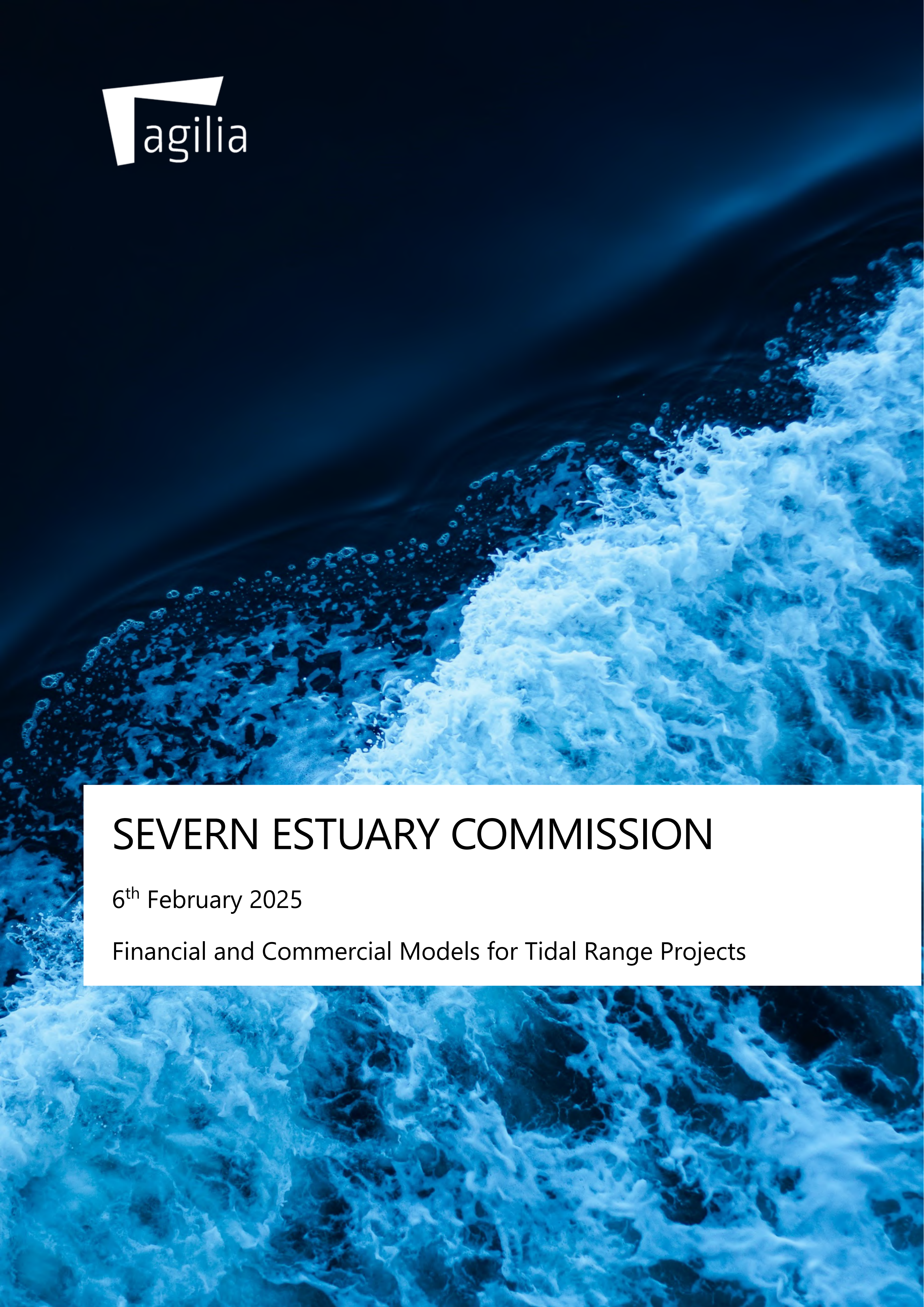

SEVERN ESTUARY COMMISSION

6th February 2025

Financial and Commercial Models for Tidal Range Projects

CONTENTS

GLOSSARY

BWACC	Bid Weighted Average Cost of Capital
Capex	Capital Expenditure
CCGT H	H-Class Combined Cycle Gas Turbine
CCUS	Carbon Capture Utilisation and Storage
CfD	Contract for Difference
DCO	Development Consent Order
DBFO	Design Build Finance and Operate
DECC	Department of Energy and Climate Change
ECI	Early Contractor Involvement
EDF	Electricité de France
EPC	Engineering, Procurement & Construction
GSP	Government Support Package
HPC	Hinkley Point C
IP	Infrastructure Provider
LCCC	Low Carbon Contracts Company
LCOE	Levelised Cost of Electricity
NESO	National Electricity System Operator
NPS	National Policy Statements
NPV	Net Present Value
NRW	Natural Resources Wales
NSL	North Sea Link
OFTO	Offshore Electricity Transmission
Opex	Operating Expenditure
PPA	Power Purchase Agreement
RAB	Regulated Asset Base Model
RFR	Risk Free Rate
SMR	Small Modular Reactor
SoSIA	Sector of State Investor Agreement
STP	Social Time Preference
STPFS	Severn Tidal Power Feasibility Study
TCE	The Crown Estate
TTT	Thames Tideway Tunnel
WACC	Weighted Average Cost of Capital

EXECUTIVE SUMMARY

Background

Purpose

Agilia Infrastructure Partners has been appointed by the Severn Estuary Commission (the Commission), to consider potential financial and commercial models for the delivery of new tidal range projects in the Severn Estuary. This report includes:

- A review of the recent history of a broad range of large, complex infrastructure projects in the UK, focussing on the funding and financing lessons which have been learned.
- An assessment of four main funding options: Design Build Finance Operate (DBFO), Cap & Floor Mechanism (C&F), Contracts for Difference (CfD), and the Regulated Asset Base model (RAB).
- Financial analysis of six indicative tidal range projects, with capital costs ranging from c. £2bn to £33bn (2023 prices), to support comparison of tidal range with other generation technologies.

Tidal Range: Strategic Benefits for the UK

Energy Security: Tidal range projects offer a predictable energy source without fuel import requirements and are protected from oil and gas price spikes due to geopolitical events. Whilst base load power remains essential, tidal range energy would complement the UK's renewable energy mix.

Predictable Generation: Unlike wind and solar, tidal energy is highly predictable on both a short- and a long-term basis, driven by the gravitational pull of the moon and sun that creates twice-daily tides whose height varies monthly and, to a lesser extent, through an annual cycle. This predictability would aid the National Electricity System Operator (NESO) in balancing demand more efficiently, reducing reliance on weather-dependent renewables across Europe.

Advantageous Location: The proximity of potential tidal range project sites to major urban and industrial centres like Cardiff and Bristol would simplify grid connections. This contrasts with the challenges faced by offshore wind farms, which require long, costly transmission solutions.

Diversification Benefits: Broadening the range of generation technologies deployed would alleviate supply chain and planning bottlenecks in the transition to Net Zero. Investing in tidal range would position the UK as a market leader in tidal technology, construction, and financing, create high-quality jobs, and possibly offer export potential.

Tidal Range: Key Features

Tidal range projects are characterised by several distinctive features that influence the approach to funding and financing:

- Very long-term asset life (at least 120 years) with high capital costs (£2bn - £33bn, 2023 prices) and extended construction periods (5-9 years).
- Relatively low operational costs and predictable power supply. Turbines may require refurbishment every 40 to 50 years, but otherwise infrequent major maintenance. Low risk of planned and unplanned outages.
- Decommissioning costs are uncertain but expected to be significantly lower than other technologies such as nuclear. It may be that the marine wall itself remains as a permanent structure.
- High, relatively uncertain construction costs, although the component technology is well proven.
- Relatively new asset class – only two comparable projects completed to date (La Rance in France, 1966, and Sihwa in South Korea, 2011). However, component technology is well proven.

Historical Context and Case Study Projects

History of Tidal Range in the UK

The UK government has explored the feasibility of tidal power in the Severn Estuary since 1925, recognising the strategic benefits of the substantial energy resource which is available in the tidal flow. Later, in 2010, after a two-year study, the Severn Tidal Power Feasibility Study (STPFS) identified three potentially viable options: Cardiff to Weston Barrage, Shoots Barrage, and Bridgwater Bay Lagoon. However, the newly elected coalition government decided that they did not wish to invest any public money into tidal power.

A proposal for a Cardiff Weston Barrage was promoted by Hafren Power in 2013 but rejected by the ECC Select Committee and the Government. The Swansea Bay Tidal Lagoon project was promoted by Tidal Lagoon Power Ltd from 2011 and received a Development Consent Order (DCO) in 2015. The Hendry Review in 2016 recommended that government support the scheme, adopting either a 60, or 35-year CfD. Ultimately, in June 2018, the government at the time decided not to progress with the project. A key factor was the high CfD strike price, driven by the large capital cost and a comparatively high overall cost of power generation when compared, using conventional metrics, to wind, solar, and nuclear projects.

Other Large Scale Infrastructure Case Studies

A number of other large scale infrastructure schemes provide relevant data points:

- Hinkley Point C (HPC) (3.2 GW nuclear plant in construction) – a CfD approach was adopted for the project, which reached financial close in 2016. The strike price was considered to be very high at the time[1] (£92.50/MWh for 35 years, 2012 prices and index linked). Under the CfD, payments only commence once the asset is operational and construction cost risk is borne by investors. This caused a high cost of finance, which accounted for approximately 67% of the CfD strike price[2].
- NuGen and Horizon (nuclear plants which did not proceed) – between 2010 and 2018, financing solutions were considered as part of these schemes to improve the viability of the CfD structure for new nuclear projects. Ultimately the CfD structure was unable to raise financing of sufficiently long tenor, at a price considered to be value for money.

Following the cancellation of the NuGen and Horizon projects and the perceived shortcomings of the CfD structure in HPC, there has been increased focus on the RAB model for large, complex projects:

- Thames Tideway Tunnel (TTT) (built and entering commissioning) – A £4.2 billion, 25km 'super sewer' financed using RAB. The model shares construction risk between investors and consumers and, in high impact, low probability scenarios, government. These commercial and regulatory structures delivered a very low cost of capital (2.497% real, 2015). TTT has commenced its commissioning phase and has been successful in delivering within its initial cost envelope.
- Sizewell C (under development) – A £20 billion (cost published in 2020 Development Consent Order), 3.2GW nuclear power station. Utilises a RAB model, which enables risk-sharing between investors and consumers, driving a lower cost of finance. A revenue difference payment is proposed to mitigate fluctuations in electricity prices.
- Under consideration for a number of other programmes, including Thames Water and Anglian Water new reservoir projects and the Carbon Capture Utilisation and Storage (CCUS) programme.

These examples highlight the challenges which the CfD model has faced in delivering good value for money on very large, complex programmes and illustrate the more recent shift in the UK towards developing projects of this type based on the RAB model, including in the power sector.

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[1] Hinkley Point C Value for Money Report, NAO, June 2017

[2] Nuclear New Build Cost Reduction, Nuclear Industry Association, 2020

Assessment of Funding Model Options

Design Build Finance & Operate (DBFO)

A DBFO is a long-term contract between a private party and a government entity for designing, building, financing, and operating a public asset and related services.

- × Short contract length (25 – 30 years) relative to tidal range asset lifespan.
- × Fixed price construction contracts and lack of construction phase revenue support.
- × The previous UK government discontinued the use of PFI and other DBFO/M structures.

Not shortlisted for further analysis.

Cap & Floor Mechanism

The Cap & Floor mechanism is a regulatory framework which sets a floor price to ensure an asset can cover operating expenses and debt service, and a cap to limit excessive profits for asset owners.

- ✓ Provides revenue certainty for investors, partially reducing investment risk.
- × Current 25-year application period provides insufficient revenue certainty given 120-year life, resulting in significant risk premium and higher price.
- × No precedents of being applied to very large, complex assets such as tidal.
- × Lack of construction phase revenue support.

Mismatch between application period and asset life likely to drive significant risk premium. Can only partially mitigate construction risk and there is a degree of merchant (i.e. dispatch) risk. There is no clear precedent of the model being successfully applied to very large and complex assets like tidal range**. Not shortlisted for further analysis.**

Contracts for Difference (CfD) Model

The CfD is a mechanism for providing price certainty by guaranteeing a 'strike price' for electricity generated. Successfully used for various renewable energy projects, particularly offshore wind.

- ✓ Provides long-term price certainty.
- × Typical CfD term (up to 35 years) mismatched with 120-year asset life – provides insufficient revenue certainty, driving significant risk premium.
- × Lack of construction phase revenue support.
- × NAO report on Hinkley Point C highlighted significant construction risk premium.

The CfD structure is not well suited to very long-term assets and can only partially mitigate construction risk for investors. **Not shortlisted for further analysis, however, a similar revenue adjustment mechanism may be applied within the RAB model.**

Regulated Asset Base (RAB) Model

RAB is a form of economic regulation commonly employed in the UK for monopoly assets, such as water, gas, and electricity networks. TTT was the first example of using the RAB for a brownfield asset. A RAB Co receives a licence from a regulator, granting it the right to charge a regulated price to users in exchange for providing the specified infrastructure.

- ✓ Attracts 50+ year investment.
- ✓ Allows revenue during construction.
- ✓ Some construction and other risks are born by consumers (and in certain low probability scenarios, government), driving a lower cost of capital.
- ✓ Can offer better long-term value by reducing overall financing costs.
- × Consumers required to start paying in advance, before completion of the asset.
- × Greater regulatory complexity.

RAB has a strong track record of securing competitively priced finance (notably on TTT), with the ability to refinance to align with very long asset lives. Despite some potential implementation complexities, the RAB model offers a good balance between investor needs, consumer protection, and project viability. **Recommended as preferred model.**

Financial Analysis Summary

There are several factors which are relevant to the financial analysis of major power projects, particularly when comparisons are made between different generation technologies:

- Cost of finance is a significant component of the overall cost to consumers, for example c. 67% of the CfD for HPC relates to financing costs, over half of which is a construction risk premium[3].
- Cost of finance is materially affected by the duration of construction and the uncertainty of overall build costs, which translates into a risk premium.
- Power projects can deliver benefits to consumers over significantly different time periods – for example, the UK still benefits from hydro projects that were built in the early 20th Century.
- Relative to other power generation technologies, tidal range has long construction times, intermediate levels of construction cost uncertainty and very long operating periods.

These characteristics mean that analysing the costs and benefits of power generation assets is particularly challenging. This section presents financial analysis which has been carried out on a selection of possible tidal range generation solutions, encompassing large and small barrages, as well as large, medium and small lagoons. It examines different approaches to assessing the financial viability and comparative costs of these technologies, considering the factors set out above.

Levelised Cost of Electricity

Levelised Cost of Electricity (LCOE) is a measure to compare different generation technologies on a consistent basis. Despite being widely used, including by DESNZ in its Electricity Generation Costs 2023 report[4], it has a number of significant shortcomings as a metric. LCOE ignores system costs such as grid integration and storage, overlooks intermittency issues, excludes environmental and social benefits / costs, and (due to discounting) assumes that future energy is not as valuable as energy today.

LCOE is particularly ill-suited to tidal range projects due to the following distinctive characteristics of these assets:

- Long asset life: Tidal range assets have very long operational lifespans (120 years+). LCOE heavily discounts generation in later years, leading to an inconsistent comparison with shorter-lived assets.
- Multifunctional benefits: Tidal range projects can provide additional benefits such as flood protection and other socio-economic impacts, which are not captured by LCOE.
- Predictable output: Unlike other renewables, tidal power offers highly predictable generation patterns, a value not reflected in LCOE calculations.

Dynamic Dispatch Model

Given the limitations of LCOE, DESNZ also uses a Dynamic Dispatch Model (DDM) approach when evaluating power generation projects. DDM enables a more comprehensive analysis of how different policies affect generation mix, costs, prices, security of supply, and carbon emissions.

In 2018, DESNZ used the DDM approach to consider the impact of Tidal Lagoon Power's (TLP) proposed programme of tidal lagoons, up until 2050. The analysis considered additional impacts to society such as the security of supply, balancing, and network costs. The Summary Value for Money Report concluded that the proposed lagoon programme would, due to its small size and limited tidal range when

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[3] Nuclear New Build Cost Reduction, Nuclear Industry Association, 2020 – reported that 67% of the HPC CfD strike price related to cost of finance, 28% of which related to the cost of finance for a typical regulated asset and 39% an additional construction risk premium.

[4] Electricity Generation Costs 2023, DESNZ, November 2023

compared with other sites on the Severn, not offer good value for money when compared to nuclear and offshore wind[5].

However, there are features of the standard DDM approach which are not well suited to the very long-term nature of tidal range projects. We make several recommendations on how the DDM approach ought to be adjusted to allow for these distinctive characteristics:

- Asset Life – the standard DDM approach considers costs and benefits until 2050 only, thereby ignoring the very long generating life of tidal range assets compared to other technologies. We recommend evaluating all assets over a 120-year time horizon, including the cost of rebuilding shorter-life assets at appropriate points on this timeline.
- Funding Solution – tidal range assets should be modelled assuming a RAB structure, rather than the 35-year CfD which was assumed in the 2018 DDM analysis.
- Discount Rate – very long-life assets such as tidal range are highly sensitive to the discount rate which used to evaluate costs and benefits. We recommend that future DDM analysis considers scenarios at a range of discounts rates and/or hurdles rates such as the Green Book long-term reduced rate[6] and the Stern Review climate change rate[7].

RAB Model – Profile of Consumer Charges

Given the limitations of the standard approaches to evaluating very long-life power generation assets, we have instead considered the profile of consumer charges expected under a RAB model for tidal range projects. This approach allows for a more nuanced comparison with other generation technologies, especially given the very long generating life of tidal range assets.

The chart below shows the expected profile of regulated charges (in real terms, 2023 prices) under the RAB model for tidal range. The two tidal solutions shown represent the most cost-effective barrage and the most cost-effective large lagoon. The medium lagoon is also within the range of the two solutions shown. The chart also shows the typical CfD strike prices for other technologies. The bands for the two tidal range options are driven by high / low assumptions for the RAB WACC (see Section 6 for detailed WACC analysis).

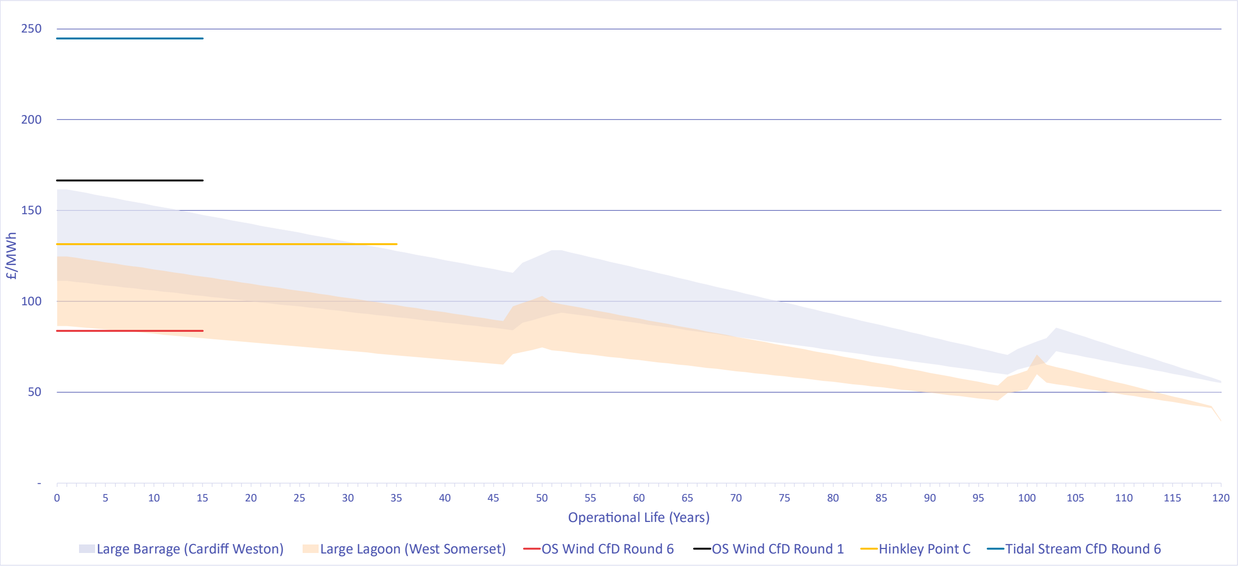

Figure 1: Expected profile of regulated charges (in real terms, 2023 prices) under the RAB model for tidal range and CfD strike prices for other technologies.

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[5] TLP Tidal Lagoon Programme: Summary value for money assessment, DESNZ, June 2018

[6] Intergenerational wealth transfers and social discounting: Supplementary Green Book guidance, HM Treasury, July 2008

[7] Stern Review Final Report, HM Treasury, October 2006

There is significant variability in the cost per unit of electricity between different potential tidal range projects. For example, the cost per unit of electricity of the small lagoon at Swansea Bay is over twice as high as the large lagoon project. This indicates that the choice of site is very important and has a significant impact on overall project viability. It may be that moving straight to a programme of medium and large lagoons offers better value for money than beginning with the small lagoon at Swansea Bay, for example. However, this would need to be balanced with the potential need for investors to see the approach proven at a smaller scale before investing in larger assets.

This analysis shows that under the RAB model, tidal range projects have higher initial costs but demonstrate significant reductions over time as the RAB depreciates. It is notable that the large lagoon and large barrage projects appear competitive with Hinkley Point C from year 1 of operations.

The detailed financial analysis in Section 6 also considers the potential generation cost impact of adopting a CfD-based approach, rather than the RAB model. That analysis concludes that, under a CfD, the strike price for a tidal range asset would likely include a significant construction risk premium over the financing cost for a typical regulated asset. This premium would significantly increase the generation price and therefore might render the project economically unviable. Even at this elevated price, it is the conclusion of this report that it is unlikely to be feasible to raise finance of sufficient quantum under a CfD approach.

Conclusion and Next Steps

This report concludes that the RAB model offers the most promising framework for balancing investor needs, consumer protection, and project viability. Whilst the Cap & Floor and CfD regimes have both been successful in key segments of the energy market, their use has generally been limited to projects with much shorter construction and operating periods than is typical for tidal range. Neither model offers sufficient flexibility in sharing risk between investors, government and consumers for very large and complex assets like tidal range.

Reviewing the history of very large-scale, complex infrastructure development in the UK over the last decade, it is clear that CfD based approaches have not been successful in securing finance for such programmes on a value for money basis. This is supported by a 2017 NAO report and subsequent analysis in 2020 by the Nuclear Industry Association, which concluded that the HPC CfD strike price included a significant premium over the cost of finance for a typical regulated asset, in part caused by construction cost risk being largely borne by investors. Our financial analysis reinforces this conclusion, highlighting that funding models which do not adequately mitigate construction risks for investors are likely to result in materially higher charges.

The financial analysis has also shown that, under the RAB model, tidal range projects can be financially viable relative to other generation technologies such as nuclear and offshore wind. This is particularly true of the medium and large assets which have been considered as part of the financial analysis.

Two initial round table discussions were held with investors between December 2024 and January 2025. These concluded that, whilst there may be limited investor appetite to finance the development phase of a tidal range project, there is interest in the construction phase and broad agreement that RAB is the most feasible structure for achieving a private financing. Refer to Appendix F for further detail on the conclusions of the investor round tables.

For large, complex infrastructure assets, government and developers are increasingly moving towards the RAB based approach which has been used on TTT and is being deployed on Sizewell C. Tidal range shares many characteristics with these projects, and we therefore recommend that the RAB model is taken forward as the preferred option.

We recommend that further work is carried out to define the next steps needed to implement the RAB model for tidal range in the Severn Estuary, including:

- Thorough stakeholder engagement and careful assessment of the long-term impacts of implementing tidal range energy. We recommend a comprehensive stakeholder engagement plan is developed, covering investors, government bodies, Ofgem, local communities, and environmental groups.
- Further business case work, including modified DDM-based analysis, to make the case for tidal range in the Severn Estuary and demonstrate the value for money of RAB relative to other delivery models.
- Specification of a suitable programme of tidal range investments, delivered on a phased basis. We recommend consideration is given to a pilot project using the RAB model to demonstrate viability and refine the approach, before larger-scale deployments. The small lagoon at Swansea Bay appears particularly expensive from a cost per unit of electricity perspective, which may drive a future programme to instead focus on medium and large projects.

1 BACKGROUND

1.1 The Severn Estuary Commission

South Gloucestershire Council operates as the accountable body for Western Gateway; the pan-regional partnership for South Wales and Western England. It stretches from St Davids in Pembrokeshire to Swindon in the East, bringing together business, local leaders and academia with the purpose of generating regional economic growth.

As many of these authorities border the Severn Estuary/Bristol Channel, they have a keen interest in the potential of tidal energy from that natural resource. Western Gateway has therefore set up the Severn Estuary Commission (the Commission) to establish whether there are feasible options for sustainable electricity generation from tidal energy in the Severn Estuary and Bristol Channel.

The Commission, chaired by Dr Andrew Garrad CBE, will provide its findings and recommendations to the Western Gateway Partnership Board by March 2025. To support this, it is undertaking the following tasks:

- Review and update the evidence base in relation to reports commissioned (technical, financial, socio-economic and environmental).
- Understand and assess:
    - The physical and ecological characteristics of the estuary, especially the importance of its unique environment and the future impact of climate change.
    - The relevant policy and legislation.
    - The current and potential future uses of the estuary.
- Collate and consider past tidal energy initiatives and the lessons learned from them.
- Review the different methods of generating electricity from the tidal range energy resource and their contribution to a future energy system.
- Identify the key socio-economic and environmental challenges and opportunities of developing tidal energy schemes.
- Identify means of financing and regulating potentially very long-term projects.

1.2 Purpose of this Report

Agilia Infrastructure Partners has been appointed to assist the Commission in considering the potential financial and commercial models for the delivery of new tidal range projects. This report includes:

- Review of the recent history of large, complex infrastructure programmes in the UK, focussing on the funding and financing lessons which have been learned.
- Assessment of four main funding options:
    a) Design Build Finance Operate
    b) Cap & Floor Mechanism
    c) Contracts for Difference
    d) Regulated Asset Base Model
- Financial analysis of four potential tidal range options, with capital costs ranging from c. £2bn to £33bn (2023 prices), to support comparison of tidal range with other generation technologies.

1.3 Option Evaluation Criteria

The four funding options are assessed across the following criteria:

- Investment Security: The degree of protection and assurance provided to investors regarding their investment and expected returns from the project.
- Cost of Capital: The impact of the model on the overall cost of obtaining finance, including interest, fees, and other associated costs.
- Revenue Stability / Timing: The predictability and consistency of income generated by the project, which affects its ability to meet financial obligations and provide returns to investors. In particular, the extent to which the model offers a return to investors during construction, which is a requirement for accessing deep pools of liquidity from the capital markets.
- Risk Allocation: How various risks (e.g. construction, operational, market) are distributed among stakeholders, including investors, consumers and government.
- Consumer Protection: Measures in place to safeguard the interests of consumers, ensuring fair pricing and efficient management of cost.
- Attractiveness to Investors: The appeal of the funding option to potential investors, considering factors such as risk-adjusted returns, market conditions, and project viability.
- Long-term Sustainability: The ability of the funding model to support the project throughout its entire lifecycle, including operation, maintenance, and potential expansion.
- Government Support: The extent and nature of government participation in the project, including regulatory support, guarantees or direct investment.

1.4 Strategic Benefits of Tidal Range

Tidal range generation assets would offer a number of potential strategic benefits to the UK:

Energy Security: Tidal range projects offer a predictable energy source without fuel import requirements and are protected from oil and gas price spikes due to geopolitical events. Whilst base load power remains essential, tidal range energy would complement the UK's renewable energy mix.

Predictable Generation: Unlike wind and solar, tidal energy is highly predictable on both a short- and a long-term basis, driven by the gravitational pull of the moon and sun that creates twice-daily tides whose height varies monthly and, to a lesser extent, through an annual cycle. This predictability would aid the National Electricity System Operator (NESO) in balancing demand more efficiently, reducing reliance on weather-dependent renewables across Europe.

Advantageous Location: The proximity of potential tidal range project sites to major urban and industrial centres like Cardiff and Bristol would simplify grid connections. This contrasts with the challenges faced by offshore wind farms, which require long, costly transmission solutions.

Diversification Benefits: Broadening the range of generation technologies deployed would alleviate supply chain and planning bottlenecks in the transition to Net Zero. Investing in tidal range would position the UK as a market leader in tidal technology, construction, and financing, create high-quality jobs and possibly offer export potential.

1.5 Other Advisors

The Commission has already contracted engineering consultant Peter Kydd of WSP, who has significant engineering experience of tidal range projects in the Severn Estuary, and Hardisty Jones of Oxford Economics who is investigating the socio-economic impact of the various alternatives. Arup has been appointed to consider power generation impacts on the grid and estimate power generation for specific projects. WSP is reviewing the environmental effects. Therefore, technical, economic and social benefits, and environmental impacts will not be directly covered in this report.

The Commission has focused on tidal range (barrage and lagoon) technologies, rather than tidal stream.

2 KEY FUNDING & FINANCING ISSUES

This section provides a summary of the key funding and financing issues associated with tidal range projects. These issues have been considered in assessing the potential funding options.

2.1 Development Phase

The development phase is challenging given the wide range of environmental issues, public sector and special interest group stakeholders, and the fact that only three comparable projects of similar scale have been completed to date (two are still operational). Implementation of a regulatory and policy framework to support the commercial scale development of a portfolio of tidal range projects may encourage the private sector to fund or co-fund the development phase. Development capital required is expected to be in the range of £35m to £50m for the first project, according to WSP estimates.

Initial round table discussions with investors have indicated that there is limited appetite for development phase investment, based on current circumstances (see Appendix F for further detail). Key conclusions from the development phase round table include:

- Development funding for the first project would likely need to come from government sources, for example, the Crown Estate and/or the National Wealth Fund. Alternatively, match funding support could be explored during the development phase, similar to the Small Modular Nuclear Reactor program (i.e. up to 50% equity).
- The following could make a tidal range programme more attractive from a development capital perspective:
    - A clear route to market and demonstrable UK government support.
    - A satisfactory regulatory and legislative framework (similar to the SMR programme and CCUS, as examples).
    - Confidence that a marine licence, planning consents and grid connections are likely to be achieved in a timely manner.
    - Confirmation that environmental risks are sufficiently mitigated.

For the purposes of this report and supporting financial analysis, we have assumed that the development stage of the programme would be funded by the public sector. This assumption ought to be revisited if a potential UK policy and framework for tidal range power projects develops and after a more detailed consultation process with potential investors.

Appendix B provides further risk analysis including potential funding sources from the public sector.

2.2 Construction costs / Long Duration Construction Phase

Given the limited number of precedents, and the scale of the capital expenditure requirement, it is unlikely that fixed-priced, turnkey construction contracts will be achievable. Although the core component technology is proven, the construction phase will likely comprise two key contracts: the Turbine and Electro-mechanical Contract, and the Civil Engineering Construction Contract.

A significant financial challenge for tidal range projects is the treatment of interest during construction. Typically, interest is capitalised over the construction phase, which for conventional projects like gas-fired power plants, usually lasts for approximately two years. However, tidal range projects have a much longer construction period, ranging from 5 to 9 years. If interest is capitalised over this extended timeframe, it will result in substantially higher total costs compared to shorter-duration projects. This prolonged construction phase, and its financial implications, is a key issue that sets tidal range projects apart from more conventional energy infrastructure developments.

The chosen funding model will need to adequately mitigate construction risks for investors and will likely require a mechanism which allows for adjustments to the cost envelope during construction.

2.3 Large Finance Quantum

The tidal range technical solutions considered in this report range from c. £2bn to £33bn (2023 prices) in capital cost. To attract private sector finance there must be acceptable risk sharing between the private sector and public sector (taxpayers and consumers), and an acceptable regulatory and legislative framework to support a low weighted average cost of capital (WACC).

Developing a smaller tidal range project first could serve to boost investor confidence, prior to developing a portfolio of tidal range projects on a staged basis. The successful completion and proven performance of such a project will likely serve to lower perceived construction risks and potentially attract private sector finance if combined with a suitable funding model. However, it should be noted that the small lagoon has a particularly high cost per unit of electricity generated (see Section 6), which should be taken into consideration when defining a programme of tidal range projects. We conclude that a first lagoon should be a commercially viable design. Our analysis shows that the medium lagoon example, or similar, could fulfil this requirement

Unit construction costs are not expected to reduce considerably throughout a programme of tidal range investments – perhaps limited to a 10% cost reduction across the programme. It is not expected to repeat the significant cost reduction which has been achieved by both PV and wind. This is because the technology is mature and has already achieved cost reduction through its use in hydropower projects.

2.4 Revenue / Funding

The economic value of the project will be the power produced, which will vary both daily and seasonally, but in a predictable fashion over an unusually long time (120 years).

For a typical project finance asset (i.e. a gas-fired power plant), energy generated is sold either directly into the market, or under long-term offtake agreements (15 years). For example, the Keadby 2 Combined Cycle Gas Turbine Power Plant in North Lincolnshire has a Power Purchase Agreement (PPA) with a duration of 15 years. This agreement helps ensure financial stability and operational viability for the plant and amortisation of debt during the PPA period. However, a PPA approach is unlikely to be appropriate for tidal range, due to the mismatch between the typical term of a PPA (c. 15 years) and the very long life of a tidal range asset. Therefore, an alternative offtake arrangement needs to be considered.

2.5 Operating costs

For tidal range projects, opex is expected to be relatively low and predictable. There may be a need to service and replace mechanical equipment/turbines every 40 to 50 years, although La Rance turbines have now been operating for 60 years and have not been replaced. Environmental risks will need to be considered on a site-specific basis.

2.6 Decommissioning

This may be relatively limited in scope if the requirement is to remove the turbines and leave the wall in place given the marine environment impacts of wall removal. A decommissioning fund will likely be required to meet any future decommissioning costs, sourced from project revenues during the asset life.

2.7 Technical Features

Broadly there are two categories of tidal range asset:

- Tidal barrage, which connects two points on opposite banks of an estuary; and
- Tidal lagoon, which generally connects two points on the same shoreline, projecting out to sea.

Options across both categories are considered in this report.

Offshore tidal lagoons, which are not connected directly to the shoreline, are also possible. However, these solutions have very high construction costs and have therefore not been considered further.

The technical features of the tidal range solutions are described in more detail in Appendix A.

3 PROJECT CASE STUDIES

3.1 Introduction

To effectively evaluate the four funding model options which are under consideration, it is useful to review relevant case study projects. This section focuses on relevant examples from the energy sector and other very large, complex programmes such as TTT.

These case studies set out where the Cap & Floor regime has been used previously and highlight the challenges that the CfD model has faced in delivering value for money on exceptionally large, complex programmes. They also demonstrate the recent shift in the UK towards developing projects of this scale using the RAB model.

3.2 Use of Cap & Floor Regime

The Cap & Floor model is a regulatory regime that has been primarily used in the UK energy sector for interconnector projects. Interconnectors are high-voltage transmission cables that allow electricity to be traded between countries. Projects which have been approved under the Cap & Floor regime include, the Nemo Link between UK and Belgium, the NSL between UK and Norway and NeuConnect which will connect UK and Germany.

Whilst subsea cable installation does present unique challenges, interconnectors are generally simpler, from a construction point of view, than tidal range.

3.3 Use of CfD Structure

The CfD structure has been extensively used in the UK energy market. Key examples include:

- Onshore and offshore wind – in aggregate, approximately 30GW of onshore and offshore wind projects in the UK have been awarded CfDs through successive auction rounds. These range in size from c. £50m capital value to c. £4bn each for Hornsea Project 1 and 2. Whilst the construction of wind generation assets presents its own set of challenges, the associated risks are generally considered to be less significant than those of highly complex, large-scale assets such as tidal range. Offshore wind assets have a design life of 35 years.
- Solar PV – approximately 7.5GW of solar PV projects in the UK have been awarded CfDs. These range in size from c. £15m capex, to c. £500m capex for projects like the Cleve Hill Solar Park. Construction risk for solar PV is typically considered to be low, based on modular construction of standardised units.
- Hinkley Point C (HPC) (3.2 GW nuclear plant in construction) – a CfD approach was adopted for the project, which reached financial close in 2016. The strike price was considered to be very high at the time (£92.50/MWh for 35 years, 2012 prices and index linked). Under the CfD, payments only commence once the asset is operational and construction cost risk is borne by investors. This caused a high cost of finance, which accounted for approximately 67% of the CfD strike price[8].
- NuGen and Horizon nuclear power station proposals – between 2010 and 2018 solutions were considered as part of these schemes to improve the viability of the CfD structure for new nuclear projects. Ultimately the CfD structure was unable to raise financing of sufficiently long tenor, quantum and flexibility and the project was cancelled.

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[8] Nuclear New Build Cost Reduction, Nuclear Industry Association, 2020

3.4 The RAB Model

Following the cancellation of the NuGen and Horizon projects and the perceived shortcomings of the CfD structure for very large infrastructure projects, there has been increased focus in the UK on the RAB model for large, complex projects which are unable to attract a fixed price construction contract:

- Thames Tideway Tunnel (TTT) (built and entering commissioning) – A £4.2 billion, 25km 'super sewer' financed using RAB. The model shares construction risk between investors and consumers and, in high impact, low probability scenarios, government. These commercial and regulatory structures delivered a very low cost of capital (c. 2.5% real). TTT has commenced its commissioning phase and has been successful in delivering within its initial cost envelope.
- Sizewell C (under development) – A £20 billion (as estimated in 2020) 3.2GW nuclear power station. SZC has been designated as the first nuclear project to use a RAB model under the Nuclear Energy (Financing) Act 2022. The model enables risk-sharing between investors and consumers, driving a lower cost of finance. A revenue difference payment is proposed to mitigate fluctuations in electricity prices.
- Under consideration for a number of other programmes, including Thames Water and Anglian Water new reservoir projects and the Carbon Capture Utilisation and Storage (CCUS) programme

Appendix D provides more detailed project case studies for HPC, TTT and Sizewell C.

4 ASSESSMENT OF FUNDING MODEL OPTIONS

4.1 Funding Models Considered

This section examines potential funding models and their suitability for tidal range projects, considering the distinctive characteristics of this technology. While many of these models offer flexibility and can be applied to a wide array of engineering solutions, their efficacy for tidal range projects requires careful evaluation.

Our analysis is based on a number of key assumptions:

- Private sector investment and sponsorship of the project.
- Electricity consumers as the primary funders (revenue stream).
- The development phase of the programme will be funded by the public sector.

We have also considered the evaluation criteria set out in Section 1 when evaluating the options.

4.1.1 Design Build Finance Operate (DBFO)

- A DBFO is a long-term contract between a private party and a government entity for designing, building, financing, and operating a public asset and related services.
- In a DBFO contract, the private party bears risks associated with construction, maintenance, and management, with remuneration linked to performance.
- DBFO contracts transfer delivery, cost, and performance risks to the private sector, protecting the public sector from delays, cost overruns, and poor performance.
- Typical DBFO contract length is 25 to 30 years.
- DBFO contracts work well where there is no natural revenue stream and provide taxpayer payments in the form of unitary charges, delivering predictable returns to investors.
- For a tidal range project, a DBFO contract is unlikely to work well due to difficulties in predicting the estimated power price and cost range (including future capex during the operation phase) over a long period.
- UK HM Treasury policy currently prohibits the use of PFI and similar DBFO/M models.
- A tidal range project might require capital expenditure every 40 to 50 years to replace turbines, which would be challenging to accommodate in a DBFO structure.

<table>
<tr><th colspan="2">DBFO – Summary Assessment</th></tr>
<tr><th>Pros</th><th>Cons</th></tr>
<tr><td>✓ Suitable for a range of assets e.g. schools, hospitals, bridges, roads.
✓ Outcomes based contracts can insulate client from unforeseen costs as risks can be passed to the construction contractor / operator.</td><td>✗ Typical 25 to 30 year contract, not suitable for very long term assets.
✗ Inflexible contract which cannot easily adjust for unforeseen changes.
✗ Not fully suitable for payment during construction (given outcome-based nature of the risk allocation), nor major capex spend during the operation phase.</td></tr>
<tr><td colspan="2">Conclusion
Unlikely to be a feasible model for an asset of the scale and complexity of a tidal range project. PFI and similar DBFO structures are currently prohibited by HM Treasury. Typical 25 to 30-year contract length unsuitable for very long-term assets such as tidal range.
Not recommended for further assessment.</td></tr>
</table>

4.1.2 Cap & Floor Price Mechanism

- A Cap & Floor price mechanism sets a floor price to ensure an asset can cover operating expenses and debt service, and a cap to limit excessive profits for asset owners. It provides a stable revenue stream, mitigating merchant price risk to attract long-term investment.
- For interconnectors, the floor requires minimum 80% availability to qualify.
- The cap can increase/decrease by 2% based on availability performance, incentivising maximum uptime.
- Cap & Floor levels are built from capex, opex, decommissioning costs, tax, and allowed return.
- Levels are flat in real terms, with 25-year duration and 5-year revenue assessments. Interconnectors can request within-period adjustments for financeability or anticipated large adjustments.

<table>
<tr><th colspan="3">Cap & Floor – Summary Assessment</th></tr>
<tr><th>Aspect</th><th>Pros</th><th>Cons</th></tr>
<tr><td>Investment Security</td><td>Provides revenue certainty for investors within a defined range (between the Cap & Floor).</td><td>Need for constant government/consumer support if revenues hit floor frequently.
Only partial mitigation of construction cost overruns within the Cap & Floor band.</td></tr>
<tr><td>Cost of Capital</td><td>Reduces perceived investment risk, leading to lower cost of capital.</td><td>Capped upside limits potential returns, deterring some investors.</td></tr>
</table>

Revenue Stability	Stabilises revenues in volatile market conditions. Revenues are index linked to CPIH.	No revenue during construction, which results in capitalised interest, increasing overall project costs. Some tidal range projects have a construction term of up to 8 years.
Risk Allocation	Ensures a fair allocation of risks between investors and consumers for specific asset classes.	Less government support/risk mitigation compared to RAB model.
Consumer Protection	Consumers benefit from limits on excessive returns, as revenues above the cap are shared or reduced.	Potential exposure to costs if revenue falls below the floor, which could increase tariffs or require subsidies.
Attractiveness to Investors	Makes tidal range projects more attractive to cautious, risk-averse investors due to downside protection.	Some investors may find the limited upside (cap) unattractive compared to other, higher-return investments.
Long-term Sustainability	Promotes the development of long-term renewable energy assets by mitigating financial risk.	Model currently only applies for 25 years, which may not be sufficient to fully realise returns on long-lived tidal range assets.
Government Involvement	Less reliance on heavy government intervention, allowing for private sector-led development.	Compared to RAB or other models, there is far less government support and risk mitigation, making the project less secure.
Revenue Timing	Provides certainty, within a band, over operational revenue once the project is generating power.	No revenue during the lengthy construction phase, leading to higher financing costs and risks during the early stages of the project.
Conclusion The Cap & Floor model provides revenue certainty and reduces investment risk, promoting renewable energy development while fairly allocating risks between investors and consumers. However, the lack of revenue during construction increases the overall cost of finance and does not allow access to deep pools of liquidity from the capital markets. It also does not adequately mitigate the construction risk associated with very large, complex assets such as tidal range. Not recommended for further assessment.		

4.1.3 Contracts for Difference (CfD)

- CfDs provide price certainty by guaranteeing a strike price for electricity, shielding developers from market volatility.
- While CfDs have successfully supported offshore wind, their application to tidal energy faces challenges:
  a) Tidal projects have significant uncertainties around costs, contract interface risks, and project risks.
  b) CfDs emphasise short to medium-term price certainty, misaligned with tidal's long development cycles.
- The HPC nuclear project saw strike prices rise significantly during negotiations due to investors bearing full risk after signing. The National Audit Office suggested risk-sharing finance models could have delivered better value.
- 35-year CfD term leaves merchant price risk beyond year 35, and decommissioning costs are funded separately.

CfD – Summary Assessment

Aspect	Pros	Cons
Investment Security	Provides long-term price certainty during the operational phase by guaranteeing a fixed "strike price" for energy produced.	CfD's are typically short-term (15-35 years) compared to the long lifespan of tidal range projects (120+ years), leaving uncertainty after the contract period.
Cost of Capital	Reduces perceived market risk, enabling cheaper financing by enabling a stable revenue during the CfD period.	Post-contract exposure to market volatility, increasing long-term investment risk. No revenue during construction. Does not mitigate construction cost risk which is significant for tidal range.
Revenue Stability	Shields investors from energy market price fluctuations during the CfD period, as any shortfall between the market price and strike price is compensated.	No revenue during lengthy construction phase, leading to higher capitalised interest and costs.
Risk Allocation	Allocates market price risk to the government or consumers during the CfD period, giving investors' confidence in revenue streams.	No protection for construction risks like cost overruns or delays, increasing risk burden for developers.

Consumer Protection	Protects consumers by capping investor returns: if market prices exceed the strike price, excess revenues are returned to consumers. CfD will not commence if construction does not complete by the long stop date.	Consumers bear the cost if market prices are consistently below the strike price, which could lead to increased electricity prices or public subsidies.
Attractiveness to Investors	Attractive to investors due to the guaranteed income over the CfD period, helping to secure finance for wind and solar projects.	Short relative CfD term (15 - 35 years) compared with 100+ year lifespan of tidal project, makes model less appealing for investors seeking long-term returns/risk sharing.
Long-term Sustainability	Ensures predictable revenues for the CfD period, making the project more bankable during its initial operational phase.	CfD doesn’t cover a long enough percentage of the asset life for tidal range assets, leaving a significant portion of the operational life exposed to market risk.
Government Involvement	Reduces the need for long-term government support, as the CfD is limited to a defined contract period.	Unlike models like RAB, the CfD provides less government-backed risk mitigation and doesn’t protect investors against the long-term uncertainties beyond the contract period and during a longer construction phase. Note HPC does have extra protections i.e. insurance back stop, through the Secretary of State Investor Agreement (SoSIA).
Revenue Timing	Provides certainty over operational revenue once the project is generating power, which is crucial for large infrastructure projects.	No revenue during the lengthy construction phase, leading to higher financing costs and risks during the early stages of the project.

Conclusion

While CfDs provide short-term price certainty beneficial for more established renewables, their limited contract durations fail to sufficiently mitigate the long-term risks associated with tidal range. The lack of revenue during construction increases the overall cost of finance and does not allow access to deep pools of liquidity from the capital markets. There is no mechanism to mitigate the construction risks associated with very large, complex assets such as tidal range.

A Nuclear Industry Association report into the HPC project concluded that 39% of the CfD strike price related to a construction risk premium over the financing cost for a typical regulated asset.

It is recommended that CfD is not considered further as a standalone funding option. However, a similar revenue stabilisation mechanism may feature as part of the RAB option (see below).

4.1.4 Regulated Asset Base (RAB)

- RAB models involve an economic regulator granting a licence to a company to charge regulated prices for using infrastructure. For tidal range Ofgem would be likely to take this role.
- By providing regulated returns, a RAB model can potentially reduce financing costs for new tidal projects, lowering consumer bills and maximising value.
- Key features of a typical RAB model include:
    - A licenced project company with a pre-set funding envelope for managing project costs.
    - Licence terms covering capital costs, depreciation, tax, etc. to determine allowed revenue.
    - Allowed revenue adjusted for cost and performance incentives, project delivery, and delays.
    - Resilience against low probability, high impact events like market disruptions or cost overruns.
    - An economic regulator to provide appropriate regulatory oversight of the project.
    - A mechanism for the regulator to set revenue amounts raised from energy suppliers during construction and operation.
    - A mechanism that will address high impact, low probability scenarios (which in the case of TTT was implemented via the Government Support Package (GSP) as further explained in Section 5.5).
- The SZC structure includes a CfD-style revenue adjustment mechanism, which helps to mitigate electricity market price risk. It is anticipated that a similar approach would be adopted for new tidal range, should the RAB model be selected (see 'Offtake Options' in Section 5.9).
- A RAB structure has the potential to attract significant project investment at lower costs to consumers and enable large-scale low-carbon power delivery. It also provides access to deep liquidity pools in the capital markets.

RAB – Summary Assessment		
Aspect	**Pros**	**Cons**
Investment Security	Allowable costs regime mitigates impact of cost overruns for investors. If RAB is combined with a CfD style revenue adjustment mechanism (like SZC), it provides long-term price certainty during the operational phase.	Significant upfront capital expenditure may still deter investors without strong government backing. Upside potential is bounded for equity investors which may deter investors seeking higher returns.
Cost of Capital	When well structured, and with an appropriate mechanism to cover high-impact low probability events, RAB based models can deliver low cost of capital compared with other privately financed approaches.	Challenges associated with designing a package which gives sufficient comfort to investors, whilst maintaining a favourable balance sheet classification (were relevant).

Revenue Stability	Provides investors with a predicable, regulated return. Able to offer revenue during construction. Where RAB + CfD-style revenue adjustment mechanism is adopted, investors are protected from energy market price fluctuations.	Consumers pay once expenditure begins to be incurred and before the asset is operational, which requires a proactive communications strategy.
Risk Allocation	Shares construction and operating risk between private sector and consumers. Where RAB + CfD-style revenue adjustment approach is adopted, investors are protected from energy market price fluctuations.	Consumers bear a proportion of cost risk through increased regulated charges against a theoretical counter-factual (i.e. fixed priced alternative).
Consumer Protection	Regulatory oversight to provide protection for consumer interests. RAB model can offer better long-term value to consumers by reducing overall finance costs.	Potential for increased costs to consumers if project overruns or underperforms, especially if government interventions are needed.
Attractiveness to Investors	RAB's stable returns and regulatory framework make it attractive to investors, facilitating access to capital. Investors begin receiving returns during construction.	Long construction periods (5-9 years or more) create uncertainty. Regulated returns may limit potential upside for investors.
Long-term Sustainability	When effectively structured, RAB encourages long-term planning and investment in sustainable infrastructure.	Inflexible regulations may hinder adaptation to changing market conditions or technological advancements.
Government Involvement	Government oversight and regulation ensure alignment with public policy objectives. There is precedent for GSPs to support efficient financing.	Balance sheet risks associated with GSP must be closely monitored.
Revenue Timing	Ensures stable revenue streams, improving attractiveness to investors. Allows investors to receive revenue during construction.	Consumers pay once expenditure begins to be incurred and before the asset is operational, which requires a proactive communications strategy.

Conclusion

The analysis concludes that the RAB model is likely to offer better value to consumers than alternatives, with a higher probability of attracting private sector investment. In 2017, the National Audit Office reviewed the TTT project and concluded that the model helped reduce the financial risk for investors, lowered the cost of capital compared to traditional funding methods and provided a mechanism to ensure that the costs of the project were spread over a longer period, reducing the immediate financial burden on consumers[9].

Key advantages of the RAB model include:

- Proven mechanism for sharing risk between investors, consumers and government.
- Returns from the first year of construction.
- Track record of achieving a comparatively lower cost of finance for very large, complex assets e.g. TTT).

The RAB model is particularly suitable for tidal range projects due to their long construction periods (5-9 years) and extended payback times. It balances risk and reward effectively, making it attractive for investors while protecting consumer interests.

Initial investor round tables indicated appetite for financing the construction phase of a tidal range project, and broad agreement that the RAB is the most feasible structure for achieving a private financing.

Based on the above analysis, we recommend that the RAB model is taken forward as the preferred model in respect of tidal range projects in the Severn Estuary.

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[9] Review of the Thames Tideway Tunnel, NAO, March 2017

5 RAB MODEL DESIGN

This section provides a summary of the principles of the RAB model and an initial design of a RAB structure for new tidal range projects, which includes the RAB licence, GSP, economic regulation, regulated revenue stream and offtake options.

5.1 The RAB Model

In the context of applying a RAB model to an energy generation asset like a tidal range project, electricity suppliers would be charged as users of the electricity system. These suppliers would then be able to pass these costs on to their consumers, who are the end users of the electricity system. This revenue stream is referred to as the project "funding" used to repay the project finance facility drawn down during the construction phase and any capex financed during the operation phase.

The RAB model was successfully applied to a single-asset construction project for the first time in 2016 with the £4.2 billion TTT sewerage project. This initiative attracted approximately £1 billion in private sector equity finance, largely from UK pension funds.

RAB-funded infrastructure has received significant quantities of investment from private sector players over the last 20-30 years.

5.2 Building on Precedent RAB Structures

The RAB model has been approved for use by HMG within the energy sector, and stakeholders are currently working on or considering implementing the model in several projects, including SZC, and the Small Modular Reactor (SMR) programme. A large-scale, new tidal asset shares several characteristics with these projects, i.e. a complex single-asset construction project with substantial upfront capital expenditure requirements, an extended construction period, the absence of a fixed-price EPC contract, and a long asset life.

In developing a potential RAB structure for tidal range projects, we would recommend adopting the models used for TTT and SZC as a starting point. The tidal range projects under consideration vary in capital expenditure from c. £2 billion to £33 billion (2023 prices). For context, TTT funding was approximately £4.2 billion, while SZC is estimated at around £20 billion.

To attract low-cost capital at the required scale, a Tidal Range RAB model would need to incorporate the following key elements:

- Establishment of a licensed project company
- An Economic Regulator
- A defined route for funds (regulated revenue stream)

5.3 Indicative RAB Structure Diagram

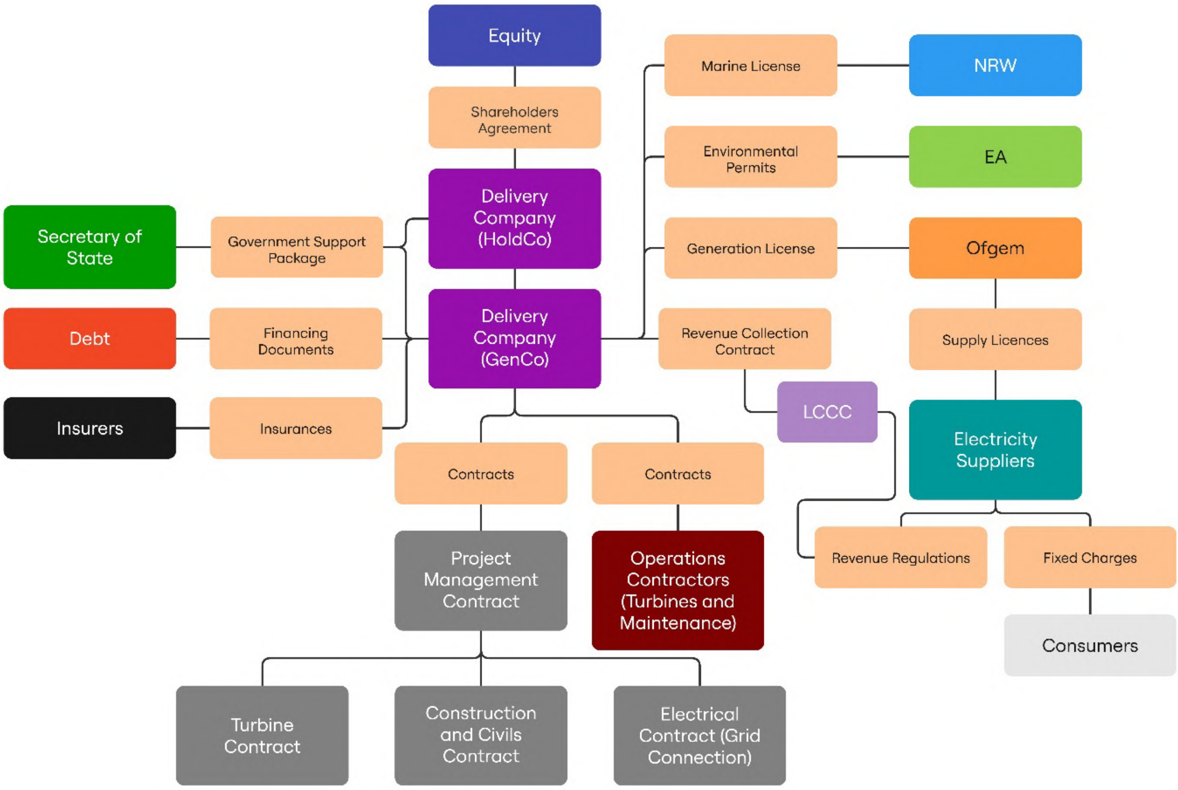


Figure 2: Typical structure for RAB model

5.4 Licensed Project Company

It is envisaged that a tidal range RAB model would require a licence to be granted by the Secretary of State for the Department of Energy Security and Net Zero, to a project company entitling it to charge the 'Allowed Revenue' (see definition below) in exchange for performing its functions (the construction and operation of a tidal project).

Allowed Revenue refers to the total revenue that a regulated company is permitted to earn from its customers over a specific period. This revenue is calculated to cover the company's operating costs, depreciation, and a fair return on its invested capital. Figure 3 provides an illustrative representation of the profile of Allowed Revenue under the SZC project.

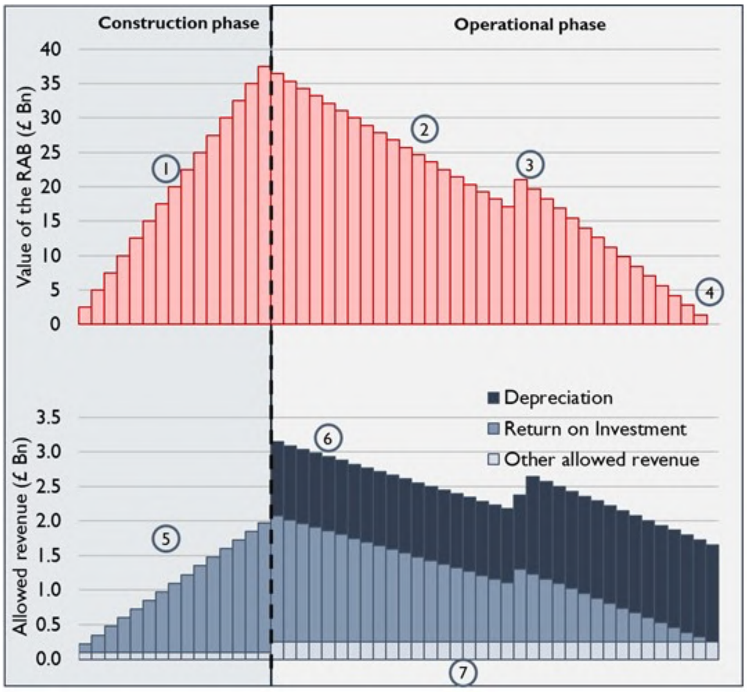
The amount of Allowed Revenue would be determined by the Regulator, and this would effectively govern the way in which risk is shared between investors and users of the electricity system (suppliers and their consumers). Essentially, this approach creates a vehicle for an infrastructure project to demonstrate a risk profile similar to a utility with an Investment Grade credit rating, thereby attracting substantial pools of low-cost capital (both debt and equity).

Typically, the Allowed Revenue would be based on a set of 'building blocks' that would enable the project company to recover its costs (if approved by the Regulator) and to generate a return on capital invested to finance those costs. Indicative building blocks are as follows:

Allowed revenue = Return on capital + depreciation + operating costs + tax + grid costs + decommissioning costs + incentives penalties and other adjustments.

Where:

- *Return on capital* = the cost of capital allowed by the regulator and the total cumulative capital expenditure as incurred and approved as being efficient by the regulator. This will include capital expenditure during the construction phase and operation phase.
- *Depreciation* = repayment of the initial capital cost of the RAB value during its operational life, so that all invested capital would be repaid by the end of its life. (Typically straight line depreciation over life of the asset).
- *Operating costs* = cost of operating the asset over the operation phase.
- *Taxes* = as determined over the asset life.
- *Grid costs* = the cost of connecting to and use of the electrical grid.
- *Decommissioning costs* = provision for costs associated with end of asset life.
- *Incentives / penalties and other adjustments* = as determined by the licence to provide protection to consumers.



① The value of the RAB increases during the construction phase reflecting capital investment in the project.
② The RAB decreases during the operational phase reflecting depreciation.
③ Additional capital investment, such as the refurbishing of equipment to extend its operational life, can be added to the RAB during the operational phase.
④ Depreciation reduces the RAB to zero by the end of the economic lifetime of the project

⑤ Investors begin receiving a return on investment during the construction phase based on the size of the RAB and the initial weighted cost of capital.
⑥ During the operational phase investors recover their initial investment in line with a depreciation profile.
⑦ The allowed revenue also covers operating costs, contributions to the decommissioning fund, several other categories of cost, and adjustments to reflect any incentive schemes.

Figure 3: Illustration of the evolution of the RAB (top) and the allowed revenue (bottom) across the lifetime of the project. All values are in base-year prices. Source: Public information note on nuclear RAB and Sizewell C, Consumer Scotland

The Allowed Revenue would be charged during both construction and operations, increasing with cumulative project spend based on project milestones. This approach reduces the financing challenge and cost to consumers over the asset life, improving deliverability and lowering costs for suppliers. However, it exposes them to the risk of funding an incomplete project. A robust due diligence process would help mitigate this 'stranded asset' risk.

Two options exist for managing construction cost risks:

1. Ex-post: The regulator periodically reviews costs, penalising inefficient spending.
2. Ex-ante: Baseline costs are set, with overruns and savings shared between investors and customers. This approach was used for TTT.

The ex-ante approach is likely more suitable for tidal projects, as it incentivises collaborative due diligence and risk management while providing certainty for long-term, single-asset projects. Combined with the GSP, it allows the government to estimate maximum exposure and investors to calculate the impact of cost overruns on returns, enabling effective pricing.

5.5 Government Support Package

To secure the necessary financing, there needs to be a mechanism to protect investors from specific, low-probability, high-impact risks that the private sector cannot efficiently bear. Under the TTT project this was achieved through the use of a GSP.

This mechanism might cover risks such as:

1. Cost overruns above a remote threshold
2. Debt market disruption
3. Uninsurable risks
4. Political risks
5. Special Administration
6. Stranded asset/asset transfer risk

The table below summarises the key components of the GSP under TTT:

Thames Tideway Tunnel GSP	
Supplemental Compensation Agreement	• The Government acts as insurer of last resort. • The Government provides cover for insurable events above the amount the market is able to provide.
Contingent Equity Support	• In the event of cost overruns above a pre-agreed level, the Government can be required to provide equity financing to fund the shortfall. On TTT this is known as the Threshold Outturn (defined below), amounting to £4.2 billion, and reflecting a P99 estimated outturn (meaning 99% probability that the actual project costs will be at or below this threshold).
Discontinuation	• Where the Threshold Outturn (defined below) is reached, or the Government elects not to pay as the insurer of last resort, the Government may elect to discontinue the project and pay compensation. • Compensation is equal to 1 x Regulated Capital Value (with adjustment for break costs).
Special Administration Offer Agreement	• An obligation on HMG to offer a price for the distressed company should it enter into special administration and remain there for a period of time.
Market Disruption Liquidity	• Inability to raise debt finance due to market disruption events • £500m committed liquidity facility in case of the above.

"Threshold Outturn" refers to a predefined level of construction costs which cap the financing obligation of investors. If the costs exceed this threshold, financiers have the option to inject further capital or government exercises its right to discontinue the project under the GSP.

5.6 Economic Regulator

An economic regulator's oversight of allowed revenue will be crucial for the financial stability and long-term success of tidal range projects under the RAB model. Ofgem, as the energy regulator, would be best suited to perform this role, as planned for SZC.

The regulator's key functions include:

1. Overseeing expenditure to ensure it is eligible.
2. Monitoring progress of the programme.
3. Making any licence determinations (such as revisions to the base case).
4. In the operational phase, determining the WACC.

This regulatory framework is particularly important for tidal infrastructure development, where initial costs and perceived risks are comparatively high. By ensuring revenue safeguards, the regulator promotes investor confidence while protecting consumer interests.

Overall, the regulatory oversight in the RAB model is fundamental to the long-term viability of tidal energy projects, balancing investment attractiveness and consumer protection.

5.7 Regulated Revenue Stream

The RAB model for tidal range projects requires a well-designed revenue stream to channel funding to the project company. Unlike the fixed strike price in the CfD model, the RAB model uses a variable £/MWh price adjustable by the regulator.

As with SZC, the regulated Allowed Revenue stream would be designed to cover core elements listed in Section 5.4 above.

The proposed SZC RAB model represents a useful precedent for the application of the RAB model to tidal range assets and includes a CfD-like market price adjustment element in its revenue structure.

SZC will recover its allowed revenue by:

1. Firstly, it is expected to operate competitively in the electricity market and any other market that it can access. This will provide it with a market-based revenue.
2. Secondly, the market revenue will be topped up through “difference payments” (i.e. the difference between allowed revenues and market revenues). These will be recovered from electricity consumers via a levy administered by the Low Carbon Contracts Company (‘LCCC’), following the same process as used during the construction phase. If market revenues exceed allowed revenues, difference payments reverse, with SZC paying the excess back to the LCCC, who redistribute it to suppliers and ultimately consumers.

This combination aims to reduce the financial risk for investors and make the project more attractive, ultimately supporting the development of new nuclear power capacity in the UK. The CfD element helps to stabilise the revenue by ensuring the sum of allowed revenues are received for the electricity generated, protecting against market price fluctuations.

5.8 Intermediary Body

A body would be needed to charge and collect payments from energy suppliers and to pass these to the tidal project company (likely to be the LCCC). As a minimum the company would need to perform:

- Billing and settlement with suppliers and the project company.

- Forecasting of supplier payment obligations in advance of payment (suppliers to reflect these costs appropriately in their consumer tariffs).
- Implementation of appropriate credit support/collateral mechanisms.

5.9 Offtake Options

There are two primary offtake options which could be adopted for a new tidal range asset:

- **Revenue collection from end users via the LCCC –** The established LCCC framework could be used to collect revenue from end users over the life of the asset. It is a proven approach which provides revenue certainty and diversifies credit risk by not relying on a single counterparty. It is the proposed revenue collection mechanism for the SZC project.
- **Power Purchase Agreement (PPA) -** A long-term contract between an electricity generator and a power purchaser. The duration of a PPA is typically 10 – 25 years and would therefore require regular renegotiation through the life of a tidal range asset. There is also the risk of a failure to pay, due to the credit quality of the offtaker. PPAs are better suited to shorter-lived generation assets such as solar or wind.

It would also be feasible to combine these two options.

Although a PPA could be entered into with an end user under the RAB model, this presents a number of challenges and potential negative impacts:

- **Additional complexity** - Adding an additional offtaker will require bespoke monitoring and step-in rights in the event of a default, if combined with the LCCC revenue collection mechanism.
- **Project credit rating -** The project credit rating will be impacted by the credit quality of the PPA counterparty for a portion of the power offtake. The risk is failure to take and pay, and PPA renegotiation risk beyond the initial term. Revenue collection directly via the LCCC provides a stronger credit, based on a well-diversified pool of counterparties.

For the reasons set out above, the recommended option is to collect revenue from end users via the LCCC, over the asset life. This is similar to the approach proposed under the SZC project.

6 RAB FINANCIAL ANALYSIS SUMMARY

6.1 Introduction

This section presents financial analysis which has been carried out on a selection of potential tidal range generation solutions, encompassing large and small barrages, as well as large, medium and small lagoons. It examines different approaches to assessing the financial viability and comparative costs of these technologies. The purpose of the analysis is to estimate the cost, per unit of generation, of tidal range relative to other generation technologies.

The analysis considers:

- The Levelised Cost of Electricity (LCOE) metric and its limitations in respect of tidal range.
- The Dynamic Dispatch Model (DDM) approach to assessing power generation projects, and how it could be adapted to better fit the distinctive characteristics of tidal range projects.
- The estimated profile of charges to consumers under the preferred RAB option for tidal range.

There are several factors which are relevant to the financial analysis of major power projects, particularly when comparisons are made between different generation technologies:

- Cost of finance is typically a significant component of the overall cost to consumers, often accounting for a substantial portion of the total project expense. For instance, approximately 67% of the CfD strike price for HPC relates to financing costs, over half of which is a construction risk premium[10]. This highlights the important role that financing plays in determining the ultimate cost of electricity for end-users.
- Cost of finance is materially affected by the duration of construction and the level of uncertainty of overall construction costs, both of which contribute to the risk profile of the project. Longer construction periods and higher levels of cost uncertainty typically translate into a higher risk premium, as investors and lenders require additional compensation for the increased risk they are assuming. This, in turn, can significantly impact the overall project economics.
- Power projects can deliver benefits to consumers over significantly different time periods, with some assets providing value for many decades beyond their initial construction. For example, the UK's hydroelectric projects built in the early 20th century continue to generate clean, low-cost electricity more than a century later. This longevity factor is crucial when assessing the long-term value and cost-effectiveness of different generation technologies.

These factors combine to create a distinctive financial profile that requires careful consideration when comparing tidal range to other generation options.

Appendix E has further details of the key assumptions underpinning the financial analysis.

6.2 Levelised Cost of Electricity

Levelised Cost of Electricity (LCOE) is a measure to compare different generation technologies on a consistent basis. Despite being widely used, including by DESNZ in its Electricity Generation Costs 2023 report, it has a number of significant shortcomings as a metric. LCOE ignores system costs such as grid integration and storage, overlooks intermittency and reliability issues, excludes environmental and

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[10] Nuclear New Build Cost Reduction, Nuclear Industry Association, 2020 – reported that 67% of the HPC CfD strike price related to cost of finance, 28% of which related to the cost of finance for a typical regulated asset and 39% an additional construction risk premium.

social benefits / costs, and (due to the effect of discounting) assumes that future energy is not as valuable as energy today.

LCOE is particularly ill-suited to tidal range projects due to the following distinctive characteristics of these assets:

- Long asset life: Tidal range assets have very long operational lifespans (120 years+). LCOE heavily discounts generation in later years, leading to an inconsistent comparison with shorter-lived assets. This discounting effect significantly undervalues the long-term benefits of tidal range projects, failing to account for their ability to provide clean, reliable energy over very long time horizons.
- Multifunctional benefits: Tidal range projects often provide additional benefits such as flood protection and other socio-economic impacts, which are not captured by LCOE.
- Predictable output: Unlike other renewables, tidal power offers highly predictable generation patterns, a value not reflected in LCOE calculations. This predictability is advantageous for grid management and energy security, allowing for more accurate forecasting and potentially reducing the need for backup generation capacity.

6.3 Dynamic Dispatch Model

Given the limitations of LCOE, DESNZ also uses a Dynamic Dispatch Model (DDM) approach when evaluating power generation projects. DDM enables a more comprehensive analysis of how different policies affect generation mix, costs, prices, security of supply, and carbon emissions.

In 2018, DESNZ used the DDM approach to consider the impact of Tidal Lagoon Power's (TLP) proposed programme of tidal lagoons, up until 2050. The analysis considered additional impacts to society such as the security of supply, balancing & network costs. The Summary Value for Money Report concluded that the proposed lagoon programme would not offer good value for money when compared to nuclear and offshore wind[11].

However, there are features of the standard DDM approach which are not well suited to the very long-term nature of tidal range projects. We make several recommendations on how the DDM approach ought to be adjusted to allow for these distinctive characteristics:

- Asset Life – the standard DDM approach considers costs and benefits until 2050 only, thereby ignoring the very long generating life of tidal range assets compared to other technologies. We recommend evaluating all assets over a 120 year time horizon, including the cost of rebuilding shorter-life assets at appropriate points on this timeline.
- Funding Solution – tidal range assets should be modelled assuming a RAB structure, rather than the 35 year CfD which was assumed in the 2018 DDM analysis.
- Discount Rate – very long-life assets such as tidal range are highly sensitive to the discount rate which used to evaluate costs and benefits. We recommend that future DDM analysis considers scenarios at a range of discounts rates and/or hurdle rates including the Green Book long-term reduced rate[12] and the Stern Review climate change rate[13].

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[11] TLP Tidal Lagoon Programme: Summary value for money assessment, DESNZ, June 2018

[12] Intergenerational wealth transfers and social discounting: Supplementary Green Book guidance, HM Treasury, July 2008

[13] Stern Review Final Report, HM Treasury, October 2006

6.4 Profile of Consumer Charges Under the RAB

6.4.1 Analysis Approach

Given the limitations of the standard approaches to evaluating power generation assets, we have instead considered the profile of consumer charges expected under a RAB model for tidal range projects. This approach allows for a more nuanced comparison with other generation technologies, especially given the very long generating life of tidal range assets.

In order to estimate the profile of charges to consumers under the potential tidal range projects which are under consideration by the Commission, we have derived the 'Allowed Revenue' under the RAB for each of the following technical solutions:

Project	Construction Cost £bn (2023 prices)	Annual Output GWh/y
Large Barrage (Cardiff Weston)	33.4	16,700
Small Barrage (Shoots Barrage)	6.8	2,800
Large Lagoon 1 (Cardiff)	12.4	5,500
Large Lagoon 2 (West Somerset)	10.9	6,500
Medium Lagoon (Stepping Stones)	2.3	1,200
Small Lagoon (Swansea Bay)	1.8	520

6.4.2 RAB Revenue Calculation

The RAB balance is assumed to build up linearly from the start of construction and runs until the end of operations. The Allowed Revenue under the RAB is calculated on an annual basis and includes the following components:

- Return on RAB – calculated on an annual basis using the WACC range set out below.
- RAB depreciation – assumed to be straight-line, over 120 years.
- Operating costs (Opex) – based on assumptions provided by WSP.
- Decommissioning fund contributions – calculated as an annual amount added to the Decommissioning Reserve Account and earning an annual return in order to fully pay the decommissioning costs.
- Tax allowance – assumed to be 25% of profit before interest and tax.

6.4.3 Weighted Average Cost of Capital

A key component of the Allowed Revenue is the Weighted Average Cost of Capital (WACC) of the RAB Company. The Allowed Revenue, and therefore the charges to consumers, are highly sensitive to the WACC. We have considered a range of WACC assumptions in the financial analysis. The 'high' and 'low' WACC assumptions are shown in the table below:

WACC scenario	Low	High
WACC Assumption (real)	2.8%	4.3%
WACC Assumption (nominal)	5.4%	6.9%
Commentary	Based on Electricity Transmission benchmark cost of equity (4.8%), cost of debt of 1.9% and 70% gearing	Based on OFTO benchmark cost of equity (7.1%), cost of debt of 1.9% and 55% gearing

For comparison, under the TTT project, the winning bidder's bid weighted average cost of capital (BWACC) was 2.497% (real). However, this was completed in a lower interest rate environment (2015) and is therefore just outside of the range we have assumed for the purposes of this analysis.

In practice the return realised by RAB investors will be established by regulator led reviews, most likely on a 5 yearly cycle. These will provide challenge to proposed costs and ensure returns to investors reflect market conditions. Financing costs would in effect decline over time as the RAB reduces.

6.4.4 Average lifetime charge

The table below shows the average lifetime charge over the life of each of the projects at both the low and the high WACC assumptions (in real terms, 2023 prices).

	Average lifetime unit charge at lower WACC (2.8% real) £/MWh	Average lifetime unit charge at higher WACC (4.3% real) £/MWh
Large Barrage (Cardiff Weston)	83	111
Small Barrage (Shoots Barrage)	89	118
Large Lagoon 1 (Cardiff)	88	118
Large Lagoon 2 (West Somerset)	64	85
Medium Lagoon (Stepping Stones)	74	96
Small Lagoon (Swansea Bay)	131	172

6.4.5 Consumer charges relative to other technologies

The chart below shows the expected profile of regulated charges (in real terms, 2023 prices) under the RAB model for tidal range. The two tidal solutions shown represent the most cost-effective barrage (Cardiff Weston) and the most cost-effective lagoon (the large lagoon at West Somerset). The bands for the two tidal range options are driven by high / low assumptions for the RAB WACC.

The chart also shows the typical CfD strike prices for a number of other technologies, all adjusted to reflect 2023 prices:

- Hinkley Point C strike price (2016)
- Offshore wind, CfD Allocation Round 1 (2015)
- Offshore wind, CfD Allocation Round 6 (2024)
- Tidal stream, CfD Allocation Round 6 (2024)

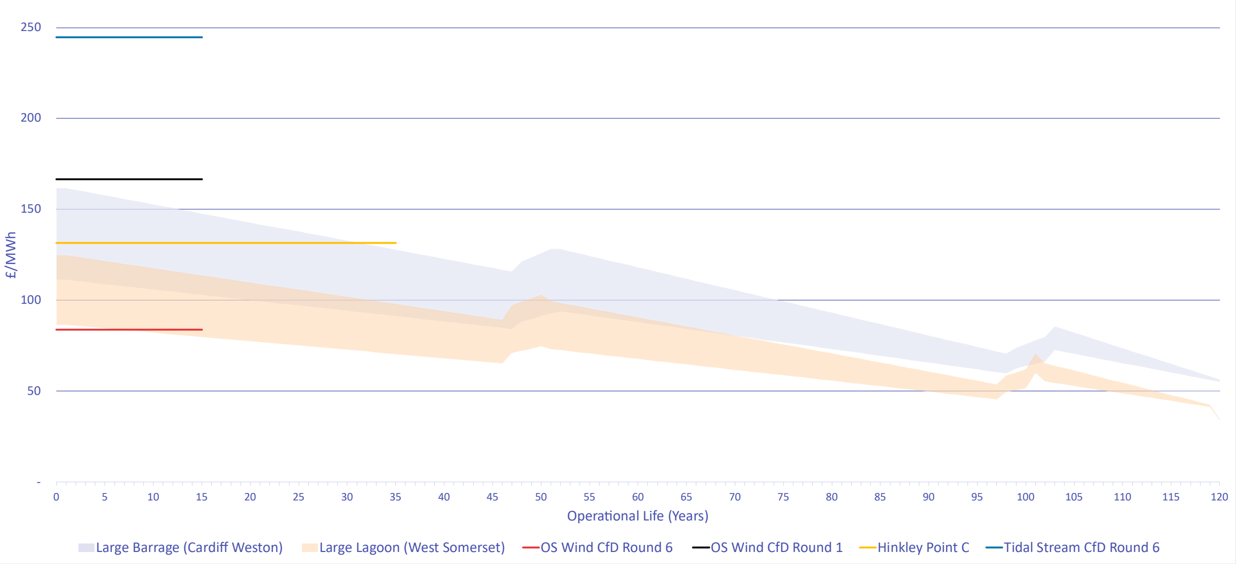

Figure 4: Expected profile of regulated charges (in real terms, 2023 prices) under the RAB model for tidal range and CfD strike prices for other technologies.

There is significant variability in the cost per unit of electricity between different potential tidal range projects. For example, the cost per unit of electricity of the small lagoon at Swansea Bay is over twice as high as the large lagoon project. This indicates that the choice of site is very important and has a significant impact on overall project viability. It may be that moving straight to a programme of medium and large lagoons offers better value for money than beginning with the small lagoon at Swansea Bay, for example. However, this would need to be balanced with the potential need for investors to see the approach proven at a smaller scale before investing in larger assets.

This analysis shows that under the RAB model, tidal range projects have higher initial costs but demonstrate significant reductions over time as the RAB depreciates. It is notable that the large lagoon and large barrage projects appear competitive with Hinkley Point C from year 1 of operations.

6.5 Impact of CfD Model

We have also considered the impact on cost of finance, and therefore charges to consumers, of adopting a CfD approach instead of the RAB based model. A 2020 Nuclear Industry Association Report into HPC[14] and concluded that 67% of the CfD strike price related financing costs, of which 28% was the base cost of finance for a typical regulated asset and 39% was a construction risk premium. This implies that the limitations of the CfD structure in adequately mitigating construction risk for investors, more than doubled the cost of finance.

Whilst we cannot make direct comparisons between generation technologies, we would expect approaches which do not mitigate the impact on investors of construction cost overruns, such as CfD, to continue to attract a material financing cost premium.

The average charge to consumers per MWh is highly sensitive to financing costs, as demonstrated in the table below, which shows the impact of increases to the hurdle rate, in 2023 prices, real terms:

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[14] Nuclear New Build Cost Reduction, Nuclear Industry Association, 2020 – reported that 67% of the HPC CfD strike price related to cost of finance, 28% of which related to the cost of finance for a typical regulated asset and 39% an additional construction risk premium.

	Large Barrage (Cardiff Weston) £/MWh	Large Lagoon (West Somerset) £/MWh
Average lifetime charge/MWh at lower WACC (2.8% real)	83	64
Average lifetime charge/MWh at higher WACC (4.3% real)	111	85

The table below also shows the impact of a 50% and 100% premium to finance costs (based on the higher WACC assumption):

	Large Barrage (Cardiff Weston) £/MWh	Large Lagoon (West Somerset) £/MWh
Average lifetime charge/MWh at higher WACC (4.3% real)	111	85
Average lifetime charge/MWh at 50% premium to higher WACC (6.4% real)	152 (+37%)	114 (+35%)
Average lifetime charge/MWh at 100% premium to higher WACC (8.5% real)	200 (+81%)	148 (+74%)

This shows that if the impact of not adequately mitigating construction risk is similar to that observed on HPC (i.e. a 100%+ increase to finance cost), charges to consumers could increase by more than 75%. This would likely render the project economically unviable. This analysis assumes that it would be possible to raise finance of sufficient quantum at all under a CfD approach, which this report concludes is unlikely.

6.6 Conclusions of Financial Analysis

The financial analysis demonstrates that, when a RAB financing solution is assumed, tidal range assets, over the long-term, appear competitive compared with other generation technologies such as nuclear (i.e. HPC) and offshore wind projects financed under the CfD regime. This is particularly true of larger assets such as medium and large lagoons, and the large barrage.

We make a number of recommendations for adjusting the financial analysis methodology which has previously been applied to tidal range projects (such as the 2018 Swansea Bay Lagoon project), so that it is better suited to the distinctive characteristics of these assets:

- Future analysis should assume a RAB financing structure, rather than a shorter-term CfD. This allows the construction costs to be amortised over the tidal range asset's 120-year useful life, rather than a 35-year CfD period.
- The standard DDM approach has limitations which mean it is not well suited to tidal range projects. We recommend a modified DDM approach for tidal range which looks at all assets over a 120-year period, to allow for a more direct comparison between technologies.
- The small lagoon project at Swansea Bay has a particularly high capital cost per unit of electricity (over double that of the large lagoon at West Somerset). There may therefore be benefits to focussing a future programme of tidal range projects on larger assets, potentially medium and large lagoons, which appear more competitive, when compared with other generation technologies, such as nuclear and offshore wind. This would need to be balanced with the potential need for investors to see UK tidal range generation proven at a smaller scale before investing in larger assets.

7 CONCLUSIONS AND RECOMMENDATIONS

This report concludes that the RAB model offers the most promising framework for balancing investor needs, consumer protection, and project viability. Whilst the Cap & Floor and CfD regimes have both been successful in key segments of the energy market, their use has generally been limited to projects with much shorter construction and operating periods than is typical for tidal range. Neither model offers sufficient flexibility in sharing risk between investors, government and consumers for very large and complex assets like tidal range.

Reviewing the history of very large-scale, complex infrastructure development in the UK over the last decade, it is clear that CfD based approaches have not been successful in securing finance for such programmes on a value for money basis. This is supported by a 2017 NAO report and subsequent analysis in 2020 by the Nuclear Industry Association, which concluded that the HPC CfD strike price included a significant premium over the cost of finance for a typical regulated asset, in part caused by construction cost risk being largely borne by investors. Our financial analysis reinforces this conclusion, highlighting that funding models which do not adequately mitigate construction risks for investors are likely to result in materially higher charges.

The financial analysis has also shown that, under the RAB model, tidal range projects can be financially viable relative to other generation technologies such as nuclear (i.e. HPC) and offshore wind projects financed under the CfD regime. This is particularly true of the medium and large assets which have been considered as part of the financial analysis.

Two initial round table discussions were held with investors between December 2024 and January 2025. These concluded that, whilst there may be limited investor appetite to finance the development phase of a tidal range project, there is interest in the construction phase and broad agreement that RAB is the most feasible structure for achieving a private financing. Refer to Appendix F for further detail on the conclusions of the investor round tables.

For large, complex infrastructure assets, government and developers are increasingly moving towards the RAB based approach which has been used on TTT and is proposed for SZC. Tidal range shares many characteristics with these projects, and we therefore recommend that the RAB model is taken forward as the preferred option.

The table below summarises the key conclusions and related recommendations arising from the work conducted as part of this report.

Ref #	Conclusion	Recommendation
1.	The RAB model is recommended as the most suitable funding mechanism for tidal range projects in the Severn Estuary.	Pursue the development of a tailored RAB model for tidal range projects, drawing on lessons from the TTT implementation and the proposed Sizewell C structure.
2.	The RAB model is expected to deliver better value to consumers than alternatives and has a higher probability of attracting private sector investment.	Conduct a detailed value for money assessment, quantifying the risk transfer under the RAB option compared to public funding alternatives. Further market engagement activity to test appetite with investors.

3.	The RAB model provides acceptable risk sharing from a proven funding model, balancing risks between investors, consumers, and government.	Develop a comprehensive risk allocation framework specific to tidal range projects, clearly defining responsibilities for each stakeholder group.
4.	The very long asset life of tidal range projects (120 years) requires special consideration in financial modelling and policy frameworks.	Define and agree bespoke evaluation methodologies, such as a modified DDM approach, that appropriately value the long-term, predictable nature of tidal range energy generation.
5.	Successful implementation will require buy-in from a wide range of stakeholders.	Develop a comprehensive stakeholder engagement plan, including investors, government bodies, Ofgem (to discuss their potential role as regulator), local communities, and environmental groups.
6.	Given the scale and novelty of tidal range projects, a phased approach may be beneficial.	Consider implementing a pilot project using the RAB model to demonstrate viability and refine the approach before larger-scale deployments. However, the small lagoon at Swansea Bay appears particularly expensive from a cost per unit of electricity perspective and this should be factored into the planning of a future programme of projects.
7.	Tidal range projects have significant environmental and social implications that must be carefully managed.	Integrate robust environmental and social impact assessments into the project development process, ensuring these factors are fully considered in the funding model.

APPENDICES

APPENDIX A: KEY TECHNICAL FEATURES OF THE SCHEMES

APPENDIX B: DEVELOPMENT PHASE RISK ANALYSIS

APPENDIX C: WSP RISK ASSESSMENT

APPENDIX D: CASE STUDIES

APPENDIX E: FINANCIAL ANALYSIS

APPENDIX F: ROUND TABLE INVESTOR FEEDBACK

APPENDIX A: KEY TECHNICAL FEATURES OF THE SCHEMES

There are generally considered to be two types of tidal power scheme, namely tidal range and tidal stream. The proposals identified for this report do not include tidal stream projects and therefore, this section will focus on tidal range solutions.

A technical report[15] has been completed by Peter Kydd of WSP, and we recommend referring to this report for a more in-depth technical analysis. However, this section provides a description of the key technical features, which have informed the overall financial analysis.

A technical understanding of the nature of the archetypes is vital to ensuring an effective delivery model is selected. Delivery models must work for the asset – as opposed to the model being super-imposed on an asset.

There are generally two archetypes for Tidal Range projects, which are:

- **Barrage** - a barrage connecting two points on opposite banks of an estuary.
- **Lagoon** - a lagoon connecting two points on the same shoreline but projecting out to sea, (it should be noted that Lagoons can also be located entirely offshore).

All two types of Tidal Range projects produce energy in a manner similar to hydro-electric plants and have the following components.

Impounding structure

A marine wall connecting the powerhouse to the shoreline (opposing shorelines for a barrage, the same shoreline for a lagoon). The marine wall is typically a sand / gravel embankment protected by stone shoulders with a final layer of large rock armour to protect from wave damage.

Powerhouse

A concrete structure housing the turbines and sluice gates, located in the deepest section of the estuary. The powerhouse may be fabricated in-situ within a cofferdam – a technique used for building bridge foundations in a river or estuary – or may be constructed remotely at a port facility and towed out to site (a caisson).

An impounding basin is formed by the combination of the powerhouse and marine wall acting as a dam. Water flows into the basin on the flood tide (either through the turbines, sluice gates or both) and is stored there until the sea level has dropped sufficiently to allow generation to begin.

Water from the basin discharges into the sea through the turbines and, towards the end of the generation cycle, through the sluice gates, to maximise the reduction in water levels within the basin. The cycle is then repeated for the next flood tide. In a Lagoon, the size of the impounding basin is the limiting factor in terms of how much energy is generated.

In a barrage, which impounds a much greater area per unit of barrage length, energy generation is limited by the number of turbines that can be accommodated.

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[15] Sustainable energy in the Severn Estuary, WSP, August 2023

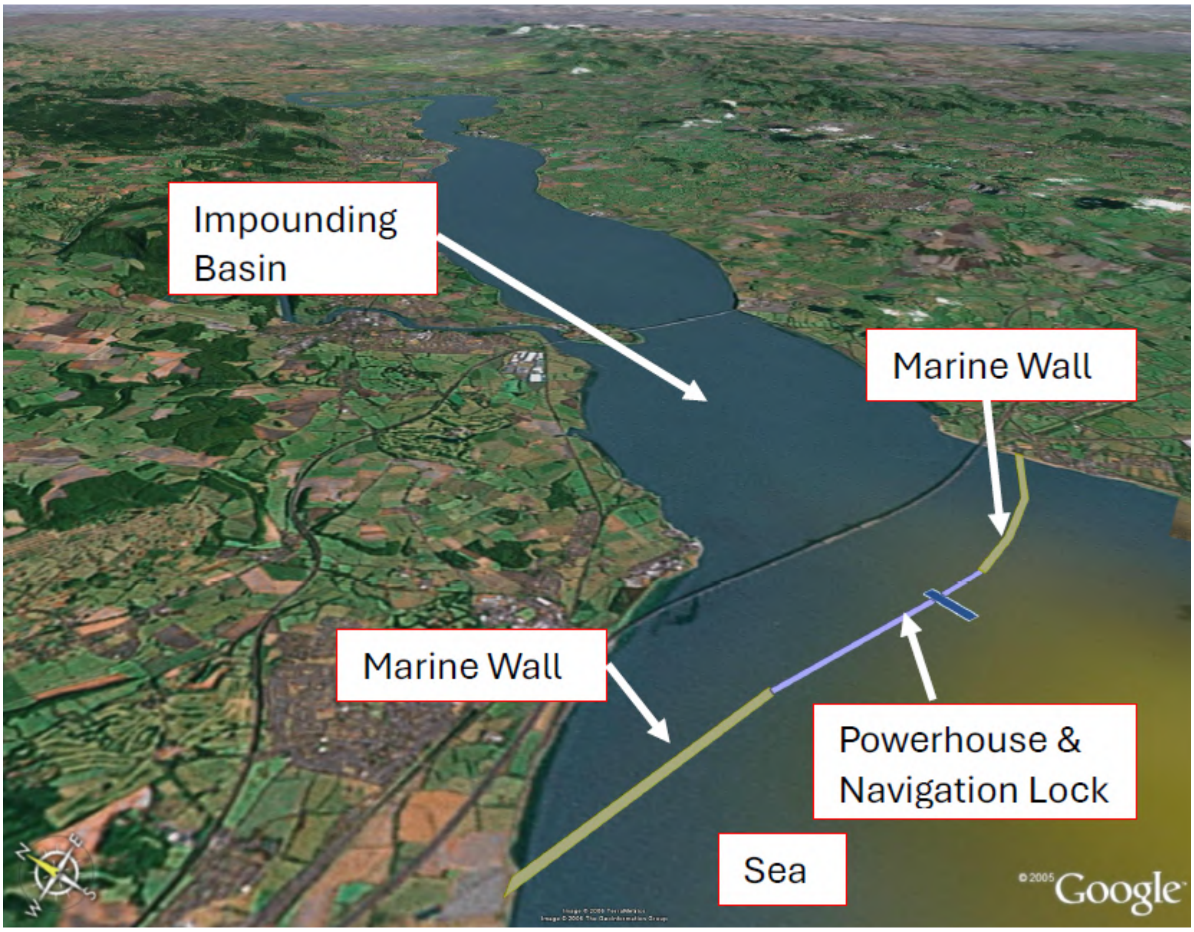


Figure 5: Key components of a Barrage scheme

Further detail on the design and construction of key elements of Tidal range projects are listed below.

Turbines

It has been assumed that all projects will use a conventional bulb type turbine manufactured by a European manufacturer such as Andritz. Andritz were the preferred turbine supplier for the Swansea Bay Tidal Lagoon project and, alongside other European manufacturers such as Voith Turbo Limited, have a long track record in hydropower turbine design and manufacture. The bulb turbine was first developed in the first half of the 20th Century and there are more than 100 examples operating around the world including at Sihwa Tidal Power Station and La Rance Tidal Barrage in France and many European run-of-river hydropower plants. The turbines can therefore be classified as well established and low risk. Their efficiencies are high leaving little room for future improvement although some innovations have been proposed including using variable speed drives (such as proposed for Swansea Bay) primarily to reduce risks to fish. They can also be operated flexibly so that projects can be configured to generate only on the ebb tide (twice per day), on the ebb and flood tides (four times per day) and also to pump (when upstream and downstream levels are similar to increase storage volume for future energy generation when the downstream tide level drops). They have an operating life of 40 years or more. The La Rance Tidal Project, in France, an example of a Tidal Range scheme in current operation, still uses the original turbines which are now over 60 years old although components have been replaced or refurbished as part of a planned maintenance programme.

The La Rance Tidal Power Project was successfully constructed in 1966 and is currently operated by EDF. La Rance has a peak rating of 240 MW, generated by its 24 turbines, it supplies 0.012% of the power demand of France.

With a capacity factor of approximately 40%, it supplies an average 96 MW, giving an annual output of approximately 600 GWh. The barrage is 750m (2,461ft) long, from Brebis point in the west to Briantais point in the east. The power plant portion of the dam is 332.5m (1,091ft) long. Power is generated from 24 bulb turbines with a 5.35m (17.55ft) diameter that rotates at 93.75rpm and is rated at 10MW at a head of 5.65m (18.54ft). The project is currently the lowest cost power generation asset in France.

Sluice Gates

A tidal power project uses sluice gates, generally located within or alongside the main powerhouse structure, to pass flows through the impounding structure, either in parallel with turbine operation towards the end of a generation cycle, or to recharge the impounding basin on a flood tide if the project generates only on the ebb tide (2 times per day). Sluice gates are well proven technology used on flood defence structures, weirs, dams and tidal power plants. Providing they are adequately maintained; sluice gates may have operating lives of 80 years or more.

Powerhouse Structure

The powerhouse structure houses the turbines and the associated operating gates and the sluice gates (although these may be located in a separate but adjacent structure). The powerhouse structure is a celled reinforced concrete structure with each cell housing a turbine and operating gates and/or sluice gates. At the crest level, a building houses the overhead craneage to operate the gates and remove turbine components for maintenance, and the switchgear and control equipment. Cables from the switchgear are routed through cable ducts in the marine wall to a shore based substation and grid connection point.

The powerhouse itself can be constructed from pre-cast concrete caissons that are constructed in or near a port facility and floated out to site before being set down into position on a prepared underwater foundation. This method has been proposed for the majority of tidal power plants and builds upon experience from around the world where the technique is used to build bridge foundations, breakwater structures and cooling water structures. Alternatively, the powerhouse structure can be constructed in-situ within a cofferdam which enables the powerhouse site to be dewatered. This was proposed for the relatively shallow waters of Swansea Bay.

Marine Wall

There are two main forms of sea wall that have been traditionally considered for tidal range projects:

Rockfill Embankment - a conventional embankment with a relatively wide crest and side slopes protected by rock armour and revetment. The crest level has to be around 5 or 6m above high tide level in order to prevent over-topping by waves which could cause the embankment to fail.

Concrete Caissons – Plain caissons can also be used instead of rockfill embankments, particularly for deeper water construction. An advantage of plain caissons is that they can be overtopped safely and therefore do not need to be constructed as high as rockfill embankments unless access is required above them.

Navigation Lock

A navigation lock is only required for a barrage to enable access to upstream ports and for larger lagoons to allow for maintenance. These are conventional structures, constructed from concrete caissons and with conventional lock gates and an access bridge.

APPENDIX B: DEVELOPMENT PHASE RISK ANALYSIS

Development Phase Risks

Developing a tidal lagoon project involves several risks and challenges typically borne by the project developer.

Environmental Impact

Risks

Tidal lagoons can significantly affect local ecosystems. The construction and operation can disturb marine habitats, affect sediment transport, and impact fish and bird populations. Ensuring minimal disruption requires thorough environmental impact assessments and mitigation strategies.

Potential environmental concerns could lead to increased mitigation measures and costs.

Mitigants

Mitigating the environmental impact of tidal lagoon projects involves several strategies:

- Careful Site Selection: Choosing locations with lower ecological risks can reduce the impact on local wildlife and habitats.
- Design Modifications: Implementing designs that allow for the free movement of marine life, such as fish-friendly turbines, fish ladders and passages, can help mitigate disruptions to migratory routes.
- Sediment Management: Monitoring and managing sediment transport can prevent negative effects on coastal erosion and sedimentation patterns.
- Water Quality Control: Ensuring that the construction and operation of the lagoon do not degrade water quality is crucial. This can involve measures to prevent pollution and manage nutrient levels.
- Monitoring and Adaptive Management: Continuous environmental monitoring allows for the detection of unforeseen impacts, enabling adaptive management strategies to be implemented as needed.
- Stakeholder Engagement: Engaging with local communities, environmental groups, and other stakeholders can help identify potential concerns early and develop mitigation strategies that are acceptable to all parties.

The Severn Estuary Commission has appointed WSP to address several of the above-mentioned Environmental risks and mitigants in a separate report by WSP previously mentioned.

Regulatory and Planning Hurdles

Risks

Obtaining the necessary permits and approvals can be a lengthy and complex process, delays will result in cost increases. This includes navigating environmental regulations, securing DCOs, and engaging with multiple stakeholders.

Mitigants

Further to the above, marine works will not commence until all necessary leases, consents and licences are in place) such as:

- Marine Lease/Seabed rights (The Crown Estate (TCE)) – to be agreed in advance of main works (marine) construction commencement;
- Marine Licence (NRW in Wales or MMO in England) – to be approved in advance of main works (marine) construction commencement;
- Third party land options (multiple landowners);
- Third party easements for cable route (multiple landowners);
- Pre-works commencement requirements as detailed in the DCO (for submission to Local Planning Authorities). All DCO requirements to be discharged in advance of main works (marine) construction commencement.
- Electrical connection agreement (National Grid).

The Severn Estuary Commission has appointed WSP to review Environmental risks, technical risks and potential mitigation measures.

Financial

Risks

The high upfront costs and long payback periods can make financing tidal lagoon projects challenging. Securing investment and managing financial risks are crucial for project viability.

Securing development funding can be challenging due to the high-risk nature of the project phase. Although the La Rance tidal project in France demonstrates proven construction and operational performance of a tidal range project, a UK tidal range project still poses significant development risks, given that such a project has not yet been completed in the UK.

Mitigants

- Government Support: Securing government grants, subsidies, or favourable policies can reduce financial burden.
- Phased Development: Implementing the project in phases can help manage costs and reduce financial exposure.
- Robust Environmental Planning: refer to WSP Report.

Technical Challenges

Designing the infrastructure, such as seawalls and turbines, in a harsh marine environment poses significant technical challenges. Ensuring the reliability and efficiency of the technology is essential.

Community and Social Impact

Projects can face opposition from local communities concerned about environmental and social impacts. Effective communication and engagement with stakeholders are vital to address concerns and gain support.

APPENDIX C: WSP RISK ASSESSMENT

Severn Estuary Tidal Power – Summary of High-Level Project Risks

This paper has been produced to summarise the principal risks associated with the development of tidal power in the Severn Estuary. It has been produced by **WSP** at the request of the Severn Independent Commission and should not be relied on for specific projects.

Strategic Risk Register

A strategic risk register has been developed to identify significant “high-level” risks and their associated potential mitigation. A traffic light system has been used to identify the level of risk AFTER mitigation.

Red: Higher risk (high impact even if probability is low) with the potential of significant reduction in return.

Amber: Mid-level risk (medium impact, medium or high probability) with the potential to reduce return on investment

Green: Low residual risk once mitigated with marginal impact on returns.

Scope	Key Risks	Comments and Potential Mitigation
Planning and Development	Project Location	Identifying the most appropriate project location is key to a successful project. A comprehensive options assessment considering cost, tidal resource, complexity, constraints, impacts and scale is the key mitigation measure to reduce the risk of investing in the wrong project (Swansea Bay had a cost of £5m/MW installed compared with other projects which are typically in the £3m-£4m range. It also was located in a zone with two-thirds of the tidal range of other projects further upstream).
	Optimistic project cost	Many infrastructure projects exceed their initial cost estimate for a variety of reasons. These include inadequate initial estimates (particularly if it is prepared to demonstrate a business case) but also the scope creep that occurs during a project’s journey from conception to construction. There are many reports on lessons learned from HS2 including HS2 itself and the NAO. The mitigation for tidal range power projects is to understand that the business case is not about achieving the lowest cost per kWh but a realistic figure that will emerge from the business case based on behavioural and systemic changes proposed from the HS2 learning programme and a robust cost estimation exercise, including reasonable contingency levels. Tidal power, as evidenced by the NG FES, has a role in the energy mix to 2050 and the value comes from its predictability which assists despatch, its stability/responsiveness which reinforces the grid as well as its acceptable (but not lowest) cost of energy for consumers.

Scope	Key Risks	Comments and Potential Mitigation
	Financing method not agreed	The financing methodology for tidal range power is key and whilst it is unlikely that a RAB methodology would be agreed ahead of defining a project to which it could be applied, early engagement with key stakeholders such as DESNZ and Treasury in considering the principles of RAB financing applied to tidal power will be important in releasing at-risk funds for developing a preferred project option.
	Lack of Government Support	At present, tidal power is not referenced in the Energy National Policy Statements (NPS) although there is a side document confirming some requirements Government would need before considering supporting a tidal project. This was developed by the previous Government and it is unrealistic in its scope. Mitigation that is required is to ensure that tidal power is referenced in the current review of NPS' and that a realistic pathway is developed that embraces Government support in terms of infrastructure financing guarantees and recognition of the value that tidal range power can play to secure net zero by 2050 (as exemplified by the NG FES). To date, Government have sought to use hydrogen and CCUS to displace the need for tidal range power but the growing recognition of the cost of hydrogen and the complexity / cost of CCUS will change the energy landscape.
	Stakeholder objections	Stakeholder objections can be mitigated (although not totally eliminated) through early engagement and collaborative working so that they become part of the solution. The RSPB hosted a series of Sustainable Severn Conferences between 2013 and 2017 to address the opportunity tidal power brought to reducing carbon emissions and identify solutions to mitigate impacts on the natural environment. Whilst Swansea Bay Tidal Lagoon didn't proceed, it did have the support of many of the environmental NGO's and the public.
	Consenting and land purchase delays	A tidal power project will have to use the DCO route for consenting. When it was introduced in 2012, the process was meant to eliminate delays in decision making with a project not being accepted for examination until it had satisfied a number of requirements and the timeframe from acceptance of the DCO application to determination being less than 18 months. However, under the last Government, several projects did not receive their consents within that timeframe with requests for further information and, in one case, a decision being made against the examination team's recommendations (although this was subsequently successfully appealed. There is therefore a latent risk, as there is with any project engaged in the DCO process, of consenting decisions being late and/or unfavourable.

Scope	Key Risks	Comments and Potential Mitigation
		Mitigation is a combination of the mitigations referenced above so that the project in question secures Government support at a policy level and that stakeholders are engaged at the earliest opportunity. This should not result in any additional cost but would change the sequencing of activities so that any potential issues are identified early on. However, there will be some residual risk that may be outside of the project promoter's control, as there is with any external regulatory decision. Land purchase delays are avoidable providing an appropriate land valuation / acquisition strategy is in place and landowner's considerations adequately understood from the outset. Securing TCE lease should not be high risk providing there is Government support for the project and TCE can adapt their normal processes to suit the unique circumstances of tidal range projects. It would be beneficial for TCE to be involved from the outset to facilitate project development.
Environment & Socio-Economic Impacts	Potential fish impact	Whether and how protected migratory fish species might interact with a tidal power structure is an uncertain science and therefore poses a risk. Hydropower has successfully overcome this risk through the use of Archimedes Screw turbines, but these are not suitable for tidal power because of the large variation in water levels. Turbine manufacturers have evolved their turbine designs to become more efficient and use variable speed generators which have shown some reduction in fish mortality should they pass through the turbines (attracted by the high flow rates). Work is also ongoing into a new turbine design that uses large diameter, slowly rotating blades which potentially could be safer for fish passage but in order to maintain efficiencies, requires two contra-rotating propellors with 6 and 7 blades each, thereby negating the advantages in terms of fish passage. There is also the issue that a new and untested turbine would pose a higher level of investor risk compared with a conventional bulb turbine (which has been used in numerous run-of-river hydropower projects and in both the large tidal plants at La Rance and Sihwa). Mitigation is therefore likely to be a research programme to understand better the fish behaviours in potential tidal power zones and to assess the effectiveness of avoidance measures in tidal water (for example fish ladders or acoustic screens). As yet only limited research is taking place which would have to be accelerated to potentially de-risk this issue.

Scope	Key Risks	Comments and Potential Mitigation
	Identification of potential compensatory habitat areas	Some projects which have an effect on adjacent protected environmental designations through variance of the normal tidal cycle will require compensatory habitats to be constructed. A key consideration is where such habitats could be located so they can, over time, provide alternate habitats of equal value in terms of the species using them. This is an opportunity area to engage with environmental stakeholders at an early stage to provide a new habitat resource. Most tidal power project studies to date have identified the quantum of compensatory habitat required rather than its location and have therefore missed the ability to offer specific wildlife groups a tangible benefit. However, the compensatory habitat for the Cardiff Bay Barrage offers a good example of a successful outcome with the RSPB running what is now known as the Newport Wetlands Nature Reserve.
	Potential impact on commercial activities including shipping, fishing and seabed cables, aggregate extraction etc	A comprehensive options assessment considering cost, tidal resource, complexity, constraints, impacts and scale is the key mitigation measure to reduce the risk of investing in a project that may require difficult constraints to be overcome. The initial step for this would be to undertake a screening exercise to identify where the constraints are and whether a project can be developed around such constraints.
	Construction disruption and long-term seascape impacts on nearby communities	The number of construction workers will lie in the range of 2,000 to 10,000 depending upon the scale of the project. Whilst there will be benefits to the local communities in terms of increased spending and provision in local services, there will also be an impact in terms of increased traffic, accommodation requirements and so on. HPC has been successful in reducing the potential disruption through building of accommodation blocks that can be repurposed after construction is complete, a new by-pass, travel plans that require construction workers to use park and ride sites with onward transport to the site by bus, and by constructing a new jetty to enable most construction materials to be delivered to site by sea. Similar mitigations are possible for a tidal power plant with the added advantage that most of the construction activity will be at sea and in dockyards. Whilst there was initially concern in West Somerset about the HPC construction work, there is now more concern about the potential reduction in the local economy once the construction workers have left. The mitigation is therefore to follow the lessons learned and best practice methods used at HPC and to use this to engage with the local communities to reassure them of potential impacts and discuss the benefits.

Scope	Key Risks	Comments and Potential Mitigation
		Seascape impacts and associated land impacts from grid infrastructure are more challenging to address. The advantage of tidal power projects in the Severn is that they are located within an area where significant grid infrastructure already exists and for some smaller or medium sized projects, any additional works would be within or adjacent to what is already there. It will however be important that the tidal power structure itself is designed to a high aesthetic standard by emulating natural features or where this is not possible, of using high quality design principles.
	Functional rather than place making designs	Whilst all designs should be functional, it does not mean they need to be alien to the landscape in which they are located. Designs should be undertaken to reflect natural features and any exposed structures finished to a high aesthetic standard. This may have a small impact on cost but could be critical to securing support for the project both at the planning stage and during the 120 years of operation.
Programme	Impact of external events such as pandemic or credit crunch	There is potential for such an event to disrupt or even cancel a particular project. However, if the need has been established for a tidal power project(s) within the UK's energy mix, the project may be delayed rather than cancelled. Cancellation would probably be triggered by another parallel event such as significant cost over-runs. Mitigation for the latter is to adopt the lessons learned from HS2.
	Tenders received higher than project estimates	The risk of having to return to the drawing board because the reference designs turn out to be more expensive than the project estimates will delay programme, either because the reference designs will have to be re-engineered and/or because business cases will have to be re-evaluated and new sources of capital identified. Mitigation is to use open and collaborative tendering processes where tenderers have a role in design and construction and the client is open to budgetary considerations. Early contractor involvement (ECI) is one method by which this can be achieved although there has to be alignment of pre tender and construction activities so that the tenderer is committed to delivering to the cost plan. The ability to share risk and reward is also critical. Forms of construction contract exist that encourage such behaviours and a good example is the delivery of the infrastructure for London's 2012 Olympic Games. Fully costed "live" risk registers also enable early identification of specific risks and greater opportunity to resolve them using a risk sharing approach.

Scope	Key Risks	Comments and Potential Mitigation
	Approvals from Regulators / Government	The extent to which this can be de-risked is limited. Early engagement and a transparent approach to key statutory consultees will help. An important element will be the negotiation of guarantees and financing arrangements. This will require substantially complete terms and costs from preferred bidders to enable completion but the financing arrangements and associated regulation should be agreed early in the planning phase of the project.
	Projects with new generation technologies	The use of untested technology for major elements such as turbine- generator units is likely to require a period of prototype testing and a clear pathway to commercialisation. This will delay programme compared with more conventional technologies. It is understood that significant new technologies in the Oil and Gas sector can take 30 years from conception to commercialisation. Mitigation is to use existing technology solutions, adapted appropriately rather than a new design concept.
	Business Case Reviews and delays in Financial Close	Business cases will exist at project level but also for investors. They will need to be periodically re-visited at key stages (for example when construction costs are confirmed with the various contractors) and may be prone to change depending upon changed money market considerations, changes in Government and so on. The extent to which this can be de-risked is limited.
Construction Cost	Adverse ground conditions	Unforeseen ground conditions have the ability to occur even if a comprehensive ground investigation has been undertaken. Hidden fault lines or variable material characteristics may be missed by a ground investigation survey or the discovery of unexploded ordnance may cause disruption and increased cost. The extent to which this can be de-risked is limited although the ability to respond rapidly and positively to new information will help reduce any cost impacts. This would involve some form of scenario planning so that solutions are readily available if a particular situation occurs.
	Adverse weather	The mitigation for this is to identify specific weather corridors in which works at sea were undertaken (for example from March to October). This makes costs more predictable but at the expense of earlier revenues from generation.
	Imported material inflation risk	During construction this is a risk, particularly as construction periods are in the range of 5 to 10 years. However, high inflation will also be reflected in higher revenues so whilst the construction cost may be at risk of increasing, the associated downstream revenues will also increase (for 120 years).

Scope	Key Risks	Comments and Potential Mitigation
	Labour disputes	There is always a risk of large infrastructure projects being used as bargaining chips where pay and conditions disputes are involved. However, recent experience in the construction of major infrastructure works shows that where disputes do take place they are confined and quickly resolved. Private sector contracting organisations have developed a sophisticated approach to dispute management and resolution so the mitigation for this risk is to propose continuance of best practice.
	Contractor claims and delays	Contractors have historically tendered low to secure the contract and have then used the contract to submit claims for increased cost and delay where they are potentially permissible under the contract. The mitigation for this is to use open and collaborative tendering processes where tenderers have a role in design and construction and the client is open to budgetary considerations. The ability to share risk and reward is also critical. Forms of construction contract exist that encourage such behaviours. Fully costed "live" risk registers also enable early identification of specific risks and greater opportunity to resolve them using a risk sharing approach
Supply Chain	Capacity	Tidal range projects are large and provide relatively stable employment opportunities. The longer timeframes provide an opportunity to upskill employees and the supply chain is likely to prioritise larger, longer timeframe projects. A challenge can be the supply of adequate types and numbers of marine vessels given the likely increase in offshore marine works for wind farms and nuclear power stations but the types of vessels used will be different in terms of scale and deployment for tidal power.
	Capability	Tidal range power projects use, for the most part, tried and tested construction methods and the increase in marine works in the UK has provided an increased confidence in undertaking works at sea.
	Financial Stability	Contractors can and do go out of business mid-contract. The mitigation for this is to undertake thorough financial due diligence during the contractor selection process and to ensure that the scale of works is commensurate with the Contractor's size and experience. Lessons learned from Carillion's collapse should be applied.
	Flexibility	The ability of the supply chain to flex as circumstances change is a pre-requisite for tidal power. As is typical for power generation projects, there are multiple contract interfaces but also several different work fronts. If the generation contractor delivers equipment late, flexibility is required on behalf of the civils contractor who is likely to be responsible for grouting in the equipment.

Scope	Key Risks	Comments and Potential Mitigation
		The mitigation for this lies with the overall Project Manager to oversee and maintain a detailed programme of works and to be able to provide notice of potential delays and solutions where interfaces exist between different contracts/organisations
	Interface Management	Unless carefully managed, the potential for different contractors to claim for delays and errors where interfaces exist (for example, ducting, equipment installation, tolerances etc) is high. The mitigation is advanced and detailed planning under the responsibility of a project manager and involves review and approval of interfaces completed by Contractor A before Contractor B works off that interface. This is not limited to physical works but extends through to delays and permits to work in specific areas, for example.
Grid Connection	Engagement with National Grid	Tidal power projects are of a size that early consideration of grid requirements is undertaken at the conceptual planning stage. Whilst there may be scope for using an existing connection point in some locations (for example, the disused Aberthaw Coal Fired Power Station), the likelihood is that new substations or extensions to existing sub-stations will be required and, for larger projects, re-wiring or reinforcing existing or new transmission lines. Whilst Swansea Bay's relatively small capacity allows it to connect to the DNO's network, most tidal power projects will be required to connect directly to the National Grid.
	Capacity for National Grid to deliver	There is precedent for the National Grid to undertake a specific study to identify potential network requirements for tidal power projects. They undertook a study for the Severn options in 2009 at the request of the Government which is available here. Since then, the HPC to Seabank transmission line https://www.gov.uk/government/publications/19-severn-tidal-power-grid-study-technical-report has been constructed and the process / timescales are likely to be similar for tidal power.
	Regulatory Consents	The extent to which this can be de-risked is limited. Early engagement and a transparent approach to key statutory consultees will help but strong Government support for a particular project(s) will de-risk this.
	Planning / Stakeholder Objections	This is only relevant where a new transmission link is required. For most of the Severn options, there are already nearby transmission line corridors but in the event that additional reinforcement was required (for example in 2010 the 8.6GW scheme required the construction of a new transmission line route between Bath and Southampton) this would be subject to its own planning consents and associated objections.

Scope	Key Risks	Comments and Potential Mitigation
		Mitigation for this is to include it as a constraint in the Options Assessment / Screening phase.
	Cost of Connection	The cost of any transmission networks is paid for by National Grid and then collected in operational charges. Tidal power, for the most part, has short and limited links and associated lower transmission costs. This is reflected in lower operational costs.
Operation	Storm damage and / or higher levels of sea level rise	Climate change is causing increased intensity and frequency of storms and sea level rise rates are at best, linear and at worst increasing. There is therefore a risk that a design undertaken today and based on future projections of wave heights and sea level rise rates may be under-estimates. Retrofitting of projects to increase the crest level is not appropriate as the integrity of the embankment will be affected. The mitigation for this is to adopt designs where over-topping of the structure can be accommodated (for example by using concrete caissons instead of embankments) or to build to a conservatively high level that takes account of potential future inaccuracies. Storm damage repair costs may increase but they are relatively low and when inflation is taken into account, the increase in energy revenues will be higher.
	Damage from ship collision	This can be mitigated through the provision of appropriate ship protection measures which would, in any case, be mandated by the Department for Transport.
	Under performance	There is always a risk in accepting a turbine manufacturer's maximum power claims for water turbines. If the manufacturer is required to provide a guarantee (for example as on Swansea Bay) on the basis of actual energy generated, their guaranteed power output would be 10% lower than their theoretical output. The mitigation here is not to base business cases on theoretical outputs but on a reduced energy output.
	Structural degradation in hostile marine environment	The mitigation here is to use a cathodic protection system so that concrete reinforcement and other unprotected steel is adequately protected from corrosion.
	Periods of high inflation	Whilst maintenance costs may increase risk, higher inflation will also be reflected in higher revenues so the net income will be significantly higher.
Decommissioning	Agreement of decommissioning plan	Forecasting the decommissioning requirements in 120 years or more is challenging – removing a Victorian water reservoir would cause a public outcry if proposed today. In 120 years, the marine infrastructure elements of a tidal power plant would have established its own ecosystem and its wholesale removal is unlikely to be acceptable to planners.

Scope	Key Risks	Comments and Potential Mitigation
		If the tidal power project was no longer in use, the understanding at the moment is that the movable parts would be removed (unless they were required to prevent flooding from sea level rise). This would need to be agreed with Government and TCE at the project planning stage.
	Funding of decommissioning and subsequent liabilities	This is likely to be funded by a sinking fund that is created by taking a small element of the annual revenues generated by the project. It would probably have to accrue sufficient funds over the first half of the project lifecycle in case early decommissioning was required. This would also create a dowry for the organisation that would take on board the management of the decommissioned structure in perpetuity (likely to be the adjacent local authorities).
	Early decommissioning	Early decommissioning would be fully funded for the latter part of the project's lifecycle but if the asset was abandoned earlier, or if the abandonment meant that the entire structure had to be removed, some or all of the costs of decommissioning would have to be met by others. The value of material in the structure would have some residual value which could support decommissioning costs.
	Contractor insolvency during construction (stranded asset)	If the structure was abandoned during construction, some or all of the costs of decommissioning would have to be met by others including any performance bonds or insurance. The value of material in the structure would have some residual value which could support decommissioning costs. Alternatively, another contractor could be appointed to complete the works if any additional costs were supported by the business case.
	Post decommissioning governance (if some elements are retained after decommissioning)	The sinking fund developed during operation would have to be sufficiently large, that when invested, its annual interest payment was sufficient to cover the operational costs of the organisations responsible for the remaining structure including any maintenance, insurance and lease liabilities.

APPENDIX D: CASE STUDIES

This section provides an overview of three specific project case studies that demonstrate the evolution from CfDs to RAB based models:

- Hinkley Point C – CfD Model
- Thames Tideway Tunnel - RAB Model
- Sizewell C – RAB Model

Hinkley Point C

HPC is a 3.2 Gigawatt nuclear power station under construction in Somerset, England.

Building new generating capacity in the UK, including nuclear power stations, is not commercially viable for private developers to without government support. The forecast revenues available in the wholesale electricity market do not cover the high upfront costs and other risks of building, operating and decommissioning low-carbon power plants. To support HPC, the government agreed a four-part deal:

- The main element is a CfD. CfDs offer developers greater certainty and stability of revenues, reflecting the cost of investing in low-carbon technologies, by setting a ‘strike price’ that the developer receives for a set period.
- The developer must set aside a proportion of its revenues, up to the value of £7.3 billion (in 2016 prices), to cover the costs of dealing with HPC’s nuclear waste and decommissioning the plant once it stops generating electricity.
- HM Treasury guaranteed up to £2 billion (in 2018 prices) of bonds that the developer could issue to finance construction, subject to certain conditions.
- A Sector of State Investor Agreement (SoSIA) through which the government underwrites the payment of compensation to the developer if government policy changes result in the shutdown of HPC.

Under the CfD mechanism to support nuclear projects, developers finance the construction of a nuclear project and only begin receiving revenue when the station starts generating electricity. This led to the cancellation of potential projects, such as Hitachi’s project at Wylfa Newydd in Wales and Toshiba’s at Moorside in Cumbria.

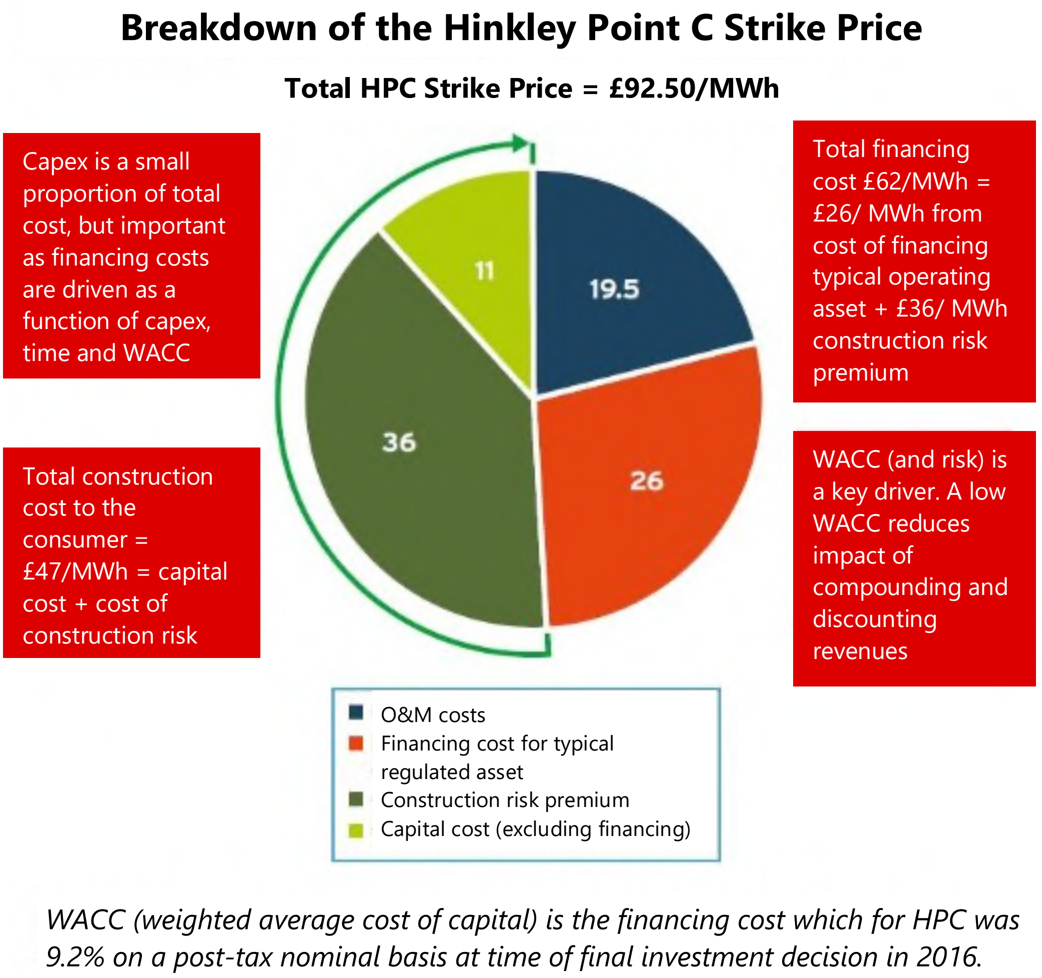
HPC’s government support through a CfD scheme effectively locks in the price for each unit of electricity generated for a period of 35 years from the start of operation. The agreed price is known as the strike price, with the costs or revenues from the scheme shared across all electricity consumers in Great Britain. Since 2014, a similar subsidy scheme has been in place to support the development of renewable electricity generation, including technologies such as onshore and offshore wind and large-scale solar PV.

The strike price, agreed in 2016, was £92.50 / MWh (in 2012 prices). This means that if wholesale prices turn out to be less than £92.50 / MWh, electricity consumers in Great Britain will pay HPC the difference between the actual wholesale price and the strike price. This payment will come through a levy on bills. Conversely, if the wholesale price is greater than £92.50 / MWh, HPC will pay back the difference.

It is important to note that the CfD term on HPC is 35 years. The strike price reflects the high construction cost and it being amortised over a short period (the economic life is estimated to be 65 years). With an even longer economic life, setting a similar CfD term will not sufficiently address the high upfront costs or long payback periods associated with tidal projects, limiting the effectiveness of a CfD in securing private investment

The CfD strike price for HPC rose significantly in the four years between the start of negotiations and a final agreement being reached because, once signed, investors face the full risk of cost and time overruns and will receive no revenue until operation begins, greatly increasing the cost of capital.

The National Audit Office suggested in their review that different finance models with greater risk sharing may have delivered better value for money for consumers given that two-thirds of the strike price is assumed to be financing costs.



Breakdown of the Hinkley Point C Strike Price

Total HPC Strike Price = £92.50/MWh

Capex is a small proportion of total cost, but important as financing costs are driven as a function of capex, time and WACC

Total construction cost to the consumer = £47/MWh = capital cost + cost of construction risk

Total financing cost £62/MWh = £26/ MWh from cost of financing typical operating asset + £36/ MWh construction risk premium

WACC (and risk) is a key driver. A low WACC reduces impact of compounding and discounting revenues

WACC (weighted average cost of capital) is the financing cost which for HPC was 9.2% on a post-tax nominal basis at time of final investment decision in 2016.

Figure 6: Breakdown of the Hinkley Point C Strike Price, Source: Nuclear New Build Cost Reduction, Nuclear Industry Association, 2020

NAO Report, 2017: "The Department has committed electricity consumers and taxpayers to a high cost and risky deal in a changing energy marketplace. Time will tell whether the deal represents value for money, but we cannot say the Department has maximised the chances that it will be"

Thames Tideway Tunnel

TTT is a £4.2 billion project involving the construction of a 15-mile-long sewer that is being bored under the River Thames.

TTT is the world's first major infrastructure project implemented using a stand-alone RAB structure (2015). The project is expected to enter full operation in 2025, both within its original timeline and below its original customer bill impact projections, after allowing for the disruption caused by Covid. This is a significant achievement for a complex and major tunnelling project, and especially one delivered across multiple construction sites within a constrained urban environment. The RAB model itself is a well-established feature of regulated utility sectors across the world.

The delivery model for TTT has the effect of altering the risk profile away from a high-risk construction project, to a low-risk utility-type investment, thus increasing the attractiveness of the project to investors. This was achieved through the following key elements:

- A RAB model, as distinct from contractual models like PFI.
- A project licence that was specifically developed to reconcile the requirements of a long construction period, including an initial regulatory allowance set at licence award, a cost of debt adjustment mechanism and clearly defined parameters for what constitutes allowed expenditure (i.e. expenditure that may go onto the RAB and be remunerated).
- A base case forecast set at P50 providing the opportunity for outperformance.
- Capex incentives consistent with generally accepted regulatory practice, resulting in the under/over performance relating to construction costs and time being shared with customers.
- Revenue from customer bills generated from the time capital expenditure commences.
- A capped financing obligation (known as the Threshold Outturn and set at £4.2 billion) with optional financing above this capped obligation from investors or HMG, or an obligation on HMG to discontinue the project on paying compensation.
- A GSP to cover low-probability but high-impact risks (e.g. costs above the Threshold Outturn, finance market disruption, or insurance coverage required beyond what is commercially available) which the private sector is unable to manage, mitigate, or price on terms representing value-for-money to consumers or the taxpayer.

The amendments to the licence and the GSP were essential features, given the nature of the asset, in achieving a strong investment grade rating for TTT, consistent with a business-as-usual regulated utility.

There were two primary tenders carried out in the formation of TTT: the first was for the construction works which was divided into three separate packages; and the second was for the ownership and financing of the project. In the latter, bidders tendered the WACC and determined the most efficient capital structure. In contrast to PFI projects, where all the debt finance required to complete construction is arranged and committed at financial close, in the case of TTT (and typical for a regulated utility) the debt was arranged progressively, initially at and then following financial close.

The outcome of the financing procurement reflected market confidence in the design and development of the project, ultimately delivering a WACC of 2.49%.

The TTT model has demonstrated the availability of deep markets of international equity and debt capital, which are able to support major stand-alone regulated construction projects, if the structure is right. The delivery model for TTT is now widely recognized as a template for delivering new infrastructure across several sectors, including new nuclear.

Sizewell C

SZC will be a 3.2-gigawatt power station generating low-carbon electricity for around 6 million homes. From an engineering perspective, it will be a close copy of HPC, which is already under construction in Somerset. The government has designated SZC as the first nuclear project to use a RAB model under the Nuclear Energy (Financing) Act 2022.

Key features:

- Privately financed through RAB structure.
- Government is an equity and debt finance provider, alongside EDF equity.
- Limited Company as client organisation.
- GSP for low-probability, high-impact risks.

- UK Government governance and oversight through highly structured Departmental sponsorship and shareholder functions, Liaison Committee and Independent Technical Assessor.
- Ofgem is the economic regulator (economic licence), Office of Nuclear Regulation is nuclear safety regulator.

Unlike the CfD approach, where construction risk sits with the developer, the RAB model will enable some level of risk-sharing between investors and consumers, while also maintaining the incentive on the private sector to minimise the risk of cost and schedule overruns. This will help to lower the cost of capital – a key driver of overall project costs.

The RAB Model, as adapted for the SZC nuclear project, allows developers to begin recovering interest rate costs during the construction phase by levying a regulated charge on consumers' energy bills. This approach lowers financing costs by mitigating interest costs compounding during a lengthy construction phase and long-term revenue security for investors over the project's operational lifespan. Crucially, the RAB model is designed to spread the financial burden over time, protecting consumers from steep immediate costs while offering investors inflation-linked returns. In the case of SZC, the project's revenues are safeguarded by oversight from Ofgem, and costs are passed through a regulated framework with protections in place for both consumers and investors.

Under the RAB model there is no traditional offtake agreement based on a fixed power price as seen in models like CfD or private wire agreements. Instead, the revenue stream is determined through periodic regulatory reviews, typically every five years, with Ofgem setting an agreed revenue allowance. This revenue is designed to cover the project's operational expenses, financing costs, capital expenditures, and provide a reasonable return to investors. The goal of these periodic reviews is to ensure the project remains financially sustainable while keeping consumer costs fair and transparent.

There will be a revenue difference payment, as there is with CfDs, though this will be linked to the allowed revenue based on the RAB mechanism rather than a strike price.

SZC will recover its allowed revenue through two routes:

- Firstly, it is expected to operate competitively in the electricity market and any other market that it can access (e.g. it could transform some of its electrical output into hydrogen and sell in a future market for low carbon hydrogen). This will provide it with a market-based revenue.
- Secondly, the market revenue will be topped up through "difference payments". These will be recovered from electricity consumers via a levy administered by the LCCC following the same process as used during the construction phase. If market revenues exceed allowed revenues, difference payments reverse, with SZC paying the excess back to the LCCC, who redistribute it to suppliers and ultimately consumers.

This combination aims to reduce the financial risk for investors and make the project more attractive, ultimately supporting the development of new nuclear power capacity in the Uk. The difference payment based on allowed revenue helps to stabilise the revenue by guaranteeing a fixed price for the electricity generated, protecting against market price fluctuations. This will result, over time, in lower costs for the consumer as the debt is amortised.

Such an approach would both reduce the scale of the financing challenge and the cost of financing (and so, increase deliverability of the financing, whilst reducing total cost to suppliers and their consumers).

APPENDIX E: FINANCIAL ANALYSIS ASSUMPTIONS

Introduction

The financial analysis has been undertaken to develop supporting evidence of the price of tidal range energy. This appendix describes the methodology and key assumptions employed in the analysis.

Our analysis has been carried out to enable the following:

- The revenue profile based on a regulated revenue model as defined under the established framework for the nuclear RAB model, expressed on a £/MWh basis;
- The comparison of the proposed tidal range solutions with other generation technologies;
- The impact of different financing solution on the cost to consumers; and
- Scenario modelling to view the financial impact of different assumptions.

The analysis enables forecasting indicative metrics of profile of regulated charges on a £/MWh basis for different financing scenarios.

The Commission has contracted engineering consultant Peter Kydd of WSP. Peter Kydd has provided key data and information for all timelines, costs and annual energy outputs for each project. The specific costs provided by WSP are:

  - Construction costs;
  - Replacement costs: and
  - Decommissioning costs.

The inputs do not include any development costs. Inherent in this is the assumption that the development phase is funded by the public sector with no return on development risk.

The decommissioning costs are low relative to nuclear projects but have been modelled assuming the building up of funds to pay costs at the end of the project.

No changes have been made to these inputs and no assessments or changes made to include any allowance for risk contingency or uncertainty.

Assumptions for other inputs are explained in this section.

Timeline

The specific timeline for each project reflects the construction costs, replacement costs, decommissioning costs and energy outputs as set out in in different phases for the given inputs:

- **Construction Phase** – In line with construction cost inputs (range from 5 years to 9 years).
- **Early operation Phase** – This has been set as the first 3 years of operation and has been distinguished separately to recognise the potential greater risks during early operation.
- **Operation Phase** – This is set out in line with annual energy output inputs. This phase is 117 years for each project (120 years less 3 years of early operation).
- **Decommissioning Phase** - In line with decommissioning cost inputs (ranges from 1 year to 3 years).

Price Base

Cost inputs are entered in real terms (2023 prices). Calculations are also in real terms (2023 prices). Comparators sourced from the DESNZ Electricity Generation Costs Report have been uplifted from 2021 prices to 2023 prices, to allow comparison with modelled outputs.

The RAB and the WACC that is applied to the RAB balance to determine the allowed revenues is calculated in real terms.

This approach is in line with the typical approach taken by Ofgem and other regulators, who estimate the WACC and determine allowed returns in real terms.

Ofgem price control models work in real constant price bases, except in respect of some calculations internal to the model that use nominal prices for tax calculations. In our analysis, we have assumed that tax capital allowances match regulatory depreciation (and accounting depreciation), so a nominal tax calculation is not required here.

Implementing a RAB

The RAB is a financial balance representing expenditure by the developer/constructor/operator which has been capitalised under regulatory rules. The developer/constructor/operator receives a return and depreciation on its RAB as a part of its allowed revenue. The RAB model is already used extensively and is recognised by Ofgem.

We have made the following assumptions in incorporating RAB modelling in the analysis:

- Consistency with the Nuclear RAB, as introduced by the Nuclear Energy (Financing) Act 2022.
- The RAB starts from the start of construction until the end of operations (before decommissioning). Depreciation is applied during the full operation period (120 years).
- The RAB and the rate of return is calculated in real terms.
- The RAB return is calculated on the average of the opening and discounted closing RAB balance.
- There is a separate RAB for turbine replacement costs with a different depreciation profile.

Cost Allowances

Operating costs (opex) is treated as “Fast Money”, flowing directly into the calculated allowed revenue for the year to which the amount relates.

Capital costs (capex) is treated as “Slow Money”. This is added to the RAB in the relevant year, contributing indirectly to calculated allowed revenue through the return on RAB and depreciation over multiple years.

RAB Calculations

The RAB balance is assumed to build up from the start of construction and runs until the end of operations. The allowed revenue under the RAB is calculated on an annual basis and includes the following components:

- Return on RAB – calculated on an annual basis using the WACC range set out below.
- RAB depreciation – assumed to be straight-line, over 120 years.
- Operating costs (Opex) – based on assumptions provided by WSP.
- Decommissioning fund contributions – calculated as an annual amount added to the Decommissioning Reserve Account and earning an annual return in order to fully pay the decommissioning costs.

- Tax allowance – assumed to be 25% of profit before interest and tax.

RAB depreciation is calculated on a straight-line basis to fully write-down the RAB over its operating life. No residual value is expected at the end of useful life. It is assumed that accounting depreciation and tax depreciation match RAB depreciation.

The tax allowance calculates a tax liability allowance on a notional basis (as a stand-alone entity), using corporation tax rates. This is achieved by multiplying the revenue before tax allowance by tax allowance / (1-tax allowance), which ensures there is no circularity.

Decommissioning

There is a separate allowance for a Decommissioning Reserve Account in the RAB finance structure allowed revenue. This has been calculated as an annual amount during the early operation and operation phases, being added to the Decommissioning Reserve Account and earning an annual return.

We have assumed that the decommissioning fund investment rate is the risk free rate (RFR), although there is functionality to set different rates through scenarios.

Return on RAB: Weighted Average Cost of Capital

The RAB calculated allowed revenue includes amounts which cover the efficient cost of raising finance from external sources, commonly referred to as the cost of capital. These amounts are calculated as a percentage return on the RAB. The allowed return on capital is an estimate of the required WACC.

This is calculated on a real basis, determined using a pre-tax real allowed return on debt percentage, a post-tax real allowed return on equity percentage and a notional gearing percentage weighting.

The WACC is calculated as:

WACC = Real Cost of Equity x (100% – Gearing %) + Real Cost of Debt x Gearing %

In deciding what the appropriate inputs to WACC are, we considered UK electricity transmission, offshore transmission (OFTOs) and interconnector benchmarks. Electricity transmission rates are part of Ofgem's ET price control.[16] OFTOs and interconnector rates were taken from Ofgem's Decision on 2024-25 Interest During Construction rates for offshore transmission projects and Cap & Floor interconnectors.[17]

The ET PCFM has the following updated economic rates, which are applied as inputs to this model:

- RFR: 1.46% real (3.96% nominal)
- Real Cost of Debt: 1.92% real (4.43% nominal)

Gearing and Cost of Equity benchmarks:

	Electricity transmission	Interconnector	OFTO
Gearing	55%	37.5%	37.5%
Real Cost of Equity	4.8%	5.4%	7.1%

For gearing we have used a range of 55% to 70%.

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[16] ET2 Price Control Financial Model, Ofgem, July 2022

[17] 2024-25 IDC Decision Letter, Ofgem, March 2024

We have modelled for different risk profiles for the construction phase, the early operation phase and the operation phase. We can apply different rates for each of the phases. For our review of RAB charges per MWh, we have used a consistent operation phase WACC. Incorporating the different components gives the following operational WACC scenarios:

WACC scenario	**Low**	**High**
Gearing	70%	55%
Cost of debt	1.9% real	1.9% real
Cost of equity	4.8% real	7.1% real
WACC	**2.8% real** **5.4% nominal**	**4.3% real** **6.9% nominal**

For the TTT project, part of the competitive IP appointment process was a requirement for bidders to submit the cost of capital that they required to be applied to calculate the IP's allowed revenues during the construction period of the project. Ofwat has stated that the BWACC is 2.497% (real). However, this was completed in a lower interest rate environment (2015) and is therefore just outside of the range we have assumed for the purposes of this analysis.

With a RAB based methodology, there will likely be five year regulator-led reviews providing challenge to ongoing costs and allowing returns to reflect market conditions. It is important to note that in practice, financing costs will reduce over time, as the RAB reduces.

APPENDIX F: ROUND TABLE EVENTS AND FEEDBACK

Two round table discussions were held with potential investors under Chatham House rules:

- Round Table 1 (12th December 2024): with strategic investors to discuss potential development capital investment for a tidal range project.
- Round Table 2 (14th January 2025): with equity and debt investors to discuss appetite for investment in a tidal range project during the construction phase.

Round Table 1 – Development Finance

The first round table included representation from institutional investors, power companies and water utilities. The discussion focussed on the appetite from investors to provide development capital into a tidal range project. Development capital required is expected to be in the range of £35m to £50m for the first project, according to WSP estimates.

There was limited interest in providing development capital for a tidal range project, based on current circumstances. A summary of the comments and observations made by investors is presented below:

- Investors stated that the following would make a tidal range programme more attractive from a development capital perspective:
    a) A clear route to market and demonstrable UK government support.
    b) A satisfactory regulatory and legislative framework (similar to the SMR programme and CCUS, as examples).
    c) Confidence that a marine licence, planning consents and grid connections are likely to be achieved in a timely manner.
    d) Confirmation that environmental risks are sufficiently mitigated.
- There was broad agreement that the RAB model represented the most feasible funding model for tidal range.
- It was suggested that that development funding for the first project would likely need to come from government sources, for example, the Crown Estate and/or the National Wealth Fund.
- Alternatively, match funding support could be explored during the development phase similar to the Small Modular Nuclear Reactor program (i.e. up to 50% equity).
- One participant suggested that government could complete the planning and marine licence consents for the first project and then run a competitive process, inviting consortia to bid for the development, construction and operation of the project. This is similar to the early stages of the development phase for offshore wind farms in Europe. However, it may not be feasible to complete the marine license prior to bidder selection, given the application will require information specific to the bidder's technical solution. According to WSP, if the "Rochdale Envelope" for nationally significant projects is applied, covering all the technical solutions, a consent in principle could potentially be obtained prior to bids being received[18].

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[18] Nationally Significant Infrastructure Projects - Advice Note Nine: Rochdale Envelope, Planning Inspectorate, July 2018

Round Table 2 – Construction Finance

The second round table included representation from infrastructure funds, institutional investors, water and power utilities and government stakeholders. The discussion covered potential funding options, focussing on the preferred RAB option.

There was interest amongst the investors that were present in providing capital for a tidal range project during the construction phase. A summary of the comments and observations made by investors is presented below:

- One investor was concerned that the RAB Model would not provide acceptable equity returns, and they would prefer to take a higher risk and thereby obtain higher returns. All other participants agreed that the RAB Model was their preferred funding option.
- There was a suggestion to look at lessons learned from the water sector, particularly the modified PPP approach adopted on HARP.
- Energy policy must be clear that the UK Government supports tidal range energy for the long term. Investors will need to be convinced that the technology will still be part of the energy mix in 120 years. The risk of a stranded asset must be borne by the UK Government via a termination payment.
- Environmental risks will be a key issue and would need to be minimised. Recent Crown Estate research in this area was highlighted as a useful data source.
- A method to determine lessons learnt ought to be passed on to each future project to benefit end users in costs reductions and efficiencies.
- There were concerns expressed about the total capital expenditure required for the larger lagoon and barrage projects. It was suggested that the smaller projects ought to be constructed first to attract capital and establish precedents.
- There was a comment that the RAB Model would likely be on HMG’s balance sheet until commencement of the operation phase (similar to SZC). Government would need to be comfortable with this position.
- CCUS projects have successfully raised significant funding recently (up to £10bn) primarily because of the RAB Model and the credit worthiness of the project sponsors.
- It was suggested that HMG should take account of socio-economic benefits and flood defence benefits in the economic assessment of the tidal range opportunity.
- There was recognition that the CfD structure on Swansea Bay Lagoon resulted in a very high strike price and that a different approach is needed.

Some comments were also made in relation to development risk and these have been incorporated into the Round Table 1 findings on the previous page.

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