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Concurrent and legacy economic and environmental impacts from establishing a marine energy sector in Scotland

Grant J. Allan [a,*], Ian Bryden [b], Peter G. McGregor [a,c], Tim Stallard [d], J. Kim Swales [a,c], Karen Turner [a], Robin Wallace [b]

[a] Fraser of Allander Institute, Department of Economics, University of Strathclyde, 130 Rottenrow, Glasgow G4 0GE, UK
[b] Institute for Energy Systems, School of Engineering and Electronics, University of Edinburgh, The King's Buildings, Mayfield Road, Edinburgh EH9 3JL, UK
[c] Centre for Public Policy for the Regions, Universities of Glasgow and Strathclyde, UK
[d] Joule Centre, School of Mechanical, Aerospace and Civil Engineering, Pariser Building, University of Manchester, Manchester M60 1QD, UK

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ABSTRACT

We examine the economic and environmental impact that the installation of 3 GW of marine energy capacity would have on Scotland. This is not a forecast, but a projection of the likely effects of meeting the Scottish Government's targets for renewable energy through the development of a marine energy sector. Energy, with a particular focus on renewables, is seen by the Scottish Government as a "key sector", with high growth potential and the capacity to boost productivity (Scottish Government, 2007a. The Government Economic Strategy. The Scottish Government, Edinburgh). The key nature of this sector has been identified through targets being set for renewable energy to achieve environmental and economic benefits. Using a regional computable general equilibrium (CGE) model of Scotland we show that the development of a marine energy sector can have substantial and beneficial impacts on GDP, employment and the environment over the lifetime of the devices, given the encouragement of strong indigenous inter-industry linkages. Furthermore, there are also substantial "legacy" effects that persist well beyond the design life of the devices.

1. Introduction and policy background

The recent UK Energy Review (Department for Trade and Industry, 2006, p. 15) concluded that:

> Over the next two decades, it is likely that we will need around 25 GW of new electricity generation capacity, as power stations—principally, coal and nuclear plants—reach the end of their lives and close. This will require substantial new investment and is equivalent to around one third of today's generation capacity.

For both environmental and energy security reasons, there is an increased recognition that existing fossil fuel technology cannot continue to be as heavily used as in the past and there is a corresponding movement towards generation technologies that operate with low, or zero, carbon emissions. These include renewable technologies, such as hydro, on- and off-shore wind, and marine (wave and tidal) devices. The use of wind technology to generate electricity has grown rapidly across the UK in the last decade. However, other renewable technologies, such as marine, have also received both financial support and political interest and the first generation of economically viable devices is now close to market.[1]

In Scotland, the situation is similar to that in the UK in that all the existing major electricity generation facilities in Scotland could be closed within 25 years (Allan et al., 2007a; Royal Society of Edinburgh, 2006). The coal-, nuclear- and gas-powered electricity generation facilities in Scotland in 2000 had a total direct employment of 1797 (full-time equivalent (FTE) jobs) and were indirectly supporting 10,035 FTE jobs in Scotland (Allan et al., 2007a). Further, at present, more electricity is produced in Scotland than consumed domestically, with roughly twenty per cent of the electricity generated in the region exported to the rest of the UK.

While energy supply decisions are strictly a matter reserved for the UK Parliament, the Scottish Government has responsibility for

* Corresponding author. Tel.: +44 141 548 3838; fax: +44 141 548 5776.
E-mail address: grant.j.allan@strath.ac.uk (G.J. Allan).

[1] Ocean Power Delivery (OPD)'s device—the Pelamis—has received an order from a Portuguese consortium to build the world's first commercial facility to generate electricity from ocean waves, which is due to be installed in late-2007. As the Managing Director of OPD, Richard Yemm said, "The Portuguese government has put in place a feeder market that pays a premium price for electricity generated from waves compared with more mature technologies such as wind power." (OPD, 2006)

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energy efficiency and encouraging renewable energy development, and has recently (November 2007) announced an increase in its already ambitious targets for renewable generation. These targets are to provide 31% of the electricity generated in Scotland by 2011 and 50% by 2020 from renewable sources (Scottish Government, 2007a, b).[2] Expressed in absolute terms, the Scottish Executive (2005a) had accepted the recommendations of the Forum for Renewable Energy Development in Scotland' (2005) that the previous 2020 target of 40% (Scottish Executive, 2003) was consistent with an installed capacity of renewables of 6 GW. Scottish Renewables (2007) estimate that the revised 50% target would be consistent with an installed capacity of 8 GW. This requires substantial growth in renewables capacity, given that renewables capacity was 2.8 GW and presents opportunities for job creation. The Scottish Government recently announced that it views energy, and especially renewables, as a "key sector" for economic development, offering the potential for high growth and productivity increases (Scottish Government, 2007a). The previous Scottish Executive's Marine Energy Group concluded that by 2020, a marine energy sector in Scotland providing 10% of Scotland's electricity production would be responsible for the creation of 7000 direct jobs, a considerable underestimate of potential total employment effects given the results we report below (Scottish Executive, 2004). The Scottish Executive's "Green Jobs" strategy identified renewable energy as one key area where Scotland could aim to be at the centre of the development and manufacture of new renewable technologies, particularly marine (Scottish Executive, 2005b, p. 8).

The additional 5.2 GW capacity required to meet the Scottish Government new renewables target (given current capacity) is intended to come from a range of sources, and no specific targets have been set for the maximum contribution made by each type of renewable technology. However, the Scottish Government has launched a consultation to determine how the Renewable Obligation Certificates (Scotland) could be amended to support generation of electricity from marine (i.e. wave and tidal) resources (Scottish Executive, 2006).[3] Boehme et al. (2006, p. 52) show that after taking into account resource availability, economic viability and technological feasibility, by 2020 wave power could contribute an installed renewables capacity in excess of 3 GW, providing, on average, around 20% of the electricity demand in Scotland. Wave energy devices are currently closer to economic costs of generation, and medium-term scenarios for the portfolio of electricity generation predict wave power playing a role (e.g. Ault et al., 2006). In this paper, the focus is on wave energy devices. Taking the figures of Boehme et al. (2006) as a feasible future for medium-term installed wave capacity, we address the impact on the Scottish economy, and the environmental benefits, due to installation, operation and maintenance of 3 GW of wave energy devices within Scotland.

In Section 2, we motivate the current paper and summarise our broad approach. In Section 3, we outline the investment profile of the wave energy installation and operation expenditures, together with the details of the central case simulation used in the remainder of this paper. In Section 4, we outline the AMOSENVI CGE model of Scotland and in Section 5, we report the "central case" results. In Section 6, we report key findings from extensive sensitivity analysis. Section 7 offers conclusions and outlines the implications of these results for energy policy in Scotland and the UK.

2. Motivation

We begin with a general discussion of the motivation for our work and then briefly outline the main features of the approach.

2.1. General motivation

Conventional economic analyses of new technologies for the production of electricity tend to focus on their commercial attractiveness as a private investment (e.g. Previsic et al., 2004). This involves assessment of the detailed private costs and benefits (revenues) associated with new investment in such technologies and its commercial viability using conventional discounted cash flow methods (Stallard and McCabe, 2007; Carbon Trust, 2006b; Boud and Thorpe, 2003; Bedard et al., 2005). UKERC has examined the empirical levelised cost estimates in general (Heptonstall, 2007) and Carbon Trust (2006a) report results of comprehensive analyses of this type applied to new marine technologies concluding that the cost of off-shore wave energy converters lies in a range between 22 and 25 p/kWh, although there is uncertainty due to difficulties in estimating device performance and operations and maintenance costs. Costs for tidal stream technologies lie in the range 12–15 p/kWh.[4] Moving to examine future costs from marine energy devices, Carbon Trust consider (2006a) conceptual and practical design improvements, economies of scale and learning at all stages of the development process. They argue that tidal stream devices could become competitive under plausible assumptions regarding learning rates, while for wave energy converters "fast learning or a step change cost reduction is needed to make off-shore wave energy converters cost competitive for reasonable amounts of investment" (Carbon Trust, 2006a, p. 22).

These analyses have been conducted for a range of wave energy devices and locations, allowing for location-specific sea states. These cost figures suggest that wave technologies are not currently competitive with onshore wind or with other traditional electricity-generating sources, and may require additional policy support to create the incentive for private sector investment. Furthermore, there is an awareness that there may be future upward pressures on the costs of providing electricity through renewables as a consequence of the need to transmit electricity from where it is generated, often peripheral sites in the case of marine renewables, to where demand is greatest, namely the major urban centres. The distances involved and the required network capacity may impose both higher connection costs and the expense of possibly major upgrades to the transmission infrastructure. Naturally, the way in which any additional infrastructure is financed may prove vital for the viability of renewables in general, and marine energy sources in particular.[5]

[2] It was announced in early 2007 that the Scottish target for 2010 had been reached 3 years ahead of schedule. The UK has recently (October 2007) announced that it is unlikely to make its target for 20% of electricity to come from renewable sources by 2020.

[3] The recent Scottish Spending Review (November 2007, p. 13) has stated that the Scottish Government will provide financial and legislative support to realise 10 MW of marine energy capacity by 2010. Additional support measures, such as the £8million Wave and Tidal Energy Support Scheme shows the Scottish Government continuing the work of the previous Scottish Executive in supporting marine energy.

[4] By way of comparison, from a survey of the literature on levelised cost estimates Heptonstall (2007) reports that the mean of cost estimates for more established UK electricity generation technologies were as follows: coal = 3.29 p/kWh, gas = 3.12 p/kWh, nuclear 3.22 p/kWh and wind = 3.19 p/kWh.

[5] Ofgem, tasked with promoting competition in the gas and electricity markets in the UK, have proposed a transmission charging regime based on encouraging generation near to sources of demand. This means greater transmission use of system charges for generators connected to the UK grid in Scotland, and particularly northern Scotland. Speaking about the impact that this would have on renewable energy development in Scotland, Jim Mather, the Scottish Government's Energy Minister, in a statement to the Scottish Parliament