

ECONOMIC AND ENVIRONMENTAL PERFORMANCE ANALYSIS OF PV SYSTEMS FOR DOMESTIC APPLICATIONS IN IRELAND

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Abstract

Long-term monthly average daily solar radiation values on horizontal surfaces at 20 locations in Ireland were used to model the performance of a 1.72 kW_p grid-connected PV system. Global solar radiation on horizontal surfaces varied between 865.1 and 1,127.9 kWh/m²/yr with a mean of 947.9 kWh/m²/yr. Annual energy yields varied between 869 and 1,156 960 kWh/kW_p with a mean of 960 kWh/kW_p. The capacity factor for the PV system varied between 9.9 and 13.2% while the mean was 11.0%.

System cost parameters, long-term annual average electricity domestic rate cost escalation were used to calculate the Net Present Value (NPV), cost of electricity production and simple payback period. The potential for greenhouse gas emission reduction was determined by calculating the quantity of CO₂ emissions avoided annually as well as the cost of CO₂ abatement from electricity generated using domestic scale PV systems in Ireland.

Introduction and Background

Ireland remains heavily dependent on fossil fuels that accounted for 96% of all energy used in 2006. Oil remains the dominant fuel and accounted for 56% of the total primary energy requirement in 2006. Energy imports increased from 50% in 1990 to 89% in 2006. In 2006, the domestic sector accounted for 23% of total energy consumed while CO₂ emissions in the sector accounted for 25% of total emissions. Electricity consumption accounted for 15% of total energy consumed in the domestic sector. Renewables accounted for only 3% in electricity production in 2006 [1]. For Ireland to reduce its dependence on imported fossil fuels, diversification of its energy sources through the development of a strong domestic renewable industry would have to be a key part of the solution.

Electricity generation in Ireland is based on exhaustible and scarce fossil fuels such as oil, gas and coal. World reserves of these fossil fuels are fast diminishing while their prices would certainly increase as they become scarce thereby causing serious problems to Ireland's economic competitiveness. It is therefore imperative that its economic growth should be decoupled from the heavy dependence on fossil fuels.

Global PV electricity generating technology has sustained an impressive annual growth rate compared with other

renewable energy generating technologies. Total global installed capacity of grid connected solar PV was 3.5 GW_p, 5.1 GW_p and 7.8 GW_p in 2005, 2006 and 2007 respectively [2]. Despite this impressive growth, Ireland still lags with virtually little or no installations.

In April 2008, the Irish Government announced a new micro and small scale electricity generation programme for Ireland. Pilot trial programmes are to be installed in 2009 for domestic PV systems with an average plant size of 1.25 kW_p [3]. This communiqué reiterated the Irish Government's desire to implement a micro-generation programme. For such a programme to be successfully implemented, it is imperative that both field trials to provide information on the annual energy yield of typical installations and studies to determine the economics as well as environmental benefits of PV systems in Ireland are necessary for informed policy implementation.

Methodology

This paper uses long-term solar radiation data on horizontal surfaces for 20 meteorological stations in Ireland together with a long-term trend of annual electricity domestic rate cost escalation to calculate the cost of PV generated electricity for use in domestic dwellings. The RetScreen software [4] was used to evaluate the energy and economic performance of the PV system while a model was developed for the environmental performance analysis. Energy performance characteristics evaluated were the quantity of electricity produced (kWh/kW_p) and capacity factor. Economic parameters included Net Present Value (NPV), electricity production cost and simple payback period.

The potential for greenhouse gas emission reduction was determined by calculating the quantity of CO₂ emissions avoided annually as well as the cost for CO₂ emission abatement. Two scenarios for CO₂ emissions associated with electricity production in Ireland notably an average based on 2007 emissions and the Electricity Supply Board (ESB) targets for 2035 were used in the environmental analysis.

Results and Discussion

Electricity generated

Annual electricity yield was found to vary between 869 and 1,156 kWh/kW_p with a mean of 960 kWh/kW_p.

Capacity factor

The capacity factor was found to vary between 9.9% and 13.2% with a mean of 11.0%.

Electricity production cost

The cost of producing electricity in the 20 stations was calculated assuming that net metering was the applicable feed-in tariff. The cost of PV generated electricity varied between 0.39 and 0.52 €/kWh with an average of 0.48 €/kWh.

Net Present Value (NPV)

It is an indicator of the PV system's worth, with a positive value signifying that benefits accrued will exceed costs over its economic life. The higher the NPV, the greater the financial benefit with an NPV greater than zero indicating a profitable investment [5, 6]. Results from the study indicate that investment in the PV system would not be economically viable in all the 20 locations. Figure 1 shows that the NPV varied between €10,667 and €8802 with the average being €10,078.

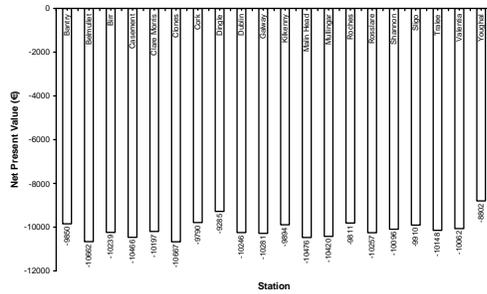
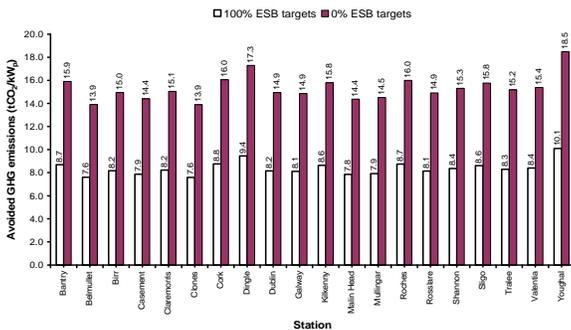


Figure 1: Net Present Value for different locations in Ireland

Environmental impact

The total amount of greenhouse gas emissions avoided was found to vary between 7.6 and 10.1 tCO₂ while the mean was 8.4 tCO₂ for the scenario where 100% of the Electricity Supply Board (ESB) targets are met. For the second scenario where 0% of the ESB targets are met, the total amount of greenhouse gas emissions avoided were found to vary between 13.9 and 18.5 tCO₂ while the mean was 15.3 tCO₂ as shown in Figure 2.

Figure 2: Avoided life cycle GHG emissions in different locations in Ireland



GHG abatement cost

The greenhouse gas (GHG) abatement cost is the cost required to make the NPV equal to zero divided by the total amount of avoided GHG emissions over the life cycle of the PV system. The results show that for 100% ESB targets achieved, the abatement cost varied between 506.8 and 817.2 €/tCO₂ with an average of 704 €/tCO₂. For the second scenario

where 0% ESB targets are met the abatement cost varied between 276.9 and 446.4 €/tCO₂ with an average of 384.6 €/tCO₂.

Conclusions

Results from this study show that on average a high efficiency PV system installed in Ireland would generate approximately 960 kWh/kW_p with a capacity factor of 11%. The capital cost of PV systems is still very high due to the small market size and the average cost of PV generated electricity is 0.48 €/kWh. High negative NPV that result from life cycle cost calculations indicate that PV systems are far from being economically viable.

On average, each KW_p of installed PV capacity would save about 8.4 tCO₂ over a service life of 25 years if the Electricity Supply Board GHG emission reduction targets for 2035 are fully attained. On the other hand, if GHG emissions associated with conventional electricity remain at 2007 levels, each KW_p PV system would save on average about 15.3 tCO₂ over the same period. This shows that there is more potential for CO₂ emission reduction if PV systems are installed now rather than later in the future.

Policies aimed at promoting GHG emission reduction using PV systems would be more cost effective if implemented sooner than later. In order to achieve large-scale adoption of PV systems within the domestic sector in Ireland, a series of policy options have to be explored to make them more attractive to potential investors. Some of these policies include: facilitating access to dump excess electricity into the national grid, financial incentives such as capital cost subsidies, soft loans, income tax incentives as well as generation-based incentives which include feed-in tariffs, net metering.

References

1. M. Howley, F. O'Leary and B. Gallachoir Sustainable Energy Ireland, Energy Statistics 1990 – 2006: 2007 report, Sustainable Energy Ireland, Energy Policy Statistical Support Unit, December 2007.
2. Renewable Energy Policy Framework (REN21) Renewables 2007 global status report. Available at: <http://www.ren21.net/pdf/RE2007_Global_Status_Report.pdf> [Accessed on 17/10/2008].
3. Sustainable Energy Ireland (SEI). Micro and small scale-generation pilot trial consultation. Available at: <http://www.sei.ie/index.asp?locID=1708&docID=-1> [Accessed on 20/11/2008].
4. RETScreen International. Renewable energy project analysis software. Available at: <http://www.etscreen.net/> [accessed on 25/9/2008].
5. J. Twidell and T. Weir, Renewable Energy Resources, Taylor and Francis, Second Edition, New York, 2006.
6. R. Martin Engineering Project Appraisal. Blackwell Science, Oxford, UK, 2001.