Feasibility Study and Cost-Benefit Analysis of Tidal Energy: A Case Study for Ireland

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Abstract

Ireland set out to produce 33% of its electricity demand from renewable sources by 2020 and reduce emissions to the level of 1990 in accordance with the Kyoto agreement. These targets require investments in a diverse range of power sources. This paper investigates if Tidal Stream Generators (TSG) can become an economically viable system. Initially a levelised cost was established for tidal and other energies at a baseline year of 2010. Due to the early stage of development of tidal energy, it is difficult to accurately predict its future capital investment and operational cost. For this reason future costs were estimated for all energy forms and a present worth was established. From this a levelised cost over the project lifetime was calculated. At this point it was found that Tidal Energy was a competitive form of energy. The feasibility of tidal energy was assessed using both constant and varying Renewable Feed In Tariffs (REFIT). Using 2010 values a profit of €1.671Billion could be achieved with a maximum investment of €135million. However if REFIT changed to 32€/MWh after the contractual 15 years, a profit of around €200million can be achieved with a maximum investment of around €213million.

Keywords: Cost Benefit, Feasibility, Tidal Energy

1. Introduction

1.1 Background

Ireland, as a nation, is almost totally dependent on fossil fuels, with 96% of its energy coming from fossil fuels [1]. On the 31st May 2002 Ireland ratified the Kyoto Protocol to limit its greenhouse gas emissions to 13% above 1990 levels by the first commitment period 2008-2012 [2].

The Government also released a White Paper, setting out goals to be reached by Ireland in order to reduce their contribution to greenhouse gases. This report pledged 33% renewable by 2020 and 15% by 2010 [3]. However due to the recession these goals have been reduced to the required values of the original agreement.

As oil levels around the world drop and fossil fuels in general, become scarcer and a greater demand placed on them, the price of buying fossil fuels will undoubtedly become more expensive. This could lead to major political problems and as a result has led to a change in global policies. These policies require Ireland to increase its dependence on renewable energies. Due to its small market size and peripheral location within Europe Ireland will not have the luxury to continue to rely on fossil fuels. This problem can be seen in Ireland's currently spending of around €7 billion per annum [1] on importing its energy needs. If Ireland does not invest in renewable energy supplies, then in the long term the country will be open to being economically dominated by energy supplying countries. This will leave Ireland at risk of being unable to compete with larger European countries with the ability to pay higher prices for fossils fuels.

1.2 Viable Energy Resource from Tidal Current

Viable tidal energy as explained by O'Rourke et al. [4] is the accessible tidal current energy resource constrained by limitations of costs, scale, grid connection and resource distribution from tidal current energy farms. In order to get a value for this it was necessary to use an economic model developed by Marine Current Turbines to determine the viability, and establish costs for each to the 11 sites identified in the study. This model was used to specify:

- The size and quantity of turbines for installation at each of the sites and then output capital costs for that specific technology,

- Only sites with a velocity greater than 2 m/s are considered economical,
- A turbine spacing of 65 meters.

Using this model an energy resource of 0.915 TWh/yr from TSGs was calculated.

1.3 Firm Power

Tidal power has a distinct advantage over other renewable energies as it is a predictable energy source over an extended period of time. With TSGs energy will be produced in four phases per day, each time the tide goes in and out. Unlike wind and solar power generation, the tidal power potential is relatively insensitive to rapidly fluctuating external influences such as changes in wind conditions and cloud cover. As a result of the predictability of tidal currents it is possible to implement a system of power management called *Firm Power*. Firm power is when TSGs are located to make use of the sequential nature of tides around the coast to produce a phasing so that the aggregate power output will be able to match a substantial portion of the base load demand [5]. In other words if TSGs are properly located it is possible to provide network stability similar to that achieved by fossil fuel plants.

1.4 Technologies Examined in This Study

SeaGen 'S' is a further development of the 1.2MW SeaGen plant in Strangford Lough, Northern Ireland. This system will see rotor diameters increase from 16 to 20 meters, giving an installed capacity of up to 2.12MW.

Figure 1: Marine Current Turbines SeaGen 'S'

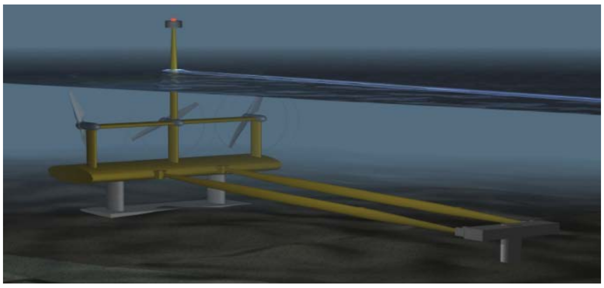

Figure 2: Marine Current Turbines SeaGen 'U'

SeaGen 'U' will be a new design, no longer using the mono-pile design of previous Marine Current Turbines (MCT) systems, instead making use of an anchored system capable of floating and being submerged. This capability results in a system that is accessible to smaller craft, making maintenance simpler and more cost effective. The main advantage of the SeaGen U design will be its ability to house 3 rotors of 20 meter diameter producing and a capacity of 3.18MW.

2. Analysis

2.1 Setup

In order to compare all technologies it was first necessary to establish a *present worth* (PW). PW can be expressed as "transforming all payments and receipts into a net equivalent monetary amount at time zero" [6]. As each power plant examined had a different design life it was necessary to apply *life cycle analysis* (LCA). LCA can be defined as "Projects with different economic lives, only one cycle for each option needs be considered, since annual worth will remain the same regardless of the number of cycles analysed" [6].

The use of PW alone does not take into account the installed capacities of the power plants. Not taking this into account gives and unequal weighting to technologies which could lead to an erroneous selection of a power plant type.

In order to give the power plants an equal weighting it was necessary to produce a levelised cost. This was achieved by converting all costs incurred by each technology into an equivalent cost of €/MWh. The main parameters considered are:

- Pre-development cost,
- Construction cost,
- Operations and maintenance costs,
- Fuel costs, transport costs,
- CO_2 emission tax.

2.2 Baseline Analysis

Time zero was initially taken as the baseline year of 2010 for all parameters considered. Results from the baseline would not produce an accurate representation of Tidal Steam Generators (TSGs), as all technologies examined apart from TSGs where in an advanced stage of development.

2.3 Sensitivity Analysis

A sensitivity analysis was carried out to give a more accurate and realistic costing. Fossil fuel power plants incur huge costs from fuel, at the baseline year it was shown that fossil fuel plants looked at in this report had fuel cost of up to 5.55 times that of the capital costs over the lifetime of the project. Thus any increase in future fuel costs would have large effect on present worth. For instance, in 2010 the Irish government announced in the budget a levy of 15€/tonne of CO_2 released into the atmosphere, this levy is set to increase to 25€/tonne of CO_2 released in 2012 and further to 30€/tonne in 2013 [7].

For this reason it was necessary to estimate the:

- Expected changes in fossil fuel prices,
- Change in cost of diesel fuel for transport,
- Effects of increasing CO_2 tax on fossil fuel plants.

As the TSGs are developed the capital costs, operational and maintenance costs will be reduced over the lifetime of the project. These reductions in costs are known as of *Rate of Learning* (Fig. 3).

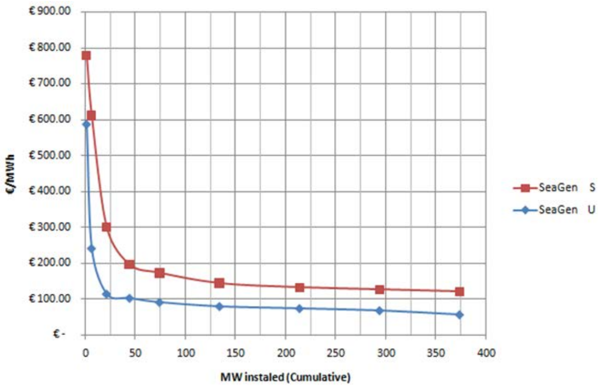

Figure 3: Rate of Learning

Since SeaGen is a first generation technology, the cost of development, construction and installation will be excessive due to high levels of uncertainty. As more TSGs are put in place the level of uncertainly will be reduced thus reducing costs. This reduction in uncertainty will be due to the development of better practices and the development of the technology performing better in a variety of harsh conditions experienced in the marine environment.

Rate of Learning for SeaGen S and U was taken from Marine Current Turbines (MCT) [8] on the devices and through interpolation it was possible to obtain the graph in Fig. 3 showing the price of the device against the expected installed tidal capacities for Ireland given by Sustainable Energy Authority of Ireland [9]

2.4 Payback Period

If the sensitivity analysis shows the TSGs to be a viable option, the next step is to establish their financial feasibility. This is to be accomplished using a *payback* method. For tidal energy to be an attractive option it needs to be shown that a good return for investment can be achieved.

This section estimated how much would need to be invested, how much will be generated by the end of the project and how long before project begins to make a profit. In order to work out the payback period it was assumed that the capital costs for the project where borrowed at an interest rate of 5.49%, the Average value for 2010 [10].

In order to establish the cost and income per annum, two steps were taken:

1. Establishing the amount of installed MW and energy output for each year that the TSGs are working. It was assumed that the TSGs will be installed over 20 years with a 20 year design life, meaning the project will run from 2010 to 2050.
2. After step 1 it is possible to estimate the cost of Operation and Maintenance (O&M) and the profit from REFIT's (Table 1) each year. The value for REFIT is given in €/MWh and the O&M given in €/MW thus in order to get a value in euro they are multiplied by the MWh and MW for each year respectively.

REFIT		
Type	Rated power	Fixed Rate (€/KWh)
Hydro	Fixed all installed power ratings	0.072

Table 1: Renewable Feed in Tariff for Ireland

Due to the current REFIT of €72/MWh for all forms of hydro power regardless of scale it would be reasonable to assume that in the future this price will be reduced to make it sustainable for bodies such as the Electricity Supply Board (ESB). As the REFIT is locked in place for 15 years [11] the project will remain the same until this point, after which a reduction is expected. As this reduction has not yet been released an assumption was made to take 32€/MWh, a price that is in between the British REFIT values for large hydro of 52€/MWh for systems between 100KW to 2Mw and 12.6€/MWh for systems between 2MW and 5MW [12]. This amount was chosen as it is reasonable to assume that when REFIT II is released it will be of a similar value as that of the UK. The lower value was found to excessively reduce the feasibility of the large scale systems, particularly as the largest systems in this project will are taken to be 3.18MW.

3. Results and Discussion

3.1 Baseline Analysis

As can be seen from Fig. 4, tidal energy is significantly more expensive than any other form of energy discussed in this paper. The main reason for this excessively high price is as mentioned before that SeaGen it the first production sized TSG in the world [13] and thus incurs the associated high costs. These high cost are mainly the Capital Costs and O&M. Cost in these areas arise from uncertainties, as there are no standard practices, nor any tried and tested methods for installation and operation.

The baseline does not accurately reflect future cost trends and can only be used to estimate a small scale project that would be built at the baseline year. In this study the TSG units will be built over a 20 year period. It is also important to note that the current instability in fossil fuel costs mean that baseline figures may be overly conservative for all fossil fuel plants, but excluding nuclear. Since these tend not to be sensitive to fuel cost as they use relatively small quantities of fuel [14].

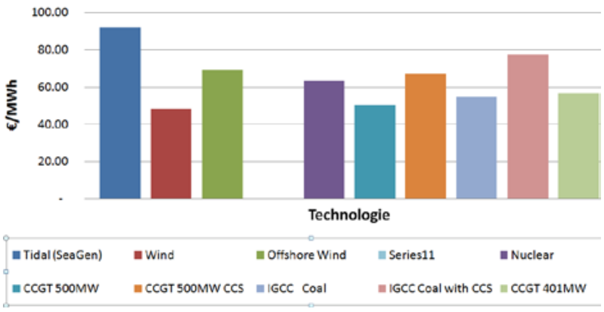

Figure 4: Base Present Worth for a range of energy sources in Ireland

3.2 Sensitivity Analysis

The results obtained from the analysis (Fig. 5) show that all fossil fuel power plants examined were sensitive to changes in the cost of fuel and taxes on their emissions, IGCC Coal plant which suffers from an increase in price of 70.67%.

It can be seen that the implementation of a carbon tax is an effective method of reducing dependency on fossil fuels, and an effective method of stimulating growth in more risky renewable projects. Without these taxes there would be significantly less incentive for investing in renewable sources, over fossil fuel power plants, in the short term.

The Uncertainty of the increasing costs of fossil fuel also helps to stimulate and encourage growth in renewable sectors. Increases in fossil fuel costs will have a negative effect on the Irish economy. Currently Ireland spends €7billion [15] to fuel their power plants. Combining this with the current economic climate, means that it is imperative for Ireland to invest in renewable technologies in order to attempt to alleviate this problem.

When SeaGen 'S' and 'U' were introduced with Rate of Learning over the lifetime of the project factored into calculations (Fig. 5). The introduction of these devises reduces the SeaGen values to 54€/MWh and 27€/MWh for the SeaGen S & U respectively

If we look at the Levelised Cost of all the power plants in Fig. 5 we see that there has been a change in viability of options in Fig. 4. It can now be seen that the well-developed wind turbines are more feasible than that of the any of the fossil fuels looked at. As for tidal predicted developments would result in power plants that produce energy at a very low specific cost (€/MWh). In order to get investors interested in TSGs over other forms of renewable, it would be necessary to present a scenario that will allow them to make a worthwhile profit on their investments. The potential for return available to an investor is dependent on the REFIT values.

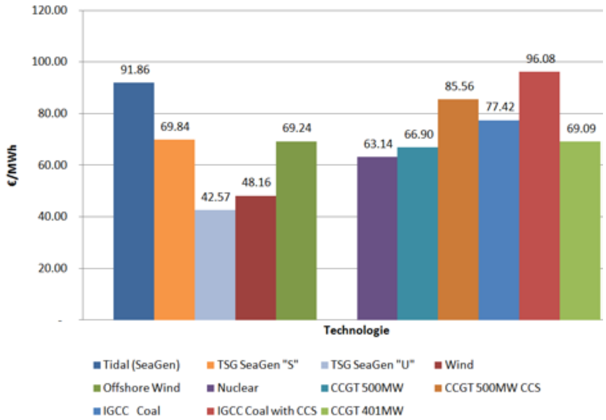

Figure 5: Future Present Worth for a range of energy sources in Ireland

3.3 Payback Period

When the REFIT was taken to be static over the project lifetime it was found that an investor would have to invest a maximum of €137million for the first 17 years. The major cost incurred from SeaGen 'S' system with cost of up to €140million and not seeing a break even until the first quarter of 2029, making a total profit of around €650 million by the end of the project.

SeaGen 'U'; due to its scale and design will break even after only 13 years, with a maximum investment of just over €24 million and a total profit of over a billion euro. When these are combined we get a profit of over €1.6billion for the entire project.

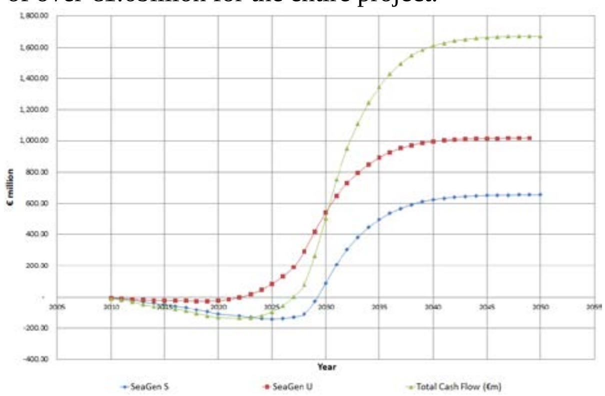

Figure 6: Payback Period with fixed REFIT.

It would be imprudent to assume that the REFIT would remain at present values, thus an altered REFIT value was added (see Sect. 2.4). With the new values it could be seen that there was still a profit to be made by the combined system. This profit was due to SeaGen 'U' which was quickly able to start making a profit, whereas the SeaGen was not able to make sufficient profits before the 15 year change over time in REFIT and was unable to generate a profit within the lifetime of the project.

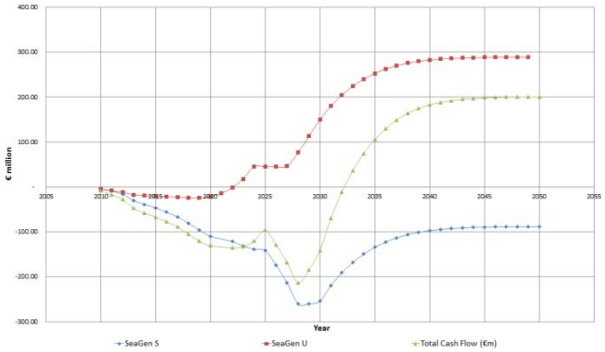

Figure 7: Payback Period with varying REFIT

4. Conclusion

The main conclusions established in this paper to support the feasibility of Tidal Stream Generators (TSG) as a viable energy supply in Ireland are the following:

1. The initial cost of Tidal energy is excessively high, however, through innovation, design and experience, the cost of TSGs will be reduced sufficiently to become competitive with other forms of renewable energy.
2. The increasing cost of fossil fuels will results in the feasibility of fossil fuel power plants being questioned, further increasing the need for the firm power abilities of tidal energy.
3. If Ireland invests in the production of TSGs it can establish its place as the leading authority on TSGs allowing skills to be transferred from Ireland to other countries providing a long term boost to the Irish economy.
4. Security of Ireland's future energy supply, protecting its economy from being negatively impacted by countries that supply fossil fuels.
5. Gives Ireland the ability to sell excess energy. It is expected that by the time the TSGs examined in this report are at full capacity, EirGrid will have fully upgraded the national grid and grid connectors between Ireland, the U.K. and beyond.
6. After investigating the cash flow for a project consisting of SeaGen S and U, it was concluded that even if the REFIT is reduced significantly to less than half its current value, the project will have a large return for investors. However, the scale of TSGs will need to increase. This is shown by the results obtained for SeaGen S and U in which the larger system performed better under lower REFIT values and would be able to produce a profit at a much lower value of REFIT than was examined in this paper.

For these reasons, assuming the current rate of development will remain, tidal energy will be feasible in the next 15 years and will continue to become more viable in the long run as new improved technologies are developed and appropriate incentives are given.

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