Renewable Energy 35 (2010) 443–455

Contents lists available at ScienceDirect

Renewable Energy

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

Case study feasibility analysis of the Pelamis wave energy convertor in Ireland, Portugal and North America

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ARTICLE INFO

Article history:
Received 16 February 2009
Accepted 1 July 2009
Available online 5 August 2009

Keywords:
Pelamis wave energy converter
H_s and T_z
Annual energy output
Cost of electricity
Feed-in tariff
Learning/production curve

ABSTRACT

The performance and economic viability of the Pelamis wave energy converter (WEC) has been investigated over a 20 year project time period using 2007 wave energy data from various global locations: Ireland, Portugal, USA and Canada. Previous reports assessing the Pelamis quote a disparate range of financial returns for the Pelamis, necessitating a comparative standardised assessment of wave energy economic indicators. An Excel model (NAVITAS) was created for this purpose which estimated the annual energy output of Pelamis for each location using wave height (H_s) and period (T_z) data, and produced financial results dependant on various input parameters. The economic indicators used for the analysis were cost of electricity (COE), net present value (NPV) and internal rate of return (IRR), modelled at a tariff rate of €0.20/kWh). Analysis of the wave energy data showed that the highest annual energy output (AEO) and capacity for the Pelamis was the Irish site, as expected. Portugal returned lower AOE similar to the lesser North American sites. Monthly energy output was highest in the winter, and was particularly evident in the Irish location. Moreover, the difference between the winter wave energy input and the Pelamis energy output for Ireland was also significant as indicated by the capture width, suggesting that Pelamis design was not efficiently capturing all the wave energy states present during that period. Modelling of COE for the various case study locations showed large variation in returns, depending on the number of WEC modelled and the initial cost input and learning curve. COE was highest when modelling single WEC in comparison to multiples, as well as when using 2004 initial costs in comparison to 2008 costs (at which time price of materials peaked). Ireland returned the lowest COE of €0.05/kWh modelling over 100 WEC at 2004 cost of materials, and €0.15/kWh at 2008 prices. Although favourable COE were recorded from some of the modelled scenarios, results indicated that NPV and IRR were not encouraging when using a €0.20/kWh tariff. It is recommended that a tariff rate of €0.30/kWh be considered for Ireland, and higher rates for other locations. In conclusion, Ireland had the most abundant wave energy output from the Pelamis. COE returns for Ireland were competitive for large number of WEC, even at peak costs, but it is recommended that careful analysis of NPV and IRR should be carried out for full economic assessment. Finally, a standardised method of COE reporting is recommended, using fixed WEC number or MW size, as well as standardised learning/production curves and initial costs, to facilitate confidence in investment decisions based on COE.

1. Introduction

This article is an economic feasibility analysis study of the Pelamis device, using wave energy data collected from 6 case study locations in Europe and North America. The study stems from the increasing need for alternative energy sources as Europe faces a renewable energy target of 20% target by 2020 [1], and some countries such as Ireland setting even higher targets of 40% for the same time period [2]. Moreover, there is rising demand by both public [3] and state for increased use of renewables in energy supply. A combination of all renewable sources, including wave energy, will be required to meet those targets. Wave energy is still in the nascent stage [4], requiring substantial subsidies and support for research and development to bring the technology to the commercial stage [5]. However, there is a lack of confidence by business and investors that renewable energy is economically feasible for commercial energy supply [6].

The cost of electricity (COE) is the benchmark criterion by which most renewable energy (RE) projects are judged [7]. COE refers to electricity cost where there is zero revenue or tariff from an electricity

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doi:10.1016/j.renene.2009.07.003

Glossary

AOE	Annual energy output
COE	Cost of electricity
CRF	Capital recovery factor
GHG	Greenhouse gases
H_s, T_z	Significant average wave height, mean period or zero crossing
IC	Initial cost
IRR	Internal rate of return
NPV	Net present value
O/M	Operation and maintenance
RC	Replacement cost
RE	Renewable energy
REC/ROC	Renewable energy credits/renewable obligation certificates
FIT/REFIT	Feed-in tariff/renewable energy feed-in tariff
RES	Renewable energy system
T_f	Technology factor
USA EC	USA east coast
USA WC	USA west coast
WEC	Wave energy converter
WEI	Wave energy input

utility company. However, COE can also be interpreted as the electricity tariff rate returning a zero net present value (NPV). This arbitrary method of defining COE is not ideal, and other benchmark financial criterion or indicators such as NPV and internal rate of return (IRR) are preferred to compare project viability [8]. Nevertheless, due to its prevalent use COE will be the major indicator of this report.

There have been many studies which have provided COE figures for wave energy projects. However at present, it is difficult to compare COE results from reports and studies due to the large variation in quoted figures. It is essential that correct COE are forecast so that investors can budget for long-term projects, as well as policy makers who are nominating feed-in tariff rates intending to support and accelerate growth in wave energy industry. COE is directly related to the quantity of energy input to the system, and thus is very dependant on location of the energy source. This paper will present wave energy data collected from various global locations and assess the corresponding COE resultant.

As with all analysis, there are many variables which can impact on the final COE result. This report will conduct sensitivity on the following variables and assess their impact on COE.

2. Impact of the cost of materials and initial cost (IC)

Steel is currently the main material constituent of a WEC, and thus has the largest influence on initial cost (IC). Steel has had major price fluctuations over the past few years (Fig. 1). Recent factors influencing steel prices fluctuation were increasing demand from China for raw materials, which led to a price escalation [9], followed by the credit crunch and global recession in mid 2008, causing steel prices to eventually fall to 2007 prices [10]. The final cost of manufactured steel, typically grade 50 (S355), painted with corrosive protection, can cost anywhere from €5000–7000/ton,[1] and this price had not substantially fallen at the time of writing this paper, although is forecast to do so in 2009. US currency conversion to Euro used in this report was 1.57 (July 2008),[2] which was the

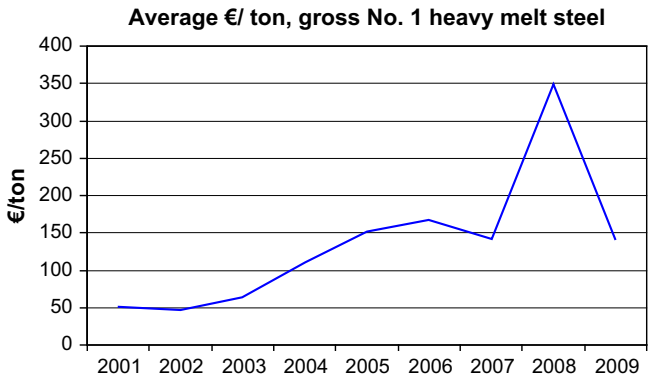

Fig. 1. Historical heavy melt steel price, American metal market, 2001-2007 (www.scrapmetalpricesandauctions.com/iron-steel).

peak recorded rate over a five year period. As a result of using this rate, costs in Euro will make final COE results in this article appear lower that they would at a lower exchange rate. Various initial costs (IC) will be modelled and their impact on COE assessed.

3. Size/number of the WEC farm and dependence on cable size

Large scale purchasing of WEC coupled with learning/production curves (defined later) has a moderating influence on IC. Additionally, a collection of WEC can be serviced by one cable, which has the required kV rating and capacity to cater for the load. Thus savings will accrue if the optimal number of WEC is matched to whatever cable size is chosen.

4. Feed-in tariffs

There is much debate at present concerning appropriate price support schemes or power purchase arrangement (PPA) to stimulate growth in the wave energy sector.

Fixed tariff or feed-in tariff (FIT) rates are gaining consent as the most successful method to stimulate RE development [11,12]. The main proponents of the scheme are Germany and Spain [13], and has resulted in a RE boom in those respective states, almost exclusively in on-shore large wind and PV projects. The Irish and Portuguese governments are the only two states that have promised an FIT or renewable energy feed-in tariff (REFIT) for electricity produced by wave energy. Ireland is promising €0.22/kWh,[3] and Portugal a range of tariffs ranging from €0.07–26/kWh [14] (Table 1). Spain, France, Denmark and Germany have also proposed wave energy FITs, but they are modest and not been implemented at the time of this paper.

4.1. Wave energy device – Pelamis

The WEC chosen for analysis in this report was the Pelamis, as it is the only WEC to date that has a published and reliable power performance matrix (Table 6). The Pelamis wave energy converter is developed and manufactured by Pelamis Wave Power (PWP) (formerly known as Ocean Power Delivery Ltd), an Edinburgh-based company originating from the Wave Power Group at the University of Edinburgh in 1998 [15,16]. The Pelamis is a semi-submerged snake-like device consisting of articulated cylindrical

[1] Personal communication Paul Collins, Malacky Walsh Engineers, Cork.
[2] http://finance.yahoo.com/q/bc?s=EURUSD=X&t=5y&l=on&z=m&q=l&c=
[3] http://www.ndp.ie/viewdoc.asp?Docid=2034&mn=newx&nID=&UserLang=EN&CatID=15&StartDate=1+January+2008