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The importance of accurate wind resource assessment for evaluating the economic viability of small wind turbines

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ABSTRACT

The techno-economic performance of a small wind turbine is very sensitive to the available wind resource. However, due to financial and practical constraints installers rely on low resolution wind speed databases to assess a potential site. This study investigates whether the two site assessment tools currently used in the UK, NOABL or the Energy Saving Trust wind speed estimator, are accurate enough to estimate the techno-economic performance of a small wind turbine. Both the tools tend to overestimate the wind speed, with a mean error of 23% and 18% for the NOABL and Energy Saving Trust tool respectively. A techno-economic assessment of 33 small wind turbines at each site has shown that these errors can have a significant impact on the estimated load factor of an installation. Consequently, site/turbine combinations which are not economically viable can be predicted to be viable. Furthermore, both models tend to underestimate the wind resource at relatively high wind speed sites, this can lead to missed opportunities as economically viable turbine/site combinations are predicted to be non-viable. These results show that a better understanding of the local wind resource is a required to make small wind turbines a viable technology in the UK.

1. Introduction

In recent years there has been considerable interest in the potential of microgeneration to contribute to a future of distributed electricity generation [8]. The UK government has promoted the growth of such technologies through a number of incentives, including the Low Carbon Buildings Programme, the Code for Sustainable Homes and the Feed-in tariffs Order [2,31]. As a result there has been an increase in the number of small wind turbines (typically defined as <50 kW) installed across the UK [3,25]. The primary benefit of small scale wind energy systems is the potential to generate low carbon electricity close to the point of use, therefore significantly reducing the energy losses in generation, transmission and distribution, as well as the carbon intensity of the generated electricity. In addition, from the perspective of the owner, a small wind turbine can produce an economic return either as a result of displacing electricity imported from the grid and/or payment for the generated electricity.

To ensure turbines are located at sites at which they are economically viable, an understanding of the energy resource is required. This is not typically a problem for large-scale wind turbine installations as extensive wind monitoring can be conducted to identify potential sites. However, due to financial constraints this is rarely possible for small scale installations; hence there is a reliance on standard assessment tools. If these tools are too optimistic, people who install small-scale turbines run the risk of disappointment and financial loss. This could lead to reluctance to support future low-carbon technologies on the basis that they too might be oversold. If however, the tools are too pessimistic, there could be a significant reduction in the investment in small wind turbines.

Globally, there has been significant research assessing the wind resource in rural locations [15,19,21] and in recent years, due to increased interest in microgeneration, a number of studies have developed techniques for urban areas [11,16,22,23,32]. Despite this, local authorities currently rely on the predictions of low resolution wind speed databases. In the UK, the DECC wind speed database has been widely used by installers and planners for a number of years to evaluate the wind resource at potential sites for a micro-wind turbine [20,31]. It provides estimates of the mean wind

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speed at a 1 km resolution at 10, 25 and 45 m above ground level. The database was produced by a mass consistent flow model, NOABL (Numerical Objective Analysis of the Boundary Layer), which interpolated wind speed data from 56 weather stations across the UK [6,9].

UK field trials carried out by Energy Saving Trust and Encraft demonstrated that the DECC database (hereafter NOABL) tends to overestimate the wind speed, particularly at locations at close proximity to buildings [12,14]. Consequently, this has led to a number of problems where consumers have been given an unrealistic expectation of the energy production and therefore the potential economic benefits of their installation. The Energy Saving Trust field trial showed that during a one year observation period, all 38 building mounted turbines monitored achieved a load factor of less than 8%. In comparison, the 17 free-standing turbines monitored performed considerably better but still only achieved an average load factor of 19%. In the Warwick wind trials showed a mean capacity factor of only 4.2% across 26 rooftop turbines.

In 2009, recognising the need to develop a tool to help local authorities and individual consumers improve the placement of small wind turbines, the Carbon Trust in collaboration with the UK Meteorological Office launched an online wind speed estimator [30]. This provided an estimate of the mean wind speed at a site based on the postcode and a brief description of its characteristics. The model was based on the National Climate Information Centre (NCIC) dataset, which comprises of data from 220 sites over 30 years, (in comparison to a 56 site, 10 year dataset for the NOABL). The NCIC was used to generate a large-scale wind climatology at a height away from the surface, which was then scaled down through the boundary layer taking into account the impact of the underlying surface using a blending height method [4]. Energy Saving Trust and Drew [10,14] showed that the Carbon Trust tool provided more accurate predictions of the mean wind speed than the NOABL. However, this tool is no longer available and consumers are now recommended to use the Energy Saving Trust Wind Speed Prediction Tool (EST tool). The EST tool is freely available online and provides an estimate of the annual mean wind speed at a height of 10 m based on the site's postcode and land use type (either urban, suburban or rural). However, little information of the calculation process is provided.

The aim of this paper is to investigate whether the tools currently available to estimate a site's wind resource are accurate enough to ensure small wind turbines are only installed at locations at which they are economically beneficial. The first section highlights the importance of an accurate assessment of a site's wind resource when estimating the techno-economic performance of a turbine. The second section considers the accuracy of the current site assessment tools by comparing the predictions with wind data collected at 91 Met Office weather stations across the UK. The final section considers the implications of any errors in a site's wind resource for the predicted energy production and economic performance of 33 small wind turbines for a range of economic scenarios.

2. Assessing the techno-economics of small wind turbines

One metric frequently used to assess the techno-economic performance of energy production technologies is the levelised production cost, LPC [1,7,17]. This is defined as the cost of the electricity at the point of connection to a load, including the initial capital, discount rate and operational costs, and can be calculated from.

$$LPC = \frac{C}{aE} + \frac{TOM}{E} \quad (1)$$

where C is the total investment cost associated with the installation of the turbine, E is the annual energy production, TOM is the total annualised operation and maintenance (O&M) cost and the annuity factor, a, is calculated from

$$a = \frac{1-(1/(1+r))^n}{r} \quad (2)$$

where r is the discount rate and n is the economic lifetime of the turbine (in years). For all calculations described in this paper an economic lifetime of 20 years was assumed with a discount rate of 5% [18].

The capital cost of a wind energy project can be broadly broken down into equipment and installation costs. A number of the equipment costs, such as the turbine and the inverter, generally scale with the size of the installation [28]. However, for other components such as the wiring, meters and isolation switches, the price is generally fixed [3]. Consequently, there is currently a large range in the specific investment cost, I, of small wind turbine installations, typically between £2000–6000 per kW [5]. In comparison, the on-going costs of an installation are relatively low, as maintenance checks are necessary every few year and are likely to cost approximately £100 [13].

The annual energy production may be represented as

$$E = 8760 f_{load} P_{max} \quad (3)$$

where f_{load} is the load factor of the turbine and P_{max} is its maximum power output. A turbine is considered to be financially beneficial to the owner if the load factor (energy production) is sufficiently high that

$$LPC < e \quad (4)$$

where e is the sale price of the generated electricity. In the UK, electricity produced by a small wind turbine is eligible for the Feed-in Tariffs, which as of March 2013 are set at between £0.23–0.326 per kWh for a period of 20 years, depending on the size of the installation [24].

Fig. 1 shows the minimum load factor, f_{load}, required for a turbine to be economically viable for a range of values of I and e. At present in the UK, the best case economic scenario, (i.e. the cheapest available turbine and the highest feed in tariff rate,

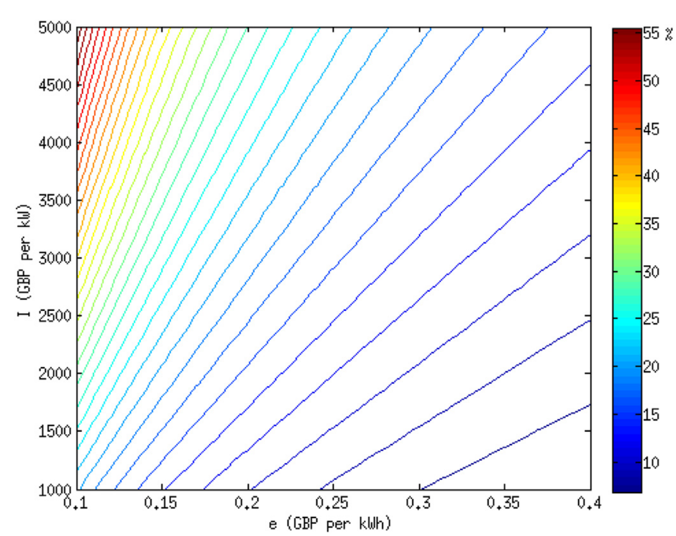

Fig. 1. The minimum load factor required for a turbine to be economically viable for a range of turbine capital costs, I and sale prices of the generated electricity, e.