Economic Appraisal of the Potential for Offshore Wind Energy Generation in Ireland

Prepared for the National Offshore Wind Association of Ireland

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September 2008

Executive Summary

This report presents an independent analysis of a number of selected costs and benefits from additional offshore wind electricity generation in Ireland in the near to long term. The report considers the expected future benefits of a significant additional investment in offshore wind generation capacity in Ireland for the country as a whole, and notably, does not address this issue from the perspective of developers, final consumers, the Exchequer, or other interested parties. The report was prepared by Indecon International Economic Consultants and was commissioned by NOW Ireland.

Ireland, like many modern economies, is facing a wide range of challenges in energy policy due to a number of factors, including: rising prices of primary inputs (especially fossil fuels), energy and fuel price risk and volatility, energy supply security, GHG emissions, non-GHG emissions, rising demand, and the requirement to invest/replace grid and infrastructure, and the creation of energy market competition and a single EU market. With these challenges to the fore, renewables policy is also an important issue for Ireland. Within the portfolio of possible renewables, offshore wind power presents a potential means for Ireland to increase the amount of electricity that is produced by emission-free power generation capacity.

Offshore wind has developed more slowly in Ireland than its onshore counterpart. Offshore wind developers have argued, somewhat similar to offshore exploration, that this was due to higher capital costs deterring investment. Due to this in part, it is suggested there has been a failure to build the larger turbines which would capture the higher wind speeds and more consistent wind volumes that could give offshore wind energy a competitive advantage in terms of generating capability.

The changing economic landscape in relation to both energy policy and climate change has brought an increased focus on offshore in both public policy and in the minds of private investors. Turbine manufacturers have responded to this increased interest and are now designing and building turbines which are specifically made for higher wind speeds and ocean environments.

While there is increased interest and optimism from the offshore wind industry, to date there has not been, to our knowledge, a comprehensive examination of the economic costs and benefits of offshore wind power in Ireland. This report undertakes the task of an economic cost-benefit analysis of offshore wind.

Indecon believes that unless the benefits exceed the costs policy should not support offshore wind energy. However, if there are net benefits offshore wind should be incentivised.

This report evaluates the economics of offshore wind in Ireland. There are three main areas of analysis:

- Financial modelling
- Quantitative analysis of additional costs and benefits of offshore wind
- Analysis of additional factors, both quantitative and qualitative.

The report looks at a "generic project" of an additional 1,000 MW of offshore wind capacity in Ireland, developed by 2012 and lasting 15 years[1].

Conceptually, the main direct marginal benefits of 1,000MW offshore wind capacity in Ireland arise due to:

- Displaced thermal generation, including
  - Fuel cost savings
  - Reduced emissions
  - Possibly reduced wholesale electricity prices; the 'merit order effect'

Conceptually, the main direct additional costs of an additional 1,000MW wind generation would include:

- Additional capital costs
- Additional operation and maintenance costs
- Additional grid and system costs needed due to strengthen the system and provide backup to wind which is variable.

Besides the above direct costs and benefits, there are a variety of other indirect costs and benefits that will arise due to our 1,000MW offshore 'project', including:

[1] It should be noted that the life-span of such projects can be longer. This is dealt with in the modelling by giving the projects significant terminal values.

- Employment[2]
- Expenditure on construction, maintenance, and the indirect employment and expenditure that a more vibrant offshore industry would generate
- Tax revenues
- Possibly additional costs either direct (e.g., feed in tariffs) or indirect (e.g., grid connections)
- Possibly avoided Kyoto/GHG fines or expenditure on carbon credits.

Finally, in addition to the above benefits and costs, some other less quantifiable but potentially significant costs and benefits exist including:

- Reduced energy price volatility
- Possible increased electricity exports.

Financial Modelling – Economics of a 1,000MW Offshore Project

To evaluate the economics of offshore wind, and provide quantitative estimates of the above factors, a number of detailed analyses and financial modelling of the generic 1,000MW offshore wind project was undertaken. The first set of analysis is a financial model on a complete cost and revenue basis. This first tranche of modelling involved simulation of the Irish electricity system using the Indecon model of electricity market simulation. The model gives a forecast of the electricity price in every hour, given input forecasts of fuel and CO_2 prices, supply and demand, and other factors. The value of fuel and carbon savings in every hour was then estimated. As the values estimated were somewhat sensitive to a number of factors which were forecasted, we present a range of benefits in the table below based on different scenarios.

[2] However account has to be taken of the opportunity cost of labour and in many cost-benefit appraisals too low a figure is used for opportunity costs which artificially inflates the overall net benefits. This issue has been addressed and is further explained in Sections 7 & 8.

Estimated Overall Net Cost-benefit of 1,000 MW of Additional Offshore Wind Capacity (€m) – Key Financial Model Results

Overall Net Benefit	Low Fuel Forecast	Medium Fuel Forecast	High Fuel Forecast
High Demand (Low Discount Rate)	562.6	972.5	1,722.4
Low Demand (High Discount Rate)	-168.3	147.0	778.8

Source: Indecon analysis.

The figures in the table above are the net present values of the 15 year[3] project based on forecast scenarios for demand (high and low), fuel price forecasts (low, medium, and high scenarios) and different nominal discount rates (7% and 9%[4], which impact the present value as well as terminal project values). The annual savings have been discounted using a Discounted Cash Flow methodology to represent the values in 2012 prices. The above net benefit figures are calculated using a value of €3.5bn as the total all-in[5] capital cost of installing 1,000MW of offshore wind capacity in Ireland on a generic and average basis (in general this later figure might vary from about €3-4bn)[6]. The figures include forecasts of the cost of carbon dioxide, but do not include other emissions such as NO_X, SO_X, and other emissions (estimates of these values are given separately). The figures also include estimates of the additional grid and system reliability costs of an additional 1,000MW of wind, and additional operation and maintenance (O&M) costs estimates for offshore wind, expected capacity savings as well as additional costs associated with a need for greater investment in peaking capacity. Using the

[3] It should be noted that the life-span of such projects can be longer. This is dealt with in the modelling by giving the projects significant terminal values.

[4] These values encompass the public and private discount rates for projects, respectively.

[5] This includes grid connection, and various estimates of additional capex, (e.g., transformers) that would have to be built as part of a large offshore windfarm. This figure is over 1bn higher than the capital cost used by the EWEA and we believe that it represents a strong basis for the model in terms of a conservative approach to not underestimating costs.

[6] It is notable that a recent EU Commission report had offshore wind capital cost figures that were somewhat lower (approximately €2.5bn). Part of the reason for a wide range in estimates of the total capital cost for offshore wind is the degree of additional infrastructure that is needed for any given offshore wind farm, the difficulty of installing turbines in different sea and sea floor conditions, the type of turbine, etc, will mean that a significant variation in capital costs exists even across current and efficient projects.

model we have designed, the results suggest that in most cases that the generic 1,000MW would produce positive net economic benefit to Ireland and would thus be economically feasible assuming medium to high oil prices.

The following table presents a breakdown of these results for two of the selected scenarios.

Breakdown of Estimated Overall Net Cost-benefit of 1,000 MW of Additional Offshore Wind Capacity (€m) – Selected Medium Fuel Price Scenarios

		High Demand (Low Discount)		Low Demand (High Discount)
		€ Millions		**€ Millions**
Costs				
Capital Cost		3,500.0		3,500.0
Additional Cost of Wind Penetration		133.3		118.0
Expected Increase in Variable O&M		253.2		224.1
Additional Capacity Cost of New Peaking Capacity		94.4		94.4
		3,980.9		3,936.4
Benefits				
Fuel Cost Savings	2,870.8		2,466.6	
CO_2 Savings	537.2	3,408.1	467.4	2,934.0
Terminal Value of Investment		1,228.3		832.4
Capacity Saving		317.0		317.0
		4,953.4		4,083.5
Overall Net Benefit		*972.5*		***147.0***

Source: Indecon analysis.

The figures presented in the previous two tables represent a financial model of the range of economic fundamentals of the project on a discounted cash flow basis, such that all of the values are converted to 2012 prices. The associated CO_2 savings amount to an average annual offset of approximately 1.3 million tonnes of CO_2 that would be emitted in the absence of this investment.

The fuel cost savings from the 1,000MW offshore wind investment deserves highlighting in the analysis. Arguably, the marginal fuel supplies used in power generation for Ireland will all come as imports. The savings will represent a reduction in imports and would thus impact positively on Ireland's macroeconomy accordingly. [7] The figures listed below do not represent the net benefits of these scenarios but rather the total estimated fuel cost saving, including the cost of CO_2, expected to accrue from the substantial investment in an additional 1,000MW of offshore wind capacity. These figures must be adjusted by among other variables, the capital cost of such an investment, in order to determine the overall expected net benefit.

Estimated Fuel & CO_2 Cost Savings Arising for 1,000 MW of Additional Offshore Wind Capacity (€ mil)

Fuel Saving Benefit	Low Fuel Forecast	Medium Fuel Forecast	High Fuel Forecast
High Demand (Low Discount Rate)	3,156.5	3,408.1	4,080.4
Low Demand (High Discount Rate)	2,727.2	2,934.0	3,519.7

Source: Indecon analysis.

Estimates of other Costs and Benefits

In addition to the fuel and carbon cost savings, and the net savings from the financial modelling, we estimated the value of additional benefits from the generic investment, including: the value of potentially reduced electricity wholesale prices or the *merit order effect*, the value of additional reduced emissions of Nitrogen Oxides and Sulphur Oxides (NO_X and SO_X), and the additional costs and benefits of employment, company profits, and tax receipts, using a standard macroeconomic cost-benefit appraisal model (CBA).

[7] Some fuel will be indigenous, such as from Corrib gas and peat.

Merit Order Effect

The merit order effect arises from the fact that, all else equal, adding wind power to the system should replace higher marginal cost plant on the system, and this in turn is likely to lower wholesale electricity prices in the all-island system as currently designed. This value was estimated using our hourly electricity market simulation model.

On a discounted basis at 9%, this value over 15 years for a selected scenario (medium fuel price forecast and low demand) was found to be €1.58 billion.

Whether the merit order effect should be fully accounted as a benefit is debatable. Some of this value may be captured by producers. [8] While this value is not likely to be entirely captured by private producers (generators), it is unclear to whom the benefits would arise. Further, there is some additional uncertainty surrounding these estimates as a) some thermal plant might need to operate out-of-merit due to technical capabilities to match wind and b) the 'all else equal assumption' may be too strong as exports, forms of support for renewables, and other factors might make electricity prices higher.

NO_X and SO_X Emissions

Another key factor for the cost-benefit analysis is non-GHG emissions reductions, which entail an external benefit. This consists of the value of avoided acid rain and other emissions, and also the value of potential other benefits for CO_2 emissions reduction (e.g., avoidance of carbon fines). We included the cost of carbon in our project fundamentals financial model, but we do not explicitly add these values, due to the uncertainty as to whom the values accrue[9], and around the values themselves, as well as due to the fact that these factors are externalities.

The annual value of avoided NO_X and SO_X emissions was estimated to be €11.1m, and on a discounted 15 year basis, the value of avoided NO_X and SO_X emissions was estimated to be €87m.

[8] A full accounting of the net cost/benefit of the merit order effect would have to model a number of additional factors, including the feed-in tariff regime and possible market power of generators.

[9] This uncertainty involves the likelihood that a very large proportion of acid rain and related environmental damage factors (e.g., mercury) are likely to fall either on other countries or in common resources, such as the sea. Working out whether this is a net benefit to Ireland, for example, if fisheries of foreign fleets are degraded, or if local tourism in neighbouring countries is reduced would add considerable difficulty to the analysis.

Macroeconomic CBA

In addition to the financial modelling and other approaches above, other costs and benefits should be considered in the evaluation of the 1,000MW offshore project. We do not add these figures directly to the project costs and benefits, as they are somewhat more difficult to quantify than the project financial fundamentals.

Potential benefits accruing from additional employment and company profits, on a direct and indirect basis, were estimated following Forfás, Department of Finance, and Indecon's own models for standard cost-benefit appraisal. This approach in essence aggregates the incremental expenditure impact on the Irish economy. One of the principal aspects of this method is the adjustment of the benefits to account for the opportunity cost of labour and capital.[10] The results of the CBA analysis are as follows.

Overview of Main Outputs from Indecon Cost-benefit Appraisal - Central Scenario (€mil)

Welfare Benefit Stream	Net Present Value
Direct Wage/Employment Benefit	101.3
Indirect Wage and Profit Benefits	4.5
Total Economic Benefit	**105.8**

Source: Indecon Cost-benefit Appraisal Model

[10] Further details of this approach are contained in Section 7 of the report.

Fuel Price Risk Reduction

One item of cost-benefit, for which the estimation is particularly challenging, but nonetheless deserves consideration, is fuel and CO_2 input price risk. Since wind will have a zero marginal production cost, the overall volatility of the fuel mix for power generation should be reduced from the substantial addition of offshore wind capacity. The recent volatility in fuel prices makes the importance of this apparent. The more wide-spread adoption of zero-fuel, zero emissions generation technologies removes fuel and carbon price risk, as the marginal cost of generation is effectively zero once installed. Offshore wind thus represents a trade-off between the risk that fuel prices fall significantly from current trends (and one has paid large up-front costs for offshore wind capacity) versus the hedge wind provides against future fuel price rises.

Overall, we estimated the risk-reduction benefit of the 1,000 MW of offshore wind by comparing the volatility of a portfolio of fuel prices, weighted by fuel mix. The resulting value was about €287m over the 15 year period. This is just one area of risk value estimation. Other factors which might yield a net cost of risk associated with wind might be important as well.

In addition to the value of emissions avoidance for Carbon, NO_X and SO_X, risk reduction and direct and indirect macro benefits, there will be a potential benefit from the possibility of the avoidance of carbon fines under the Kyoto Protocol.

Kyoto Fines

While there may be a number of avenues for avoidance of Kyoto fines for exceeding Ireland's agree limits, given the business as usual scenario as the counterfactual, Ireland is likely to incur fines[11]. Based on Indecon calculations, the cost of exceeding Kyoto emissions quotas is predicted to be approximately €1.17 billion, assuming business as usual and other reduction potential is not available, over the period 2008 to 2012. The estimated level of fines avoided as a result of the investment in 1,000MW of additional offshore wind capacity is €70.4 million, over this same period.

[11] Recent estimates from the ESRI suggest that not only are Ireland's emissions not falling, but that they rose by 4.6% in 2007 (*Irish Times*, 28-08-08).

The following table summarises the additional benefits estimated to accrue to the investment in an additional 1,000MW of offshore wind capacity on the Irish system. These benefits are additional to the net benefit arising from the financial model wherein the estimated fuel and CO_2 savings were offset against the capital cost of the investment. As one can see, these additional benefits are estimated to be considerable at €2.13 billion.

Summary of Additional Estimated Benefits

	€ Millions
Merit Order Effect	1,580.0
Savings Associated with Reduced NO_x & SO_x Emissions	87.0
Estimate of Carbon Fines Avoided (2008 – 2012 only)	70.4
Macroeconomic Benefit	105.8
Estimate of Fuel Risk Reduction	287.0
Total of Additional Quantifiable Benefits	***2,130.2***

Source: Indecon analysis.

Conclusion

In testing the economic fundamentals of the development of offshore wind, we developed a model based on the costs and benefits that the installation of 1,000MW of offshore wind energy would have on the Irish economy. The model and inputs were built in a robust manner, seeking at all times to offer a realistic and measurable basis for the assumptions made over the 15 year period. The model was based on production commencing in 2012, the date given by the industry in Ireland as the likely start point for any such development.

While this report considers 1,000MW of offshore wind, we are aware that the offshore providers in Ireland are currently planning in excess of 2,000MW and that the industry believes there is potential for 5,000MW in Irish waters. This report does not cover the economic impact of this scale of development, nor does it make significant comment on the economic benefit that significant interconnection might have for Ireland in the context of export of energy.

The key sensitivities identified in the report are fuel prices, the capital cost of offshore wind, and the discount rate. We also make provision in the model for changes in the price of carbon and electricity demand. These figures are arrived at through extensive modelling.

Overall, the financial modelling of the project fundamentals shows positive NPVs (*i.e.*, net benefit) for the generic 1,000MW offshore wind project under the main and central scenarios; but with higher discount rates and low fuel prices the results lead to negative NPVs. If recent trends of rising fuel prices continue over the lifetime of the study, then investment in offshore wind will be economically viable and commercially profitable. Likewise, if fuel prices were to fall significantly over the next fifteen years, offshore investments could be below the break-even point. Capital costs per MW are also significantly uncertain with respect to offshore wind development. These may ultimately be reduced due to technological advancement. Allowing for the possibility that the inputs to the model may vary from the forecasts that we have estimated, the results show that offshore wind offers a positive return to Ireland in most scenarios assuming medium or high energy prices – based on what we consider to be reasonable inputs and assumptions.

We also indicate that there are likely to be further external benefits, which are somewhat more difficult to quantify, but which may well add to the economic merit of developing this energy source as an option for meeting our renewable energy targets. Such further benefits would include employment, cost of carbon fines avoided and the reduction of fuel price risk. These external benefits could strengthen the case for development and support.