Energy Conversion and Management 117 (2016) 420–430

Contents lists available at ScienceDirect

Energy Conversion and Management

journal homepage: www.elsevier.com/locate/enconman

A holistic method for selecting tidal stream energy hotspots under technical, economic and functional constraints

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ARTICLE INFO

Article history:
Received 3 December 2015
Accepted 5 March 2016

Keywords:
Tidal stream energy
Levelised cost of energy
Economic map
Functional constraints
Bristol Channel

ABSTRACT

Although a number of prospective locations for tidal stream farms have been identified, the development of a unified approach for selecting the optimum site in a region remains a current research topic. The objective of this work is to develop and apply a methodology for determining the most suitable sites for tidal stream farms, i.e. sites whose characteristics maximise power performance, minimise cost and avoid conflicts with competing uses of the marine space. Illustrated through a case study in the Bristol Channel, the method uses a validated hydrodynamics model to identify highly energetic areas and a geospatial Matlab-based program (designed *ad hoc*) to estimate the energy output that a tidal farm at the site with a given technology would have. This output is then used to obtain the spatial distribution of the levelised cost of energy and, on this basis, to preselect certain areas. Subsequently, potential conflicts with other functions of the marine space (e.g. fishing, shipping) are considered. The result is a selection of areas for tidal stream energy development based on a holistic approach, encompassing the relevant technical, economic and functional aspects. This methodology can lead to a significant improvement in the selection of tidal sites, thereby increasing the possibilities of project acceptance and development.

1. Introduction

The European Commission adopted in 2007 the so-called EU climate and energy package, which aims to provide 20% of the EU's energy consumption through renewable energy sources by 2020 [1]. The need for increasing the share of renewable energies in the total energy production has resulted in a growing interest in marine energies – less developed than other renewables at present but with high potential [2]. Among them, tidal stream energy is one of the most predictable and reliable resources [3]. With a number of full scale prototypes in operation [4] and the plans for commercial tidal arrays well advanced [5], this energy has the potential to make significant contributions towards a low carbon energy mix and a green energy economy in a number of areas worldwide, including straits between islands [6], sites in the nearby of headlands [7], or enclosed bodies of water, like estuaries [8]. A case in point is the Bristol Channel – of national strategic significance as the single largest resource area for tidal energy in the UK [9].

The tidal stream resource in the Bristol Channel has been the subject of previous assessments[1], in which areas with a peak flow velocity in excess of 2.5 m s^{-1} were identified [10]. Predictions about the extraction of this energy suggested that a capacity of 0.6 GW could be installed on the English side of the Outer/Inner Bristol Channel by 2030 [11]. In addition, a further capacity of 0.36 GW would be available around Hartland Point, Lundy and Lands End [12]. The Welsh part, in both in the inner channel and Pembrokeshire, also has a sizeable potential [13], conservatively estimated at up to 0.14 GW of installed capacity [12]. 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 [12].

Notwithstanding, the previous results might exceed the actual potential. Indeed, the theoretical resource can be fundamentally altered by technological [14], economic [15] and functional constraints – aspects of great relevance that have not been jointly considered so far. Being a young industry, the accurate prediction of the tidal stream energy resource, subject to all the aforementioned constraints, is nevertheless fundamental to attracting investors (both from the public and private sector), to boosting the development of this renewable energy through accurate policies [16], and to attaining, as a result, grid parity with conventional sources of energy [17]. The challenge for Government and industry

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[1] References of studies on tidal barrage schemes were not included, but can be found in e.g. [54,55].

http://dx.doi.org/10.1016/j.enconman.2016.03.012
0196-8904/

is to find ways to harness this energy at an acceptable cost, which maximises the real economic value generated [18] while balancing the impact on other marine users and economic interests [19].

The objective of the present work is to develop a new methodology for selecting tidal stream hotspots and to apply it to a case study, in order to thus show how the potential for tidal energy development can be altered by several constraints – technological, economic and functional. The case study is the Bristol Channel. First, the most energetic areas (with mean spring velocities above 1.5 m s^{-1}) are identified by means of a hydrodynamics model, calibrated and validated with field data.

Second, the energy that can be harnessed in these areas is computed by means of a geospatial Matlab-based program designed *ad hoc*, which allows for taking into account the power curve of a specific tidal turbine and in particular, the cut-in and cut-off velocities – the SeaGen turbine is chosen for the case study, but the method can be applied to any turbine [20]. Third, the spatial distribution of the levelised cost of energy (LCOE) is calculated, and areas with LCOE values below £0.25 per kW h – the minimum cost to provide adequate returns for investors over a 20-year period and to maintain momentum in the tidal stream energy sector [21] – are selected as potential tidal sites. The relationship between the LCOE and spatial variables is also investigated, and it is found that water depth and distance to shore are two of the main cost drivers in offshore projects. Finally, restrictions due to overlap with other marine uses, such as fishing or shipping are considered. As a result, potential, conflict-free areas for economically viable tidal stream energy exploitation are identified.

The method, which can be applied not only in the Bristol Channel but elsewhere, is a new decision-making tool at the disposal of policy-makers and investors, which can contribute to reducing the economic uncertainties of future tidal stream energy projects, and therefore to the development of marine renewables.

2. Material and methods

The methodology herein developed lies in the production of a set of combined results, namely resource assessment, technical potential, spatial distribution of the cost and a freely combinable set of excluding uses. This combination allows for the formulation of scenarios of technological and cost development interlinked with functional constraints that come with tidal stream energy development at a large scale. The methodology has been applied with the data and procedure described below.

2.1. Data

The study area is the Bristol Channel (UK), extending from the mouth of the Severn to the Celtic Sea, with the open ocean boundary between St Govan's Head and Trevose Head (Fig. 1). The assessment of the tidal stream resource was based on results from a

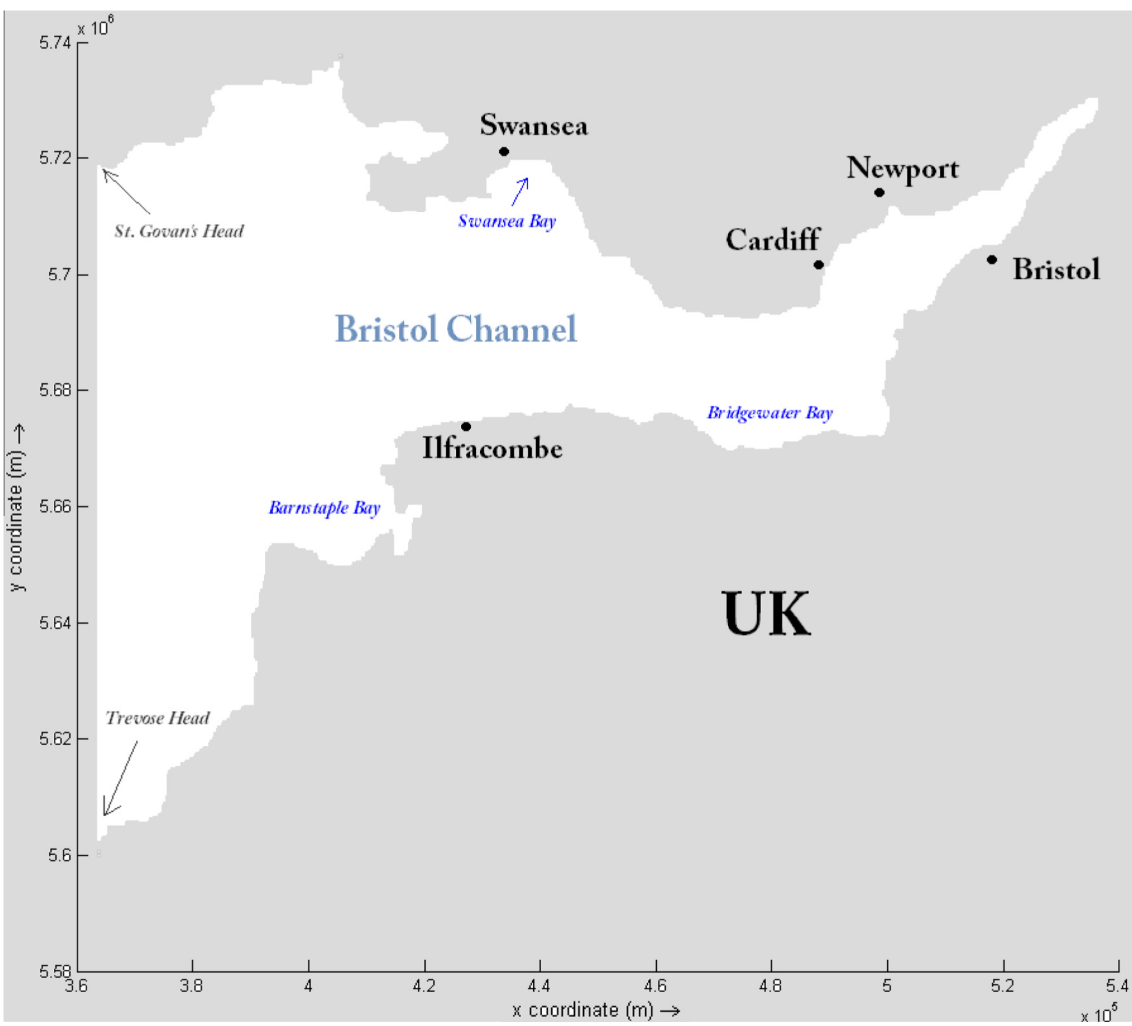

Fig. 1. The study area (Bristol Channel).