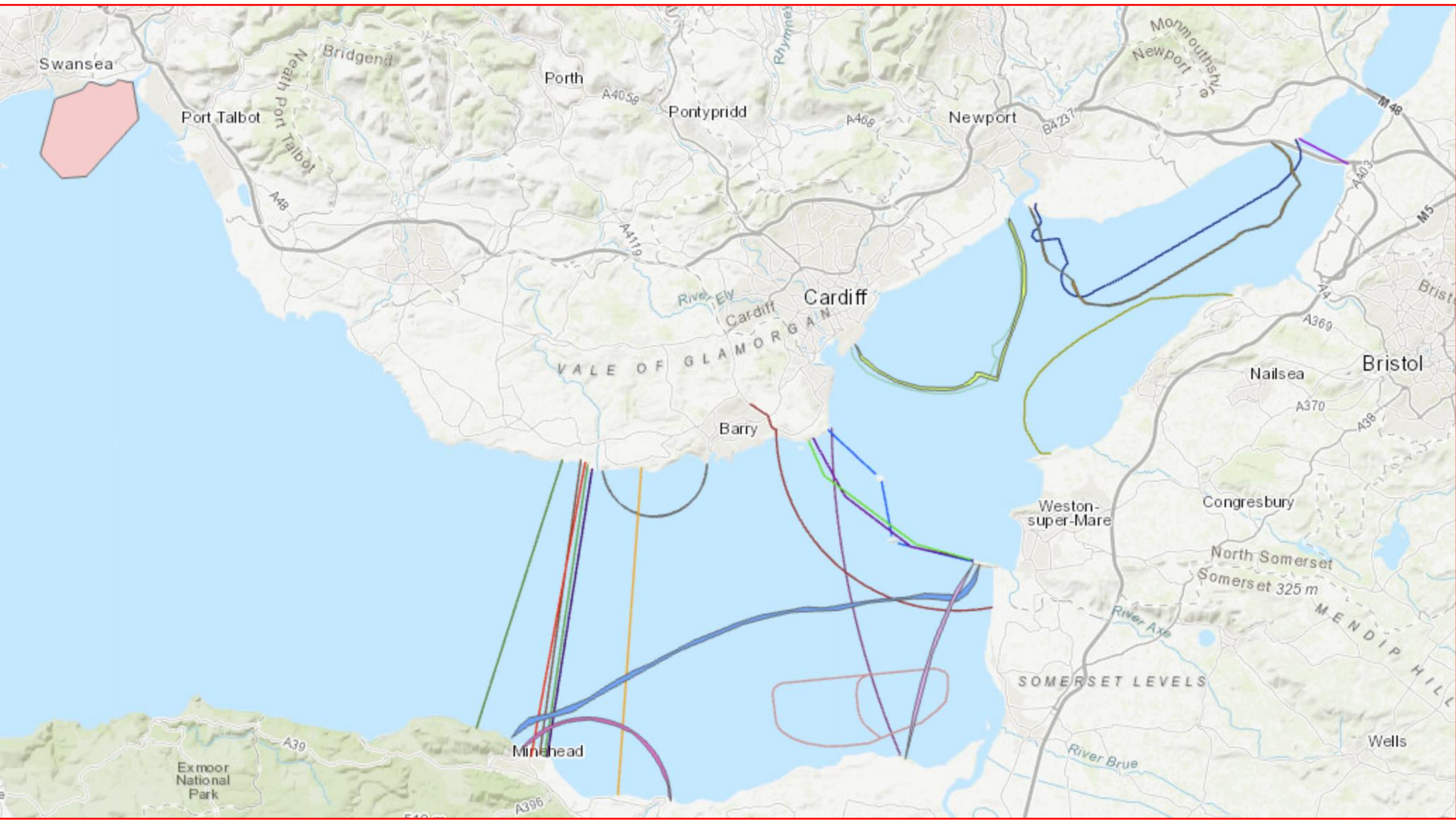
Western Gateway

SUSTAINABLE ENERGY IN THE SEVERN ESTUARY

Evidence Base and Framework



AUGUST 2023

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Evidence Base and Framework

INTERNAL

CONFIDENTIAL

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EXECUTIVE SUMMARY

Scope

This report has been prepared to outline the work undertaken by WSP to consolidate the publicly available evidence of previous tidal power studies and projects in the Severn Estuary, in the UK and internationally. The evidence base itself is available as a separate excel workbook containing the detailed data and analysis, and in an ARCGIS system summarising the data in a spatial context.

Where possible, this report and its associated workbook and GIS data include hyperlinks to external websites giving details of projects and studies as published on the internet. Please note that there is no guarantee that these publicly available websites will continue to be maintained in the future. During the course of preparing this report, Tidal Lagoon Power (TLP) removed their tidal lagoon website and so links to their projects have now been amended to the Hendry Review which studied the TLP programme of lagoons.

This report also provides an over-arching assessment of the evidence base including a 2023 cost of energy assessment and relevant caveats, lessons learned and the changed circumstances of today compared with the conditions pertaining at the time each of the studies and projects was originally undertaken.

The main focus of the report, following on from the evidence base assessment, is to provide guidance to the Independent Commission which is being established by Western Gateway to understand whether there are feasible options for tidal energy from the Severn Estuary. The guidance framework covers a number of themes for the Independent Commission to consider but focuses on existing and potential future policy considerations, stakeholder engagement identification and prioritisation and the changed energy and environmental situation of today. It also looks at lessons learned from previous studies and projects to ensure these are integrated into the framework.

Tidal Power – Current Status

Although developing tidal power from the Severn Estuary has been studied since the 1930's, the most authoritative reports and analyses were undertaken between 2007 and 2010. The Sustainable Development Commission produced a report in 2007 called "Turning the Tide" and studied the potential for tidal power generation in the UK with two sub-reports focusing on the tidal range and tidal stream resource in the Severn Estuary. Black & Veatch produced the Severn Estuary tidal range report and concluded that the Shoots and Cardiff to Weston Barrage proposals (the latter developed by the Severn Tidal Power Group through the 1980's) warranted further study. AEA studied the tidal stream potential of the Severn and concluded *"The deployment of tidal current technologies is not well suited to the Severn Estuary, primarily because of the high tidal range and shallow depth…… the tidal current velocities are too low to make the technology economic especially when compared with other locations around the UK "*.

In 2008, the Government commissioned a multi-departmental assessment of tidal power in the Severn Estuary – the Severn Tidal Power Feasibility Study (STPFS), led by the Department of Energy & Climate Change (DECC). This was a 2 year multi-million pound study that invited proposals from the market to supplement previous projects that had been studied which were then assessed on a level playing field basis before five were shortlisted for more detailed study. The STPFS integrated a full Strategic Environmental Assessment and also examined engineering, social, economic, energy market and cost dynamics.

The STPFS Final Report was published in 2010 and concluded that:

- Three shortlisted options were deemed feasible – the Cardiff to Weston Barrage, the Shoots Barrage and the Bridgwater Bay Lagoon;
- Uncertainties, including the location and scale of inter-tidal compensatory habitats, the data available on fish movement, far field effects from the largest project and behaviours and the economic impact on the Port of Bristol, prevented definitive conclusions;
- Tidal lagoons offered an advantage over barrages in reducing the impact on ports and environment but at a cost premium;
- Embryonic technologies, such as tidal stream, produced less energy and were more expensive, than the tidal range options studied in the Severn.

DECC's Final STPFS Conclusions Report also applied optimism bias in combination with private sector investment rates which is unusual (and may have been because of the uncertainties following the 2008 credit crunch). Normally, optimism bias is applied in conjunction with the Green Book's social discount rate used on publicly managed projects. Consequently, as DECC's Final Report compounded optimism bias with contingency costs and relatively high (10% vs 8%) private sector lending rates, final costs are much higher than they would normally be. The under-lying reports (also published) provide a more conventional assessment of costs.

The newly elected Coalition Government concluded that tidal power did not warrant use of public funds given the costs involved but did say that it would not object if the private sector pursued tidal power projects through their own funding sources.

At the same time, Peel Energy, who had been studying a tidal barrage on the Mersey, concluded that their project was not viable.

In 2013, a private consortium, Hafren Power, submitted a business case to Government for the development of a tidal barrage between Cardiff and Weston-super-Mare using a new tidal range low head turbine, as yet untested. They proposed the use of a hybrid bill to secure consent and an optimistic programme. Their costs were based on the underlying technical reports from the STPFS but their business case effectively used a zero percent discount rate on the grounds of the long project lifespan. A Select Committee Inquiry took evidence in 2013 and concluded that Hafren Power's proposals were unrealistic. The Government response agreed.

In 2014, a private company, Tidal Lagoon Power, backed by private investors and two large infrastructure funds, submitted an application for a Development Consent Order (DCO) for a 320MW tidal lagoon in Swansea Bay. The project had widespread public support with the impounded waters being used for a variety of leisure and sporting activities and the project being seen as a catalyst for regeneration of the Swansea waterfront. It was granted a conditional DCO in 2015 and awarded a series of preferred bidder contracts to value engineer previously submitted bids. At the same time, they submitted proposals for a negotiated Contract for Difference (CfD) to DECC. These faltered due to the relatively high cost per unit of energy. In 2016 the Government commissioned an independent review by former Energy Minister Charles Hendry whose 2017 report concluded that there was a case for developing a tidal lagoon power sector and that Swansea Bay, although expensive, should be seen as a "no-regrets" pathfinder option.

In 2018, the Government concluded that the Swansea Bay project and the subsequent lagoon programme did not offer value for money compared with offshore wind and Hinkley Point C. No CfD was awarded and, when TLP's planning consent lapsed in 2020, they had not received either a Marine Licence nor a Crown

Estate lease. TLP went to the High Court to challenge the lapsing of planning consent but lost. TLP entered into a Voluntary Arrangement with its creditors and released its employees.

Swansea Council had been taking an active interest and started to promote the Dragon Island concept in 2018 of floating real estate in the lagoon to enhance its value. This then transitioned to the Blue Eden project which is using a similar location, but different design to TLP's tidal lagoon as a basis for battery, solar and other low carbon technologies, promoted by DST Innovations.

In 2020, the Welsh Government undertook soft market testing of its Tidal Lagoon Challenge and in 2023, launched a £750k research programme covering a number of potential tidal power research areas.

Each year the Future Energy Scenarios team at National Grid publish their forecasts for future energy generation to achieve net zero by 2050. In both their 2022 and 2023 scenarios, up to 8GW of marine power is included in the final decade before 2050, including a tidal lagoon in all but one of the four scenarios considered.

What has Changed?

With so many projects studied but none implemented in the Severn Estuary, what has changed to justify taking a fresh look at tidal power in the Western Gateway region?

Changes include:

- Increased urgency in achieving net zero to mitigate the effects of climate change – primarily excessive heat and the impact on human health, increased flooding and droughts, and sea level rise;
- The opportunity to create a large number of jobs and support economic growth,
- Instability of world energy markets arising from an imbalance of supply and demand, exacerbated by the war in Ukraine and also the need to increase electricity demand in order to decarbonise the heat and transport sectors;
- Need for long term security of cost as well as security of supply, affordability and low carbon generation;
- Of the 26 years remaining to 2050, a significant proportion of the UK wind turbine fleet will require re-powering, solar panels replaced and electricity transmission and distribution grids upgraded. As it typically takes ten years to consent new projects and, in some cases, nearly as long to build them,

there is an urgency for a fresh review of tidal power policy to capitalise on existing knowledge and increase relevant workplace / supply chain skills (in addition to those required for nuclear / hydrogen / wind / solar projects).

- Large infrastructure projects have always been challenging to finance but new financing models such as Regulated Asset Base (RAB) have been applied to single infrastructure projects over the past decade, notably the Thames Tideway Tunnel. Tidal power would benefit from a similar review of financing methods and assessing what mechanism would be most appropriate.
- Independent Reviews, including the Hendry Review on tidal lagoons in 2017 and the 2023 MISSION ZERO - Independent Review of Net Zero (publishing.service.gov.uk) by Chris Skidmore MP have identified the strengths the UK has in tidal power with the latter concluding "For tidal range projects, one of the main barriers is the high upfront building costs, with suggestions that the sector would need similar deals as provided to the nuclear industry to become cost-competitive."
- National Grid's Future Energy Scenarios, published annually, have also included between 1GW and 8GW of tidal power in the forecasts to 2050 in their most recent (2023) forecast.

Potential Areas of Future Focus

Previous studies have, by the nature of their terms of reference, concentrated on a conventional approach to financing and operating tidal power. However, whilst low carbon support mechanisms such as the CfD and the capacity mechanism benefit existing technologies, they are not optimal for tidal range power generation. Tidal range projects can be operated both as low carbon generators and as capacity and grid support generators. Integration of tidal power into the Severn Estuary energy system should therefore be an area of focus.

Tidal range projects have a high capital cost so alternative financing methodologies are an area of future focus as is consideration of how future inflation could benefit future generations in reducing real costs and providing long term security of cost.

The environmental challenges are significant but most previous studies have tended to focus on an engineering solution initially and then test its impact on the environment. Taking a more nature centric focus from the outset could prove beneficial to the development of a tidal power project in the Severn estuary.

Although the SDC Turning the Tide Report and the STPFS confirmed that the Severn Estuary isn't the best location for tidal stream technologies, there are lessons to be learned from the tidal stream sector in terms of promoting tidal power to Government. The current Government view of tidal range power development has been coloured with failed projects whilst the tidal stream sector has received two pots of £20m and £10m respectively to ring fence the tidal stream allocations at the CfD auctions. An area of focus is therefore to improve the reputation of tidal range in Government.

This report includes a summary of lessons learned and identifies uncertainties that have arisen from previous work. DECC's Final STPFS suite of technical reports published in 2010 provides a substantial evidence base that continues to form the baseline for technical evidence. An important first step will be to use this as the foundation for any future work and engage with the relevant stakeholders at an early stage to use their understanding of where the evidence gaps and uncertainties exist, and how they would resolve them, to inform the Independent Commission's future work programme.

Further areas of focus should be on spatial planning considerations for the estuary as a whole in terms of the best use of the estuary for generating sustainable energy. This will include environmental considerations, the effect of tidal barrages and lagoons on the Severn's commercial ports, consequential changes in land drainage and flooding (including future sea level rise) and cumulative development effects including the potential blighting effects of one project on subsequent projects (for example, building an upstream barrage at the Shoots channel would effectively reduce the business case for any subsequent downstream barrage).

Finally, the Welsh Government has launched the Tidal Lagoon Challenge and this offers an opportunity to collaborate and understand outcomes from the different research projects that will be awarded funding.

BACKGROUND

Introduction

WSP was appointed by Western Gateway to undertake an evidence based systematic review of national policy relevant to tidal energy and an assessment of tidal energy schemes in the Severn Estuary and the Bristol Channel. In addition, other tidal energy projects elsewhere in the UK and internationally were reviewed so that a comprehensive assessment could be made of lessons learned. The outputs from this are presented in a GIS spatial database. A stakeholder identification and prioritisation exercise has also been undertaken. Collectively, these outputs have then informed the development of a framework that identifies the necessary considerations for implementing tidal energy projects within the Western Gateway zone of influence to assist Western Gateway's Independent Commission in their role to oversee opportunities for feasible options for sustainable energy from the Severn Estuary.

WSP has an extensive track record in tidal power engineering having worked with the UK and Welsh Governments and The Crown Estate, local authorities and tidal power developers since the original Severn Tidal Power Group (STPG) proposals of the 1980's.

The Severn Estuary

Geography

The Severn Estuary is generally described as the area of the Bristol Channel upstream of a line from Sand Point near Weston-super-Mare and Lavernock Point west of Cardiff (shown as a dotted line in Figure 1 below). This is the area used by the International Hydrographic Organization (IHO) and the Severn Estuary Partnership. However, the Severn Tidal Power Feasibility Study (STPFS) considers a wider area, upstream of a line from Worm's Head on the Gower Peninsula to Minehead (shown as a solid line in Figure 1). It is the latter area that is used in this report.

The Severn Estuary has, at Avonmouth, the third highest tidal range in the World (only the Bay of Fundy and Ungava Bay, both in Canada have higher) and its tidal power potential has been studied since the 1930's. The estuary's shape is the main reason why the tidal range is so high with the estuary progressively narrowing eastward of a line between Aberthaw and Minehead. The tidal range increases rapidly from around 10.5m at mean high spring tides at Aberthaw to 14.4m at Avonmouth. Westwards of this line, the tidal range reduces to 8.6m at Swansea Bay and continues to reduce along the rest of the southern and western coastline of Wales, this reduction also being reflected on the English coastline west of Minehead.

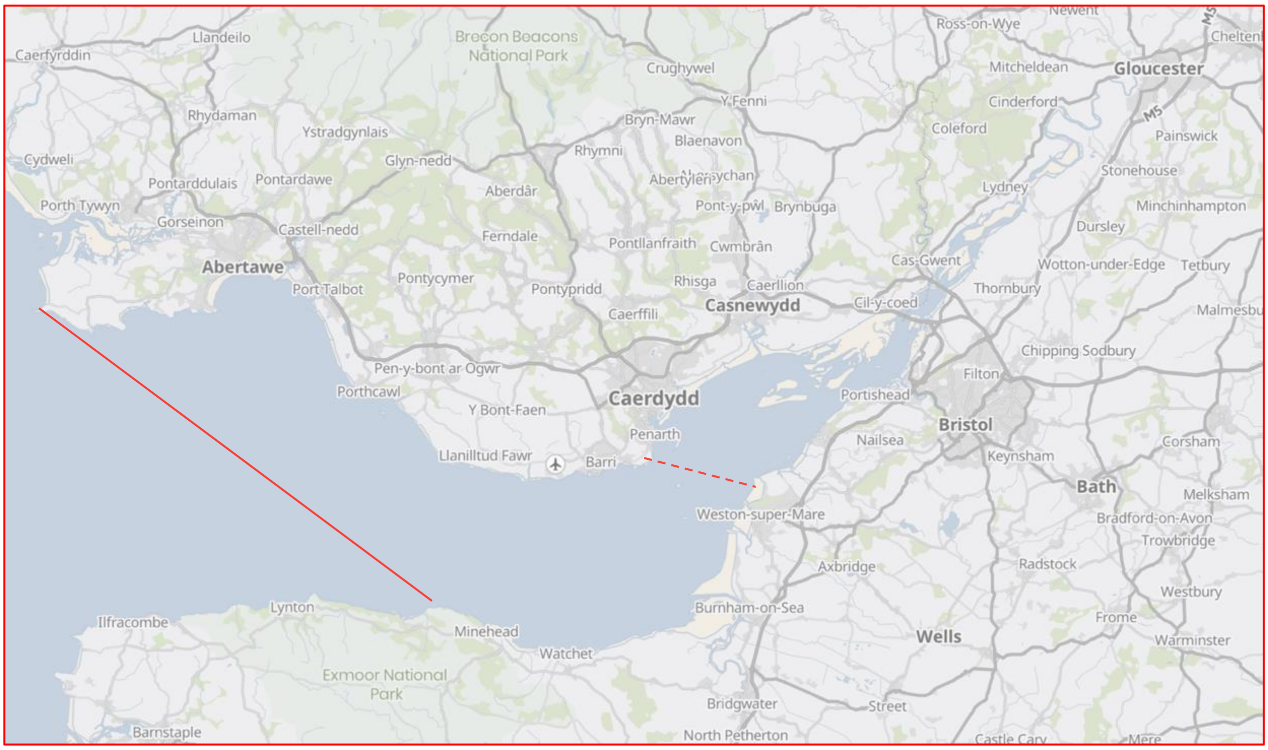


Figure 1 The Severn Estuary and Bristol Channel

The Severn Estuary hosts a number of large population centres including Bristol/West of England, Gloucester, Newport/Cardiff and Swansea. There are two major road crossings upstream of Avonmouth taking the M4 and M48 motorways into Wales whilst the Great Western mainline crosses the estuary in tunnel close to the M48 bridge. Pedestrians and cyclists can also use the 2mile long M48 bridge to cross the Severn and Wye. There are no further crossings until the city of Gloucester. The tidal limit is just to the south of the City of Gloucester.

The environment in and around the estuary is of international importance whilst the estuary also supports fishing, aggregate extraction, shipping businesses and attracts tourists and recreational users.

Commercial Shipping

The estuary is also a major commercial shipping route with Ports at Swansea, Barry, Cardiff, Newport, Sharpness and the two large Bristol Port Company facilities at Avonmouth and Portbury. Significantly smaller facilities also exist at Lydney and Bridgwater. The ports are a significant economic resource and centres of employment and concerns over the potential impact a tidal barrage could have on the larger ports has been highlighted as a concern in previous studies. Bristol, in particular, hosts a number of very large vessels that can only access the port on spring tides. The Bristol Port Company objected to the Cardiff – Weston Barrage during the STPFS study and subsequently for two reasons. Firstly the changes in upstream water levels would require their existing locks to be modified requiring partial closure of the port (and subsequent loss of trade and jobs) and secondly, because shipping would have to transit a new set of locks on the Barrage potentially resulting in the loss of container traffic to the port (container ships choose to dock at deep water berths to minimise turn-round times). Connected with this, the Bristol Port Company have planning consent to develop a new deep water port although this has not yet been built for commercial reasons. Consequently, a barrage between Cardiff and Weston would appear to be a challenging proposition. It would also impact Newport and Cardiff Docks. However, the Shoots Barrage, located by the Prince of Wales Bridge, has fewer constraints.

Environment

The Severn Estuary is of international, European and national nature conservation significance. Upstream from a line between Lavernock Point and Hinkley Point line the estuary has a number of environmental protection designations including the European Special Area of Conservation (SAC) and Special Protection Area (SPA), and the international Ramsar wetland designation. Parts of the estuary have also been designated a Site of Special Scientific Interest (SSSI). The SSSI includes most of the foreshore upstream from Cardiff and Brean Down and most of the upper estuary as far as Sharpness.

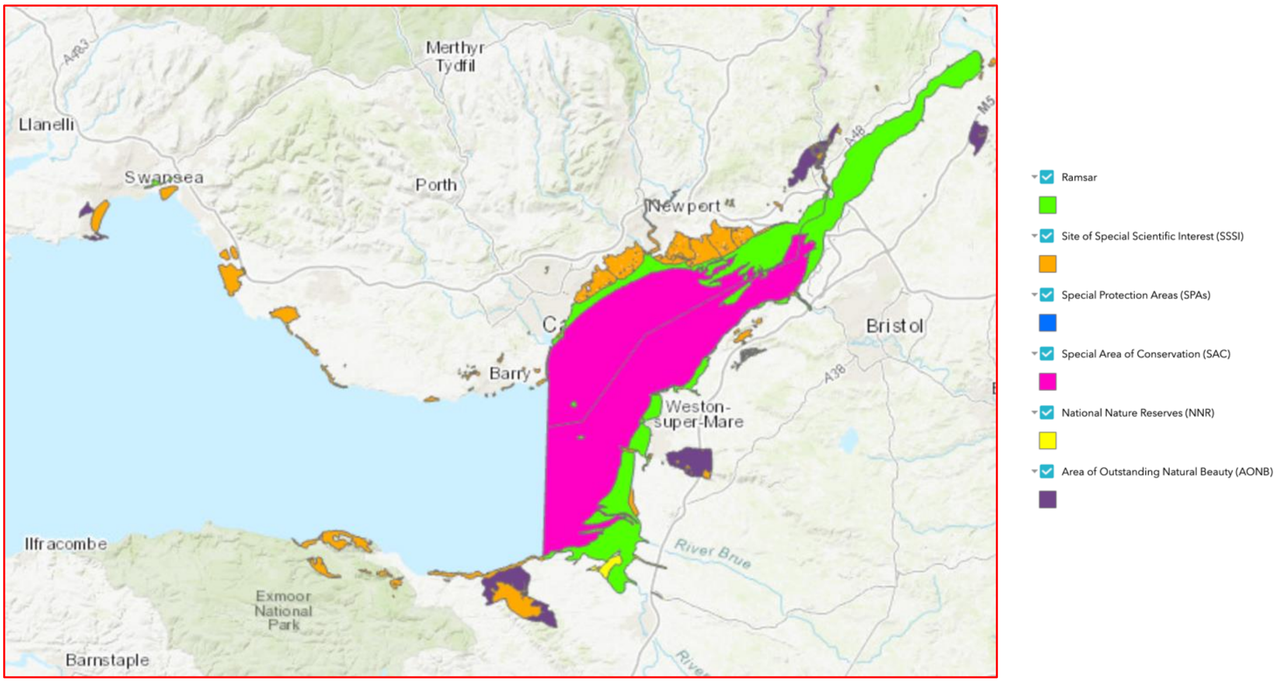


Figure 2 The Severn Estuary Environmental Designations

The Rivers Wye and Usk, which flow into the Severn estuary, are also designated as SACs. Together, they represent around 1.3% of all the UK's designated SAC habitat. These rivers provide important spawning habitats for species of migratory fish, including five species protected under the Habitats Directive (allis and twaite shad, sea and river lamprey and Atlantic salmon) which travel up the Severn estuary on the way to these spawning grounds. At least six waterbird species occur in internationally important numbers (ringed plover, curlew, dunlin, pintail, redshank and shelduck), and are protected as part of the SPA and Ramsar site designations. The overall waterbird assemblage using the Severn estuary during winter has been calculated to be approximately 73,000 birds and is one of the most important wintering grounds for dunlin, Bewick's swans and European white-fronted geese.

The estuary also contains Scheduled Ancient Monuments (SAMs) and Areas of Outstanding Natural Beauty (AONBs). A Severn tidal power scheme would impact significantly on natural and historic conservation sites both upstream and downstream of any scheme. The landscape and seascape of the Severn estuary would be significantly altered with the addition of a scheme.

The Strategic Environmental Assessment (SEA) undertaken as part of the STPFS in 2010 set out what the estuary might look like in the future. It is already being affected by climate change – by 2000 water levels in the region had already increased by between 2.5 and 3.5cm from 1990 levels. By 2050, the SEA predicted that water levels could be around 20-30cm higher than in 1990, and by 2095 (when a tidal scheme if built would still be generating) they could have increased by between 50-90cm. In addition, water temperatures were also predicted to rise by almost 4°C by 2140 and salinity could increase as fresh water flowing into the River Severn from snow melt and rainfall is predicted to decline.

The SEA highlighted that the estuary is gradually changing because of climate change and this created some uncertainty as to how the Severn Estuary, its rivers and those species that occur there respond to long term effects from climate change. The SEA provided some examples of changes with some migratory birds already remaining on the east coast of Britain in response to warmer winters. It concluded that whilst the species which use the Severn estuary may change it will remain an important site for wintering and passage birds and, at times of severe weather, for birds currently wintering further east.

Flood risk and land drainage

The tidal floodplain of the Severn Estuary is currently protected from flooding by extensive tidal defences on both banks. These protect existing property, infrastructure and agricultural land. Some 90,000 properties and commercial assets are at risk of flooding in over 500 km2 of low-lying tidal floodplains of the Severn estuary (approximately 35,000 properties in Wales and 54,000 properties in England) with high concentrations in the urban centres of Cardiff, Newport, Burnham on Sea and Weston-super-Mare.

For tidal power projects, the water levels in the impounding basin are held back before generating electricity, meaning that mean high water levels will rise and land may take longer to drain in the event of rain and high tides. This, as well as the potential for faster erosion of existing defences, could increase fluvial flood risk but could be mitigated through measures to upgrade land drainage systems and improve flood defences. Land upstream of impounding basins would benefit from a lower risk of tidal storm surges as the highest tides would be reduced. For some projects, primarily the Cardiff to Weston Barrage, the STPFS and subsequent studies have identified that a reflective wave may be generated temporarily increasing water levels downstream by up to 10cm.

Water Quality and Geology

The STPFS found that a tidal power scheme in the Severn would produce clearer, calmer waters but noted that the extreme tidal nature of the Severn estuary would be much reduced, meaning some habitats

including saltmarsh and mudflat would be reduced in area, potentially reducing bird populations.

The estuary is characterised by a large amount of retained sediment that moves up and down the estuary with the tides. Sediment concentrations increase as the tides move upstream. Fine sediments are retained in the upper part of the water column. Sedimentation is likely to have an adverse impact on tidal power projects located upstream in the inner estuary and / or for projects with smaller or shallower impounding basins.

From a geological perspective, the estuary is characterised by Triassic sandstone and mudstone overlain by marine deposits of mud, sand and gravel. The geology varies throughout the estuary with up to 20m of mobile sand at the surface between Newport and the Prince of Wales Bridge whilst under the bridge itself is exposed rock. Further downstream, the estuary is characterised by marine deposits overlaying rock with exposed rock on the Welsh coastline between Aberthaw and Barry.

Power Generation

In power generation terms, the estuary is home to a number of power stations including decommissioned nuclear sites at Oldbury, Berkely and Hinkley Point, decommissioned coal at Aberthaw and Usk, biomass plant at Usk and combined cycle gas turbines Seabank. A new nuclear station is being constructed at Hinkley Point with a new transmission line from there to Seabank. Onshore wind generation is also evident with a number of wind turbines in the Avonmouth area, including the largest in England. A tidal stream device, not connected to the grid, was trialled at Lynton in 2003 as a for-runner to the Strangford Lough 1.2MW turbine in Norther Ireland. Previous studies have concluded that the Severn Estuary's tidal stream resource is relatively weak, primarily because of weak currents, the high tidal range limiting the depth available for tidal stream devices and the co-incidence of deeper water with commercial shipping routes. The tidal stream market has preferred to consider more favourable tidal stream sites in the Orkneys, Northern Ireland, Anglesey, Pembrokeshire and the Channel Islands. The tidal range resource is significant but requires the financing of large infrastructure and appropriate environmental mitigation and compensation to deliver. The market has attempted to deliver a tidal range project, most recently with the tidal lagoon in Swansea Bay but without success to date.

Energy Context

Today's energy environment is different since the last major study on the Severn was undertaken between 2008 and 2010. The challenges of delivering secure low carbon energy at reasonable cost have been exacerbated by the impact of the war in Ukraine. Although the scale of increase in electricity generation required to deliver net zero by 2050 has been known for some time, the Climate Change Committee (CCC) and National Grid Future Energy Scenarios (NG FES) have produced formal forecasts which are similar with the NG FES specifically referencing the need for tidal power in both their 2022 and 2023 reports. However, there is limited support from Government for tidal power relative to other low carbon technologies.

The different tidal power technologies are explained in more detail below. The most recent technology, tidal stream, has benefitted from ring fencing allocations of £20m and £10m for the fourth and fifth round CfD auctions respectively. Unfortunately, the tidal stream resource in the Severn Estuary is relatively poor by comparison with other locations in the UK and the reduction in Government support, halving the ring fenced allocation, will make the development of tidal stream projects in other parts of the UK more challenging in future.

Previous studies have identified the Severn Estuary as having the greatest potential for tidal range power generation in the UK but there is no specific Government policy on this, other than a checklist produced in a consultation response but omitted from specific policy documents. This is in contrast to the widely held views of the tidal power sector that there is now a greater recognition, compared with previous Government positions, of the long term benefits of tidal range power projects, including its ability to deliver long term security of cost and hedging inflation risk. The Regulated Asset Base (RAB) model has been demonstrated as an effective method to finance large scale infrastructure projects such as Sizewell C nuclear power station and the Thames Tideway Tunnel. Independent reviews such as that undertaken by the former Energy Minister Charles Hendry in 2016 have recognised that a similar model may be appropriate for the development of large scale power generation infrastructure in the Severn Estuary.

Given that even a small tidal power project is a large infrastructure project that takes at least ten years from conception to operation, the current lack of in-depth policy support is acting as a constraint on tidal power development, particularly from the investment community and project developers with the financial standing required to undertake a billion pound plus construction project. However, this provides an opportunity for Western Gateway working with other public sector organisations such as the Liverpool City Region Combined Authority, and the Welsh Government to influence future policy direction and demonstrate how tidal power can be delivered in collaboration with stakeholders and the environment, supported by the CCC and NG FES forecasts.

Tidal Power Definitions

There are two principle types of tidal power technology:

i) Tidal Range

ii) Tidal Stream

There are also a number of hybrid options, mainly based on tidal stream principles. Wave energy is a further marine energy technology but generating power derived from the waves rather than the tidal range or tidal currents.

Tidal Range

Tidal Range technology is based on a high tide filling a basin created by an impounding structure and then releasing the water through turbines a few hours later when the tide has receded.

The impounding structure can take three forms:

i) A barrage connecting two points on opposite banks of an estuary (for example the Severn Barrage that was previously proposed between Lavernock Point and Brean Down);

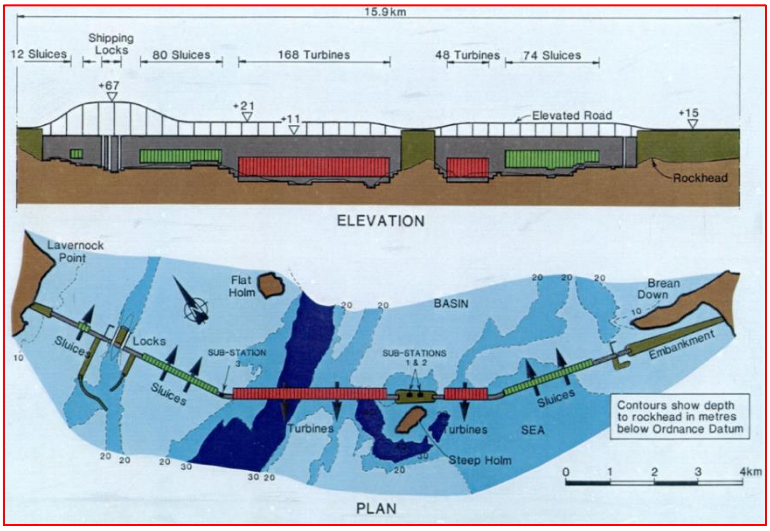


Figure 3: Cardiff to Weston Elevation and Plan imagery from STPG.

ii) A lagoon connecting two points on the same shoreline but projecting out to sea (for example the Swansea Bay Tidal Lagoon or the Stepping Stones Lagoon shown below in Figure 4).

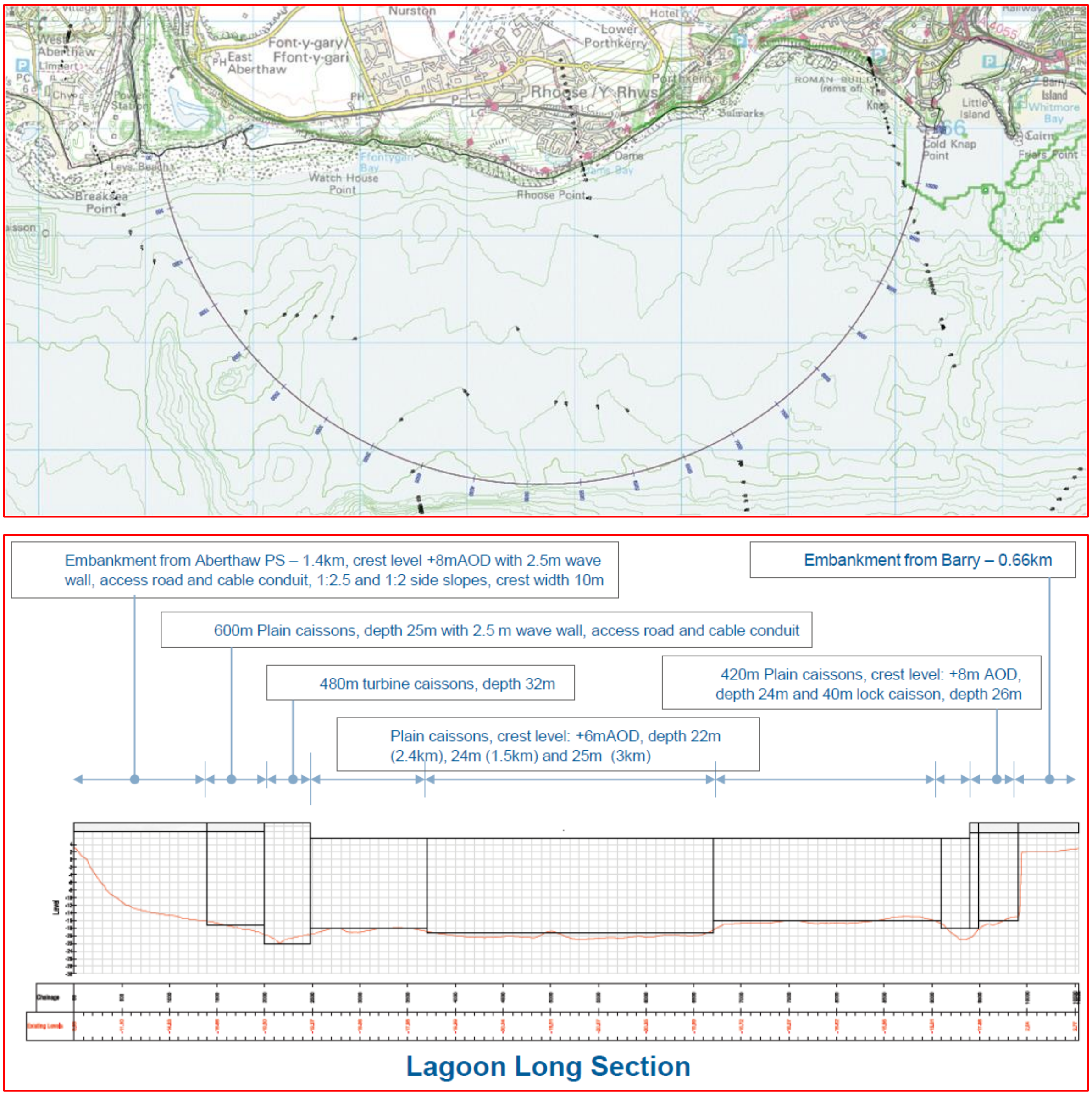


Figure 4: Stepping Stones Tidal Lagoon Plan and Elevation.

iii) A lagoon located entirely offshore to form a continuous structure located in the sea (for example Ecotricity proposed the concept of an offshore lagoon as an alternative to the Swansea Bay Tidal Lagoon). Compared with a land connected lagoon, this has the advantage that there is little or no loss of inter-tidal habitat (because the natural coastline tidal regime is unchanged) but does require a greater and potentially deeper length of marine wall for the same impounded volume thereby increasing costs.

Figure 5: Offshore Lagoon imagery from Ecotricity

Tidal Range technology operates in the same way as a hydro-electric plant and requires a minimum depth of water of more than 6m to be economically feasible although turbines can operate, with some loss of efficiency, on differences in water level of 1m. The power produced is a function of the head, gravity and the flow. Efficiencies are 90% or more.

Tidal Range has two potential operating modes:

Ebb only: The turbines are designed to operate in one direction only with the flood (inflow) tide passing through sluices before being held as the tide ebbs and then generating on the ebb tide when the difference in water level is sufficient. This mode of operation requires turbines with a higher power rating as the differential head is greater during the periods of generation. Although the period of generation is shorter, the energy generated is similar to other operational modes but just delivered over a shorter period of time and requiring greater grid connection capacity. The turbine can also be used in pumping mode for a limited time at high water to increase the volume of storage in the impounding basin above the height of the natural high tide. Tidal turbines operate with a higher efficiency in one direction (c93%) but pumping efficiency is lower. Figure 6 shows the upstream and downstream water levels over several days typical of an ebb only operating mode.

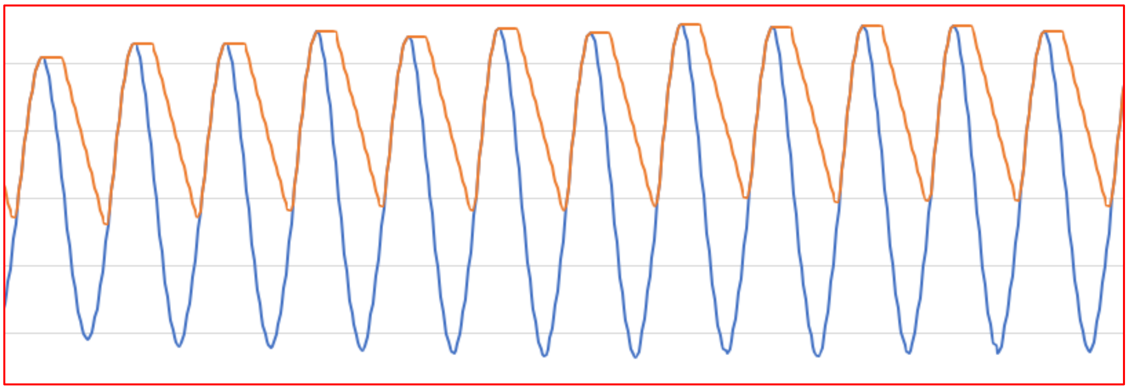


Figure 6: Impounding (orange) and Natural (blue) Tide Levels – Ebb only operation – with significant loss of intertidal areas in the lower half of the tidal prism

Ebb and Flood: The turbines are designed to operate in two directions (but with a lower efficiency compared with single direction turbines) and generate on both the flood and ebb tides so that water flowing into the basin generates power as well as the outflow. The total amount of energy generated is similar to ebb only but it is generated in four periods during the day (as opposed to two with ebb only) but the total power output on each cycle is lower. Pumping can also be used to increase power output by pumping at low heads (when the tide turns) and generate the same volume at higher heads as the tide ebbs and floods. Sluicing can also be used to enhance the generation head towards the end of the generation phase. Turbine efficiencies for two-way generation are between 80 and 93% depending upon direction and turbine two-way design optimisation. If used in pumping mode, efficiencies are lower. Two-way generation also requires a draft tube (the outlet passage from the turbine) to be replicated on both sides of the turbine, increasing the width and cost of turbine caissons.

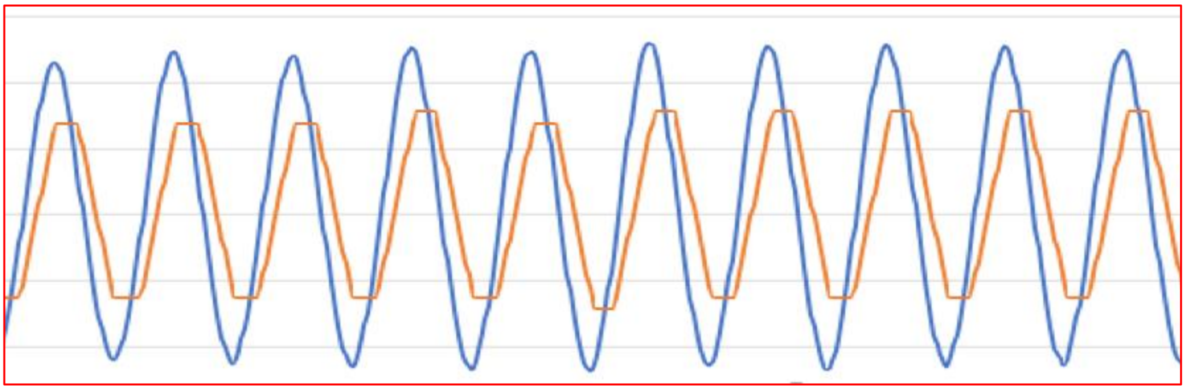


Figure 7: Ebb and Flood operation – with impounding levels showing symmetrical losses at high and low tides.

Tidal Stream

Tidal stream operates in the same way as a wind turbine using the tidal currents to rotate the turbine rotor blades. The principles of power generation are the same as for wind in that power is a function of the swept area of the rotor blades and the cube of the fluid velocity. The difference is that the density of the fluid is significantly higher for sea than it is for air. Tidal stream turbines are therefore significantly heavier than their wind equivalents but the turbine blades can be shorter. However, they are still large for relatively low power outputs as the power density of a tidal stream turbine is much lower than a tidal range turbine.

Examples of tidal stream turbine include Strangford Lough (an early 1.2MW prototype with twin rotors mounted on piles that projected above the water line to enable the rotors to be raised for maintenance) and the MayGen project in Scotland which is currently powered by 4 nr 1.5MW turbines and has been operating since 2017.

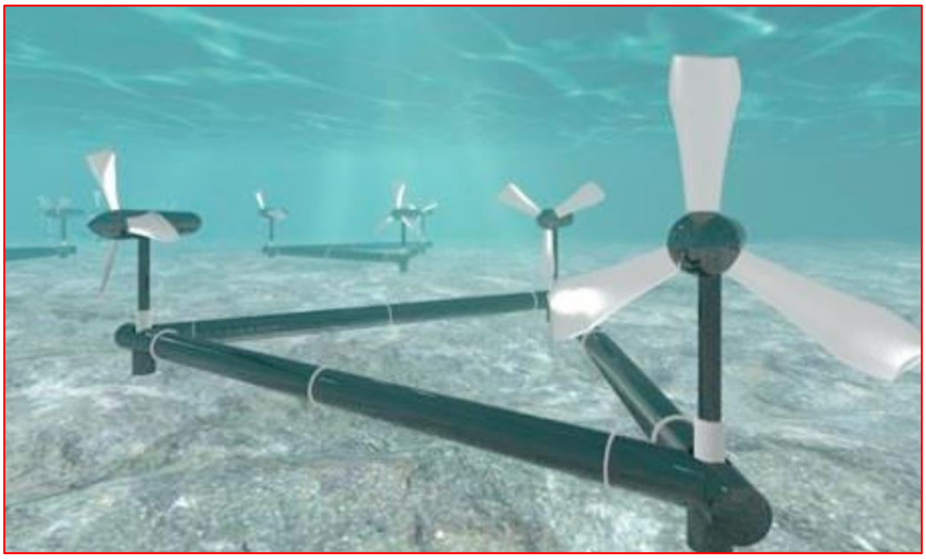


Figure 8: An illustration of tidal stream turbines proposed for Ramsey Sound (from Tidal Electric Limited)

Hybrid Options

A Tidal Fence is primarily based on tidal stream technologies and include configuring a large number of tidal stream devices as a fence running across an estuary. The resistance caused by a large number of tidal stream turbines aligned in a row creates a small level difference across the turbines which increases the power output. The level difference is an order of magnitude lower than with tidal range. The lower power densities result in significantly less energy being taken out of the estuary than a tidal range equivalent but the environmental impact is correspondingly lower. An example was published as part of the Severn Embryonic Technologies project in 2010 (SETS) although it was relatively expensive. This technology is best categorised as a variant of tidal stream.

Figure 9: An illustration of a tidal fence (reproduced from IT Power)

Other hybrid options have included a "low head" turbine which Rolls Royce started to develop for tidal range applications. This used large counter rotating turbine rotors to enable high water volumes to pass at lower heads when compared with conventional tidal range technologies. This was also developed as part of the SETS programme in 2010 but Rolls Royce decided not to pursue the concept. There were concerns on cost and the large number of contra rotating turbine blades which had not been tested for safe fish passage although the rotor tip speeds (a key metric when considering fish passage) were considered to be satisfactory. Although taking elements from tidal stream technology such as the large turbine blades this is more of a tidal range application.

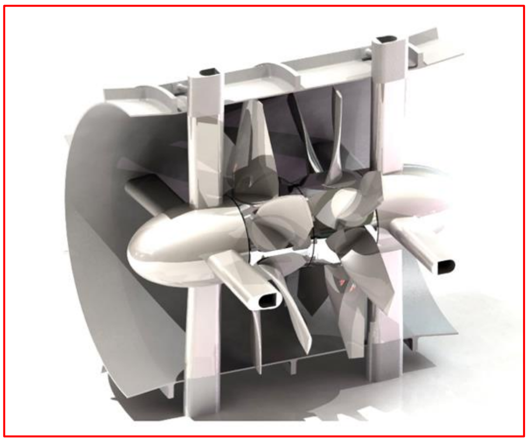


Figure 10: A cut-away of a low head turbine developed by Rolls-Royce and reproduced from their published SETS report.

Wave Energy

Wave energy devices float on the surface of the ocean and are typically articulated or axis mounted so that they can move with the waves. The movement of the device absorbs the energy from the waves. Because it is a reciprocating rather than rotational movement, the energy absorbed is used to compress a fluid which then drives a turbine to produce energy. Compressed air is commonly used as the compression medium directly driving a Wells Turbine (a compressed air turbine).

An articulated device called Pelamis was tested at the EMEC test centre in Orkney and became the first offshore wave machine to generate electricity into the grid in 2004.   Pelamis Wave Power then went on to build and test five additional Pelamis machines including the Pelamis P2, shown in Figure 11, which was tested off Orkney between 2010 and 2014. Pelamis Wave Power went into administration in November 2014, with the intellectual property transferred to the Scottish Government body Wave Energy Scotland. Development of wave power devices has been challenging and the Wave Hub, a £28m wave device grid connection facility 10 miles offshore from Hayle in Cornwall has been repurposed as a floating wind connection hub having been unable to host any wave devices since its commissioning in 2010.

Figure 11: The Pelamis 2 Wave Device

1 PROGRESS TO DATE

Previous Studies

Marine energy has been studied in the UK since the 1930's but there are very few examples of marine energy projects operating in the UK. EdF in France built the 240MW la Rance Barrage in Brittany in 1967 and it has been operating successfully ever since. It illustrates one of the conundrums of tidal range power. In the 1980's, three major reports were published, part or wholly funded by the Government. These were:

- Energy Paper 46 – the Bondi Report on Tidal Range Power from the Severn Estuary
- Energy Paper 57 – Severn Tidal Power Group's Report on the Severn Barrage
- Wave Energy Programme Report (1982) – 7 year £15m research programme on wave energy

Since then, marine energy development has not been supported by the UK Government until the 2006 Energy White Paper. This led to a number of major studies, the most prominent of which were the 2007 Sustainable Development Commission report "Turning the Tide"[1] and the 2010 Severn Tidal Power Feasibility Study[2] (STPFS) Report.

Summary of Literature Review

The most relevant reports and other evidence for tidal power development in the Severn Estuary are shown in Table 1 below. More detail on the literature review undertaken, including details of other UK and international projects, is given in the accompanying Western Gateway Tidal Energy Evidence Base workbook.

Table 1: Summary of Severn Estuary Tidal Power Literature Review

Title	Author and Date	Summary
Turning the Tide	Sustainable Development Commission (2007)	A review of tidal power commissioned following the 2006 Energy White Paper to assess its contribution to sustainable energy policy. The main report and its supporting reports (which examined different technologies for the Severn and tidal power in general). It favoured two barrage options for the Severn, the Cardiff to Weston Barrage and the Shoots Barrage but was also open to lagoon development. A key conclusion was that the need to construct new compensatory habitats could provide the UK with a leadership position given the need for new habitats worldwide. It also looked

[1] Turning the Tide, Tidal Power in the UK · Sustainable Development Commission (sd-commission.org.uk), 2007
[2] Severn Tidal Power Feasibility Study – Department for Energy and Climate Change, 2010

Title	Author and Date	Summary
		at the use of tidal stream technology in the Severn Estuary and concluded: *"The deployment of tidal current technologies is not well suited to the Severn Estuary, primarily because of the high tidal range and shallow depth. Most tidal energy concepts currently under development require a minimum water depth of 30m and a mean spring peak velocity of more than 2.5 m/sec. Although water depths in the Bristol Channel downstream of the Cardiff-Weston alignment are suitable for tidal current technologies the tidal current velocities are too low to make the technology economic especially when compared with other locations around the UK. Large-scale deployment of tidal current turbines could also obstruct busy shipping lanes."* Following the publication of the SDC's Report, the Government commissioned the Severn Tidal Power Feasibility Study in 2008.
Severn Tidal Power Feasibility Study (STPFS)	DECC on behalf of the UK Government, Welsh Government and SW RDA (2008 – 2010)	The STPFS was undertaken over a two year period. Phase 1 assessed a long list of potential tidal power options and reported in January 2009. Also included was a Strategic Environmental Assessment Scoping Study, development of a tidal power cost base, a "fair basis" options assessment of potential projects and a review of financing options. A threshold of £200/MWh was the principal criterion on which projects were selected for further consideration. The objective was to identify options that also had an acceptable impact on the environment. Five projects were selected for more detailed study in Phase 2 on these criteria as follows: B3 Cardiff to Weston Barrage with one and two way generation variants; B4 Shoots Barrage with one way generation; B5 Beachley Barrage with one way generation; L2 Welsh Grounds Lagoon with one way generation; L3d Bridgwater Bay Lagoon with two way generation. Phase 2 studies included optimisation of each option, a detailed Strategic Environmental Assessment and Habitats Appropriate Assessment and socio-economic, grid connection and supply chain studies. The Phase 2 studies concluded in April 2010, just before the 2010 General Election. The principal conclusions were: • The B3 Cardiff Weston Barrage, the B4 Shoots Barrage and the L3d Bridgwater Bay Lagoon were all feasible options • further research was required to resolve uncertainties of cost (consequently, DECC applied both optimism bias and contingency had been applied to the final cost estimates), habitat compensation locations, compensation ratios (2:1 replacement ratio was used in the final report), fish passage, behaviour and mortality

Title	Author and Date	Summary
		• Economic impacts on the Port of Bristol were challenging favouring the option of tidal lagoons or an upstream barrage that did not block the passage of shipping into the main Severn Ports • Impacts on flood risk were both positive and negative for all options depending on location. The incoming Coalition Government published the reports in October 2010 stating that they did not wish to support tidal power with public investment but that the private sector were free to develop their own proposals. The suite of published reports including the SEA represents the baseline of knowledge available to tidal power developers and stakeholders / consultees.
ECC Select Committee Inquiry into "A Severn Barrage"	ECC and organisations submitting written and oral evidence (2013)	Hafren Power proposed a tidal barrage between Cardiff and Weston using low head turbines and held initial discussions with the Prime Minister before proposing a hybrid bill approach to consenting. The ECC Select Committee held an inquiry and took a wide range of evidence before publishing their report. Their report concluded that the proposals were unrealistic and should not be taken forward. The subsequent Government response agreed although confirming that it still supported a market led approach.
Planning Application for Swansea Bay Tidal Barrage	Tidal Lagoon Power (TLP, 2014)	The next market led approach was from Tidal Lagoon Power who submitted an application for a Development Consent Order (DCO) in 2014 for a tidal lagoon at Swansea Bay. The Planning Inspectorate published the TLP application and supporting documents on their web site and recommended award of a DCO which was granted on a conditional basis in 2015. The majority of the detailed planning documents have been removed from the Planning Inspectorate's web site although the concluding documents remain. TLP have also removed all documentation from their web site. Although the Swansea Bay Tidal Lagoon received its DCO, conditions were imposed in terms of environmental monitoring and performance. The project's planning consent lapsed in 2020 because TLP had not been able to successfully conclude CfD negotiations with the Government (based on value for money considerations) nor had they received a Marine Licence from NRW (because of a prolonged delay in agreeing methodologies for assessing impacts on fish behaviour and mortality).
EIS and WA Joint Select Committee Inquiry into "Swansea Bay Tidal Lagoon"	Written and Oral evidence submissions (2018)	The inquiry did not produce a final report as the Government had, following the evidence submissions to the Inquiry, determined that it could not award a CfD to TLP on value for money considerations. However, TLP did submit to the Inquiry a number of previously confidential documents that were published including designs, costs, business case models and correspondence.

Title	Author and Date	Summary
Government announcement on Swansea Bay Tidal Lagoon	BEIS (2018)	BEIS compared the Swansea Bay lagoon with Hinkley Point and Offshore Wind using a cost per unit energy metric. It concluded that Swansea Bay was up to 3 times more expensive. It should be noted that the BEIS announcement did not cover the whole lifetimes costs and benefits in these comparisons but did include a decommissioning figure of £1bn which was significantly higher than estimated by TLP.

Summary of Different Technologies

Tidal Stream

The tidal stream concept of tidal power generation was pioneered by a small organisation called Marine Current Turbines. Based in Bristol, they had been founded in 2000 and in 2003, they installed a 300 kW experimental tidal turbine near Lynmouth, Devon which proved the concept although it was not grid connected. In 2008, they installed a larger, grid connected 1.2MW turbine at Strangford Lough, Northern Ireland. These two turbines were the pathfinder projects for the tidal stream industry. Since then, there has been a degree of consolidation in the tidal stream sector with a number of bankruptcies, but a number of organisations have emerged with consented projects. These are based in areas of high tidal current resource – predominantly the Pentland Firth, Northern Ireland, Anglesey, Pembrokeshire, the Isle of Wight and the Channel Islands. The Severn Estuary has relatively low tidal currents and potential projects studied in the Severn Tidal Power Feasibility Study showed that the tidal stream resource, with the exception of localised hot spots, was not sufficient for tidal stream technologies.

Tidal stream technologies still face several challenges. They need to be more robust than wind turbines due to the relative increase in water density compared with air. They are more expensive in cost per MW terms than tidal range and have a much shorter asset life. However, as they have a relatively low power density, their impact on the environment is less pronounced.

Tidal Range

This is a more established technology and the 240MW La Rance Barrage in Brittany has been operating successfully since 1967. More than 25 different projects put forward for development in the Severn Estuary over the past fifteen years. Other projects have been proposed in North Wales, on the Mersey and in the North West up to the Solway Firth. To date no tidal range projects have been developed in the UK although the 320MW Swansea Bay Tidal Lagoon did receive its Development Consent Order in 2015. However, it could not reach agreement on a satisfactory strike price in its CfD negotiations with the UK Government and the project has not progressed, except as a revised concept, known as Blue Eden, similar in location to the Swansea Bay project, but with a differently designed lagoon and with augmented energy assets such as batteries and floating solar.

Another project that is being developed is the Mersey Tidal Power project by Liverpool City Region Combined Authority. It was initiated in 2018 and is progressing its development work based on either an offshore lagoon or a tidal barrage. It is currently undertaking environmental and engineering studies prior to submitting a development consent application. This would be 700MW or more.

A smaller project in the same region is the Port of Mostyn's proposals for a 128MW tidal lagoon. This is still at an early development stage.

Tidal range projects are sometimes proposed by consortia of private individuals and there are currently two examples of such developments – the West Somerset Tidal Lagoon and the Great Western Power Barrage. These groups produce interesting conceptual designs but lack any substantive financial backing.

The largest challenge facing tidal range projects is the lack of direct Government policy support. Of all the marine technologies, it is the most developed technically (being based on hydropower engineering) and the least expensive in cost per MW of installed capacity. However, it requires a financing mechanism suited to large infrastructure projects and it has a relatively large environmental footprint.

Wave Energy

Wave energy has few active examples in the UK. The EMEC test facility in Orkney has had the largest number of wave devices but most of these have either failed technically and/or through the organisation behind them failing. In England, the Wave Hub in Cornwall was a project developed by the South West Regional Development Agency but failed to host any wave devices and has now been re-permitted as a floating offshore wind test site.

It is difficult to see what progress wave energy will make in the forthcoming decades without significant policy, financial and strategic support. Major challenges are the cost of developing a prototype and progressing to a commercially acceptable and tested design, the lack of current UK policy and strategy the logistics and cost of transmitting the energy many kilometres on-shore.

From the perspective of the Severn Estuary, there is limited wave energy resource – in the South West the best wave energy resource is off the Cornish coastline around the Atlantic Approaches.

National Grid Future Energy Scenarios

The National Grid Future Energy Scenarios (NGFES) published in July 2023 include marine energy (tidal range, tidal stream and wave) in all four of its scenarios with the smallest requirement being a 1GW tidal lagoon by 2050 and a requirement of 8GW of marine power in the most ambitious scenario.

Lagoons vs Barrages vs Tidal Stream

The last major Government study into the development of tidal power from the Severn (the Severn Tidal Power Feasibility Study or STPFS in 2010) identified that tidal lagoons, although more expensive in cost of energy terms (10 to 15%), offered some significant benefits over the tidal barrages for areas located downstream of the Ports of Bristol and Newport. Primarily, a tidal lagoon does not impose an obstacle to commercial shipping. Unlike a barrage, it can also be scaled to reduce adverse environmental and hydrodynamic impacts although a smaller impounding basin will produce less energy. However, a barrage located upstream of the main Severn Ports in the Shoots channel also showed some benefits with reasonable energy generation, a lower environmental footprint and a shorter length of marine wall compared with a tidal lagoon of similar power output. The STPFS also studied tidal stream technologies, configured as tidal fences but, whilst their impact on the environment was relatively low, so too was their energy output whilst costs were high. Energy output was constrained by the relatively low tidal currents.

A concern with multiple projects developed in one estuary is the impact of cumulative development. Each successive project will have an impact on the wider hydrodynamic regime and this is likely to have an adverse impact on cumulative energy generation as further projects are developed. Aside from the legal complexities if the projects are developed by different organisations, there is a need to understand the impacts from cumulative development of two or more tidal range projects in the Severn Estuary in terms of energy yield and also on the environment, flood risk and access to ports.

Building on Progress to Date

There is now a substantial evidence base available, including lessons learned and understanding of opportunities to improve outcomes compared with previous studies. There are still significant uncertainties and/or challenges such as fish movement, development of compensatory inter-tidal habitats and achieving the new biodiversity net gain requirements, particularly for tidal range projects.

Evidence from previous studies, primarily the SDC's Turning the Tide Report, the STPFS and the ABPmer Tidal Atlas suggests that, for the Severn Estuary, the tidal range resource is significantly larger and more viable than the tidal stream resource. Although there are small areas in the Bristol channel where tidal stream could be developed, tidal stream developers have focused on areas in the UK where the tidal stream resource offers higher potential. The STPFS included a number of projects based on tidal stream technologies but their performance was technically and financially inferior to the tidal range projects studied.

Tidal stream technology is still in its embryonic stage but a pre-requisite for any future technology and commercial development is adequate tidal currents and water depths. Tidal range is a more mature technology having been based on low head run-of-river hydro-electric plants. With the exception of reviewing what can be achieved in terms of more innovative marine wall designs and construction methods, the technology has been refined to close to the limit.

However, there are opportunity areas for more research and policy development, including:

- contribution to grid stability and other energy system benefits (for example working with green hydrogen production facilities);
- understanding, through whole system analysis, marginal cost of tidal range power over its lifetime and potential benefits to future generations;
- developing a model application for using innovative forms of funding and financing for large tidal power projects, such as Regulated Asset Base (RAB) financing or other alternative;
- taking a more nature centric approach to project evolution;
- understanding the potential socio-economic effects from the development of tidal power, including potential supply chain benefits but also attitudes and needs to inform better policy support;
- understanding non-technical barriers in the development of tidal power;
- development of low cost/high impact support mechanisms to facilitate tidal power development;
- reviewing "stranded asset" and "end-of-life" decommissioning options;
- developing a greater understanding of environmental challenges and potential solutions.

The Welsh Government have launched a call for research proposals for their Tidal Lagoon Challenge. This will run to a parallel timescale to the Western Gateway's Independent Commission. It is only likely to focus on a small number of the above research opportunity areas.

2 POLICY CONSIDERATIONS

Existing Energy Policies

A summary of the overarching policies for achieving net zero by 2050 is set out in the research briefing on UK Government policy in the House of Commons Library. This provides a comprehensive overview of the key policy and research documents.

Energy policy objectives are driven by the 2008 Climate Change Act and the amendment of the target through the Climate Change Act 2008 (2050 Target Amendment) Order 2019, which commits the Government to achieving a 100% reduction of greenhouse gas emissions by 2050 compared with 1990 levels. Net zero requires that any emissions are offset by an equivalent by carbon sequestration schemes such as planting of trees or using technology like carbon capture and storage.

The Net Zero Strategy (Build Back Greener), updated in April 2022, sets out policies and proposals for decarbonising all sectors of the UK economy to meet the Government's net zero target by 2050. The Net Zero Strategy builds on the Government's Ten-point plan for a green industrial revolution which was published on 18 November 2020.

These policies were updated in March 2023 with a suite of publications under the policy paper, Powering Up Britain that included the Powering Up Britain: Net Zero Growth Plan.

Other policy documents include:

- Green Finance Strategy, March 2023
- British energy security strategy, April 2022
- Transport decarbonisation plan, July 2021
- Industrial decarbonisation strategy, March 2021
- Hydrogen strategy, August 2021
- Heat and Buildings Strategy, October 2021
- Energy net zero white paper, December 2020

The Government is assisted in its policy formulation by the work of the Climate Change Committee (CCC), an independent, statutory body established under the Climate Change Act 2008. It advises Government and reports to Parliament on progress made in reducing greenhouse gas emissions and preparing for and adapting to the impacts of climate change. Its sixth carbon budget, published in 2020, set out different pathways to achieve net zero. Its 2022 Progress Report to Parliament contains information on emissions trends, progress towards net zero, and an assessment of relevant policies.

The Government responded to the Climate Change Committee's (CCC) Annual Progress Report 2022 Recommendations in March 2023.

In September 2022, the Government commissioned an Independent review of net zero conducted by former Energy Minister Chris Skidmore MP.
The review made 129 recommendations to Government and proposed 25 key actions. In March 2023, the Government published its response to the review stating that:

"We agree with the review's conclusion that net zero is the growth opportunity of the 21st century and could offer major economic opportunities to the UK – but that decisive action is needed to seize these."

The Government's Energy Bill 2022-23 has not yet been enacted but covers energy production and security and the regulation of the energy market.

The Government's Carbon Budget Delivery Plan (March 2023) fulfils statutory duties under the Climate Change Act 2008 that enable Carbon Budgets 4-6, which cover the periods 2023-27, 2028-32 and 2033-37 respectively, to be met.

The plan estimates that its quantified proposals and policies will give over 100% of savings required to meet Carbon Budget 4 and 5 and 97% of the savings required to meet Carbon Budget 6.

The relevant policies on funding are covered by the following:
Funding

- The Autumn Budget and Spending Review 2021 confirmed that since March 2021 the Government committed a total of £30 billion of public investment for the green industrial revolution in the UK.
- The Autumn Statement 2022 made available £6 billion additional funding to drive improvements in energy efficiency.
- The Spring Budget 2023 made up to £20 billion available for Carbon Capture, Utilisation and Storage (CCUS).
- Net Zero Innovation Portfolio, March 2021, is a £1 billion fund to accelerate the commercialisation of low-carbon technologies, systems and business models in power, buildings, and industry.

A number of other research briefings have been produced by UK Parliament including:

- The role of local government in reaching net zero, June 2023
- Independent Review of Net Zero, February 2023
- Electric vehicles and infrastructure, February 2023
- Government support for marine renewables, December 2022
- Sustainability of burning trees for energy generation in the UK, December 2022
- Estimates Day debate: The Spending of the Department of Business, Energy and Industrial Strategy on action on climate change and decarbonisation, July 2022
- The future hydrogen economy, June 2022
- Where will Britain's future energy supply come from?, May 2022
- Aviation, decarbonisation and climate change, September 2021

In Wales, there are a number of documents focusing on the opportunity and policy areas to deliver net zero. The most recent is the Welsh Government Net Zero strategic plan published in September 2022.

Specific Marine Energy Policy

Specific tidal power policies are very limited compared with other low carbon energy technologies. Tidal stream technologies have received some recent financial support mechanism with £20m set aside in the fourth round of Contract for Difference (CfD) auctions to support tidal stream applications. The fifth auction round (results of which will be announced in late summer 2023) will also see a further £10m set aside but it is likely that these will be directed at existing tidal stream proposals in Orkney, the Isle of Anglesey and the Perpetuus project near the Isle of Wight. The Severn Estuary has lower currents than are desirable for tidal stream generation with the consequence that power generation would be relatively lower than other locations and the cost of energy higher. As a consequence there are no active tidal stream projects being pursued in the Severn Estuary.

The December 2022 briefing on marine renewables, referenced above, reflects the Government's position on marine renewables and states:

"Wave and tidal power increased little over this period and its contribution to UK generation was less than 0.01% in each year. At the end of September 2022, three tidal energy projects in the UK had received planning permission. They have a total capacity of 97 megawatts (MW) and all are in Scotland. Around 7,300 MW of offshore wind generation was under construction at the same time."

“The Government held a call for evidence on the potential of innovative marine energy projects in Great Britain, such as floating offshore wind (wind turbines moored to the seabed in deeper waters), tidal stream and wave energy, in 2020. This sought views on options to grow these industries while reducing the costs of these early-stage technologies. The Government has not yet published a response to the call for evidence.”

Tidal Range has very limited policy support. The Severn Tidal Power Feasibility Study (STPFS) published in 2010 was intended to be the fore-runner for a National Policy Statement on tidal power but this never materialised when the incoming Coalition Government determined that it did not offer best value for public funding. Although it allowed the private sector to present proposals if they were financially viable, no specific policy support was provided except for the over-arching EN1 National Policy Statement (NPS) for Energy and any generic rules that applied from EN3 NPS for Renewables. It was under these policy documents that the Tidal Lagoon Power proposals for Swansea Bay was awarded a conditional DCO in 2015.

When the July 2013 Supplementary Memorandum for the Energy Act was published, paragraph 21 on page 3 included a mechanism by which certain technologies for which generic terms were unsuited (for example, nuclear, CCUS and tidal range) could negotiate different terms. The generic CfD terms stipulated a 15 year contract length and a strike price which is now derived through auction rounds. The Swansea Bay CfD contract negotiations offered a variety of different contract lengths, strike prices and indexing proposals but was not accepted by the Government on the Value for Money criteria. This followed the independent Hendry Review commissioned by the Government which was largely supportive of tidal lagoons. However, the principle of negotiations remains relevant to tidal range although it is noted that Government has offered a Regulated Asset Base mechanism for new nuclear projects (but not any other technology).

The most recent consultation on revisions to the Energy NPS’s included representations from the tidal range sector but the Government in its response did not consider tidal range to be a candidate for its own NPS or to be covered more specifically in the EN3 Renewables NPS. Instead it provided a checklist for tidal range developers to achieve before submitting any proposals to the Department for Energy Security and Net Zero in Appendix C (reproduced in Appendix C of this report) to its response to the NPS consultation. Although it was published in a consultation response, it will not be included in the revised NPS when they are published later this year.

However, the 2023 Mission Zero - Independent Review of Net Zero (publishing.service.gov.uk) by Chris Skidmore MP identified the strengths the UK has in tidal power, stating “For tidal range projects, one of the main barriers is the high upfront building costs, with suggestions that the sector would need similar deals as provided to the nuclear industry to become cost-competitive.”

Another recently closed Government consultation is on changes to the CfD from 2024 including proposals to exclude private wire arrangements to offshore oil and gas facilities, policy updates in relation to maintaining the balance between market exposure and investor certainty for CfD holders, the interaction between the CfD scheme and Capacity Mechanism on matters of eligibility and the potential consideration of whether other factors beyond price should be taken into account in contract awards.

Scope for Influencing Future Energy Policy

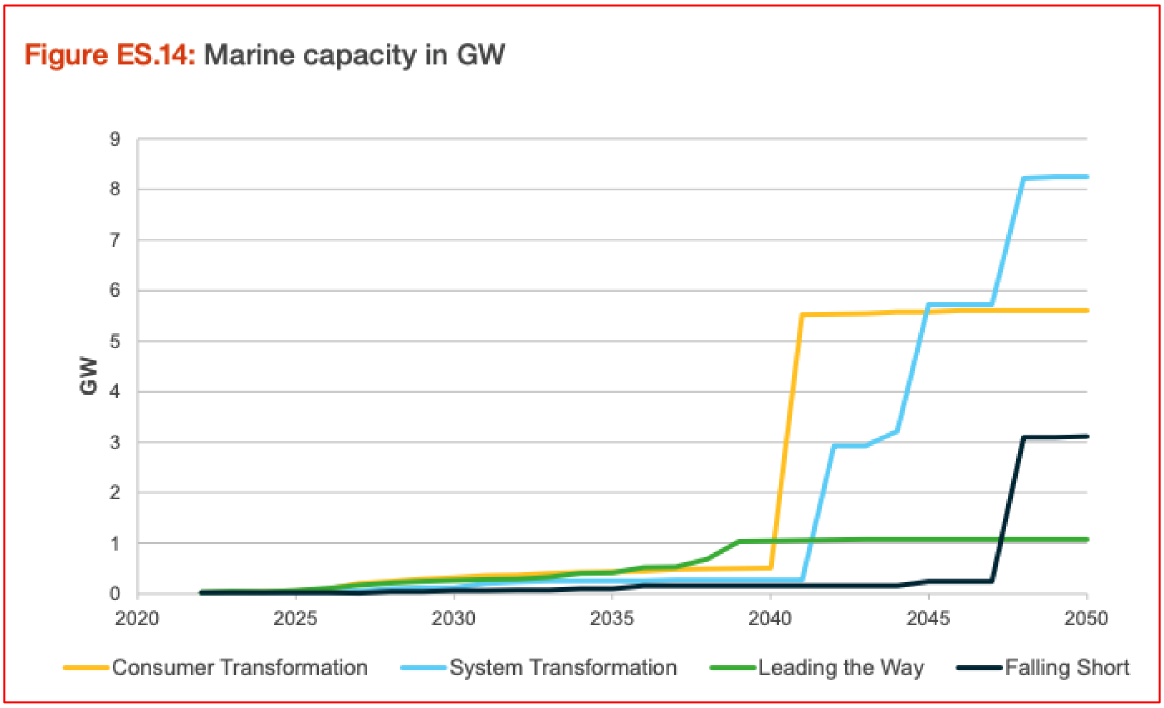
Responding to Energy Forecasts

Although there is no specific NPS for tidal range, any planning need has to be substantiated by the over-arching energy policy (EN1) and any relevant parts of the renewables NPS (EN3). This requires a case to be made that a tidal range project will be required to contribute to the achievement of the UK's energy goals as set out in EN-1. There is some strong evidence already available to support that, including the fact that the Swansea Bay Tidal Lagoon was awarded a Development Consent Order and that the National Grid Future Energy Scenarios (NGFES) published in July 2023 include marine energy (tidal range, tidal stream and wave) in all four of its scenarios with the smallest requirement being a 1GW tidal lagoon by 2050 and a requirement of 8GW of marine power in the most ambitious scenario.

This is how the NG FES describe how they have incorporated main energy into their FES planning:

"In all scenarios we see many small tidal stream installations as well as wave generation. In Consumer Transformation, successive tidal range projects in the early 2040s bring capacity up to just over 5 GW by 2041. The same projects are completed slightly later in System Transformation, but they reach a greater capacity (just over 8 GW by 2050) to meet security of supply standards. The first tidal lagoon in Falling Short is operational just before 2050."

The following figure (ES.14) is taken directly from the NG FES July 2023 report. It indicates that marine energy varies from 1GW to 8GW depending upon the scenario being considered. Given that tidal stream and, to a greater extent, wave are more expensive on a per MW installed basis than tidal range, even before the additional cost of offshore grid connections, it is interesting to see how NG believe they can contribute up to 1GW by 2050 in the *Leading the Way* scenario. Netting out tidal stream and wave, sees tidal range capacities of 2, 4.5 and 7GW for the *Falling Short*, *Consumer Transformation* and *System Transformation* scenrios respectively in operation by 2050.



(reproduced from National Grid Future Energy Scenarios, July 2023)

The NG FES report underlines that the demand is there and that a range of technologies will be required to meet it, including tidal range. The Climate Change Committee in their Sixth Budget Report also forecast a significant increase in electricity demand as the transport and heat sectors are decarbonised. This is illustrated in Figure 12 below:

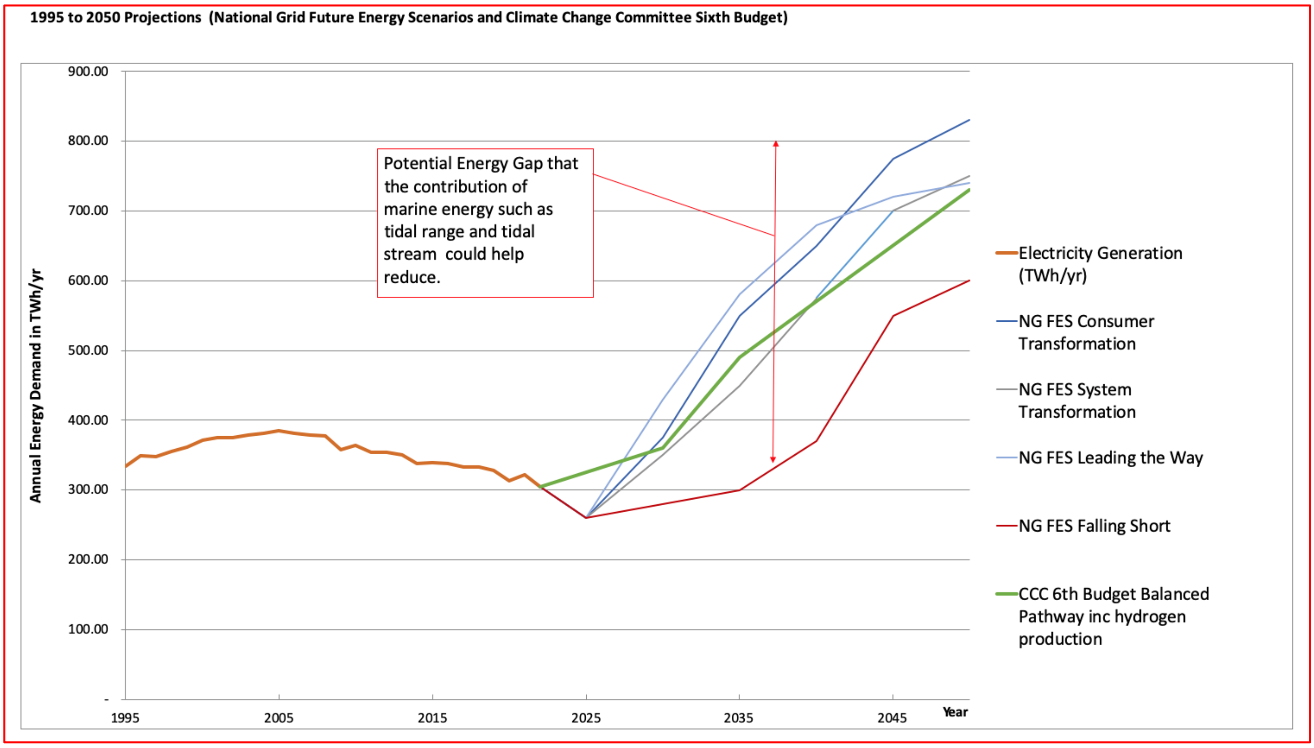


Figure 12 Energy Demand projections to 2050

Whilst these forecasts support the need for generation and storage technologies of all kinds, and re-affirm the need to consider potentially feasible tidal range projects at the earliest possible time (taking account of the time required to plan, consult, consent, invest and construct a tidal range project), they do not resolve the challenges of tidal range power projects – namely financing costs and mitigation of impacts on the environment. The latter challenge is covered by environmental legislation and regulation and is covered in the section below on environmental policy.

Alternative Methods of Financing

However, an important area to exert influence is related to financing and to make the case that tidal range should benefit from similar financing support as other large infrastructure projects in the energy and utilities sector. This could include assessing the application of RAB financing on tidal range projects using similar methodologies being proposed dor new nuclear power stations, or some other form of innovative financing mechanism that recognises the long term benefits of a project that can operate for 120 years or more.

Logically, if nuclear, CCUS and tidal range power were specifically able to negotiate CfD contracts, the application of, for example, RAB financing under the same Regulator should be considered for the same technologies. The Government has not yet accepted this argument and a common request from Western Gateway and Liverpool City Region Combined Authority would be a first step in opening discussions with DESNZ.

Select Committee Support

There is support from for a fresh look at Tidal Power from the Environmental Audit Select Committee in their 2021 Inquiry :Technological Innovations and Climate Change: Tidal Power". Although they did not produce a specific report, they wrote to the then Secretary of State for BEIS in these terms:

> *"Tidal power can offer numerous benefits and potential for the UK, which boasts over 7,500 miles of coastline and unrivalled resources to generate reliable power supplies without the vagaries of sunlight or wind."*

> *"While we appreciate the Government's concern about the potential initial cost to the taxpayer to support early-stage tidal stream and tidal range structures, the benefits outweigh the costs. Support for tidal stream is likely to lead to a rapid fall in generating costs similar to, if not steeper than, the fall*

experienced in offshore wind. Tidal range projects are relatively cheap to maintain once the initial costs are paid off, offering – in the longer term – a potentially affordable contribution to make to the UK's renewable energy mix."

"It is clear that there is a strong current of interest in tidal power, with clusters set to thrive around the UK, if it is given Government backing. It is imperative that the Government fully considers the benefits of this reliable renewable energy and have constructive discussions with the sector."

Regional Position

At present, with the exception of Hinkley Point C and the Celtic Sea FLOW projects, the South West and Wales's ambitions in terms of electricity generation infrastructure is confined to relatively small scale assets, predominantly land based wind and solar. The possible changes that OFGEM is consulting on to a nodal system of charging may provide a greater incentive for the South West and South Wales to be more self sufficient in electricity generation.

Electricity Market Review

The UK Government is also undertaking a Review of Electricity Market Arrangements ("REMA") that is considering a wide range of options for updating GB electricity market arrangements to ensure that the UK's commitment to a decarbonised and secure electricity system by 2035, at least possible cost to consumers, can be delivered.

Business Case Appraisal

A further consideration in terms of energy policy is the appropriateness of project appraisal methodologies. Typically, these have been undertaken ignoring future inflation rates. This leads to a bias when comparing projects with different characteristics (for example comparing a gas powered generation facility with relatively low capital costs and higher running costs to a tidal range project with a relatively high capital cost but low running costs), favouring the lower capex / higher opex alternative. This bias is compounded when higher private sector interest rates are used, particularly for long life projects where the future value is heavily discounted.

Summary of Policy Influencing Opportunities

There is therefore scope for the proposed Independent Commission to considering the following influencing opportunities:

- Promoting tidal power as a significant infrastructure project rather than a modular energy project and that a "one size fits all" approach is not fit for purpose in terms of energy market policy levers (this has to some extent been recognised through new nuclear being considered for RAB financing);
- Emphasising what has changed since the last tidal power projects were considered and rejected by Government. Changes include:
    - Increased urgency in achieving net zero to mitigate the effects of climate change – primarily excessive heat and the impact on human health, economic activity, increased flooding and droughts and sea level rise;
    - Instability of world energy markets arising from an imbalance of supply and demand, exacerbated by the war in Ukraine and also the need to increase electricity demand in order to decarbonise the heat and transport sectors;
    - Need for long term security of cost as well as security of supply, affordability and low carbon generation;
    - Of the 26 years remaining to 2050, the entire UK wind turbine fleet will require re-powering, solar panels replaced and electricity transmission and distribution grids upgraded. As it typically takes ten years to consent new projects and nearly as long to build them, there is an urgency for a fresh review of tidal power policy to capitalise on existing knowledge and increase relevant workplace / supply chain skills (in addition to those required for nuclear / hydrogen / wind / solar projects).
- Promoting the benefits of tidal power in a different way than has been the case before where in cost of energy terms it was compared with nuclear and offshore wind when it does not have the same decommissioning costs and/or offshore grid connection costs, and has a significantly longer asset life;
- The benefits include:
    - Long term security of cost as it is an indigenous resource with the majority of costs being short term during construction;
    - Year on year reduction in real term cost as ongoing costs are low whilst energy yields are high giving significant protection from future inflation;
    - Predictable energy output providing resilience with energy generated every day and only short durations of back-up resources required;

- Long life (offshore wind farms will be repowered five times during a tidal range project's lifetime);
- Tidal Power adds to the diversity and resilience of the energy mix – in particular, it will facilitate reaching net zero by 2050 if policy and financing improvements are enacted in the near-term;
- Ability to operate in concert with nuclear to produce green hydrogen and / or charge batteries, particularly during off peak periods where energy outputs may exceed demand;
- Ability to provide grid support as tidal range turbines can be used to stabilise frequency response at times of peak demand response;
- Utilises technologies that have been tried and tested over decades
- Learning from La Rance both in terms of cost of energy and the value in being used to regulate the grid (the most expensive form of energy on EdF's grid when first built, now the lowest cost of energy on the EdF network).

- The culmination of the above is to influence the development of a specific tidal range energy policy that facilitates promotion of tidal range through:
  - Reference and support for tidal range in a specific National Policy Statement;
  - Introduction of a RAB mechanism for prospective tidal range projects;
  - Consideration of the use of future inflation scenarios in business case / value for money determinations;
  - Consideration of wider issues such as co-production with green hydrogen / battery storage, grid resilience in future business cases;
  - Promoting tidal energy policy on the basis of technical and environmental professional practice rather than by reference to a failed private sector development.

Although not an influencing matter, none the less, the Welsh Minister's recent announcement on the £750,000 Tidal Lagoon Challenge provides an opportunity for consortia led by research institutions to investigate Environment, Engineering and Technical, and Finance and Socio-Economic areas that could lead to identification / removal of barriers preventing tidal lagoon development, identify benefits to tidal lagoon development, support the building of a knowledge base that will smooth the path to future tidal lagoon delivery in Wales and raise the profile of tidal lagoon sector in Wales.

The deadline submission of initial applications is 18 September 2023 with awards of grants up to £250,000 taking place in March 2024.

Existing Relevant Environmental Policies

The over-riding legislation applicable to tidal power projects is The Environment Act 2021 in England and The Environment Act 2016 in Wales. Other legislation includes:

- The Wildlife and Countryside Act 1981.
- The Planning Act 2008.
- The Well-being of Future Generations (Wales) Act 2015.
- The Planning (Wales) Act 2015.
- The Water Environment (Water Framework Directive) (England and Wales) Regulations 2017.
- The Conservation of Habitats and Species (EU Exit) Regulations 2019.

The current process for considering environmental matters in the development of tidal power is through the examination of projects after they have applied for a Development Consent Order. The process in England and Wales is slightly different in that in England any marine project over 100MW is required to apply for a Development Consent Order, whilst in Wales, projects up to 350MW are examined in a parallel process by Welsh Ministers. In both cases marine licences are required issued by the Marine Management Organisation (MMO) and Natural Resources Wales (NRW) respectively.

The process to be followed for planning in Welsh Waters is described in the NRW schematic (Figure 13) below.

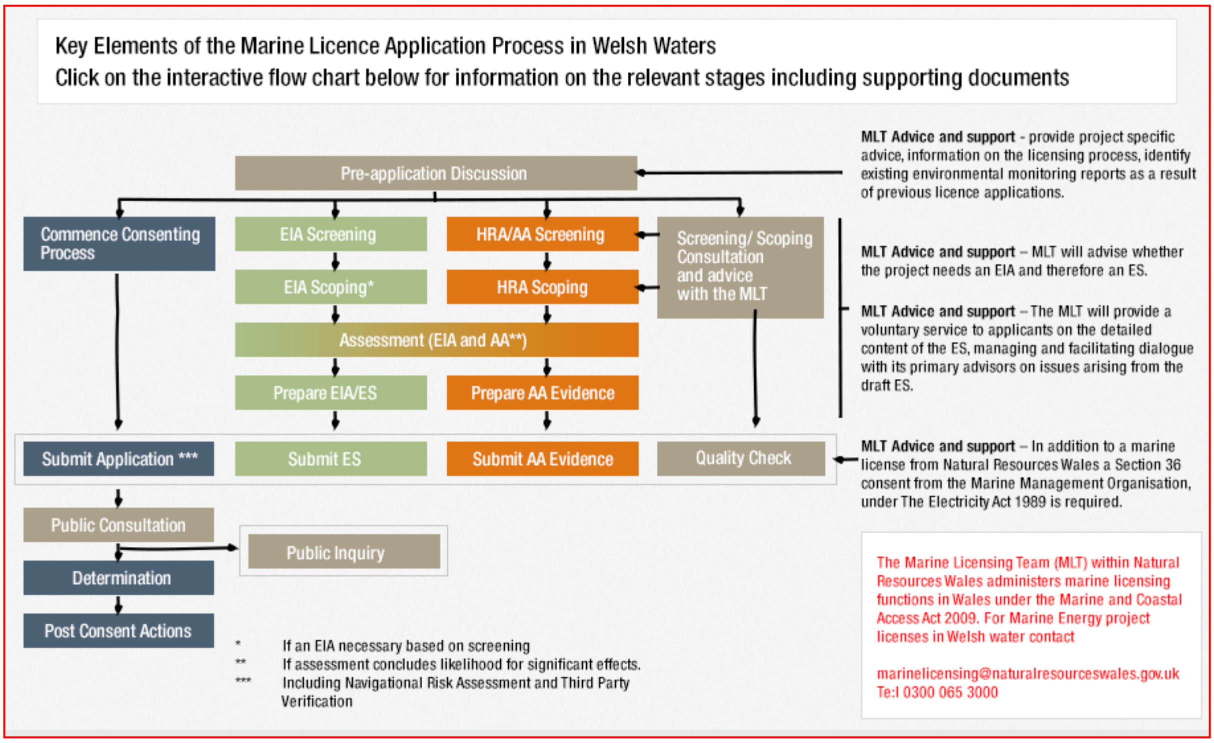


Figure 13: The Consenting Process for Tidal Projects in Wales

The process is similar in England but with different supporting teams and resources including Natural England, the Environment Agency, the Marine Maritime Organisation and Historic England. In Wales, CADW, responsible for historic structures, should also be consulted in addition to NRW and additional stakeholders as outlined in the Stakeholder and Identification section of this report.

Depending on the size and nature of tidal power projects, developments may require Environmental Impact Assessment (EIA) as set out under Schedule 1, of the Infrastructure Planning EIA Regulations 2017 and the Marine Works (EIA) (Amendment) Regulations 2017. Given the likely scale of any proposed development in the Severn Estuary it is likely that an Environmental Statement (ES) will need to accompany the Application. In England, the introduction of Environmental Outcome Reports (EOR) will replace the EIA in due course however in Wales the Welsh Government have yet to reach this decision to embrace the EOR's.

The Habitats Regulations apply to both England and Wales and require that European sites (Special Areas of Conservation (SAC) and Special Protection Areas (SPA) are protected and any projects that could create changes to them will be required to undertake a Habitats Regulation Assessment (HRA). This also applies to proposed SACs, potential SPAs, Ramsar sites (wetlands of international importance - both listed and proposed) and areas secured as sites compensating for damage to a European site. A large part of the Severn Estuary has these European and international designations and it is likely that all tidal power projects, even those not directly in the protected areas, in the Severn Estuary would be required to undertake an HRA as the hydrodynamic changes of generating tidal power will give rise to far-field effects. The European and international designation areas are shown in Figure 14 below (the SAC is in pink, whilst the SPA and Ramsar area is shown in green):

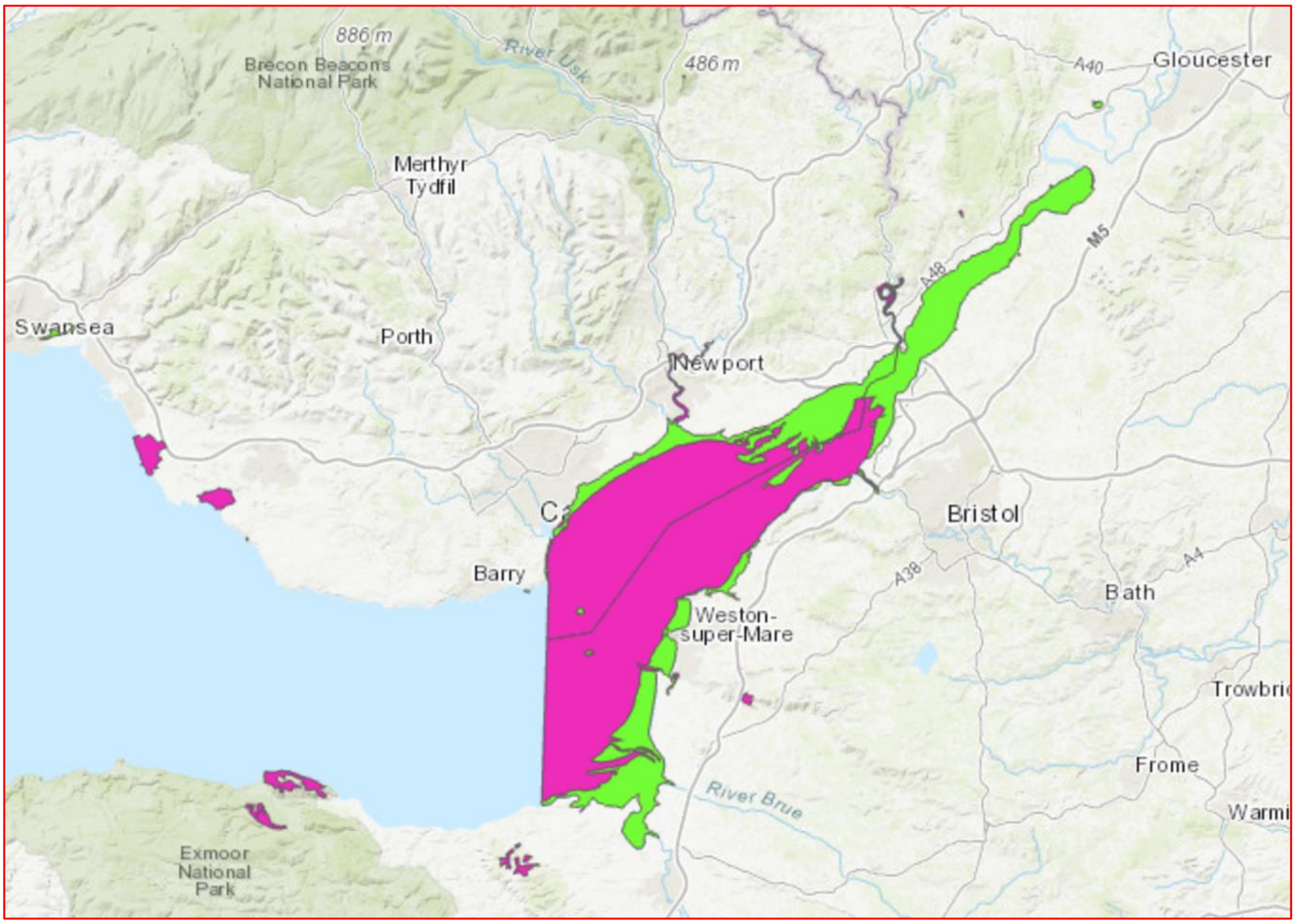


Figure 14: European and International Designated Areas

Environmental designations in the Severn Estuary include:

- Severn Estuary Special Area of Conservation.
- Severn Estuary Special Protection Area.
- Severn Estuary Ramsar.
- Severn Estuary Site of Special Scientific Interest.
- Upper Severn Estuary Site of Special Scientific Interest.
- Bridgewater Bay Site of Special Scientific Interest.

- Sully Site of Special Scientific Interest.
- Flat Holm Site of Special Scientific Interest.
- Steep Holm Site of Special Scientific Interest.
- Newport Wetlands Site of Special Scientific Interest.
- Wye Valley Area of Outstanding Natural Beauty

If protected habitats are shown to be impacted by the HRA, but if the project can demonstrate Imperative Reasons of Overriding Public Interest (the IROPI principle) and there are no reasonable alternatives, new habitats can be created to compensate for any loss of or negative impact on existing habitats. These compensatory habitats should provide effective new habitat before the existing habitat is lost and this may mean creating a larger habitat reflecting the less effective nature of new habitats.

The most significant form of habitat loss from tidal range power will be the loss of inter-tidal habitats because of the reduced tidal prism in the impounded basin once the tidal power scheme starts operation. Ebb-only operation causes the largest loss of inter-tidal habitat because the lower half of the tidal prism is typically lost upstream of the barrage. There can also be a small loss of high water level which can impact salt marsh and entry clearances into existing ports (the distance between high water and the lock entry cill). Ebb and flood operation reduces the amount of inter-tidal habitat loss although there is a larger loss at high water level which creates additional challenges for ports as navigation clearances over lock cills are significantly reduced. Additional sluicing and pumping during the operational cycle can marginally reduce the loss of inter-tidal habitat.

One of the challenges for potential projects in the Severn Estuary will be the need to achieve cross-border working to satisfy both the English and Welsh legislative regimes in a cost effective and efficient manner. Such a challenge highlights the need for early and collaborative engagement so that outcomes and processes are designed to comply with the appropriate requirements without repetitive effort. The two systems are similar in process and practice but will involve different agencies and ministerial decision making. The Severn Estuary is within the Wales National Marine Plan (adopted 2019) and the South West Marine Plan – South West Inshore (adopted 2021). Both include specific policies on cross-border cooperation and plan compatibility and set the context and requirements of cross-border working and decision-making. As well as the specific cross-border policies, there are other marine plan policies that have cross-border relevance including the impacts of large-scale infrastructure or because of the transboundary nature of ecosystem features, such as marine mammals.

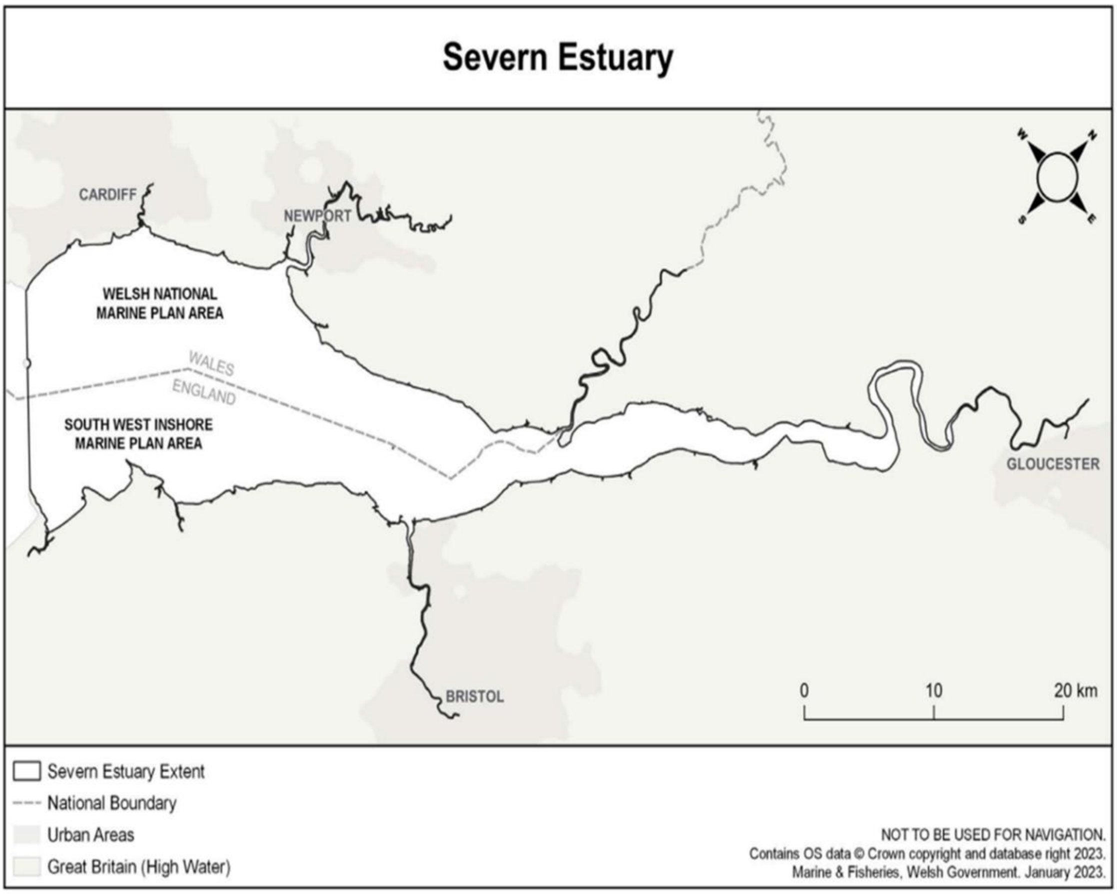
In 2023, the Welsh Government and the Marine Management Organisation produced a document to assist with cross border co-operation: [The Severn Estuary: A cross-border marine planning guide, July 2023]. This applies to both Plans and Proposals.

To facilitate understanding of the plan areas, natural resources and human uses alongside planning policy, both parties maintain and regularly update online portals – the Wales Marine Planning Portal and Explore Marine Plans with relevant marine spatial data.

Proposals will require evidence of appropriate consideration and compatibility with relevant statutory plans and any relevant related supplementary material. They will need to demonstrate consideration of any relevant cross-border impacts including any likely positive or adverse economic, social, and environmental impacts, and address impacts in line with the applicable marine plan policy. A key element will be consultations conducted with relevant stakeholders.

Figure 3 from the guidance document delineates the split of legislation requirement due to the boundary between Wales and England.

Figure 3: Severn Estuary defined extent and marine plan areas



Changes to Legislation

Much of the environmental and other associated legislation has changed since the previous tidal power studies and project development activities which largely preceded 2015. Some of the most significant changes (existing and proposed) relevant for tidal power development include:

- The Environment Act (2021) sets out the policies to be applied for projects in England. In Wales, the Environment Act (2016) sets out the overarching environmental policy with the national natural resources policy sitting under it.
- The Future Generation of Wales Act 2015 puts in place seven goals including: a prosperous Wales, a resilient Wales, A more equal Wales, a healthier Wales, a Wales of cohesive communities, a Wales of vibrant culture and thriving Welsh language and a globally responsible Wales. The definition of the Act is "The process of improving the economic, social, environmental and cultural well-being of Wales by taking action, in accordance with the sustainability development principle aimed at achieving the well-being goals". In Wales there are 48 public bodies covered by the Act and therefore decisions involving public bodies in relation to tidal development in the Severn Estuary will be required to take this Act into account.
- The Marine Policy Statement is an overarching UK framework for preparing Marine Plans which underpins decisions taken on the marine environment. The MPS and subsequent Marine Plans will form a new basis for the marine planning system in accordance with legislation providing a spatial planning approach to marine resources.
- The government intends to require developers to demonstrate the Biodiversity Net Gain requirements for NSIPS with a biodiversity net gain statement for NSIPs to be produced later this year. Marine infrastructure undergoing consent through the NSIP and TCPA progress will be defined by the government to clarify how the marine licensing and planning regimes will put into place statutory credits so that both intertidal and coastal projects can meet net gain obligations through payments. It remains to be seen as to whether the devolved nations will also follow Marine Net Gain. The Welsh National Marine Plan will require environmental enhancement of projects and states the definition of 'enhancement' applied for this study is closely related to the so-called 'net gain' concept, which is generally understood to be a development that leaves the environment or biodiversity in a better state than before. Either way it will need to be considered as part of any tidal development in the Severn Estuary.
- As a result of Brexit a new system of environmental assessment is being proposed by the UK government which includes the Environmental Outcome Reports (EOR) detailing proposed new environmental assessment procedures. Once enacted powers will be granted that allow the

government and devolved administrations to replace the EU legislation relating to both SEA and EIA processes. The EOR looks to simplify and streamline the environmental assessment process and deliver greener infrastructure for the economy. The assessment criteria for EIA screening will be made clearer and if enacted will relate to tidal renewable projects going forwards. It has yet to be decided by the Welsh Government whether they will follow the EOR process once enacted which could generate cross-boundary legislation differences for development within the Severn Estuary.

- On the 12th June 2023 the Infrastructure Bill was introduced to the Senedd Cymru in a move towards net zero emissions by 2050. A unified consenting process for Wales has been proposed to enhance investment within both renewable energy and significant infrastructure projects. The bill if ratified will apply to both the land and territorial sea which would include any tidal projects in the Severn Estuary. The bill will replace the Developments of National Significance regime consolidating planning requirements under one system. The bill will be of relevance to Significant Infrastructure Projects and aim to enable Infrastructure Consent. This new legislation will contain defined parameters for projects to be assessed and applied against. If passed, the Bill is expected to receive Royal Assent in Mid-2024. The IC regime is expected to be fully operational by Mid-2025.

Opportunities for influencing environmental policy to suit tidal power are relatively small given the widespread nature of environmental law and regulation. Instead, the key point for the Western Gateway's Independent Commission is to embrace the environmental community and integrate them as a team player in achieving the objective of developing the Severn Estuary's tidal energy resource whilst delivering net biodiversity gain and newly emerging policies and legislation.

3 ANALYSIS OF PROJECTS

Introduction

A literature review has been undertaken to identify the data sources and details of tidal energy projects studied in the Severn Estuary, elsewhere in the UK and internationally. These have then been compiled into an Excel Workbook which accompanies this report (the Western Gateway Tidal Energy Evidence Base). The workbook provides the published data for each project updated to a March 2023 cost base with analysis of the financing costs and identification of lessons learned (Section 4 of this report provides a summary of the lessons learned from these previous projects / studies).

The analyses use the developer or original study data, and the independent assessment is then undertaken on a quantitative and qualitative basis to assess whether estimates of cost and energy outputs are realistic or not. The data used in the independent assessment to reach such conclusions is set out in Appendices A (cost data) and B (energy) of this report.

Severn Estuary Projects Considered

Table 2: Summary of Severn Estuary Tidal Projects

Programme	Project	Data Source
Bondi Commission (1981)	Cardiff to Weston Tidal Barrage	Energy Paper 46 (not available on line)
Severn Tidal Power Group – STPG (1989)	Cardiff to Weston Tidal Barrage	Energy Paper 57 (not available on line) 2002 Update
	English Stones Barrage	
Sustainable Development Commission – SDC (2007)	Cardiff to Weston Barrage	SDC Reports
	English Stones / Shoots Barrage	
	Tidal Lagoons	
Severn Tidal Power Feasibility Study – STPFS Phase 1 (2009)	B1 Aberthaw to Minehead Barrage	STPFS Phase 1 Reports (not available on line)
	B2 Cardiff to Hinkley Point Barrage via Weston	
	B3 Cardiff to Weston Barrage	

Programme	Project	Data Source
	B4 Shoots Barrage	
	B5 Beachley Barrage	
	R1 Tidal Reef	
	L2 Welsh Grounds Lagoon	
	L3 Tidal Lagoon Concept - Peterstone Flats - English Grounds - Bridgwater Bay - Offshore (Bridgwater Bay)	
	U1 Severn Lakes	
	F1 Severn Tidal Fence	
Severn Tidal Power Feasibility Study – STPFS Phase 2 (2010)	B3 Cardiff to Weston Barrage	STPFS Final Reports
	B4 Shoots Barrage	
	B5 Beachley Barrage	
	L2 Welsh Grounds Lagoon	
	L3d Bridgwater Bay Lagoon	
Severn Embryonic Technologies Scheme – SETS (2010)	Minehead to Aberthaw Tidal Fence	STFC SETS Report
	Minehead to Aberthaw or Cardiff to Weston Venturi Fence	VerdErg SETS Report
	Minehead to Aberthaw or Cardiff to Weston Tidal Bar	Atkins Rolls Royce SETS Report
Post STPFS (2012)	Stepping Stones Lagoon	Bristol Tidal Forum Presentation
Hafren Power (2011 - 2013)	Hafren Power Barrage	Select Committee Inquiry

Programme	Project	Data Source
Tidal Lagoon Power (2011 - 2018)	Swansea Bay Tidal Lagoon	NSIP Planning Portal Hendry Review Select Committee Inquiry Government Response
	Cardiff Lagoon	NSIP Planning Portal
	Newport Lagoon	Hendry Review
	Bridgwater Bay Lagoon	Hendry Review
TEES (2016 to date)	West Somerset Lagoon	Project Website Summary Report (not available on line)
DST Innovations (2021)	Blue Eden Project (formerly Dragon Energy Island)	Swansea City Press Release
(2023 to date)	Great Western Power Barrage	Project Website

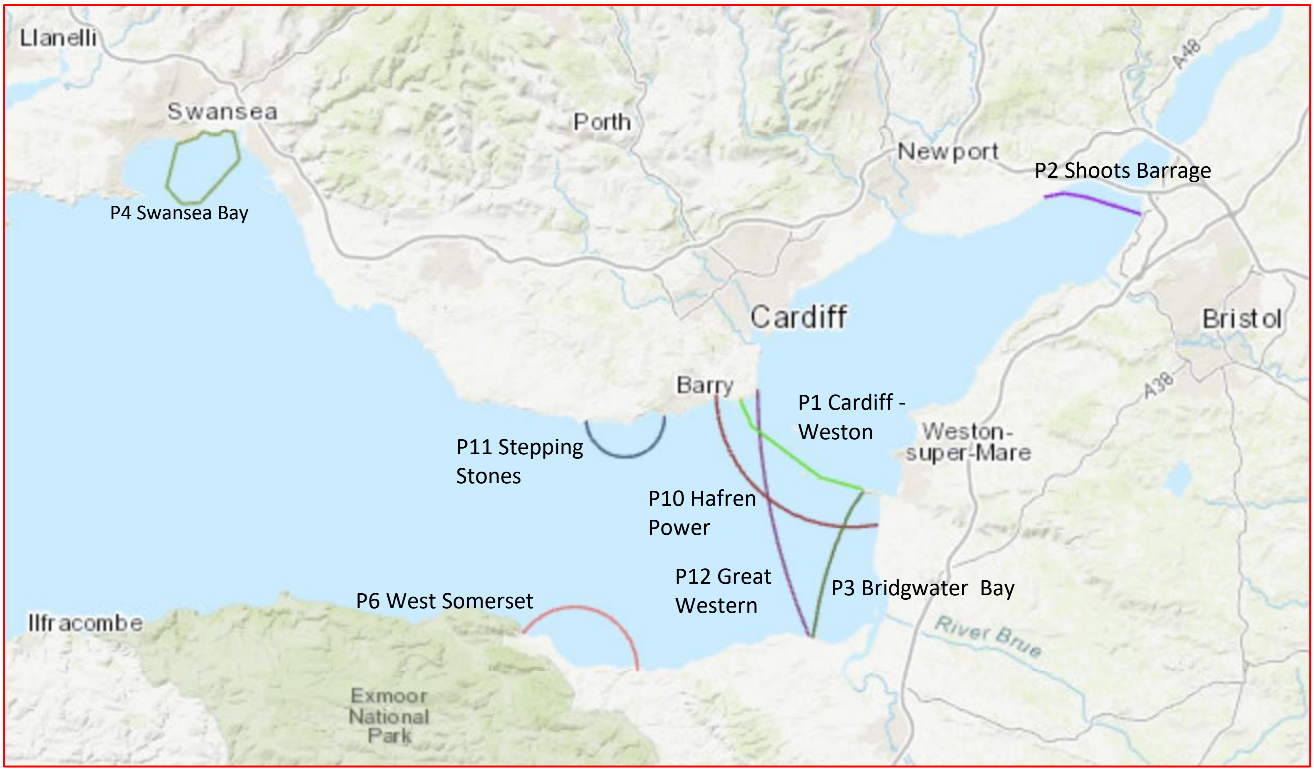


Figure 15 Severn Estuary Tidal Power Projects

Figure 15 shows the location of the different projects referenced above that are either active or identified as potentially feasible in the STPFS. The Hafren Power proposal has also been included because, although it failed to secure support when promoted in 2013, nevertheless, it has similar unit costs to the STPFS shortlisted projects.

Other UK Projects Considered

Table 3: UK Tidal Range Power Projects

Developer	Project	Data Source
The Wash Tidal Barrier Corporation (2008)	The Wash Barrage	Project Website
Peel Energy (2009 – 2011)	Mersey Tidal Barrage	Ocean Gateway Website
Solway Gateway (2009 – 2011)	Solway Barrage	Solway Energy Gateway Website
Britain's Energy Coast (2009 - 2010)	Duddon Barrage	Duddon Estuary Feasibility Report (not available on line)
Natural Energy Wyre / Simec Atlantis (2012 – 2016)	Wyre Barrage	Natural Energy Wyre Website
North Wales Tidal Energy (2012 – date)	North Wales Tidal Lagoon	Project Website
Tidal Lagoon Power (2014-18)	West Cumbria Tidal Lagoon	Hendry Review
Tidal Lagoon Power (2014-18)	Colwyn Bay Tidal Lagoon	Hendry Review
Northern Tidal Power Gateway (2014 – date)	Morecambe Bay to Duddon Estuary Barrage	NTPG Website
Port of Mostyn (Mostyn SeaPower) (2018 – date)	Mostyn Lagoon	Port of Mostyn Website
Liverpool City Region Combined Authority (2018 – date)	Mersey Tidal Power	LCR-CA Project Update Website
Centre Port Holdings (2023)	The Wash Barrage	Project Website

Table 4: UK Tidal Power Projects – Tidal Stream

Developer	Project	Data Source
EMEC	EMEC Tidal Stream Test Site	EMEC
SAE Renewables	Meygen Tidal Stream Development	SAE Renewables

Developer	Project	Data Source
Fair Head Tidal (DP Marine Energy and BDME)	Fair Head Tidal Stream Project (dormant)	Fair Head Tidal (DP Marine Energy and BDME)
Formerly Tidal Ventures Ltd (now dissolved)	Torr Head Tidal Stream Project (dormant)	Northern Ireland Department for the Economy
SEA Renewables	Strangford Lough Demonstration Project (decommissioned)	Recharge News
Formerly SEA Renewables	Skerries Tidal Array, Anglesey (discontinued)	Tethys OES Environmental Metadata
Minesto	Minesto - Holyhead Deep, Anglesey	Minesto Project Website
Menter Mon	Morlais – Holyhead, Anglesey	Menter Mon Website
Nova Innovations	Bardsey Island - Enlli Tidal (dormant)	Marine Energy Wales
Tidal Electric	Ramsay Sound, Pembrokeshire (decommissioned)	Tethys OES Environmental Metadata
META	META Test Site, Pembrokeshire	META Website
Perpetuus	Perpetuus Test Site, Isle of Wight	Perpetuus Web Site
n/a	Tidal Stream Potential Locations	Jan 2012 Cardiff University Paper by Kadiri, Ahmadian, Bockelmann-Evans, Falconer

International Projects Considered

Table 5 International Tidal Power Projects

Country	Project	Data Source
Canada	20 MW Annapolis Royal Tidal Barrage, Bay of Fundy (1984 to 2019)	Tethys OES Environmental Metadata
Canada	1MW Open Hydro Tidal Stream, Bay of Fundy (2018-19)	News Article
Canada	Fundy Ocean Research Centre for Energy (2009 – date)	Force Website

Country	Project	Data Source
China	960 kW BaiShakou Tidal Power Station (1978 – 2011)	Tethys OES Environmental Metadata
China	4.1 MW Jiangxia Pilot Tidal Power Plant (1980 – date)	Tethys OES Environmental Metadata
France	240 MW La Rance Barrage (1967 – date)	EdF Website La Rance - 50 Years Operational Feedback - Lessons Learned BHA Conference 2009 (not available online)
Netherlands	1.25 MW Oosterschelde Tidal Power Project (2015 – date)	Tethys OES Environmental Metadata
South Korea	254 MW Sihwa Barrage (2011 – date)	Tethys OES Environmental Metadata
South Korea	1 MW Uldolmok Tidal Power Station (2014 – date)	Tethys OES Environmental Metadata

Assessment

The accompanying Western Gateway Tidal Energy Evidence Base workbook provides more details of these projects but the key conclusions, from a global perspective, are:

France and South Korea are the only countries to have developed large scale tidal power plants, both based on tidal range technology. La Rance was constructed in 1967 and has been operational ever since with only one major refurbishment (servicing of the turbines and replacement of the control system). It was constructed in a cofferdam that spanned the estuary and consequently the original eco-system declined and has been replaced with a new, different eco-system reflecting the changes in water levels. This would not be acceptable today. It was the most expensive form of power on the EdF system when it was first built but it is now the least expensive and has the benefit of being operated flexibly to stabilise the grid as well as producing low carbon energy. The Sihwa plant was constructed more recently in 2011 and is a tidal power plant retrofit into an existing tidal lagoon.

Other international projects have been small in scale – the largest at Annapolis Royal in the Bay of Fundy was a single 20MW turbine installed to enable monitoring of environmental conditions as a fore-runner to a larger tidal barrage. It was constructed in 1984 and continued in operation until 2019 when it suffered an equipment failure. It was decommissioned in 2021 after it was refused an environmental licence that would have enabled the failed equipment to be replaced. The Bay of Fundy has subsequently focused on the development of tidal stream technologies using its FORCE programme to help tidal stream developers undertake the appropriate consenting and monitoring required for testing.

China has developed two power plants, both relatively small, and only one continues to operate. The Netherlands has trialled a retrofit turbine on its flood defence structures but again this is small scale at present.

In the UK, the only examples of tidal power in operation have been using tidal stream technologies, again mainly as test beds for future development. A 1.2MW twin rotor turbine at Strangford Lough in Northern Ireland was the first grid connected turbine and this operated from 2008 to 2019. There have been many proposals for tidal stream developments in the key resource areas of Anglesey, Orkney and Northern Ireland but with some exceptions, these have been characterised by developers withdrawing or mothballing their proposals. The exceptions are the MeyGen project in the Orkneys being developed by Simec Atlantis Renewables (SAR) and the Anglesey projects by Mentor Mon at Morlais and Minesto at Holyhead.

The MeyGen is the most advanced of these, having secured a Crown Estate lease in 2010 and now has 6MW of tidal stream capacity deployed. There is potential for 398MW of tidal stream in total, but costs require extensive subsidy at the moment through grants from The Crown Estate and Scottish Government. The UK Government allocated £20m of ring fencing to tidal stream in the fourth CfD auction, the majority of which benefitted the MeyGen project which received a CfD contract of £178.54/MWh for 28MW of new tidal stream development.

The Morlais project in North Wales is also making progress having received planning consent and is now focusing on grid connections which will be shared with the Minesto Holyhead development.

There have been no tidal range developments in the UK although there have been many projects studied since the early 1980’s. In 2023, projects are being promoted by public authorities including the Liverpool City Region Combined Authority (Mersey Tidal Power) and Swansea Council (who are facilitating the Blue Eden project in Swansea Bay). There are also projects being studied by the private sector including a tidal lagoon on the Somerset coast, a tidal lagoon at the Port of Mostyn and the Blue Eden project. A challenge for the private sector is the scale of tidal range projects which have more in common with large infrastructure projects conventionally promoted by public agencies. New nuclear projects have faced the same challenge and, assisted by UK Government energy policy, they now have access to Regulated Asset Base (RAB) financing which reduces the cost of energy by up to 40% albeit at the expense of charging consumers during the construction period.

Analysis

The numerical analyses have been undertaken on those projects in the Severn Estuary are undertaken in the accompanying Excel workbook but are reported on in summary form in this section. The analysis has looked at all the credible projects that have been studied over the past five decades. They are presented as individual projects for those that have been shortlisted for more detailed study from the various research programmes along with individual projects being promoted by the private sector. Projects that were not shortlisted from the research programmes are also included although the depth of analysis is less detailed.

The projects that were analysed in detail are set out in Table 6:

Table 6: Potential Severn Estuary Tidal Power Projects

Reference	Project	Notes
P1	Cardiff to Weston Barrage (STPFS)	This is traditionally referred to as The Severn Barrage originally proposed by the Bondi Review in 1981, developed in more detail by STPG in the 1980's and studied by STPFS in 2008.
P2	Shoots Barrage (STPFS)	This was originally referred to as the English Stones or Hooker Barrage as a smaller alternative to the Severn Barrage.
P3	Bridgwater Bay Lagoon (STPFS)	This was identified as a viable tidal lagoon by STPFS in 2009.
P4	Swansea Bay Tidal Lagoon (TLP and Blue Eden)	The Swansea Bay Tidal Lagoon was first conceived by an American entrepreneur in the early 2000's but rejected in a subsequent DTi report in 2006. Other developers considered the concept before TLP developed it in detail between 2011 and 2018. Swansea Council then facilitated an alternative approach which has resulted in the Blue Eden project.
P6	West Somerset Tidal Lagoon (TEES)	The West Somerset Tidal Lagoon is located in the middle estuary to the West of the Hinkley Point Nuclear Power Station. It is promoted by a small group of retired tidal power professionals.

Reference	Project	Notes
P10	Cardiff Weston Tidal Bar (Hafren Power)	The tidal bar was proposed by Hafren Power as a low head tidal barrage using a new type of large diameter high flow turbine (not in commercial development). It was the subject on a Select Committee Inquiry in 2013 and did not progress.
P11	Stepping Stones Tidal Lagoon (post STPFS)	The Stepping Stones Tidal Lagoon is located in the middle estuary to the East of Aberthaw Power Station. It was conceived after the STPFS concluded to assess whether there were benefits to developing a proposal in this location.

There was also a project referenced P12 which has been initiated in 2023 called the Great Western Power Barrage. This has not been studied in detail because the developer has not yet undertaken any detailed studies.

GIS data has also been developed giving a snapshot of the different tidal projects in the Severn Estuary with a brief summary. An example of the GIS output is shown in Figure 16. The outer estuary is considered to be west of Minehead and the inner estuary east of Barry.

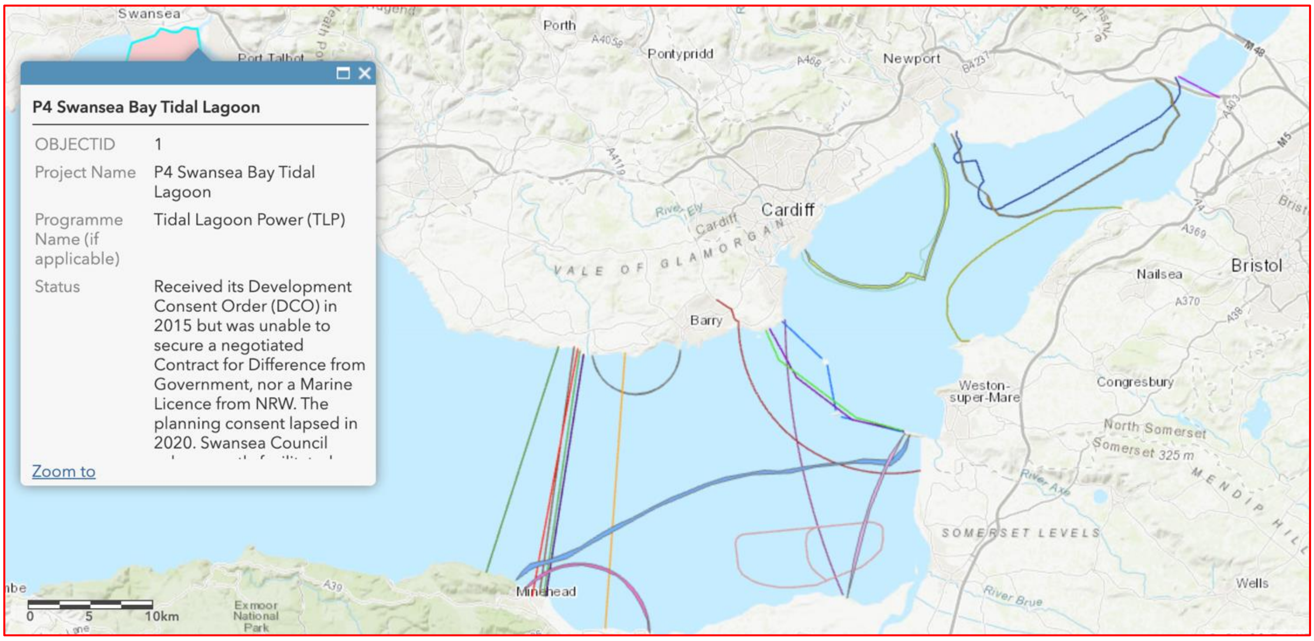


Figure 16: Screenshot of GIS Output showing tidal power projects and an example of a call-out data card.

The project analysis has been undertaken in terms of cost of energy based on an 8% discount rate (the private sector proxy rate) which amplifies differences between the proposals to aid interpretation. The graph below shows the distribution of project cost of energy performance against installed capacity. The larger the circle, the greater the error bounds of the developer's data.

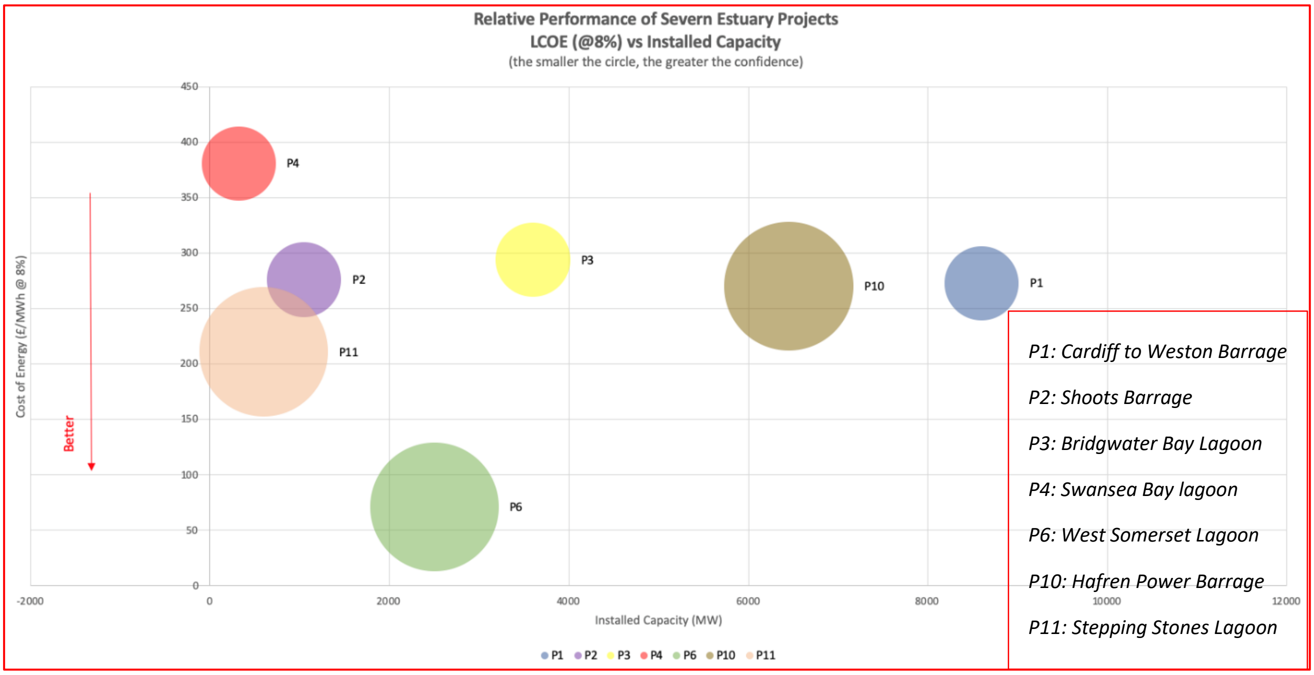


Figure 17: The relative performance of tidal power projects shown in unit energy costs and installed capacity

The second graph in Figure 18 is similar except that the results are plotted against the ratio of energy output and capital expenditure. The best projects are those located closest to the x axis and furthest to the right from the y-axis.

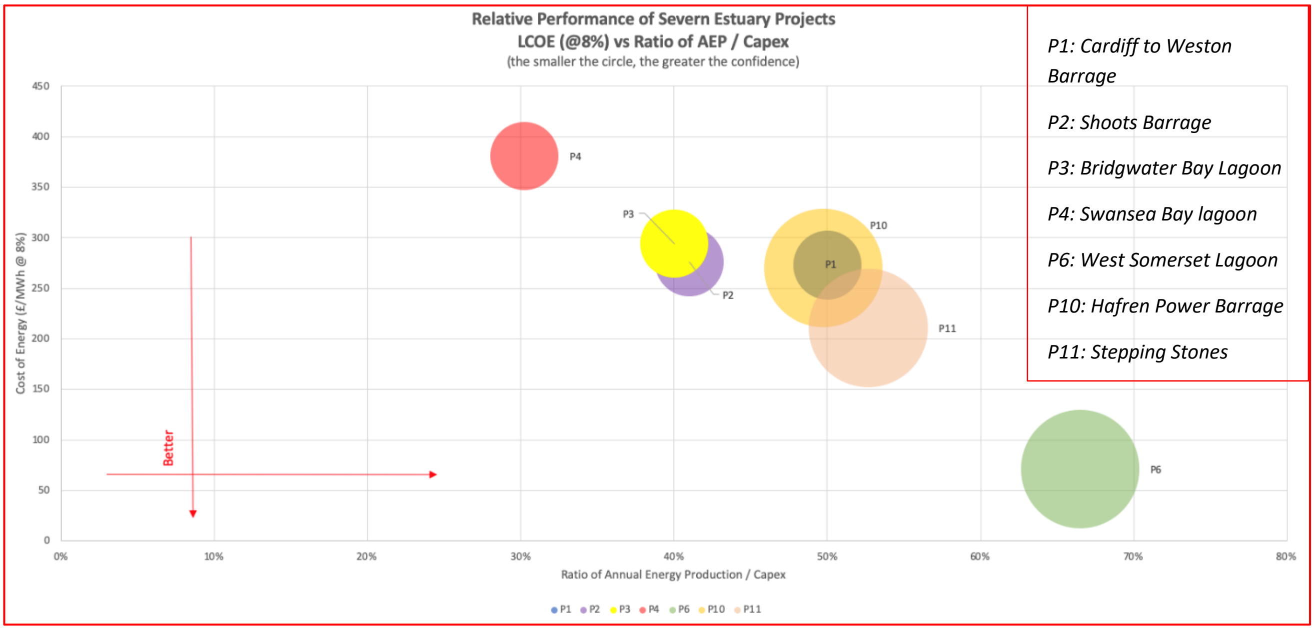


Figure 18: The relative performance of tidal power projects shown in unit energy costs against ratio of Energy to Capex.

These graphs show that Projects P6 (West Somerset Tidal Lagoon) and P11 (Stepping Stones Tidal Lagoon) are the best in terms of performance but with significant caveats around confidence of costs and energy outputs as they have not been subjected to detailed study. However, both these projects are located in the middle estuary which has fewer environmental designations and suggests that this should be a priority area for the Independent Commission to review when assessing potential tidal power locations. The previously favoured Cardiff to Weston alignment (P1 and P10) also comes out strongly in this analysis whilst the Shoots Barrage (P2) and Bridgwater Bay Lagoon (P3) appear less efficient. Swansea Bay Tidal Lagoon (P4) is the least efficient and most expensive of the options considered.

The Projects not shortlisted for detailed study are included in the programmes set out in Table 7:

Table 7: Tidal Power Programmes featuring projects not shortlisted for further study.

Reference	Programme	Notes
P5	Tidal Lagoon Power (TLP)	TLP's programme of Severn Estuary lagoons after Swansea Bay were Cardiff, Newport and Bridgwater Bay
P7	Severn Embryonic Technologies (SETS)	SETS projects were undertaken as a parallel workstream to the STPFS and the programme was designed to explore whether embryonic technologies could provide a more environmentally acceptable solution.
P8	Severn Tidal Power Feasibility Studies (STPFS) – Phase 2	Phase 2 of the STPFS studied five projects in detail but two of these were not considered to be viable projects and are covered in worksheet P8.
P9	Severn Tidal Power Feasibility Studies (STPFS) – Phase 1	Phase 1 considered a long list of potential tidal power projects – of these five then progressed to be considered in more detail in Phase 2 – those that didn't progress to Phase 2 are covered in worksheet P9.

The accompanying Excel workbook under the worksheet *Summary of Outputs* also includes an analysis of both the projects and programme cost ranges in terms of cost of energy using the 8% (private sector) and HMT (public sector) discount rates and the RAB modelling outputs to highlight the different cost of energy arising from the different financing scenarios. Details of the financing scenarios is included as Appendix D.

Conclusions

Reflecting on the progress made to date, internationally, nationally and in the Severn Estuary, it is clear that the status quo is unsatisfactory, particularly so far as tidal range (which is the best tidal resource in the Severn Estuary) is concerned.

In addition to influencing future policy improvements for tidal range projects, the analysis of past projects and programmes confirms the following:

- Tidal lagoons are preferred to the larger tidal barrages in the Severn Estuary because of the potential economic impacts associated with the latter in enabling commercial shipping to continue uninterrupted but smaller barrages such as the Shoots may also be a viable option;
- On the basis of the analyses above, the middle estuary appears to offer the best possibilities for development of new tidal range projects with a high tidal range and fewer environmental designation areas, although changes in the hydrodynamic regime may impact adjacent designated areas. Accordingly, the Cardiff Lagoon or the Shoots Barrage, which are both located in protected areas, also merit continued consideration whilst all options, including the larger barrage proposals, should not be prematurely discounted, pending discussion with key stakeholders;
- Existing projects have used conventional methods of marine wall construction and the tidal power sector would benefit from a research programme to review and test new, less expensive and/or material intensive forms of impounding wall construction, particularly in areas such as the middle estuary where ground conditions include rock. Similarly, research into more innovative forms of infrastructure financing and overcoming environmental uncertainties would be merited;
- Environmental impacts have traditionally been considered in parallel with or after the development of conceptual designs – there is merit in including environmental matters in at the initial concept design stages to promote the best engineering and environmental solution.
- Achieving 10% biodiversity net gain has not been considered in previously studied projects – this will also require a different approach.

Section 4 of this report brings together the lessons learned from both policy and project considerations.

4 ANALYSIS OF LESSONS LEARNED

Introduction

This section provides a brief summary of the key lessons learned from the analysis of previous projects and associated Government policies. Some of these are included elsewhere in this report but reproduced here for ease of reference.

What has Changed

Emphasising what has changed since the last tidal power projects were considered and rejected by Government. Changes include:

- Increased urgency in achieving net zero to mitigate the effects of climate change – primarily excessive heat and the impact on human health, economic activity, increased flooding and droughts and sea level rise;
- Instability of world energy markets arising from an imbalance of supply and demand, exacerbated by the war in Ukraine and also the need to increase electricity demand in order to decarbonise the heat and transport sectors;
- Need for long term security of cost as well as security of supply, affordability and low carbon generation;
- Of the 26 years remaining to 2050, the majority of the UK wind turbine fleet will require re-powering, solar panels replaced and electricity transmission and distribution grids upgraded. As it typically takes ten years to consent new projects and nearly as long to build them, there is an urgency for a fresh review of tidal power policy to capitalise on existing knowledge and increase relevant workplace / supply chain skills (in addition to those required for nuclear / hydrogen / wind / solar projects).

Lagoons vs Barrages vs Tidal Stream

The last major Government study into the development of tidal power from the Severn (the Severn Tidal Power Feasibility Study or STPFS in 2010) identified that tidal lagoons, although more expensive in cost of energy terms (10 to 15%), offered some significant benefits over the tidal barrages for areas located downstream of the Ports of Bristol and Newport. Primarily, a tidal lagoon does not impose an obstacle to commercial shipping. Unlike a barrage, it can also be scaled to reduce adverse environmental and hydrodynamic impacts although a smaller impounding basin will produce less energy. However, a barrage located upstream of the main Severn Ports in the Shoots channel also showed some benefits with reasonable energy generation, a lower environmental footprint and a shorter length of marine wall compared with a tidal lagoon of similar power output. The STPFS also studied tidal stream technologies, configured as tidal fences but, whilst their impact on the environment was relatively low, so too was their energy output whilst costs were high. Energy output was constrained by the relatively low tidal currents.

A concern with multiple projects developed in one estuary is the impact of cumulative development. Each successive project will have an impact on the wider hydrodynamic regime and this is likely to have an adverse impact on cumulative energy generation as further projects are developed. Aside from the legal complexities if the projects are developed by different organisations, there is a need to understand the impacts from cumulative development of two or more tidal range projects in the Severn Estuary in terms of energy yield and also on the environment, flood risk and access to ports.

Stakeholder Engagement

The Severn Tidal Power Feasibility Study (STPFS) undertaken between 2008 and 2010, by its nature, required a comprehensive approach to stakeholder engagement. The work involved a Strategic Environmental Assessment and the opportunity was taken to include non statutory consultees on the SEA Steering Group which oversaw the SEA process. By providing stakeholders such as the consortia of nature based NGO's led by RSPB, and the Severn Estuary ports with formal representation at the start of the project, more informed discussion was achieved with fewer defensive positions taken. Other stakeholders such as Friends of the Earth and Greenpeace were also engaged with at an early opportunity so that they could use the emerging evidence base to inform their own positions. In addition, there were large stakeholder events, attended by as many as 400 people. This encouraged a wide spectrum of views, enabled everyone to be heard and allowed an informed consensus on the approach to be followed.

In order to manage the complexities of stakeholder engagement, the STPFS had five stakeholder engagement groupings as follows:

- Ministers, MP's and AM's
- Media
- Statutory Consultees, including the designated Harbour Authorities
- Local Authorities
- Special Interest Groups including NGO's, commercial interests such as the ports and campaign groups, professional societies and the General Public

Each had a different focus and with the exception of the public meetings for the general public which acted as an opportunity to update on project progress and early findings. The stakeholder engagement with special interest groups was facilitated by their representation on the SEA Steering Group.

The Swansea Bay Tidal Lagoon team at Tidal Lagoon Power also consulted early but adopted a slightly different approach. Their early focus was to engage locally with politicians, NGO's and the general public to develop a groundswell of positive public opinion to facilitate their discussions with central government and the statutory consultees. This proved successful in part but earlier and more substantive / collaborative engagement with NRW may have resulted in an earlier determination of their marine licence (in practice the planning consent lapsed before the marine licence assessment concluded).

The key lessons here are to engage widely and early, and to be transparent with emerging data analysis.

The STPFS and Swansea Bay demonstrated the importance of stakeholder engagement and a key learning for future projects is not to under-estimate the time and cost of effective stakeholder engagement.

It also became apparent that the specialist stakeholder engagement firm used initially in the STPFS was not as effective as using the members of the technical and client teams to undertake the stakeholder engagement. This change provided an enhanced degree of transparency and honesty.

Some external organisations such as professional societies and the RSA held their own events in addition to the STPFS engagement and these were attended by at least one member of the project team to ensure a balanced approach was taken.

Management of Long Term Projects

Tidal Range power projects have a life of 120 years or more and there is a need to ensure that the public sector is involved in oversight if not direct engagement. The Sustainable Development Commission in their 2007 Report "Turning the Tide" concluded that large long life projects should not be developed in the private sector alone but that long term risks and rewards should be retained by the public sector on behalf of the population. This is particularly important when it comes to operational benefits following the financing phase and the question of future decommissioning (and the associated influence / requirements from The Crown Estate) and adaptation of the assets to future risks such as sea level rise.

The application of a RAB financing methodology or similar public sector innovative financing mechanism would provide the public sector oversight required through the regulator whilst allowing the private sector to do what it is best placed to do, namely finance, build and operate the asset within a regulated framework.

Financing of Large Scale Infrastructure Projects in the Energy Sector

The Government's Energy Act of 2012 saw the introduction of two primary market mechanisms to ensure the Government's energy strategy objectives were realised. These were:

- the Contracts for Difference (CfD) regime for low carbon generation where developers agreed to a strike price (the price per kWh they would be paid, now set by auction) and a contract length (standardised as 15 years or 60% of the projected asset life), and
- the Capacity Mechanism which is auction based and pays generators a premium to generate power at short notice to balance the system.

It is not possible to benefit from both mechanisms. This creates an issue for tidal range in that tidal power can generate both low carbon power and be used as a fast demand response to stabilise the grid, as EdF do with the La Rance tidal barrage.

A recently closed Government consultation on changes to the CfD from 2024 includes proposals to look at the interaction between the CfD scheme and Capacity Mechanism on matters of eligibility and the potential consideration of whether other factors beyond price should be taken into account in contract awards. However, the key point about tidal range projects is that they are not the same as modular wind and solar power projects but large infrastructure projects that have to be constricted as a single entity rather than in phases. Consequently, the "one size fits all" approach of the CfD as being the only mechanism to incentivise low carbon power generation is not appropriate.

This has been recognised by the Government who are now taking a different approach to financing new nuclear projects using a Regulated Asset Base (RAB) approach. Tidal Power shares many similarities with new nuclear including generation of predictable low carbon energy, high capital cost and long asset lives. It therefore seems logical that adopting a RAB or potentially different but equally innovative financing approach to tidal range, is merited subject to further analytical and regulatory considerations. If a regulated approach is used, this could also address the issue of public oversight of the long life responsibilities of a tidal power project whilst also mobilising the skills of the private sector in financing, constructing and operating a tidal power project. To illustrate what is being proposed for new nuclear power stations, further detail on RAB financing is set out in Appendix D of this report.

Integrity of Project Information

A common issue with the tidal power projects proposed by the private sector is a tendency for over-optimism in construction costs and programme duration. This is exemplified by the Swansea Bay Tidal Lagoon proposals by TLP. In 2014, their published estimate of the cost of construction was between £800m and £900m. It was on the basis of this figure that they submitted their Development Consent Order (DCO) application for examination. By the time the DCO had been determined some 18 months later, the published costs were in excess of £1.3bn. This challenged their business case and the evidence of the analyses undertaken in this report suggest that, of the many projects considered in the Severn Estuary, there are other projects in locations further upstream and of larger size with better financial potential. However, the key points here are not relative performance levels but taking time to develop reliable cost estimates and realistic construction programmes. A key to this is the initial investment in critical investigations that can have an influence on cost estimates.

In the case of Swansea Bay, more extensive ground investigations would have improved confidence levels of construction costs whilst earlier and more collaborative consideration of the fish impact studies would have reduced post consenting delays. TLP, Swansea Bay Tidal Lagoon's developer, did procure tenders from credible tidal power supply chain participants, and proceeded with a value engineering exercise. With hindsight, earlier engagement with the supply chain rather than a post tender value engineering exercise may have resulted in a more equitable financial result. Similarly, earlier engagement with the environmental regulators may have resulted in less contentious issues being considered as part of the marine licence determination. The root cause of these issues was a degree of (understandable) impatience on behalf of the developer and investors so that the overall development programme was overly ambitious and resulted in the opposite of what it set out to achieve.

Assessment of Construction Costs and Energy Outputs

This is described in more detail in Appendices A and B which describe how the cost and energy estimates from previous studies have been converted into parametric values to enable independent assessment of project costs and energy outputs. The values used for the outputs from the various projects referenced in this report have been taken directly from the study or developer's published figures and uprated to 2023 values. The independent assessment has then been used to qualify any claims made by a study or developer if there is a significant variance and also to categorise how robust a project's claimed figures are. This is indicated by the size of the circle in the analysis graphics set out in Section 3 of this report – the larger the circle, the larger the variance between the developer's data and the independent assessment carried out as part of this report.

Programme

For the Independent Commission, it will be important to develop a programme that is realistic from the outset and allows adequate time for consultation, engagement and negotiation. Whilst there will be an inevitable tension between the time taken and the cost of resources, potentially at-risk during the development phase, the final outcome will be improved. However, this does mean appropriate budgeting will be one of the most important activities during the development phase. It also means that development investment should be focused on the project most likely to succeed with an options assessment and risk management process undertaken early in the development phase.

Risk Management

Tidal range projects have high capital costs and the associated development costs are correspondingly high (around £20m per £1bn of construction cost). Costs from inception to financial close (immediately before construction commences) are considered very high risk as there is no guarantee that they will be recovered. They are in essence sunk costs until and unless a positive final investment decision is made. Such costs cover:

- conceptual and detail design, including site investigation, bathymetric and land surveys
- consultation and stakeholder engagement activities
- consenting and licensing costs including preparation of DCO application, associated EIA and bilateral agreements with landowners and other interested parties
- land ownership / leasing costs (unless these are conditional on the project going ahead)
- preparation of tender documentation and assessment/negotiation of tenders
- negotiations and fees for grid connection agreements
- negotiations with Government on RAB or CfD
- negotiations with investors, and
- appointment of contractors.

The construction phase is also high risk in that increased costs and delays can reduce returns to investors. Financing rates tend to reflect this. Once the construction phase is complete, and the plant is operating satisfactorily, the residual risks are low and financing rates can be renegotiated to reflect this.

How to manage the initial project development risks from the outset will be a critical function for the Independent Commission to consider.

Management of Habitat Loss and Biodiversity Net Gain

The requirements for management of impacts on habitats is largely set down in legislation and a new requirement is to provide an increase of 10% biodiversity net gain (BNG) related to any project. One of the lessons learned from the STPFS was that, whilst legislation provided the framework, it did not consider some of the more detailed ramifications. For example, in terms of lost inter-tidal habitat and its compensation requirements:

- the required compensation ratio - 1:1 equates to replacement of an equal amount of new habitat but because new habitat may not be as effective as the older habitat it is replacing, a larger area may be required to compensate. The STPFS used a range of 1:1 to 1:3 with the central figure of 1:2 used in the final analysis. However, there were limited case studies and monitoring programmes to confirm which ratio should be used and over what time a new habitat would become effective. This resulted in compensation ratio's being potentially higher than needed (although a higher ratio may facilitate achievement of 10% BNG).
- The issue of where to locate the compensatory habitat split expert opinion with some stating that it had to be close to the lost habitat and others arguing that it was feasible to locate it elsewhere providing the integrity of the EU's Natura 2000 network was maintained;
- Barrister opinions on the interpretation of the compensatory habitats requirements also differed, primarily around the IROPI principle (Imperative Reasons of Overriding Public Interest) and the definition of reasonable alternatives. The Government later published further guidance on this here.

There is a case for more powerful circular economy principles to be applied at an early stage of project development to recognise the benefits of using waste material such as surplus soil (transported by sea) in the creation of new habitats as has been achieved with the spoil arising from the Crossrail project in London which provided the fill for the Wallasea nature reserve. 3.5 million tonnes of the earth were shipped to Wallasea to form a mosaic of lagoons, islands and bays. According to the RSPB, 12,000 wintering birds arrived within 2 years of construction and those numbers have increased to 20,000 today. Data such as this is useful in determining how quickly compensatory habitats can become effective and therefore what compensation ratio should be applied.

Energy Systems Considerations

Tidal range power operates either twice or four times per day depending upon the mode of operation. Lagoons typically generate more energy if operated on the ebb and flood tides (four times per day). Each tidal cycle is approximately 12.5 hours in length and there will be periods, as the tide is turning, where operation is not possible. Rather than thinking of a tidal range project as a single project, it is more beneficial to think of tidal power's contribution to the wider energy system. For example, unlike wind or solar, tidal power operates every day of the year and is predictable over its entire operating life (nominally 120 years). Previous studies have tended to focus on the maximum amount of low carbon energy that can be generated as that is how the UK's energy system values low carbon energy.

A key lesson going forward is to consider the systems benefits of tidal power. It can be used in a number of different ways:

- It can either generate the maximum number of low carbon kWh, or
- because it is predictable, it can be brought on line to inject energy into the grid very quickly to stabilise the grid's frequency response (for example if a sudden surge in demand is experienced) albeit at the loss of some kWh from the optimal operating regime;
- if synchronous generators are used, it can both generate the maximum number of low carbon kWh and provide spinning mass inertia to the grid to maintain grid frequency with fewer external grid interventions required;
- it can be used in a private wire arrangement as the energy source for green hydrogen, or as part of an integrated grid based energy source for hydrogen production alongside nuclear, providing off-peak energy for green hydrogen production;
- it can increase South Wales and/or West and South West England's low carbon generation capacity with the associated resilience benefits.

Management of Environmental Uncertainties

One of the key outcomes from the STPFS, and re-affirmed by some aspects of the Swansea Bay Tidal Lagoon consenting process, was the importance of understanding uncertainty, particularly in relation to the ecological impacts. This requires early dialogue and analysis so that all parties (developers, stakeholders, regulators, decision makers) understand the extent and sensitivities of different uncertainties and can develop appropriate strategies to enable jointly agreed modelling with realistic error bounds to enable consenting decisions to be made. This is particularly important with respect to fish and potential impacts on their populations from tidal range developments. This also extends to compensatory habitats (discussed above) and the challenges of accurately assessing cumulative sedimentation (where any mathematical modelling accuracy limits may also be compounded to over or under estimate siltation). Other uncertainties include consideration of far field effects (such as increase in water levels on other countries) and the effect of prolonged standing water levels on old flood defence structures.

Specific lessons learned are summarised below:

Fish

Severn Tidal Power Feasibility Study (STPFS)**:** Uncertainties, such as the lack of data available for fish, the impact of turbines on fish and other marine life and any other data source where there were insufficient records made reaching definitive conclusions problematic in the STPFS. Other uncertainties related to the potential timings, locations, costs and replacement ratios for compensatory habitats and the impacts of numeric modelling boundary locations / conditions.

Swansea Bay Tidal Lagoon: No marine licence was awarded due to a dispute on fish modelling processes and outcomes. Mortality rates are likely to increase with two-way operation and use of pumping compared with ebb only generation. If the Blue Eden project wishes to take a similar approach to the Swansea Bay tidal lagoon, it should seek to identify how it can improve on the design and processes used by TLP so that these issues are addressed.

Sedimentation and Flooding

STPFS: Tidal power projects can both reduce and increase flood risk. With the Cardiff Weston Barrage, there was concern that the standing high water level prior to generation combined with wind driven wave action could damage upstream flood defences. Land drainage systems may be tide locked for longer or not operate at all requiring new pumping stations. The barrage itself presents a reflective wall which can increase flood risk downstream of the barrage and also cause far-field flooding impacts in Cardigan Bay and potentially on the east coast of Ireland. However, the presence of a barrage can have positive impacts such as protecting upstream areas from the impacts of sea level rise and storm surges. Located further upstream, the Shoots Barrage shares some, but not all, of the conflicting outcomes but with an increased risk of sedimentation due to its more upstream location.

Swansea Bay: The challenge of managing the turbine wake and associated sedimentation into the impounding basin was raised as a concern following modelling by Cardiff University.

Habitat Compensation and Biodiversity Net Gain

STPFS: Cardiff to Weston Barrage: The scale and potential locations of the compensatory habitat required to offset inter-tidal habitats lost because of changed water levels once the barrage was operating was a major challenge. Although there were a number of successful habitat compensation projects in the Severn (notably the Newport RSPB reserve built as compensation for the Cardiff Bay Barrage and the EA's Steart Peninsula), the scale of compensation required would have resulted in other locations in the UK and possibly Europe being considered to provide the required areas. There was also the possibility of legal disputes as the EU's Habitats Directive was unclear in some respects and potentially contradicted the EU's Renewables Directive, forcing the Government to write to the EU requesting clarification. The Shoots Barrage and Bridgwater Bay Lagoon projects, because they were smaller, had reduced impacts on inter-tidal habitats. Although the potential locations for compensatory habitats have not been identified, it is more likely that suitable sites could be identified within the Severn Estuary. One of the original design concepts for the Shoots Barrage identified the use of poldering to stop silt moving through the barrage and create new habitat. The Bridgwater Bay Lagoon, because it uses ebb and flood mode of operation, has the lowest loss of inter-tidal habitat related to its energy output.

Biodiversity Net Gain (BNG)

The current requirement for BNG, is that above the Mean Low Water Springs at least 10% habitat compensation is required. Any marine net gain habitat compensation below the Low Water Spring Mark is still in the process of being clarified by DEFRA, for implementation on marine schemes and is a complex process involving numerous factors where a different approach to net gain could be required. The concept of BNG was not a factor in the development and/or. Studies of previous proposals but would be related to the ratio of compensatory habitat areas required with a 1:1 ratio no longer being acceptable.

Political Engagement

Political engagement features in a number of lessons learned. One of the most intense periods of political engagement was for the Severn Tidal Power Feasibility Study (STPFS) which was itself commissioned by the Government. Although the work was led by BERR / DECC, it also involved HM Treasury, the Cabinet Office, Defra, DfT, DCLG, the Welsh Government, Government Office for the South West and South West Regional Development Agency. Consequently, political engagement and knowledge of the study was high and it also attracted strong media interest at the time. However, a change of Government and tidal power policy demonstrated how quickly political engagement can be lost.

The announcement in 2010 that the newly elected Coalition Government was not supportive of public funds going into tidal power development in the Severn Estuary resulted in a widespread loss of interest not just from politicians but officials, stakeholders and the media.

Hafren Power's emergence following the Energy Minister (Charles Hendry) announcement that the private sector could propose tidal power projects to the Government providing they didn't require public funds, prompted a renewed interest – at least in stakeholders and the technical press. Statements that Hafren Power had meetings with the Prime Minister following the publication of their proposals prompted a Select Committee Inquiry (A Severn Barrage) in 2013. The evidence to the Inquiry largely was against the proposal and the Government Response confirmed that their policy would remain unchanged by the Hafren Power proposal. The Hafren Power proposal differed in some respects from the STPFS study in that it proposed a new type of turbine (not yet developed commercially) and operation using low head differences resulting in reduced loss of inter-tidal habitat. However, it proposed using a Parliamentary Bill to achieve consenting and was generally very optimistic in its claims.

The next private sector proposal came from the Swansea Bay Tidal Lagoon who focused initially on building public sector support and associated political support. It secured its Development Consent Order in 2015 but there were subsequently major political changes following the Brexit referendum which resulted in some discontinuity in political support. It was also noteworthy that the negotiations for a CfD were absorbing officer time and appeared to be less promising than the equivalent negotiations taking place for Hinkley Point C. In 2016, the Government concluded that the Swansea Bay did not offer adequate value for money to be considered for a negotiated CfD. Interestingly the Welsh Government took a different view but this was insufficient to influence the Government's position.

In 2018, the Mayor of Liverpool City Region's Combined Authority launched the Mersey Tidal Power project. Although this project has received internal funding and is progressing to the preparation of a DCO application, the Government has not amended its tidal energy policy to accommodate this initiative. It is not known how much political engagement has been undertaken with regards to the Mersey Project but the summaries above show that positive and continuous political engagement will be a pre-requisite for Western Gateway's energy initiatives. The Western Gateway APPG is a helpful contributor in this regard but a key challenge to overcome is the history of failed tidal energy projects and the potential apathy that might, as a consequence, exist when tidal energy, particularly tidal range, is discussed in the Department for Energy Security and Net Zero.

5 STAKEHOLDER IDENTIFICATION AND PRIORITISATION

Introduction

The authorities responsible for marine planning related decision-making within the Severn Estuary area include:

• Environment Agency (England).

• Local Planning Authorities (England and Wales).

• Natural Resource Wales (Wales).

• Natural England (England).

• Planning Inspectorate (England).

• Port and Harbour Authorities (England and Wales).

• The Marine Management Organisation (England).

• UK Department for Business, Energy, and Industrial Strategy (England and retained functions for Wales).

• UK Department for Digital, Culture, Media, and Sport (England).

• UK Department for Environment, Food and Rural Affairs (England and retained functions for Wales).

In addition, there are important stakeholders such as the environmental Non Governmental Organisations, the Severn Estuary Partnership, the Wye and Usk Foundation and special interest organisations.

Key Stakeholders

To manage the engagement of stakeholders, it is helpful to consider the key stakeholders as four groups:

- Government and Statutory Consultees: DESNZ (energy), Defra (environment), Treasury (funding and financing), DCLU (socio-economic and planning), DfT (navigation and ports), Welsh Government (devolved matters), Environment Agency (flooding and environment), Natural England (environment), Natural Resources Wales (flooding and environment), Historic England and CADW (archaeology), The Crown Estate, Harbour Authorities.
- Non Governmental Organisations: including RSPB, WWF, WWT, British Ornithological Trust, National Trust, Severn Estuary Partnership, GreenPeace, Friends of the Earth and other campaigning organisations
- Local Authorities: specialist functions within the Western Gateway Partnership
- Special Interest Groups: including energy trade groupings such as Regen, REA and MEW, Universities, Potential Investors, potential contractors, ports, Sea Bed Owners (for example the upper estuary), Trinity House and other Interested Parties

Not all stakeholders need to be involved from the outset and indeed some stakeholders will require substantial information before being able to contribute. The prioritisation / planning for stakeholder engagement has therefore taken account of:

- Timing
- Substance

Stakeholder engagement will have two main objectives. The first is to understand the specific requirements and concerns from stakeholders and how these need to be weighted and addressed. The second is to treat stakeholders as a critical friend and engage them so that they feel part of the solution rather than being threatened by the process. This is particularly important for tidal power where stakeholder views can be polarised and informed through past experiences of tidal power projects.

There is a third strand of stakeholder engagement the Independent Commission will need to consider and that is communications with the media and the general public. Whilst the views of the general public are unlikely to be as informed as the stakeholder groups referenced above, nevertheless, it will important that their views are understood and responded to.

Stakeholder Directory

We have developed a stakeholder directory, categorised into the groups above, with contact details (at department level where several departments of the same organisation need to be engaged separately). An outline prioritisation / stakeholder engagement plan has also been developed. These four groups are summarised below:

Stakeholder Groups

1. Government and Statutory Consultees

   (DESNZ (energy), Defra (environment), Treasury (funding and financing), DCLU (socio-economic and planning), DfT (navigation and ports), Welsh Government (devolved matters), Environment Agency (flooding and environment), Natural England (environment), National Resources Wales (flooding and environment), Historic England and CADW (archaeology), The Crown Estate, Harbour Authorities)

2. Local Authorities:

   (the local authorities within the Western Gateway Partnership with specific key points of contact for each)

3. Non Governmental Organisations

   (including RSPB, WWF, WWT, British Ornithological Trust, National Trust, Severn Estuary Partnership, GreenPeace, Friends of the Earth and other campaigning organisations)

4. Special Interest Groups:

   (including energy trade groupings such as Regen, REA and MEW, other WG energy initiatives and associated stakeholders, Universities, Potential Investors and Contractors, Ports, Sea Bed Owners (for example the upper estuary), Trinity House and other Interested Parties)

The Stakeholder Directory (set out in Appendix E) provides a listing of different organisations likely to have an interest in the development of tidal power from the Severn Estuary and the nature of their interest as well as their relevant jurisdiction. They have also been prioritised depending upon the specific engagement required. For example, DESNZ will be a high priority stakeholder in terms of influencing energy policy but the nature and timing of engagement will depend upon the successful engagement of other stakeholders with differing levels of priority. It is therefore not possible to rank individual stakeholders in terms of a specific priority but instead they have been grouped into three priorities:

- Essential: Engagement is a priority to ensure that stakeholder views are captured and that there is an opportunity to influence policy or funding provision to move forward tidal developments;
- Desirable: Engagement is important to ensure that stakeholder views are captured and that they are fully informed in order to influence regulatory bodies, policy makes and stakeholders to enable market conditions to be optimal for development; and
- For Information: Engagement is important to ensure that stakeholders are fully informed of future proposals in order to influence the enablers.

Outline Stakeholder Engagement Plan

Whilst the Stakeholder Directory provides a listing of different organisations likely to have an interest in the development of tidal power from the Severn Estuary and the nature of their interest, an outline plan is also required to guide how and when stakeholders should be engaged.

An outline plan is shown below in Table 8.

Table 8: Outline Stakeholder Engagement Plan

Timing	Objective	Stakeholders to be engaged
Inception:	To brief interested parties on Western Gateway's Sustainable Severn Estuary Energy Objectives	DESNZ, Welsh Government, NRW, EA, NE, Western Gateway APPG, Project Steering Group, WG local authorities (Stakeholder Groups 1 and 2)
Independent Commission Start Date:	Update on Independent Commission (IC), their formulation and terms of reference and their stakeholder engagement strategy	All stakeholders
Q1 Discovery:	Outreach to local / regional stakeholders to gain different views and perspectives on the project's objectives and	Stakeholder Groups 2, 3 and 4
Q2 Assessment:	Consideration of Stakeholder responses and integration into Commission's analysis of the proposed progression of the development of tidal power from the Severn Estuary	
Q3 Feedback:	Soft testing of WG IC Assessment and refinement as appropriate	Stakeholder Groups 2, 3 and 4

Timing	Objective	Stakeholders to be engaged
Q4 Finalisation:	Specific engagement with Government and Statutory Consultees on proposed way forward and associated policy instruments. Development of draft policy proposals for Sustainable Energy from the Severn Estuary	Environment: Statutory Planning Consultees Energy Planning and Policy: DESNZ, Welsh Government, National Grid Financing/RAB: HMT Sea bed leasing: The Crown Estate Socio-economic impacts / opportunities: WG Local Authorities, Welsh Government Investment: Potential infrastructure investors Supply Chain Opportunities: Potential engineering contractors
Q5 Feedback:	Second round of soft testing including a round of public engagement / media meetings	All stakeholders
Q6 Reporting / Consultation:	Consultation on finalised policy proposals for Sustainable Energy from the Severn Estuary	All stakeholder groups plus media / general public

6 INDEPENDENT COMMISSION FRAMEWORK

Objective

The Independent Commission will provide independent scrutiny and oversight of Western Gateway's "Sustainable Energy from the Severn" workstream. To achieve this, its membership needs to cover the spectrum of skills involved in developing tidal energy and its integration into a regional and national energy network. However, it also needs to demonstrate independence with no conflict of interest, real or perceived. This requirement, by definition, rules out the involvement of any tidal power professionals who are or who have recently been engaged by a developer to provide advisory or design services on a tidal power project in the Severn Estuary or Bristol Channel. This report, plus the evidence base workbook that accompanies it, will provide summaries and links to the technical knowledge the Commission will require to undertake its duties but the commission may decide that they need some form of ad-hoc technical advisory service to rely on to help them navigate through the evidence base and to be able to respond to questions the Commission may have during the course of their tenure.

Constitution

The Independent Commission should be led by a chair who has expertise in navigating large infrastructure projects through Government, through policy influence and/or delivery. The members of the commission should have a diverse range of policy and implementation (if appropriate) expertise including planning, the environment, civil engineering/construction, hydrodynamic modelling and flooding, options assessment and appraisal, financing of major infrastructure projects, energy systems, power generation/transmission, socio-economic policy considerations and stakeholder engagement. The composition of the commission will depend to some extent on how well candidates are able to cover one or more of these topic areas. In some circumstances, external technical expertise may be required to support the Commission in understanding the complexities of specialist areas such as fish behaviour, modelling and deterrents.

In other areas, a practical evidence base may already exist – for example the creation of new wildlife habitats with reference to case studies such as the Steart Peninsula, Wallasea Island and the Cardiff Bay Barrage compensatory habitat. A good example of how the Independent Commission could "hit the ground running" is early engagement with those organisations charged with running newly created habitat / nature reserves such as the RSPB.

Because of the conflict of interest requirements, the commissioners may have little or no direct experience in tidal power so it is important that they are experienced in quickly understanding the key issues and challenges and are able to bring their combined expertise to recommend the most appropriate solution for advancing the generation of tidal energy from the Severn and utilising it in the most effective way to support the region's transition to net zero.

Areas of Focus

On the basis of the lessons learned from previous experience, the Independent Commission should focus both on:

- the overall objective of developing sustainable energy on the Severn in the context of a Western Gateway energy system and the contribution it can make to the net zero economy, and
- the barriers and challenges that need to be overcome to enable tidal power to be developed.

Whilst the Independent Commission is not expected to favour specific projects, it will be appropriate for the Commission to show leadership, particularly in terms of influencing change to existing policy where this is impacting the development of tidal power.

Previous studies have confirmed that the vast majority of tidal energy resource in the Severn Estuary is based on its tidal range rather than the tidal currents or wave energy. Tidal currents are limited both in terms of locations and the maximum currents. The highest currents are also co-incident with the main shipping channel. The wave energy of the Bristol Channel is restricted to the westernmost Cornish coastline. As a consequence, one of the earliest considerations for the Independent Commission will be to confirm the extent to which they will focus on tidal range rather than tidal stream or wave technologies.

In considering this, the Independent Commission should recognise the work being undertaken by other parties and build on this. For example, the Welsh Government's Tidal Lagoon Challenge is based on research themes related to environment, economics and engineering. Similarly, The Crown Estate have shown that they are willing to facilitate development work where it will result in leasing income. However, for the research themes to be applied, and for any initiative to contribute positively to reducing the UK's carbon emissions, it will require a tidal project of some sort to be identified and supported.

A key challenge for the Independent Commission will be in their assessment of how to take a project concept and navigate it through to success. At a high level, this will require an options assessment of potential routes to project development, for example, research led, private sector led, public-private partnership, regulated or public sector led? At the next level, what location, what scale and what selection criteria? For comparison, the Liverpool City Region Combined Authority determined it would be the lead on the Mersey Tidal Power project , at least for project development and have proceeded to focus on two potential development sites. In contrast, the Welsh Government, in the Tidal Lagoon Challenge, undertook a market testing exercise before studying the implications of leading the at-risk development phase of site selection and consenting. However, their final decision was to commission research to reduce costs and uncertainties in tidal lagoon development.

At the moment, based on its 2010 response to the Severn Tidal Power Feasibility Study, the Government's approach has been to be led by the market. This has not proved successful for tidal range and only partially for tidal stream technologies which have benefitted from £20m of ringfenced funding but with only 6MW in operation. The strike price for tidal stream at the last CfD auction was nearly £180 at a 2012 cost index (equivalent to £235/MWh in today's terms) for 40MW, the majority of which was for Scotland's MeyGen project in an area where tidal currents are significantly higher than in the Severn.

The second challenge for the Independent Commission will therefore be to position tidal range more favourably in policy terms than it is today. How it achieves this will be dependent upon the outcome from the initial options assessment work. If, on the basis of evidence, it can quickly reach a conclusion that tidal range is preferred, it can start to consider how tidal range could perform in the estuary in a 2023/4 national and regional policy context to determine where barriers and uncertainties exist and address how they can be overcome.

The role of the All Party Parliamentary Group – Western Gateway provides an immediately available forum for raising the profile of tidal range power from the Severn Estuary, projecting it as one of the most under-utilised natural energy resource areas of the UK and highlighting the significant contribution it could make to a Western Gateway energy system embracing tidal, nuclear and hydrogen.

Spatial Planning

One aspect the Independent Commission will have to address is the spatial planning considerations for the estuary in the context of resolving the best use of the estuary for generating sustainable energy. This will include contributing to the Estuary's sense of place and associated environmental considerations, assessing the effect of tidal barrages and lagoons on the Severn's commercial ports, any consequential changes in land drainage and flooding (including future sea level rise) and cumulative development effects including the potential blighting effects of one project on subsequent projects.

Consideration of potential project blight requires some system of governance so that the most appropriate locations and projects are brought forward. This would best be undertaken in conjunction with The Crown Estate who also have a strong interest in optimising power generation from their sea bed leases whilst complying with environmental and other regulations. Examples of project blight include the case where building an upstream barrage at the Shoots channel would effectively reduce the business case for any subsequent downstream barrage, and vice – versa. Similarly, a tidal lagoon or a tidal stream project would have to be constructed downstream of a barrage. Over-development of an area by a number of different lagoons will result in a reduction in energy output from one or more lagoons, potentially leading to legal disputes if the projects are proposed by different organisations.

Identifying potential areas for tidal power development is therefore important because it will determine the type and scale of tidal power technology to be used. It is important this is both informed by the existing evidence base and lessons learned, as well as through stakeholder engagement. Whilst the evidence base suggests that tidal lagoons have been a preferred option recently, barrages are still a potential option providing they do not adversely impact commercial shipping and port operations.

For example, the Bristol Port Company have vigorously objected to the Cardiff – Weston Barrage for two reasons. Firstly the changes in upstream water levels would require their existing locks to be modified requiring partial closure of the port and secondly, because shipping would have to transit a new set of locks on the Barrage potentially resulting in the loss of container traffic to the port (container ships choose to dock at deep water berths to minimise turn-round times). Connected with this, the Bristol Port Company have planning consent to develop a new deep water port although this has not yet been built for commercial reasons. Consequently, a barrage between Cardiff and Weston would appear to be a challenging proposition, and it also impacts Newport and Cardiff Docks. The Shoots Barrage also includes a large lock to allow navigation through to Sharpness and Gloucester Docks. However, shipping to these docks has to wait on appropriate tide states to navigate upstream of the Shoots tunnel so the time taken to navigate through the locks is less of an issue and the higher water depth from the impounded water may provide a longer and safer navigation window. The challenge for a Shoots Barrage is therefore not from a commercial shipping angle but instead from environmental impacts and sedimentation.

The Independent Commission should therefore consider both tidal lagoons and tidal barrages but in a spatial planning context. If the Independent Commission, having reviewed the evidence base, concludes that they should consider tidal stream technology as well, this should also be in a spatial context.

Securing public support for the location, scale and type of technology involved will be a critical aspect of influencing future tidal energy policy.

Operational Framework

A budget will be necessary to fund the Independent Commission, the Western Gateway officer support, ad-hoc technical support and any work the Commission will need to instruct to enable them to complete their work. It is understood that the Commission will conclude its first phase of work by April 2025 and that a budget has been established.

The first phase of work will be to appoint the Commission Chair (by Western Gateway) and the commissioners themselves (by the Chair and Western Gateway).

The Chair and Western Gateway may also wish to consider the values proposition for the Commission covering objectives, principles of operation (for example, collaborative, timely, creative and productive) and associated desired behaviours, and the over-arching vision.

Once the Commission is established, it would be desirable to hold a number of workshops to enable the Commissioners to understand the evidence base and any associated subtleties. These workshops would each last 90 minutes split equally between presentation and questions/discussion. A suggested sequence is:

1. Tidal Power – an introduction
2. The Evidence Base
3. Lessons Learned and application to the Commission.

This would best be delivered as an extension of the work associated with this report.

Governance issues will be a matter for Western Gateway, working with the Commission Chair but clarity on reporting, transparency, responsibilities and accountabilities should be set down in the terms of reference for the Commission. The Chair will have their own views on frequency of meetings but the Western Gateway team should consider how frequently they wish to be updated on the Commission's work, noting that meeting and report frequency should not be onerous and divert from the Commission's productivity.

Research Priorities

The Independent Commission's research programme is likely to be focused on evidence based policy and strategy formulation in relation to developing tidal power from the Severn. A critical success factor will be overcoming the legacy of previously failed tidal power projects in the Severn Estuary and influencing Government policy on the potential benefits. A further factor will be to ensure that the evidence base set out in the STPFS published reports is used as the foundation stone given the independent scrutiny they have received and their comprehensive nature, particularly in the context of the Strategic Environmental Assessment carried out.

The main opportunity areas for more research and policy development, include:

- contribution to grid stability and other energy system benefits (for example working with green hydrogen production facilities);
- understanding, through whole system analysis, marginal cost of tidal range power over its lifetime and potential benefits to future generations;
- developing a model application for using innovative forms of funding and financing for large tidal power projects, such as Regulated Asset Base (RAB) financing or other alternative;
- taking a more nature centric approach to project evolution;
- understanding the potential socio-economic effects from the development of tidal power, including potential supply chain benefits but also attitudes and needs to inform better policy support;
- understanding non-technical barriers in the development of tidal power;
- development of low cost/high impact support mechanisms to facilitate tidal power development;
- reviewing "stranded asset" and "end-of-life" decommissioning options;
- developing a greater understanding of environmental challenges and potential solutions.

From a technical perspective, many of the future research priorities for tidal power from the Severn Estuary are captured in the list of research objectives identified by the Welsh Government in their Tidal Lagoon Challenge research programme. Whilst some of these may be directed at supporting the Welsh economy, they can equally be applied to the English areas supporting tidal power projects. The outcomes from Tidal Lagoon Challenge research should help expand the available evidence base available to the Commission. The list of Tidal Lagoon Challenge Research topics is summarised in Appendix F.

Conclusion

The Framework outlined above is focused on the establishment of the Commission and a suggested set of activities and considerations to be pursued initially. After that, it will be for the Chair and Commissioners to determine the areas on which to focus and the resources required, paid for from the operating budget.

It will be important for the Commission to focus on areas that they can influence in their two year term. This suggests that strategic considerations should be prioritised. They should focus on not only what has changed (for example the volatility of imported energy costs) but also on what needs to change (for example, challenging the short term nature of decision making in energy infrastructure and the impact that has on future costs for future generations). They can rely on a strong evidence base from the Severn Tidal Power Feasibility Study and from the lessons learned from failed attempts to develop tidal power from the Severn Estuary. They should avoid focusing on short term topical issues such as grid capacity (which should be informed by specific future projects rather than dictate where they are) and instead consider opportunities for change (energy funding and financing, nature centric development pathways, policy support and public perception) and provide assurance on resource areas that offer the most future potential without significant challenge.

The most important critical success factor will be for the Commission to advance the thinking on tidal power development from the Severn Estuary through increased political and public support, improved policy formulation and challenging the status quo on current methodologies used to determine the cost of energy. The latter tends to be short term, ignores future inflation forecasts and wider energy system costs. The emphasis should also be on the wider benefits to the region and the UK as a whole of promoting an efficient and integrated energy system. This would consider how the region's nuclear, hydrogen, and renewable (including tidal) aspirations can provide the most efficient, just and effective economic, environmental and social solution for the region's energy demands as the UK transitions to net zero by 2050.

7 APPENDICES

A. Cost Assumptions

B. Energy Assumptions

C. Appendix C from Government's Energy NPS Consultation Response

D. Financing Methodologies

E. Stakeholder Directory

F. Welsh Government's Tidal Lagoon Challenge

A Cost Assumptions

Estimating the costs of marine walls is complex and published cost data varies across a significant range with costs being influenced by the length of the marine wall, its form of construction, its service requirements and its context. Offshore sea walls for flood defences are generally very expensive because they require high mobilisation costs and are often very short in length which converts to a relatively high unit cost per metre length.

The primary cost database for tidal power is the only published cost build-up which was undertaken by Cost Consultants Corderoy between 2008 and 2010 for the Severn Tidal Power Feasibility Study (STPFS). This is more relevant than the Environment Agency's Cost Database for offshore structures (2015) which focuses mainly on short structures or landside coastal defences or the Scottish Natural Heritage equivalent which dates back to 2000. The STPFS cost database has therefore been used as the baseline data source for costs but benchmarked against the Peel Energy study on the Mersey and the published preferred bidder costs for the Swansea Bay Tidal Lagoon. The unit costs included in the STPFS have been reviewed and updated to a 2023 cost base.

Whilst the analyses of the individual projects largely use STPFS estimates, some proposals are based on developer's own estimates. These have been carried forward by the study and carried forward after indexation up to a 2023 cost base. Where developer's data has been used, this has been compared with the equivalent STPFS empirical data to assess whether cost estimates are under or over-estimated. This is then used to comment on the likely accuracy of the cost estimates in the project database.

Inflation

As there is little recent contemporary evidence, it is necessary to update historic costs to a March 2023 cost basis. It should be noted that DESNZ evaluate renewable energy costs under the Contracts for Difference (CfD) mechanism to a 2012 cost base so this should be born in mind when comparing data with external sources.

The inflation factors used in the toolkit are based on the Bank of England Inflation Calculator which is based on Costs and derived from the Office of National Statistics. Inflation from 2010 to 2021 averaged 2% per annum. 2022 is significantly higher in the range of 8 to 12%. (Note energy retail prices have historically risen at a faster rate than construction costs and thus the value attributed per unit of energy should be inflated using specific energy indices).

Inflation Adjustment to March 2023 Cost Basis	
£1 in 2010	1.44 (2023)
£1 in 2012	1.34 (2023)
£1 in 2015	1.29 (2023)
£1 in 2016	1.28 (2023)

Empirical Cost Data

The empirical cost data used in reviewing project data estimates has been derived as set out below the relevant data sources. It is presented in two primary sections – Mechanical and Electrical Costs and Civil Engineering Costs.

Mechanical and Electrical Engineering Costs

These cover all the mechanical and electrical elements from the turbines and sluice gates through to the switch gear, control systems, cabling and grid connection. They are presented as a global figure on a per MW basis synthesised from previous study data, as per the table below:

Data Source and Detail	**Summary (@ 2023 cost basis) £m/MW**	
	Central Ebb and Flood Unit Cost	*Ebb Only Unit Cost*
Severn Tidal Power Feasibility Study (2010) - *p238 (of 403) from the SEA ODR V3 Volume 2 Report (https://www.gov.uk/government/collections/severn-tidal-power-feasibility-study-conclusions):* (£7,081m for 8640MW ebb only Cardiff Weston Barrage (£0.819m/MW) to £8,765m for 8,640MW ebb and flood Cardiff Weston Barrage (£1.014m/MW) including grid connection and all M&E requirements. Lagoon estimates were based on ebb and flood performance and resulted in a unit costs of £3,697m for 3,600MW ebb and flood Bridgwater Bay Lagoon (£1.027m/MW)	1.5	1.2
Swansea Bay Tidal Lagoon Published Data (2016) - *https://www.parliament.uk/globalassets/documents/commons-committees/business-energy-and-industrial-strategy/Correspondence/Swansea-Appendices-B1-D3-17-19.pdf* 320MW GE-Andritz tendered cost at 2016 prices of £316m or £0.99m/MW	1.26	1.16

Civil Engineering Works and Services

The civil engineering works cover the main elements of the project and the M&E costs above are also reproduced here on the basis that the Civil Engineering Contractor would be Prime and all other suppliers acting as Sub (nominated or otherwise). The table below shows the cost breakdowns per major contract and also by component to provide two perspectives.

Items		Description	Original Unit Cost	Summary (@2023 cost base)	
				Units	*Central Estimate*
Capex Costs by Contract		*These contract figures are derived from equivalent aggregate values from the STPFS (2010) and published tendered values for Swansea Bay. They are presented on a per MW basis (for the advance works and powerhouse contracts) and a per km basis (for the marine wall)*			
1	M&E	*See Details above. Summary figures rounded*		£m/MW	1.5 (ebb and flood) 1.26 (ebb only)
2	Marine Wall	*Swansea Bay received three tenders for their marine wall contract which varied from £340m to £360m with two received from major European marine contractors. The embankments figure for the Bridgwater Bay Lagoon in the STPFS was £638m, 22% of the total Civils Costs of £2.902bn. Adding 22% of the general overhead costs of £617m would give an equivalent marine wall cost of £638m+£135m=£773m for a marine wall length of 13.2km (caissons form the balance of the 16.5km total length).*	Adopting Swansea Bay's higher figure of £360m gives a rate of £40m/km at 2016 cost base. The STPFS Bridgwater Bay example is £54.60m/km . Bridgwater Bay costs are higher because of the very poor ground conditions. A reasonable range of marine wall costs on a per km basis, updated to 2023 cost base is therefore between £55m to £85m.	£m/km	70
3	Powerhouse	*There are four reference points for the civil engineering costs for the Powerhouse. The Swansea Bay figures ranged from £240m (original tender) to £490m (after risk erosion) - £360m is the central value and is for in-situ*	Central estimate of £1.4m/MW applies for ebb and flood schemes although costs may vary from £1.1m/MW to £1.7m/MW depending upon site characteristics, tidal range and other	£m/MW	1.4 (ebb and flood) 1.1 (ebb only)

Items		Description	Original Unit Cost	Summary (@2023 cost base)	
				Units	*Central Estimate*
		construction which incurs additional cofferdam costs. Bridgwater Bay and Cardiff Weston data comes from the STPFS and assume floated in caissons. Peel Energy's Mersey proposals had a cost of £870m for a 700MW turbine installation which was constructed in-situ.	factors. Costs for ebb only projects could be reduced by 20%		
4	Contingency	*For the STPFS in 2010, cost estimates were based on 10% escalation in unit rates plus a 15% contingency giving a total contingency of around 20%. Contingencies in the civil engineering sector can range from 10% for very low risk projects up to 66% for public sector promoted projects incorporating optimism bias.*	Max Optimism bias would skew central estimate so a central figure of 20% has been used.	% of total cost	20%
5	Client Costs excluding navigation and environmental mitigation	*This has been derived from the STPFS and includes all estimated costs outside of the main contracts but excludes navigation and environmental costs which will vary significantly by location.*		% of total cost	3.6%
Capex Costs by Component					
1	Turbine and Sluice Caissons	*As powerhouse analysis above for turbine and sluice caissons.*		£m/MW	1.15 (ebb and flood) 0.95 (ebb only)
2	Rockfill Embankments	*Swansea Bay rate of £53 per cu m (2015) or Bridgwater Bay Lagoon from STPFS which had a cost of £505m for embankments with volume of 11,700,200 cu m which equates to £43.16 per cu m(2010).*	For a 2023 cost basis, the Swansea Bay rate is £67.65 and the STPFS rate is £62. The Swansea Bay rate has been used as it is more recent.	£ per cu m	68.0

Items		Description	Original Unit Cost	Summary (@2023 cost base)	
				Units	*Central Estimate*
3	Plain Caisson Costs	*For plain caissons, WSP's work for The Crown Estate estimate was £55,000 per m of caisson assuming 23m depth, 30 m length and 20 m crest width using 2012 cost basis. This equates to £80,000 per m at 2023 prices. Converting this to a per cu m basis gives a cost of £175 per cu m of caisson volume.*	The crest level of the plain caisson can be close to high water as the structure offers structural protection against overtopping unlike rockfill embankments which require a 5m freeboard to protect against wave damage. A rockfill embankment will be higher than its caisson equivalent but will have a reduced crest width	£ per cu m of caisson volume	175.0
4	Other Civil Engineering Costs	*Other civil engineering costs, excluding navigation locks, are typically for buildings to house the electrical equipment and operating personnel, together with advance works to provide access roads and other site related infrastructure.*	A figure of between £120,000 and £160,000 per MW of installed capacity is proposed. This would equate to a sum of between £40m and £50m for a project the size of Swansea Bay. This compares with their advance works contract value of £34m at 2016 cost base	£/MW	140,000
5	Navigation Locks	*Costs for navigation locks are dependent upon the size of the lock and the STPFS in 2010 estimated costs ranging from £20m for small craft and maintenance dredging vessels through to over £1bn for full scale post Panamax commercial shipping. There are no unit rates for navigation as a consequence.*			
6	Compensatory Habitat	*Compensatory habitat costs were researched extensively for the STPFS. Key issues were the replacement ratio for habitat lost a consequence of changed water levels and their location.*	STPFS used a figure of £45k per hectare for compensatory habitat and a replacement ratio of 2:1. AT 2023 cost levels, this is £65 for every hectare of new habitat or double this figure if measured on the extent of lost habitat.	£/ha of lost habitat	130
7	Other Environmental Mitigation Costs	*Other environmental measures were also included resulting in mitigation costs of between 1% and 5% of the construction costs.*		% of construction cost	3%

Items		Description	Original Unit Cost	Summary (@2023 cost base)	
				Units	*Central Estimate*
8	Decommissioning Costs	*Decommissioning costs need to include, as a minimum, the removal of all mechanical and electrical plant. Removal of the impounding structures may be more challenging as they will have developed their own eco-system communities. However, they will require a fund to help maintain them after closure.*	The range for decommissioning costs ranges from 5% to 50% of the original construction cost depending upon the scale of decommissioning required.	% of construction cost	28%

B Energy Assumptions

Energy assumptions have been tested using two methodologies – one using a capacity factor, the other an empirically derived algorithm based on impounded area and tidal range. These, like the cost assumptions, have been used to assess the appropriateness of developer's own data and to provide a commentary on whether they are over or under optimistic. However, it is the developer's own data that is reproduced and updated to a 2023 base rather than the independent assessment (again echoing the approach used to assess costs). An empirical data assessment is no substitute for a detailed model that simulates the operation of a tidal project to assess energy outputs and the degree of energy modelling undertaken is critical in the assessment of developer's estimates.

Modelling Approaches

Conventionally, a first pass for assessment of annual energy production (AEP) would be undertaken using a 1-D model whereby the water flows through a turbine are modelled against the changing head and tail waters driven by the tidal cycles and the selected operating regime (both mode of operation such as ebb and flood with pumping and the detail of the operating sequence such as the head difference available at the start of generation and the sluicing regime).

Once this had been optimised (for example to confirm the best combination of starting heads for different tidal states, the sluicing regime and the operation mode), more extensive studies would be carried out using a 2-D model. This would model the interference from adjacent turbines and natural currents and what effects this would have on energy output. As a rule of thumb, previous studies have shown that 1-D models over-estimate energy yields by as much as 10% compared with 2-D models.

Another complication is the effectiveness of pumping. In theory, pumping water in or out of the impounding basin when the level difference between the tide and basin is near zero should mean that whatever volume of water is pumped at negligible head could be used to generate more electricity than consumed by pumping if it is released at a higher head. Previous studies have identified energy gains of between 5 and 15%. However, there are at least two practical problems. Firstly, because pumping can only take place over a relatively short period of time, the shape of the impounding basin has a major influence on the potential additional energy. This is because it takes time for water pumped at the powerhouse location to reach the shore. The closer the shoreline, the quicker the lagoon water levels will stabilise (when pumping first starts, the water level will be higher than the water level at the shoreline – simplistically, this results in the pumping head required being double that of the average increase in water level over the entire lagoon area). The net energy gain from pumping is therefore likely to be higher for smaller lagoons than larger ones. The second issue is the cost of pumping. Whilst net energy production may increase, costs for pumping will be variable depending upon the time of day and therefore the increase in energy may be offset in part by the higher costs of pumping.

There is also a potential issue with fish passage. Using the turbines in pump mode increases turbulence and reduces efficiency and these can have a negative impact on fish passage through the turbines. If pumping is to be used, measures need to be in place to eliminate fish from being able to pass through the turbine passages. In addition, if a developer advocates leisure pursuits in the newly created impoundment, exclusion zones would be required to ensure the public are prevented from being at risk from the increased currents during turbining, sluicing and pumping.

Calculating Energy Outputs: Method 1 – Capacity Factor

This is the simplest method and assumes 20% for ebb and flood operation and 25% for ebb only operation. Previous studies have shown a range of 14% (West Cumbria) to 22% (Bridgwater Bay) for tidal lagoons operating in ebb and flood mode and 23% (Cardiff Weston) to 30% (Shoots – English Stones) for tidal barrages operating in ebb only mode. The Swansea Bay and Cardiff tidal lagoons proposed by Tidal Lagoon Power had similar capacity factors of 18% but a default value of 20% has been used as both Swansea Bay and Cardiff lagoons have higher installed capacities than would typically be expected. The higher the installed capacity, the lower the capacity factor for a given energy output (which is typically governed by the area impounded rather than installed capacity for tidal lagoons).

As can be seen, the equation is simple:

Installed Capacity x Capacity Factor x 24 hrs x 365 days = Gross Annual Power Output

Losses are then deducted. They take two forms:

i) the loss in output from the generator terminals to the grid connection point (default = 5%) and

ii) the loss in output due to lack of availability because of outages (default availability = 98%, therefore losses are 2% of gross output).

For a 300MW project with a 20% capacity factor, the final output is 525GWh/yr reducing to 490GWh/yr after 10GWh losses due to outages and 25GWh losses to the grid connection point.

Calculating Energy Outputs: Method 2 – Impounded Area and Tidal Range

This method applies only to tidal lagoons as it is based on the impounded area. Tidal barrages tend to impound larger areas than they need for energy generation purposes and this method is likely to over-estimate energy output from barrages – consequently, this method is only used for tidal lagoons.

The table below sets out the calculation steps using this method. Essentially, the impounded area and tidal range are used to calculate the annual energy production through correlation of outputs from previous studies. The correlation formula is

*Gross Annual Energy (GWh/yr) per sq km = ((((tidal range-5)/5)*0.04)+0.015)*1000*

The energy output per sq km is then multiplied by the impounded area to produce the Gross AEP before adding pumping net energy gain before applying losses as per Method 1. Using a 300MW example, a tidal range of 8.6m and an impounded area of 12 sq km would give an energy yield of 525 GWh/yr before losses.

C Appendix C from the Government Response to Energy National Policy Statement Consultation

The Government's response to the Energy National Policy Statements Consultation included a checklist that they expect to see for tidal range projects. This is reproduced below.

Appendix C – Guideline Criteria for a 'Well Developed' Tidal Range Proposal

1.1 This appendix details the kind and quality of evidence that Government expects tidal range developers to provide in order to demonstrate that their project is well developed.

1.2 The criteria set out here are published for indicative purposes only, and do not constitute a definitive or exhaustive list of requirements.

1.3 Moreover, these criteria specify only the minimum level of detail necessary for Government to give initial consideration to a proposed development. Satisfaction of these criteria – either in whole or in part -- will not guarantee the Government's entry into negotiations, whether financial or otherwise.)

1.4 So far as is reasonably practicable, all information supplied to Government in connection with the criteria set out here should be supported by robust evidence and/or verification by independent third parties

Table – Guideline Criteria for a 'Well-Developed' Tidal Range Proposal

Thematic Criterion	Evidence Required
1. Demonstration of Energy System Benefits.	Detailed modelling of energy system costs/benefits, including e.g. any effect on electricity system balancing costs, transmission costs, system inertia, and security of supply.
	Detailed information on the expected generation profile of the station, to be verified by an independent engineer. This should be expressed in terms of a high/low range of outputs, and should be periodised to the smallest useful time-interval. The expected average output plus expected standard deviation should also given.
	Detailed information on the turbines to be used, including likely manufacturer and/or supplier.
	Where the proposal depends on commercially unproven technology, developers should provide: 1. Evidence of commitment from a turbine manufacturer and any associated information of relevance concerning patents and intellectual property.

Appendix C – Guideline Criteria for a 'Well Developed' Tidal Range Proposal		
		2. Evidence of plans to move from concept stage to commercialisation, including in-situ testing. 3. Information from testing, including on a full size prototype in a comparable environment (for example with the range of fish species expected), to inform realistic predictions of turbine operations, including energy output. 4. Detailed summary of lessons on viability and feasibility of the technology gleaned from testing, such as lessons on blade survivability in the marine environment. 5. Evidence of contingency plans for system failing to meet predicted performance after full scale testing.
		Detailed assessment of the whole-life carbon impacts of the project.
	2. Demonstration of Credible Environmental Impact Mitigation Strategy	Evaluation of potential flood impacts throughout the lifecycle of the project. (Impacts should be quantified in absolute terms, and also expressed in terms of impacts on standards of protection and life of existing defences, so as to enable third parties to make judgements on the significance of the impacts.) An environmental scoping and impact report to include the following:
		6. A description of the proposed development, including the physical characteristics, land use requirements and build materials. 7. A specification of the site selection criteria and the main alternatives considered, taking into consideration the potential environmental impacts. 8. Realistic modelling of potential environmental impacts, including detailed assessment of likely impacts on fish populations; habitats and fisheries; birds; and water quality. 9. Assessment of the above impacts, as well as impacts on wider fauna and flora, air, water, soil, climate, heritage, landscape, and any interrelationship between these receptors. 10.Assessment of any pertinent indirect, secondary, and/or cumulative impacts
		In light of the above, detailed plans on how environmental impacts will be avoided, reduced, mitigated and (if required) compensated for, including statement of approach to biodiversity net gain
		Evidence of extensive environmental stakeholder engagement, ideally including letters of support from relevant stakeholders.

Appendix C – Guideline Criteria for a 'Well Developed' Tidal Range Proposal

3. Demonstration of Value for Money.	Detailed funding strategy including specific information on expected sources of debt and/or equity during the design, construction and operation phases. Ideally to include views and feedback from specific potential investors.
	Where the project depends on commercially unproven technologies, an analysis of how project costs could vary as those technologies move from concept to commercialisation
	Visibility of the project's financial model on an open book basis in order to test all relevant assumptions
	Supply chain management strategy including critical path analysis and information on how inputs have been cost-benefit evaluated and will be secured throughout project life. This should include a construction plan describing in detail the necessary programme of works, associated risks, and timeline for their completion.
	End of asset life strategy, including rationale for leaving infrastructure in situ or costed plans for decommissioning. Where applicable include statement of options for repowering.
	Evidence that relevant data can be made available to enable a value for money assessment to be undertaken, according to the relevant value for money framework.
4. Demonstration of Socio-Economic Impacts and Benefits.	Substantiation of the project's claimed economic benefit, including e.g. a statement of expected capital and operational spend in the UK, and independently audited net and gross job creation projections.
	A cost-benefit report to include: 11.Analysis of impacts on relevant local industries (such as commercial and recreational fisheries; aggregates). 12.Analysis of impacts on ports and navigation. 13.Plans for any mitigation or compensation required in light of the above.
	Evidence of extensive stakeholder engagement (including with local communities and any affected industries). Letters of support from relevant stakeholders should ideally be included.
	Evidence and accounting of any additional benefits, including e.g. coastal erosion protection, flood defence, recreation, tourism and broader community benefits

Appendix C – Guideline Criteria for a 'Well Developed' Tidal Range Proposal	
1.5	Additionally, developers should provide a detailed project delivery plan including the anticipated timetable for securing all necessary leases, consents and grid connections. A post-construction plan for operational monitoring and maintenance should also be given.
1.6	Such a plan should also include documentation of the potential delivery risks and associated mitigation actions, as well as a summary of the project's governance arrangements. A holistic assessment of delivery confidence in the project as a whole should also be given.

D Financing Methodologies

Three different methods of financial assessment have been used emulating private sector, public sector and Regulated Asset Base (RAB) applications.

Private Sector Investment Models

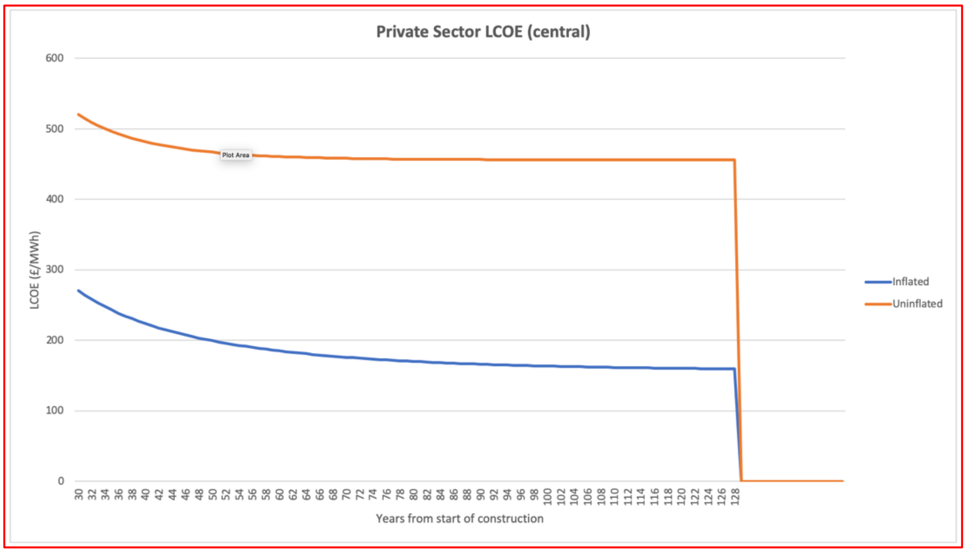
This is a conventional discounted cash flow analysis of the annual costs and energy outputs to produce a levelized cost of energy. Costs and energy outputs are discounted on an annual basis (ignoring any tax or other commercial considerations) using a discount rate range of 5 to 11% with a central value of 8%. This represents the typical cost of capital for an energy project developed in the private sector. In theory, this will be higher during construction and lower once the project is operational, reflecting the reduced risk. However, a single blended central value is used over the life of the project to enable comparison of different options, with sensitivity analyses using the low and high values. The sum of the annual discounted costs and discounted energy values is recorded each year so that the cost per MWh can be seen for any period of time. The worksheet covers the full life of the project (that is the sum of the construction, operating and decommissioning periods).

In the example below, after 30 years of operation, the central levelized cost value is £493/MWh. This is derived from the cumulative value of discounted costs in Year 36 (1,619) divided by the cumulative value of the discounted energy in the same year (3,286).

Year	Costs	Energy	Discount Rates			Discounted Costs			Cumulative Discounted Costs			Discounted Energy			Cumulative Discounted Energy			Levelised Cost (£/MWh)		
	(£m)	(GWh/yr)	Low	Medium	High	Low	Medium	High	Low	Medium	High	Low	Medium	High	Low	Medium	High	Low	Medium	High
1	300.0	0	5%	8%	11%	300	300	300	300	300	300	0	0	0	0	0	0			
2	300.0	0	5%	8%	11%	285	276	267	585	576	567	0	0	0	0	0	0			
3	300.0	0	5%	8%	11%	271	254	238	856	830	805	0	0	0	0	0	0			
4	300.0	0	5%	8%	11%	257	234	211	1113	1064	1016	0	0	0	0	0	0			
5	300.0	0	5%	8%	11%	244	215	188	1357	1278	1204	0	0	0	0	0	0			
6	300.0	0	5%	8%	11%	232	198	168	1589	1476	1372	0	0	0	0	0	0			
7	20.6	472	5%	8%	11%	15	12	10	1605	1489	1382	347	286	235	347	286	235	4623	5199	5889
8	20.6	472	5%	8%	11%	14	11	9	1619	1500	1391	330	263	209	677	550	444	2392	2729	3137
9	20.6	472	5%	8%	11%	14	11	8	1633	1511	1399	313	242	186	990	792	629	1649	1907	2223
10	20.6	472	5%	8%	11%	13	10	7	1646	1520	1407	298	223	165	1288	1015	795	1278	1498	1770
11	20.6	472	5%	8%	11%	12	9	6	1658	1529	1413	283	205	147	1570	1220	942	1056	1253	1500
12	20.6	472	5%	8%	11%	12	8	6	1670	1538	1419	269	189	131	1839	1409	1073	908	1091	1322
13	20.6	472	5%	8%	11%	11	8	5	1681	1545	1424	255	174	117	2094	1582	1190	803	976	1197
14	20.6	472	5%	8%	11%	11	7	5	1691	1552	1428	242	160	104	2337	1742	1294	724	891	1104
15	20.6	472	5%	8%	11%	10	6	4	1701	1559	1432	230	147	92	2567	1889	1386	663	825	1033
16	20.6	472	5%	8%	11%	10	6	4	1711	1564	1436	219	135	82	2786	2024	1468	614	773	978
17	20.6	472	5%	8%	11%	9	5	3	1720	1570	1439	208	124	73	2993	2149	1541	575	731	934
18	20.6	472	5%	8%	11%	9	5	3	1729	1575	1442	197	114	65	3191	2263	1606	542	696	898
19	20.6	472	5%	8%	11%	8	5	3	1737	1579	1444	188	105	58	3378	2368	1664	514	667	868
20	20.6	472	5%	8%	11%	8	4	2	1744	1584	1447	178	97	52	3557	2465	1716	490	642	843
21	20.6	472	5%	8%	11%	7	4	2	1752	1587	1449	169	89	46	3726	2554	1762	470	621	822
22	20.6	472	5%	8%	11%	7	4	2	1759	1591	1450	161	82	41	3887	2636	1803	453	604	805
23	20.6	472	5%	8%	11%	7	3	2	1766	1594	1452	153	75	36	4039	2712	1839	437	588	790
24	20.6	472	5%	8%	11%	6	3	1	1772	1597	1453	145	69	32	4185	2781	1872	423	574	777
25	20.6	472	5%	8%	11%	6	3	1	1778	1600	1455	138	64	29	4323	2845	1900	411	562	765
26	20.6	472	5%	8%	11%	6	3	1	1784	1603	1456	131	59	26	4453	2904	1926	400	552	756
27	20.6	472	5%	8%	11%	5	2	1	1789	1605	1457	124	54	23	4578	2958	1949	391	543	748
28	20.6	472	5%	8%	11%	5	2	1	1794	1607	1458	118	50	20	4696	3007	1969	382	534	740
29	20.6	472	5%	8%	11%	5	2	1	1799	1609	1458	112	46	18	4808	3053	1987	374	527	734
30	20.6	472	5%	8%	11%	5	2	1	1804	1611	1459	107	42	16	4915	3095	2003	367	521	728
31	20.6	472	5%	8%	11%	4	2	1	1808	1613	1460	101	39	14	5016	3134	2018	360	515	724
32	20.6	472	5%	8%	11%	4	2	1	1812	1614	1460	96	36	13	5113	3169	2030	354	509	719
33	20.6	472	5%	8%	11%	4	1	0	1816	1616	1461	91	33	11	5204	3202	2042	349	505	716
34	20.6	472	5%	8%	11%	4	1	0	1820	1617	1461	87	30	10	5291	3232	2052	344	500	712
35	20.6	472	5%	8%	11%	4	1	0	1824	1618	1462	83	28	9	5374	3260	2061	339	496	709
36	20.6	472	5%	8%	11%	3	1	0	1827	1619	1462	78	26	8	5452	3286	2069	335	493	707

With the higher discount rates used to emulate private sector development, the long term value quickly trends to zero after 30 to 40 years which is a shortcoming of this method of analysis when applied to long term projects.

Historically future inflation effects have been largely ignored by standard levelized cost calculations, but their inclusion is very beneficial to tidal range projects which have a relatively short period of risk relating to inflation of costs but a very long period where the value of energy produced is enhanced by inflation.



Public Sector Investment Models

This, like the private sector model, uses a conventional discounted cash flow analysis of the annual costs and energy outputs to produce a levelized cost of energy. Costs and energy outputs are discounted on an annual basis using the Treasury's long term discount rate as set out in the Green Book. This starts at 3.5% reducing in 0.5% increments every thirty years to 2.0%. The long term value of tidal range projects is better captured with the lower and reducing discount rate compared with the private sector and, as with the private sector model, inflation effects also have a significant beneficial effect as can be seen from the graph overleaf. Using the same cost inputs the levelized cost reduces to £270/MWh (Uninflated) or £100/MWh (inflated) after 36 years. However, for this model to be used, public sector funds would have to be utilised for construction which is unlikely for large capital cost projects such as tidal range.

The UK Government has consequently looked at the use of a Regulated Asset Base (RAB) model to overcome this challenge for new nuclear. As new nuclear and tidal range have similar characteristics and were both treated on a negotiated CfD basis for Hinkley Point and Swansea Bay (rather than 15 year CfD auctions), it is logical that if a RAB model can be successfully applied to new nuclear, it can also be applied to tidal range at some point in the future.

Regulated Asset Base Models

The Regulated Asset Base (RAB) approach is typically used for funding UK monopoly infrastructure such as the water market. Unlike “normal” electricity market mechanisms, it is not concerned with the unit cost of energy – it is solely concerned with securing the best value for money from the construction of an asset. It focuses entirely on how owners/investors are paid for their role in financing and operating an asset with an agreed performance requirement. Revenues are therefore based on allowable costs (overseen by a regulator) rather than on a per kWh basis. As RAB models only include consideration of costs (the energy output is considered to be a requirement rather than a variable), future inflation is less relevant and so inflation is ignored.

Unlike a conventional CfD where the developer only receives income when the power station starts operation, the RAB model pays the developer an income (financed from consumer bills) from the start of the agreement. The amount paid is dependent on the value of the asset at the time of the income payment. This minimises the compounding of finance charges (interest) as the developer is paid from the start of construction. The developer is therefore not reliant on having to wait for revenues to be received from power generation, making it a more attractive investment for pension funds.

The developer’s revenue stream is built up of a number of building blocks based on the value of the asset. The asset value includes the cost of capital during construction and then reduces over the lifetime of the project as the asset value depreciates (i.e. becoming worthless after it is decommissioned). The asset value therefore starts and finishes at zero and is at its maximum when it starts operating. The developer's investors receive revenues made up of:

- The weighted average cost of capital
- Costs associated with depreciation
- Operating costs
- Taxes
- Grid costs
- Decommissioning costs
- Any costs associated with incentives less any penalties

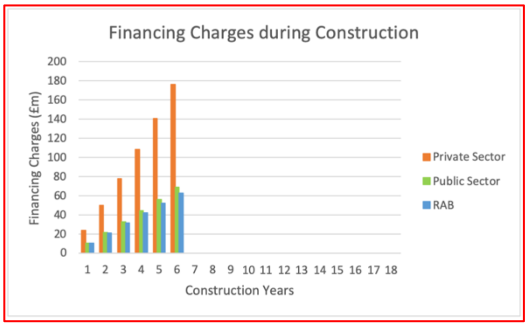
The key points of RAB financing compared with conventional power projects receiving income from a CfD are:

- There is no revenue stream based on the number of kWh produced.
- RAB financing is only concerned with the elements that make up the cost of the energy generation facility. It is funded from a surcharge on the electricity consumer's bill.
- RAB financing agreements are based on paying the developer a revenue stream based on the asset value, determined by the cumulative agreed costs.
- The objective of the regulator is to achieve the construction, operation and decommissioning of a power generation facility at a specified performance for the lowest possible cost.
- The costs arising from risks - such as construction cost over-run are shared between the developer and the consumer, and are adjudicated by the regulator who will review costs and prices on a periodic basis (typically 5 years). Extreme risks (high impact / low probability) are typically covered by a separate Government guarantee.
- The RAB revenue stream paid to the developer is based on the value of the asset and varies over time.
- Paying the developer an income from the start of the agreement minimises compounding financial charges, which leads to significant cost reduction.

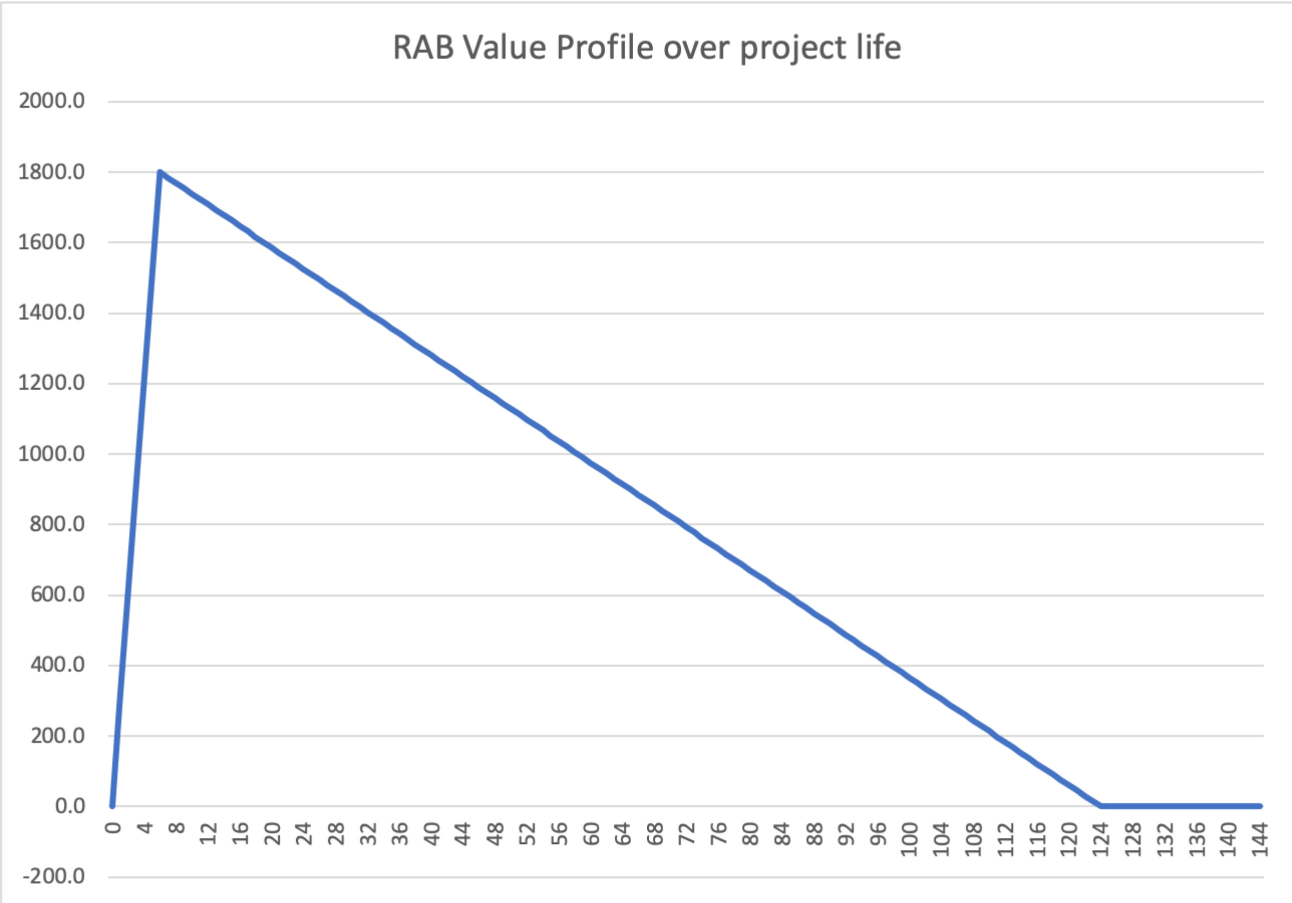
As RAB uses "open book" accounting and relies on reducing the weighted average cost of capital as well as the apportionment of risks and their associated costs, transparency is needed from the outset. This is particularly true when setting the terms of the Government Support Package (GSP – to cover low risk but high impact events), the construction contract (including a risk sharing 'formula' for cost over-runs) and the change in WACC (the Weighted Average Cost of Capital) that can be applied at the end of the construction phase once the project is operating.

The WACC value depends upon a number of things including the extent of a Government Support Package (which is designed to enable the private sector to reduce the borrowing rate as some of the large risks are covered by the Government), the scale and complexity of the project and how much competition there is in the financial markets. The WACC realised on the Thames Tideway Tunnel contract was around 3% following a competitive tendering exercise. It is possible for a tidal range project WACC to be in the range 3 to 5% given that it is a proven technology. We have assumed a 5% WACC on the basis that some of the costs that make up the asset base valuation are not included at this stage (for example tax considerations and cost over-run sharing).

The developer is paid from the start of construction by the regulator who in turn charges electricity customers via their electricity bill. The charge to the customer is equivalent of the financing charges for that year meaning that interest charges are not compounded during construction. As a consequence, the financing charges using RAB are lower as a % of the total construction cost resulting in lower overall costs but charges to consumers start earlier (at the start of construction rather than when the plant starts to sell electricity).



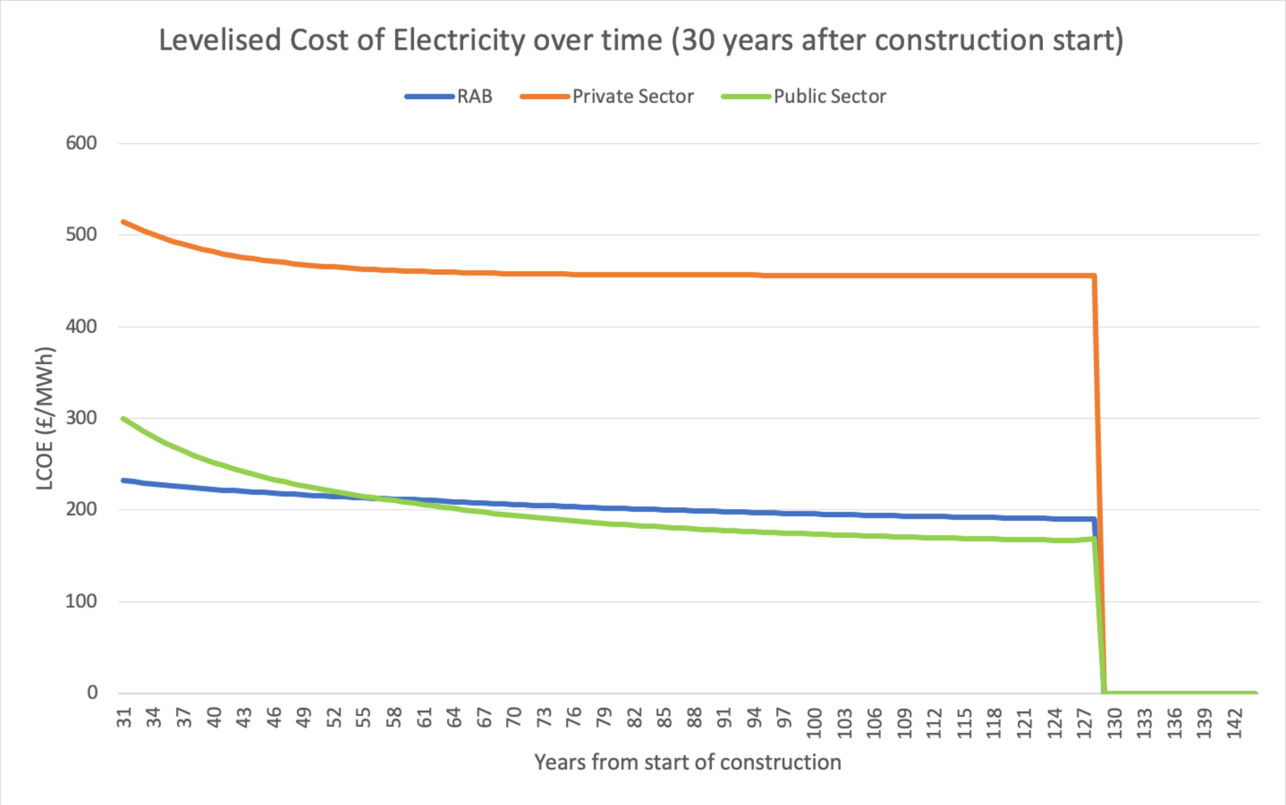
The value of the asset starts and ends at zero but climbs to a maximum at the end of construction before reducing each year through a depreciation payment as shown in the graph below.



The cost of energy is computed by taking the charges to consumers and then using the Green Book's Long term Discount Rate to determine the levelized cost of electricity.

The levelized cost of electricity is therefore calculated from a consumer perspective rather than the developer (who receives his revenues based on the WACC). Although the project is financed and delivered by the private sector, it is funded by the electricity consumer and the levelized costs are therefore based on the HMT social or long term discount rate rather than a private sector discount rate (which is already covered by the WACC).

Although financed by the private sector, the RAB model produces outcomes that are similar as if the project was paid for by the public sector as illustrated by the output graph. The downside is that customers fund the project from the start of construction rather than when it operates and it is necessary for a Government Support package to oversee regulation and underwrite the low probability but high impact risks.



Appendix E: Stakeholder Directory

Stakeholder Group	Contact Details	Western Gateway Objective (Enabler, Influencer, For Information)	Priority (Essential, Desirable, For information)	Jurisdiction
Group 1: Government and Statutory Consultees				
Department for Energy Security and Net Zero	Claire Coutinho MP, Secretary of State (claire.coutinho.mp@parliament.uk) Rt Hon Graham Stuart MP, Minister of State (grahamstuartmp@parliament.uk) Ministerial Correspondence Team 1 Victoria Street London SW1H 0ET United Kingdom Director General, Energy Infrastructure: Ashley Ibbett Director General, Net Zero, Nuclear and International: Lee McDonough DESNZ Chief Scientific Adviser: Professor Paul Monks	To enable the development of policy for tidal range technology and RAB financing.	Essential	UK Government
Department for Environment, Food and Rural Affirs	Secretary of State: The Rt Hon Thérèse Coffey MP Minister of State (Minister for Biosecurity, Marine and Rural Affairs): The Rt Hon Lord Benyon Director General for Environment: David Hill Director General for Science and Analysis and Defra Chief Scientific Adviser: Professor Gideon Henderson	To be kept informed on project development.	For Information	England
HM Treasury (funding and financing)	Note: HMT specifically request enquiries to be routed through the lead Government department (in this case DESNZ).	At the appropriate point through DESNZ to discuss RAB and financing methods	Essential	UK Government

DCLU (socio-economic and planning): Department for Levelling Up, Housing and Communities	Knowledge & Information Access Team Department for Levelling Up, Housing and Communities 2nd floor NW, Fry Building 2 Marsham Street London SW1P 4DF United Kingdom Email: mhclgcorrespondence@levellingup.gov.uk	To influence levelling up agenda through socio-economic benefits from tidal power in the Severn.	Essential	UK Government
DfT (navigation and ports): Department for Transport	Parliamentary Under Secretary of State (Aviation, Maritime and Security): Baroness Vere of Norbiton Director General Aviation, Maritime and Security: Dr Rannia Leontaridi OBE FRSA	For information and communication	For Information	UK Government
Welsh Office	Secretary of State for Wales: The Rt Hon David TC Davies MP Director, Office of the Secretary of State for Wales: Glynne Jones CBE Office of the Secretary of State for Wales William Morgan House 6-7 Central Square Cardiff Wales CF10 1EP correspondence@ukgovwales.gov.uk	To facilitate, with DESNZ, the development of policy for tidal range technology and RAB financing.	Essential	Wales
Welsh Government (devolved matters)	Deputy Director, Waste and Resource Efficiency Division, Welsh Government: Jasper Roberts (jasper.roberts@gov.wales) Energy Advisor: Ron Loveland (ron.loveland@gov.wales)	Enabler	Essential	Wales

	Programme Director, Local Partnerships' Welsh Government Energy Portfolio (WGEP): Mike Williams (mike.williams@localpartnerships.gov.uk) Welsh Government Cathays Park Cardiff CF10 3NQ Call: 0300 0604400 (Monday to Friday, 8:30am to 5pm)			
Environment Agency (flooding and environment)	Ex officio Defra board member and Chair: Alan Lovell Chief Executive: Philip Duffy Executive Director of Flood and Coastal Risk Management: Caroline Douglass Area Director, Wessex: Emma Baker Emma.baker@environment-agency.gov.uk Environment Agency, Rivers House, East Quay, Bridgwater TA6 4YS	To agree appropriate environmental mitigation for scheme delivery in the Severn Estuary.	Essential	England
Wessex Regional Flood Committee	Wessex RFCC Secretariat Rivers House Sunrise Business Park Higher Shaftesbury Road Blandford Forum DT11 8ST WessexRFCC@environment-agency.gov.uk		Desirable	England
Natural England (environment)	Chair and Ex officio Defra board member: Dr Tony Juniper Adrian Jowett, Principal Advisor (adrian.jowitt@naturalengland.org.uk) Natural England, Horizon House, Deanery Rd, Bristol BS1 5AH	To agree appropriate environmental mitigation for scheme delivery in the Severn Estuary.	Essential	England

National Resources Wales (flooding and environment)	Head of South Central Wales Operations - Mike Evans Head of South East Wales Operations - Steve Morgan Head of Development Planning and Marine Services - Rhian Jardine Email: enquiries@naturalresourceswales.gov.uk Call: 0300 0653000	To agree appropriate environmental mitigation for scheme delivery in the Severn Estuary.	Essential	Wales
Historic England	Fermentation North (1st Floor), Finzels Reach, Hawkins Ln, Bristol BS1 6JQ Tel: 0117 975 1308	To agree appropriate mitigation for scheme delivery in the Severn Estuary.	Essential	England
CADW (archaeology)	Welsh Government Ty Afon Bedwas Road Caerphilly CF83 8WT Tel: 03000 252239 Email: cadwplanning@gov.wales	To agree appropriate mitigation for scheme delivery in the Severn Estuary.	Essential	Wales
The Crown Estate	Head of New Ventures: Nicola Clay Nicola.Clay@thecrownestate.co.uk M: +44 7734 742 344 T: +44 20 4534 5403 Senior Development Manager Marine Energy and Tidal Power Lead: Marion O'Dowd marion.odowd@thecrownestate.co.uk M: +44 746 908 8820 T: +44 20 4534 5407 1 St James's Market, London, SW1Y 4AH	To influence the process of scheme development and delivery in the Severn Estuary.	Essential	UK
Gloucester Harbour	Stewart Henderson, Harbourmaster		Essential	England

Trustees	Navigation House, The Docks, Sharpness, Berkeley GL13 9UD Tel: 01453 811 913			
Port of Bristol Harbour	External Affairs and Special Projects Director: John Chaplin John.chaplin@bristolport.co.uk Bristol Port Company, St Andrews House, St Andrews Road, Avonmouth, Bristol		Essential	ENgland
ABP Harbours	ABP Ports Julian Walker, Regional Director, Wales Queen Alexandra House, Cargo Road, Cardiff, CF10 4LY Tel: 0870 609 6699		Essential	Wales
CEFAS	Pakefield Road, Lowestoft, Suffolk, NR33 0HT 01502 562244 The Nothe, Barrack Road, Weymouth, Dorset, DT4 8UB 01305206600	To agree appropriate environmental research and mitigation for scheme delivery in the Severn Estuary.	Desirable	UK
Joint Nature Conservation Council	Joint Nature Conservation Committee, Quay House, 2 East Station Road, Fletton Quays, Peterborough, PE2 8YY Tel: 01733 562626	To agree appropriate environmental research and mitigation for scheme delivery in the Severn Estuary.	Essential	UK
Group 2: Local Authorities (Statutory)				
Swansea Council	City and County of Swansea Civic Centre, Oystermouth Road, Swansea, SA1 3SN. Tel: 01792 636000	To inform stakeholder groups of potential schemes in the Severn Estuary, understand perspectives and influence policy.	Essential	UK
Neath Port Talbot	Neath Port Talbot CBC, Civic Centre, Port Talbot SA13 1PJ	To inform stakeholder groups of potential	Essential	

	Tel: 01639 686868	schemes in the Severn Estuary, understand perspectives and influence policy.		
Vale of Glamorgan	Civic Offices, Holton Road, Barry, CF63 4RU Tel: 01446 700111	To inform stakeholder groups of potential schemes in the Severn Estuary, understand perspectives and influence policy.	Essential	
Cardiff	Cardiff Council, County Hall, Atlantic Wharf, Cardiff, CF10 4UW. Tel: 029 2087 2087	To inform stakeholder groups of potential schemes in the Severn Estuary, understand perspectives and influence policy.	Essential	
Newport	Newport City Council, Civic Centre, Godfrey Road, Newport; South Wales; NP20 4UR Tel: 01633 656 656	To inform stakeholder groups of potential schemes in the Severn Estuary, understand perspectives and influence policy.	Essential	
Monmouthshire	County Hall, The Rhadyr, Usk, NP15 1GA Tel: 01633 644644	To inform stakeholder groups of potential schemes in the Severn Estuary, understand perspectives and influence policy.	Essential	
Forest of Dean	High Street, Coleford, Glos, GL16 8HG Tel: 01594 810000	To inform stakeholder groups of potential schemes in the Severn Estuary, understand perspectives and influence policy.	Essential	
Gloucestershire County Council	Shire Hall, Westgate Street, Gloucester, GL1 2TJ	To inform stakeholder groups of potential schemes in the Severn	Essential	

		Estuary, understand perspectives and influence policy.		
South Gloucestershire	Nigel Rigler, Director, Department for Place	To inform stakeholder groups of potential schemes in the Severn Estuary, understand perspectives and influence policy.	Essential	
Bristol City Council	Bristol City Council, City Hall, PO Box 3399, Bristol BS1 9NE Tel: 0117 922 2000	To inform stakeholder groups of potential schemes in the Severn Estuary, understand perspectives and influence policy.	Essential	
West of England Combined Authority	David Gibson, Director of Infrastructure Roger Hoare, Director of Environment directorinfrastructure@westofengland-ca.gov.uk Tel: 0117 428 6210	To inform stakeholder groups of potential schemes in the Severn Estuary, understand perspectives and influence policy.	Essential	
North Somerset	Town Hall, Walliscote Grove Road, Weston-super-Mare, BS23 1UJ	To inform stakeholder groups of potential schemes in the Severn Estuary, understand perspectives and influence policy.	Essential	
Somerset County Council	Kirsty Larkins, Service Director for Climate and Sustainability Neil Ogilvie, Service Manager Flood & Water Management County Hall, Taunton, TA1 4DY	To inform stakeholder groups of potential schemes in the Severn Estuary, understand perspectives and influence policy.	Essential	
Group 3: Non-Government Organisations (Non-Statutory)				

Trinity House	Trinity House, Kings Dock; Swansea, Glamorgan SA1 8QT Tel. 01792 657000	For information and communication re navigation	For Information	UK
RSPB	RSPB The Lodge Potton Road Sandy SG19 2DL Tel: 01767 680551 Wales Headquarters Castlebridge 3 5-19 Cowbridge Road East Cardiff CF11 9AB E-mail: cymru@rspb.org.uk	To inform stakeholder groups of potential schemes in the Severn Estuary, and understand perspectives. .	Desirable	UK
WWF	WWF Cymru Churchill House 17 Churchill Way Cardiff CF10 2HH t: 029 2045 4970 f: 029 2045 1306 e: wales@wwf.org.uk	To inform stakeholder groups of potential schemes in the Severn Estuary, and understand perspectives.	Desirable	UK
WWT	Chair: Barnaby Briggs Note: David Tudor, ex Crown Estate on tidal power is also a Trustee. Another Trustee is Alan Law, Deputy Chief Executive of Natural England WWT, Slimbridge, Gloucestershire, GL2 7BT	To inform stakeholder groups of potential schemes in the Severn Estuary, and understand perspectives.	Desirable	UK

British Ornithological Trust	BTO, The Nunnery, Thetford, Norfolk, IP24 2PU Email:info@bto.org Tel: +44 (0)1842 750050	To inform stakeholder groups of potential schemes in the Severn Estuary, and understand perspectives.	Desirable	UK
National Trust	Heelis Kemble Drive Swindon SN2 2NA Email: enquiries@nationaltrust.org.uk	To inform stakeholder groups of potential schemes in the Severn Estuary, and understand perspectives.	Desirable	UK
Severn Estuary Partnership	Rhoda Ballinger, Chair Severn Estuary Partnership School of Earth and Environmental Sciences Main Building Park Place Cardiff CF10 3AT Email: severn@cardiff.ac.uk	To inform stakeholder groups of potential schemes in the Severn Estuary, and understand perspectives.	Essential	UK
GreenPeace	Richard Lancaster *(Bristol)* Greenpeace Bristol Greenpeace, Canonbury Villas, London N1 2PN Tel: 020 4525 3241	To inform stakeholder groups of potential schemes in the Severn Estuary, and understand perspectives.	Desirable	UK
Friends of the Earth	Mike Birkin Mike.birkin@foe.co.uk South West Campaigner Friends of the Earth 10-12 Picton Street BRISTOL BS6 5QA	To inform stakeholder groups of potential schemes in the Severn Estuary, and understand perspectives.	Desirable	UK

	0117 9420128 07798 555737			
Wye and Usk Foundation	The Wye and Usk Foundation The Right Bank The Square Talgarth Brecon LD3 0BW admin@wyeuskfoundation.org 01874 711714	To inform stakeholder groups of potential schemes in the Severn Estuary, and understand perspectives.	Desirable	Wales
Trinity House	Trinity House, Kings Dock; Swansea, Glamorgan SA1 8QT Tel. 01792 657000	For information and communication re navigation	For Information	UK
Other campaigning organisations	N/A	To inform stakeholder groups of potential schemes in the Severn Estuary, and understand perspectives.	For information	UK
Group 4: Special Interest Groups (Non-Statutory)				
Regen (renewable energy not for profit)	Merlin Hyman OBE mhyman@regen.co.uk Johnny Gowdy jgowdy@regen.co.uk Regen Bradninch Court, Castle Street, Exeter, EX4 3PL T: 01392 494399	To influence regulatory bodies, policy makes and stakeholders to enable market conditions to be optimal for development.	Desirable	UK

REA: The Association for Renewable Energy and Clean Technology	Chair: Martin Wright Chief Executive: Nina Skorupska OBE York House 23 Kingsway London WC2B 6UJ T: 02079 253570 Email: info@r-e-a.net	To influence regulatory bodies, policy makes and stakeholders to enable market conditions to be optimal for development.	Desirable	UK
MEW: Marine Energy Wales	Marine Energy Programme Manager: Tom Hill tom.hill@marineenergywales.co.uk Marine Energy Project Manager: Jay Sheppard jay.sheppard@marineenergywales.co.uk Marine Energy Wales, Marine Energy Hub, 2nd Floor, Pier House, Pembroke Dock, Pembrokeshire, SA72 6TR	To influence regulatory bodies, policy makes and stakeholders to enable market conditions to be optimal for development.	Desirable	Wales
Universities	Swansea: Professor Ken Morgan (k.morgan@swansea.ac.uk) Cardiff: Professor Reza Ahmadian Bristol: Emeritus Professor Colin Taylor UWE: Prof James Longhurst Bath: Furong Li (eesfl@bath.ac.uk)	To influence regulatory bodies, policy makes and stakeholders to enable market conditions to be optimal for development.	Desirable	UK
Potential Investors	InfraRed Capital Partners Limited Level 7, One Bartholomew Close, Barts Square London EC1A 7BL. Email: london@ircp.com Tel: 020 7484 1800 Infracapital 10 Fenchurch Avenue, London EC3M 5AG	To enable development opportunities to proceed within the Severn Estuary.	Desirable	Worldwide

	Email: info@infracapital.co.uk Tel: 020 8162 3072			
Potential Supply Chain Contractors	Balfour Beatty: 5 Churchill Place, Canary Wharf, London E14 5HU. BAM Nuttall: BAM Nuttall, St James House, Knoll Road Camberley, GU15 3XW Tel: 01276 63484 Costain: Costain House, Vanwall Business Park, Maidenhead, Berkshire SL6 4UB Andritz: Bernd Hindelang, Andritz Large Hydro Division, Ravensburg, Germany Laing O'Rourke: Bridge Place 1 & 2 Anchor Boulevard, Crossways Dartford Kent, DA2 6SN Tel: 01322 296200	To enable development opportunities to proceed within the Severn Estuary.	Desirable	Worldwide
South West Infrastructure Partnership	Linda Irwin, South West Net Zero Hub, 70 Redcliff Street, Bristol, BS1 6AL linda.irwin@westofengland-ca.gov.uk	To influence regulatory bodies, policy makes and stakeholders to enable market conditions to be optimal for development.	Desirable	UK
ICE South West	Miranda Housden, M: + 44 (0)7917508039 | E: miranda.housden@ice.org.uk	To influence regulatory bodies, policy makes and stakeholders to enable market conditions to be optimal for development.	Desirable	UK
ICE Wales	Part 2nd Floor, Cambrian Buildings, Mount Stuart Square Cardiff CF10 5FL Email: wales.cymru@ice.org.uk Tel: +44 (0)29 2063 0561	To influence regulatory bodies, policy makes and stakeholders to enable market conditions to be optimal for development.	Desirable	UK
Tidal Range Alliance	Chair: Ioan Jenkins, Prosperity Energy Ltd info@prosperity-energy.com	A Working Group established by the	Desirable	UK

	Prosperity Energy Waterloo Industrial Estate Pembroke Dock Pembrokeshire SA72 4RR	British Hydropower Association to promote tidal range power in the UK.		

Appendix F: Welsh Government's Tidal Lagoon Challenge

The outcomes from Tidal Lagoon Challenge research should help expand the available evidence base available to the Commission. The list of Tidal Lagoon Challenge Research topics is summarised in Table F1 below to which has been added a "critical" or "desirable" classification and a brief commentary, based on the available evidence base.

Table F1: Welsh Government's Tidal Lagoon Challenge Research Objectives

Research Objective	Classification and Commentary
Environmental	
Conduct baseline data and site characterisation studies to understand the environmental conditions and inform future development.	*Critical* An example is the lack of fish tagging data and understanding of fish behaviours which has been a challenge for previous projects and studies. Fish tagging is however expensive and time consuming so it may be more pragmatic to assess what can be achieved without the expense and time constraints of physical survey work.
Identify and verify potential environmental compensation/mitigation measures that would be most appropriate to address the impact of a tidal range project.	*Critical* This is particularly important for assessing the effectiveness of fish deterrents and understanding potential locations for compensatory habitats
Better understand the potential impacts of tidal range development on key environmental receptors such as fish, birds, physical processes, benthic and water quality.	*Desirable* The STPFS undertook a significant amount of research in this area but climate change effects result in an ever changing baseline
Assess the regional scale impacts of tidal range development on the environment, and particularly on protected species and habitats.	*Desirable* The STPFS undertook a significant amount of research in this area but climate change effects result in an ever changing baseline
Investigate the potential biodiversity benefits of a tidal range project as an artificial reef and other potential environmental gains from a tidal range project.	*Desirable* This would be a new area of research and could prove valuable in encouraging a nature centric approach if considered as an integral part of a tidal power project.
Evaluate the potential impact of tidal lagoon projects on coastal flooding, including their role in adaptation to climate change.	*Critical* This would be very project specific but flood defence and sea level rise protection effects have previously been both positive and negative. Attempts to quantify different probabilities and costs would be helpful.
Inform IROPI evaluation and WFD compliance assessment.	*Desirable* The STPFS undertook a significant amount of research in this area but this work needs updating post Brexit.
Potential for interactions between project resulting in cumulative or in-combination effects.	*Critical* The modelling required to achieve meaningful results is significant so the effectiveness may be constrained by budget.

Research Objective	Classification and Commentary
Assess the environmental impact of pumping in a tidal lagoon scheme	*Critical* There is mixed understanding of the issues around pumping and most previous studies have assumed a benefit based on simplistic modelling. A key area of concern is the passage of fish through pumping turbines, water profiles during and after pumping, and the cost / extent of energy required to pump.
Suitability of lagoon water for recreation and aquaculture	*Desirable* Understanding the wake from a large turbine installation in a confined body of water would benefit improved knowledge of what is and is not possible.
Consider how climate change may interact with a tidal lagoon structure	*Desirable* Sea Level Rise is the primary concern and understanding the best strategy for maintaining adequate freeboard over forthcoming decades would benefit design and cost considerations.
Assess the environmental impact of using a tidal lagoon for energy storage	*Critical* This is necessary to realise one of a tidal lagoon's potential advantages.
Engineering and Technical	
Understand approaches to develop more cost-effective / environmentally protective turbine technologies to improve the efficiency of power generation.	*Desirable* The challenge here is that most of the data required to achieve this is commercially sensitive to the turbine manufacturers. In addition, much of the potential optimisation has already taken place, as demonstrated by GE Andritz in their proposals for a triple regulated turbine for Swansea Bay.
Investigate ways to improve marine wall/caisson design to reduce overall project cost, improve buildability or deliver carbon savings	*Critical* This is necessary to challenge the conservative civil engineering design assumptions that have been used by most studies
Understand how marine walls can be designed that are adaptable/flexible to future anticipated sea level rises to improve the long-term viability of tidal lagoon projects.	*Desirable* Sea Level Rise is the primary concern and understanding the best strategy for maintaining adequate freeboard over forthcoming decades would benefit design and cost considerations.
Develop new approaches to construction in different sea-bed geologies to improve the efficiency and cost-effectiveness of tidal range projects.	*Critical* The location of a tidal lagoon in a rock formation could be used to reduce wall costs if the rock can be mobilised as part of the wall design.
Understand approaches to minimise time-to-first power. A specific focus on best practice, including approaches to turbine installation in a marine environment.	*Desirable* This is more relevant to modular marine technologies – the challenge with a tidal range project is that it requires completion of a major impounding structure before first generation can be undertaken and it is the structure rather than the turbines that is on the critical path.

Research Objective	Classification and Commentary
Investigate ways to decarbonize the materials and / or supply chain to reduce the embedded carbon of tidal range projects.	*Desirable* Whilst embodied carbon represents a small proportion of the total carbon benefits of a scheme, it is nevertheless important to minimise embedded carbon content and maximise circular economy opportunities in project construction.
Consideration of how to ensure the sustainability and resilience of the supply chain.	*Desirable* The supply chain will only become engaged when they are convinced that there is a real project and funding to enable them to participate. A higher priority would be in project development and specification to promote the use of sustainable materials and transport.
Develop effective decommissioning strategies to ensure liabilities are appropriately managed within the current legal framework.	*Desirable* Decommissioning requirements for tidal stream are clear but the case is less clear for tidal range. Having an understanding of different decommissioning options and costs to be incurred in 120 or more years time is beneficial but given the time scales is likely to be repeated once a project is in development.
Consider beneficial applications of Artificial Intelligence for improved Operations & Maintenance	*Desirable* This research goal is predicated on maximising the output from a tidal power project but is likely to have less of an impact on project economics than assumptions around projected availability, demand and potential energy storage uses.
Consider the role of tidal lagoons in grid balancing, or other energy system impacts	*Critical* This is necessary to realise one of a tidal lagoon's potential advantages and should also review the use of double regulated synchronous or triple regulated turbines in terms of contributing inertia to the grid.
Approaches to dredging for maintenance	*Desirable* This research is already available from the practices adopted by the Severn Estuary Ports and, in terms of project location, a better option is to locate tidal power in areas where dredging is not necessary.
Socio-Economic and Financial	
Develop effective and progressive government support packages to encourage the development of tidal lagoons in Wales.	*Critical* The design of effective Government Support is critical for facilitating the development of tidal power at lower cost and better value to the consumer and taxpayer.
Investigate different financial models for delivering a viable tidal lagoon project.	*Critical* This is critical to reducing the cost of capital element of total construction cost which can be as high as 50% through compounding of interest.

Research Objective	Classification and Commentary
Identify low-cost, high-impact support mechanisms to reduce the overall project cost of tidal lagoon development.	*Critical* This is critical to reducing the total construction cost by appropriate risk management and extreme risk underwriting.
Evaluate the potential supply chain and job opportunities associated with tidal lagoon development.	*Desirable* This research is already available from previous studies and projects but would merit updating.
Assess the impact of tidal lagoon development on local industries and develop strategies to multiply any positive effects / mitigate negative impacts.	*Desirable* This research would be merited at project identification stage.
Investigate legislative barriers to bring forward tidal range projects and identify potential solutions.	*Critical* This is critical to developing a coherent tidal power energy policy.
Develop community ownership and benefit models to ensure that local communities benefit from tidal range development.	*Desirable* This research would be merited at project identification stage.
Conduct social research on attitudes and needs related to tidal range development to inform policy and decision-making.	*Desirable* This research would be helpful but probably requires a subject project(s). Different concerns tend to be project based.
Assess the value of the pattern of tidal range energy generation to the UK energy system	*Critical* This is necessary to demonstrate the tidal lagoon's whole system advantages.
Consider the added value of storage strategies to the financial model / energy system	*Critical* This is necessary to demonstrate the tidal lagoon's potential storage advantages.
Consider how to encourage, facilitate and embed local engineering and technical skills	*Desirable* This should be undertaken as a wider STEM and apprentice initiatives.
Cost effective education and training opportunities in areas with skills shortage	*Desirable* This should be undertaken as a wider STEM and apprentice initiatives.

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