WIND FARM NOISE ASSESSMENTS: ETSU-R-97 and The Three Legged Stool

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English planning law does not mandate any set separation distance between wind turbines and dwellings, with the minimum separation set by use of a sixteen-year-old noise assessment methodology. In the mid-1990s the wind energy industry persuaded the then DTI to replace the usual regulatory framework for industrial noise assessment (BS4142) with an alternative called ETSU[1] specifically and only for wind turbines. Turbines being built during the mid-1990s were typically of 30-40m hub height with rotors of around 25m radius. Sixteen years on, ETSU remains unchanged but the size of the turbines now being installed has increased dramatically with hub heights of 80m and rotors of 45m radius with correspondingly very different noise generation profiles.

Wind turbine noise can be masked by existing background noise, so ETSU compares the predicted turbine noise at each at risk property with the derived background noise at these same locations over a range of winds from around 2m/s (a light breeze) to 10-12m/s (a strong breeze) at 10m above ground. If the turbine noise exceeds the background by 5dB then the property concerned is considered to be at risk. The entire assessment process is complex, requiring an understanding of basic acoustics, meteorology and statistical analysis. Clearly, it is important that this process should be based on secure and proven science, yet the science or lack of it behind the assessment process is increasingly coming under fire from engineers and scientists from different fields[2].

In essence the ETSU methodology is a three legged stool. The first leg is the measurement of the background noise at various wind speeds, the second is the predictions of the turbine noise, and the third is the comparative analysis of these data. For the first, rather than at the façade of any at risk property, ETSU asks for microphone measurement in a nearby 'free field' location at a height of 1.2-1.5m above ground. The screening effect close to a façade can result in background noise around 3dB lower than at a free-field location whereas reflection of a specific noise such as from a turbine can be 3dB higher, giving up to a 6dB difference in the developer's favour by using the free-field location.

Similarly, to prevent contamination of the data by wind induced noise, microphones should be adequately shielded but in practice this is almost never done. Wind induced noise is impossible to identify in measured noise data and will always work in the developer's favour. All this measurement uncertainty is compounded by the recommended practice of taking data over a very limited time period of perhaps only two weeks giving an absurdly limited sample of the annual noise climate at each site. Furthermore, it is increasingly being realised that many assessments should be modified to account for wind direction, for example in places where the noise climate is dominated by road traffic and so determined by wind direction and time of day.

Figure 1 shows an example of how ETSU suggests these background data are to be processed. The measured noise is plotted against the average wind speed over the same 10-minute time intervals. It is by no means unusual for the measured background noise at any one wind speed to show a range of up to 20dB around the average, equating to a possible doubling or halving of the loudness. This entire data scatter is then summarised by a 'best fit' (average) curve and the curve value at each whole number wind speed is taken for comparison with the predicted turbine noise.

There is no science to guide the choice of curve and almost any curve that gives a statistically reasonable fit can be used. This isn't science or statistics, and sometimes the result is just plain silly[3]. In Figure 1 the curve

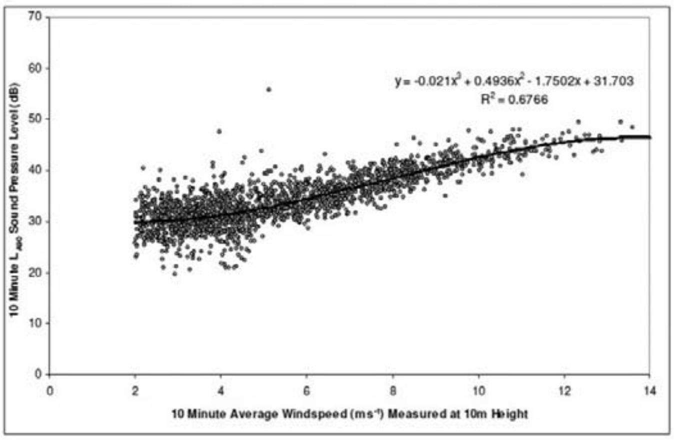

Figure 1: A typical summary plot for wind farm background noise data

suggests that in still air at the dead of night in a very quiet rural location there is a background noise of 32dB when 20-25dB would be typical. More worryingly still, due to the averaging process, at most wind speeds there is a wide range of measured values that can either double or halve the value that will be carried forward into the comparison. Worst case situations of low background noise levels are essentially ignored.

The second leg of the stool is equally unsupported by science. ETSU uses the turbine manufacturer's noise output data as an input into a very simple model based on the ISO9613-2 standard to estimate the noise propagation at distance. This standard was designed for low height, non-wind speed dependant stationary noise sources where wind shear, turbulence and wake effects are not significant. Despite claims to the contrary, ISO9613-2 has never been independently and properly validated for use with modern tall turbines in high wind shear conditions. ISO 9613 predicts a +/-3dB level of prediction uncertainty for the conditions for which it is valid, but, for high level noise sources under high wind shear, turbulence and high wind speeds the degree of prediction uncertainty is likely to be significantly greater.

The rate of change of wind speed with height, known as *wind shear,* enters into these assessment predictions twice. First, through its effect via the refraction of the sound waves, it plays a major role in the propagation of outdoor noise, an effect not considered by the current guidance. Second it affects the wind speeds at different heights used in the final comparison. ETSU assumes a constant and low level of wind shear that gives the predicted 80m wind speed as some standard multiple of that measured at, say, 10m. This ignores years of meteorological experience. More recently wind power developers have been measuring wind shear but are applying shear corrections based on average values, not worst case situations where high shear can occur for significant periods of time.

The correct way to estimate hub height wind speed is to measure wind speeds from a meteorological mast at a series of heights to find the so-called shear exponent that quantifies the change in speed with height for each and every period for which data exist and then use this to estimate the hub height wind speed. Figure 2 plots the shear exponent (alpha) against wind speed for a year's worth of data at a meteorological mast in the Midlands.

Clearly, there is a spread of wind shear exponents at each and every wind speed (negative values imply that the wind decreases rather than increases with height), much of which is due to a diurnal cycle in which the shear is at maximum at night in calm, settled conditions and at a minimum around midday. We are not aware of any analysis in the academic literature of the climatology and geography of wind shear, but our analysis of mast data at four sites across the Midlands suggests that what are normally considered to be high values are found to occur for roughly 10% of the time, usually during the evening and night time. ETSU's failure properly to factor this variation into a noise assessment results in both an under-prediction of the wind speed at the hub (and thus turbine noise) and an over-prediction close to the ground (and thus greater masking noise than is the case). This doubly disadvantages anyone living near the turbine and the result is almost certainly for wind farms to be consented at shorter separation distances than are safe.

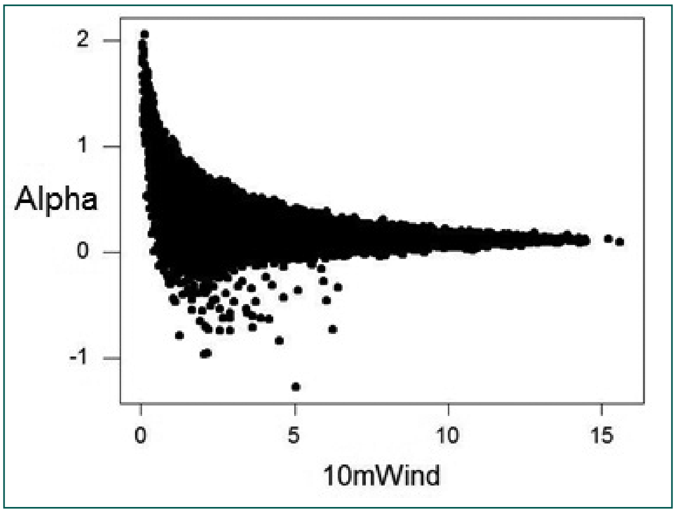

Figure 2

Underlying all these concerns is a single issue that must be of concern for the integrity of the third leg of the stool in which these two data sets are compared. ETSU seems to assume that the entire process contains no scientific error or uncertainty. If true, this must make wind turbine acoustics the only exact science known to mankind other than hindsight. Using conservative estimates of the error at each step we estimate that the ETSU assessment methodology has a total uncertainty of around 9dB in the headroom between background and predicted turbine noise.

WHY THIS MATTERS

Today, industrial wind turbines measuring in excess of 125m to rotor tip are being sited less than 500m from adjacent residential properties, a process justified by citing noise assessments that show them to be 'ETSU compliant' but with 'headroom' of less than 3dB and even less than 1dB. This is lunacy[4]. Given the uncertainties and scope for error associated with this ageing and eccentric assessment methodology we would not be surprised to see a substantial increase in turbine-related noise complaints in years to come.

References

1: ESU-R-97 (1996) *The Assessment And Rating Of Noise From Wind Farms* (ITSY for the dti) 153 pages

2: For more details of the arguments in this note see Cox, R., Unwin, D. and T Sherman (2012) *Wind farm noise assessment: where ETSU is silent*, 41 pages, and Cox, R. and Unwin D. with Bingham, D. and R. Greenough (2013) *The 'Bad Science' behind Wind Turbine Noise Guidance* (Powerpoint Presentation, 86 slides with notes). Both are available from the author at david.unwin@onetel.net

3: Greenough, R and D Unwin (2013) A neglected source of uncertainty in potential wind farm noise assessment using the ETSU_R-97 process. (Accepted for publication in *Acoustics Bulletin*, May 2013)

4: The *Institute of Acoustics* recognised these concerns and reconvened a wind industry-dominated working group to develop draft a *Good Practice Guide* to the process. Regrettably, the result, launched in late May does not address any of the fundamental issues raised in this note.