The Royal Academy of Engineering

Severn Tidal Power Phase One Consultation

Department of Energy and Climate Change, South West RDA and the Welsh Assembly Government

April 2009

1. Introduction

1.1. Proposals for a barrage across the Severn have been in existence since at least 1849 and the Thomas Fulijames proposal, although not all have been for the purposes of harnessing the tides for electricity production. Fellows of the Royal Academy with expertise in the field of engineering have been involved in the detail of many of the more recent proposals including minimising the environmental impacts of such engineered solutions.

1.2. In May 2008, the Academy hosted a discussion meeting on the Severn Barrage Proposals in support of the DECC Severn Tidal Power Feasibility Study[1], the transcript of which, along with the key note address by Malcolm Wicks MP, is available on the Academy's website[2]. The Academy, in partnership with the major engineering institutions, has provided experts to act as an expert peer review group to the study[3] as well as nominating one member to the Strategic Environmental Audit Steering Group. This response draws extensively on this group of experts as well as other expertise within the Academy.

1.3. The Academy is active in studying and providing advice on all aspects of UK energy supply and consumption. Through that work, it has become clear that the emission reduction targets needed to mitigate the effects of climate change are so challenging, that all technological solutions must be pursued. Thus, a balanced portfolio of conventional renewables, nuclear, some fossil fuelled thermal and the emerging technologies of tidal stream and wave are most likely required in the fullness of time.

1.4. In this context, the addition of significant power generation from the Severn tides must be given serious consideration. The Academy therefore welcomes the Government's consultation on tidal renewable energy, particularly in the Severn Estuary, and the funding that it has provided towards the many studies that have taken place.

1.5. Given that mitigation of climate change and security of supply are the main drivers behind the proposals to harness tidal energy from the Severn Estuary, The Academy is concerned that the Minehead to Aberthaw barrage has been excluded at this stage. The UK is now legally committed to reducing greenhouse gas emissions by 80% by 2050 and this will require the fullest possible utilisation of all renewable energy options. The Minehead to Aberthaw barrage proposal represents the largest contribution of renewable energy of all the proposals but would be fatally compromised in economic terms in the future if a Cardiff to Weston barrage were already built. If the maximization of renewable energy output is a primary criterion for the selection of proposals, then the Minehead barrage must be retained at this stage. The reason for excluding the Minehead to Aberthaw barrage appears to be based solely on a financial and does not take into account additional carbon savings or additional flood protection for the Somerset Levels and potential benefits for fish migration and other environmental impacts.

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[1] http://severntidalpowerconsultation.decc.gov.uk/feasibility_study_overview
[2] http://www.raeng.org.uk/events/pdf/Severn%20Barrage%20transcript.pdf
[3] http://www.berr.gov.uk/energy/sources/renewables/explained/severntidalpower/thefeasibilitystudy/governance/page47474.html

2. Consultation Questions

2.1. Is the feasibility study taking the right issues into account?

2.1.1. We support the engineering analyses that have been undertaken so far. However we consider it important that, in the next phase of studies, full consideration is given, not only to optimising scheme output/costs but also to the best ways of mitigating the important environmental impacts that can take place. For instance, installing more sluices and turbines, with the option of pumping, could mean that the basin water levels would follow the natural tidal cycle more closely and less of the inter-tidal areas would be lost. The appropriate balance between energy, cost and environmental impact could then be selected.

2.1.2. We support the focus on tidal renewable energy in the Severn Estuary, because of the particularly high tidal ranges in the region, but feel that it is also important to consider any major energy provision scheme as part of a holistic tidal energy programme across the UK and not just the Severn in isolation.

2.1.3. We note that the schemes would require revenue support and the larger schemes would also need capital support. Determining how this support can be provided within the framework of a competitive electricity market will require considerable investigation.

2.2. Are there other aspects or other evidence that should be taken into consideration?

2.2.1. It appears that little consideration has been given to the probable effects of projected sea level rise during the life of the structures, at least 120 years and probably more.

2.2.2. We are concerned that there is evidence from other tidal power schemes that does not appear to be taken into account. For instance the experience from La Rance shows that, despite losing one third of the inter-tidal area, the habitat carrying capacity has increased.

2.3. Have we given due weighting to the different benefits and impacts under consideration in our analysis?

2.3.1. It appears that, in assessing the environmental issues a precautionary approach has been taken, leading to a worst case environmental impact assessment. We would expect phase two studies to identify more certainly the likely environmental impact of the various schemes, along with mitigation measures that could be adopted.

2.3.2. For instance, the Sustainable Development Commission quoted the area of intertidal mudflats that would be lost for the Cardiff-Weston line as 14,500ha. We believe that this was on the basis of mean low tide. This to us seems a reasonable approach. However the consultation document quotes the areas lost as down to Lowest Astronomical Tide (LAT) and calculates this loss to be 20,000ha. This is a tidal level that is only reached about once a year. Thus, for instance, this would not be able to support any particular species as one tide a year would not be sufficient time for the species to last until the next LAT. No clear reason is given for this enlarged area. This extra area is

then required to be compensated for with a greater (double or more) area elsewhere. We consider that a more meaningful criterion would be mean low tide as this would reflect actual current ability to support biodiversity and bird population.

2.3.3. In considering the inter-tidal habitat loss associated with any scheme, no account has yet been taken of sea level rise and the corresponding natural reduction in the inter-tidal area during the life of the structure.

2.3.4. With a sea level rise of about 1m projected for 2100 and more thereafter during the remainder of the life of the structures, storm surges coupled with sea level rise would breach the current sea defences. Considerable sums would need to be spent on raising sea defences or on abandoning many thousands of homes. We believe that the flood defence benefit of some of the schemes should be taken into account.

2.4. Do you think that it is better to wait for new and perhaps less environmentally damaging technologies to be developed, or to move ahead more quickly with available proposals?

2.4.1. The Stern Review on 'The Economics of Climate Change'[4] explicitly accepted the science of the International Panel on Climate Change and the presumption that the anthropogenic contribution to climate change is significant. It took a global standpoint in examining economic impacts of climate change and made the case for early and sustained investment in mitigation, adaptation and prevention strategies, but was unable to recommend specific actions or technologies to achieve this in an optimal timeframe.

2.4.2. In terms of mitigation, it is through the application of engineered systems and technologies that a significant proportion of achievable reduction in CO_2 emissions on both the supply and demand sides of the energy industry will be realised. The concept of stabilisation triangles and wedges leading to the stabilisation and eventual reduction of CO_2 emissions, developed by Socolow and Pacala[5], has gained acceptability in the climate change literature, but significant effects require an early start for each wedge. If engineering is to have significant impact on emissions reduction, the technologies applied will be those currently known about and the bulk of effort must be put into commercialisation, scalability and deployment rather than early stage research.

2.4.3. In meeting targets for the proportion of energy consumed to be renewable by a certain time (either 2020 or 2050) it is only important that a tidal energy proposal on the Severn is generating at the time specified in the target. However, if the ultimate aim is to mitigate the effects of climate change, the Severn Tidal Power proposals must move ahead as soon as possible, as every year that the final proposal is generating low-carbon electricity it is contributing to the effort to reduce the rise in, and ultimately reduce, the atmospheric concentration of CO_2.

[4] Stern Review: The Economics of Climate Change (2007) page 207.
[5] Pacala, S. and R. Socolow (2004): 'Stabilization wedges: Solving the climate problem for the next 50 years with current technologies', Science, **305**: 968-972

2.4.4. However, any tidal power scheme is likely to be in use for at least 120 years, so it is important that any potential improvement is not lost. That means balancing the potential benefit of a new technology with the likelihood of it being able to be of full scale benefit in a reasonable time.

2.4.5. The Academy is therefore of the opinion that it is correct to move ahead with proven technologies rather than waiting for advances in unproven technologies or relying on performance assumptions that cannot be substantiated.

3. Regional Economic Impacts study.

3.1. Do you agree with the conclusions of the DTZ study and are there any other factors that the feasibility study should be aware of?

3.1.1. The area of expertise that The Academy can competently contribute to lies within the field of engineering. While this does include the costs and economics of the proposed schemes, it does not extend to the socio-economic issues allied to the regional economic impacts studies conducted by DTZ. However we believe that, for some of the schemes, the caissons for the turbines and sluices are likely to be constructed outside the Bristol Channel and the Severn Estuary regions. In addition the rock armouring is likely to come in by sea from elsewhere. The form and location of construction of the tidal barriers does not appear to have been considered properly in the DTZ study.

3.1.2. Based on experience of La Rance – a much smaller structure – we are also surprised by the low number of jobs that DTZ predicts in the Severnside Region relating to any barrage construction as well as commissioning and maintenance.

3.1.3. We do not believe that DTZ have taken sufficient account of the increased recreational activity that is likely to arise in the estuary as a result of the reduced turbidity and increased water clarity, associated with the reduced currents and tidal ranges for a Severn Barrage operating under ebb-tide generation only.

4. Financing and Subsidy Mechanism

4.1. Do you agree with Price Waterhouse Coopers analysis on ownership and delivery of a Severn scheme?

4.2. Are there any other options for delivery or subsidy that should be considered?

4.2.1. Regarding long term energy costs, we believe that with the greater proportion of electricity in the energy supply mix, and the greater proportion of renewable electricity, electricity costs will have to rise appreciably in real terms over the years ahead and we would have in mind rises of 50% to 100%.

4.2.2. Within a commercially driven market where electricity prices rise and fall based on factors over which some generators have no control (such as oil and gas prices), the expected rise in electricity costs will not be sufficient to offset the significant financial risks associated with building and operating an

asset of this size. It is clear that the Government is considering revenue support for all proposed schemes and capital support for the large schemes. The problem for the Government is how to intervene. It may be preferable to leave the MWh market alone but give such revenue support that limited and unpredictable revenue from MWh does not matter too much to investors.

4.3. Government believes that the private sector is best placed to design, build and operate a Severn tidal scheme. Government's role would be to set the conditions in which a scheme could come forward. Do you agree?

4.3.1. How the scheme will be financed with an uncertain revenue stream is a major question. The Renewables Obligation with the variable quantity obligation guarantees a revenue stream, however, the capacity of the some of the proposals are such that they could have a distorting effect on the price of Renewable Obligation Certificates, introducing further risk.

4.3.2. The financeability, and hence the financing cost, of the project, will depend critically on the extent to which the Government is prepared to alleviate the risks involved in the construction of the asset, and also the extent to which it is prepared to underwrite the subsequent pricing risk. The more quantifiable the two risks are, the more easily the project can be financed. Although it would be a huge undertaking, given the appropriate level of risk, we believe that there would be infrastructure investors who would be capable of putting the funds together.

5. Impacts on Energy Markets

What are the impacts and potential risks of tidal intermittency on the balancing and energy market?

5.1.1. The generation profile for a tidal scheme (when and how much power will be produced) is easily predictable. As discussed elsewhere (para 5.2.1), because of the size and financing of such a scheme, it would be likely to be operated in such a way as to generate the maximum amount of power for the maximum time, i.e. it will operate at maximum capacity at every opportunity.

5.1.2. While the balancing of the electricity system will be complicated by the phase of the tides, its predictability would make it relatively easy to deal with. The effect of that intermittency on other generators on the system would be less easy to predict. Price signals within the market would become influenced by the tide times in the Severn. The impact such an asset would have on the market is difficult to judge at this point, because by the time it becomes operational the generation mix would have changed substantially, with the disappearance of a number of nuclear and large coal fired stations. However, if it were to run as base load then the frequency with which it would set the marginal price would be quite low.

5.1.3. It is also possible that a Severn tidal power scheme could contribute to balancing the system during periods when generation is high, but this would rely on some of the scheme's capacity being held in reserve and being able to be brought online at short notice.

5.1.4. The impact of intermittency could be alleviated by generating on both flood and ebb tides and additionally using pumping under low heads, i.e. at low and high tides. This would have the additional benefit of potentially reducing a barrage's environmental impact and being able to control the operation of the barrage more flexibly for flood defence. We believe that these options deserve attention in Phase 2.

5.1.5. Given the timescale for construction and the life time of the proposed assets, it should be borne in mind that advances in electricity storage and smart grid infrastructure will be likely to ameliorate the cost of intermittency over time. Also, off-shore grid infrastructure to support off-shore wind farms is likely to significantly increase interconnector capacity to the European mainland likely in a similar timeframe.

Is it worth considering the option of demand management?

5.1.6. Demand management must be a key component of any conceivable UK energy policy, especially when high penetrations of renewable electricity generation are required. The normal use of demand management is to reduce the peak daily demand and potentially to shift some non time-sensitive demand away from any peak. The generation profile of a tidal scheme brings the potential for some major electricity users to time their peak demand periods to match the phase of the tides. This aspect of demand management warrants further study in the context of a Severn tidal power scheme.

5.2. Do you consider that a Severn tidal scheme could impact on investment in other energy supply capacity, and if so in what ways?

5.2.1. It is likely that a large tidal power scheme would have to be operated in a "must run" way – meaning that to make a meaningful return on investment; the scheme would need to generate power on every tide regardless of system demand. If a tidal scheme were, for example, generating 9GW on a spring tide, the system had a good proportion of relatively inflexible nuclear base load and the wind were blowing, the spot price for electricity would be likely to approach zero. This situation would not be a problem for wind generators as they could expect to receive the value of a Renewable Obligation Certificate for each MWh generated, but nuclear operators would face considerable risk. A Severn tidal power scheme might, therefore, have an impact on regulation and financial framework for investment in new generation nuclear plant.

6. Short-listing process

For context the order of questions 12 and 13 in the consultation document are reversed.

6.1. Do you agree that the test of economic feasibility should be relative to the cost of other renewables?

6.1.1. Yes, but in the context of the UK having to reduce greenhouse gas emissions from all energy sources, including transport, by 80% by 2050. This will be a considerable, and expensive, challenge. As carbon trading markets mature and the price of carbon emissions firms, it can also be expected that renewables will become cost effective against some forms of

thermal generation. Similarly, the playing field for renewables is not entirely level and economic feasibility when compared to other renewables will depend upon banding of Renewable Obligation Certificates depending on the maturity of technologies and this aspect should also be taken into account.

6.1.2. A number of scenarios and projections suggest that de-carbonising the UK economy will be achieved in a large part by widespread electrification, with higher reliance on electric transport (including electric road vehicles) and electric heating in the form of heat pumps. This vision has the potential to increase the UK's electricity demand by up to 100%. De-carbonising the electricity supply therefore becomes an imperative and the relative economic feasibility of all renewables is improved.

6.2. Do you agree with the factors that have been used to determine the short-list for further study?

6.2.1. Because of the need to provide even more renewable energy, greater consideration should be provided to maximising the renewable energy source available. For instance, if a lagoon scheme were built then it would still be economical to construct a large barrage, however, if the Cardiff-Weston line were constructed then it would probably preclude maximising the energy output from the Severn Estuary with a further barrage at the Minehead to Aberthaw line, producing at least 25 TWh/year.

6.2.2. We consider that there is too much emphasis on financeability now. This has had the effect of ruling out a total cut-off for the Minehead to Aberthaw barrage, see the Summary on the DECC web site. What needs to be considered is the financeability at the time that finance is needed and that is some years away. Timescales dictate that decisions on finance methods, and hence financeability, will be for the future and therefore, while it is important to present the costs at this stage, attitudes as to what is financeable and what is not may change with time. Thus we consider that current financeability should not be a make-or-break criterion.

6.2.3. The Shoots barrage and the Cardiff-Weston lines have been studied in some detail and decisions can be taken on them with some confidence. However, the Minehead-Aberthaw line has only been studied in outline by Bondi and PB. To make a proper comparison it would need to be studied to a similar level of detail. In our opinion there would be few – if any – additional environmental impacts between a Minehead to Aberthaw barrage relative to a Cardiff to Weston barrage. In fact, the Minehead line barrage would have the benefit of providing additional flood defence to the Somerset Levels.

6.3. Do you have any further comments on Parsons Brinkerhoff's Interim Options Appraisal Report?

6.3.1. In our view, this is a good initial assessment of the options. However the environmental aspects have been treated with an overly precautionary approach, identifying the worst case that could happen and too little consideration being placed on the effects that long term climate change is likely to bring and on potential mitigation measures. We also believe that insufficient emphasis has been focused on the flood risk benefits and improved aspects of water quality, in terms of reduced turbidity, increased

clarity and increased dissolved oxygen, of some of the barrage schemes and particularly the Cardiff to Weston barrage.

6.4. Do you agree that the two lagoon options selected for further study represent a good basis for studying lagoons?

6.4.1. The two lagoon schemes chosen are undoubtedly the best two available.

6.5. Given the short-listing criteria, are there any proposals on the short list which are not suitable? Please support your response with evidence where appropriate.

6.5.1. We have commented above that some of the short listing criteria need amending. Financeability should not be an absolute cut-off until nearer the time when finance would be needed.

6.5.2. We note that in para 175 of the consultation document a figure of £170/MWh was chosen as a high cost threshold but that the Welsh Ground scheme has a unit energy cost of £183/MWh, significantly above the cut-off level. By contrast the Minehead to Aberthaw line has a unit cost of £131/MWh.

6.5.3. La Rance at 240MW has been an effective prototype and proved the technology works, so there is no reason to fund or construct a further prototype. In that case we consider that any scheme that does not produce at least say 15% of the ultimate output available from the resource should not be considered unless there is an absolute reason why a larger scheme could not be acceptable.

6.5.4. We are concerned that the likely sedimentation in the basins of the Shoots and Beachey barrage schemes could well adversely affect their viability. We are also concerned that these two barrages might not operate as efficiently as calculated to-date using a 1-D analysis. These concerns would need to be studied further during Phase 2.

6.6. Does the short-list represent an appropriate level of ambition given the energy potential of the estuary?

6.6.1. No. We deal with that in our answer to Q18 immediately below.

6.7. Are there any other schemes that, in your view, should be shortlisted? Please provide appropriate evidence wherever possible and refer too the short listing criteria.

6.7.1. In our view the Minehead to Aberthaw barrage line should be included in the short list. See the criteria below.

- Impact on energy market

  The Minehead scheme provides the largest potential energy, nominally 25TWh/year, towards the 2050 requirement of 80% of energy from renewable resources. It also provides the maximum carbon reduction. Grid connections would be an issue, but these have been costed into the unit energy price and would be subject to further study. A possible enhanced link to continental Europe might be appropriate.

- Technical risk

  The technology is that utilised at La Rance. The barrage line is deeper than the others, but this would be an advantage as the turbine caissons would be generally founded on rock and would need much less soft sediment dredging.

- Cost and amount of energy

  The unit energy cost is £131/MWh which is about the mean of the other shortlisted schemes. At 25TWh/year it would be the largest Severn scheme providing about 7.3% of our current electrical energy needs. Two way generation could also provide even higher levels of annual energy yield, as well as reducing the environmental impact on the estuary.

- Environmental impact.

  This provides 50% more energy than the Cardiff Weston line but with much less than 50% extra impact.

  The main concern relating to fish is primarily whether salmon would wait in the area of the turbines and sluices. This scheme is not near any important salmon river mouth and its impact is likely to be less than other barrages.

  The area of intertidal habitat lost would be increased. However this scheme, with its greater water depth, has greater opportunity to increase the number of sluices and turbines and thus allow the basin to follow the natural tidal level more closely. This could much reduce the intertidal area lost. It is possible that the loss of intertidal area caused by the Minehead Aberthaw line might be less than that from the Cardiff Weston line. This has not yet been studied but needs to be.

  The extra loss of known archaeology is very low.

  The area of Bridgwater Bay has several international designations. However the sea area west of Bridgwater Bay and up to the Minehead Aberthaw line appears to have none.

- Regional level economic and social impacts.

  The economic and social impacts are assessed as positive for all schemes so there seems no reason to doubt that this would be of greater benefit for the Minehead Aberthaw Line.

  The extra benign area provided for sailing recreation would be about 50%.

  Extra port impact would be Barry port only, with no difference from the Cardiff Weston line on Bristol Port or the other ports.

  A very important social aspect is the defence against tidal flooding. There are large areas around the Severn Estuary and Bristol Channel that are at risk from storm surge flooding. Climate change, with a 1m rise

projected by 2100, is going to exacerbate this flood risk. For instance Somerset County Council state that by 2060 there is a 1 in 17 year risk of some 30,000 homes flooding from sea inundation. With rising sea levels, perhaps to 3m during the life of a barrage, the risk will increase substantially. With a barrage able to shut its gates to exclude storm surges there would be great flood protection given to low lying land "upstream". The Minehead line would provide protection not only to the Gwent levels but also to the Somerset Levels, the M5 the only dual carriageway into the South West, and the railway lines. No account of this benefit was taken during the phase one studies. It should be considered.

6.7.2. For these reasons we urge that the Minehead to Aberthaw line be included in the shortlist of schemes to be studied in phase 2.

7. Strategic Environmental Assessment

7.1. Which plans, programmes or environmental protection objectives are most significant for this strategic-level environmental assessment?

7.1.1. No comment.

7.2. Is there any additional information that could help supplement the baseline data? Any further information relating to baseline indicators, existing problems and trends over time would be very useful.

7.2.1. Greater use of the extensive experience from the La Rance scheme would be very helpful to provide hard evidence of what is actually likely to happen, rather than precautionary speculation.

7.3. Is there any important information that has not been addressed in view of the SEA scope?

7.3.1. Evidence from operation of the La Rance tidal scheme.

8. Next steps

8.1. Do you agree with the work plan, as outlined in Chapter 6. if not please specify any other areas to be studied.

8.1.1. Sea level rise.

8.1.1.1. Since the scheme would last at least 120 years and probably more like 200 years in reality, long term sea level rise would need to be taken into account. In the very long term the scheme might become a sea defence scheme, rather than a tidal power scheme. It is important to have an up-to-date prognosis of sea level rise which would also be used on the 'do nothing' scenario.

8.1.2. Flood risk benefit

8.1.2.1. Flood risk benefit needs proper consideration, both in the medium and long term.

8.1.3. Basin water level regime.

8.1.3.1. There are a number of ways of minimising the environmental impact by adapting the design and operation. For instance some schemes could be designed and operated for the basin water level to follow the natural cycle more closely. For instance this could be done for some schemes by increasing the number of turbines and sluices by putting the sluices above the turbines, possibly also supplemented with low head pumping. These aspects need to be studied to ensure that the optimum is achieved between unit energy cost and environmental impact.

8.1.4. Fish studies

8.1.4.1. Further studies of fish mortality are required. La Rance offers an opportunity to carry out such studies on an operating barrage with bulb turbines very similar to those that would be used in a Severn barrage and the Academy would suggest that this opportunity should be pursued to the full.

8.1.5. Compensation areas.

8.1.5.1. This needs careful study as experience from La Rance has demonstrated that, although there was a loss of 1/3 of the intertidal areas, the habitat carrying capacity increased. Thus the requirement for compensation areas needs careful evaluation.

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