Bristol Channel Energy

A Balanced Technology Approach

Discussion Document

November 2012

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Bristol City Council

West of England Local Enterprise Partnership

Bristol tidal energy

South West Marine Energy Park

marine energy matters

Contents

Note on Sources and Methodology

This document draws on various assessments and reports relating to marine energy in the Bristol Channel. These sources often have different baseline assumptions, or calculation methodologies which make direct comparison of costs and energy yield difficult. There is also a debate about the appropriateness of standard treasury "greenbook" models to assess long term energy projects. Rather than try to deal with these complex issues in this document we have endeavoured to collate the key issues around energy extraction from the reports available to help define a future development approach. Detailed further work will be needed establish common assumptions and a more refined analysis using a consistent methodology.

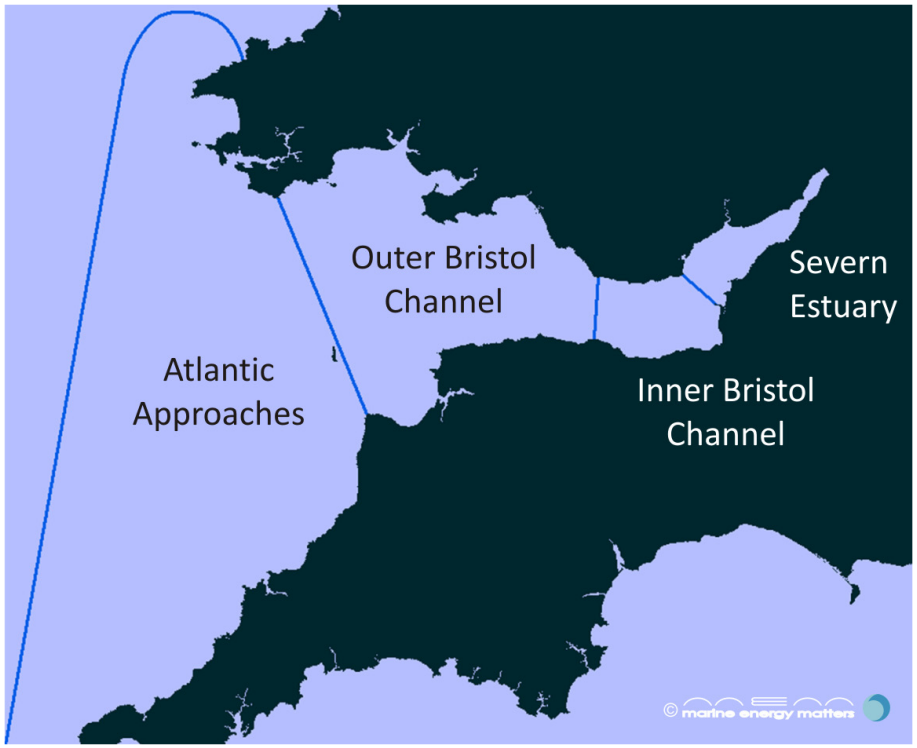
The resource estimates draw principally from the Offshore Renewable Resource assessment and Development Project (ORRAD), the Marine Renewable Energy Strategic Framework (MRESF) which looked at Welsh waters, and the Severn Tidal Power Feasibility Study. The report does not draw directly from the recent Crown Estate Wave and Tidal Key Resource Area Review, which focused on theoretical resource levels, although the analysis from this study underlines the massive energy potential of the Bristol Channel .

01 Introduction

The recently published Wave and Tidal Key Resource Area review (The Crown Estate) has again highlighted that the energy resource in the Bristol Channel is of national strategic significance to meet the future demand for low carbon energy, and is the single largest resource area for tidal energy in the UK. The Bristol Channel is however a complex hydrodynamic system which supports a wide range of marine habitats, marine communities and economic interests, as well as providing a major sea transport route into the UK heartland.

The challenge for Government and industry is to find ways to harness this energy at an acceptable financial cost, which maximises the real economic value generated while balancing the impact on the environment, other marine users and economic interests. Over the decades several schemes have been proposed, and a number of strategic reviews conducted to understand where deployment might take place. To date however proposed large scale schemes, although they may have been technically feasible, have fallen in terms of the cost of energy, risk and their environmental and socio-economic impact.

This discussion paper proposes an alternative "balanced multi technology approach" which has been developed from an on-going dialogue with industry through the **Bristol Tidal Energy Forum and South West Marine Energy Park**, as well as input from a number of economic and environmental stakeholders. The basis of this approach is to consider how multiple technologies could be deployed over time to harness the range of energy resources throughout the Bristol Channel in a way which will generate significant energy and economic benefits in balance with the environment and other marine users.



Bristol Channel regions

Through analysis of the major studies undertaken to date in Wales and South West England, the first part of the paper gives an overview of the technologies which are available today, or are being developed for the future, and matches these against the resources available in the Bristol Channel. While a number of the technology solutions described are still under development it is significant that the UK is at the forefront of the marine energy technology revolution. There is a cluster of leading

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tidal developers, research organisations and consultancies based around Bristol and in South Wales, and so the Bristol Channel offers an important opportunity to showcase UK innovation and export technologies around the globe.

The second section considers at a high level how these technologies could be combined in a sustainable way within the Bristol Channel taking into consideration their impacts on the environment, energy costs, economic impact and the interdependency between technologies.

The final section of the document brings the technologies together to present an overview of what a "Balanced Technology Approach" might look like in terms of an overall spatial plan and energy system. While not presenting a prescriptive solution, it also offers some commentary on the key elements of this approach and the advantages it might bring including reduced risk, achievability, lower impacts and the ability to develop and exploit new technologies as they become cost competitive.

A more constructive approach

Meeting the challenge of global climate change requires large scale energy projects - as well as the widespread adoption of energy efficiency and other forms of distributed generation. The success of large scale energy schemes in the Bristol Channel must be based on a strong consensus and secure support from communities on both Welsh and English sides of the channel.

In recent months publicity around the proposals to develop a large barrage scheme has once again put the energy potential of the Bristol Channel into the spotlight. There is a real concern however that the single focus on a potentially divisive project, which is framed in terms of a battle between energy and the environment, and between competing economic interests, is in fact damaging for the industry.

The intention of this paper is to provide a basis for a more inclusive discussion, and to enable government, industry, environmental groups and local stakeholders to work together to utilise new technology which will generate significant low carbon energy and sustainable jobs.

Feedback welcome

If you would like to comment on this paper or contribute to the development of the marine energy sector please contact Johnny Gowdy at Regen SW **jgowdy@regensw.co.uk**

02 Resource and Technologies

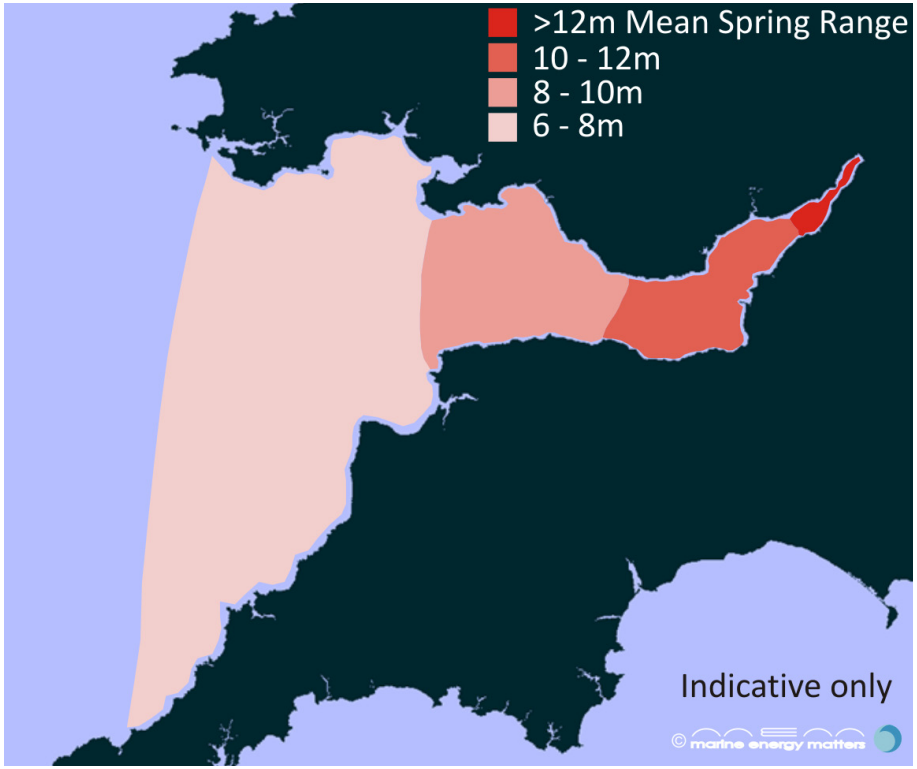
Tidal Range

The Resource

With a tidal range of up to 14 m, one of the largest in the world, the Severn Estuary/ Bristol Channel offers a massive resource potential to provide the UK with clean, low carbon energy.

Over the decades there have been a number of studies looking at how this energy could be harnessed. One of the most recent and comprehensive studies - the Severn Tidal Power Feasibility Study (STP Study 2008-2010) - concluded that the most viable barrage/lagoon schemes could be between 1 GW and 8.6 GW[1]. The largest installation, a Cardiff-Weston scheme could provide approximately 5%[1] of current UK electrical consumption. The estimated construction costs of the projects range from £4.7bn (Shoots barrage) to £23.2bn (Cardiff Weston barrage) or £7bn to £34bn if you include optimism bias, the additional Treasury contingency for publicly funded projects.

While the energy resource estimates from the STP study confirmed the energy potential of the Severn Estuary, the report also highlighted in stark terms the challenge and risks of harnessing this energy in a way that is both cost effective and has an acceptable impact on the environment and other users of the estuary. As a result of these findings in late 2010, the government concluded that a large



Bristol Channel tidal range resource

scale Severn tidal project was not a strategic priority and should not currently receive public funding while other low carbon options represent a better deal for taxpayers and consumers.

1 Severn Tidal Power Feasibility Conclusions and Summary Report

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Tidal Range Technologies

Barrage

Barrage schemes impound water behind a dam between two coasts. Conventional tidal barrage schemes are likely to use civil engineering and standard turbines from the hydro-dam industry. To date the only tidal barrage generating installation in Europe is La Rance in France – a 240 MW installation built in 1966.

La Rance Tidal Barrage France

Lagoons

Lagoons are civil structures that impound water along a stretch of coastline rather than running between two coasts as in the case of a barrage. Similar hydropower turbine technology as used in a barrage would be used to generate energy as the tides move in and out of the lagoon. To date there are no known lagoon generating schemes in operation although, along with locations around the UK, other countries such as France and South Korea are considering the concept. The STP study considered various lagoon schemes and concluded that a large Bridgwater Bay lagoon was feasible.

In the period since the STP study other Lagoon schemes have been proposed including schemes in Swansea Bay and the "Stepping Stones" lagoon proposal between Aberthaw and Barry.

New Technologies - Low Head Turbines

In addition to conventional hydro-turbine technologies operating with barrages and lagoons, there are new innovative options being explored.

Low head turbines, such as the concept design developed by Rolls Royce/Atkins, could be used in conjunction with barrage or lagoon schemes. This technology has the potential to generate on both ebb and flood tides; with a reduced truncation of the low water tidal range and subsequent loss of inter-tidal habitat. However, while probably better in terms of habitat loss, the generation of energy on both ebb and flood will have an impact on the high water range - potentially affecting upstream ports and marine users - and may have a greater impact on fish migration.

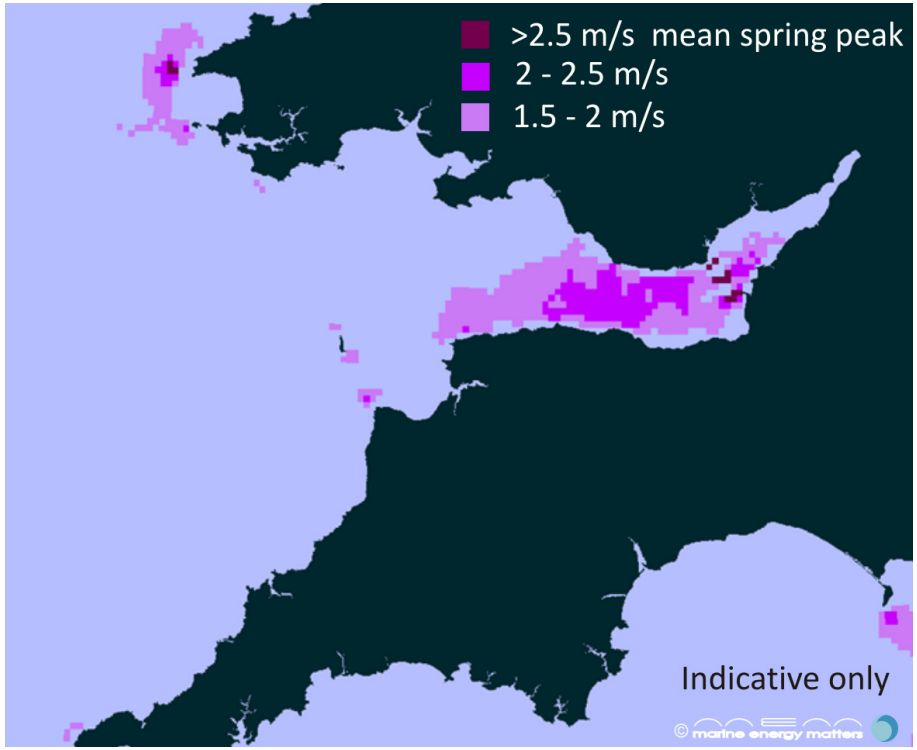
It is important therefore, that low head turbine concepts are fully proven through incremental projects, such as the Stepping Stones lagoon proposal, so that their environmental impacts understood.

02 Tidal Stream

The Resource

Tidal Stream technologies capture the kinetic energy of the tidal flow as opposed to potential energy stored behind a barrage or lagoon due to rising and falling tides.

Areas of the Bristol Channel achieve a peak flow in excess of 2.5 m/s, which is less than that found in the extreme situations in the Pentland Firth and Channel Islands but it does cover a large area. The ORRAD[2] project (2010) suggested that 0.6 GW could be installed on the English side of the Outer/Inner Bristol Channel (by 2030) with a further 0.36 GW available around Hartland Point, Lundy and Lands End. The Welsh MRESF[3] project also recognises the Bristol Channel tidal stream resource both in the inner channel and in Pembrokeshire. Conservatively, these are estimated at up to 0.14 GW of installed capacity. In combination these studies suggest a total resource of 1.1 GW with at least 0.7 GW in the Outer and Inner Bristol Channel.



Bristol Channel tidal stream resource

Tidal Stream Technologies

Tidal Stream technologies are currently dominated by horizontal axis rotor devices similar to wind turbines, although there are other technology principles such as hydrofoils, cross flow and venturi based devices. Full-scale prototypes are now being deployed with first arrays forecast before 2020. Operating at depths from 10 m each turbine is likely to have an operating capacity of 0.5-1.5 MW.

Horizontal axis rotor turbine- Marine Current Turbines

2 The Offshore Renewables Resource Assessment and Development Project (SW RDA 2010)
3 Marine Renewable Energy Strategic Framework, 2011

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Hydrofoil Turbine – Pulse Tidal Energy Ltd

Seaflow, the UK's first tidal turbine was installed in the Bristol Channel in 2003. Now decommissioned there is a proposal for a new test site at the same location with a recent seabed lease granted to Pulse Tidal Energy Ltd.

Three of the leading technology developers are centred around the Bristol Channel establishing the area as global development hub for tidal stream technology.

New concepts - Tidal Fence

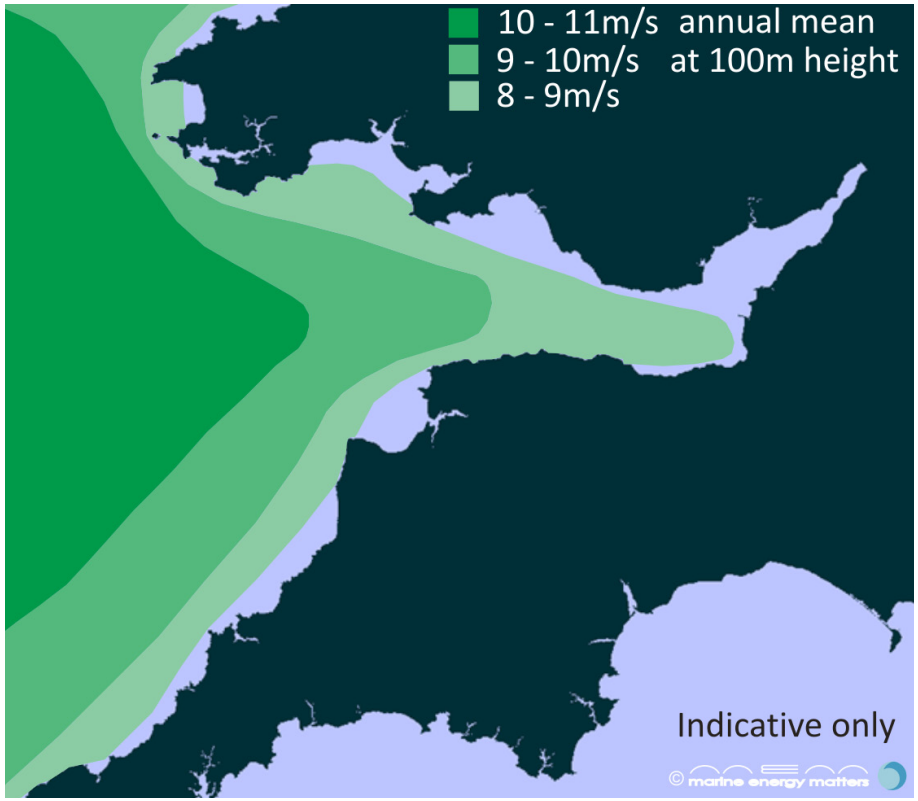
Tidal "fence" designs are based on the deployment of an array of tidal turbines on a fixed structure which, as well as capturing tidal stream resources, also acts to create a tidal head. As well as potential cost savings during deployment, a tidal stream fence can potentially improve system performance, particularly in shallow water/ moderate flow regimes such as the inner and outer Bristol Channel.

Tidal Fence Concept

02 Offshore Wind Energy

The Resource

The offshore wind potential in the Bristol Channel is significant with mean wind speeds exceeding 9 m/s in the outer Bristol Channel and the Atlantic Approaches although accessing the higher western resources brings new challenges due the increased depth of water.



Bristol Channel offshore wind resource

The Bristol Channel already has the Atlantic Array Project (1.5 GW) in development, as part of the UK's offshore wind programme which aims to install over 20 GW of capacity in UK waters by 2020. There is increasing interest in the deployment of "floating wind" technology in deeper waters which will open up opportunities for deployments in deeper waters to the west of Lundy and the Atlantic Approaches.

Fred Olsen Bolt wave energy device – FaBTest, Falmouth

Offshore Wind Technologies

The offshore wind energy industry is the most developed of the four marine renewable energy generation sectors. There are now several well established global companies building and installing wind turbines offshore. Nearly all now operate horizontal axis, three bladed devices at capacities often exceeding 5 MW per turbine spaced about 1 km apart.

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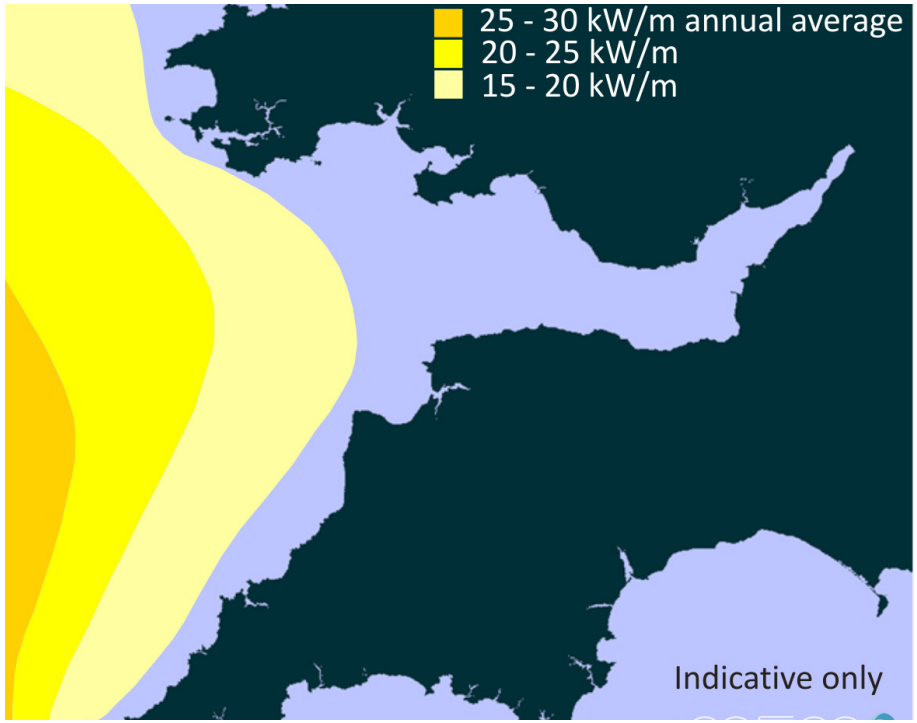
Wave Energy

The Resource

The Atlantic Approaches has some of the best accessible global wave resources. The installation of Wave Hub in west Cornwall in 2010 provides a first location for pre-commercial arrays of wave devices and has elevated Cornwall as a primary location for wave energy demonstration and commercial deployment in the UK.



Bristol Channel wave energy resource

The ORRAD[4] project estimated that 1.2-2.7 GW of offshore wave energy resource can realistically be deployed in south west England waters by 2030, over 0.6 GW of which is located in the Atlantic Approaches of the Bristol Channel.

Wales' MRESF suggests that up to 4.5 GW of wave energy could be deployed within 12 nm of the coast around Pembrokeshire.

Wave Energy Technologies

The Wave energy industry is the least developed of all the offshore energy technology sectors but a number of full scale prototypes are now being tested in-sea. There are about 100 active technology developers world-wide and concepts for harnessing wave power are still very diverse, ranging from attenuators which absorb the physical energy of the approaching wave and point absorbers such as the Bolt 2 device being tested at FaBTest (Falmouth) to oscillating water column (OWC) devices which indirectly generate energy though air pressure that is created when a wave passes under a partially submerged chamber. Ocean Energy, an OWC device, is due to deploy at Wave Hub in 2013.

4 The Offshore Renewables Resource Assessment and Development Project (SW RDA 2010)

03 Sustainability and Technology Adoption

The Bristol Channel is a complex hydrodynamic system which supports a wide range of marine habitats and marine communities as well as providing a major sea transport route into the heartland of the UK's manufacturing base.

The future strategy for harnessing offshore energy in the Bristol Channel is therefore about much more than just the resource and technology. The cost impacts of each technology upon one-another, their potential environmental impact and their contribution to economic development all need to be taken into account.

Tidal Range

Barrage

Severn Tidal Project (STP) Findings

The largest barrage project considered feasible by the STP study (Cardiff-Weston) could be 8.6 GW, providing 5% of the UK's electricity consumption. The other potentially feasible barrage identified by the STP study was the much smaller, but still significant, Shoots Barrage (1 GW).

Environmental Impact

The STP study concluded that environmental impacts of a Cardiff-Weston Barrage were the greatest of all tidal range schemes considered, with the loss of 40-50% of intertidal habitat (118-196 km^2) and significant down stream impacts on the coastline. Improvements in long term sea level rise resilience upstream would accrue as a result of smaller high tides behind the barrage, however these are offset by the increase in tidal range downstream of the barrage and the increased flood risk caused by erosion and drainage issues during "tide lock" conditions[5]. The Shoots Barrage is considered to have less environmental impact in terms of intertidal habitat loss and downstream impacts. All the projects studied under the STP study identified significant issues for local fish species.

Economic Impact

The greatest absolute economic impact of schemes considered by the STP study was the Cardiff Weston scheme (8.6 GW) at £2.4bn GVA (Gross Value Added) over 40 years. Whilst substantial, this level of economic benefit is only marginally greater then the much smaller Bridgwater Bay lagoon scheme (£2.3bn GVA). The net job creation from the Cardiff-Weston barrage was also much lower. This is largely due to the considerable negative impact a Cardiff-Weston Barrage will have on Bristol Port and the hinterland of industries and distribution networks which rely on port access. The much smaller Shoots Barrage delivers £0.9bn GVA over the 40 years.

Cost of Energy

Under the Government's standard appraisal, the levelised cost of energy (LCoE) at investor rates of return (10%) was calculated by the STP study to be between £211/MWh (Cardiff- Weston) and £228/MWh for the Shoots Barrage. A very large energy project at these costs could have a significant impact on consumers' energy bills in the financing period but would thereafter have a downward influence for the remainder of its operating life.

5 Severn Tidal Power Report, Flood Risk and Land Drainage 2010

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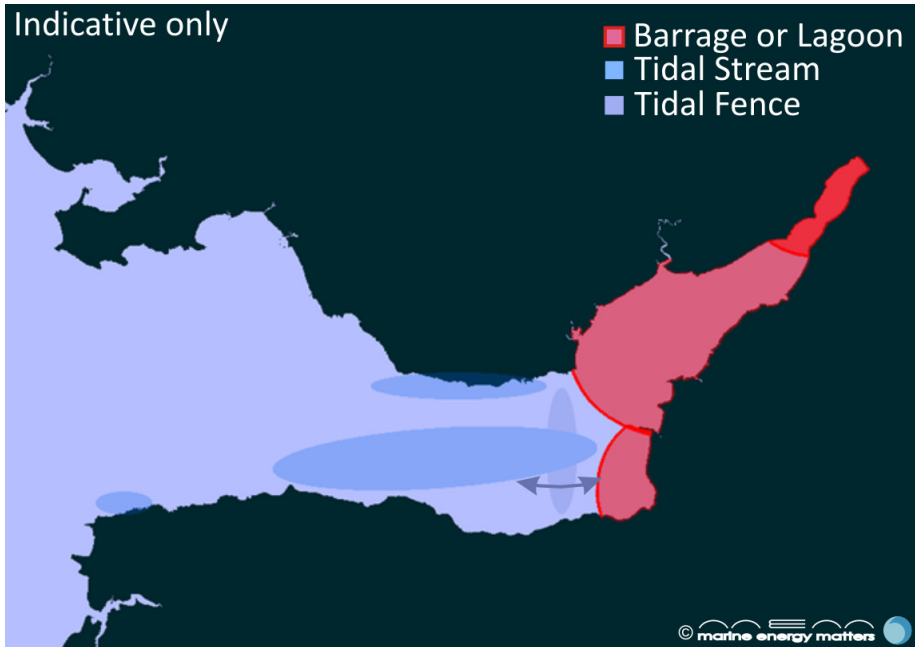
Inter-Technology Impact

The adoption of tidal range projects will impact on the development and deployment of other technologies, and will largely depend on the type, size, and location of projects. For example, the adoption of a large single barrage will impact on downstream flow and hence tidal stream generation potential. A small barrage near the head of the estuary is much less likely to have a significant impact on the tidal stream resource.



STP study tidal range possible deployments & potential tidal stream development zones

Lagoons

Environmental Impact

The environmental impact of any lagoon will depend on its size and location. The Bridgwater Bay Lagoon, which was considered feasible under the STP study, has some significant environmental impacts but much less effect on the key issues of intertidal habitat loss (5-8%) and downstream conditions than the Cardiff Weston Barrage, although the land drainage area impacted is still significant. As with all the projects studied in the STP study, there are uncertainties around impacts on local fish species.

Cost of Energy Produced

Under the standardised cost methodology used in the STP study, the Bridgwater Bay Lagoon would have a levelised cost of energy of £248/MWh, slightly higher than the barrage schemes. Cost estimates for the smaller Stepping Stones Lagoon using the same methodology are £190/MWh[6] .

Economic Impact

The economic impact (GVA) of the Bridgwater Bay Lagoon (£2.3bn) would be similar to the much larger Cardiff Weston Barrage. This is largely as a result of much more limited impact on Bristol Port.

Inter-Technology Impact

The impact of lagoon projects on the tidal stream will be dependent on their size, shape and location. In some situations it is possible that a lagoon scheme could enhance tidal flow - verification will require detailed modelling.

6 http://regensw.s3.amazonaws.com/120831_stepping_stones_tidal_lagoon_presentation_for_bristol_tidal_forum_ead4881f6fce116d.pdf

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New Technology

In addition to the lagoon and barrage schemes considered under the STP study, a separate development project (the Severn Embryonic Technologies Scheme or SETS) awarded funding for alternative approaches to harnessing the power of tidal range in the Severn in a Cardiff-Weston scenario.

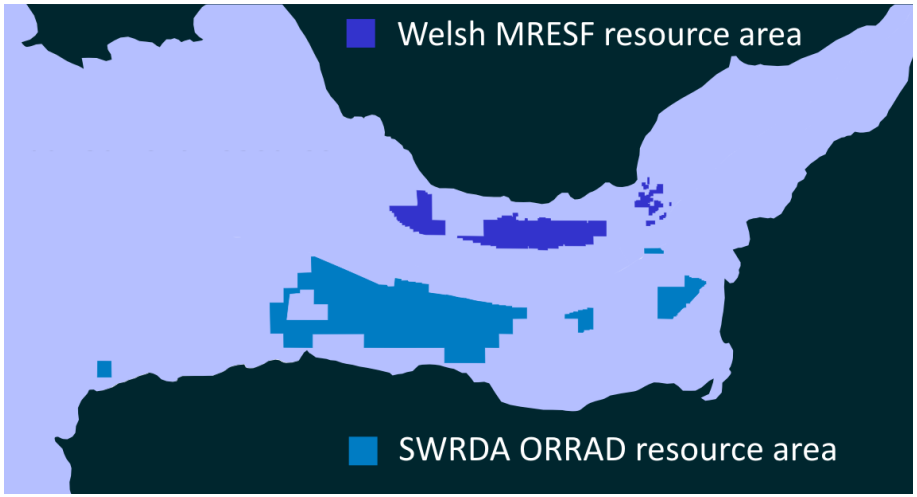
The three shortlisted projects produced alternative designs from new low head turbines designs in barrages through to tidal stream technologies in "fence" arrangements all with the objective of reducing the environmental impacts and in some cases the negative economic impact associated with a high head barrage concept, at reasonable cost. At the extreme low-head end, the "tidal fence" uses both the current (i.e. tidal stream) as well as some head differential to produce energy – whilst it therefore produces less energy, it has significantly lower environmental impacts and does not require ship locks to allow navigation upstream. Both other options (a Venturi fence and a low head barrage) require ship locks and also involve higher variations in head so their effect on the water environment is also more significant. Costs for the low head barrage option[7] were similar to a conventional barrage but with reduced environmental impact whilst the tidal fence option had a levelised cost of energy approximately 10% higher than a Bridgwater Bay lagoon.

The tidal fence concept with its relatively low environmental impact, reduced impact on navigation and similar levelised energy costs to more conventional options, appears to offer a potential technology which could harness the tidal flows of areas like the Bristol Channel.

7 Severn Tidal Power Feasibility Options Definition and Severn Embryonic Technologies Reports

Tidal Stream

The ORRAD Project (south west England waters to 2030) and MRESF (Welsh Waters – no time constraint) suggest a combined tidal steam capacity of approximately 1.1 GW in the Bristol Channel with much of this capacity in the outer and inner sections of the channel. The ORRAD study did not include the STP Project area as a separate project was being undertaken at the time.



ORRAD and MRESF developable tidal stream resources

Note:

ORRAD developable resource area: Velocity (msp) > 2.0 m/s greater than 5 m depth

MRESF developable resource area: Velocity (msp) > 2.0 m/s, greater than 10 m deep and within 5 km from shore.

03

Environmental Impact

In arriving at their capacity conclusions and broad location areas, the ORRAD and MRESF projects considered the range of environmental constraints impacting on technology deployment. As the technology is still in development there are elements of environment impact that are still unknown, however we are beginning to understand more from the data that is being gathered at tidal test sites such as EMEC and at Strangford Lough.

Cost of Energy

Tidal stream technologies are still at an early stage and so their "first of a kind costs" are still very high. The UK Government has set a tariff for the first arrays allowing developers to claim 5 ROCs (Renewables Obligation Certificates) for each MWh produced. However this is recognised as a short term level of support (until April 2017) - as learning progresses and scale increases, it is expected that the cost of energy will decrease substantially, with the longer term target of becoming competitive with offshore wind by 2025. This would place the cost of tidal stream energy at around £100-120/MWh. Whether this level of cost reduction can be achieved within this timeframe in lower energy (flow) sites such as the Bristol Channel will depend on the rate of technology development and the scale of deployment.

Economic Impact

No assessment of economic impact of tidal stream technologies is available for Welsh waters. The ORRAD project, which looked at the south west of England, concluded that the regional GVA associated with tidal stream deployments to 2030 amounts to £512m.

A significant proportion of GVA in this sector will be regionally focussed due to a significant developing regional tidal stream presence - two of the leading technology developers (Tidal Generation Limited and Marine Current Turbines) are based in Bristol, with Tidal Energy Ltd based in South Wales. In addition there are a number of regionally based consultancies with global reach specialising in this sector.

Inter-Technology Impact

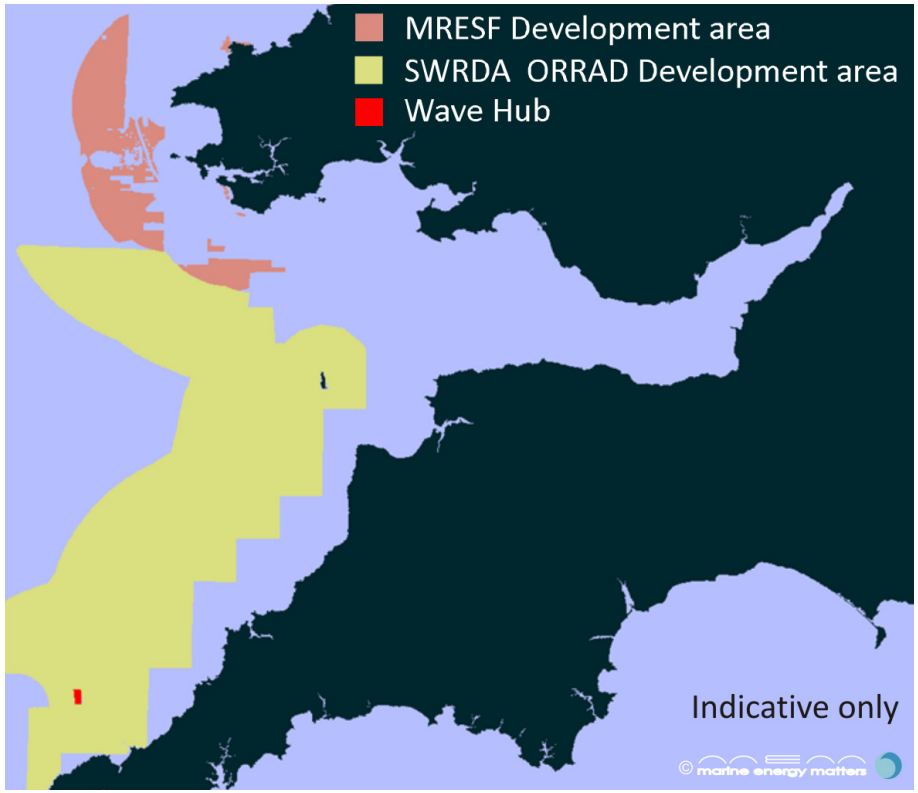
As tidal technologies modify the hydrodynamic regime, co-location of technologies will have some inter-dependencies. The largest inter-technology impact/conflict occurs between tidal stream deployments in the Outer and Inner Channel and a single large barrage structure across the Channel (e.g. Cardiff Weston barrage). For example, a barrage could significantly impact the tidal flows in the Estuary and render the Inner/Outer Channel area unviable for tidal stream deployment (subject to confirmation from specific detailed modelling of the relevant schemes).

Tidal stream technology deployment is likely to be compatible with Shoots Barrage studied as part of the STP project. The inter technology impact of tidal stream and large lagoons such as the Bridgwater Bay lagoon will require further modelling to understand better specific inter-actions but are likely to be compatible subject to this validation. Tidal stream technology deployment should be able to work in conjunction with smaller lagoon systems.

Tidal stream and wind energy deployment are not likely to take place in the same locations (assuming wind developments do not take place to the east of the Atlantic Array site) as tidal stream resources decrease to the west whilst wind resources increase.

03 Wave Energy

The ORRAD Project (south west England waters to 2030) and MRESF (Welsh Waters – no time constraint) suggest a combined wave energy capacity of 2 – 5+ GW in the Bristol Channel with much of this capacity in the Atlantic Approaches.



ORRAD and MRESF developable wave resource areas

Note:
ORRAD developable resource area (2030) to 50 km minus hard constraints
MRESF developable resource areas with medium constraints.

Environmental Impact

In arriving at their capacity conclusions and broad location areas, the ORRAD and MRESF projects have considered the range of environmental constraints impacting on technology deployment. As the technology is still in development there are elements of environment impact that are still unknown, however test sites such as EMEC and Wave Hub will provide valuable early understanding.

Cost of Energy

Wave Energy Technology is the least developed of the current offshore energy technologies and until the technology is demonstrated at full scale at sites such as Wave Hub it is difficult to estimate a future levelised cost of energy. In the short term Wave Energy will benefit from the UK Government's proposed 5 ROCs (Renewables Obligation Certificates) tariff to 2017, and learning and scale are expected to reduce costs over time.

Economic Impact

No assessment of economic impact of wave technologies is available for Welsh waters but the ORRAD project concluded that the GVA associated with wave deployments in south west England waters to 2030 amounts to approximately £900m. A significant proportion of the GVA in this sector will be regionally focussed due to facilities such as Wave Hub and utilisation of the local supply chain.

Inter-Technology Impact

As the wave and wind resources are spatially similar, there is potentially conflict between the technologies. However constraints on the possible deployment locations for wind energy reduce this conflict considerably, restricting it largely to the northern part of the Atlantic Approaches.

Wave energy resource does not generally conflict with tidal resources, with perhaps minor exceptions along the north Devon coast and the eastern part of the north Cornwall coast and the western tidal stream resources around headlands such as Land's End in Cornwall.

03 Offshore Wind Energy

Although resource levels favour deployment in the Bristol Channel there are a number of physical and environmental constraints that restrict the area of development. Despite these hard constraints, deployment capacity is estimated at 3 GW[8] in the Bristol Channel to 2030.

Environmental Impact

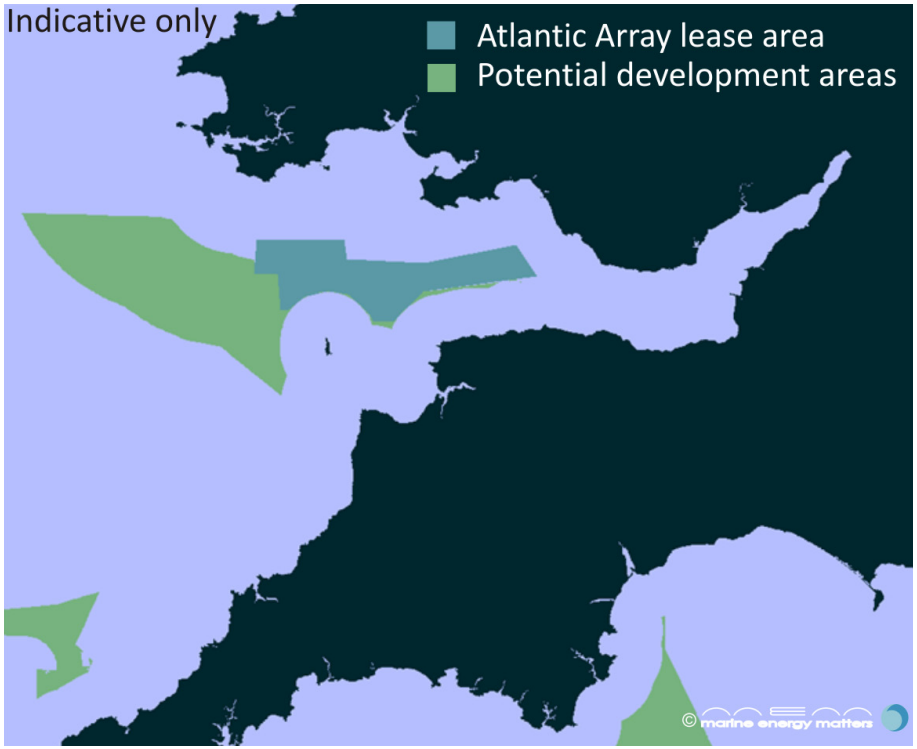
The environmental impacts of wind energy are probably the best understood of all offshore renewables technologies. The environmental constraints governing deployment are considerable. The diagram opposite (ORRAD project - English south west waters only) provides an illustration of the possible development areas (potential resource within 50 km of the coast minus hard constraints) and the leased Atlantic Array area..

Cost of Energy Produced

In the run-up to the Electricity Market Reforms due in 2017, the UK's recent consultation[9] suggests that the number of ROCs available to the offshore wind industry will reduce from 2 to 1.8 over this period, suggesting a current cost of energy at around £140-150/MWh. The government's medium-term aim (2020) is for the offshore wind cost of energy to be reduced to achieve a target of £100/MWh.

Economic Impact

The UK wind market is a global leader but unfortunately there are currently no UK wind turbine manufacturers, hence economic development from installation is limited. However, UK government is providing incentives to encourage turbine manufacture in the UK and is now targeting 50% UK content of future developments. The operations and maintenance activities associated with the very significant deployment brings with it very considerable economic benefit - estimated at £3.4bn GVA[10] to 2030 for all south west England Waters (5.5 GW).



ORRAD developable wind areas and Atlantic Array leased area

Inter-technology Impact

The deployment of wind technology has very limited impact on tidal derived energy in the estuary and inner parts of the Bristol Channel. The resource areas further west are unlikely to clash with potential resource areas for wave energy. However due to the spacing of wind turbines, technology co-location may be feasible.

8 ORRAD Project 2010

9 Consultation on proposals for the levels of banded support under the Renewables Obligation for the period 2013-17 and the Renewables Obligation Order 2012, DECC, 2012

10 ORRAD Project (2010)

03 Technology Summary

Technology Interaction

- **Compatible Technologies**
  Resource locations and deployment constraints mean wind wave and tidal (combined stream and range) technologies are largely compatible in the Bristol Channel.

- **Potentially Compatible Technologies**
  Tidal Stream and some tidal range technologies (small barrage and lagoons) are potentially compatible depending on scale and location of the tidal range technology deployment locations.

- **Incompatible Technologies**
  Tidal stream technologies in the inner and outer Bristol channel are unlikely to be compatible with a large tidal barrage structure. Any marine energy project located upstream of a barrage would not be compatible.

Cost of Energy

- Offshore wind technology is the most developed and currently has the lowest cost of energy, providing the benchmark for other offshore energy technologies.

- The current cost of tidal range projects are higher than offshore wind projects at investor rates of return - so large projects could lead to an increase in consumer bills although over the long term (after 25 years of operation) costs will fall due to their long operating life.

- Tidal stream technologies currently have a high cost of energy, but it will progressively reduce as technology develops and greater numbers are built.

- Wave technology is currently the least well developed of all technologies and consequently has a high cost of energy. Although perhaps a little slower than the tidal stream, industry cost reductions should take place over time and, once developed, this technology has the potential to provide low cost energy.

Economic Impact

- Deployment of offshore renewables in the Bristol Channel is likely to have a significant economic impact over the next 30-40 years.

- In some areas such as tidal stream technology – the Bristol Channel region is already a leading development area.

- Development of a single large barrage will produce the largest single economic gain (GVA) in absolute terms but the other technologies, including lagoons, are likely to provide a better economic development return on the capital invested. The Cardiff-Weston barrage also had a lower net jobs. This is largely due to the negative economic impact that a large barrage project will have on Bristol port and other ports upstream of the barrage) and on the hinterland of industries that are dependent on the port.

- With the exception of a large downstream barrage, all major Bristol Channel ports are likely to benefit from offshore renewables deployment in future decades

- Facilities such as Wave Hub, FaBTest and potentially a tidal stream centre will help catalyse marine energy development.

03

Environmental Impact & Constraints

- All recent major projects acknowledge and detail the constraints on offshore renewables development - some technologies such as wind have only a limited potential deployment area due to constraints. Many of the reports to date have approached deployment potential (capacity) by considering the likely constraints and these are included in their deployment estimates.
- Large tidal range projects can have very significant environmental impacts. A large Cardiff-Weston barrage project is identified as having the most severe impact in the STP study.

Overall Development Potential

The various strategic studies undertaken over recent years consider different aspects of the resource and deployment over different timeframes; however the areas where resources are mutually compatible suggest there is very significant potential in the Bristol Channel area. As the various studies undertaken to date have different approaches it is very difficult to accurately estimate a combined technology installation capacity. However, the combined installation potential is possibly in the range of 10-15 GW capacity with or without a large barrage.

04 A Balanced Technology Approach

Objectives of a Balanced Approach

As the analysis above shows, developing an energy strategy for the Bristol Channel requires a number of factors to be considered including the energy yield, cost of energy, environmental impact and impact on other sea users and industries.

Given the level of complexity, and that the Bristol Channel straddles Welsh and English waters, previous studies have tended to focus on specific geographical areas or resource use. While these studies have provided valuable analysis there has not been a coherent strategy to harness the energy, and maximise the economic potential, of the Bristol Channel as a whole. The consideration in isolation of mega-projects such as a Barrage has also led to a polarised debate, leading to an inevitable hiatus and uncertainty, which has hindered alternative technology deployment and investment.

The basis of a "Balanced Technology Approach" is to consider how multiple technologies could be deployed over time to harness the range of energy resources throughout the Bristol Channel, in a way which generates significant energy and economic benefits and is "in balance" with the environment and other marine users. This approach would still support large projects, a tidal lagoon for example would still be the biggest single tidal energy project in the world today.

The essence of the approach would be to:

- Treat the Bristol Channel/Severn as a holistic energy system with a range of energy resources within each spatial area including tidal range, tidal stream, wind, floating wind and wave energy resources
- Consider technologies in combination – understanding their impacts and interdependencies to produce a high energy output but at an acceptable environmental and socio/economic cost
- Adopt a time based strategy to develop and deploy a portfolio of technologies – allowing new technology to be developed and brought on stream when proven, risks understood and costs reduced
- A focus on technologies which can be built out on an incremental basis so that individual and cumulative impacts and risks can be understood and mitigated
- Invest to support technology development as a solution to the UK's energy needs, whilst stimulating Bristol Channel economies and new sector growth in the global energy market

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The advantage of a balanced technology approach would be to:

- Generate a significant energy output to support the UK's low carbon energy needs
- Bring forward financially viable projects which are more likely to be built
- Minimise the risk of negative environmental and socio-economic impact
- Spread economic benefits across both sides of the Bristol Channel - avoiding a zero-sum economic impacts with big losers and winners
- Enable deployments to start earlier, initially at demonstration scale, but then commercially at larger scale as technology develops
- Adopt new technologies as they become proven and cost effective
- Enhance and support the area's position as a leading centre for technology development

What might a balanced approach look like?

The intention of this document is not to define a detailed technical or spatial proposal for the Bristol Channel; such an approach would be premature given the current level of technology development and understanding of all the issues. We can however draw on the previous studies which looked at individual technologies and areas alongside work within the **Bristol Tidal Energy Forum** group to present a high level vision of what a future Balanced Technology Approach in the Bristol Channel might look like.

The Severn Embryonic Technology Study (SETS) identified a number of potential technology solutions including Tidal Fence technologies, lagoons and low head turbines. Since then consultancy firms such as IT Power have continued to look at innovative cross-flow tidal devices which could be deployed as tidal stream technologies or incorporated within a tidal "fence".

Drawing on the work done as part of the STP, Parsons Brinckerhoff have continued to look at the potential use of tidal lagoons including the development of new caisson design and site suitability as part of their Stepping Stones project. Black and Veatch, working with the ETI, have begun to develop a more sophisticated resource model of the estuary which could be used to model the interdependencies and impacts of multiple projects.

There has also been a renewed interest in tidal stream devices which are designed to operate in comparatively shallow water (<30 m) and obtain efficiencies in medium flow velocities. The Pulse Tidal demonstration project which is planned for deployment at Lynmouth is one example of this type of technology, there are however a number including Verdant, Seapower Gen, Verderg, Kepler, Aquascientific and Tidal Stream Ltd.

In addition to the current innovation taking place in the Bristol Channel surrounds, Tidal Energy Limited, Marine Current Turbines and Tidal Generation Limited (three of the leading global tidal stream developers) are present with a cumulative skill base of around 100 people. These organisations provide a technology development centre of excellence gathered around the Bristol Channel.

Looking at the developments in tidal energy technology, together with progress in wave energy through FaBTest and Wave Hub, and alongside an increasing focus on floating wind, it's possible to begin to map out a potential development path for the Bristol Channel - one which could deliver very significant renewable energy capacity from a combined technology approach, in addition to capturing economic development by supporting these new industries.

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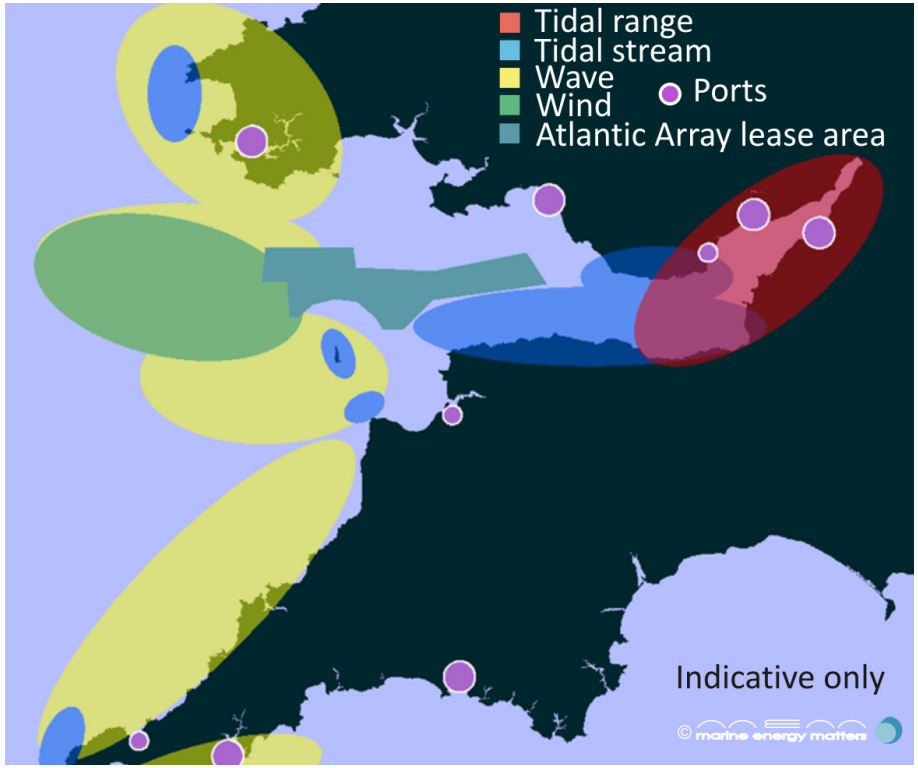
The diagram below outlines in broad the main potential resource development areas for wind, wave and tidal energy in the Bristol Channel through analysis of existing reports.



The development areas are deliberately indicative and further work is needed to understand the interactions between technologies (particularly in the Inner Bristol Channel and Severn Estuary). However, indications from existing studies and discussions with stakeholders suggest a multi technology approach could include

Technology	Possible Scale
Tidal Range Located in the Severn Estuary, Inner and Outer Channel potentially including a small barrage (Severn Estuary) and tidal lagoons (Severn Estuary and Inner/Outer Channel).	1-5 GW
Tidal Stream (inc tidal fence) Shallow & medium depth tidal stream and tidal fence technologies in the Inner/Outer Bristol Channel and around headlands and Islands such as Lands end, Lundy and Pembrokeshire.	0.5-1.25 GW
Wave Development in the Atlantic approaches off the North Cornwall Coast and Pembrokeshire	2-5+ GW
Offshore Wind - Completion of the existing Atlantic Array project followed by deployment of deeper water (floating?) wind west of Lundy	1.5-3+ GW

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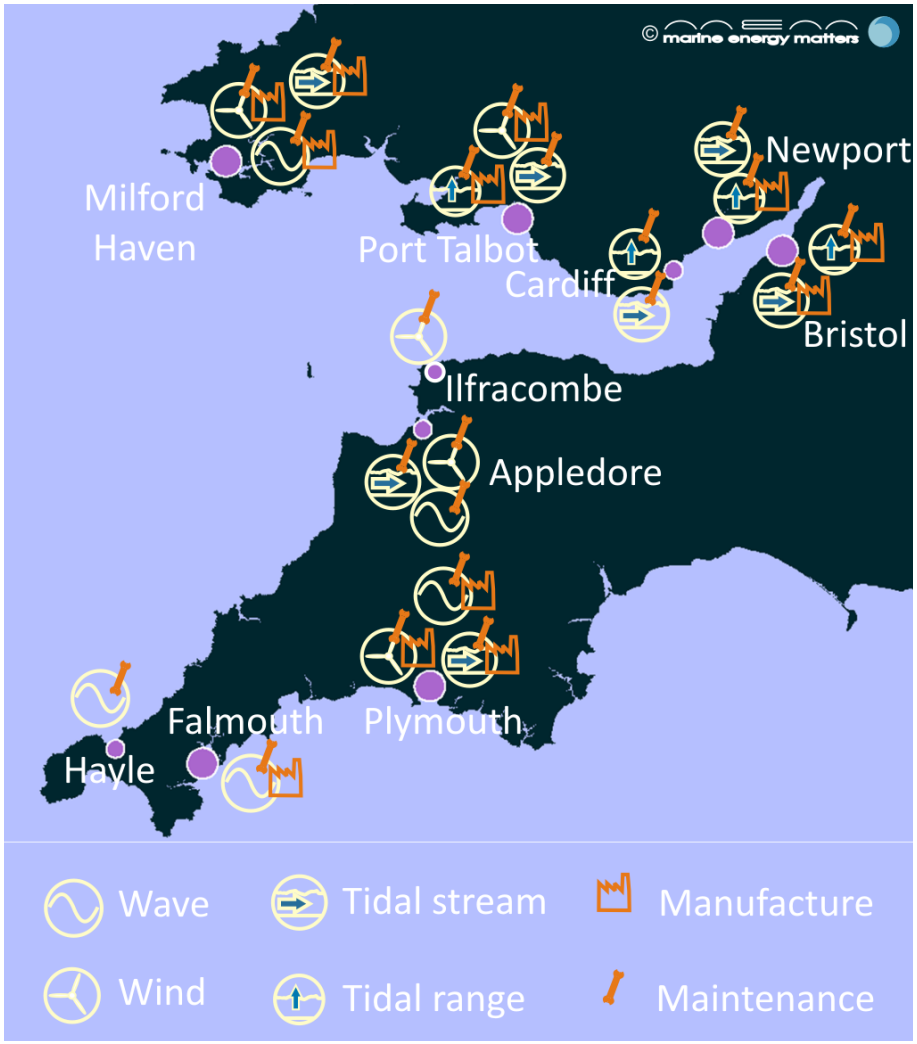
Using our Ports – spreading investment and jobs

How our ports and the infrastructure around them integrate with offshore energy development is a critical component of future strategy – we need to ensure they are not impacted negatively by developments, and have the opportunity to become part of the emerging industry. One of the biggest benefits of a balanced technology approach would be to support investment in port infrastructure and jobs on both Welsh and English sides of the Bristol Channel. By contrast a single large barrage scheme would have serious detrimental impact on individual ports behind the structure.

The diagram (right) indicates the possible offshore energy focus of our major ports in the Bristol Channel.



Possible Port specialisations

05 A Way Forward

No significant scale energy scheme of any technology in the Bristol Channel will succeed without a strong support from stakeholders on both the English and Welsh sides of the channel. It is essential therefore that a consensus is established about how to balance the need to generate green energy with the wider environmental, economic and social interests that will be affected.

Our intention is that this discussion document will provide a useful catalyst for this process and could provide a basis for future dialogue between industry and wider interests to formulate direction and secure the development of an exciting new industry.

To support this, a number of things need to happen:

- **An open forum** - The Bristol Tidal Energy Forum and South West Marine Energy Park will continue discussions with the industry and all major stakeholders to develop the multi technology approach outlined in this paper. To build consensus however we would welcome the development of a wider forum – which brings together industrial and wider stakeholders on both English and Welsh sides of the channel.
- **Proper governance** – A holistic approach to marine spatial and energy planning, which lies at the heart of the balanced technology approach, requires the UK Government, Welsh Government and its agencies to work together to provide governance and leadership - It cannot be achieved by individual project developers and consortia.
- **Support for technology development** – Many of the technologies highlighted in this paper are at an early stage of development, others are still at the concept design phase. It is essential continued funding and investment is available to enable technology to mature from concept design, through prototype and demonstration to full commercial deployment. The Severn Embryonic Technology Scheme (SETs) was a useful start and should now be enhanced with a new funding stream for tidal technology development.
- **A focus on collaborative research** – There are still many unknowns and uncertainties surrounding the deployment and interaction of significant scale projects – engineering questions range from the precise engineering and energy yield, the interaction between energy devices in an array, between schemes and between technology types. Environmental issues such as impacts on marine species, coastal processes and cumulative impacts of deployment all seek answers. Working in isolation no single organisation can address these issues but by working together in an integrated programme of research the universities and institutions around the Bristol Channel, together with the private sector, could provide the answers to many of these questions.

Terminology

STP Study — **Severn Tidal Power Feasibility Study (2008-2010)**
The Severn Tidal Feasibility Study was funded by government and examined the potential of utilising the tidal range in the Bristol Channel. It consider five major schemes in detail, assessing the potential energy, economic and environmental issues of each scheme.

ORRAD — **Offshore Renewables Resource Assessment and Development (SW RDA 2010).**
The ORRAD project considered offshore renewable energy deployment that could take place in south west England Waters (out to 50 km) by 2020. An Economic Assessment was also undertaken.

MRESF — **Marine Renewable Energy Strategic Framework (2011)**
The MRESF conducted by the Welsh Assembly considers potential deployment areas and capacities for the wave and tidal energy deployment around Wales taking into account the likely constraints.

GVA — **Gross Value Added**
Economic impact is measured in terms of Gross Value Added (GVA) to the economy. Economic– both the ORRAD project and the STP defined GVA as part of their output, although over different time frames. The MRESF (Wales) project does not have an economic analysis.

LCoE — **Levelised Cost of Energy**
LCoE is an economic assessment of the cost of the energy-generating system including all the costs over its defined lifetime including an appropriate rate of return.

ROCs — **Renewables Obligation Certificates**

Green Book — **The Green Book** is HM Treasury guidance for Central Government, setting out a framework for the appraisal and evaluation of all policies, programmes and projects.

SW RDA — **South West Regional Development Agency**

SETS — **Severn Embryonic Technologies Scheme**

Optimism Bias — A factor applied to development costs to account for the optimism of the project appraiser, in the case of the STP, around 30%. Optimism Bias is often used in Green Book appraisals.