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Innovation and cost reduction for marine renewable energy: A learning investment sensitivity analysis

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ABSTRACT

Using learning curves as an analytical tool for technology forecasting involves making assumptions over a range of key uncertainties, often implicitly. In this paper, we present an explicit treatment of the key uncertainties involved in learning rates' analyses of marine energy innovation (wave and tidal stream) — technology fields attracting considerable interest, but whose commercial prospects depends on substantial learning and cost reduction. Taking a simple single factor learning rate model, we describe a range of plausible *learning investments* required so that marine energy technologies become cost-competitive with their 'benchmark' technology: offshore wind. Our analysis highlights the sensitivity of marine energy to three key parameters: the capital cost of first devices, the level of deployment before sustained cost reduction emerges, and the average rate of cost reduction with deployment (learning rate). Figures often quoted within the marine energy sector for the parameters of starting cost, learning rate, and capacity at which sustained cost reduction occurs (*metrics conventionally used for learning rate analysis*) can be seen to represent very attractive scenarios. The intention of this paper is to display that even small changes to input assumptions can have a dramatic effect on the overall investment required for a sector to reach parity with benchmark technologies. In the short term, reaching cost competitiveness with offshore wind is a necessity if marine energy is to reach commercialisation. Additionally, an assessment of the plausible total investment (and inherent uncertainties) in a global wave and tidal deployment scenario will be presented. The paper also considers the implications of these uncertainties for marine energy innovation management. While the benchmark against *offshore* wind will generally be used as a performance indicator, in order to achieve similar and sustained cost reductions to other, more mature, renewable energy technologies (and thus achieve a competitive price for marine technologies, securing their place within the energy mix), the marine energy sector needs a targeted innovation focus to fulfil the desired objectives, and a development pathway very different to offshore wind must be used.

1. Introduction

There is an increasing recognition of the need to accelerate the rate of energy system change, and for accelerated low carbon technological innovation [1–3]. For renewable energy technologies, the 'accelerated innovation' imperative presents both an opportunity and a challenge: An opportunity, because policymakers and investors are prepared to actively engage in innovation support where tangible and credible results can be identified, but also a challenge, because imperatives for accelerated change brings risks of unrealistic short term expectations.

In responding to more urgent imperatives for change, it is important to recognise that different classes of renewable energy technologies are at different levels development, and present different opportunities and risks. For example, onshore wind and solar PV technologies, the most mature 'new' renewable energy technologies, have shown significant cost reductions and market growth in recent years [4,5]. While

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wind and solar PV are likely to be the mainstays of renewables growth over the short and medium term, other, less mature, renewables have longer term potential for commercialisation and deployment. Among these more emergent renewables is marine energy (wave and tidal stream) — a technology field attracting considerable interest internationally [6,7].

The definition "marine energy" in the context of this paper includes only wave and tidal stream energy technologies. Both wave and tidal stream technologies are analogous to offshore wind farms where many different sites can be exploited (at locations where suitable resource exists), and multiple modular devices add up to provide a larger overall farm capacity. Tidal barrage technology is considered to be a more mature technology, with very different financial and environmental requirements to wave and tidal stream, and so is not considered within the scope of this paper.

The UK has substantial wave and tidal energy resources. Studies suggest that wave and tidal energy could meet up to 20% of UK electricity demand [8,9]. Fig. 1 indicates the distribution of wave and tidal energy around UK shores. The commercial development of marine renewable energy technologies in the UK could help meet two very important policy objectives: providing secure low carbon energy, and creating an attractive home and export market for UK industry. However wave and tidal energy is still in the early stages of demonstration and is not yet cost competitive with conventional and more mature renewable technologies. The wave and tidal sector still needs to prove reliable technology operation in addition to achieving substantial cost reductions in order to secure a significant place in the future UK energy portfolio [10,11].

The UK is not alone in having a significant marine energy resource, or in its interest in commercial exploitation. The total European extractable tidal stream resource has been estimated to be in the region of 12.5 GW [13]. Earlier reports suggested an annual electricity generation of 48 TWh was feasible from tidal stream energy [14]. In the USA the wave resource is estimated to be in the region of 2640 TWh/year [15]. The Canadian tidal resource is estimated to be approximately 370 TWh/year [16]. Other countries that have significant marine resources include Portugal, Australia, New Zealand, South East Asia and Chile [14]. Global wave energy resource has been estimated as in excess of 2 TW [17].

In recent times, the UK has missed out on economic development opportunities from renewable energy technology development, with economic benefit going elsewhere [11]. Indeed, until recently, UK energy policy did not prioritise the development and deployment of renewables. While this 'laggard rather than leader' strategy reduces the economic and business risk associated with being a first-mover, it also precludes participation in the major economic and social benefits from successful development and deployment [18]. For example, the UK still has no indigenous large scale wind

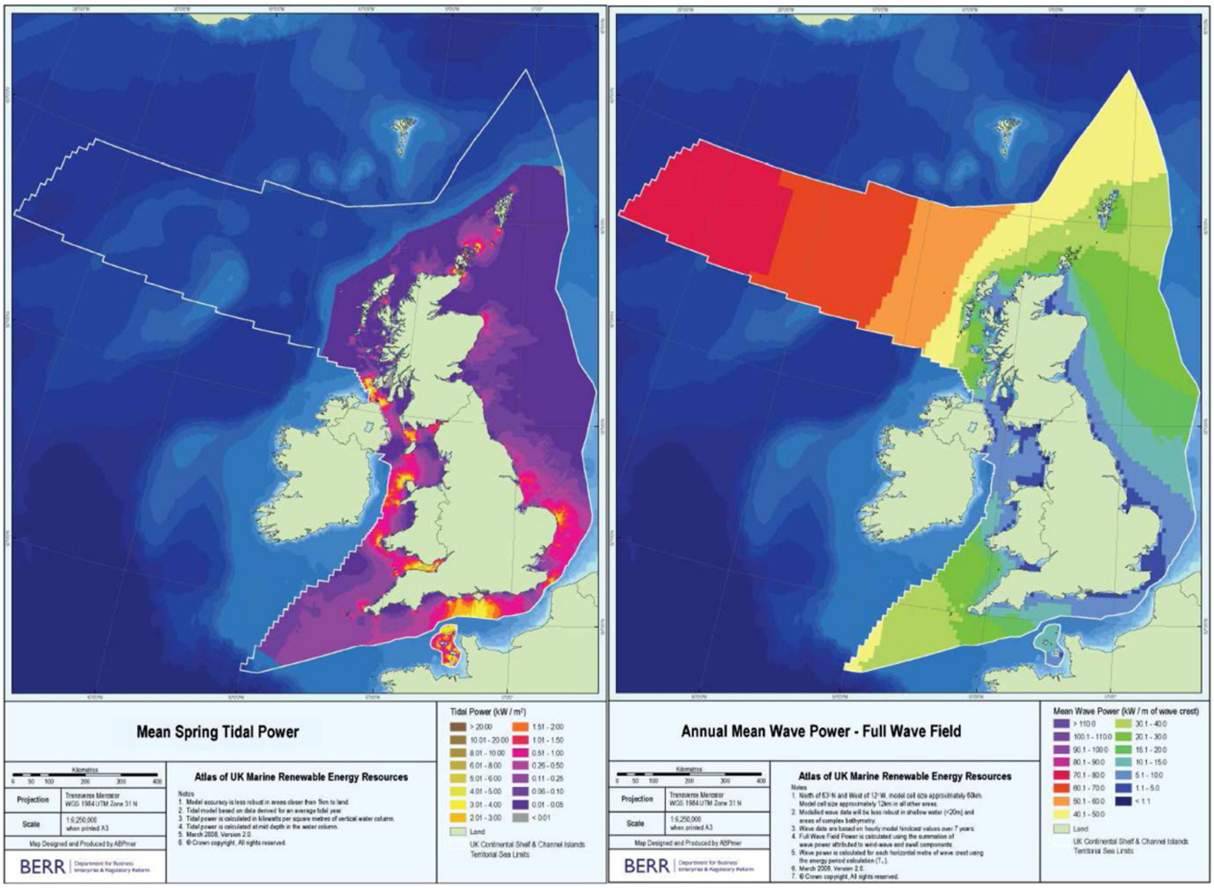

Fig. 1. Average tidal power and mean wave power in the UK (source: [12]).