Marine Policy 43 (2014) 122–131

Contents lists available at ScienceDirect

Marine Policy

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

# The economic impacts of marine energy developments: A case study from Scotland

G.J. Allan [a,*], P. Lecca [a], P.G. McGregor [b], J.K. Swales [a]

[a] Fraser of Allander Institute, Department of Economics, University of Strathclyde, 130 Rottenrow, Glasgow G4 0GE, United Kingdom
[b] Department of Economics, University of Strathclyde, 130 Rottenrow, Glasgow G4 0GE, United Kingdom

ARTICLE INFO

*Article history:*
Received 13 December 2012
Received in revised form
4 April 2013
Accepted 7 May 2013
Available online 10 June 2013

*Keywords:*
Marine energy
Regional economic impact modelling

ABSTRACT

Delivering the ambitious renewable energy targets set by the Scottish Government will require significant expenditures. Plans have been set out to develop 1.6 GW of marine (wave and tidal) energy capacity between 2010 and 2020 in the Pentland Firth and Orkney Waters area (off the north coast of Scotland) with construction costs estimated at £6 billion. This paper uses multi-sectoral economic models to explore the impact that these (temporary) expenditures could have on the Scottish economy. It is shown that the standard Input–Output (IO) modelling approach significantly overstates the employment and value added impacts compared to Computable General Equilibrium (CGE) methods—in which short-run scarcity of factors of production are explicitly modelled. CGE results (under myopic and forward-looking model specifications) produce smaller impacts during the timespan of expenditures but, unlike IO methods, identify non-trivial "legacy effects" after the expenditures cease.


## 1. Introduction

Over recent years, governments have used energy policy to promote renewable electricity generation technologies. While onshore wind has typically provided the largest growth in renewables capacity over the last decade, in recent years governments have specifically encouraged other technologies. Among these, marine technologies are now considered to be approaching commercial status. In addition to environmental and energy security concerns, energy policy has often emphasised the (positive) economic development impacts that could occur from renewable energy, including marine technologies (see [1,2]).

This paper seeks to model the potential economic impact from marine energy developments. Specifically, it explores the economic impacts of projected expenditures on constructing and installing 1.6 GW of marine energy devices in the Pentland Firth and Orkney Waters (PFOW) area—off the north coast of Scotland—between 2010 and 2020.[1] Expenditure figures come from a study completed by the United Kingdom (UK) Crown Estate [3]. To capture the impact of these expenditures on the economy of Scotland, two multi-sectoral system-wide modelling frameworks are used.[2]

This is an important contribution for a number of reasons. Firstly, Scotland (like many regions across the world) has set ambitious targets for renewable energy [4] and has stressed the economic benefits of renewable energy for the region [5]. By using economic models the mechanisms through which renewables might contribute to economic activity and employment can be better understood.

Secondly, the PFOW area contains significant marine energy resources. The tidal stream resource could accommodate upto 1952 MW of tidal energy capacity by 2020 [6]. The Pentland Firth has been estimated to be able to provide around 30% of the total (20.6 TWh/year) UK practical tidal current resource [7]. The practical wave energy resource for the UK is estimated at 50 TWh/year, which is "focused off the north-West coast of Scotland and off Cornwall"[7].

Thirdly, the Crown Estate—the owner of the seabed out to 12 nautical miles from shore in the UK—has leased exclusive rights to the PFOW seabed to developers seeking to install 1.6 GW of marine energy devices (600 MW wave/1000 MW tidal) between 2011 and 2020. A

* Corresponding author. Tel.: +44 141 548 3838.
*E-mail address:* grant.j.allan@strath.ac.uk (G.J. Allan).

[1] The potential for Scottish development of marine capacity leading to exports of technology to other countries is not the specific focus of this paper, although it is a route through which there might be long-term economic impacts to Scotland. We return to this point in Section 2.2.

[2] The estimated marine energy resource in Scotland is significantly greater than that just in the PFOW area, estimated at 14 GW of wave and 7.5 GW of tidal energy [6]. This paper has used the development case study for the PFOW area as financial expenditures have been published for the development of marine capacity in this area. The portion of these expenditures made directly in Scotland will create significant additional demand for Scottish goods, and the impact on the Scottish economy is the purpose of this paper. It is possible that the economic and employment impacts of this development will be significant in coastal regions, close to the site of development although this is not the focus of the study.

0308-597X/$ - see front matter © 2013 Elsevier Ltd. All rights reserved.
http://dx.doi.org/10.1016/j.marpol.2013.05.003

total of nine sites have been selected. Taking all nine projects together, there is a significant investment programme over these ten years with upwards of £6 billion (2011 prices) spent over the next decade. This is an example of a "mega-project", which might be anticipated to will have knock-on effects on the wider regional economy [8].

Finally, economic modelling techniques have been used to evaluate the "whole economy" impact of the expenditures on renewable energy development. These studies require a set of economic accounts for the area in question, and in most cases use Input–Output (IO) methods in which specific assumptions are imposed [9,10]. Economic accounts for Scotland have been produced officially since the 1970s, providing the basis for the IO and CGE modelling in this paper. A more sophisticated modelling approach, Computable General Equilibrium (CGE) modelling typically extends the IO approach.[3] It includes more details on non-production activities and income flows as well as detailed behavioural specifications including (unlike IO) modelling of the availability of factors of production. In CGE models, the impacts of *temporary* demand shocks are likely to be quite different depending on whether agents' behaviour is forward-looking or myopic. Under myopic behaviour, firms and households are assumed to make production and consumption decisions based on current observed values of variables, including prices, wages and profitability of investments. With forward-looking behaviours, agents will base such decisions on maximising their utility over the whole period covered by the simulation. It has previously been shown that the long-run impact of permanent demand shocks under forward-looking and myopic behaviours are identical [11].

Having all four aspects together: the policy support for marine renewables as an economic development policy, significant marine energy resources, highly developed plans for marine energy capacity (and expenditures), and a set of economic accounts for the area, this paper is intended to provide a case study on the economic impacts of marine energy development.

IO and CGE modelling approaches to determining the scale of regional economic impacts from marine energy expenditures have been compared before [12]. This paper extends the literature in two ways. Firstly, the expenditure figures used are for actual, rather than hypothetical, marine projects. Secondly, IO results are compared to two sets of CGE results: (1) assuming myopic behaviour on the part of households and firms [8,12]and, (2) a version of the same model with an explicitly forward-looking specification [11].

The paper proceeds as follows: Section 2 reviews recent developments in marine renewables policy in Scotland and how the economic impacts of renewables have been estimated in Scotland to date. Section 3 describes the Pentland Firth and Orkney Waters (PFOW) area, the leasing process undertaken by The Crown Estate and the plans for marine energy developments in the PFOW area between 2010 and 2020. Section 3 also summarises the necessary process of estimating the temporary demand disturbances, and mapping these to specific sectors of the Scottish economy. Section 4 describes the modelling approaches used and the modelling strategy. Section 5 explains and compares the results of each modelling approach. Section 6 offers some conclusions.

## 2. Wave and tidal stream technologies in Scotland

### 2.1. Policy support

The Scottish Government has stated that renewable energy technologies, in particular offshore wind, wave and tidal energy, have the potential to confer significant economic benefits to Scotland. This is stated in both the economic strategy [5] and the energy strategy of the Scottish Government [13]. The Scottish Minister for Energy stated that the Scottish renewable electricity target, "is necessary to reindustrialise Scotland through 21st century technologies and seize the opportunities to create tens of thousands of new jobs and secure billions of pounds of investment in our economy" ([14], p. 2). This document notes that the "benefits are not only in terms of energy generation and future security of supply, but can underpin our economic recovery over the next decade and beyond" ([14], p. 8). The Offshore Wind Industry Group (consisting of Scottish marine industry representatives) reported that, "the large scale development of offshore wind represents the biggest opportunity for sustainable economic growth in Scotland for a generation" [15]. The First Minister of Scotland, Alex Salmond, has stated that "Scotland is becoming the Silicon Valley of marine energy worldwide" [16].

Since devolution in 1999, the Scottish Government has increased early-stage support for marine technologies as well as restructured the renewable support mechanisms [17]. Between 2006 and 2008, the Scottish Ministers' Wave and Tidal Energy Support Scheme devoted funding of £13 million to the installation and deployment of pre-commercial marine energy devices at the EMEC centre. The Scottish Government fund the Marine Renewables Commercialisation Fund, which aims to provide capital support of £18 million to upto two marine energy array projects in Scottish waters [18]. Further, the Saltire Prize (announced in 2008) introduced a £10 million bonus to be won by a marine energy facility operating in Scottish waters before 2017 [19].

The mechanism through which renewable electricity generation is encouraged in Scotland (and the UK) is the Renewable Obligation (RO). Recently the RO mechanism has introduced "banding" of certificates, through which technologies receive differing amount of ROCs for MWh of electricity produced. Banding was designed to encourage early-stage (typically more expensive) technologies. In the latest announcements, the UK government has maintained support for tidal stream and wave developments at double the support given to onshore wind (2 ROCs per MWh compared to 1 ROC per MWh), while limiting the number of ROCs earned per MWh at 5 for facilities smaller than 30 MW [20]. Currently wave and tidal energy developments in Scotland receive a higher level of support than in the rest of the UK, receiving 3 and 5 ROCs per MWh respectively and the most recent Scottish Government proposals are to increase this both to 5 ROCs per MWh from April 2013 [21].

### 2.2. Modelling the possible economic impacts of renewables

There are several routes through which development of marine energy technology could lead to economic benefits for the host region. Firstly, electricity is a vital input to all modern economies. Renewable technologies do not use fossil fuels to produce electricity and so are not exposed to either fuel price volatility or anticipated secular price increases. An economy with renewable technologies in its generation mix might therefore have electricity prices which are less volatile than one reliant upon fossil technologies.[4] In addition, innovation in high-technology energy applications could have important impacts on other areas of the economy, for example permitting the formation of clustering of firms working in different technological fields. Secondly, through first-mover advantages and the skills of academics and engineers, firms with

[3] Input–Output can be considered a special case of Computable General Equilibrium modelling, while in the case of demand-side shocks (such as examined in this paper) CGE models are explicitly able to capture induced consequences of changes to the supply-side of the economy.

[4] It is also likely that over the longer term ceteris paribus the level of energy prices will be lower the lower the share of fossil fuelled generation in the electricity mix.