

UK Wave and Tidal Key Resource Areas Project

Summary Report

October 2012

Executive Summary

This report describes new findings about the size and distribution of wave and tidal resources around the UK, from a study The Crown Estate has undertaken to improve understanding of the future potential for wave and tidal project development.

We conducted the study using our Marine Resource System (MaRS), with support from Black & Veatch Ltd., input from industry, and in association with the Marine Management Organisation (MMO), Northern Ireland Executive (Department of Enterprise, Trade and Investment), Scottish Government (Marine Scotland), the Welsh Government and RegenSW. While not the first study of the UK's wave and tidal resources, the work improved on previous studies in producing a consolidated view of wave, tidal stream and tidal range resources and making improvements in spatial analysis to determine the geographic distribution of resources.

The results are theoretical estimates of the wave and tidal energy resources available in broad geographic areas around the UK, stated in terms of both energy (TWh/year) and power (GW).

Total theoretical UK resources are estimated to be follows:

- Wave: 69 TWh/year (27 GW);
- Tidal stream: 95 TWh/year (32 GW);
- Tidal range (barrage schemes): 96 TWh/year (45 GW); and
- Tidal range (lagoon schemes): 25 TWh/year (14 GW).

Scottish waters offer the majority of the UK's wave resources, and there are also significant resources off southwest England and Wales. There are similar amounts of tidal stream resources in English, Scottish and Welsh waters, and also tidal stream resources off Northern Ireland. England and Wales share the largest single area of tidal range resources, in the Bristol Channel and Severn Estuary.

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Figure 3, tidal range inset updated to make consistent with associated results in Figure 2 and to correct a presentational error.

1 Introduction

Thank you for downloading this report from The Crown Estate website. This section gives an overview of the UK Wave & Tidal Key Resource Areas study, outlines what the report covers and the study approach, and discusses how the findings in the following section should be interpreted.

1.1 Overview

This report describes new findings about the size and distribution of wave and tidal energy resources in areas of seabed around the UK. These findings come from a study that we, The Crown Estate, have undertaken to improve understanding of the future potential for wave and tidal project development.

We undertook the study in accordance with our remit to enhance the value and act as stewards of the marine estate¹. We are sharing the results in order to help develop a common view across the industry and government about the potential for wave and tidal projects, so that when the industry is ready to take up this potential, we can provide leases and other appropriate development rights.

As well as completing the study, we have recently undertaken an industry engagement exercise to invite views from project developers, other companies in the industry and stakeholders about our future approach to leasing wave and tidal projects². The deadline for responses was 21 September 2012. We are currently reviewing the responses and updating our approach to wave and tidal leasing, and will be making a further announcement in due course.

For more details of The Crown Estate's work in wave and tidal energy, see:

<http://www.thecrownestate.co.uk/energy/wave-and-tidal/>

Marine planning

In the UK, several organisations have statutory responsibility for marine planning, including the Marine Management Organisation (MMO) in England and the governments of Wales, Scotland and Northern Ireland. These organisations are developing marine plans, and at present, this work is at various stages of completion. The Crown Estate recommends that, when considering future wave and tidal projects, developers consider the marine plans under development by these organisations, obtaining information from and liaising with the organisations as appropriate.

¹ See The Crown Estate website for details.

² See <http://www.thecrownestate.co.uk/news-media/news/2012/wave-and-tidal-industry-invited-to-shape-future-leasing/>

1.2 This report and study approach

This report sets out the main results of the study, after briefly explaining how the study was undertaken and giving guidance on how the results should be interpreted. A separate companion report, which gives further details about the study methodology, is currently being prepared and will also be available to download from the Crown Estate website.

The study was conducted by The Crown Estate using our Marine Resource System (MaRS), with support from consultants Black & Veatch Ltd and input from the industry. The work was undertaken in association with a number of government bodies. These included the Marine Management Organisation (MMO), Northern Ireland Executive (Department of Enterprise, Trade and Investment), Scottish Government (Marine Scotland), the Welsh Government and RegenSW. The study findings are informing work by organisations with responsibility for marine spatial planning³ (including the Northern Ireland Department of Environment).

The work also built upon several other recent studies, including a wave and tidal stream energy resource assessment study by the Carbon Trust⁴, which was co-funded by The Crown Estate and involved other organisations including Amec plc. Information on tidal range resources was provided by the Energy Technologies Institute, drawing on its current project to model tidal energy resources on the UK continental shelf⁵.

Our study included the following steps:

- a) Reviewing existing literature on UK wave and tidal resources and resource estimation methodologies;
- b) Identifying seabed areas which may have future potential for project development, by virtue of the existence of appropriate levels of wave or tidal energy resources and water depths⁶;
- c) Estimating the electricity that might possibly be generated in these areas, if generation devices were deployed across them. Analysis methodologies were carefully considered and the resulting estimates necessarily reflect some assumptions about project locations and device spacing; and
- d) Summation of the results for each area by type of resource and region of the UK.

³ The Scottish Government (Marine Scotland) is developing sectoral marine plans and regional locational guidance to facilitate sustainable development of wave and tidal energy in Scottish waters.

⁴ In connection with the Carbon Trust's Marine Energy Accelerator. See for instance the report UK Tidal Current Resource and Economic Assessment, available to download at <http://www.carbontrust.com/resources/reports/technology/accelerating-marine-energy>

⁵ This included a literature review of potential UK barrage options and model results for tidal lagoon projects. For further information on the ETI project, see http://www.eti.co.uk/news/article/modelling_tidal_energy_resources

⁶ Wave: Power density ≥ 20 kW/m, water depth 10-200 m. Tidal stream: Mean spring peak current ≥ 1.5 m/s, water depth ≥ 5 m. Tidal range: Range ≥ 4 m, water depth 15-25 m.

While not the first study of the UK's wave and tidal resources (various data have existed for some years⁷), ways in which this study improved on previous ones include –

- Making improvement in spatial analysis to determine the geographic distribution of resources;
- Producing a consolidated view of wave, tidal stream and tidal range resources; and
- Taking a collaborative approach with marine spatial planning organisations.

Emerging nature of wave and tidal resource assessment

In this study we sought to use the latest available data and techniques. However, scientific understanding of wave and tidal resources is still emerging and at present, it is necessary to make a number of simplifying assumptions, some of which have a significant bearing on the results. For this reason, the results should be regarded as indicative of current understanding rather than conclusive for all time. It is likely that the findings will be refined by further work in future.

1.3 Interpreting the findings

The results of the study are theoretical estimates of the wave and tidal energy resources available in broad geographic areas around the UK. Figures are stated in terms of both annual energy (TWh/year) and power (GW), the latter generally being simple translations of the former using assumed capacity factors⁸.

Conceptually, the results were obtained by imagining generation devices are deployed across large areas of seabed, and estimating how much electricity the devices would generate. It is important to understand that the study did not take into account existing sea uses, sensitivities or environmental factors which are likely to constrain deployments to smaller areas of seabed in practice. This is not because such factors are unimportant, but since at the industry's present stage of development, it is difficult to quantify these constraints⁹. A consequence is that the generating capacity that may ultimately be deployed is likely to be less than the power figures stated. Future work will clarify the resources that are practically available.

It should also be noted that the study did not attempt to estimate the total amount of electricity that could be produced if the various wave and tidal generation technologies were deployed in an optimised manner. The wave, tidal stream, tidal range (barrages) and tidal range (lagoons) figures should be read separately.

⁷ Including data associated with the Atlas of UK Marine Renewable Energy Resources, which was published last decade. See <http://www.renewables-atlas.info/>

⁸ With the exception of the tidal range results from the ETI work, that took a more sophisticated approach.

⁹ The estimation methodologies did make some allowance for environmental effects of energy extraction.

Timing of wave and tidal development in relation to offshore wind

The findings show that, overall, the theoretical size of wave and tidal resources is large, in context of opportunities for utility-scale power generation to meet UK electricity demand. However, it may be some years before wave and tidal projects can be constructed and become fully operational at large-scale. To prepare for this, work is currently underway to further develop and test generation technologies, and prepare to construct and operate demonstration schemes. The Crown Estate is highly supportive of this work.

Previous studies have shown there is also considerable potential for offshore wind to supply the UK. Due to the relative maturity of wind turbine technologies and previous industry experience, offshore wind farms are being constructed and operated at large-scale today. It is essential this work continues apace for 2020 renewable energy and carbon emissions reduction targets to be met by the UK government and devolved administrations. The Crown Estate has a target of 25 GW of offshore wind to be operational or in construction by 2020. Longer term emissions reduction targets and other energy policy objectives (including objectives related to security of supply) point to the need for offshore wind, wave, tidal and other low carbon technologies to operate alongside each other as parts of the electricity supply mix¹⁰.

From The Crown Estate's perspective as landowner, the findings presented here have no effect on existing zone agreements, project agreements for lease or other existing development rights. In particular, existing rights for offshore wind projects in any area take precedence over speculative interest in wave or tidal projects in the same area. The findings do not constitute a plan or programme which sets a framework for future development consents/approvals.

In relation to planning, the National Policy Statement (NPS) for Energy Infrastructure states that "given the level and urgency of need for new energy infrastructure ... the [Planning Inspectorate] should be guided in considering alternative proposals by whether there is a realistic prospect of the alternative delivering the same infrastructure capacity (including energy security and climate change benefits) in the same timescale as the proposed development".

For more details on The Crown Estate's work in offshore wind, see:

<http://www.thecrownestate.co.uk/energy/offshore-wind-energy/>

¹⁰ See for example the Renewable Energy Review published by the Committee on Climate Change in May 2010, <http://www.theccc.org.uk/reports/renewable-energy-review>

2 Findings

This section sets out the main results of the study at UK-wide and regional levels.

2.1 UK-wide summary

Total theoretical UK resources are estimated to be follows:

- Wave: 69 TWh/year (27 GW);
- Tidal stream: 95 TWh/year (32 GW);
- Tidal range (barrage schemes): 96 TWh/year (45 GW); and
- Tidal range (lagoon schemes): 25 TWh/year (14 GW).

Essentially, wave resources are continuously distributed around the northwest of Scotland, southwest Wales and southwest England, whereas tidal resources occur at a set of discrete sites all around the UK. Despite the analysis not considering practical constraints to development, there is likely to be a larger number of potential sites for wave projects than tidal ones.

2.2 Regional breakdown

The resources are distributed around the UK as indicated in Figures 1 and 2. Key findings are that:

- Scottish waters offer the majority of the UK's wave resource, and there are also significant wave resources off southwest England and Wales;
- There are similar amounts of tidal stream resources in English, Scottish and Welsh waters, and also tidal stream resources off Northern Ireland; and
- England and Wales share the largest single area of tidal range resources, in the Bristol Channel and Severn Estuary.

Figure 3 gives further information about the distribution of resources. The arrows and circles indicate the approximate locations and relative sizes of resources in terms of indicative maximum power, symbolically, like a weather map. Note that the symbols do not depict geographic extents of resources (i.e. the area which they cover).

Location	Indicative annual energy [TWh/year]	Indicative maximum power [GW]
England and Wales	23	8.7
Scotland	46	18
Total	69	27

Figure 1: Distribution of wave energy resources across the UK

Source: Black & Veatch, referencing work by Amec.

Notes:

- The error bands for these results are estimated to be $\pm 25\%$.
- Due to the way wave energy in the Atlantic is incident on the British coast south of the island of Ireland, it is not possible to define a definite split between England and Wales. These figures incorporate energy that passes through French and Irish territorial waters.
- Waters off Northern Ireland do not have particularly high wave energy levels due to the lack of exposure to the Atlantic.

Type	Location	Indicative annual energy [TWh/year]	Indicative maximum power [GW]
Tidal stream	England	34	11
	Wales	28	9.5
	Scotland	32	11
	Northern Ireland	1	0.5
	Total	95	32
Tidal range: barrage schemes	England	57	27
	Wales	23	8
	Scotland	16	10
	Total	96	45
Tidal range: lagoon schemes	England	14	8
	Wales	7	3.5
	Scotland	4	2.5
	Total	25	14

Figure 2: Distribution of tidal energy resources across the UK

Sources: Black & Veatch (tidal stream) and Energy Technologies Institute (tidal range).

Notes:

- The error bands for the tidal stream results are estimated to be -30% and +45%, and the tidal range results, $\pm 25\%$.
- The three sets of tidal results have been computed separately, in each case imagining the other technology types are not deployed. Since in practice the resources cannot be used in all ways at once, the sets should not be summed.
- In some places, it may be possible to exploit the tidal resource using more than one technology option, or a combination of technologies could exist. For illustration, the tidal range results reflect technology options considered in this study which would generate the largest amount of electricity in theory. This is not to imply these projects are in any way preferable or more likely to be built than others in practice.
- The Bristol Channel and Severn Estuary is the largest single area of tidal range resources around the UK. Various barrage and lagoon options have been proposed. Consistent with the last point, the results reflect the largest option, the 'Severn Outer' scheme, with 16 GW potential capacity. Similarly, in the River Dee, the figures reflect the 'Dee/Wirral' lagoon option.
- The resources which occur in the Bristol Channel and Severn Estuary, and the River Dee, have been split equally between England and Wales. The resource in the Solway Firth has been split equally between England and Scotland.

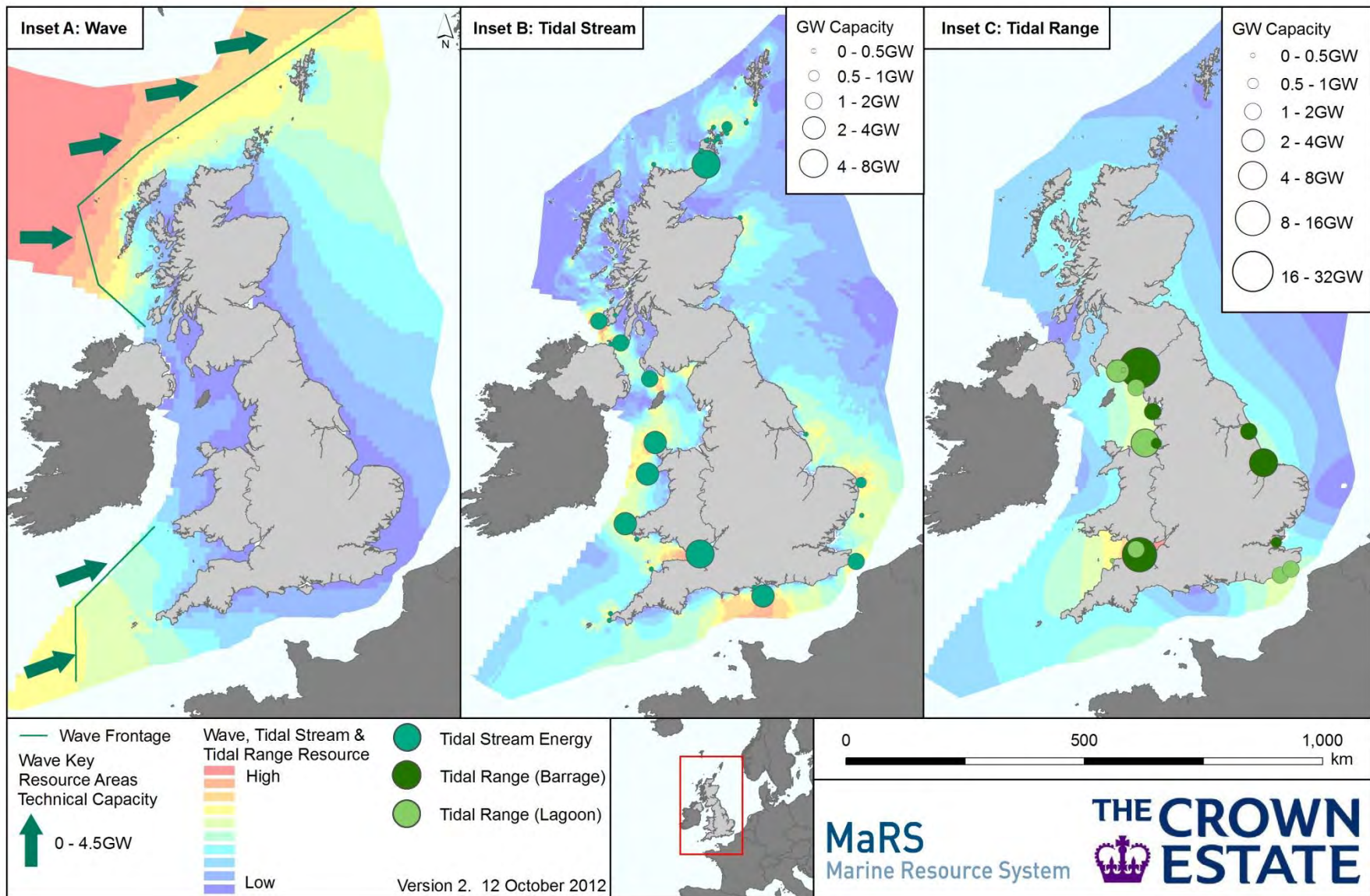


Figure 3: Distribution of wave, tidal stream and tidal range energy resources

Source: The Crown Estate.

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- Regarding the tidal insets, see the notes to Figure 2. As with the results in Figure 2, the tidal range inset shows technology options which would generate the largest amount of electricity in theory.
- The Pentland Firth and Orkney waters area contains 13 discrete areas of tidal stream resource, with a cumulative capacity of up to 6 GW.