Final Report

Severn Barrage Costing Exercise

to

The Renewable Energy Forum Ltd

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IPA Energy + Water Consulting

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to

The Renewable Energy Forum Ltd

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1 INTRODUCTION

IPA Energy + Water Consulting (IPA) have been commissioned by The Renewable Energy Forum Ltd to undertake a high level review of the Severn Barrage Proposals (Cardiff-Weston Scheme) in relation to the following aspects:

- Comparison of Generation Costs between the Severn Barrage and other "large scale" generation technologies.
- Investigate the contribution that a Severn Barrage Scheme would have to Security of Supply.
- Investigate the effects of a Severn Barrage scheme on the GB electricity system.

In 2007 the Sustainable Development Commission (SDC) undertook a wide ranging review of tidal power in the UK, including an evaluation of proposals for a Severn Barrage. If developed a barrage in the Severn Estuary could supply 4.4% of UK electricity supply (17 TWh), generating electricity for over 120 years.

This report draws heavily upon, and reviews, the recent findings of the Sustainable Development Commission Marine Energy Study (*Tidal Power in the UK: Research Report 3 – Review of Severn Barrage Proposals*, Final Report, May 2007.).

In addition we draw upon the PB Power report (*Powering the Nation: A review of the costs of generating electricity*, March 2006), the DTI's generation costs as published in the 2006 *Energy Review* and data from VGB PowerTech on costs of generating electricity from various technologies in comparing costs of different generating sources.

2 COMPARISON OF GENERATION COSTS

In this section we provide a comparison of the energy costs of the Severn Barrage Proposal (Cardiff-Weston Scheme) compared to other generation sources, at various discount rates. In addition we provide an analysis of the effects of Carbon prices on the different generation sources and also identify the potential capacity that could be developed at the costs of the barrage proposal.

2.1 Energy Costs

We have carried out a thorough and wide-ranging review of the costs of generating electricity from different sources, using the following sources for the data:

- PB Power's Summary Report, *Powering the Nation, A review of the costs of generating electricity*, March 2006;
- Sustainable Development Commission Report, *Tidal Power in the UK, Research Report 3 – Review of Severn Barrage Proposals*, May 2007';
- VGB PowerTech, 'Role of Electricity, Building Block Supply, 2006, Parts I and II; and
- The DTI *Energy Review 2006*.

Each of these sources provides cost data for a range of technologies. For this study we have concentrated on those technologies that have the potential to be developed on a large scale in the near future. These technologies include:

Table 1: Technologies Investigated

Thermal	Renewable
Gas, CCGT	Onshore Wind
Coal, Pulverised Fuel	Offshore Wind
Coal, IGCC	Severn Barrage (Cardiff-Weston)
Coal, Pulverised Fuel with Carbon Capture & Storage	
Nuclear	

The data sources above provide a range of costs for various parameters which contribute to the costs of generating electricity, including

- capital costs;
- financing parameters;
- fixed operation and maintenance costs;
- non-fuel variable costs;
- fuel costs;
- carbon costs (non-renewable generators only);
- expected load factors;
- expected efficiencies; and

- waste disposal and decommissioning costs.

In building up the overall costs of generation for each of the technologies the different sources have used different cost components and slightly different operating parameters, such as load factor and efficiency, resulting in a range of overall generation costs for each technology.

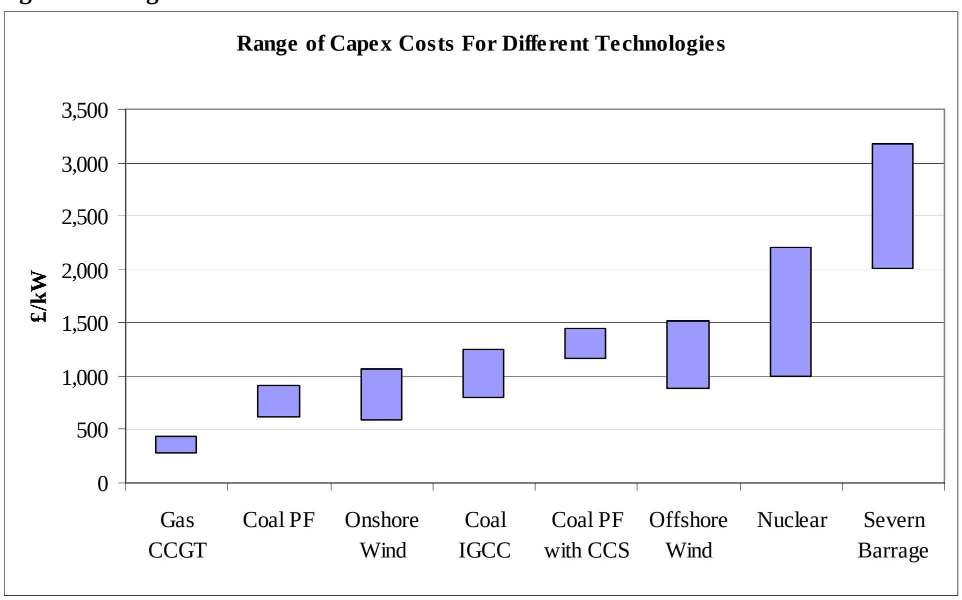
Some of the data sources split the total costs into constituent parts, and others provide an overall cost. It is therefore difficult to be certain whether the same costs have been accounted for by each of the sources.

All the costs reported in the following sections have been sourced from these documents. However, in order to make comparisons between the overall generation costs from each of the sources, we have applied consistent assumptions on discount rates, operating parameters and fuel costs, whilst exploring the range of capital costs provided, to calculate a range of levelised costs of generation for each technology.

2.1.1 Capital Costs

This section provides the range of capital costs presented by each of the data sources. These are shown in Figure 1 below.

Figure 1: Range of CAPEX Costs



The capital costs for the Severn Barrage are significantly higher than the other technologies, reflecting the significant development that is required to develop the resource. The next most expensive is nuclear, with conventional gas and coal being the cheapest.

2.1.2 Financing Parameters

This section provides a description of the financing parameters assumed in calculating the overall generation cost, in particular the discount rates used for financing the capex and the finance repayment term.

Discount rates for the financing of the capital costs varied between the various information sources, with the range varying between 3.5% and 15%. In this section we assume a mid-range discount rate of 8% for all technologies (investigation of a range of discount rates is provided in Section 2.2).

Finance repayment terms have been based on typical durations taken from the various sources.

Table 2: Technology Specific Finance Repayment Term

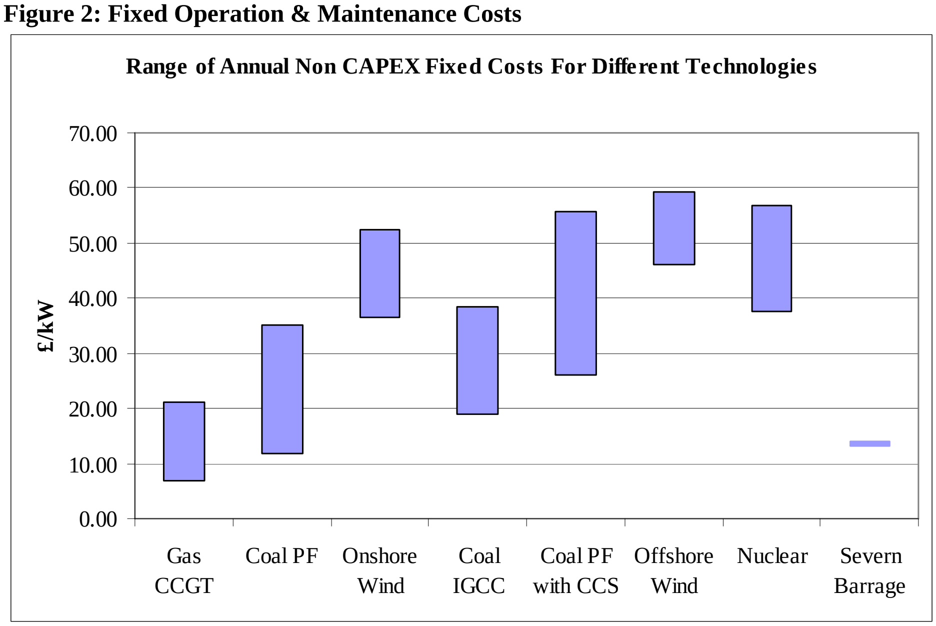
Technology	Repayment Term, years
Gas, CCGT	20
Coal, PF	20
Coal, PF with CCS	20
IGCC	20
Onshore Wind	20
Offshore Wind	20
Nuclear	35
Severn Barrage	40

Note that the terms for nuclear technologies and the Severn Barrage are significantly longer than those assumed for the other technologies, reflecting longer expected lifetimes.

2.1.3 Fixed Operation & Maintenance Costs

This section presents the range of annual fixed Operation & Maintenance costs provided by the various sources.

Figure 2: Fixed Operation & Maintenance Costs



2.1.4 Operational Parameters

The operational parameters assumed are presented in the following table. We have applied consistent values to each technology.

Table 3: Operational Parameters

Technology	Maximum Load Factor, %	Gross Efficiency, %	Carbon Intensity Out, $tCO_2/MWh(e)$
Gas, CCGT	85%	55%	0.336
Coal, PF	90%	43%	0.737
Coal, PF with CCS	90%	37%	0.857
IGCC	90%	45%	0.704
Onshore Wind	33%	100%	0
Offshore Wind	33%	100%	0
Nuclear	84.4%	36%	0
Severn Barrage	22.5%	100%	0

It is interesting to see from the above table that the Severn Barrage has the lowest load factor of all the technologies investigated, even lower than wind, the output of which is more unpredictable. The more conventionally 'fuelled' technologies have the greatest load factor, although their gross efficiency (the conversion of primary fuel input to energy) is significantly lower than the renewable technologies, as would be expected. Nuclear has the worst gross efficiency of all the technologies investigated.

2.1.5 Fuel and Variable Costs

This section presents the fuel and variable cost component of the overall generation costs for each technology. This can be a significant proportion of the overall generation costs for thermal technologies and is determined by fuel prices and the efficiency of the plant.

Commodity prices for financial year 2008/09 have been sourced from market data[1] and applied to the relevant technologies.

Table 4: Commodity Prices

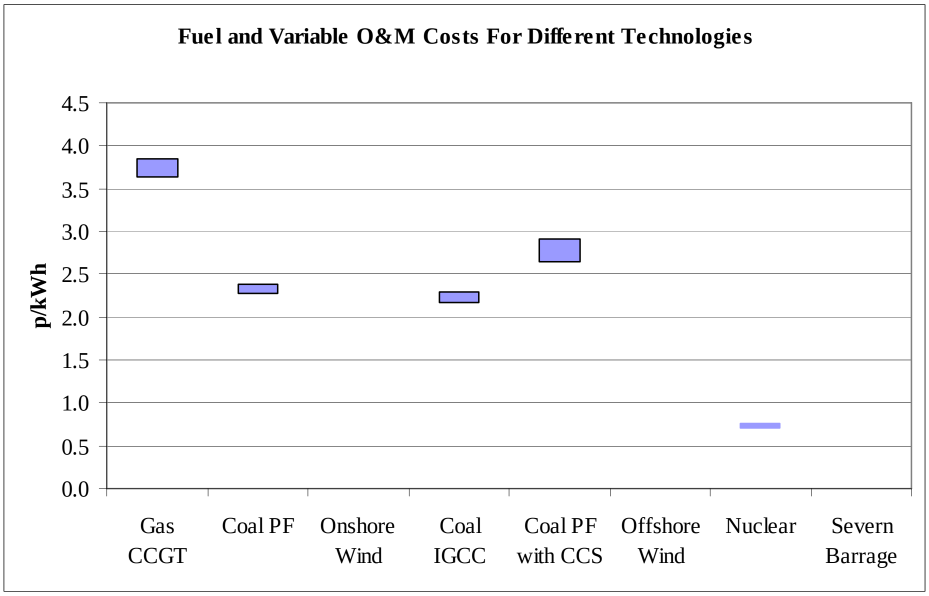
Carbon Price, €/tCO_2	Gas Price, p/th	Coal Price, \$/tonne
20	58.725	140

It should be noted that there has historically been significant variation in commodity prices and the figures presented here at correct the time of writing, and it is recognised that these prices may rise or fall.

Applying the efficiencies as determined above in Section 2.1.4, the range of variable costs is shown in the following figure. Clearly, renewable technologies such as wind and the Severn Barrage do not have fuel costs.

[1] Spectrometer, 26th February 2008

Figure 3: Fuel and Variable O&M Costs



2.1.6 Waste Disposal & Decommissioning Costs

This section presents the waste disposal and decommissioning costs identified for each of the technologies, where available.

The decommissioning costs for the technologies have not been reported by the sources of data investigated, apart from Nuclear. For Nuclear, waste disposal and decommissioning costs have been indicated to be £0.4/MWh and £0.7/MWh respectively by the data sources.

Illustrative decommissioning costs for the Severn Barrage have been reported in the Sustainable Development Commission's report at levels of between 4.42p/kWh and 5.14p/kWh but note that these costs are highly uncertain. We have therefore not included them.

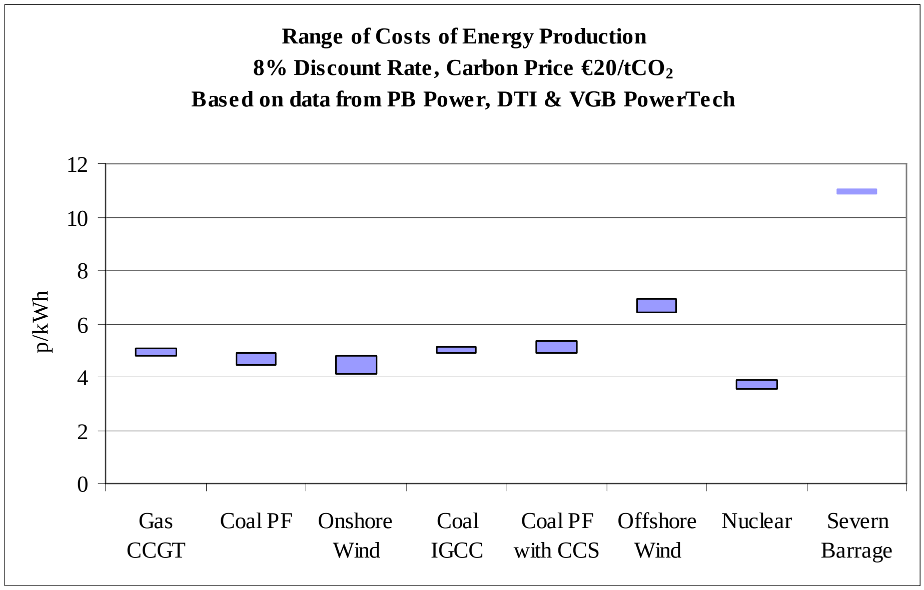
2.1.7 Levelised Costs

Combining the different parameters discussed above, a range of levelised cost for each technology can be derived. For this we have assumed some common parameters between the technologies. These are:

- An 8% discount range for the financing of the capex; and
- A Carbon price of €20/tCO_2;

The levelised costs are shown in the following figure.

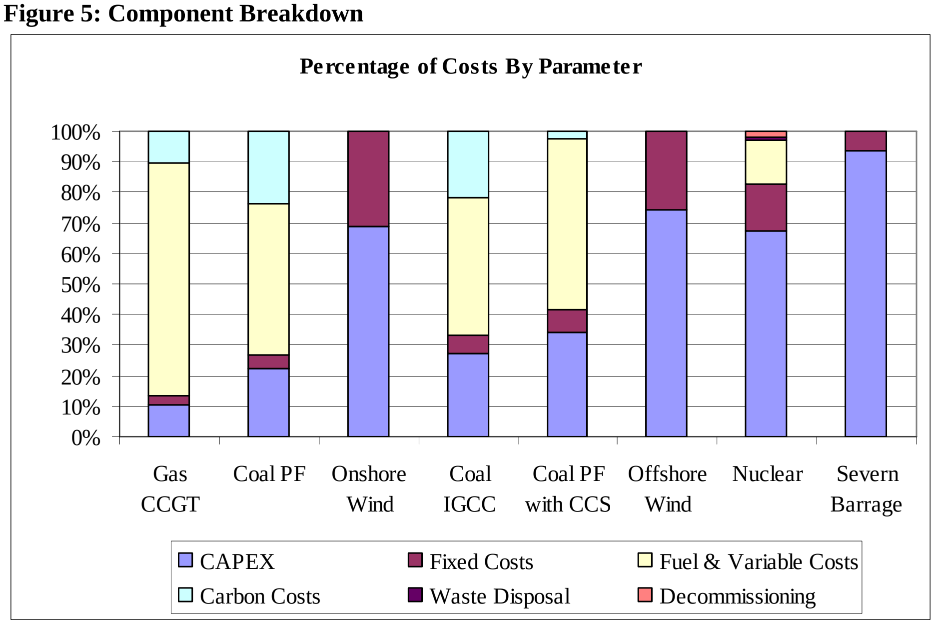
Figure 4: Levelised Costs



It can clearly be seen that the Severn Barrage has a higher levelised cost (approximately double) at an 8% discount rate, compared to the other technologies investigated.

Using the central capex, fixed and variable costs for each technology we can see which components comprise the majority of the costs and will therefore affect their generation costs the most.

Figure 5: Component Breakdown



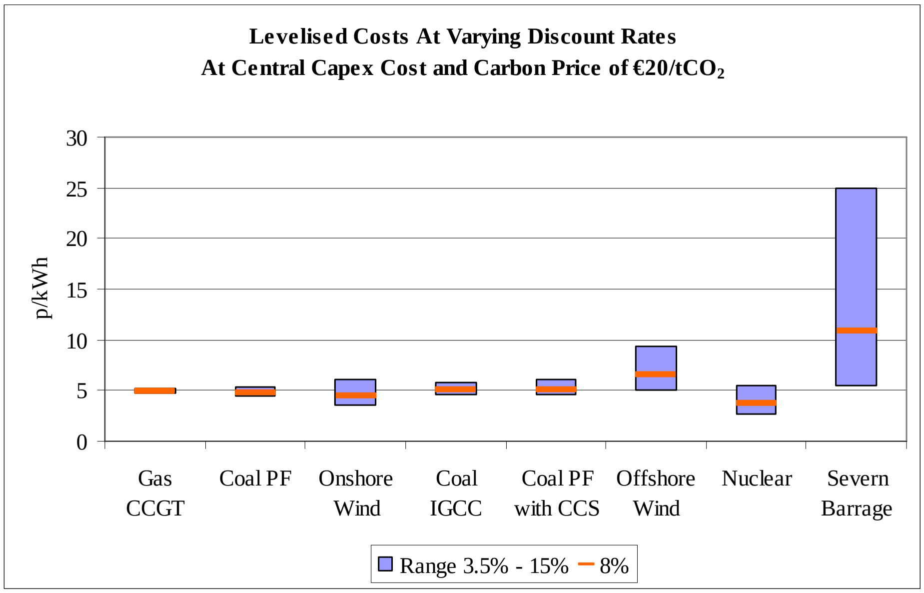
As the Capex components comprise the majority of the costs for onshore wind, offshore wind, nuclear and the Severn Barrage their overall generation costs will be affected the most by changes to the discount rates. Alternatively, the overall costs for coal and gas technologies will predominately be affected by the fuel and carbon prices. These parameters are investigated further in the following sections.

2.2 Discount Rate Sensitivity

Different developers will require different levels of return for their investment and, in order to investigate the effect this has on the levelised costs, we have varied the discount rate between 3.5% and 15% - the range of discount rates used in the Sustainable Development Commission's study *Tidal Power in the UK*.

The ranges of levelised costs, using central capex, fixed and variable costs and a carbon price of €20/tCO_2, are shown in the following figure.

Figure 6: Range of Levelised Costs at Varying Discount Rates



As stated earlier, those technologies with significant capex components are affected the most by the changes in discount rates.

Discount rates applied to energy projects are one of the most important economic factors when considering whether a project will be built. The discount rate takes into account numerous factors such as the rate at which debt can be sourced, the amount of debt in the project as well as the perceived risk of the project, whether technical, regulatory, commercial and so on.

The SDC report considers 4 different discount rates, 3.5%, 8%, 10%, and 15%. Of those considered a discount rate of 3.5% would be unlikely to attract any commercial investors.

In fact, the SDC report states that "*The rate of 3.5% has been included at the request of the SDC to reflect the social discount rates*[2] *used by HM treasury…*". Whilst relatively low discount rates have been seen in energy projects (for example the Sizewell B project was approved at a 5% public sector discount rate in 1987), the sector has changed significantly over recent years. Therefore, we judge that a

[2] The discount rate used to estimate the social value (or value to the community as a whole) of an enterprise.

discount rate of 3.5% applied to the Barrage scheme is unrealistic in any true commercial sense.

As highlighted, there are a number of different factors that will affect the discount rates for energy projects and these will often be different for different energy sources, as well as for different investors. In the table below we consider the derivation of the more commercial discount factors used in the SDC report for a constant debt interest rate (Bank of England base rate of 5.5% plus 120 basis points (6.7%)).

Table 5: Derivation of Discount Factors

	Debt Amount			
Equity Return	95%	90%	85%	80%
10%	6.87%	7.03%	7.20%	7.36%
15%	7.12%	7.53%	7.95%	8.36%
20%	7.37%	8.03%	8.70%	9.36%
25%	7.62%	8.53%	9.45%	10.36%
30%	7.87%	9.03%	10.20%	11.36%

From this high level analysis, depending on the amount of debt in the project and return on equity, discount rates of 8% and 10% would appear reasonable given that nature of the Barrage project (reliable technology but with output "price" risks), although the 10% value is probably likely to be at the higher end of acceptable discount rates. Therefore, a discount rate of 15% could be considered too high, and based on this analysis would either require a level of debt of around 40% at a 20% equity return or a return on equity of 62% at 85% debt.

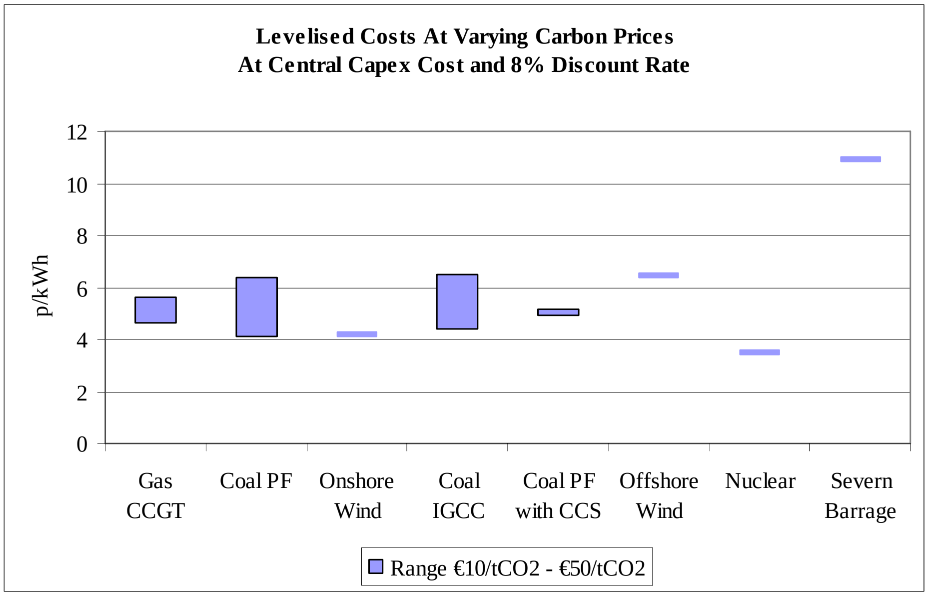
Clearly though, this is only a simplistic picture and a number of different factors would need to be taken into account, but it does suggest that a barrage scheme could be developed at the lower end of the discount rates suggested by SDC on a commercial basis.

2.3 Carbon Price Sensitivity

The economics of renewable energy projects are independent of the carbon price and therefore their levelised costs will remain flat as the carbon price fluctuates. They would of course benefit from the carbon price by making them more cost competitive than fossil fuelled generation plant.

We have investigated the effect that a range of carbon prices between €10/tCO_2 and €50/tCO_2 will have on the relativity of the levelised costs of the technologies. This is shown in the following figure. The line on the graph for the non-fossil fuelled technologies represents the generation costs, which is independent of the Carbon price.

Figure 7: Range of Levelised Costs At Varying Carbon Prices



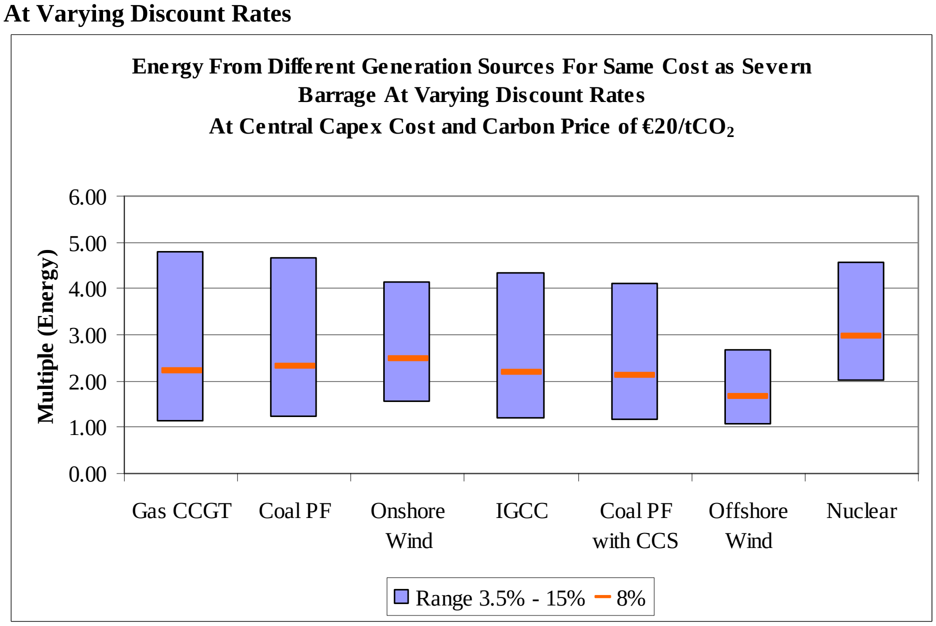
As the carbon price increases the costs of the conventional fossil fuelled technologies increase.

2.4 Potential Capacity From Other Generation Sources

We have investigated the amount of energy that could be generated from each technology for the same cost as developing the Severn Barrage, for the two sensitivities presented above – at varying discount rates and at varying carbon prices.

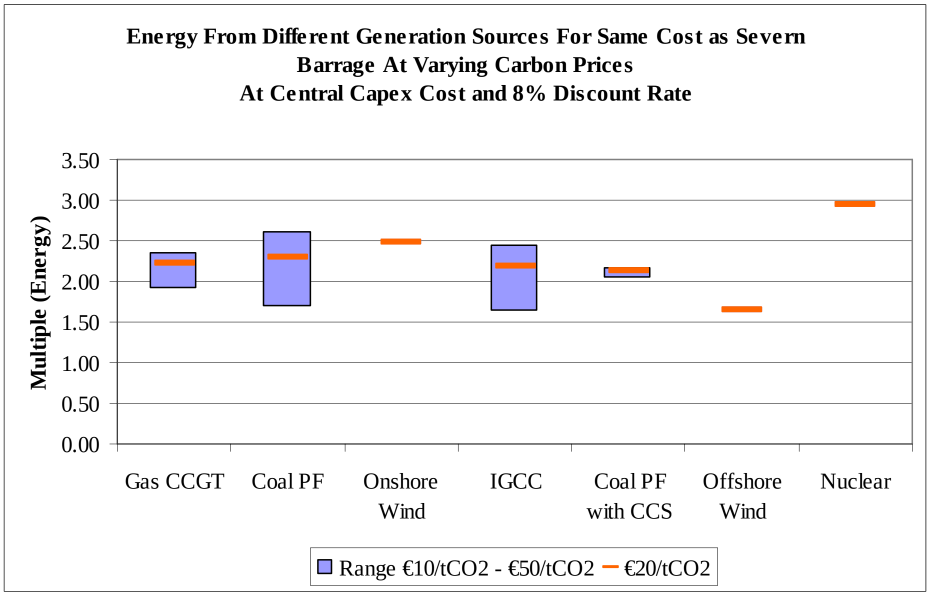
This analysis was carried out using the central capex, fixed and variable costs for each of the technologies. The results are shown in the following figure.

Figure 8: Energy From Different Technologies For Same Amount as Severn Barrage At Varying Discount Rates



This indicates that the most energy would be produced from nuclear generation for the same costs as constructing the Severn Barrage.

Figure 9: Energy from Different Technologies For Same Amount as Severn Barrage At Varying Carbon Prices



As the Carbon price increases the competitiveness of the fossil fuelled technologies decreases and less energy is produced for the same cost as the Severn Barrage.

Again this indicates that the most energy would be produced from nuclear energy for the same costs as constructing the Severn Barrage.

2.5 Summary

In this section we have undertaken a comparison of the levelised energy costs of the Cardiff-Weston Barrage scheme compared to other potential large scale generation sources, based on a number of referenceable data sources. In addition we have provided sensitivity analysis on carbon prices and discount rates and commented on the discount rates used in the SDC study. Our findings for this section can be summarised as follows:

- Of all of the different technologies investigated the Severn Barrage proposal has the greatest capital costs at a range of between £2,000/kW and ~£3,200/kW. The next most capital intensive technology is nuclear, with gas fired CCGT's offering the cheapest capital cost at less than £500/kW.

- Compared to the other generation sources the O&M costs of the Barrage proposal are low.

- Based upon a central case for each of the technologies, the energy production costs of the Severn Barrage is significantly greater than for the other generation sources.

- Sensitivity Analysis: Discount Rates & Carbon

    - Those technologies with significant capex components are most affected by changes in discount rates. At the lower end of the discount rates investigated, the Severn Barrage becomes competitive with other generation sources, whereas at the upper end it is significantly greater.

    - The SDC report considers 4 different discount rates, 3.5%, 8%, 10%, and 15%. Of the different discount rates considered a discount rate of 3.5% would be unlikely to attract any commercial investors in the project. Depending on the amount of debt in the project and return on equity, discount rates of 8% and 10% would appear reasonable given the nature of the Barrage project. However, a discount rate of 15% could be considered too high.

    - The economics of renewable energy projects are independent of the carbon price, however, they would benefit from the carbon price by making them more cost competitive than fossil fuelled generation plant. However, even with a carbon price of €50/tCO_2 the Barrage scheme delivers significantly higher energy costs that the other technologies investigated.

- Based on the analysis of the referenceable data it was shown that for all generation sources investigated, with the possible exception of offshore wind, the other technologies could produce at least twice as much energy for the cost the Barrage scheme (central case).

- By varying the Carbon price between €10/tCO_2 and €50/tCO_2 the other technologies produce between 1.7 and 3 times as much electricity as the Severn Barrage scheme (central case).

3 CONTRIBUTION TO SECURITY OF SUPPLY

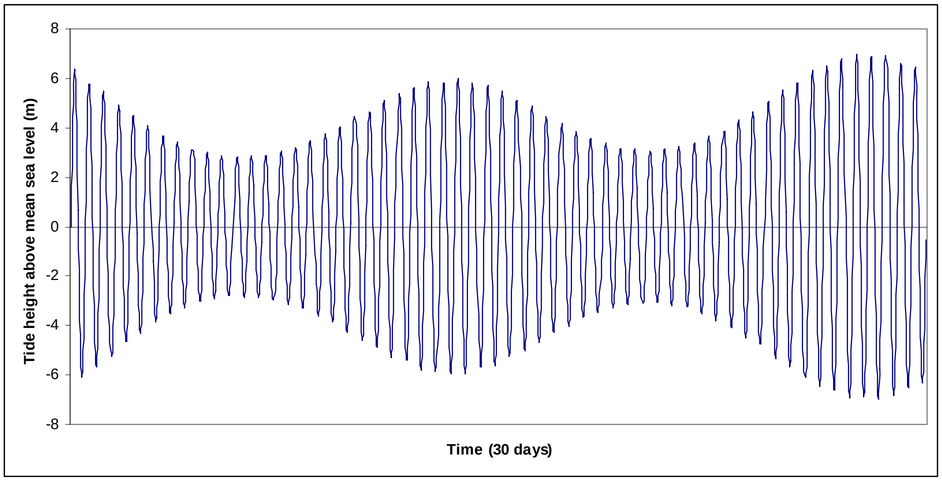
The output from any Severn Barrage tidal generation scheme will be cyclical reflecting both the daily and monthly tidal fluctuations. The Cardiff-Weston Barrage would be expected to generate around 17 TWh of energy per year, and although the output profile would be entirely predictable, the cyclical nature of the output would mean that the scheme may not be generating over peak demand periods. This section looks in more detail at the energy generation profile, the flexibility associated with any generation profile and the resulting level of capacity contribution that could be associated with the Barrage scheme.

3.1 Barrage Output Profile

Tides exhibit cyclical behaviour on two time scales (see Figure 10) below:

- The semi-diurnal tide cycle (the familiar rise and fall of the tides). A full cycle of two high and two low tides occurs every 24 hours and 50 minutes.
- The spring-neap tide cycle, in which the range of the tides varies over a 29.5 day period, with the range having two maxima and two minima during this period.

Figure 10: Typical behaviour of Cardiff-Weston tides over 30 days showing one spring-neap cycle and semi-diurnal cycles.



The tidal variations have particular implications for timing of electricity generation from a tidal barrage. Although tides are fully predictable, there is a complex relationship between the timing of barrage generation and electricity demand.

Tidal barrages can in principle generate on both ebb (falling) and flood (rising) tides. Studies on the Cardiff-Weston barrage have shown that the mode of operation that optimises energy output is ebb-flow generation. Energy output might be optimised further by pumping water upstream during the flood near high tide (a mode of operation referred to as ebb-flow generation with flood pumping).[3]

[3] Currently, the world's largest tidal barrage is at La Rance in Brittany (240MW). This barrage can generate and pump in both directions. In 1996 the turbines were operated in ebb-generation mode for 72%

For the Cardiff-Weston Barrage (ebb-flow barrage design), the generation profile which maximises energy yield would typically start between 2.5 and 5 hours after high tide (with the delay in the onset of generation after high tide being greatest at neaps when the tidal range is lowest), with generation lasting for around two to six hours, depending on the tidal range at the current point in the spring-neap cycle.

A typical generation profile is shown with tide profiles Figure 11 and Figure 12 below for spring and neap tides respectively.

Figure 11: Relationship between tide cycle and barrier generation at springs. This should be read as indicative rather than as a precise calculation of the actual generation profile.

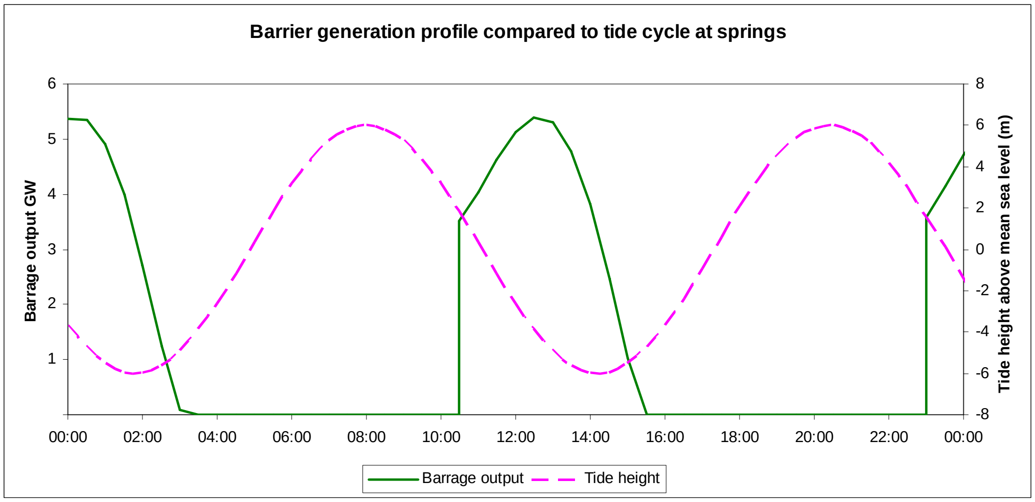
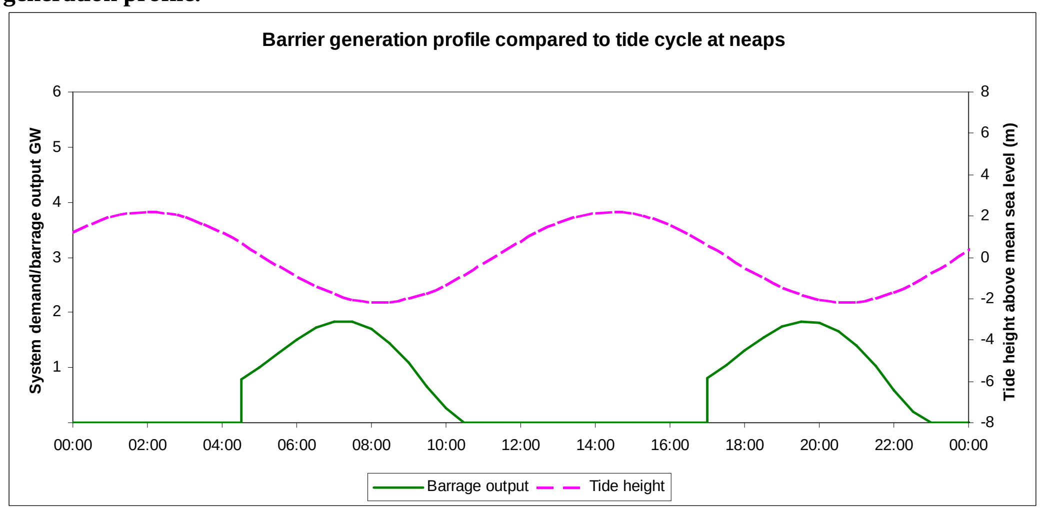


Figure 12: Relationship between tide cycle and barrier generation at neaps. This should be read as indicative rather than as a precise calculation of the actual generation profile.



of the available time, flood-generation mode for 6% of the available time and as reverse pumps for 22% of the available time.

3.2 Barrage Flexibility

There is some scope for flexibility in the timing of generation, although this would be at the expense of energy output. The scope for flexibility would depend on the tidal range at the time of generation. Flexibility in the timing of barrage generation would allow output to be better matched against electricity demand profiles, but the level of flexibility is relatively limited without significantly reducing the amount of energy generated.

It is possible to flex the generation profile with a reduction of energy yields of no more than 25% by:

- At springs (when the tidal range is greatest), advancing the start of generation by up to one hour, or delaying it by up to two hours.
- At neaps (when the tidal range is lowest), advancing the start of generation by up to two hours, or delaying it by up to one hour.

There is not as much scope for delaying the end of the generation period as there is for delaying the start, as this would involve extending generation further into the period when the tide is rising.

3.2.1 Additional basins

In principle it is possible to gain more energy output from the Cardiff-Weston barrage and obtain greater flexibility in its operation, by constructing additional basins. There have been two main proposals for building additional basins in conjunction with the Cardiff-Weston scheme:

- A two basin ebb and flood generation scheme. This would involve an additional basin on the English side of the Bristol Channel, downstream from the main barrage (with landfall close to Minehead). The estimated cost of construction of the second basin is 85% of the cost of the original barrage. It would allow the generation of 5.2 TWh additional energy per year (compared to 17 TWh for a barrage without additional basins).
- A two basin pumped storage scheme. This would involve a second basin in the middle of the Bristol Channel, downstream of the barrage. This can be considered as a low head pumped storage scheme with an operating efficiency of 100%.

The SDC report[4] notes that the significant cost of constructing long lengths of embankment means that if the Cardiff-Weston project were to go ahead, it is unlikely that it would involve additional basins.

[4] Sustainable Development Commission, *Tidal Power in the UK, Research Report 3 – Severn Barrage Proposals*. ,October 2007.
http://www.sd-commission.org.uk/publications/downloads/TidalPowerUK3-Severn_barrage_proposals.pdf

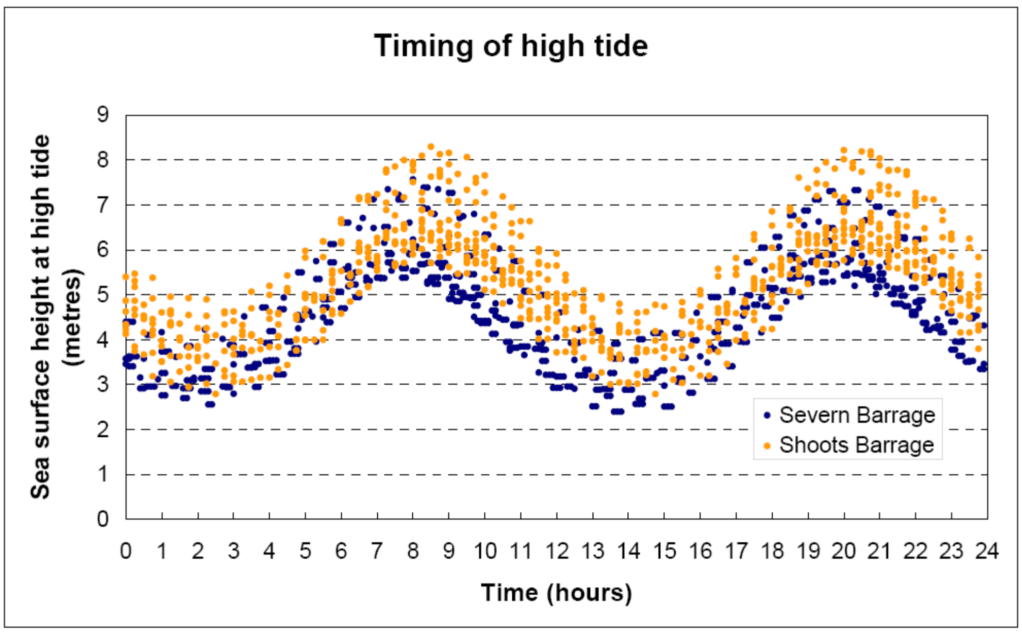
3.3 Barrage Capacity Contribution

The capacity contribution associated with the barrage will be dependent upon the minimum level of generation that can be guaranteed at the peak demand for electricity. This will be dependent upon both the optimal generation profile as well as the flexibility around this generation profile.

The timing of the semi-diurnal and spring-neap tide cycles is such that at a particular stage in the spring-neap cycle, high tide is more likely to occur at certain times of day than others. The relationship between the timing of high tide and the spring-neap cycle is shown in Figure 13. At the location of the proposed Cardiff-Weston barrage:

- At springs, high tide is most likely to occur between 8 and 9 AM and between 8 and 9 PM.
- At neaps, high tide is most likely to occur between 2 and 3 AM and between 2 and 3 PM.

Figure 13: The way that the timing of high tide relates to the spring-neap cycle. Source: SDC[5].



The monthly cycle of neap-spring tides and associated timing of high and low tides means that for the Cardiff-Weston barrage, within-day peak output is more likely to coincide with within-day peak electricity demand at neaps, when the tidal range, and consequently barrage output, are lower. When the tidal range is highest, barrage output will not be well synchronised with peak electricity demand. On average, greatest barrage output will occur in the early afternoon and the early hours of the morning. Typical contributions of the Cardiff-Weston barrage to meeting total system demand for a typical winter day at spring and neap tides are shownin

[5] Tidal Power in the UK. Research report 3 – Review of Severn Barrage Proposals. Sustainable Development Commission May 2007.

Figure 14 and Figure 15. It can be seen that on a neap tide the barrage would contribute around 2 GW over peak demand, while on a spring tide the barrage contribution could be almost zero

In section 3.2 the potential to flex the generation profile of the barrage was discussed. It is possible to delay the start of generation on a spring tide by up to 2 hours whilst only losing 25% of the energy over the tidal cycle. Delaying the generation cycle also creates a different generation profile. Unfortunately little information is provided in the SDC report on the adjusted generation profiles. However IPA has estimated the generation profiles based upon a high-level analysis of the data provided in the SDC report. The resulting generation profile is shown in Figure 16. This suggests that during springs, it might be possible to increase barrage generation at system peak from zero to almost 1.5 GW by flexing the generation profile, although this would be at the expense of reducing overall energy output.

Figure 14: Typical contribution of Cardiff-Weston Barrage to total demand at neaps. Source SDC.

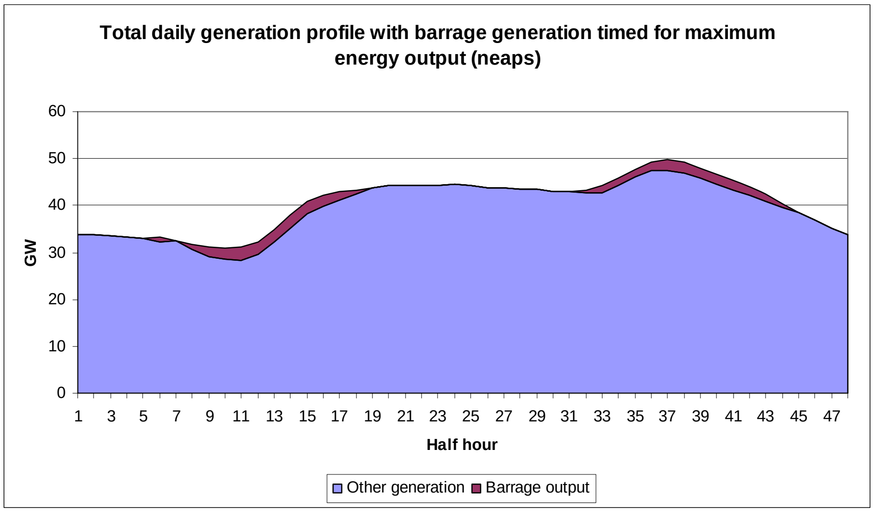


Figure 15: Typical contribution of Cardiff-Weston barrage to total demand at springs. Source: SDC.

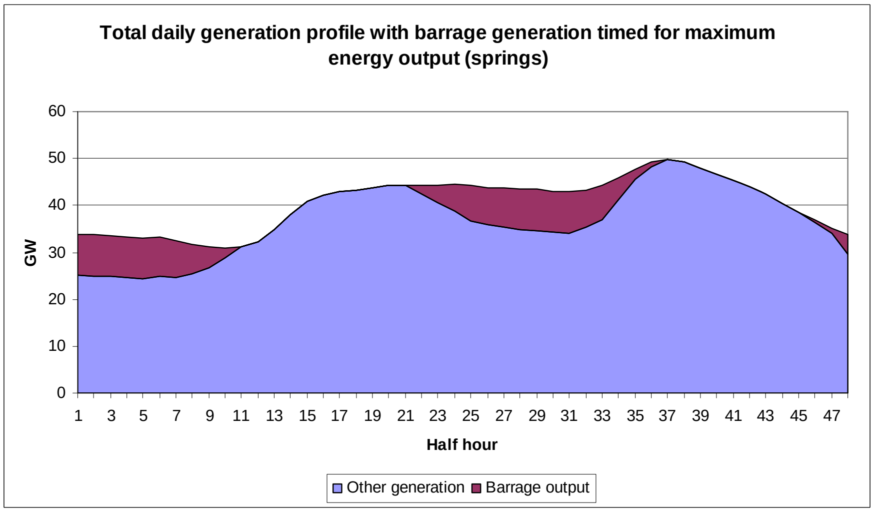
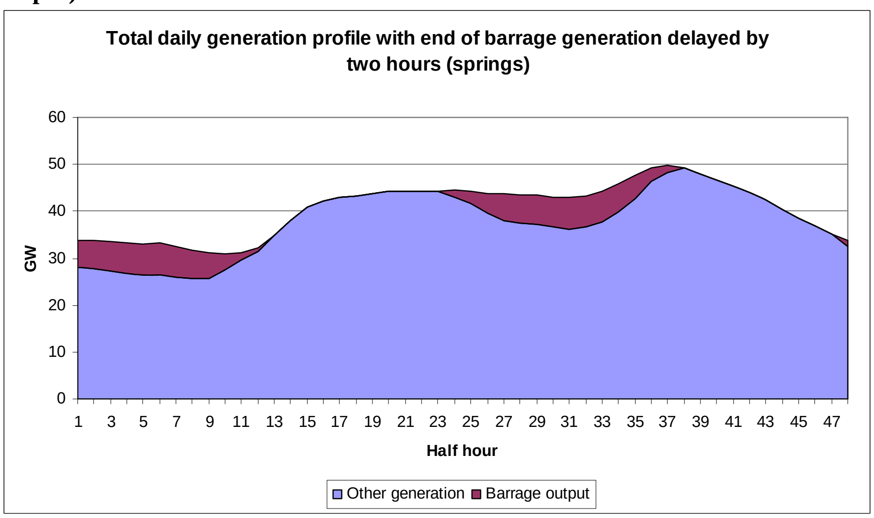


Figure 16: Contribution of Cardiff-Weston barrage to total generation at springs, showing effect of delaying the end of the generation period by two hours (relative to the timing that optimises energy output).



3.4 Summary

The proposed Cardiff-Weston barrage would provide a regular and predictable source of power, but the output will be intermittent and cyclical based upon the daily and monthly tide cycles.

Power generation will vary significantly over the 29.5 day spring-neap cycle, with the amount of energy generated per high tide ranging from 40 GWh/day (at springs) to 15 GWh/day (at neaps).

Unfortunately the timing of the spring-neap tide cycle means that whilst the optimal generation profile from the barrage would be likely to provide around 2 GW of power around winter peak electricity demand, it would provide almost no contribution to winter peak demand over a spring tide. However, it is possible to introduce some flexibility into the generation profile although this reduces the total level of energy output. Our analysis suggests that flexing the generation output profile could increase the minimum barrage generation to around 1.5 GW over winter peak electricity demand. This would constitute the barrage having a capacity ƒcredit of around 17%.

4 BARRAGE EFFECTS ON THE ELECTRICITY SYSTEM

The construction of the Severn Barrage would have a significant impact upon the operation of the GB electricity system. The introduction of an 8.6 GW tidal barrage into a system with a peak demand of around 55GW, will have a significant impact upon the operating schedules of conventional plant, and it is likely that significantly more flexibility would be required across the system as a whole.

4.1 Pump Storage Generation

The GB electricity system has around 3 GW of installed pumped storage generation. This generation plant is extremely flexible and could in principal be used to significantly flatten the fluctuations in generation required from conventional generation as a result of introducing the Severn Barrage.

Pumped storage plant has the ability to both pump and generate, meaning that the total power swing that can be provided by 3 GW of pumped storage plant is 6 GW. Thus, pumped storage has the flexibility to significantly reduce the output fluctuations required from conventional generation.

The generational profile associated with conventional generation to meet a demand over a typical winter day, assuming the Severn Barrage to be generating on a spring tide is shown in Figure 17. The impact of operating the pumped storage plant to minimise the flexibility required from conventional generation is shown in Figure 18. Note that demand from pumped storage pumping increases demand and so reduces flexibility required from conventional generation. It can be seen that the optimal operation of the pumped storage plant would significantly reduce the flexibility required from conventional generation.

To operate economically pumped storage requires a relatively large spread (~40%) between electricity market prices when pumping and when generating. Thus, the operation of the pumped storage plant may not serve to reduce the flexibility required from conventional generation as significantly as suggested in Figure 18. However this is in part mitigated by the fact that there is some flexibility in barrage operation, allowing the generation profile to be flexed to better match the electricity demand profile. This is investigated in Figure 19 below and it can be seen that this realistic generation profile also significantly reduces the level of output flexibility required from conventional generation.

Figure 17: Cardiff-Weston barrage generation at springs and conventional generation output.

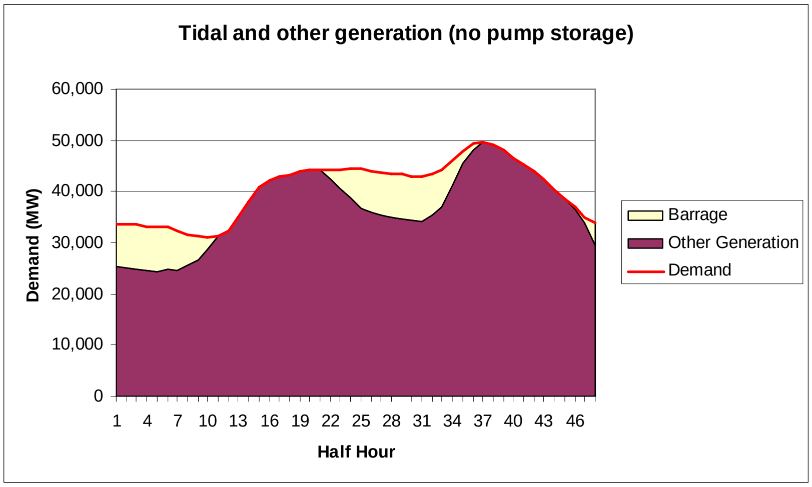


Figure 18: Optimal pumped storage in conjunction with Cardiff-Weston barrage generation at springs.

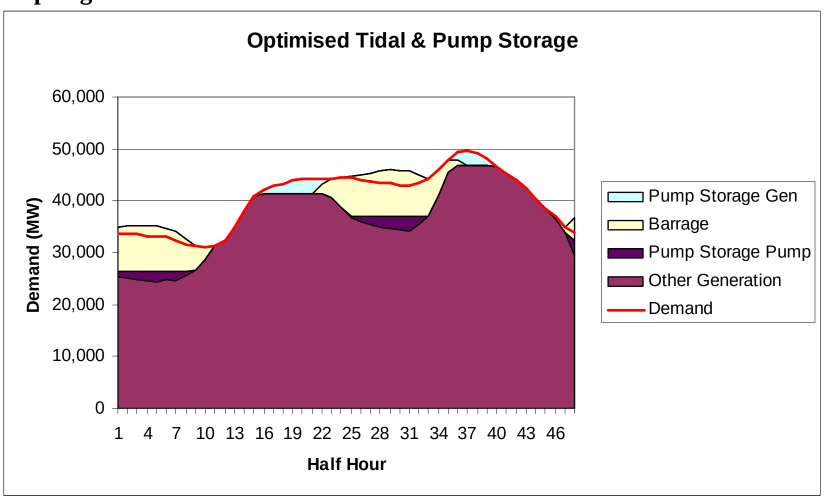
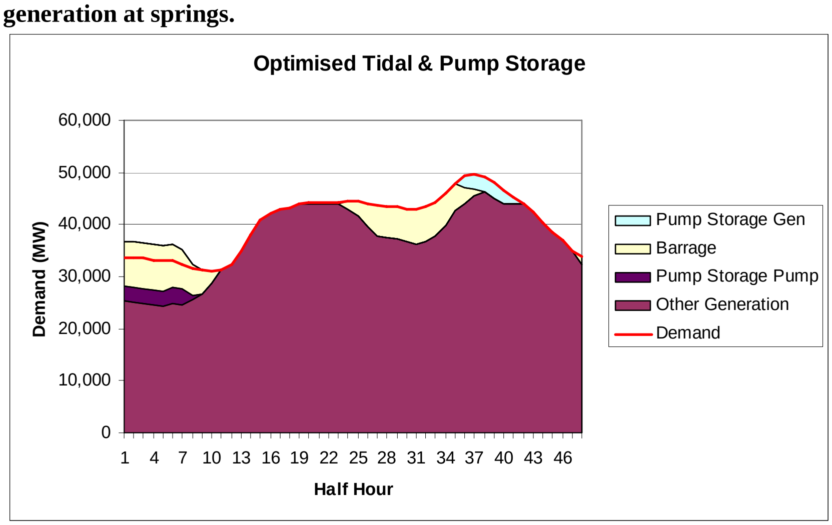


Figure 19: Economic pumped storage in conjunction with Cardiff-Weston barrage flexed generation at springs.



4.2 Summary

The analysis provided in the previous section shows that the introduction of the Severn Barrage onto the GB electricity system would have a significant impact upon the generation profile associated with conventional generation. However, this impact may in part be mitigated through increased use of pumped storage as well as flexing the barrage generation profile.

The barrage generation requires increased inter-day flexibility from conventional generation. A particular issue for a typical winter day over the spring tides (which provides the most challenging conditions) is that the barrage will greatly reduce overnight generation requirements (this could also be problematic over summer minimum demand periods). This will increase the magnitude of the morning ramp and require increased flexibility during the day.

Whilst it is possible that existing plant would be able to provide the output flexibility to accommodate the Severn barrage, it would require a greater degree of flexibility than is currently required to meet the existing demand profile. This would be likely to increase the costs of generation from these plant, as plant are likely to have to increase the number of start-ups, the amount of part-load operation and two-shifting.

5 CONCLUDING REMARKS

This report has undertaken a high level assessment of the proposed Severn Barrage (Cardiff-Weston) scheme investigating the following key aspects:

- Comparison of Generation Costs between the Severn Barrage and other "large scale" generation technologies;
- The contribution that a Severn Barrage Scheme would have to Security of Supply; and
- The effects of a Severn Barrage scheme on the GB electricity system.

A summary of our main findings are highlighted below.

Comparison of Generation Costs

- A comparison of the levelised energy costs of the Cardiff-Weston Barrage scheme compared to other potential large scale generation sources (coal, gas, onshore wind, offshore wind and nuclear) was undertaken.
  - Of all of the different technologies investigated the Severn Barrage proposal has the greatest capital costs.
  - Compared to the other generation sources the O&M costs of the Barrage proposal are low.
  - Based upon a central case for each of the technologies, the energy production costs of the Severn Barrage is significantly greater than for the other generation sources.
- A sensitivity analysis was carried out on the Discount Rates & carbon price.
  - Those technologies with significant capex components are most affected by changes in discount rates. At the lower end of the discount rates investigated, the Severn Barrage becomes competitive with other generation sources, whereas at the upper end it is significantly greater.
  - The SDC report considers 4 different discount rates, 3.5%, 8%, 10%, and 15%. Of the different discount rates considered a discount rate of 3.5% would be unlikely to attract any commercial investors in the project. Depending on the amount of debt in the project and return on equity, discount rates of 8% and 10% would appear reasonable given the nature of the Barrage project. A discount rate of 15% could be considered too high.
  - The economics of renewable energy projects are independent of the carbon price, however, they would benefit from the carbon price by making them more cost competitive than fossil fuelled generation plant. However, even with a carbon price of €50/tCO_2 the Barrage scheme delivers significantly higher energy costs that the other technologies investigated.
- Based on the analysis of the referenceable data it was shown that for all generation sources investigated, with the possible exception of offshore wind, the other

technologies could produce at least twice as much energy for the cost the Barrage scheme (central case).

- By varying the Carbon price between €10/tCO_2 and €50/tCO_2 the other technologies produce between 1.7 and 3 times as much electricity as the Severn Barrage scheme (central case).

Contribution to Security of Supply

- The proposed Cardiff-Weston barrage would provide a regular and predictable source of power, but the output will be intermittent and cyclical based upon the daily and monthly tide cycles.
- Power generation will vary significantly over the 29.5 day spring-neap cycle, with the amount of energy generated per high tide ranging from 40 GWh/day (at springs) to 15 GWh/day (at neaps).
- Unfortunately the timing of the spring-neap tide cycle means that whilst the optimal generation profile from the barrage would be likely to provide around 2 GW of power around winter peak electricity demand, it would provide almost no contribution to winter peak demand over a spring tide. However, it is possible to introduce some flexibility into the generation profile although this reduces the total level of energy output. Our analysis suggests that flexing the generation output profile could increase the minimum barrage generation to around 1.5 GW over winter peak electricity demand. This would constitute the barrage having a capacity credit of around 17%.

Barrage Effects on the Electricity System

- The introduction of the Severn Barrage onto the GB electricity system would have a significant impact upon the generation profile associated with conventional generation. However, this impact may in part be mitigated through increased use of pumped storage as well as flexing the barrage generation profile.
- The barrage generation requires increased inter-day flexibility from conventional generation. A particular issue for a typical winter day over the spring tides (which provides the most challenging conditions) is that the barrage will greatly reduce overnight generation requirements (this could also be problematic over summer minimum demand periods). This will increase the magnitude of the morning ramp and require increased flexibility during the day.
- Whilst it is possible that existing plant would be able to provide the output flexibility to accommodate the Severn barrage, it would require a greater degree of flexibility than is currently required to meet the existing demand profile. This would be likely to increase the costs of generation from these plant, as plant are likely to have to increase the number of start-ups, the amount of part-load operation and two-shifting.