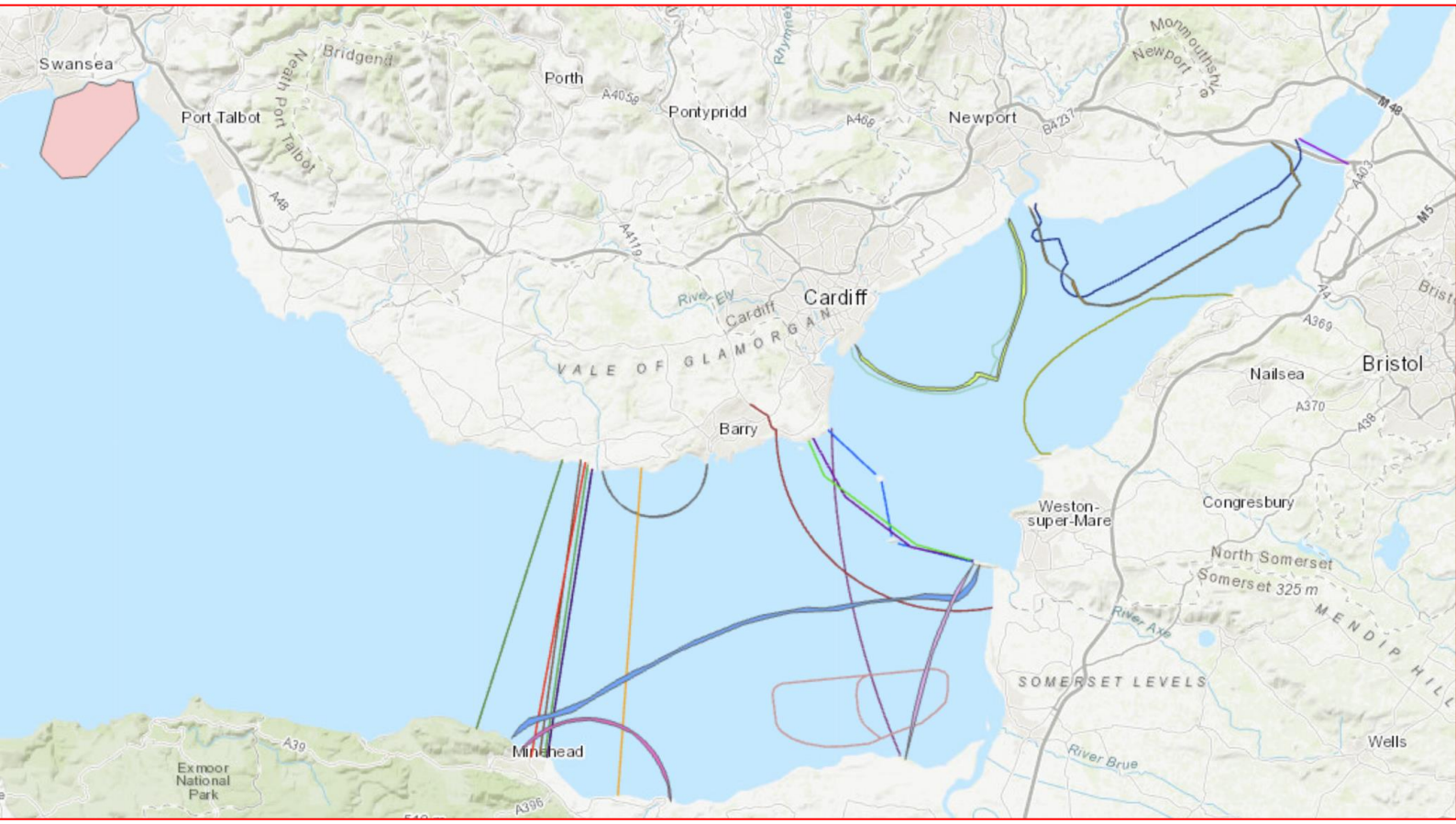
Western Gateway

SUSTAINABLE ENERGY IN THE SEVERN ESTUARY

Evidence Base and Framework



OCTOBER 2023

Western Gateway

SUSTAINABLE ENERGY IN THE SEVERN ESTUARY

Evidence Base and Framework

Summary Report

PROJECT NO. 70109278

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CONTENTS

EXECUTIVE SUMMARY

Scope

This summary report has been prepared to outline the work undertaken by WSP in 2023 to consolidate the publicly available evidence of previous tidal power studies and projects in the Severn Estuary, in the UK and internationally.

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.

Tidal Power – Current Status

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 Technology 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 potentially feasible – the Cardiff to Weston Barrage, the Shoots Barrage and the Bridgwater Bay Lagoon. Uncertainties

identified included the location and scale of inter-tidal compensatory habitats, the data available on fish movement, far field effects potential economic impact on the Severn Ports.

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.

Since then, 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. This was examined by a Select Committee Inquiry who raised a number of concerns which were shared by Government in their response to the Inquiry. In 2015, Tidal Lagoon Power, received a Development Consent Order (DCO) for a 320MW tidal lagoon in Swansea Bay. In 2016 the Government commissioned an independent review by former Energy Minister Charles Hendry which 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. However, 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.

Although Tidal Lagoon Power's proposals for Swansea Bay had not been successful, Swansea Council supported the concept of a tidal lagoon in Swansea Bay including the Blue Eden concept proposed by DST Innovations. Other developers are also proposing tidal power projects elsewhere in the estuary including a lagoon in Somerset and new concepts for a tidal barrage.

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.

Outside of the Severn Estuary, the Liverpool City Region Combined Authority are progressing their plans for a tidal range power project. Tidal stream projects have also been progressed primarily in the Pentland Firth and Anglesey.

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 emphasis 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;
- 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;
- The opportunity to create a large number of jobs and support economic growth,
- 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."
- As it can take up to ten years to consent new tidal power 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).
- 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 over time 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.

This report includes a summary of lessons learned and identifies uncertainties that have arisen from previous work. An important first step will be to use the evidence base presented in DECC's Final STPFS suite of technical reports published in 2010, supplemented by subsequent studies as the foundation for any future work. Engagement with the relevant stakeholders at an early stage to understand where the evidence gaps and uncertainties exist, and how they would resolve them, will also 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.

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.

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.

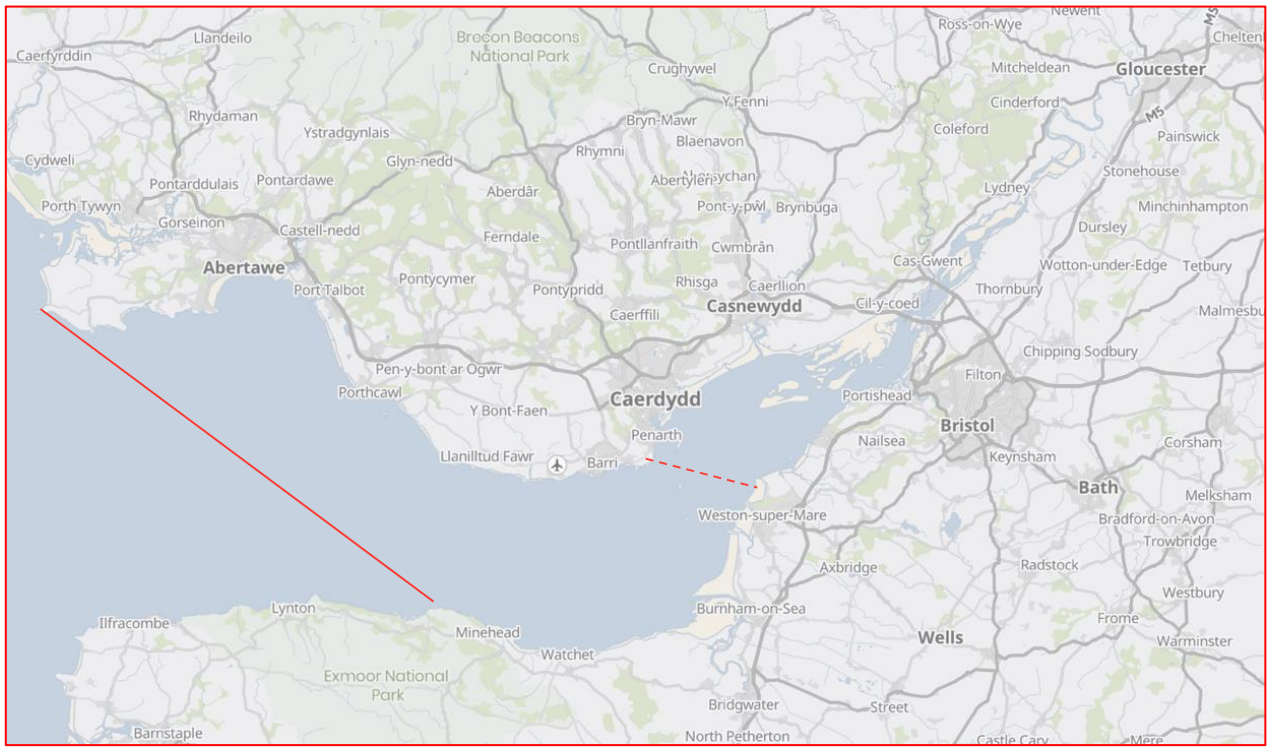

Figure 1 The Severn Estuary and Bristol Channel

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.

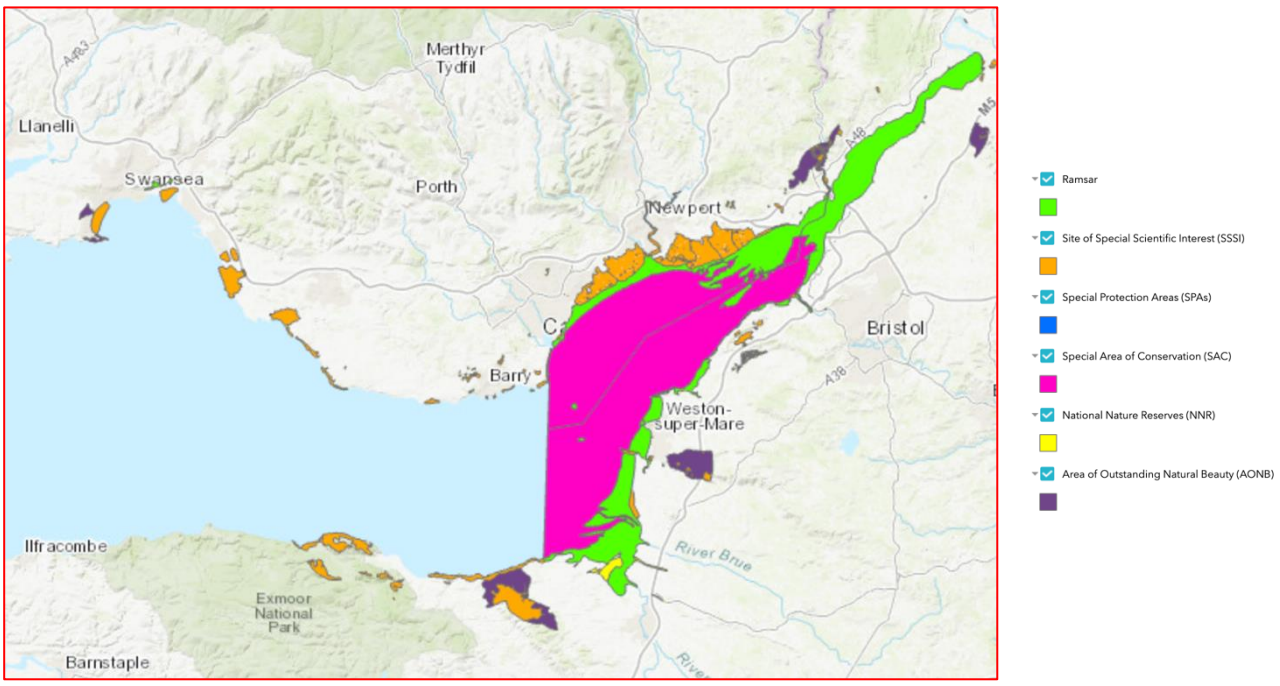

Figure 2 The Severn Estuary Environmental Designations

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).

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 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);

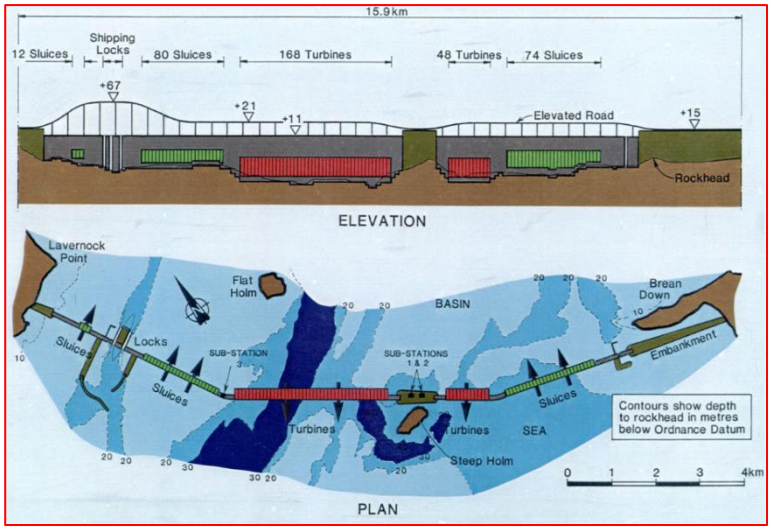

Figure 3: Cardiff to Weston Elevation and Plan imagery from STPG.

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).

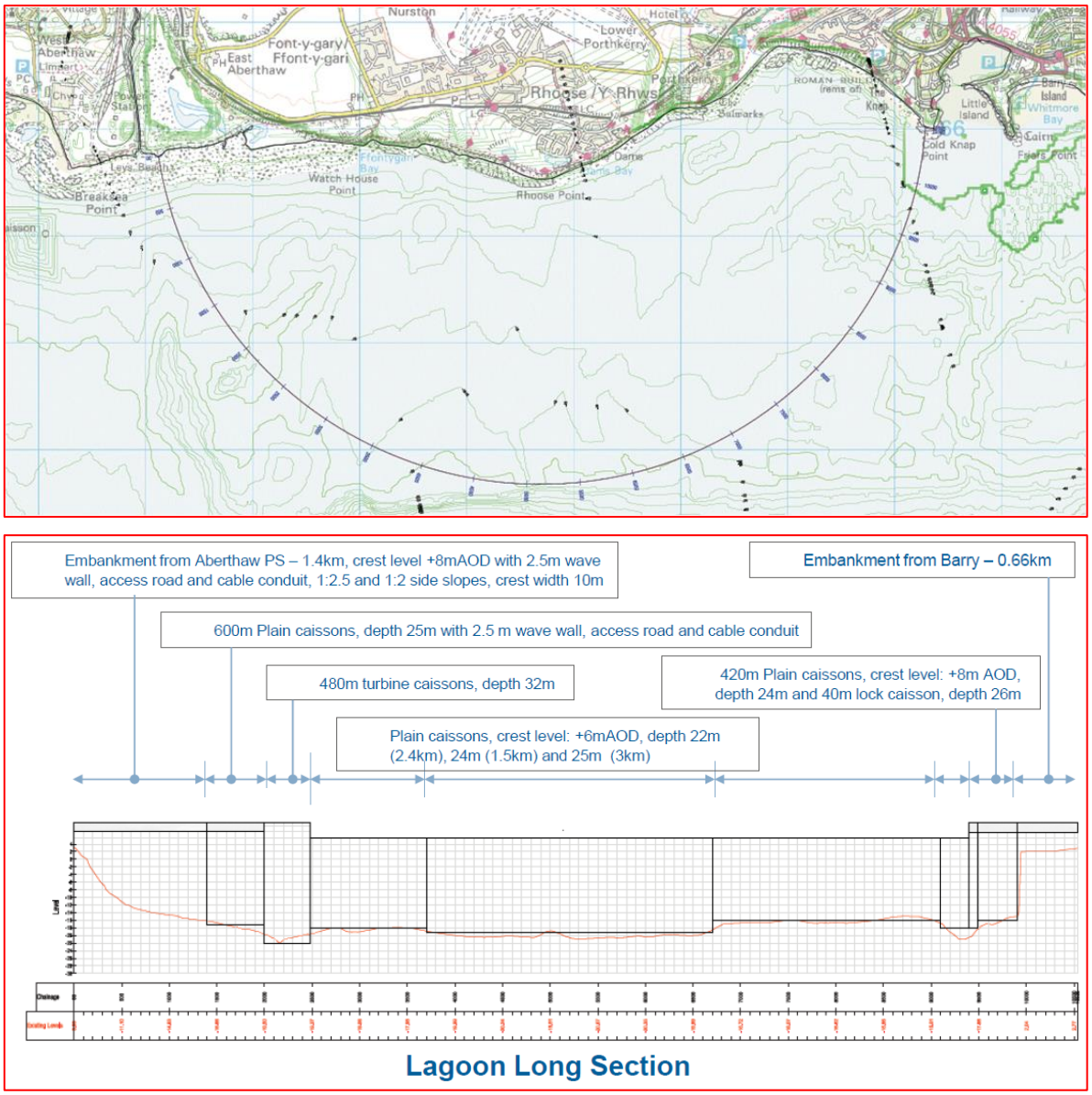

Figure 4: Stepping Stones Tidal Lagoon Plan and Elevation.

iii) A lagoon located entirely offshore to form a continuous structure located in the sea. 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.

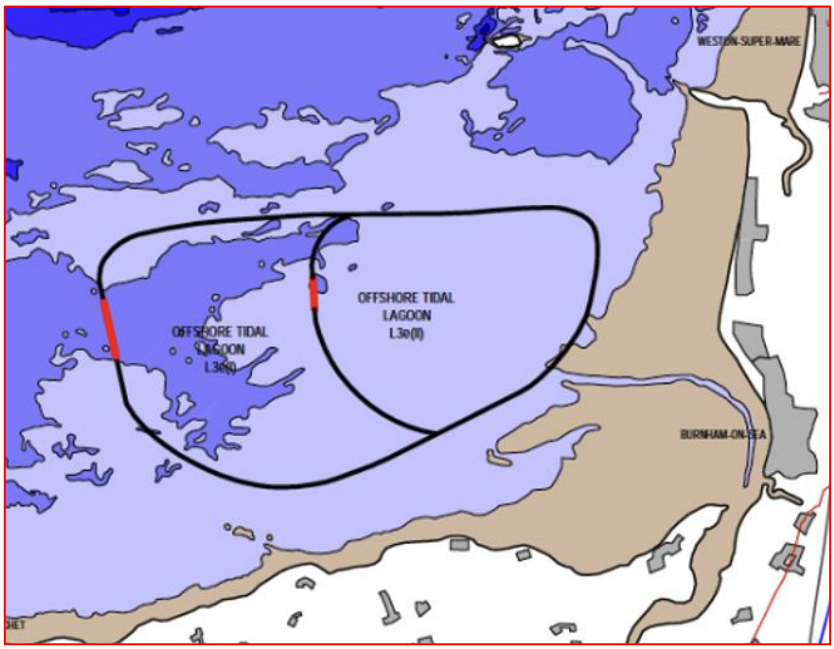

Figure 5: Two Offshore Lagoon Options studied in the STPFS

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.

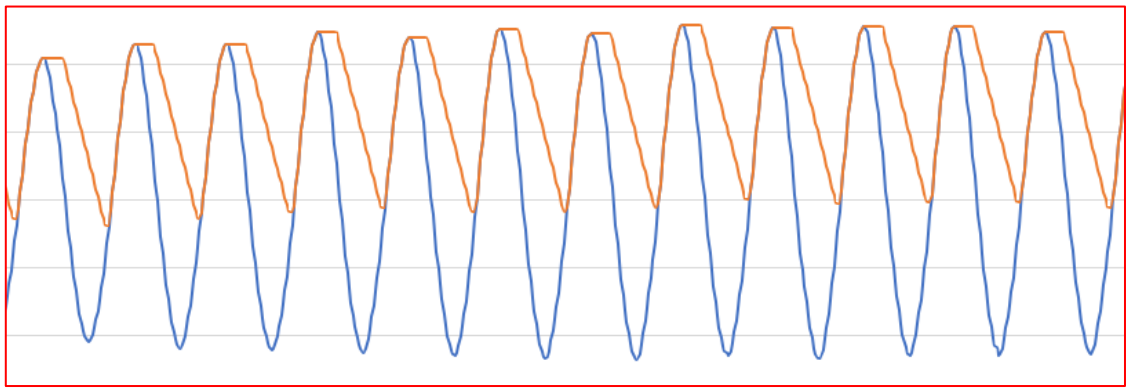

Figure 6: Impounding (orange) and Natural (blue) Tide Levels – Ebb only operation – with significant loss of intertidal areas in the lower half of the tidal prism

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.

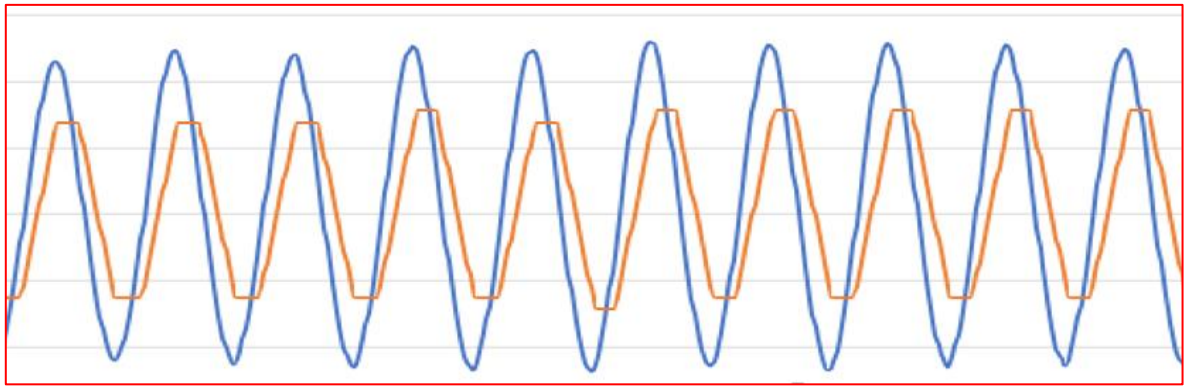

Figure 7: Ebb and Flood operation – with impounding levels showing symmetrical losses at high and low tides.

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.

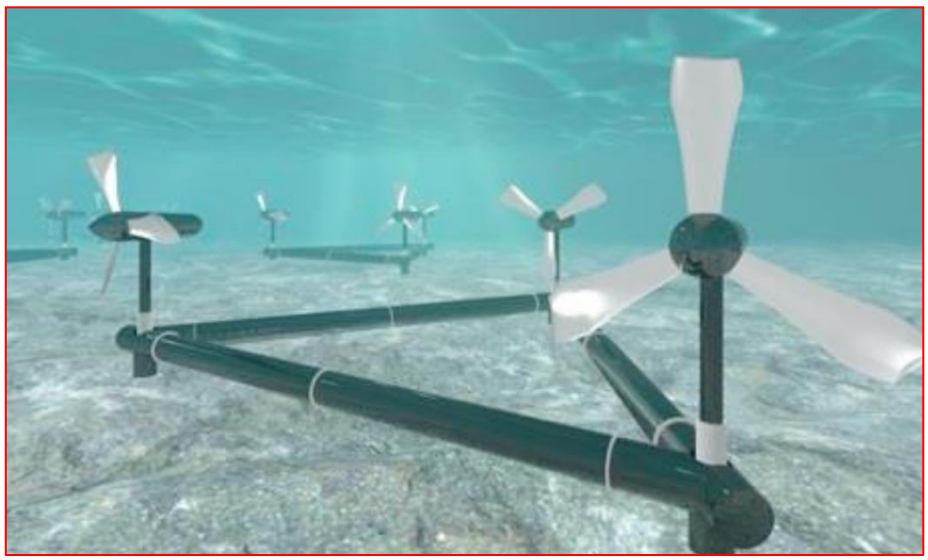

Figure 8: An illustration of tidal stream turbines proposed for Ramsey Sound (from Tidal Electric Limited)

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.

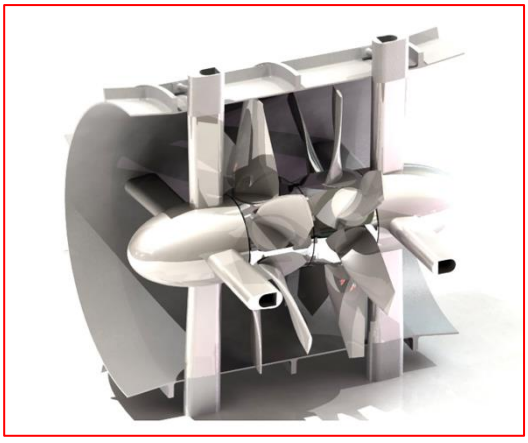

Figure 10: A cut-away of a low head turbine developed by Rolls-Royce and reproduced from their published SETS report.

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.

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 examined different technologies for the Severn and tidal power in general. 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 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…"* Following the publication of the SDC's Report, the Government commissioned the Severn Tidal Power Feasibility Study in 2008.

[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
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. 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.
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 project's planning consent lapsed in 2020. 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.
EIS and WA Joint Select Committee Inquiry into	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

Title	Author and Date	Summary
"Swansea Bay Tidal Lagoon"		confidential documents that were published including designs, costs, business case models and correspondence.
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 more expensive.

Tidal Power Deployment

Tidal Stream

Th first example of a tidal stream turbine was a 300 kW prototype installed near Lynmouth, Devon. It was not connected to the grid but did provide proof of concept. In 2008, a larger, grid connected 1.2MW turbine was installed at Strangford Lough, Northern Ireland. A number of different tidal stream designs emerged but there has been a degree of consolidation with a number of bankruptcies, although 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 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 have been studied 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.

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.

Wave Energy

Wave energy has few active examples in the UK. The EMEC test facility in Orkney has hosted the largest number of wave devices. Many wave energy developers have failed financially. 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.

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 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 and identifying locations for the 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.

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;
- 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:

- Welsh Government Net Zero strategic plan
- Engagement approach around Climate Change 2022-26
- Public Sector Net Zero data and recommendations
- Net Zero Wales Carbon Budget 2 (2021 to 2025)
- Net Zero Wales: sustainability appraisal
- Working together to reach net zero: all Wales plan

In particular, in Welsh Government's Programme for Government, they set out that they will hold a tidal lagoon challenge, as part of their commitment to make Wales a world centre for emerging tidal technologies. In March 2023, the First Minister announced the £750,000 grant fund for the Tidal Lagoon Challenge. The tidal lagoon challenge will directly support innovative research that will work to:

- Reduce or remove a barrier that is currently preventing tidal lagoons being developed.
- Quantify a potential benefit of tidal lagoon development.

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 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 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:

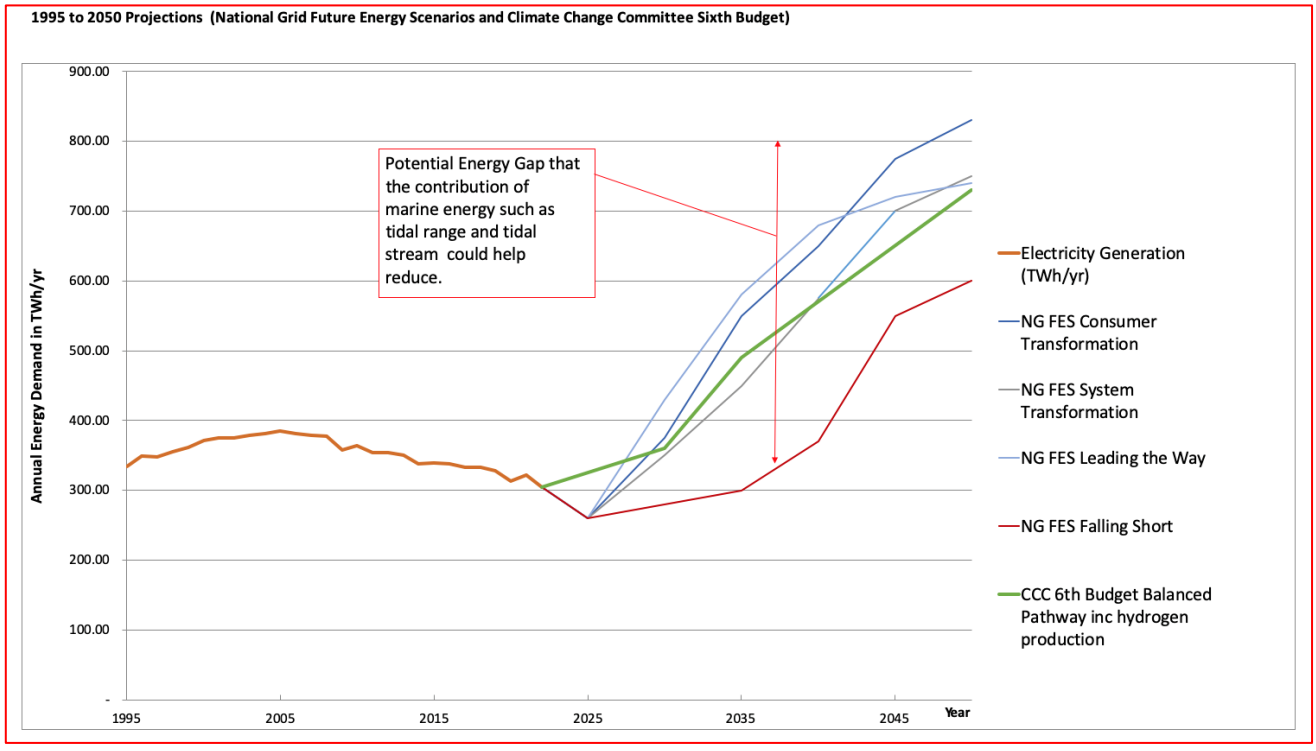

Figure 12 Energy Demand projections to 2050

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.

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, specifically the variance in inflation rates from CPI for construction cost and wholesale energy costs. 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

As illustrated by the issues above, there is significant scope for the proposed Independent Commission to review and influence future tidal power policy. Some of the potential 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 shorter durations of back-up resources required;
- Long life;
- Contribution to the diversity and resilience of the energy mix;
- 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;

- Mature technology
- 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).

Realising such benefits will be facilitated if a case can be made for inclusion of support for tidal range in a specific National Policy Statement, introduction of a new financing mechanism for prospective tidal range projects, consideration 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 and understanding why previous tidal range projects have failed to progress.

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.

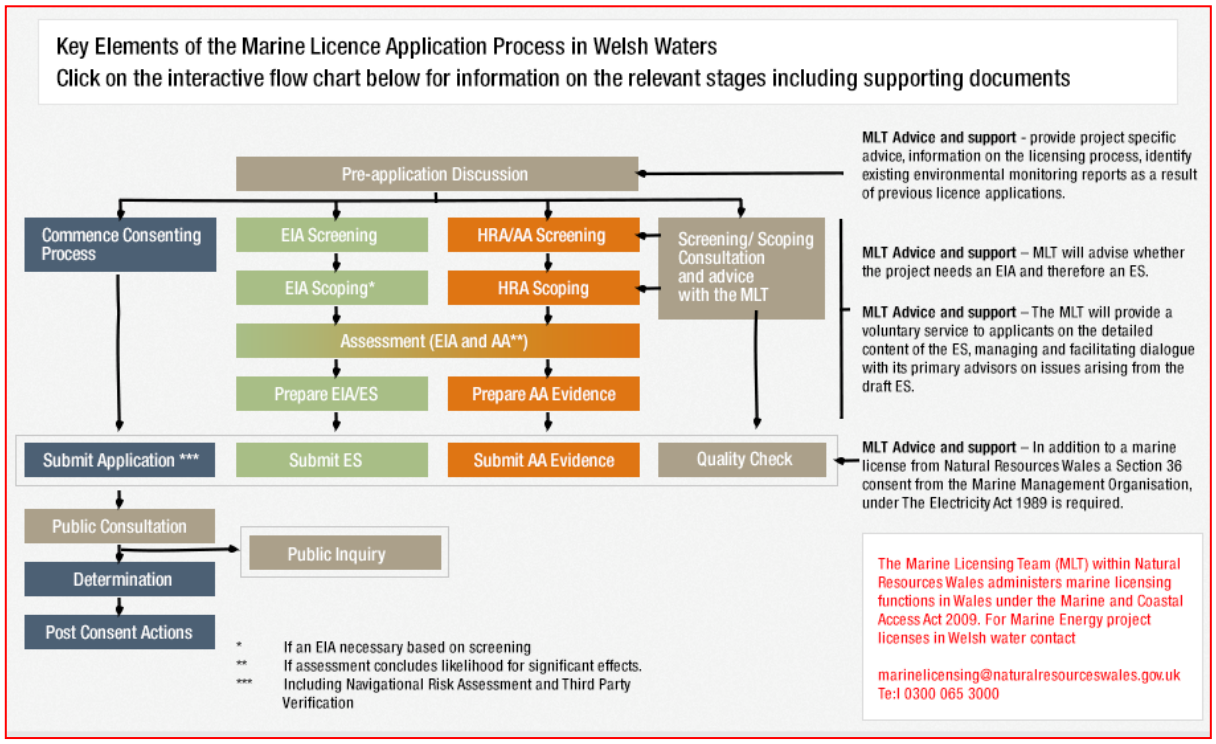

Figure 13: The Consenting Process for Tidal Projects in Wales

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):

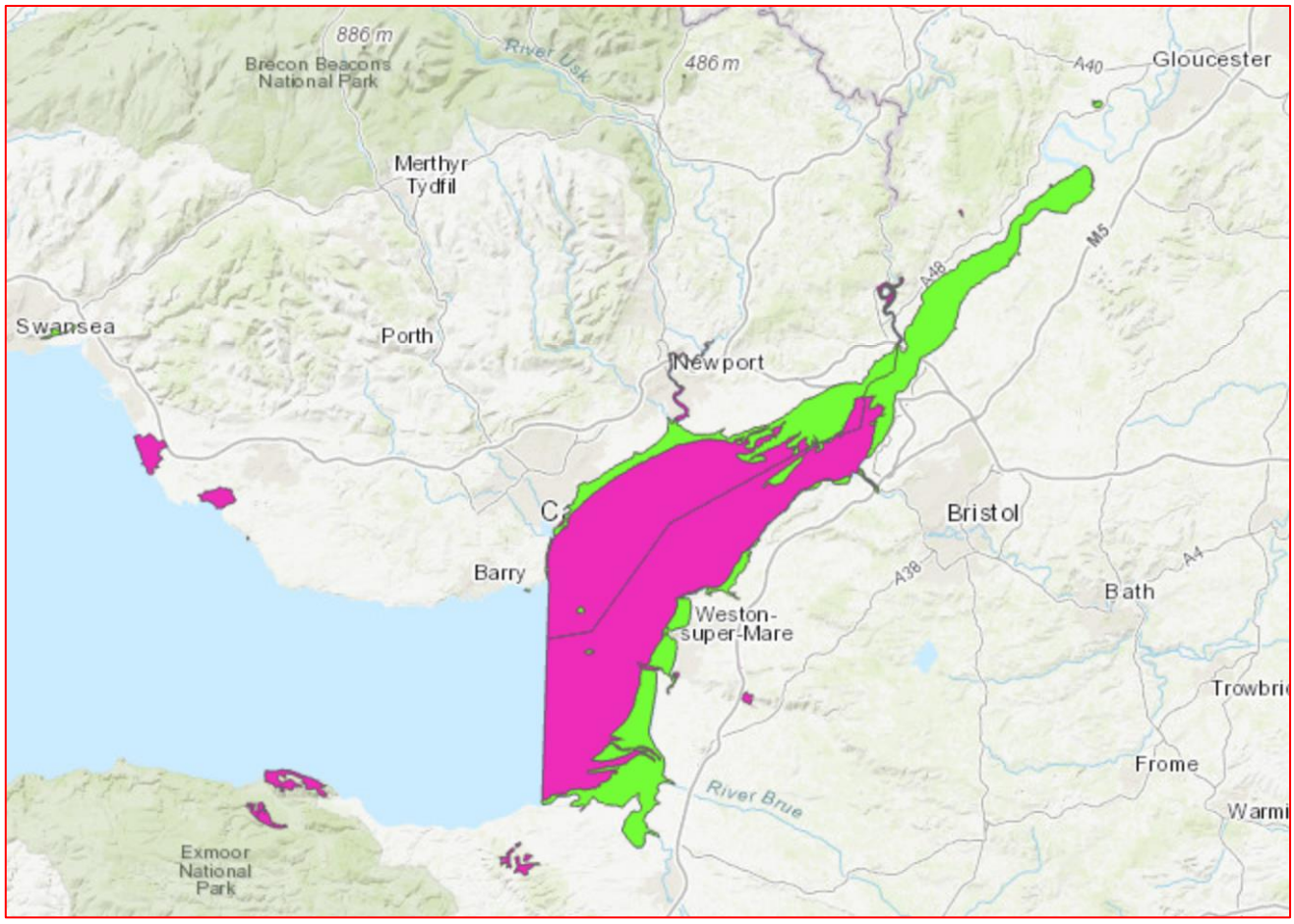

Figure 14: European and International Designated Areas

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.

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.

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)
	English Stones Barrage	2002 Update
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	
	B4 Shoots Barrage	
	B5 Beachley Barrage	
	R1 Tidal Reef	

Programme	Project	Data Source
	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
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

Programme	Project	Data Source
	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

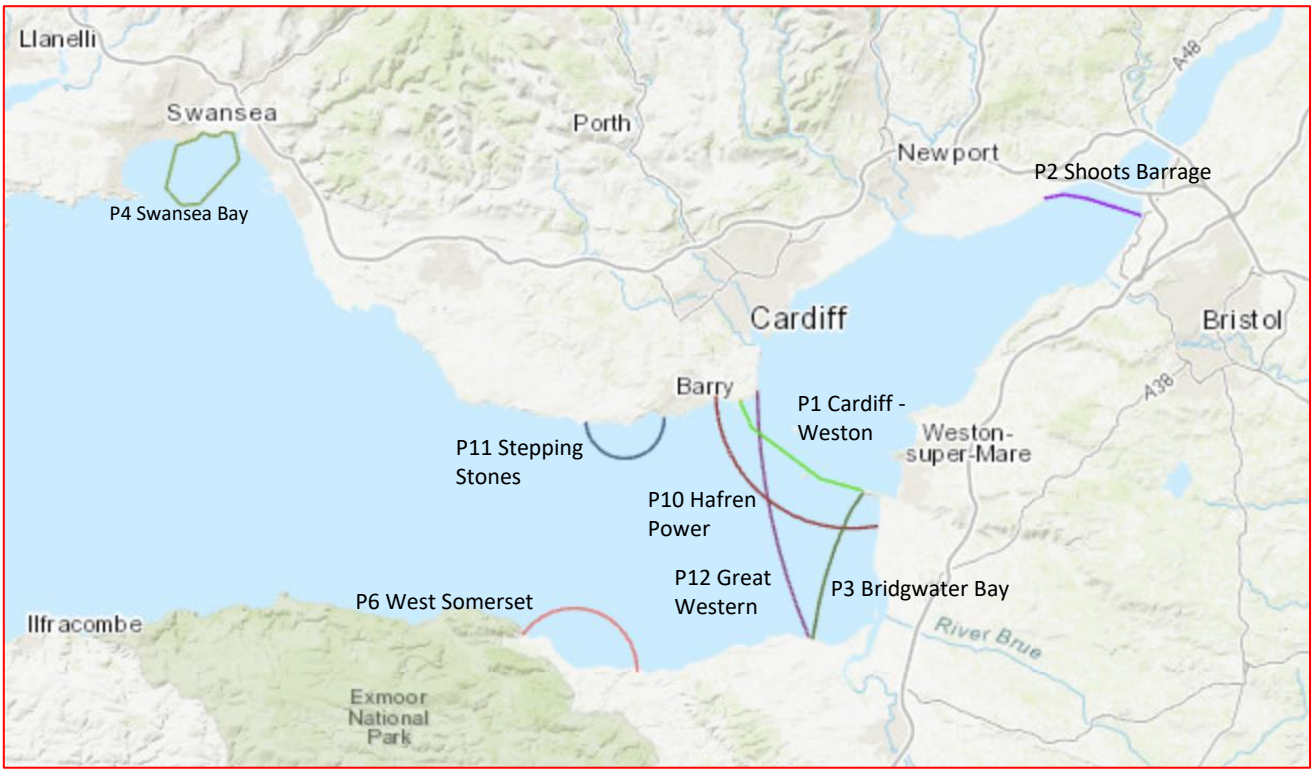

Figure 15 Severn Estuary Tidal Power Projects

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
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

Developer	Project	Data Source
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
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

Country	Project	Data Source
		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 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 analysis has looked at all the credible projects that have been studied over the past five decades.

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.
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.

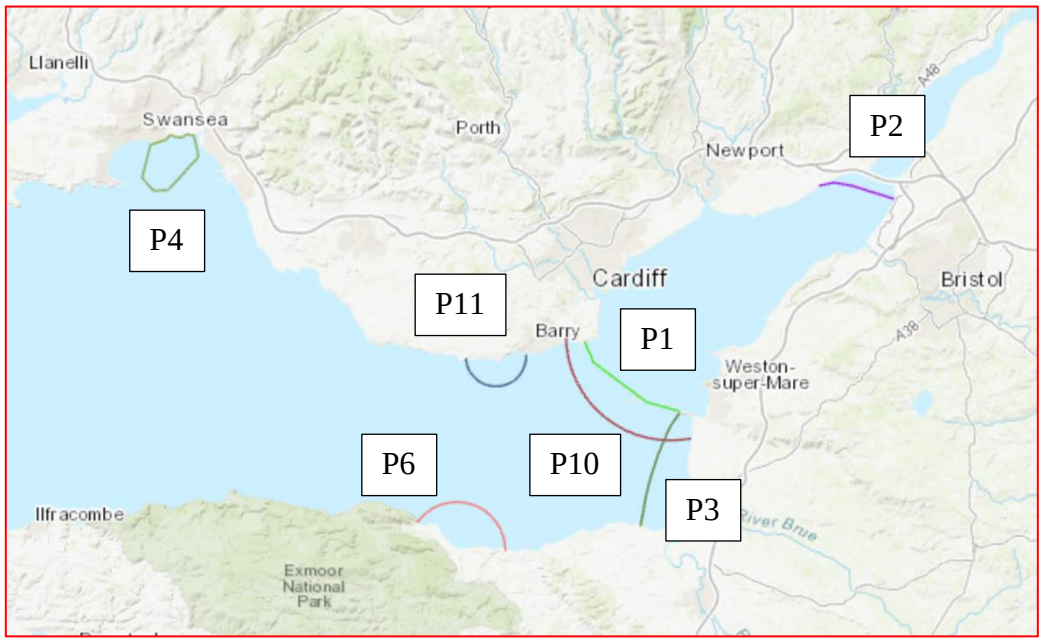

Figure 16: Tidal power projects Locations.

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 analyses show that the best in terms of performance are those that have not been subjected to detailed study. There are therefore significant caveats around confidence of costs and energy outputs but notwithstanding this, the middle estuary shows promise for future tidal power development with its reasonable tidal range and reduced environmental sensitivity compared with the inner estuary. However, the inner estuary has the highest tidal range and projects in this area should not be discounted albeit that they are located within a highly protected part of the estuary. Swansea Bay Tidal Lagoon (P4), with its lower tidal range, had the most expensive unit cost of energy of the projects considered.

The projects not analysed in detail because of conclusions from their previous studies are 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.

Conclusions

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

- Tidal lagoons may be 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 or Bridgwater Bay Lagoons or the Shoots Barrage, which are 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;

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. 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. 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.

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.

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.

The key point about tidal range projects is that they are not the same as modular wind and solar power projects (for which the CfD regime was designed) 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 has been problematic for large infrastructure scale projects.

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.

Integrity of Project Information

A common issue with infrastructure projects proposed by the private sector is a tendency for over-optimism in construction costs and programme duration. Evidence of the analyses undertaken in this report suggest that, of the many projects considered in the Severn Estuary, it is important that costs and programmes are developed in a consistent manner, so the most promising projects are developed first. The key point is therefore about effective governance in spatial planning and taking time to develop reliable cost estimates and realistic construction programmes.

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.

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.

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.

The second challenge for the Independent Commission will 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. 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.

From a Port's perspective, changes in water levels from a barrage located downstream of their facilities may require their existing locks to be modified requiring partial closure of the port and, because shipping would have to transit a new set of locks on the barrage, transit times and responsibilities would need careful consideration and could potentially result in the loss of container traffic to the port (container ships choose to dock at deep water unobstructed berths to minimise turn-round times). Consequently, a barrage between Cardiff and Weston would appear to be a challenging proposition, as it impacts Bristol, Newport, Cardiff and Sharpness 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 may be less of an issue and the higher water depth from the impounded water should 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.

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;
- reviewing "stranded asset" and "end-of-life" decommissioning options; and
- 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.

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 and delivered by the Western Gateway Officers and advisors.

It will be important for the Commission to focus on areas that they can influence in their 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.

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SUMMARY REPORT