has been caused by failure by some in the media and elsewhere to distinguish between the terms electricity and energy. Electricity demand is about 19 % of UK energy consumption. The barrage output would be equivalent to about 0.8 % of current UK 'final' energy consumption which was around 2,050 TWh/y in 2005 (5).

Construction of the 62 million tonne (mt) structure comprising 370 reinforced concrete caissons would take place at numerous locations around the UK and even Europe. The hollow concrete caissons (17 mt) would be filled with sand for ballast (29 mt) and joined to each coast by rock-fill walls comprising a further 16 mt of aggregates (around 8 mt of this aggregate could be avoided by using silt in geotextile bags).

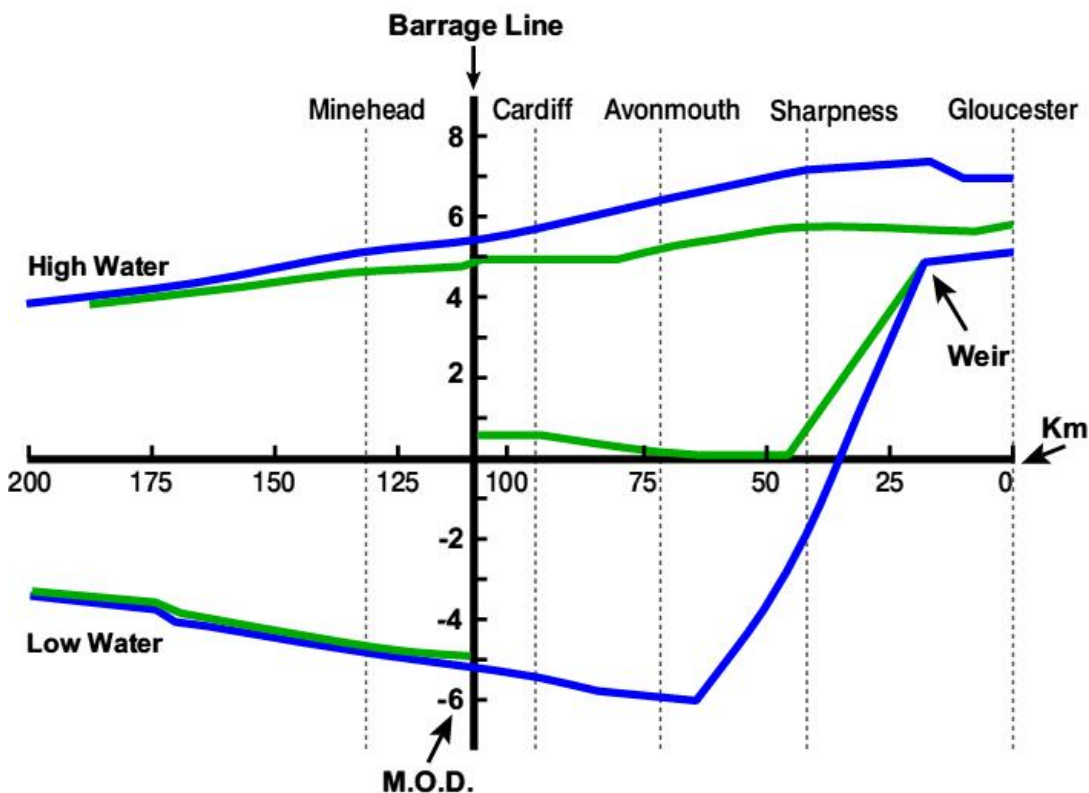
Around 18 million cubic metres (around 30 mt) of seabed material would have to be moved to create a level foundation. The caissons would then be carefully located in position during good weather and neap tides at a rate of about two caissons per month. This would take about 84 months if all went according to schedule. The barrage could probably be built by around 2019.

### 1.3 Why the barrage would be environmentally damaging

The barrage's 'ebb flow' mode of operation would require the permanent impoundment of the lower half of the existing tidal range to create a 'head' of water from which to generate electricity. Consequently, the tide in the 185 square mile basin would vary over the top half of its current 11 metre range at Lavernock Point. This would result in about 60 % of the current inter-tidal area being permanently submerged, an area of around 46 sq miles.

Figure 1 Water levels in the Severn Estuary and river (courtesy The Severn Barrage, STPG Presentation, June 2006)

## Water Levels - Estuary and River Spring Tides



**KEY**

Levels: Existing —————

Barrage, no pumping —————

M.O.D. - Mean Ordinance Datum

Not only would the spring tidal range in the basin reduce from about 13 meters to 5 meters the tidal cycle would also be altered to maintain high water levels to create the head of water. This would reduce the time that the remaining inter-tidal zone is exposed by an hour or more.

So a significant part of 77 square mile inter-tidal habitat, feeding grounds for tens of thousands of birds, would be lost, only around 30 square miles would be left. Among the 65,000 birds that typically winter on the estuary are six species of international importance which are protected.

The incoming tidal surge eventually bores up river and on spring tides salty water inundates exposed low-lying areas which have become salt marshes. The barrage would moderate this tidal surge by up to nearly two metres and alter the frequency and extent of inundation of this rare and protected habitat. Substantial erosion and loss would almost certainly result.

The Severn Bore would possibly be significantly reduced in height and strength though much would depend on the amount of flood pumping within the operating regime. The barrage would also significantly alter the energy of current flows in the estuary, which would impact on the sediment regime, on silt deposition, and to some degree salinity. Tidal current speeds would be reduced by half and the 4 - 30 million tonnes of sediment scoured and carried on the neap to spring tides would substantially reduce.

The reduced energy in the water column would result in mud deposition and the reduced turbidity would allow greater sunlight to enter the waters generating more marine life. The 1989 barrage studies indicated that some changes caused by the barrage could or would bring benefits to some habitats and some species as the remaining inter-tidal area would become more biologically rich.

It could be that the basin water and the remaining inter-tidal flats would become more biologically productive, possibly supporting as many, if not a greater number and species of birds. Yet the RSPB says that the habitat changes would likely result in a change of species composition, away from the acknowledged conservation features and protected species of the site. The 1989 tripartite studies identified that three important bird species would not only be displaced but would not be able to find alternative sites elsewhere in south western England or Wales.

More specific studies since that time have not fundamentally altered the 1989 findings. A recent study on redshanks following the building of the Cardiff Bay barrage did find that displaced birds had poorer body condition and lower survival rates (6). Other studies have found reductions in numbers of some migrating bird species occurring since about 2000. This may be caused by birds finding favour and 'short-stopping' at sites around a warming North Sea.

Yet climate change will further affect all these sites over time and it would not be a good strategy to incrementally encroach on any or all protected habitats on the basis of what could be short or medium term trends in bird behaviour. The STPG agree that further studies, albeit more focused, would need to be done.

#### **1.4 Impacts on fish**

The effect of fish species of conservation interest (particularly lampreys, salmon and shad) also has to be further studied. The barrage wall and turbine operations could have a significant impact on any of seven migratory species in particular.

Migratory fish would have to pass through the sluices, turbines or fish passes. Migrating fish spawn in fresh water and out-migrate to salt water before returning to spawn close to the location of their birth. Consequently, such species would be instinctively required to pass through the barrage structure at least twice. The mortality rate for fish passing through low-head turbines is about 6 %. Fish ladders can also have a similar mortality rate, depending on the success of the design, and also fish may avoid them. Those species which migrate within the estuary may also have to cross the line of the barrage.

Those fish that successfully negotiate the barrage structure, would then pass into the calmer basin where the change in current flows, sedimentation, directional clues and predation could either benefit or disbenefit differing species.

## **1.5 Sea level rise**

The STPG say that sea level rise due to global climate change will adversely affect the existing habitats and that has to be included in future decisions about conservation. Yet, whatever adverse effects there could be, it hardly compares with the 'sea level' changes in the basin area that the barrage would cause.

The latest projections for sea level rise range up to around 1.2 metres over the next century (see section 2.4 below) resulting in gradual habitat changes. This would allow species and UK flood defence strategies decades in which to adapt. The barrage would result in a 'sea level' rise of around 5 metres or more within one year, submerging 60 % of the inter-tidal area almost instantaneously, allowing species no time to adapt.

The draft Severn Coastal Habitat Management Plan (CHaMP) predicts a 10 – 20 % loss of inter-tidal habitat over the next 100 years. Without compensating measures this would likely exacerbate the waterfowl population changes seen from other factors but the Severn will continue to be an internationally important destination for migrating birds.

Protection from an increasing rate of coastal erosion caused by increased climate-related storm intensity and frequency in combination with sea level rise has also been cited as a benefit by the STPG. However, the Environment Agency has stated that 'claims of tangible flood defence benefits are therefore marginal to the overall case for a barrage' (7).

## **1.6 Barrage effects westward of the structure**

Any investigation should also include the potential erosion effects caused by the barrage on the westward coastlines. The diversion or reflection of tidal and wave energy back on to the very vulnerable coastline of Bridgwater Bay is a particular case in point (see Flood avoidance section 2.5). The barrage structure would resist tidal movements. Even though the basin area remains about half full permanently, resulting in much less basin volume to fill on the flood tide, the tidal height would be less than currently is the case, by one metre or so at Newport. Flood pumping would be required to raise the basin level further (see Figure 1).

All told, the features which comprise the conservation interest of the estuary would be significantly adversely affected by a Severn barrage. It is difficult to compare new habitats that would be created by the barrage with the current habitats, or the habitats modified by climate change, in the coming decades.

### **1.7 La Rance barrage**

Positive impacts have also been cited with reference to a barrage across a narrow, rocky estuary at La Rance in France. However, the various studies of barrage schemes and potential sites generally indicate very site specific effects.

The 240 MW La Rance barrage, which operates in both ebb and flow mode, is around 20 times smaller than an 8,640 MW Severn scheme. It is barely half a mile long, compared to nearly 10 miles, impounds just 9 rather than 185 square miles, and generates around 0.64 TWh per year, less than 4 % of what the Severn barrage would.

The ecology, the geography, and the scheme design itself are all different between La Rance and the Severn and comparisons are of limited relevance. There has also been a lack of pre and post barrage studies at La Rance on which to base authoritative conclusions about ecological effects.



## 1.8 Law and Policy considerations

The Severn Estuary and its tributaries are protected under a range of national and international designations. The estuary has three Site of Special Scientific Interest (SSSI) designations for various habitats and species (Upper Severn Estuary, Bridgwater Bay and Severn Estuary).

It is also designated as a Wetland of International Importance (Ramsar) and a Special Protection Area (SPA). The inter-tidal area is protected as an SPA under the Wild Birds Directive and two tributaries, the rivers Wye and Usk, are designated Special Area of Conservation (SAC's), the highest protection, in part because of migratory fish. The UK nature conservation agencies and JNCC have recommended to the UK Government that the Severn Estuary be put forward as a SAC.

The estuary is part of the Natura 2000 network of sites of European importance for wildlife and habitats. These sites, which are recognised for the interlinked nature of their species and threats, are the cornerstone of the EU's nature protection policy. Member states are required in law to protect them.

If a barrage were to be built it would have to be assessed for compliance under the EU Birds Directive and Habitats Directive. Adverse impacts, or risk of impacts, particularly on the identified species and habitat 'features' would have to be identified. It would have to be assessed against alternatives in terms of energy generation and flood protection as climate change will result in changes, probably disturbance and loss.

Any adverse effects or risks would then have to be justified for 'imperative reasons of overriding interest'. It would have to be demonstrated that alternative solutions are not available either in the area or wider afield.

Under the Habitats Directive, compensatory measures would also have to be proposed for habitat losses if the scheme were to be considered further. Yet the New Appraisal report notes that 'within the basin formed by the barrage the hyper-tidal nature of the estuary would alter significantly and no measures to compensate for the loss of this particular feature could be engineered'. This is a crucial point, which was further clarified by the government's decision to refuse the application for a deep water port at Dibden Bay in agreement with the

inquiry inspector's recommendation. There is doubt that the coherence of Natura 2000 could be secured if the barrage scheme were to go ahead.

The proposal would also have to be considered under the Water Framework Directive which requires that there is no deterioration of water quality and for restoration of water quality. Flushing would be restricted by the structure and several gravity-fed sewage outfalls would have to be dealt with.

The government's own statutory advisers state that 'a Severn Barrage development would not be possible within the current legal framework provided by the EU Habitats and Birds Directives. Adverse effects on the integrity of the habitats and species of international importance appear inevitable' (8).

## Section 2 The case against the barrage

In this section the case put forward by the STPG, particularly in their New Appraisal report, is critiqued by Friends of the Earth Cymru. The value of barrage power claimed is looked at in detail and alternative solutions in terms of energy generation, emission reductions and flood defence are proposed.

### 2.1 New Appraisal Report

The construction cost of the barrage has always been considered a major hurdle to its viability. Construction estimates currently vary around £ 14 billion (at 2005 prices) depending on a number of factors ranging from the cost of finance, to the provision of road and or rail link, and the size of the lock system required for future shipping.

In the 2002 New Appraisal report a barrage cost of £ 55 - 65 /MWh (2001 prices) was estimated using a discount rate of 6 % and other variables. Around a further £ 5 /MWh reduction would depend on who pays what for the substantial grid connections.

The STPG proposed this cost would be covered by the sales of power (estimated at £ 20 - 27 MWh), plus a credit for avoiding carbon dioxide emissions (£ 30 /MWh), plus a value for avoided future flood damage (£ 20 /MWh).

However, Friends of the Earth Cymru consider that various cost benefits have been overestimated:

- the 6 % discount rate is a subsidised rate and is considerably less than the conventional 10 % (8 – 15 %) market rates which, if used, would put the kWh cost into double figures. Mega-construction projects also have a history of over-running, which also increases costs.
- the value of emissions avoided figure (for reasons set out in 'The value of avoided emissions' section below – which considers more cost-effective carbon dioxide reduction strategies and electricity generation technologies which can harness indigenous resources)

- the value of flood avoidance (for reasons set out in section 2.2 below - which considers alternative flood defence strategies)
- the value of barrage power (for reasons set out in section 2.2 below)

The discount rate at which construction capital is raised significantly affects the cost of electricity from any scheme be it barrage or lagoons. Typical discount rates are 8 or 10 % and delays in construction can also add to the output cost. The following cost of electricity figures were put forward at a SDC 'tidal power options' workshop in Cardiff in March 07.

**Cardiff-Weston barrage:**

**5 year build time:** 8.54 p/kWh at 8 % discount rate and 11.18 p/kWh at 10 %

**7 year build time:** 9.24 p/kWh at 8 % discount rate and 12.37 p/kWh at 10 %

**Shoots barrage:** 6.8 p/kWh at 8 % discount rate and 8.62 p/kWh at 10 %

**Swansea lagoon (TE Ltd):** 4.2 p/kWh at 8 % discount rate and 5.1 p/kWh at 10 %

**DTI / WDA study:** 17.0 p/kWh at 8 % discount rate and 23.0 p/kWh at 10 %

Note the difference in the cost of barrage power at usual commercial discount rates. Also note the differences in lagoon output cost between TE Ltd funded studies and DTI / WDA study. TE Ltd says that much larger lagoons would be cheaper (~ 3 p/kWh than their Swansea scheme (~ 3.4 p/kWh) due to economies of scale.

Accounting for what Friends of the Earth Cymru concludes as the likely overestimates, the value of barrage power may well be more like £ 40 /MWh rather than up to £ 77 /MWh put forward by the STPG in the New Appraisal report. This compares with the STPG's costs estimate of around £ 55 - 65 /MWh (in 2001 prices) at a 6 % discount rate.

Note that a generating cost of £ 55 – 65 /MWh equates to 5.5 – 6.5 pence/kWh. A generating cost of around 7 pence per kilowatt hour (p/kWh) has been put forward by the STPG in 2006 (9).

## 2.2 The value of avoided emissions

The New Appraisal report estimated that the barrage would avoid emissions of around 17 million tonnes of carbon dioxide per year (mtCO<sub>2</sub>/y) worth £ 30 /MWh. This is because the output of fossil fuel power stations would be turned down when the barrage was generating and turned back up again when the barrage stopped generating after each tide. This is known as 'load-following'. The daily variations in UK electricity demand are currently met by coal power stations varying their output to match the national grid demand. Yet, by 2019 load-following power stations will emit much less carbon dioxide. So a re-evaluation is needed.

The 'avoided emissions' figure is based on about one tonne of CO<sub>2</sub>/MWh avoided from the very dirtiest coal power stations operating (emitting up to 1 million tonnes of CO<sub>2</sub> per 1 TWh) in 2001, and a carbon trading price of £ 30 / tonne of CO<sub>2</sub>. By the time a barrage could be built, probably 2019, the specific emissions from modernised or new IGCC 'clean coal' power stations (possibly in CHP mode) are almost certainly likely to be much lower due to significant efficiency advances and policy requirements. And, by 2019 it is likely that ageing 'mid-merit' CCGT gas power stations may be performing a large share of load-following duties.

New, more efficient 'super-critical' boilers can be fitted to some of the UK's existing coal power stations. With moderate co-firing (9 %) modernised coal plant may well be emitting around two thirds ( 0.65 mtCO<sub>2</sub>/TWh) of the figure used by the STPG ( 1.0 mtCO<sub>2</sub>/TWh ). So, by 2019 the barrage would probably displace about 11 mt CO<sub>2</sub> per year if displacing coal-fired generation. So the value of emissions avoided by a barrage would be equivalent to more like £ 20 /MWh or less rather than £ 30 /MWh estimated by the STPG.

It could well be that the emissions avoided would be even less than 11 mtCO<sub>2</sub> per year. By 2019 there could well be more gas power stations (CCGTs) and less coal power stations in the UK. So some ageing 'mid-merit' CCGTs may also be needed for load-following duties

and emissions from such CCGT plant would be around 40 % lower (0.42 mtCO<sub>2</sub>/TWh) than even modernised coal plant (i.e. 7.2 mtCO<sub>2</sub>/y).

Gas generated electricity is forecast by the DTI at 55 % of total UK electricity demand by 2020 and nuclear power may account for approaching another 20 % of the baseload\*. Such a scenario would leave only around 25 % of demand to include all the non-barrage renewables (16 % by 2020) plus the twice daily tidal 'pulses' of power from the barrage (4 %) plus all the remaining coal capacity (5 %). The largest coal station, Drax in Yorkshire, is 4 GW, which even at a low load factor of 60 % would provide 5 % of annual demand.

The barrage's output pulses last between 2.5 – 6.5 hours. The peak level of the pulses would be between 3 - 8.6 GW, rising from zero by a huge 1.5 - 8 GW per hour. The peak level would reach between 8 % - 21 % of the average daily grid demand of 40 GW in winter. The peak would be even more in summer as demand is lower. In such a scenario it does not look possible for what little coal capacity that may remain to load-follow the twice daily pulses without CCGT's.

The emissions avoided by a barrage may be further reduced because a rising proportion of coal and gas power stations may also be fitting carbon capture and storage (CCS) equipment after about 2015. Drax may be one such station.

Consequently the barrage output may only avoid between 7 - 11 mt CO<sub>2</sub>/year by the time it could be built. This would be worth £ 20 /MWh at best in the STPG example depending on the mix of coal and gas power taken off load to balance the barrage output (assuming a price of £ 30 /ton CO<sub>2</sub>).

Such issues considered, the value of barrage's avoided emissions would probably be less than £ 20 /MWh rather than the £ 30 /MWh estimated by the STPG in the New Appraisal report.

Note : Friends of the Earth response to the energy review showed in detail that much greater low-carbon, load following capability, and numerous other benefits, could be realised by fitting CCS to existing and or new IGCC coal gasifier stations as opposed to building new nuclear power stations (10). Achieving 'good quality' CHP status with as much of this capacity as possible would also benefit energy security and carbon reduction targets.

### 2.3 The value of flood defence

Over time, without preventative measures, the low lying areas around the Severnside region would become more at risk of increased flooding due to storm surges and sea level rise caused by climate change. Yet coastal flood defence schemes can be built relatively quickly and sea level is forecast to take decades, if not a century or more, to rise to a point at which a barrage could possibly be justified on coastal protection grounds.

In 2001 the International Panel on Climate Change (IPCC) published their Third Assessment Report (TAR) which projected that the global average sea level would rise by between 9 and 88 cm between 1990 and 2100 depending on various scenario assumptions.

Also in 2001 a DEFRA study into flood damage around Severnside estimated that the annual average damage cost associated with flood risk at £ 1,000 - 5,000 per hectare (11). It stated that costs could rise over 100 times by 2075 due to the effects of global warming and sea level rise. This valuation was based on an absence of mitigating measures.

Based on the DEFRA study the 2002 New Appraisal report calculated a cost associated with the flood 'risk' area at £ 40 - 200 million per year rising at least £ 4 billion per year by 2075. Such figures were derived using a 40,000 hectare estimate for the area of land below the 2001 flood defence standards which the barrage could protect. The STPG then valued the barrage's average flood protection at £ 20 MWh/y, or £ 350 million per year, over its 50 year pay-back period.

However, it would not require what would amount to an ongoing 'payment' of £ 350 million per year, which is what £ 20 /MWh would represent, to prevent such flood risks. Since 2001 additional flood protection measures have and are being put in place by the Environment Agency and a new Gwent Levels protection strategy is expected in early 2007. Indeed, increased funding for the Severnside area could be very cost-effective.

Damage to the tune of anything like £ 40 - 200 million per year around Severnside would amount to £1 billion within the ten years before a barrage could be built. The current annual budget for flood risk management in England and Wales is currently about £ 600 million per year.

## 2.4 Future sea level rise

The IPCC Fourth Assessment Report (4AR), which was released on 2<sup>nd</sup> February 2007, included revised projections of sea level rise based on latest agreed evidence (12). These revised estimates include a contribution from Greenland and Antarctica but, due to timing, excluded possible major collapses or significantly increased melting.

The 4AR estimates that the one hundred year global average rise to the end of this century lie within the range 18 – 59 cm depending on various emission scenarios and a global temperature increase ranging from 1.1 – 6.4 Centigrade. The three central emission scenarios estimate rises of about 20 – 48 cm for a 2.4 – 2.8 Centigrade warming by 2100.

However, 59 cm is not the full ‘worst case’ scenario. According to a detailed critique by one authoritative researcher several significant factors have been excluded (13). The A4R scenarios do not include the full ice sheet uncertainty which could add 20 cm or even more. They do not include the full ‘likely’ temperature range given in the AR4 which could roughly add another 15 cm. Nor do the projections account for the fact that past sea level rise is underestimated by the models for reasons that are unclear. Furthermore, an AR4 map of regional sea level changes indicates that European coasts would experience a rise by 5 - 15 cm more than the global mean rise.

Warnings of a possible rise in sea level ‘measured in meters’ by 2100 have been made by James Hansen, head of the NASA Goddard Institute (14). He estimates globally devastating rises of up to 0.5 meters per decade or more would be caused by emission increases under anything like business-as-usual scenarios. The resulting warming would cause disintegration of the West Antarctic and Greenland ice sheets. He recommends that atmospheric carbon dioxide concentrations are kept below 450 parts per million. A 5 meter rise would submerge large parts of western Europe and the populated world and international efforts to limit atmospheric concentrations to such levels are gaining momentum.

In response to all the above issues, a sea level rise of up to around 1.2 meters by 2100 is considered for the purposes of this report. More detailed projections based on the possibilities of major melting of Greenland and or Antarctica may be included in the next or subsequent IPCC assessments. Such a 1.2 meter rise, even given increased storm surges,



suggests that shoreline coastal defences rather than a barrage would be a reasonable and appropriate strategy unless future assessments indicate otherwise.

Sea level is forecast to continue rise in future centuries due to inertial effects long after greenhouse gas concentrations have been stabilised. Beyond the IPCC 4AR estimates of an 18 - 59 cm rise by 2100, forecasts become more uncertain.

Over the next 500 years thermal expansion is estimated to cause between 40 – 110 cm given reasonable progress in reducing greenhouse gas emissions. Earth's small glaciers could contribute up to another 50 cm. However, melt water due to deglaciation of Greenland and the West Antarctic Ice Sheet could increase the maximum rise up to about 4 or 5 m by 2500. If the ice sheet collapsed a rise to about 9 meters could result by 2500.

Much depends on progress made in the next several decades to reduce emissions. Various climate models indicate that keeping atmospheric CO<sub>2</sub> concentrations to 450 ppm could limit rises to below a meter in 2500, excluding the Antarctica contribution which may be 20 cm or more per century.

Given these estimates the barrage would unlikely play a significantly greater role in flood defence or protection against sea level rise compared to other measures around Severnside for decades, if not a century or more. This allows sufficient time to assess global emission reduction measures and refine sea level rise forecasting before deciding if, where, or what design of barrage or other defences could play a useful role.

Note: Roger Hull of McAlpines and STPG conceded in the Guardian (31<sup>st</sup> July 2007) that the Severn barrage would not have had an impact on the recent floods (around Gloucestershire) as they happened on a neap tide.

## **2.5 New techniques in coastal protection and management**

New flood defence, habitat creation and coastal realignment techniques (managed retreat or forward building) are being developed around Europe and may well start to play a role in the Severn. The use of geo-textile bags filled with dredged material has also been used successfully. UK company HR Wallingford have carried out studies of such techniques for MAFF (15).

In recent years the requirements for disposal licences has resulted in a number of ports within or near marine SACs considering using dredged material for inter-tidal recharge schemes and salt marsh restoration schemes (16). Around 4.5 million tonnes a year of silt is dredged from the shipping channels of the Severn for maintenance reasons most of which is disposed at sea. Some of this material could be used for coastal protection (see Annex A).

In July 2006 the £ 7.5 million DEFRA funded Wallasea Wetland Creation Project in Essex was completed, described as one of the most significant wetland creation projects in Europe. It included a new one mile section of inland sea wall and a 1.3 mile, 4.5 metre high '1 in 200 year' earth embankment sea wall. The later wall was built in 12 months. This flood defence scheme created 110 hectares of new mudflat and salt marsh habitat by raising the existing ground level using 700,000 tonnes of non-polluted navigation dredgings. Saltmarsh has been described as 'more rare than rainforest' (17).

So much has and is being done, and more could cost-effectively be done, in terms of building a high degree of flood defences even before a barrage could be built or before it could offer any further protection if it were built. And such flood defences could be designed to enhance the very biodiversity for which the estuary is protected.

## **2.6 Westward of the barrage**

There is also a question of who would be accountable if the barrage itself caused coastal erosion and or flood risk on its seaward side. This could occur as the energy of the incoming tide and wave action is partly diverted or reflected back off the barrage structure. The barrage studies identified potential problems around the highly vulnerable eroding coastline around Bridgwater Bay, an important habitat with a high bird density.

It may be that the use of coastal defence strategies outlined above, including use of dredged material and geo-textile bags, could provide sea defences in Bridgwater Bay. However, this begs the question that they could also be used along other stretches of the Severn.

A very large area of the Somerset Levels would be flooded by a significant (at least several metres) rise in sea level, far greater than any areas around Severnside. The proposed barrage would not protect this area. This has caused some to call for a barrage along a line from Minehead to Aberthaw. However, this alignment is longer and the sea several metres deeper, so such an alignment would be even more expensive.

## **2.7 Rail link possibility**

In the coming decades, should the need arise, there may be an opportunity to provide additional flood protection for low lying Gloucestershire using a transport link in a different location to the barrage. The possibility of a new rail tunnel to replace the ageing, leaking but still serviceable Severn Tunnel route, opened in 1886, has been discussed recently. One new concrete lined single-track tunnel would be built and the existing tunnel would be used to accommodate a second concrete lined, single-track tunnel.

Alternatively it may be possible and cost-effective to build a new rail link on a bridge incorporating a retractable flood barrier or along the top of a proposed 'Shoots' barrage (see below). Such a rail bridge – barrier, could be built on the English Stones, a rock reef lying just east of the Second Severn Crossing. This would be the likely location for smoothest connection to the existing route. The estuary is about 2 miles wide at this point and at low tide 1.75 miles of the Stones are exposed. Such a construction could preclude or impede barge access to the small port of Sharpness but this would be small disbenefit relatively.

Similar ideas are not new. In 1933 a committee recommended the construction of a hydro-electric power station on a barrage located at the English Stones reef, which would utilize the tidal flow of the Severn. This plan, which was interrupted by World War II, was revived in 1945, when engineers confirmed the practicability of the scheme and projected an output of 2.2 TWh per year.

There is also a flood risk to low-lying Gloucestershire from storms and heavy rainfall in the River Severn catchment area causing high water levels to travel down river. A Cardiff-Weston or Shoots barrage would reduce this risk by preventing the incoming tides from pushing against the outward flow of the swollen river. Alternatively, a combination of a barrier, coastal defences and land management techniques along the course of the river, which reduce the rate of run-off, could also moderate this flood risk.

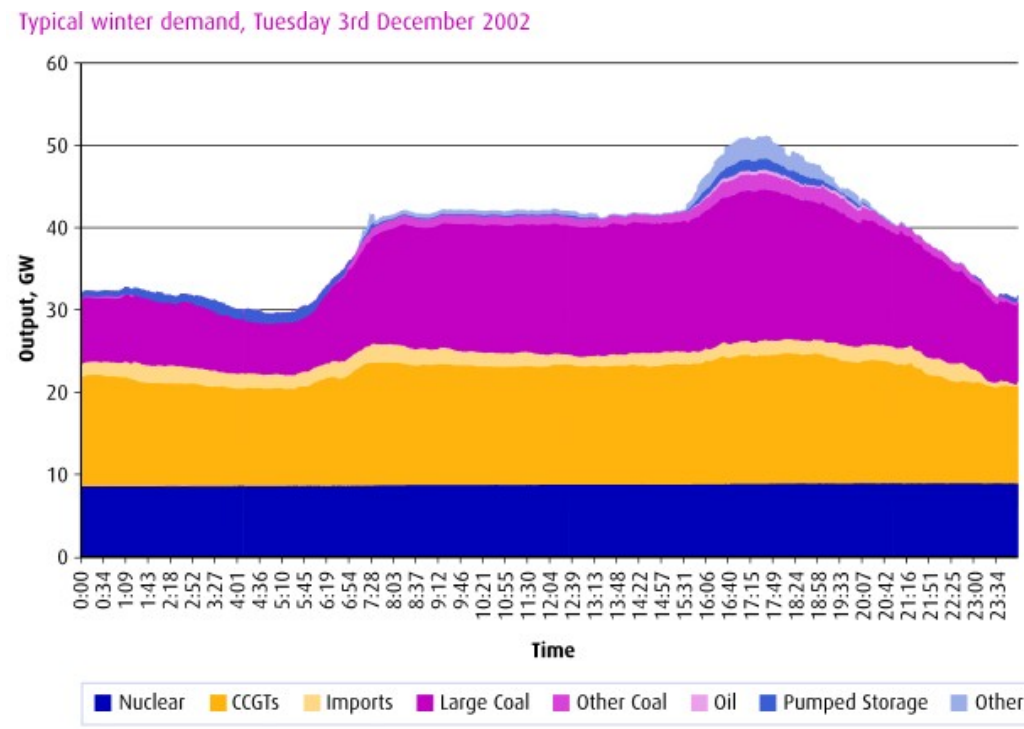
## **2.8 The value of barrage power**

Tides occur twice in about 24 hours and 50 minutes, each high tide advancing by about 25 minutes following the lunar cycle. So the barrage's huge pulses of power, which follow after each tide, would generally not be well timed to the usual daily variations in grid demand.

Some power stations have to vary their outputs so that changes in demand on the grid can be met. This type of operation is called 'load-following' and is mainly performed by the UK's large coal power stations.

The New Appraisal report indicates that the barrage's output timing could be varied or 'retimed' between one and two hours, with some loss of power, to achieve a better fit with the demand on the grid. The report estimates this capability could or would add £ 7 /MWh to the value of the barrage output.

Yet the huge pulses of barrage power would often add greatly to the variations on the grid and would require a significant degree of load-following themselves. This would likely cause wear and tear on the load-following power stations and would incur costs. Figure 2 shows a typical winter day's demand on the grid. The barrage's pulses of power could reach the height of the blue section (over 8 GW) twice a day and would last for a few hours each time.

**Figure 1 Typical winter demand on the grid (SDC report Wind Power in the UK, 2005)**

There would be times when the barrage's pulses of output are moving, or could be shifted, in line with the changes in grid demand. Yet this may only delay the time when fossil fuel-fired plant has to come on line anyway, so any cost benefits would probably be marginal. There would also be occasions, probably daily, when the barrage and grid outputs would be moving in opposite directions. This would require retiming to avoid major adverse swings in load.

Altering the optimum output timings to match grid movements or minimise adverse situations would likely incur some loss of power, estimated at between 0 – 25 % per cycle (19). Yet even an average loss of 6 % would result in a 1 TWh per year reduction, a loss in emission savings and potentially net income.

During the morning 'switch on' and evening winter peaks UK electricity grid demand can rise by around 5 GW per hour, falling off at a rate of around 3.5 GW per hour. In meeting this, coal plant ramps up by 4.5 GW per hour on winter mornings and 2 GW per hour during the evening peak. Gas-fired plant and pumped storage meet the remainder of the demand increase. The New Appraisal report indicates possible swings in barrage output of between 1.5 - 8 GW per hour depending on tide times and retiming decisions.

The New Appraisal report notes that highest spring tides in the Severn estuary lie within the period from 6.30 – 9.30 am and 6.30 – 9.30 pm. Yet such times are less than helpful for barrage operations. On these powerful spring tides maximum energy extraction is achieved if generation begins three hours after high tide. Although generation could be brought forward by one hour or delayed by two hours, at up to 25 % power loss, the retimed spring tide outputs would still not coincide with the daily surges or falls in grid demand which occur around 6 – 8 am and 3.30 - 5 pm.

Flood pumping during spring tides would occur around the time of peak daily grid demand adding further demand at just the wrong time. How this spike-shaped demand would be addressed is not clear.

Load following plant, typically coal power stations rather than gas power stations (CCGTs), is required to meet the large swings in daily grid demand. This is because steam turbines are significantly better than gas turbines at load-following. However, the thermal cycling and thermal shocks to coal plant, and more so to gas-fired plant, result in less than optimum efficiency and increased maintenance spend.

The rate of change of barrage output, averaging possibly over 4 GW per hour, would be comparatively very large (the largest UK coal station is Drax at 4 GW). If repeated up to 3 times a day, it would likely put the load following coal and gas stations under considerable strain. Such costs, which accrue to the load following generators, do not appear to have been considered in the barrage calculations.

A storage capability, such as a suggested secondary basin of 9 square miles, could also be added but this too would incur additional costs (20). So it would require further detailed study to identify what such output and timing changes may have on the 'headline' 17 TWh/y annual output, or the resulting annual income, or the costs to other load-following plant.

## 2.9 Predictability versus variability

Much is made of the barrage's 'predictable' power output and energy security. Yet it would not compare at all well with a significantly greater output of 'variable' wind power.

A recent study into renewables 'intermittency' estimated that the instantaneous output of widely distributed windfarms around the UK would likely vary by less than +/- 2.5% of their overall capacity per hour, and by only +/- 20 % per hour about once a year (21).

Consequently, even if all the 20 % by 2020 renewable electricity aspiration ( 80 TWh/y) were generated by windfarms, a massive 26 GW of capacity supplying nearly five times more annual power than the barrage, the likely hourly swing would be much less the barrage's (see Annex B).

The windfarms would likely experience an output swing of less than 0.65 GW per hour, albeit up or down, which is much less than the barrage's 'water limited' minimum of around 1.5 GW per hour even on a neap tide (22). A swing in wind power output of 5 GW per hour would happen about once per year. Barrage output swings of over 4 GW per hour could happen potentially up to 4 times every 25 hours for a significant part of the year.

Coincidentally, about 80 TWh/year could potentially be generated by wind power by 2020, with roughly 30 TWh/y from onshore farms and 50 TWh/y offshore (23). Indeed, 11 GW of onshore wind farms could provide twice as much power annually than the barrage with only a fifth to a tenth of the likely hourly load change.

Large power pulses could be moderated if re-timing towards 'water limited' operation were routine but this would incur power loss. Large pulses to the grid could also be reduced by using barrage power in electrolyzers to generate hydrogen, or using other potential fuels or energy storage systems instead. As electrolyser prices fall hydrogen production may become a cost-effective solution, as may the use of future inter-connectors.

## 2.10 Inter-connectors

The use of the 2 GW capacity inter-connector to the European mainland has also been suggested by the STPG to help dissipate the output pulses over a much larger network. The STPG claim that because the annual flow through the inter-connector has been almost entirely into the UK, swings of 4 GW could be accommodated.

By 2020 and beyond, due to the increasing renewable electricity capacity and variable output both in the UK and in Europe, it would be reasonable for UK grid operations to move to a net inter-connector flow around zero to help balance swings of up to 2 GW in either direction. So the capacity of the existing inter-connector could be required for general balancing duties so limiting is flexibility to around 2 GW swings. Indeed, the inter-connector could then help balance a massive 40 GW of cumulative UK wind farm capacity, which would have a likely swing of less than 1 GW per hour.

However, it is possible that the first new UK link, of what could become a European electricity 'super-grid', of high voltage, direct current (HVDC) links may be in place by 2012 and so could be used to export barrage power. This link is the £ 400 m, 1 GW 'BritNed' cable to the Netherlands. Such links would be designed to carry very large power flows very long distances to distribute and balance Europe's various renewable energy and hydro storage resources, and also link to vast Saharan solar and wind resources (24). Indeed, the 17 TWh/year of barrage power could be generated by, and be imported from, concentrating solar power schemes in an area of hot, relatively barren Saharan desert just one sixth (6 miles by 5 miles) of the impoundment basin area.

Airtricity, the developers of a proposed very large 10 GW windfarm in the southern North Sea propose to connect it to both the UK and continental Europe via 5 GW HVDC links (25). So it would be possible to export some power in the 0 – 5 GW range via this link when the windfarm would not itself be generating. As windfarms typically generate power at some level for 70 % of the time, even this link would probably be of limited usefulness for the barrage.

However, by 2025, there may be other HVDC super-grid links between the UK and continental Europe, possibly importing renewable electricity to the UK most of the time. Such links could enable barrage power to be subsumed on the wider EU grid.



## Section 3

### Effect of the barrage on other generating technologies

It would hardly be reasonable or lawful to cause significant damage to an internationally important and designated ecological site on the grounds that it would be likely that an aspirational renewable energy target for 2020 would not be met by other means.

The barrage would also physically preclude the development of other renewable technologies in the basin area of the Severn estuary or possibly effect marine turbine deployment on the seaward side. For this reason it is appropriate that the energy review stated that a study of energy technologies in the estuary would be of a comparative nature.

#### **3.1 'Overriding public need' in meeting electricity demand**

It would be a requirement under the Habitats Directive to consider alternative ways of meeting any identified benefits of the barrage to assess if there is an 'overriding public interest' for the scheme. Yet, depending on forthcoming energy policies, the barrage may have a significant adverse effect on the development of other renewable or low carbon technologies and schemes around the UK which could also provide low carbon electricity.

As the scheme would take between six and eight years to construct, assuming no delays in what would be a unique £ 14 billion civil engineering project, decisions to build the scheme would have to be taken before 2010 if it were to contribute to 2020 targets. The STPG propose a Government decision in 2007. Yet how could there be any certainty, before 2010, or even by 2015 that the 20 % by 2020 renewable electricity target could not be met by other renewable energy technologies.

If a barrage were built it is probable that some other generating schemes would not get built. The STPG say that its output could comprise nearly one third of the Government's 2015 renewables target. It is unlikely that it could be built by 2015 but it could generate a fifth to a

quarter of the Government's 20 % by 2020 renewables 'aspiration'. So it could displace the deployment of other electricity-generating technologies including other renewables.

The STPG also say that the scheme could be financed by private capital alone, if long-term carbon credits become available (though it also appears that other forms of public funding are also being sought). Yet there are finite funds for capital allowances and Renewables Obligation (RO) support, and a limited number of carbon credits within a trading scheme. So, depending on how policy is formulated following the energy review, the barrage would very likely displace some other schemes and technologies.

The review signalled that there would be moves to greater reliance on carbon trading to encourage the most cost-effective low carbon technologies, along with the possible 'banding' and 'extension' beyond 2015 of the RO to achieve the 20 % by 2020 aspiration. Consequently, the barrage could end up directly competing with other renewable energy schemes for a limited pot of carbon credits, capital funding and or 'ROC' certificates up to the obligation's final year in 2027.

Renewables currently supply around 18 TWh/y, the much-touted 'aspirational target' of 20 % by 2020 may equate to around 75 TWh/y and the barrage would supply 17 TWh/y. This would leave around 40 TWh/y from all other renewables. Yet the BWEA in its submission to the energy review estimated that on and offshore wind farms, plus a small contribution from tidal and wave devices, alone might generate around 75 TWh/y by 2020.

The 20 % by 2020 aspiration is not necessarily very aspirational as it is, especially if technological advances enable faster deployment and higher output. So a barrage could further compromise the development of other renewables.

To counter such unhelpful potential conflicts the barrage could be excluded from the RO, as are large hydro schemes. Alternatively, the renewables target could be revised upwards by including an 'impoundment band'. Without such provisions, the barrage could adversely affect the investor confidence needed for the construction of offshore windfarms, tidal stream devices, wave arrays, biomass and co-firing schemes, carbon capture and storage infrastructure, and other low carbon and renewable technologies. This is especially so in the 2015 - 2020 period as ageing UK power stations are required to close.

Any diversion of RO certificates, carbon credits and or capital allowances and possibly other resources, to a one-off, site specific concrete construction could damage technological leads that UK industries have in aspects of these developing technologies. This could have implications for technology transfer, exports and hence UK business, manufacturing and jobs.

Investment in tidal stream and wave technologies where the UK has an advantage in natural resources and a technological lead are a case in point. Initial schemes will have capital and revenue support from the Marine Deployment Fund. Generating costs will hopefully fall quickly as production scales up. So it would not be helpful if the barrage then crowded out further larger scale commercial deployments.

Similarly, even if a clash with other renewables were avoided, the barrage could still squeeze the development of other more cost effective low carbon technologies (i.e. CHP, offshore wind farms, CCS), or indeed energy efficiency measures, as there would be finite public funds for capital allowances for major programmes and or credits and commitments for CO<sub>2</sub> emission reductions.

One proposed development, the Airtricity 10 GW Offshore Wind and Transmission Foundation Project, offers an illustration for investment in a more CO<sub>2</sub> effective energy scheme which would also have wider developmental value than the barrage. The €20 billion scheme (£ 13.2 billion, about the same as the barrage) was put forward in detail in evidence to the Energy Review.

At a nominal 39 % load factor the scheme's 2,000 turbines would generate about 34 TWh/year, twice as much as a barrage in the critical coming 25 years period. The turbines would then be removed (and the metals recycled) and could well be replaced with new, possibly 50 % more powerful turbines, on the same foundations. The foundations and cables would likely be designed for such 50+ year operational life and re-powering. So the re-powering may be less than half the initial investment as the actual turbines comprise around 40 – 45 % of scheme costs.

In such a scenario the windfarm would generate as much power in 50 years (2,000 TWh) than the barrage would in its 120 year design life, for possibly just £ 5.3 - 6 billion more. This

assumes that sea level rise over the 120 year period does not significantly reduce the barrage efficiency by reducing the head of water.

In terms of cost-effectiveness, it is reductions in carbon dioxide emissions in the next twenty years rather than the next 120 years which are most needed to tackle climate change. This is because CO<sub>2</sub> emissions have an effect over a period of around 100 years.

The recent publication of the Stern report adds further weight to focusing on the earliest, most cost effective carbon reducing measures (26). In the Summary of Conclusions it states 'The investment that takes place in the next 10 – 20 years will have a profound effect on the climate in the second half of this century and in the next.'

Airtricity's Foundation Project would also give a major boost to the development of a European hv-dc super-grid, and a possible UK lead in developing an offshore wind industry. Indeed, an innovative British design for a vertical axis 'V' blade 10 MW offshore turbine could be ready for commercial development by around 2012. The 'aerogenerator' turbine by Windpower Ltd, with a possible design life of around 40 years, would be mounted on a concrete caisson base (fixed or potentially floating) which could have a design life of 80 years.

### 3.2 Carbon Capture and Storage

In terms of low carbon power generation, carbon capture and storage (CCS) technology could well provide a less damaging alternative. At a price of £ 30 / tonne for CO<sub>2</sub> it may be significantly more cost-effective to fit CCS equipment to coal and or gas power stations which would reduce their emissions by around 90 %. Consequently, such technology in itself would strongly challenge the case for a barrage on the grounds of 'overriding public need' which would be required under the Habitats Directive.

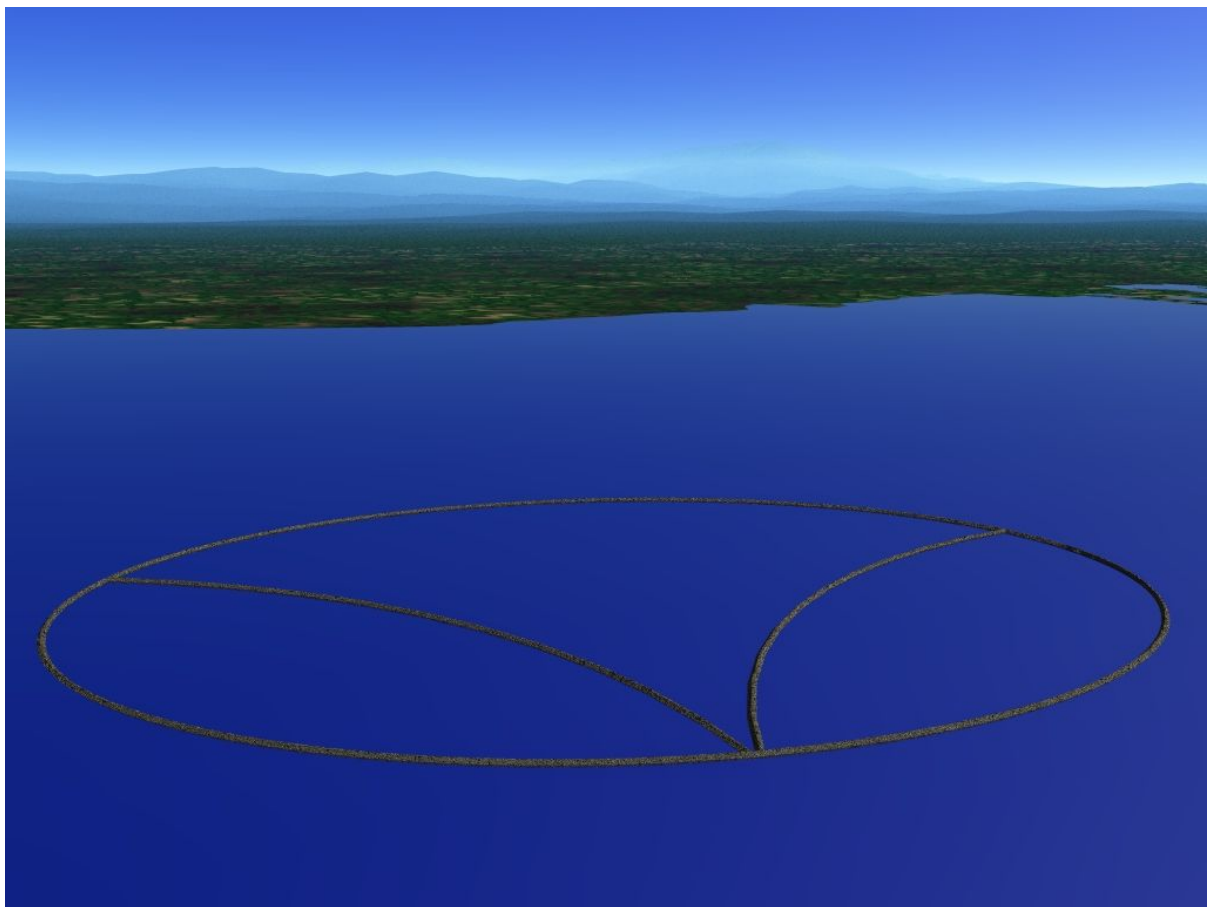
Generation cost estimates for coal and gas-fired power stations fitted with CCS are just below the 4 p/kWh mark. The DTI is currently considering funding a CCS demonstration project to test the technical feasibility and cost viability of commercial scale CCS fitted to coal or gas power stations. The cost of carbon dioxide at which CCS is currently considered by industry experts to become viable is £ 18 - 38 /tonne.

Progressive Energy, proposers of an 800 MW 'clean coal' gasifier on Teeside estimate that up to 5 GWe of such low-carbon power stations with capture and storage infrastructure could be built by 2015. Such a 5 GWe, £ 5.5 billion investment would generate about 33 TWh/year (at 75% load factor), nearly twice the 17 TWh/year barrage output. The gasifier is expected to be capable of up to 30 % co-firing, which could make the technology carbon-negative to a degree. At 20 % co-firing about 6.5 TWh/year of the 33 TWh/year of electricity would be from renewable biomass. If 5 GW of clean coal capacity (with or without CCS) were built as 'good quality' CHP then, at 20 % co-firing, about 13 TWh/year of renewable energy (electricity + heat) would be generated.

### 3.3 Other impoundment technologies in the Severn Estuary

The construction of the Cardiff - Weston barrage would preclude renewable energy generation from other tidal impoundment technologies east of Lavernock Point. Most probable schemes would be rubble-mound tidal lagoons and the Shoots barrage near the Second Severn Crossing. Lagoons in the basin area and a Shoots barrage are not mutually exclusive options and could work in combination.

#### Photomontage of Swansea Bay tidal lagoon (courtesy Tidal Electric Ltd)



There could also be the possibility of even concrete-walled tidal fences or fences with rows of propeller or vane type tidal stream turbines on monopiles supporting a rail bridge. These structures could also have a lifespan of, or in excess of, 120 years and could be cheaper and or less environmentally damaging to build. So even in terms of renewable power output over 120 – 200 years the barrage may not claim any unique advantage.

Furthermore, tidal lagoons generate on both the ebb and flow so the problems of pulsed power are roughly halved. Lagoons could also minimise or avoid the problem altogether and also become very useful grid-balancing 'all states of the tide' storage / generation schemes by using a 'multipool' design, and varying the operating regime, albeit at lower power per unit area. About 1 mtCO<sub>2</sub>/year could be avoided for each 400 MW of renewable grid 'back-up'. Currently, there is about 1.2 GW of fossil fuelled grid back-up.

### 3.4 Tidal Lagoons

Tidal Electric Ltd, the company promoting tidal lagoons says schemes impounding an overall area of around 50 square miles in the more easterly area of the basin could generate as much annual power as the 185 square mile barrage impoundment (27). This is a point of great difference between proposers of the respective technologies. The STPG has stated quite clearly that it would take a lagoon the size of the basin area of a barrage 'to generate as much as the barrage' (28).

Tidal Electric Ltd's (TE Ltd) claimed output with moderate pumping (see below) would amount to 340 GWh per square mile per year in the 12 metre tidal area of the basin. The barrage output would be 92 GWh per square mile per year from a slightly lower range (partially raised by pumping).

TE Ltd says the difference is partly explained by a lagoon's ebb and flow mode of operation using the full tidal range, as distinct from the barrage's 'stepped' ebb only mode, and partly because the barrage would impound 46 square miles of the less productive inter-tidal areas. The operating regime proposed for the Severn barrage does not use the full tidal range, but holds the water level at an artificially high level because it cannot sluice in enough water to fill the basin area if it were emptied on the ebb.

Estimating outputs is not easy, as the formula is quite complex, though power is proportional to the square of the tidal range. Yet, several respected engineering consultancies have confirmed TE Ltd's output figures (including MWH Engineering, RW Beck, WS Atkins, Delta Marine Engineering and AEA Technology). In response pro-barrage supporters, and a consultant to the DTI (currently hired by the Sustainable Development Commission),

continue to maintain that lagoons cannot possibly be more efficient than the barrage, despite the very different structures and operating regimes.

A detailed engineering study of a tidal lagoon proposal in Swansea Bay has been carried out by consultants WS Atkins. The scheme could be the world's first. Specialist consultants estimated an output of 0.187 TWh/year from the 1.9 square mile lagoon which equates to an output of 98 GWh per square mile per year in an 8.5 metre (spring) tidal range. The generating cost was estimated at 3.4 pence/kWh (29). Larger schemes may cost less due to economies of scale and enhanced pumping techniques.

A 2006 report 'on behalf' of the DTI (by a Severn Barrage veteran) estimated about 17 p/kWh at 8 % discount rate. This report was heavily rebutted by Tidal Electric Ltd.

**Cost estimates have been made for the proposed Swansea Bay lagoon scheme:**

<b>Atkins (2005)</b>	3.3 p/kWh at 10 % discount rate
<b>Tidal Electric Ltd (2005)</b>	3.1 p/kWh at 10 % discount rate
<b>AEA Technology (2002)</b>	2.5 p/kWh
<b>OFGEM (2005)</b>	6.0 p/kWh based on higher contingency numbers
<b>NM Rothschild (2005)</b>	3.6 p/kWh at 8 % discount rate

One criticism or question of tidal lagoons that tends to be raised at public meetings and conferences is that they would silt up. Tidal Electric Ltd has responded by saying that siltation would be avoided because the water within the lagoon would be turbulent as it enters and exits with considerable force. Also the internal walls would be steep and the impoundment would not be completely emptied. Currents of water could be directed to scour any pockets of siltation if any were to occur and in the unlikely event that larger pockets of siltation occurred then they could be removed by dredging. Other commentators at such public events have suggested that any silt be used to fill geotextile bags which could then be used in lagoon walls and or coastal defence structures.

Tidal Electric Ltd has widely stated that the proposed Swansea Bay lagoon would be built with private funds and could have already been built had they had political support. However, the company says that the DTI has been hostile to their proposals and some officials have referred to tidal lagoons a 'dead end' technology (30). This has diminished the company's confidence to apply for consents which would be very expensive.



In October 2006, the House of Commons Welsh Affairs Committee tried to address the DTI's hostile stance in their report 'Energy in Wales: Government Response to the Committee's Third Report of Session 2005 - 06'. It stated in paragraph 36 that:

*'Regardless of the merits and economic viability of the Swansea Bay tidal lagoon scheme, we have concerns about the DTI's handling of the scheme and the damaging effect that this has had on investor confidence and potential commercial development. We are pleased that the DTI has now withdrawn its technical objections to the scheme, but the errors made by the DTI officials have undermined and delayed a highly promising project. We recommend that the DTI takes urgent steps to address the damage it has caused, and to set out clearly its strategy for rebuilding investor confidence in this scheme.'*

Tidal Electric Ltd says little has changed since that time and Friends of the Earth Cymru is not aware of any support of any kind for tidal lagoon technology either from the DTI (now Department for Business, Enterprise and Regulatory Reform BERR) despite the widest public support in Wales and the UK for the development on the UK's tidal resources.

### **3.5 Potential power output from tidal lagoons**

In June 2007 Tidal Electric Ltd put forward its most recent and refined estimate of the potential contribution from lagoon schemes distributed over the range of possible suitable locations in the Severn estuary. Lagoon design would normally include 'moderate' pumping to enhance output by around 25 – 30 %. However, this should not be confused with a paper by Cambridge academics which suggested that further enhancement in a higher and deeper lagoon design could increase output per unit area by several times (31). This significantly higher output would be achieved by a pumping regime that utilises as much as possible of the lagoons' spare capacity during the lunar month.

Essentially a series of tidal lagoons could smooth their overall output and shape it to the daily demand of the national grid. This would be done by sequencing the output and by utilizing pumped storage along with the tidal resource. By pumping, storing and dispatching optimally, the round trip mechanical efficiency of the storage would at times exceed 100 %.

In comparison, the round-trip efficiency of the Dinorwic pumped storage schemes is about 75 %. By pumping at night and dispatching during the afternoon peak in grid demand the revenue stream from the output would be highly attractive, making the economic viability robust.

Using excess windfarm output and dispatching it predictably, a large scale tidal lagoon programme could minimise the variability issues of building wind power capacity well over the 20 % of electricity demand currently estimated to be the amount not needing specific back-up measures. Storing some of the night time output of fossil fuel stations would reduce their load-following requirements and reduce the peaking plant and reserve capacity needed to meet the afternoon demand peak (about 10 GW in winter) by several GW.

The possible locations and associated outputs for lagoons are listed by TE Ltd below (the 'output with pumping' figure is probably the most appropriate for consideration and comparisons at this stage). If accurate, the output of two or three large lagoons in the basin area (behind the barrage) with moderate pumping would equal or exceed the 17 TWh/year Cardiff - Weston barrage output.

Note that the Shoots barrage, if built, could add a further 2.75 TWh/year. However, this would exclude the possibility of a lagoon scheme on Oldbury Sands which could generate up to about 1.5 TWh/year with moderate pumping.

Note also that marine current turbines, which could be located in deeper water further west in the estuary, would not be affected by lagoons and could generate around 0.5 TWh/year (around 200 MW of capacity according to MCT Ltd).

**Lagoon Outputs (TE Ltd estimates)**

	<b>Area (sq km)</b>	<b>Mean Tidal Range</b>	<b>Capacity MW</b>	<b>Load Factor</b>	<b>Output TWh/yr</b>
<b>No pumping</b>					
Oxwich Bay	4	6.5	48	33 %	0.139
Swansea Bay	5	7	60	36 %	0.189
Porthcawl/Scarweather	24	7	300	38 %	0.999
West Nash	8	7	100	38 %	0.333
Culver Sand	10	7	120	40 %	0.420
Watchet/Blue Anchor	8	7	95	40 %	0.333
Bridgewater Bay	91	10	1900	55 %	9.154
Weston-super-Mare	4	10	90	55 %	0.434
Sand Bay	3	10	70	55 %	0.337
English Grounds/Longford	40	10	850	57 %	4.244
Cardiff-Newport	72	10	1500	57 %	7.490
Welsh Grounds	72	10	1500	57 %	7.490
Oldbury Sands	12.5	10	270	57 %	1.348
Total Severn Estuary			6903		32.910
Total Behind Barrage			4280		21.343
<b>With moderate pumping (+ 25 to 30 %)</b>					
Total Severn Estuary					41.137
Total Behind Barrage					27.746
<b>With enhanced pumping 'high-output'</b>					
Total Severn Estuary					98.730
Total Behind Barrage					68.297

The possibility of building a significant capacity of 'high output' tidal lagoons in the Severn estuary, generating possibly in excess of 10 % of UK electricity demand (40 TWh/year) and with a storage potential of several Dinorwic pumped storage schemes, deserves serious investigation.

The 2007 EU spring summit agreement to generate 20 % of EU energy (not just electricity) by 2020 from renewable sources adds to the need for the UK to identify and deliver more than the Government's current 20 % by 2020 renewable electricity aspiration.

### **3.6 Aggregate requirement comparisons between barrages and lagoons**

One criticism of the lagoon technology has been the scale of aggregates required compared to the Cardiff-Weston barrage for the equivalent annual output. However, when an overall comparison is made of the quantity and the quality of the aggregates, as distinct from silt (in geotextile bags), then there could be little difference in megatonnes per unit of electricity output.

The STPG estimates that about 62 million tonnes (mt) of materials, of which 50 mt would be aggregates (assuming 8 mt could be silt in geo-textile bags) would be required for the construction of the Cardiff - Weston barrage :

- 17 mt of concrete caissons
- 29 mt sand/gravel ballast within caissons
- 16 mt rock walled coastal link sections (core fill capped with armourstone, possibly up to 50 % by weight silt in geo-textile bags)

Tidal Electric Ltd recently estimated that about 100 million tonnes of materials, of which about 50 mt would be aggregates and about 50 million tonnes would be silt-filled geotextile bags, would be required for a 'behind-the-barrage' lagoons scenario (in the basin area) generating the equivalent output to the Cardiff - Weston barrage. The construction would comprise:

- 16 mt of armourstone (huge 2+ tonne boulders)
- 34 mt of core fill (unsorted aggregate from dust up to around 8 inches diameter)
- 50 mt dredged materials (loose silty material) within geotextile tubes

The geotextile tubes would typically be tens of meters long and of oval cross-section 6 feet high by 15 feet wide in situ. The dredged material de-waters once inside the bags.

TE Ltd says that there would be little requirement for what is typically called 'aggregates' (graded rocks from pea to golf ball sized) except what comes incidentally from quarry runs (ungraded output from the crusher). Presumably the barrage's rock-walled coastal abutment sections (16 mt) could be constructed out of silt filled geotextile bags (8mt), plus core fill and armourstone (8mt).

The dredged material could be silt from the routine maintenance dredging within the Severn estuary and or scrapings from the sea-bed within the lagoon impoundment. In the case of the Swansea Bay lagoon TE Ltd estimates that roughly half the wall material could be obtained by scraping the top 3 inches of the impounded area (incidentally this could increase the power output in a 'high-output' pumping regime).

PB estimates that the Shoots barrage construction would require about 12 million tonnes of materials:

- 1 mt concrete caissons
- 1 mt sand ballast within caissons
- 10 mt of rock wall coastal links

Presumably, as with lagoon walls and the Cardiff-Weston barrage abutments, the rock walls could comprise silt-filled geotextile bags (50 % of weight) plus core fill, capped with armourstone). So the aggregates requirement could be around 7 mt for the Shoots scheme.

Comparing the tonnages of aggregates required to build the tidal lagoons, the Shoots barrage and or the Cardiff-Weston barrage (assuming silt in geotextile bag construction where possible) reveals that they would all need broadly similar amounts of aggregates to generate the same annual output.

Consequently, the lagoons scenario or lagoons/Shoots barrage scenario of equivalent energy output to the Cardiff - Weston barrage would possibly require roughly the same tonnage of aggregates (around 50 mt) as the Cardiff - Weston barrage. The lagoons would require 50 mt of silt in addition yet there is plenty of silt available in the estuary some of which has to be dredged and dumped anyway (for example in the CEFAS area off Swansea).

### 3.7 Procurement of aggregates and construction emissions

Aggregates for the construction of any of the lagoon or barrage schemes would probably be obtained from coastal quarries around Europe. Norway would be a strong contender as UK prices are relatively high. In terms of the logistics for delivering 50 million tonnes of aggregates, and the carbon dioxide emissions released in construction, a comparison with coal is instructive.

In 2005 the UK consumed about 64 million tonnes of coal. About 20 mt of coal was deep-mined or from opencast in the UK. A further 44 mt was imported, including 13 mt from South Africa and 4.5 mt from as far as Australia (32). In comparison, the Severn barrage would require on average about 8 mt of aggregates a year during a 7 year construction period and a large lagoons scenario possibly around 6 mt per year.

Much of the coal was used for electricity generation at a rate of around 4 TWh for each million tonnes of coal, releasing 3.7 mt of carbon dioxide in the process. Carbon dioxide emissions arising from the production of 17 mt of 'carbon-intensive' concrete for the barrage, which would require about 2.6 mt of cement, would be around 3 mt CO<sub>2</sub> including quarrying (33).

Emissions arising from the transport of aggregates, and construction using silt filled geotextile bags, is more difficult to estimate, because it depends on the location of quarries and other factors. However, a US government study estimates that indirect emissions associated with coal transport (loading, transport, unloading, etc) for existing coal-fired generation is around 2.5 % of the total emissions ( 2.5 % of 1.02 mt CO<sub>2</sub>/TWh = 25 kt /TWh ) depending on distance (34).

Assuming each TWh requires 0.25 mt of coal then the CO<sub>2</sub> arising from 50 million tonnes of aggregate delivered would be roughly 5 mt CO<sub>2</sub>. In comparison, the 17 TWh/year of electricity from the barrage or equivalent lagoons scenario would avoid around 7 – 11 mt CO<sub>2</sub> from gas or coal power stations (see section 2.2) each and every year.

In summary, given that the lagoons or barrages would likely be generating for well over 100 years the energy used and overall emissions arising from construction would be relatively very small.

### 3.8 Lagoon deployment

Lagoons would also have to prove that they would not cause unacceptable harm to the estuary's conservation interests and there have been no cost studies for very large lagoons in the Severn. So, further verification of the power output of lagoons per unit area in the areas where they could be built, and construction costs, would inform public debate should form part of any future studies.

Lagoons would typically be built about one kilometre to a mile off the coast and would not impound the inter-tidal feeding areas, or impede fish or navigation along the estuary. Unlike the barrage, lagoons would not provide any coastal defence role against sea level rise or very high tidal surges. However, a lagoon's rock walls may well provide significant coastal defence against wind-driven, storm surge, wave action. Possibly, lagoons could be pumped out in advance of a predicted storm surge on a spring tide and so might be used to moderate critically high water levels in the Estuary by timely generation.

A 2004 report commissioned by the Foresight Marine Panel, local authorities and Halcrow Group Ltd studied, amongst other things, the potential for tidal lagoons to protect Bridgewater Bay from erosion (35). A very limited number of devices were considered worthy of further consideration for application in Bridgewater Bay, and one, a tidal impoundment scheme, was specifically recommended for more detailed review. Its advice was ignored by central government.

Specific lagoon schemes, given the uncertainties of putting any large structure in coastal waters, could cause adverse coastal and or sedimentation effects or damage shallow submerged sandbanks which are protected by the Ramsar designation. Alternatively, they may create new habitat and scour shipping channels, depending on their construction, size and location.

A large lagoon scheme in Bridgewater Bay may well protect the Bay's long vulnerable shoreline but on balance it may currently be more damaging to important waterfowl conservation value of the area. Yet at some point, climate induced storm and sea level rise may change any such balance. And at some point later the whole stretch of coast from Hinkley Point to Brean Down may need to be defended to protect the Somerset levels.

Taking an overview, it appears possible that lagoon schemes could be constructed sequentially to reach the optimal overall capacity for energy extraction from the estuary without incurring significant harm to the range of conservation interests. Initial estimates by TE Ltd suggest that lagoons could readily generate as much power as a barrage though an environmentally benign optimum capacity may be much less, or possibly much more.

A great strength of the lagoon system however is that it can be developed in a modular fashion, so that impacts of one scheme can be monitored and understood before building more, or larger, lagoons. With a Cardiff - Weston barrage it is all or nothing.

### **3.9 Shoots barrage**

Recently, a 1 GW 'Shoots Barrage' plan with rail link has been proposed just west of the Second Severn Crossing by the company Parsons Brinkerhoff Power Ltd (36). This 2.75 TWh/year scheme is estimated to take four years to build at a cost of £1.8 billion, resulting in power which is 20 % cheaper than the Severn barrage. Any decision to build a hydro-electric barrage or a retractable barrier would again depend on environmental assessments of this sensitive area.

### **3.10 Tidal fences**

The concept of concrete walled tidal fences, which impound an area by building out from an adjacent shoreline, has not been studied in terms of Severn estuary potential (37). They could be built completely offshore to avoid inter-tidal areas but they then effectively become a lagoon type impoundment. Alternatively, they may have a capability to protect vulnerable sections of coast. Again, site specific studies would be needed to assess their feasibility and viability, and their energy potential or flood defence role in the Severn.



### **3.11 Effect of renewable technologies seaward of the barrage**

The barrage would permanently retain an enormous volume of water in the basin area (roughly 185 square miles by 5 metres deep). The structure appears also to resist flow into the basin area reducing spring tide levels in the basin area by about a metre. These factors would moderate the tidal current flow in the narrow part of the channel on the seaward side of the scheme where there is the possibility of locating marine current turbines of one form or another. Changes in flow rate may prove to be small or negligible but are as yet not well understood. Consequently, even if the tidal stream energy available may not be affected, investor confidence in building tidal stream schemes there may well be.

## Section 4 Other perspectives

### 4.1 Energy Security

The barrage is being promoted in terms of its indigenous power and hence to future UK energy security. Such a benefit needs to be placed in context for informed consideration.

Cost effective efficiency reductions and lifestyle choices may reduce UK primary energy supply (currently approaching 2,900 TWh/year) by up to half over the next few decades, even with a growing population (38). After that time the affordability of zero carbon power coupled to more efficient use could well moderate further consumption reductions. So UK energy demand could level out at around 1,500 TWh/year by 2050, about half of current primary energy supply.

If built, the power generated by the barrage in such circumstances would provide around 1.1 % of 2050 UK energy demand. Its output would perhaps be around 2 % of power supplied from indigenous sources if the output from such sources rose to around 800 TWh/year, requiring imports of around 47 % of demand.

Comparisons are informative. About 1,000 offshore wind turbines (averaging 5 MW capacity) or 3,250 onshore turbines (averaging 2 MW capacity) would generate the same annual output as the barrage. Germany, with a land area 40 % greater than the UK but very similar population density, has to date deployed nearly 18,000 onshore wind turbines, half of built within the last five years. So a reasonable capacity of onshore UK wind farms could provide probably more than double the barrage's annual output. The limitations for exploiting the UK's huge offshore wind capacity are difficult to estimate.

A 1.1 % contribution to the assumed 2050 UK energy demand is, while useful, not substantial from a security point of view. This is in no way to decry such a contribution. It is to show the barrage in context given some public over-estimation of its potential.

It would be difficult to claim on energy security grounds an 'overriding public interest' in significantly damaging a major internationally important ecological site to derive between 0.75 % and 1.1 % of future UK energy demand from indigenous sources.

## **4.2 Climate change contribution**

The New Appraisal report estimated that the barrage would reduce emissions by 17 mt CO<sub>2</sub>/year. This figure is impressive and would be accurate if the barrage were opened this year replacing dirty coal stations. Yet, year on year as UK CO<sub>2</sub> emissions fall, the emissions avoided by all renewables would reduce, so the emission savings also need to be set in context.

The barrage would generate essentially carbon free electricity for a design period of 120 years and probably considerably longer, excluding emissions arising from a 17 million tonne concrete construction. On opening, around 2019, the barrage would reduce UK carbon dioxide emissions from the electricity generating sector from probably between 7 - 11 Mt CO<sub>2</sub> a year if replacing a mix of fossil fired generation.

By 2020 with good progress on carbon reducing policies across all sectors annual UK emissions should have fallen to below 60 % of 1990 emissions (1990 emissions were 577.7 mt CO<sub>2</sub>/year). A 60 % reduction would result in around 330 mt CO<sub>2</sub>/year by 2020.

So by the time a barrage would be fully operational in say 2020, it may reduce UK annual CO<sub>2</sub> emissions of around 3 % if displacing a mix of coal and gas fired generation. Emission savings would fall to very little if the barrage simply displaced other forms of very low carbon generation, such as CCS, or if it was built instead of other renewables, including other tidal technologies in the Severn.

### **4.3 Longer term considerations**

Low cost power has been cited by the Assembly Government as a reason for the barrage and so needs to be considered in the wider context to assess its value.

The longer term value of the barrage output once it has paid back its debts around 2070 would arise from the difference between the cost of generation from the low carbon technologies in operation in 2070 and beyond, minus the barrage's annual costs. Such barrage costs comprise operation and maintenance (O&M) and 'off barrage' costs which were jointly estimated at £ 112 m per year (at 2001 prices) in the 2002 New Appraisal report. This suggests annual costs of around 0.8 pence/kWh at most at current prices.

The overall cost of other renewables and low carbon technologies may average around 3 - 4 pence/kWh (at 2006 prices) so there would be a saving for the investors from that time. Yet it is likely that the owners would charge the market rate for power and there would be no direct benefit to the public.

So, in terms of economic benefit after the debt was repaid, for a scheme generating 1.2 % of 2070 UK energy demand, the effect would amount to about a 1 % saving in UK energy costs if the benefits were in some way to fully accrue to 'UK plc' (see Annex C). Such a saving is welcome but marginal.

### **4.4 Impact on ports and shipping**

The Severn Estuary's deep water channel permits ships to access the ports of Bristol (Avonmouth and Portbury), Cardiff and Newport. However, navigation to the ports would be affected by the Cardiff-Weston barrage and could result in a major loss of trade to the ports, especially Bristol. A major loss of trade through Bristol would have knock-on transport and environmental impacts around the UK.

The dynamics of the estuary keep this channel naturally scoured and free from siltation. The largest port, Bristol, today accepts very large ships up to 130,000 tonnes deadweight, but is limited by a ship lock to 14.5 metres draught. So the port is currently seeking approval to

construct a deep sea container terminal in the estuary able to handle ultra-large container ships of up to 16 metres draught.

These ultra-large ships would require every available metre of tide height, as do all of today's larger ships needing to access any of the estuary's ports. Yet the Cardiff - Weston barrage would cause about a one metre reduction in high tide level in the basin area and a potential increase in siltation. This would critically reduce the draught available for these ships on a large number of tides each year. Consequently, many trades could simply be lost to other ports in the UK or Europe.

The barrage would also form a physical barrier through which ships must pass. Ship locks are proposed, but in current plans these are too small for many of the larger ships, thus larger locks would be needed. This would incur additional cost. The 1989 Severn Barrage Project design incorporated a lock system for vessels of 70,000 dwt. Yet, shipping size has since increased to 130,000 dwt and is still rising.

Shipping would also suffer delays and additional costs in passing through the lock, over and above any benefit once they are within the permanently raised basin level. Additional significant maintenance dredging may also be required.

From the wider UK environmental view point the geographic location of ports in the Severn Estuary has major transport benefits. They are located considerably closer to the industrial heartland of the UK than other ports such as Felixstowe or Southampton. Bristol Port has had a twin track railway link installed in the 1990's. As a result, onward road or rail journey distances to the UK destination of the containers are shorter, thus reducing HGV 'miles' and traffic congestion and associated greenhouse gas emissions and fuel energy use. It has been estimated that the port of Bristol has an average of 33 mile advantage over Southampton and 68 miles advantage over Felixstowe, when compared on a container's round trip mileage.

The Cardiff - Weston barrage could result in the loss of viability and or major losses of trade to the ports, especially the ultra-large container ships. Consequently, this issue must be taken seriously both in terms of the regional economy around Bristol and the knock-on transport impacts around the UK. In contrast, tidal lagoons and or a Shoots barrage would not affect navigation or trade to these ports.

## 4.5 Economic development

The STPG say that the barrage would contribute significantly to regional economic development which would therefore be included as part of any sustainable development assessment. Yet any assessment should also compare the economic development potential of alternative strategies.

Direct jobs would be generated in barrage construction, operation, and technology export could follow. The STPG say the region would also benefit indirectly from inward investment due to the road and possible rail link, increased land and property values and new recreational opportunities.

However, spending £ 14 billion on any UK energy generation technology would give rise to significant employment, regional development (albeit around the UK) and export opportunities. Indeed, the barrage would displace other and cheaper alternative low carbon or renewable energy technologies in which the UK may have a technological lead.

Direct jobs in construction, operation and maintenance may also accrue to the Severnside area itself if alternative renewable technologies were built in the estuary. Indeed, the barrage could significantly damage the prospects of some Severnside ports, including Bristol, as larger shipping may be impeded. Shipping size has since increased to 120,000 dwt and is set to rise further). Whereas for example, tidal lagoons and a Shoots barrage would not impede shipping of any size accessing the established ports, infrastructure and hinterlands.

Barrage proponents say increased recreational use of the Severn would be an economic benefit. Yet the disturbance to birds, habitats and some existing recreational activities would have negative consequences too. Any inward investment generated by the barrage, particularly new waterfront developments, and its road link, would tend to generate further development and traffic around the major road junctions around the region. Extensions to a proposed business park at Junction 33 on the M4 could quickly be sought. Increasing traffic would probably have negative consequences on the Gwent Levels SSSIs especially if the planned M4 Gwent Levels motorway is built.

The barrage roadway would also generate additional traffic on the existing road networks around Lavernock and Cardiff airport and cause various development pressures in rural Somerset. A roadway, if incorporated, would probably be a dual carriageway which could carry traffic flows of up to 50,000 vehicles a day. Such flows could easily comprise mainly a mixture of commuters, travellers to Cardiff and Bristol airports, and sightseers to the barrage itself.

The barrage would undoubtedly quickly become a tourist attraction. Sightseeing, housing tourist and other developments around viewing areas along adjacent coastlines would spring up, though the setting of the National Trust owned headland at Brean Down on the Somerset coast would be hugely impacted by the close proximity of the barrage's rock wall embankment

Around Severnside there would be more economic activity, certainly development activity, and there would be positives and negatives in the various structural changes. Tourism would benefit but the ports east of the barrage could well lose out to deeper water ports at Swansea and elsewhere. Cardiff and Bristol airports, around 30 miles apart, would likely attract more passengers on a wider range of flights and destinations Overall, the net economic effect of the barrage at UK level would unlikely be more than marginal as other areas and regions would attract proportionally less investment and receive potentially more freight traffic if the Severn ports were badly affected.

## Conclusions

The Cardiff - Weston barrage would significantly damage internationally important and legally protected habitats. The structure would retain a body of water 5 metres high, permanently submerging over half of the inter-tidal mud and sand flats which are important feeding grounds for tens of thousands of birds including rare and threatened bird species. It would also disrupt the passage of migratory fish and probably moderate the Severn Bore.

Depending on the details of emerging energy policy, any decision to commence building the barrage, certainly before 2020, would probably displace or undermine the construction of, and investment in, other renewable energy technologies. Such technologies include tidal lagoons and a Shoots barrage within the basin area of the estuary which the barrage would preclude.

Outside the basin area technologies include offshore windfarms, marine current turbines, wave devices and or low carbon combined heat and power (CHP), and carbon capture and storage (CCS) schemes. So the barrage would likely breach the Habitats Directive as the scheme would have to be of 'overriding national interest' which could not be addressed in alternative ways. It could also have negative consequences for developing UK manufacturing and employment.

We believe that new shoreline coastal defence techniques and possibly a Shoots barrage or flood barrier could address the increasing flood risk to Severnside and Gloucestershire caused by climate related storm surge intensity and sea level rise. Such techniques would be the most appropriate, and potentially an ecologically enhancing, strategy to defend against sea level rise of up to around 1.2 metres by 2100 based on projections in the latest IPCC Fourth Assessment.

We acknowledge that the Fourth Assessment projections exclude additional significant rises in sea level due to a possible major disintegration or significantly increased melting of the Greenland and or Antarctica ice sheets. However, we believe that shoreline coastal defences, rather than a barrage, are a reasonable and appropriate strategy unless future assessments indicate otherwise. We are also concerned that the effects of the barrage on the estuary's westward coasts may be adverse and not yet well understood.



New techniques in flood defence, such as managed retreat or forward building using dredged material, possibly in conjunction with silt-filled geo-textile bag constructions, are being developed. We believe that developing coastal defences using new flood defence techniques could avoid significantly adverse coastal erosion and habitat changes in the estuary that could result from global warming. Such techniques would protect and possibly enhance the highly designated conservation interests of the Severn estuary and its tributaries and their part of the wider network of Natura 2000 European sites.

If necessary, in the coming decades, a retractable flood defence barrier on the English Stones just east of the Second Severn Crossing could be considered or a 'Shoots' barrage just to the west. Such a barrier or barrage would protect low lying areas of Gloucestershire while maintaining unimpeded shipping access to Bristol and other Severn ports further west. A replacement rail link for the ageing Severn tunnel could be integrated into the construction, and the alignments are fortuitous.

The Cardiff - Weston barrage may be funded solely by private investment despite its high capital cost and risk. However its promoters cite flood defence and other benefits which may attract some form of government financial and or political support. It difficult to see how any such support would not impact adversely on other renewable or low carbon energy technology development and deployment.

The water-retaining structure would also preclude the subsequent development of potentially large scale, long lasting tidal impoundment technologies in the Severn estuary east of the scheme and or the Shoots barrage. Tidal lagoons in particular appear to have the potential to generate power more cost effectively, and possibly significantly more power annually than the barrage, without direct impoundment of the inter-tidal areas or impediment to shipping. Lagoon schemes could also be built sequentially to achieve the maximum environmentally benign energy extraction whereas with the Cardiff - Weston barrage it is all or nothing.

The barrage, which could be operational by around 2019, would generate large pulses of electric power for a few hours after each tide over its long lifetime. Such pulses of power, while predictable, would not be easily integrated onto the national grid and would require significant and probably very unwelcome load following operations by other UK electricity generators.

Power swings of up to 8 GW per hour, albeit in a known direction, would greatly exceed the likely hourly swings in the cumulative output of a major windpower programme generating 20 % of 2020 UK demand, five times more power annually than the barrage. Flood pumping would also result in awkward power demands on the national grid. Power integration problems could be minimised, albeit at further cost, by the construction of new low loss direct current inter-connector links to continental Europe, and or hydrogen generation, or other storage technologies which may become cost effective by the 2020's.

The barrage would generate about one percent of 2050 UK energy demand which is, while useful, hardly vital to UK energy security. Depending on future energy imports it may account for around 2 % of indigenous supply. Yet such power may otherwise be generated indigenously or imported from less ecologically sensitive areas rather than an internationally designated marine conservation area.

It is for these reasons that Friends of the Earth Cymru maintains its opposition to the construction of the Severn Barrage and supports the government's energy review statement for a comparative assessment of the potential of all tidal technologies in the Severn estuary, not just a barrage.

A barrage across the Severn Estuary between Lavernock Point and Weston would be a monumental and iconic structure, a landmark in British history. If it is ever to be built it must be built for the best of reasons and at the most appropriate moment in time.

At the present time, there is no clear need to build the barrage for energy security, greenhouse gas reduction or coastal defence reasons, not for decades or a century at least, and one would hope not at all. If the effects of global warming have been underestimated, and melting Greenland and Antarctic ice sheets are likely to cause a sea level rise of several metres or more, then there would still be many years to assess the predicament and plan structures of the necessary height, strength and location.

To build the Severn barrage at this time would be an act of poor global leadership. Destroying unique and internationally important and legally protected conservation areas under the guise of energy security, climate protection and or coastal defence would set a damaging precedent. Much more could be done to address energy security and protect the

climate in the next few critical decades by investing in less damaging and more powerful renewable energy generating technologies, including in the Severn estuary itself, which would tackle future storms and sea level rise directly.

The possibility of building a significant capacity of 'high output' tidal lagoons in the Severn estuary, generating potentially in excess of 10 % of UK electricity and with a storage potential of several Dinorwic pumped storage schemes, deserves serious investigation.

For these reasons, Friends of the Earth Cymru recommends that an environmentally benign tidal lagoon demonstration scheme is given strong political support at least, and built as soon as possible be it Swansea Bay or other location.

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\* The contractor was Sir Robert McAlpine Ltd on behalf of the Severn Tidal Power Group. The views and judgements expressed are those of the contractor and do not necessarily reflect those of ETSU / DTI.

\*\* UK 'primary energy' demand (around 2,900 TWh/year) is actually much greater than final energy consumption but includes conversion losses (e.g. thermal losses at power stations, refineries, etc) in generating electricity or transport fuels. Many renewable technologies generate electricity directly, including barrages, so do not incur any such conversion losses.

## Annex A

The volume of silt dredged from the Severn estuary is around 2.5 million cubic metres per year. A flood defence wall of silt filled geo-textile bags 3 metres high covering a width of 10 m at its base, tapering to 5m, would require only 25,000 cubic metres of material per kilometre. Hence there would be more than enough material dredged in one year to build many miles of wall if needed.

Tidal Electric Ltd has indicated that silt filled geo-textile bags could be used in lagoon construction, as part of the core of the impoundment wall. This could significantly reduce aggregate requirement.

## Annex B

'The most likely change in power output from a diversified wind power system from one hour to the next is less than +/- 2.5 % of the total installed wind power capacity. Larger changes from one hour to the next do occur - a change in hourly output equal to +/- 20 % of the installed wind capacity is likely to happen about once per year. Over the long term, around 99.99 % of all the hourly changes in wind power output from a diversified system will be less than +/- 20 %.'

$$80 \text{ TWh/y} = 24 \text{ GW} \times 8.76 \times 38 \%$$

Wind output rate of change less than 600 MW per hour likely (2.5 % of 24 GW = 0.6 GW)

Wind output of 4.8 GW rate of change of per hour would occur about once per year (20 % of 24 GW = 4.8 GW )

## Annex C

$$(98.8 \text{ energy units} \times 4 \text{ pence} + 1.2 \text{ energy units} \times 0.8 \text{ pence}) / (100 \text{ units} \times 4 \text{ pence}) = 0.990$$

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