Tidal Energy and the Severn Barrage

Generative Energy Discourses

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Abstract

The aim of this paper is to critically review and question the current discourses on the Severn Barrage, Wales UK. The research highlights the generative energy mechanism of the project and questions the key objections with regard to the Barrage and other tidal-energy based projects specifications put forward for the Severn Estuary. The paper is divided into three main sections: the first attempts to review the Severn Barrage concept as potential generative tidal power solution within its historical context, the second section hopes to situate the above projects within the accompanying theoretical frameworks and the final section then hopes to locates elements within these theoretical constructs that have clearly been misread and possible direction out of this gridlock. This last section will also consider the lessons one can learn from the Rance tidal dam (1966) in Brittany, France, the first and for almost 50 years the only one of its dimension. In conclusion the paper argues that the misreading of both the Estuary's physiology and its potential conservation/preservation needs to be urgently addressed along with its inevitable incision for survival.

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1. Introduction

One major characteristics of renewable energies is that they are linked to a territory. You can extract oil, coal, and so on, somewhere, transport it, and harness that energy source anywhere else, but not so with sun, wind, or tides. Tidal energy requires very particular geo-morphological and tidal conditions. Paradoxically, those "clean" energies have an obvious impact on the ecosystems they require and may alarm environmentalists. They question our relationship to "nature" (supposedly untouched and untouchable). While it is reasonable not to completely destroy ecosystems, we can discuss conservationist attitudes which reject any change, as if nature itself was not constantly changing. If we accept changes, we can imagine sustainable and integrated planning. The unavoidable link of tidal energy to a territory can become an asset in a renewed conscience of inhabitants regarding energy.

Fig. 1 The Severn Barrage proposal 2010 as presented by Hafren Power.

We would like to argue that the very definition of architectural and urban design sensibility has made a slight shift in order to integrate the current discourses on ecological and sustainable design studies. To our understanding, the term 'sustainable' now intricately connects architecture and urban design studies to environmental study – both at a conceptual and structural level. This paper is an attempt to succinctly put forward the main discourses, perception and at times misconception of the factors involved in harnessing tidal energy from the Severn Estuary, Wales and further attempts a brief comparison with the Rance Barrage in France.

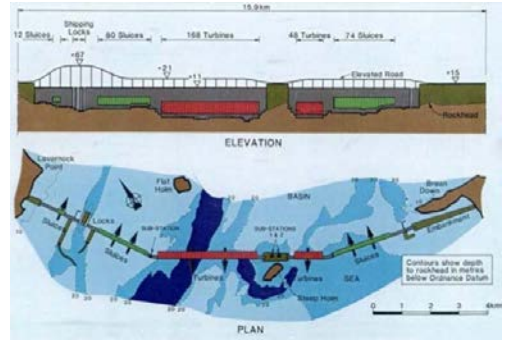


Fig. 2 Western Barrage proposal 1980 as presented by Severn Tidal Power Group (STPG)

2. Historical Context

On 10 September 2013 the House of Commons, Energy and Climate Change Committee, published a report entitled: *A Severn Barrage?: Government response to the committee's second report of the session 2013-2014: Fourth special report of session 2013-14*. The principal objection and concerns put forward in this report included, ''the lack of substantial

evidence to credibly demonstrate; value for money, economic benefits, energy saving and environmental impact mitigation''. [1] It is interesting to note that five years earlier on 22nd May 2008, at the Royal Academy of Engineering 2008 symposium on the Severn Barrage, the then Minister of State for Energy Mr. Malcolm Wicks MP, in his keynote lecture, had identified almost similar factors with regard to the 1980 proposed Severn Barrage scheme. According to the Minister, the proposed study had been categorized into six main areas of further research:

1. Environmental work, gathering the evidence of the impacts on biodiversity and wildlife, land and seascapes, flood management and geomorphology. …we are looking at the geomorphology and we are looking at water quality and considering compensatory habitat issues. That is a very important feature of our environmental work. We will be looking at the issue of compensation and suggested – whether there is an environmental opportunity in linking environmental compensation measures to climate adaptation. 2. The second stream of work is about engineering and technical aspects, considering issues such as the cost, design and construction of the proposed tidal power schemes and their potential impacts on the electricity network. 3. The third stream of work is about economics, considering how a project or scheme could be financed, and looking at ownership options. We will be looking at the full range of possibilities, including the need for any government support and we have appointed PricewaterhouseCoopers to provide advice on those issues. 4. Fourth, there are the regional impacts, looking at the regional, social and economic impacts, including the impacts and benefits on local business. 5. The fifth stream of work is about planning and considering regulatory compliance issues, although this will come later in the process. 6. Finally, and very importantly, throughout the project communications work and engagement with interested parties and the public will be key to the successful delivery of our study. [2]

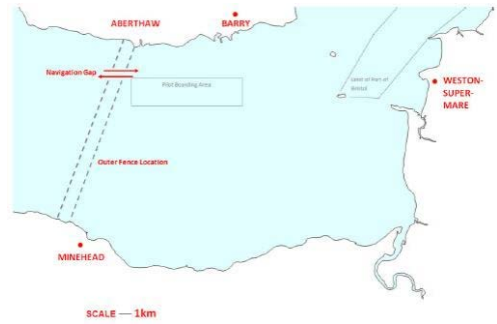


Fig. 3 Severn Tidal Fence 2010 as presented in the Severn Tidal Fence Consortium, Final Report p.11

The study was also to include a strategic environmental assessment, to ensure a detailed understanding of the estuary's environmental resource, recognizing its national, European and indeed international nature conservation significance. Given the above comprehensive list of suggestions provided by the Ministry of Energy, initially in 2008 and later again in the 2013-14 parliamentary report, this section attempts to document and critically review the Severn Barrage schemes along with alternate tidal energy based projects that have continuously been submitted for possible consideration and rejected.

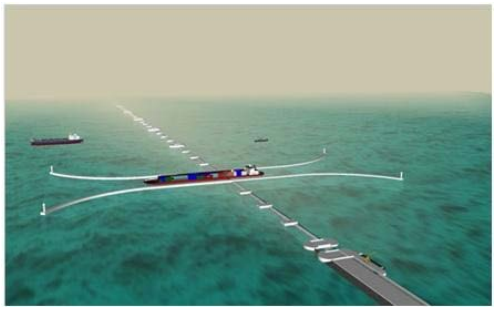


Fig. 4 Severn Tidal Power Reef 2008 as presented by the Rupert Armstrong Evans of Evans Engineering and endorsed by the new Atkins-Rolls Royce report commissioned by DECC (Department of Energy and Climate Change)

The above mentioned Parliamentary Report is directed towards the 2010 Severn Barrage proposal (Fig.1) submitted by Hafren Power, a company established in 2008 as a consortium of companies forming a tidal energy business and involved in engineering and construction to lead the promotion of the Severn Barrage. It is interesting to note that the proposal submitted took into consideration past research and studies on tidal power projects, and clearly suggested that it had based its final design strategy on one that was developed in detail by the Severn Tidal Power Group (STPG) in the late 1980s (Fig. 2). The proposal outlined that; ...whilst other technologies have been considered more recently (such as the tidal fence (Fig.3), the tidal reef (Fig.4)), this proposal is to use tried and tested technology throughout to minimize construction and subsequent operational risks and in order to secure private investment for the development. Coincidentally, this approach will allow greatest flexibility in terms of providing the most economic solution: the balance between the revenues from the tidal power generation and the environmental enhancement measures to be provided in connection with the development. This approach realizes the first part of the proposal which is to provide a sustainable supply of 'green energy'. [3]

Given the above justification provided by the consortium of internationally acclaimed specialists and companies comprising Hafren Power in their proposal presentation, along with the fact that in the May 2008 keynote lecture by the Minister of Energy, Mr. Wicks had also announced the appointment of a consortium led by consulting firm Parsons Brinckerhoff, to manage the strategic environmental assessment [4] – it does seem a bit out of place to be informed that the 2010 Severn Barrage proposal was unable to provide "substantial evidence to credibly demonstrate; value for money, economic benefits, energy saving and environmental impact mitigation". Furthermore given this consortium under Hafren Power was established in 2008 and included specialist academics and companies forming a tidal energy business, it can be assumed that the consortium was aware of the 2008 address given by Mr. Wicks, along with probable access to Parsons Brinkerhoff's research led studies on management of strategic environmental assessment. It does seem extremely unlikely that a team of specialist would not take into account the relevant research and recommendations put forward by Parsons Brinkerhoff along with the six salient factors that the Minister of Energy had very clearly outlined.

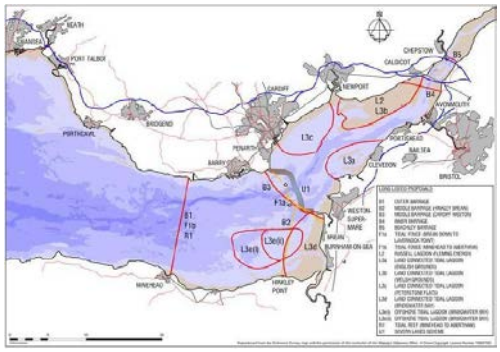


Fig. 5 Long listed STP proposal map (April 2010) as presented in the Welsh Assembly Tidal Energy Report.

It is interesting to note that in its concluding remarks the 2010 Parliamentary report recommends that:
...a more incremental approach using alternative technologies(such as tidal lagoons) may have the potential to provide a lower-risk, lower-impact option than the Hafren Power barrage scheme. Whether these alternatives offer better value for money is far from clear at this stage. Any alternative proposals to the Hafren Power scheme would need to demonstrate the same robust evidence about the costs, environmental and socio-economic impacts which we require for the Hafren Power scheme. We recommend consideration is given to first developing a smaller scale tidal project, in order to build a stronger evidence base for assessing impacts, risks and costs before proceeding with any larger scale scheme. The Government should take this into consideration before approving the development of projects in the Severn estuary. (Paragraph 114) The Government agrees with this approach in principle. A smaller-scale tidal range scheme could in particular provide important information on the operation of the innovative turbines, which Hafren Power proposes to use. It is worth noting, however, that, given the considerable scale of a Cardiff-Weston type barrage and the unique environment of the Severn Estuary, a smaller scale tidal range project would not necessarily provide wider evidence readily comparable to the type of impacts from a larger scheme. Smaller schemes, including tidal lagoons, are still likely to be challenging and to have high capital costs. As set out by the Committee, smaller schemes would also need to demonstrate strong evidence of value formoney, economic benefits, carbon saving and environmental impact mitigation. [1]

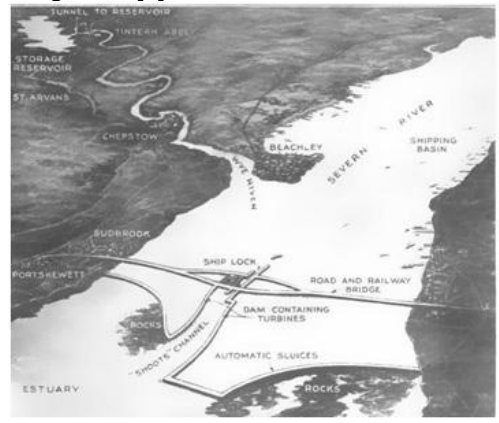


Fig. 6 Woodruff (1921) A diagrammatic aerial view of the Severn River tidal-power project: In the foreground is the 2.5 mile dam with its automatic sluice gates; behind it the shipping basin of 27 miles; in the upper left corner, the big storage reservoir of the secondary plant, 10 miles away on River Wye. In Popular Mechanics, March 1921

This again has already been attempted and a detailed overview was presented

in an April 2010 publication entitled: Severn Estuary Tidal Power by the National Assembly for Wales. The paper provides briefing on the current situation of tidal power development within Severn Estuary (including both lagoons and barrage proposals, Fig. 5). It furthermore provides a Welsh perspective and the views of relevant stakeholders. [5] In its final paragraph the 2010 Parliamentary report suggests that: the Government should continue to examine the energy generating potential of the Severn region in the event of Hafren Power's proposed barrage scheme not going ahead. *We therefore recommend that the Government consider how a more proactive approach to Severn resource management could stimulate growth in the marine renewables industry and drive forward tidal projects in the region.* (Paragraph 116) (10).

Fig. 7 Thomas Fulljame (1849) design for a barrage across the River Severn (Newport Museum of Art Gallery, Gwent)

This in a sense brings the whole concept of Severn Barrage back to its original stance i.e., to the 1921 'potential' Barrage proposal presented by Woodruff (Fig.6) and given the fact that there is also the reservation on the design of turbines and technologies presented in the parliamentary report, the Barrage theme is further relegated to the conceptual sketches of the Barrage as presented by Thomas Fulljames 1849 watercolor rendering. (Fig. 7).

2. Theoretical Constructs

With its swift and high tides and its rocks and treacherous sandbanks the Severn estuary in the late 19th century was both a hazard to navigation and a formidable barrier to cross [6]. It provided both a challenge and an innovative opportunity in the engineering circles. In 1849 Thomas Fulljames (1808–1874) an architect, surveyor and civil engineer, with an in-depth knowledge of the Severn river, its tides, and its shipping, submitted a design of a barrage extending from Aust to Beachley. His design (Fig.7) incorporated a two-tier viaduct, arcaded, castellated, and turreted in the style of the 13th century. The upper level would carry a double-track railway and the lower level a carriage way. The estuary above the barrage would be formed into a lake of consistent depth, thus improving access to the canal at Sharpness, and the water level controlled by sluices in the barrage. [7] Although structurally unfeasible, the project provided theoretical underpinning for future research.

The 1921 Severn Barrage further delved on the Estuary tidal energy potential and highlighted that: ...non-interference with established shipping is a necessary element in the selection of such a site, but entirely aside from this condition, the Severn's mouth is remarkable for its natural fitness for the project. The maximum range of the spring tides at that point is 38ft., and the minimum neap range is 20ft., giving a mean range of 29ft. The width of the estuary, on the line where the Severn tunnel now carries the

tracks of the Great Western Railroad from west England to Wales is about 2.5 miles. In the center is a natural sandstone channel, of ample width and from 60 to 100 ft deep.

This convenient canal is bordered by nearly a square mile broad rocky shelves, exposed at low tide, and the banks on either side are low-lying and fairly flat. Above the tunnel line is a basin which with the tide controlled, would extend over 27 square miles, and accommodate the largest ships... the first work to be undertaken would be the construction of a reinforced-concrete dam on the rocky shelves of the river mouth, its walls extending laterally from each shore as far as the central channel, and then turning upstream along its sides and terminating in a lock, large enough to accommodate any vessel.

In the lateral parts of the wall it is the intention to hang automatic sluice gates, opening inwards when the tide presses against them, and then closing to prevent the escape of impounding water. Built into the parts of the dam paralleling the channel will be the power plant itself, equipped with a huge battery of vertical mixed-flow turbines, 10ft in diameter, the channel serving as their tail race.(Woodruff, 1921)

This proposal although very rudimentary in its detail essentially led to future feasibility studies on the Severn Barrage proposals of the 1980s and 2010.

	Cardiff-Weston	La Rance (1966)	Annapolis (1984)
Length of barrage	16.1 km	0.75 km	0.20 km
Basin area	480 km2	22 km2	N/A
Turbine generators	216 x 40 MW (8,640 MW)	24 x 10 MW (240 MW)	1 x 19.6MW
Runner diameter	9.0m	5.35m	7.6m (Straflo)
Average annual energy	17,000 GWh	540 GWh	<50 GWh
Sluices	166 (35,000 m2)	6 (900 m2)	2 (130 m2)
Ship locks	2No 360x50 m	1	N/A
Construction period	5-10 years	6 years	

Fig. 8 Abidi (2008) Comparison with alternate tidal power schemes.

One of the probable main advances in design strategy of the 1980 and 2010 Severn Barrage proposal as compared to the earlier attempts would have been the technological feasibility. The 2010 proposal quite categorically declared that although there were other options such as the tidal reef and tidal lagoons, but the final choice of Barrage was maintained. This decision may have been partly taken by one of the specialist academic partner in the Hafren group; Prof. Roger Falconer. As according to Prof Falconer's 2008 keynote lecture, the mean tidal range of Swansea Bay lagoon in 8.5m and the energy output is 124MW pa, and in comparison, we would need 135 lagoons to give us the same power as the barrage. [4]. The 1980 Barrage proposal and its further development in the 2010 Severn Barrage proposal remains an ambitious and exceptionally complex yet it seems a practical proposition. According to the Halcrow Severn Barrage Vision report presented in October 2010; ...there are a number of benefits that would accrue from the construction of the barrage and the changed flow regime upstream; because of the general lowering of water levels upstream of the barrage (typically 0.5 to 1.0m during bb generation), the risk of flooding and thus

the need to invest in strengthening flood defences will reduce accordingly. This is apart from the ability of the barrage to manage water levels upstream. The physical, chemical and biological quality of the water upstream of the barrage will change: the suspended sediments carried by the water will reduce resulting in clearer water with the ability to support greater photosynthetic activity and thus increase the biodiversity – birds etc. These changes will also help with pathogen kill and so further help to improve water quality. [3]. This ability to improve water quality has proven to be a vital environmentally positive factor in the Sihwa Power Plant in South Korea (Fig. 9).

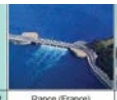
Overview				
Name of Plant	Rance (France)	Annapolis (Canada)	Jiangxia (China)	Sihwa (South Korea)
Spring Tide (m)	13.5	8.7	8.39	9.16
Capacity (MW)	240 (10 × 24 units)	20 (20 × 1 unit)	3.2 (3.2 × 1 unit)	254 (25.4 × 10 units)
Construction Completed	1966	1984	1985	2011
Annual Power Output (Millions of kWh / year)	544	50	6	552.7
Generation Type	Double-effect type	Single-effect type	Double-effect type	Single-effect type (flood generation type)
On-Line since	1967	1984	1986	2011
Sluice Gates	6 units (15m × 10m)	2 units (9.2m × 7.3m)	5 units (3.3m × 4.2m)	8 units (15.3m × 12m)

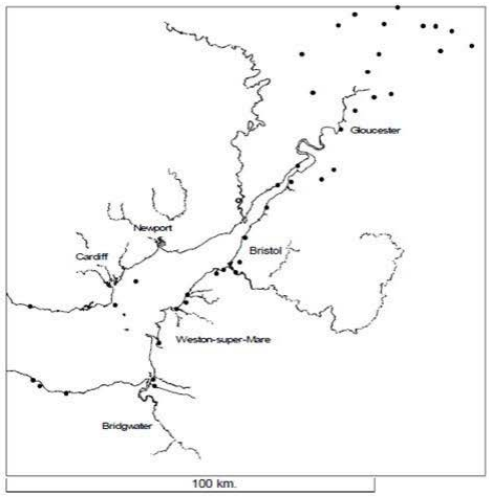
Fig. 9 Sihwa tidal power barrage (2011) details in comparison with other tidal barrages. Source: Korea Water Resource Corporation Report

In comparison to the Sihwa and La Rance Barrage, the proposed Severn Barrage on the sole basis of its gigantic size alone remains an extremely ambitious and expensive project to take on. The proposal presented however highlighted the fact that the project could be delivered without recourse to significant input of public monies. It claimed that the private sector is willing and able to develop, implement and operate the power station with Government support through delivering an appropriate planning route and providing a stable future electricity market with incentives that will shape a sustainable vision for UK.(18) Yet the Parliamentary Report found reasonable doubt to accept this proposition, along with environmental concerns, which seem quite incomprehensible, as it does seem plausible that these aspects were taken into account by the 2010 Severn Barrage proposal. Thus within the theoretical constructs presented with regard to the proposed Severn Barrage, it does seem that there remains a series of inconsistencies and loop holes as far as its subsequent evaluations by the official panels are concerned. This clearly needs to be taken into consideration, should a future Barrage proposal is ever submitted. This paper argues that atleast theoretically speaking the task to set up a Severn Barrage does not seem to be a problem of presenting a feasible design for a very large power generating project with ample technological expertise and environmental considerations intact. It simply remains a case of misunderstood priorities and lack of concise information sharing amongst the various groups and individuals involved. There is also this added dimension of distrust amongst select stakeholders and environmentalist as far as the project implementation is concerned.

3. Misreading

One of the most significant misreading of the Severn Barrage is that it will destroy or ‘trash our own important ecological habitats’’ as Greenpeace argued in support of preserving the ecosystem. According to Dr Parr, some of the most

important habitats of international significance that we have in the UK are the mudflats: the Severn, because of its large tidal range has a lot of mud. It is certainly, true that the wading birds on the Severn have led to the designations of international importance on the Severn.



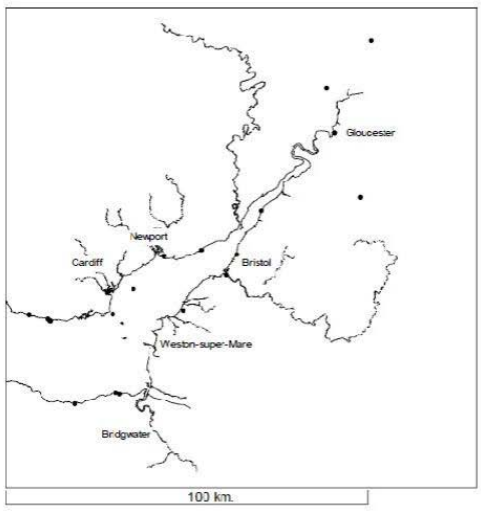


Fig 10a. Locations of some of the larger discharge consents to the Severn Estuary system. Consents for the discharge of sewage, based on Dry Weather Flow (value >1000m3/d). 10b. Locations of some of the larger discharge consents to the Severn Estuary system. Trade consents, and miscellaneous sources of effluents, expressed as Maximum Daily Flows (value >500m3/d). From data supplied by the Environment Agency (Wales South West and Midlands Regent) NB. No distinction has been made between continuous and intermittent discharges.

The above is a valid concern as clearly a shift in the physical foundation of an international habitat so rich in composition would clearly be an unwise and irresponsible option to take on. The exceptionally detailed 2009 report entitled; the Severn Estuary/European Marine Site documents and identifies a range of external factors that are already responsible for a drastic change in the estuary's physical makeup and composition. Factors such as habitat loss due to vegetation succession, dredging and erosion, industrial pollution, changes in water quality resultant from improvements to waste water discharges and changes in recreational disturbance are suggested as priorities in any future Level 2 assessment [8]. However it should be noted that , birds are more frequent and more numerous in place where they are openly protected. If we exchange 10 hectares of wild habitat with birds with 5 hectares of specially designated reservation for birds the population increase. (there is significant increase) There are two well known preserves in Ille et Villaine (careil and sougéal) which may be taken as examples.

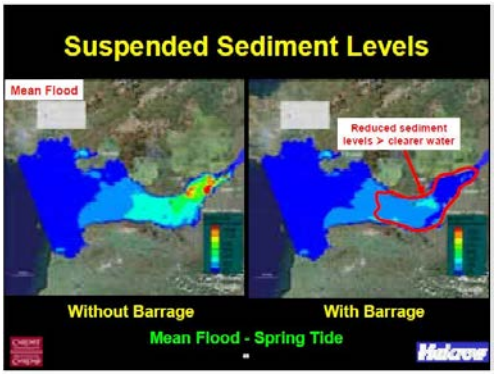


Fig. 11 Falconer (2008) Suspended sediment levels study.

A detailed study conducted on the Rance Barrage provides concrete evidence that most species pass through the turbines without much damage, because of the large size and low speed of the turbines, this is further discussed below. Passageway for the ships is a pure design consideration which we would like to argue can be resolved with alternate design solutions presented and put forward if the project is ever given the chance to move to the level of implementation. The proposed size of the proposed Severn barrage at 16.1km remains the most debated part of the project. Peter kydd (2014) in his review believes that; …Its size also has some other implications. For example, the basin area that a Severn Barrage would impound is much greater than is required for power generation, and it is the basin area that suffers many of the adverse environmental impacts, with loss of habitats and changes to the natural environment. This is one of the reasons why land-connected lagoons outperform barrages in terms of environmental impacts, as the basin area of a lagoon is tuned to its energy output and is therefore smaller for a given power output when compared with a barrage. [9] In an equally compelling argument Falconer (2008) had suggested that a comparative analysis between a proposed lagoon off Swansea Bay as compared to a barrage would mean; The mean tidal range is 8.5m and the energy output is 124 MWh pa and, if we equate like for like, we would need 135 lagoons to give us the same power as the barrage.[4] Irrespective of whether the Severn estuary is given a single large incision in the form of a barrage or several smaller ones as suggested in alternate proposals such as Swansea Bay Tidal Lagoon [10], an 11 km2 impoundment generating 400 GWh/yr which is currently going through the UK planning regime, and the Stepping Stones Tidal Lagoon [11], impounding 18 km2 and generating 1,200 GWh/yr, which is at conceptual design stage. The misreading of both the Estuary's physiology and its potential conservation/preservation needs to be urgently addressed along with its inevitable incision for survival.

4. Rule and the Model: Rance Barrage

The Rance tidal power station was constructed in 1966 and was the world's first tidal station, and for 45 years the largest one in the world. This tidal barrage was not the first project imagined in Brittany, and one could draw a history parallel to that of the Severn barrage, the only difference being that the Rance barrage has become a reality. The Rance Barrage was intended to be an initial step and a principal model that was to assist in the development of a much larger tidal energy project - which would have encompassed the Mont-Saint Michel bay.

Unfortunately this ambitious project was abandoned at the outset, with the result that, in France, after this initial fundamentally successful project was constructed, tidal energy was not further taken into consideration for the next few decades. In comparison, the Severn Estuary has continued to remain a principal source of interest and various proposed tidal energy projects and studies have been reviewed and discussed on paper, with little to no prospect of a clear direction on defining the next step

Fig. 12 Rance Tidal-Power Barrage (François Lang 2014)

Given the concerns discussed above with regard to the Severn Barrage, and the lack of a follow up project in France after the successful construction of the Rance Barrage, was the Rance Barrage such a disaster that the tidal energy fundamentally deserved to be rejected? After almost 50 years the Rance Barrage remains both productive and functional, and will remain to be so for many more decades. It furnishes electricity for the equivalent of a 200000 inhabitants town, such a town as Rennes, for instance, which is not far. It has taken 20 years to account for the construction costs (which was high because it was a prototype), but now it needs only light maintenance and, obviously, its "fuel" (the tidal energy) is free. Its electricity production costs are then now much lower than those of nuclear production costs, without the (geopolitical) problems of uranium extraction and transport, of the possibility of Fukushima like accidents, and the jeopardizing of the future implied by waste disposal and facility decommissioning.

5. Environmental Concerns

There were not much environmental concerns at the time the Rance barrage was constructed, and obviously draining the estuary for two years was a mistake. There were no ecological studies conducted at the time, and we can assume that if such a drastic step was proposed today, it would be strongly questioned and most probably rejected. Having said that, however it should be noted that after almost fifty years later, the appraisal of the consequences of the barrage is not so catastrophic, though some claim the contrary *("L'écosystème estuarien a disparu"* - the esturian ecosystem has vanished. [12], which remains an exaggeration and, one that was addressed in a very comprehensive study carried out in the 1996 by a group of naturalists, who unanimously concluded that: ...In spite of artificial variations of tidal range, very different from natural fluctuations of tide, and although an ideal compromise between energy production and biological needs of marine flora and fauna is hard to achieve, animal and vegetal populations of the ria have found a new equilibrium, and keep a remarkable richness able to give pleasure to any naturalist. [13]. Obviously, the estuarian ecosystem is

different from the one which would have been present if the Rance barrage had not been built, but to determine whether it would have been preserved as is seems both a myth and a misconception given the constant deteriorating condition of the Severn Estuary without any major intervention attempted. There are several factors that intervene and affect the ecosystem within estuaries, and perhaps a comparison with other sites should be attempted for a better understanding of this complex and controversial issue – except that no two sites are exactly alike. One of the main objection put forward is the case of silting. However it should be noted here that the role of the barrage in primarily facilitating silting remains questionable, as it is also a problem in estuaries with no tidal barrage. But to our understanding perhaps what is more important is to question why silting is considered “bad”. It was objectively bad (for business) when relatively large (and economically necessary) boats had to attain ports far inside estuaries. But people have forgotten that at that time there was silting too, and that measures were taken
(dredges) in order to pull out silt and clear channels for navigation. From an ecological point of view, silting remains a natural process, the normal evolution of that type of estuary. Whatever the ecological consequences of the Rance barrage, it remains both an excellent rule and a model for further understanding the merits and complexity of tidal energy generating process and its ecological repercussions. Given the issues and concerns put forward by the studies conducted to support the Severn tidal energy projects, perhaps the most clear indication to study the Rance Barrage is to clarify the many misconceptions present, such as safe fish passage through the Barrage. At the Rance most fish species are able to pass through the turbines with ease, due to the (large) size and (low) speed of those turbines. Detailed studies have been conducted to support this claim. [13-14]

6. Discussion of tidal energy concerning sustainable planning

Our research team on the project “Estuaries and energy of tides” is currently working on this issue. One of the topics of this research is an “integrated” vision of energy harnessing. If we compare ancient tidal mills (very numerous in the Rance estuary), we notice that while silting was increased in their basins, silt was dragged and used as soil-enrichment product. With the barrage, silting was not taken into account by the engineers, and is only viewed as a problem (for navigation, landscape “beauty”, and even the functioning of the barrage) which should be solved by technical solutions. Why not consider the production of silt, and its extraction, as a resource to be used? Another example of this narrow way of thinking is the road on the barrage, which turned out to be a crucial asset and allows to economize oil and time when going from Saint-Malo to Dinard, but was not at first envisaged by engineers who were only thinking in terms of electricity production.

7. Sustainable architecture and urban design and the role of tidal energy

A tidal powerplant, as any structure, has to be conceived, designed and built, and is not only the result of engineering. For instance, the French architect Louis Arretche (1905-1991) the architect whom amongst other realisations was in charge of the reconstruction of Saint-Malo, designed the built structures around the Rance barrage, which are now registered as landmarks of 20th century architecture. That it is not specific to renewable energy. After all, Claude Parent (b. 1923), an influential architect, known for his“fonction oblique” theory and beautiful drawings, also designed nuclear powerplants.

Fig. 13. Beauchet tidal mill in the Rance estuary (François Lang 2014)

8. Generative Design Mechanism

We believe, a tidal energy settlement should be envisaged as a generative design mechanism that defines a territory – one which can contribute to our understanding of architecture as part of a greater whole, and not as some insertion inside a context supposedly untouched. Without being too nostalgic, we want to learn from the past – the tidal mills, and how they were part of the landscape. These buildings (the mill, plus sometimes the miller's house) are apparently very similar to other vernacular architecture used for agriculture, though technically, in order to resist greater constraints, their foundations and the construction of the dyke of the basin required much skill. Why not imagine such settlements for the 21th century, in which housing, working, and energy production (tidal but also from other renewable sources) would be designed intricately with the landscape, where the interaction with the landscape would not be thought only in terms of aesthetics, but essentially functional and sustainable, i.e., organically, in the same way as many of the sites that we now find remarkable in ways that they have been conceived.

Acknowledgements

This paper was a collaborative discourse with Dr Marie-Pascale Corcuff Ecole Nationale Supérieure d’Architecture de Bretagne, Rennes and Prof Herve Regnauld Professeur de Géographie Physique, Université Rennes 2, France. The Authors would like to acknowledge the support of the Interdisciplinary Research Program “*Ignis Mutat Res* Looking at Architecture, the City and the Landscape Through the Prism of Energy”, 3rd session 2013-2015, Ministry of Culture and Communication, Architectural Urban and Landscape Research Bureau, France) for making this research possible.

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