Call for evidence on the proposed Severn barrage scheme

Energy and Climate Change Committee

This is an *Engineering the Future* response to the Energy and Climate Change Committee: Call for evidence on the proposed Severn barrage scheme

The development of this response has been led by:

- **The Royal Academy of Engineering**

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- The Institution of Chemical Engineers
- The Institution of Civil Engineers
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Engineering the Future is a broad alliance of engineering institutions and bodies which represent the UK's 450,000 professional engineers.

We provide independent expert advice and promote understanding of the contribution that engineering makes to the economy, society and to the development and delivery of national policy.

Introduction

The 2010 Severn Tidal Power Feasibility Study by DECC detailed a number of conclusions which led to DECC's decision not to proceed with public investment into the Cardiff-Weston scheme considered. Since then, an alternative scheme has been developed, Hafren Power barrage, which addresses some of the conclusions reached. This evidence answers the ECC questions with respect to the Hafren Power Barrage scheme where possible, but we would like to make the Select Committee aware that details of this scheme are not in the public domain.

Some general issues relating to a Severn barrage are addressed in *The Royal Academy of Engineering, Academy briefing: The Severn barrage*[1].

[1] http://www.raeng.org.uk/events/pdf/Severn%20Barrage%20transcript.pdf

Summary

We would like to make the Committee aware that the engineering community has differing views on proposals for a barrage. This response aims to represent these different viewpoints in a balanced, evidence-based argument.

The key points are:

- There are issues related to the fact that a Severn barrage would only generate power for limited periods of the day, but these could be addressed. The overall energy economics, socio-economic and environmental impact of the scheme would need further exploration.
- A tidal power scheme in the Severn Estuary could be important in the overall achievement of a secure low-carbon electricity supply but local environmental and economic impacts must be taken into account, as well as the cost of its electricity production compared to other sources.
- Computer model results for ebb/flood generation, similar to the Hafren Power scheme, indicate the barrage would defend against flooding from the sea.
- It is expected that the barrage would affect several aspects of existing environment and wildlife. These include positive and detrimental changes. Risks to bird habitat need to be clarified but could potentially be partially mitigated through engineering interventions.
- While capital costs are high, tidal generation would work reliably for >100 years with low operating costs, few breakdowns, predictable power and some flexibility in energy generation. Challenges created by the output profile of the barrage would need to be addressed.
- The barrage would provide several positive opportunities for local communities, local employment and marina development. However, shipping times and navigation would be negatively affected. The tidal window for accepting large ships would be reduced and shipping times lengthened. The engineering interventions to mitigate these changes need further study.
- Development of a Severn barrage would create international interest. Successful development of the barrage could lead to other schemes being built using UK-based low-carbon engineering and technology. The UK is also well placed to export engineering and project development, delivery advisory services, and its policy expertise.

Q1 - What contribution could the Cardiff-Weston barrage make to UK energy security and climate change objectives?

Overview of Hafren Power scheme

1. The subject of DECC's feasibility study of the Cardiff-Weston barrage was an ebb generation barrage leading to two spells of power generation each day with a maximum power output of about 8 GW. This would provide about 11 hours generation each day.

2. This response focuses on the scheme proposed by Hafren Power (HP). The HP scheme includes the use of Very Low Head (VLH) contra-rotating turbines and would generate in both ebb and flood tides. This would have four generation phases a day. Generation would be for about 15 hours a day with a peak power output of about 6 GW. The amount of energy generated by the HP scheme would be similar to that of the scheme considered by DECC.

3. Summary of the HP scheme benefits (compared to the scheme considered by DECC):

    - lower cost
    - better generation profile and higher load factor
    - reduction in flood risk
    - better scope for private financing.

Contribution to UK energy security

4. The UK electricity system has a peak demand of around 60 GW. The proposed HP Severn barrage could provide large volumes of low-carbon electricity, for an indefinite period, with peak outputs up to 6 GW. Over a year, this could provide up to 5% of the total present UK electricity demand.

5. In contrast with many forms of low carbon energy, for example wind and solar, electricity generated by the barrage would be available at predictable times each day. The amount of power that would be generated could be calculated for any period in the future. However, the timing of energy production would vary with the tides and the amount of power generated would vary significantly between spring and neap tides. Even though there are engineering possibilities to hold back and control water flow through impoundments, there would be some days every month when electricity was produced at times when ordinarily demand would be very low.

6. All tidal power varies in the amount of energy generation depending on the size of the tide. The HP ebb/flood scheme, with its four pulses a day, would generate more energy for a greater proportion of each day when compared with the ebb-only scheme of only two pulses. The energy is predictable and this short term intermittency of about three hours could be mitigated, initially by conventional back-up, and by developing energy storage technologies or controllable sources of electricity demand that exploited the daily predictability of the output, such as electric vehicle charging. Storage technologies are already being researched and tested and should be developed not just to exploit generation from the barrage but also for other renewable energy sources.

7. The scheme would add much-needed diversity to the UK's renewable energy portfolio. Given the barrage's generation characteristics, it could complement nuclear and wind and reduce the reliance on imported gas, providing the UK with flexibility for the future.

8. Tidal barrages have a far longer life expectancy than most other forms of electricity generation infrastructure. A Severn barrage would be expected to contribute to the UK's energy needs for over a century, at a low cost for most of its life once the capital cost is repaid. The anticipated maintenance costs for the barrage would be very low and if designed well, lower than any other form of generation as demonstrated by the La Rance project. In addition, a barrage would have limited end of life issues, all of which could be managed with currently known technologies.

9. The cost of electricity from the project versus alternatives is a major consideration. Without valuing predictability, the studies undertaken for DECC in 2010 do not give great cause for optimism in this regard, with quoted costs of 30p/kWh. That compares with around 15p/kWh for offshore wind today, which is expected to fall by 2020. It has been noted that the HP scheme appears to offer the potential for significant reduction, possibly to the level of current offshore wind costs, but this requires further analysis and validation.

10. Should it prove possible to reduce costs of construction significantly through innovation in turbine design, civil works and method of operation, to the point where costs were comparable with other low carbon options currently being pursued in the UK, then the predictability of output would bring a potential additional source of value, provided ways could be found to exploit it.

11. Before any decision is made to proceed further, a comprehensive assessment of full energy system costs should be undertaken, considering scenarios with and without a Severn barrage using the latest HP cost and performance data. Should this show a favourable outcome, then independent third party review of the cost and performance data would be advisable before further commitment by government.

Contribution to UK climate change objectives

12. If a Severn barrage could produce 5% of the electricity demand, without excessive embodied carbon, it would make a significant contribution to meeting the post-2020 targets. Assuming that the HP scheme were commissioned in the mid-2020s, the barrage would allow an annual carbon dioxide saving of 1-2 million tonnes (using a conversion factor based on the current carbon intensity of the UK grid). The emission savings would be expected to decline as more low carbon energy generation was brought into the generation mix, thus lowering the carbon intensity if the grid and hence the conversion factor. The value of 1-2 million tonnes is calculated using the current, and more aggressive, DECC energy conversion figures which push for 0.1kgCO_2/kWh by 2030.

13. It is crucial that the methodology for estimating carbon savings is well established by adopting the principles of Life Cycle Assessment (LCA). LCA is a tool used to assess the environmental impacts of a product from design to disposal, that is, across its entire lifecycle. The methodology for LCA should be fully transparent so the lifetime carbon benefits are articulated in the proposal. This can then be compared with other energy generation alternatives of similar scale such as nuclear power, use of fossil

fuels with carbon capture and storage (CCS), wind power, and solar capture with *high-voltage, direct current* transmission.

Q2 - What risks and opportunities could it pose with regard to flooding in the Severn Estuary, and how might any risks be mitigated?

14. HP has undertaken computer model studies for flood risk assessment for their Business Case presented to DECC, but these results are not currently in the public domain.

15. Professor Roger Falconer FREng, Director of Hydro-environmental Research Centre at Cardiff School of Engineering, leads a team that has been undertaking simulations to establish the hydro-environmental impacts of a barrage. His team has studied the impacts of different barrage configurations including ebb/flood generation with traditional turbines and with boundary conditions set just beyond the Continental Shelf. The specific details of the turbines in the HP scheme have not been made available and have not been used at Cardiff. Other simulations have been undertaken with the HP scheme (work not undertaken by Cardiff) but boundary conditions only taken to the edge of the Bristol Channel.

16. The Cardiff computer model results for ebb/flood generation with traditional turbines (similar to the HP scheme but not modelling the same turbine) indicate that:

    - Flood risk upstream would be *reduced* with the barrage lowering the maximum water levels by between 1-2 m for spring tides.
    - For ebb/flood generation, the peak water level is reduced by typically 0.2 m just downstream of the barrage in the Severn Estuary. However, in the Bristol Channel the peak water levels *increase* by up to 0.2 m for 764 bulb turbines, primarily in the Swansea region along the South Wales coast.
    - There is no significant change (less than 0.05 m) in the water levels outside the Bristol Channel for ebb/flood generation, i.e. far-field effects. In contrast, ebb-only generation shows significant regions of the Irish Sea where the water levels are increased by typically 0.1 m.
    - Flood risk caused by surges would be *reduced.* In an event of a storm surge, the turbine generation on the flood tide could be reduced and then stopped, thereby controlling the basin water level.
    - Models have shown that the mean estuary water level upstream of the barrage remains similar to the status quo and there will be little or no change in the mean ground water level. The peak spring tides (with a current range of about 14 m) are reduced to less than 10 m.
    - The land inundation extent that would be protected from flooding as a result of a barrage is estimated to be of the order of 50,000 hectares.

17. The region just outside the line of the main barrage, such as Somerset, has been considered. The hydrodynamics of the Somerset area have been modelled. The peak tidal level outside the barrage is predicted to be about 0.2 m lower with the barrage than without it. Thus a barrage would slightly reduce the flood risk in the region of the Somerset Levels and reduce the expenditure by the Environment Agency and others in having to raise the coastal flood embankments to cope with climate change induced sea level rise.

18. The barrage would likely be in operation for over a hundred years. In the long term, the barrage would continue to control maximum basin levels, and defend against

flooding from the sea with only a small loss of power during peak spring tides. Any small increased risk to properties or communities would need to be addressed in a more comprehensive and case by case design study by the developer.

19. With sea level projected to rise up to 0.76 m by 2095[2], putting much of the UK coastline under threat, a region free of or at least defended against flooding is likely to be attractive for international industrial investment. Therefore, the barrage has a role in climate change adaptation.

Q3 - What risks and opportunities could it pose to wildlife and habitat in the Severn Estuary, and how might any risks be mitigated?

20. A barrage would affect several aspects of existing environment and wildlife. These include positive and detrimental change.

21. Changes to wildlife and habitat posed by the HP barrage could include:

- Loss of inter-tidal habitat (the spring tidal range would be reduced from 14 m to less than 10 m).
- Reduced tidal currents upstream of the barrage.
- Reduced suspended sediment levels upstream and therefore a reduction in sediment bacteria transport.
- Increased light penetration because of less sediment present in the water column.
- Increased dissolved oxygen.
- More stable bed of the estuary due to lower spring tide velocities which are the prime cause of erosion, thus allowing biodiversity a more stable base.
- Increased primary productivity and a changed biodiversity on the bed of the estuary.

22. These changes would increase the biological productivity of the area and the water would be significantly clearer.

23. To mitigate the loss of inter-tidal habitat, material dredged from beneath the caissons and from the shipping channels could be used to raise the bed of the estuary in selected places replacing some of the bird feeding habitat that would become submerged. However, more work is required to clarify the impact of existing habitat and the extent and nature of the remedial work required.

24. Fishing in the Severn Estuary is limited. There is concern for salmon which occur in the Usk, Wye, and Severn. Along with most UK rivers, the number of salmon in these rivers has reduced considerably in the last few decades. There is little evidence available about how and when salmon migrate. There is also concern for eel populations. Before any scheme went ahead, HP would have to demonstrate how the VLH contra-rotating turbines (which have a slower blade speed) would affect salmon, and other species, in the estuary.

Q4 - What lessons can be learned from the successful development of the La Rance tidal barrage in France and other tidal power projects?

[2] UK Climate Projections 2009, UKCP09: Briefing report, http://www.ukcip.org.uk/wordpress/wp-content/PDFs/UKCP09_Briefing.pdf

25. The La Rance scheme was built on the Brittany coast near St Malo during the early 1960s. It dams off a long thin estuary to produce tidal power using bulb turbines. It has been operating continuously ever since, producing about 240 MW of tidal power on an ebb-only generation mode.

26. The La Rance project is different from the Severn for several reasons. One is the narrowness of the estuary, which meant that the scheme was constructed in a coffer dam, cutting off all migratory species and changing the salinity. Another is that no proper environmental base studies were done before the scheme was built. For these reasons, there are very few environmental lessons to be learned. Other, more recent, tidal barrier schemes may offer more such insight, including the Eastern Scheldt in the Netherlands and Annapolis Royal in Canada.

27. However, the La Rance scheme has demonstrated that tidal power can work very reliably, that maintenance and breakdowns are very low, and that there is some flexibility in energy generation. EDF, the operator of the scheme, claims that the resultant environment is a good environment in itself, albeit significantly different from that what was there before. We would like to make the Select Committee aware of the work of Vincent de Laleu, Marine & Offshore Wind Senior Engineer at EDF R&D, in which he describes the lessons learned as including proven low operating costs, long-life, predictability of power, and a degree of controllability[3].

Q5 - What risks and opportunities could it pose to local employment and community, and how might any risks be mitigated? In particular, what are the consequences for current ports, fishing and aggregate extraction industries in the estuary?

Local employment and community

28. Many of the towns on either side of the estuary have high unemployment levels and the barrage could offer opportunities for employment in these areas.

29. There are currently minimal opportunities for recreational activities in the estuarine and coastal waters because of strong currents. For example, the Waverly cruises in the summer[4] are often cancelled because of strong currents. With a barrage in place, the tidal currents would be reduced, the waves in the basin much smaller as ocean waves would be precluded by the barrage, and the water clearer, making the estuary much safer for yachting and other recreational activities. This could encourage opportunities for marina developments at towns such as Newport and Weston. The clearer water could also make the waterfront on either side of the estuary more attractive for restaurants and small businesses.

30. The major connection between South Wales and the South West of England could also bring benefits through additional infrastructure links.

Current ports

[3] Vincent de Laleu, Presentation at BHA Annual Conference, Liverpool, 14-15 October 2009, La Rance tidal Power Plant: 40-year operation feedback – lessons learnt, http://www.british-hydro.org/downloads/La%20Rance-BHA-Oct%202009.pdf
[4] Waverley is a paddle steamer, http://www.waverleyexcursions.co.uk/index.htm

31. The main port in the Severn Estuary is Bristol Port which currently operates down to mid tide, with ship movement occurring on average for 12 hours per day. Avonmouth and Portbury are part of Bristol Port and are accessed by locks.

32. The HP scheme would include a large lock in the barrage and a new deep water channel. An analysis would need to be done but it is likely that shipping times would be lengthened, slowing down the turnaround time of ships by about 40 minutes each way. Choosing ebb/flood generation would reduce basin water levels making it likely that the window for accepting large ships would be reduced.

33. This disruption to shipping could be mitigated by constructing deeper entrance locks to the ports and this was considered as part of the previous DECC studies. However, the owners of Bristol Port have expressed great concern at the proposals for development of a barrage and their concerns should be properly investigated. Bristol Port is the largest in South West England and a major UK facility, handling 1.5 million TEUs (twenty-foot [cargo container] equivalent units) per year and has seen investment of over £450 million since its privatisation in 1991. The port supports around 8,000 jobs and outline plans for still greater investment (£600 million) exist[5] to accommodate major forecast growth in containerised traffic.

34. HP proposes to construct the barrage caissons in a new deep water facility near Port Talbot. HP proposes that, after the end of caisson construction, this be converted into a Ultra Large Container Ships port. This could be a good use of such a facility. However, onward transport of containers would need to use the M4 or the Victorian rail tunnel under the Severn. While rail is well-suited to dealing with large, bulk cargos, the increasing size of shipping containers poses challenges. “High Cube” containers (9ft 6 inches tall) are becoming more common and can only be carried in wagons that have a higher weight and lower capacity than standard flatbed wagons[6], meaning that fewer can be carried per train with implications for track capacity and the Severn rail tunnel’s maintenance regime. In the longer term, a route could be provided along the barrage to link with the existing rail and road system. These aspects would need further study.

Q6 - Would the project require support under the proposed new Contracts for Difference mechanism? If so, approximately what level of strike price would be required to make the project economically viable?

35. Undoubtedly the project would need support under the proposed new Contracts for Difference (CfD) mechanism. Presumably, private financing would be conditional on this. There would of course be many complexities associated with negotiating for the CfD but this should be no different from that presently going on for nuclear and, in the future, for abated gas and coal plant. In the case of the Severn barrage there is limited scope, if any, for competitive tendering. However, this is not dissimilar to the situation the government has already encountered with the new nuclear build programme and the CCS competition.

Q9 - Are any other proposals for tidal power projects in the Severn Estuary currently under consideration?

[5] http://www.bristolport.co.uk/home
[6] Network Rail, Freight Utilisation Strategy 2007, http://www.networkrail.co.uk/browse%20documents/rus%20documents/route%20utilisation%20strategies/freight/freight%20rus.pdf

36. Since the DECC feasibility studies, three proposals of different scales have been reported. These are:

- HP's barrage using VLH contra-rotating turbines – the primary subject of the current inquiry (details have not yet been published).
- The considerably smaller Stepping Stones Tidal Lagoon concept (600 MW generating 1.2 TWh/yr) – a hybrid commercial/research proposal located so as not to compromise future development of any other option and inform future development of those options through operating experience (a first step if a more incremental approach was taken).
- A yet smaller option in Swansea Bay promoted by a private company that has recently submitted a scoping report to the Planning Inspectorate (250-350 MW project generating 0.4 TWh/yr).

Q10 - What could be the wider international implications of the scheme for UK engineering and UK low-carbon industry?

37. The development of a Severn barrage would create international interest, with several countries already showing interest in barrage research. It could generate interest in UK engineering, specifically low-carbon energy generation technologies developed in the UK. The turbines proposed by HP are a new development of VLH contra-rotating turbines. As far as we know, this is a unique design and there are no such turbines operating anywhere else in the world. If the scheme went ahead with these turbines and was successful, then they would then be available for other tidal power schemes in the UK and export around the world. Examples of potential large schemes in the UK include the Solway Firth and the Mersey, and potential international schemes include northern Russia, and India. There could be export opportunities if turbines were developed that demonstrate significantly improved performance. In addition, the UK has the potential to develop low or carbon neutral material solutions, for example low carbon concrete. Successful development of the Severn could lead to other schemes being built using UK-based low-carbon engineering and technology.

38. The UK is also well placed to export engineering and project development and delivery advisory services. The Olympics demonstrated the UK ability to deliver massive infrastructure projects. This would be further demonstrated by the barrage and transferable to other areas. While tidal barrage schemes for energy are limited internationally, coastal flood protection schemes will be in demand around the world with sea level rise. This would be a major business opportunity.

39. Opportunities for the UK need not only be in the construction and technology aspects. As with other low carbon technologies, a Severn barrage is only feasible with an appropriate and sustainable policy regime. The UK government is currently grappling with a pioneering Electricity Market Reform to enable a balanced and secure low carbon generation portfolio at modest cost to consumers. If it succeeds, then there may also be potential for the UK to export its policy expertise. Whilst this might be difficult to commercialise, the growing body of knowledge on designing, financing, constructing and operating a complex system of less dispatchable, low carbon generation sources may provide more commercial potential. Proven expertise on redeveloping transmission networks, managing different forms of intermittency, incentivising and managing investment in back-up (especially fossil fuels), and perhaps even integration of demand-side measures such as a smarter grid and

appliances and increasingly electrified heat and transport may be attractive to overseas investors.

Annex

Additional input: Transmission requirements

Although outside the scope of the questions, the IET believes that it would be useful for the Select Committee to have an understanding of the transmission requirements of a barrage and its impact on costs and public opinion.

The grid can cope technically with so much electricity going into it but as new power stations are built in different areas, new lines and upgrades to existing parts of the grid will be required.

The capital costs of any transmission connection or reinforcement works undertaken by National Grid would normally be borne by National Grid. The grid costs would therefore not be included in the capital cost of the tidal generation project. National Grid would make the investments, build and commission the assets, and then recover the allowed remuneration in accordance with the regulatory arrangements, via the locational transmission tariffs. These tariffs are paid by the owners of new generators once they commence operation. Although the grid costs are not borne by the generation developer, the developer is liable for these costs if the project is cancelled and the costs and investments become redundant and stranded. To cover this liability, a generation development is required to provide the appropriate financial securities, which will increase over the construction programme.

National Grid was asked in 2010 to consider how the DECC scheme could be connected to the grid and whether this would require any new infrastructure or uprating of existing infrastructure.

The study by National Grid[7] concluded that for a Cardiff-Weston barrage the optimum solution was for an equal amount of power (4.32 GW) to be taken off on the English and Welsh sides. It identified three options – one with no transmission cables across the barrage and two with cables (one AC and one DC). All have similar costs of between £2.25 billion and £2.35 billion, though the option with no cable across the barrage could take at least three years longer to complete because that option may need a 125 km new overhead line to the south coast.

The study found that in principle it should be possible to accommodate this level of tidal generation and gave indicative costs for the works necessary. However, there were concerns over both system stability and electrical inertia that would require further detailed study and might require significant further investment to resolve. These also assumed greater levels of international interconnection and use of smart technology to manage demand and power flows.

[7] Non-technical summary:
http://www.decc.gov.uk/assets/decc/what%20we%20do/uk%20energy%20supply/energy%20mix/renewable%20energy/severn-tp/662-grid-study-nontechnical-summary.pdf
The full National Grid technical report:
http://www.decc.gov.uk/assets/decc/what%20we%20do/uk%20energy%20supply/energy%20mix/renewable%20energy/severn-tp/663-stp-grid-study-technical-report.pdf