5th International Conference
on
Wind Turbine Noise
Denver 28-30 August 2013

Projected contributions of future wind farm development to community noise and annoyance levels in Ontario, Canada

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Summary

Wind turbines produce sound during their operation; therefore, jurisdictions around the world have developed regulations regarding the placement of electricity generating wind farms with the intent of preventing unacceptable levels of ‘community noise’ in their vicinity. However, as survey results indicate that the relationship between wind turbine noise and annoyance may differ from noise-annoyance relationships for other common noise sources (e.g., rail, traffic), there are concerns that the application of general noise guidelines for wind turbines may lead to unacceptably high levels of annoyance in communities. In this study, previously published survey results that quantified wind turbine noise and self-reported annoyance were applied to the predicted noise levels (from turbines and transformers) for over 8000 receptors in the vicinity of 13 planned wind power developments in the province of Ontario, Canada. The results of this analysis indicate that the current wind turbine noise restrictions in Ontario will limit community exposure to wind turbine related noise such that levels of annoyance are unlikely to exceed previously established background levels of noise-related annoyance from other common noise sources. This provides valuable context that should be considered by policy-makers when evaluating the potential impacts of wind turbine noise on the community.

1. Introduction

Annoyance is a well known potential impact of community noise exposure, (Babisch 2002; WHO Europe 2011). Therefore, it is not surprising that noise from wind turbines has been correlated with annoyance in a number of studies (e.g., Bakker et al. 2012; Janssen et al. 2011; Pedersen and Persson Waye 2004; 2007; Pedersen et al. 2009; Pedersen 2011). In light of this, many jurisdictions have developed wind turbine siting regulations (i.e., distance and noise limits) intended to limit community noise exposure and resulting annoyance. These regulations have generally been developed based on the assumption that annoyance from wind turbine noise will exhibit a similar dose-response relationship as annoyance from other more common noise sources such as rail, road and traffic noise.

However, a number of key differences between annoyance from wind turbines and from other noise sources have been reported. For instance, people receiving an economic benefit from the wind turbines report almost no annoyance from wind turbine noise even though they are exposed to the highest noise levels {{898 Bakker, R.H. 2012;899 Janssen,S.A. 2011;902 Pedersen,E. 2009;876 Knopper,L.D. 2011;}}. In contrast, people who do not receive an economic benefit from the turbines report higher levels of annoyance at lower sound pressure levels than would be predicted for other community noise sources (Bakker et al. 2012; Janssen et al. 2011; Pedersen et al. 2009). It has been hypothesized that the differences in these dose-response relationships could be driven by numerous factors including the modulating character of audible (and inaudible) wind turbine noise and/or subjective factors such as visual impact, attitudes towards wind turbines (e.g, see Bakker et al. 2012; Janssen et al. 2011; Pedersen et al. 2009),

personality traits (Taylor et al. 2012; 2013) and conflict between the community and the wind farm developers (Shepherd et al. 2011). Additionally, traditional noise dose-response relationships for rail, road, and air traffic were derived using data from urban areas, where residents may have less of an expectation of quiet/ more tolerance for noise than residents of rural areas where turbines are typically constructed.

Due to these apparent differences, concerns have been raised by some that existing wind turbine noise limits may not adequately protect residents living near wind turbines from noise-related annoyance. This study explores these concerns by using a wind turbine specific dose-response relationship previously reported by Pedersen et al. (2009) and Bakker et al. (2012) to predict annoyance from wind turbine noise for over 8000 individual receptor locations (i.e., buildings, dwellings, campsites, place of worship, institutions and/or vacant lots) located in the vicinity of 13 proposed or approved wind power projects in the province of Ontario, Canada.

2. Experimental design

Publicly available noise assessment reports for 13 wind power developments that had been approved since 2009 or were under Ministry of the Environment (MOE) review as of July 2012 (see details in Table 1), were downloaded from the websites of the individual projects. In each of these assessments, the standard method ISO 9613-2 (ISO, 1996) was applied to predict the total wind farm-associated noise that will be experienced (outdoors) at existing or potential receptor locations (i.e., buildings, dwellings, campsites, place of worship, institutions and/or vacant lots) within 1500 m of a project associated wind turbine or within 1000 m of a project associated transformer substation. The noise sources considered in the noise assessment modelling included all wind turbines and transformer substations (if present) associated with the project as well as any adjacent (< 5 km) existing or publicly disclosed proposed wind farms. Although the noise produced by wind turbines tends to increase with increased wind speed, all noise modelling in the reports was performed assuming the maximum noise emission level for turbines based on manufacturer supplied emission levels. Therefore only a single ‘worst-case’ noise level was provided for each receptor location with respect to wind turbine contributed noise. In addition, all modelled noise contributions from transformer substations included a 5 dB adjustment for tonality (MOE, 2008). In total, the data assembled from these reports represented over 8000 existing or potential receptor locations for which the anticipated wind farm related noise had been modelled.

Table 1: Ontario wind power developments included in this study

Project (nearest town)	Maximum rated electric capacity per turbine (MW)	Number of turbines	Number of transformer substations	Number of receptors considered (participants : non-participants)
Conestogo Wind (Arthur)	2.3	10	0	118 (6: 112)
Gesner (Duart)	2.0	5	0	136 (9: 127)
Grand Renewable (Fisherville)	2.2	67	1	1310 (79: 1231)
Kent Breeze (Thamesville)	2.5	8	0	292 (1: 291)
McLean's Mountain (Little Current)	2.5	29	0	346 (0: 346)
Ostrander Point (Picton)	2.5	9	0	13 (0: 13)
Port Dover Nanticoke (Port Dover)	1.8	60	0	806 (20: 786)
South Kent (Tilbury)	2.2	124	2	2138 (263: 1875)
Springwood (Belwood)	2.1	4	0	167 (3: 164)
St. Columban (Huron East)	2.2	15	0	146 (5: 141)
Summerhaven (Nanticoke)	2.2	58	1	2545 (132: 2413)
Whittington (Whittington)	2.1	3	0	88 (3: 85)
Zephyr Farms (Watford)	2.5	4	0	18 (0: 18)

The modelled sound pressure levels for each identified receptor from all of the noise assessment reports were compiled in a single Excel™ file. For each receptor, the distance to and identity of the nearest noise source (i.e. was the receptor closest to a wind turbine or a transformer substation?) was also recorded. Subsequently, the predicted Ontario noise level results were categorized as defined by Pedersen et al. (2009) and Bakker et al. (2012): <30 dB(A), 30-35 dB(A), 36-40 dB(A), 41-45 dB(A), and >45 dB(A). This categorization allowed for a direct comparison of the Ontario based dataset to the survey results from Pedersen et al. (2009) and Bakker et al. (2012) in which annoyance (for indoor and outdoor scenarios) in terms of the noise categories listed above was measured on a 5-point ordinal scale made up of the following responses: 1) do not notice; 2) notice, not annoyed; 3) slightly annoyed; 4) rather annoyed; and 5) very annoyed. Levels of wind turbine noise related annoyance in Ontario were then estimated by assuming that similar levels of annoyance would occur

in Ontario at the same predicted sound pressure levels as reported in Pedersen et al. (2009) and again in Bakker et al. (2012). In addition, in order to simplify presentation of the results, Ontario receptor locations were also grouped based on distance to the nearest wind turbine or transformer substation as follows: 0 to 550 m, 550 m to 1 km, 1 to 1.5 km, 1.5 to 2 km and > 2 km.

3. Results

3.1 Overall relationship between predicted noise level and distance to nearest wind-farm related noise source

Predicted wind farm related noise levels (from turbines and transformers) were compiled for 8123 individual receptor locations (Figure 1).

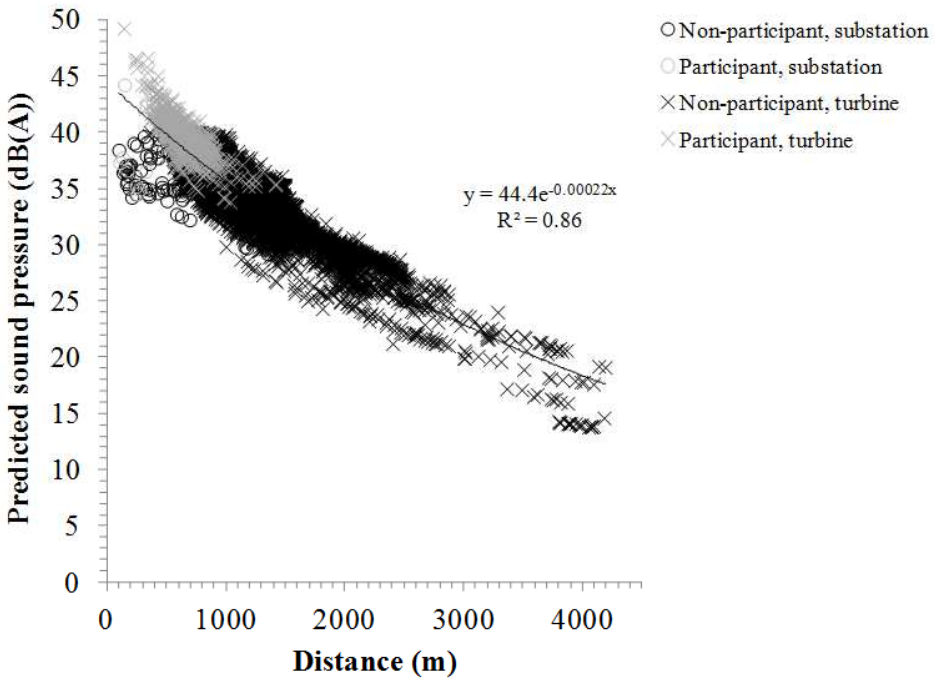

Fig 1. Modelled sound pressure levels (dB(A)) for participating and non-participating receptors with respect to distance from nearest noise source (wind turbine, ×, or transformer substation, ○).

Although distance to the nearest noise source explained a large proportion (86%) of the total variance in predicted sound pressure levels, it should be noted that predicted sound pressure levels at a set distance varied by approximately 5 to 10 dB(A) and the

distance at which a set sound pressure level was met varied by approximately 1000 m (Figure 1). These variations reflect differences in the noise model inputs such as the physical design and noise emission ratings of the turbines (and transformer substations, if present) used in different projects and the total number of turbines (and transformer substations, if present) in the vicinity (< 5 km) of the receptor location. Given that noise levels can vary substantially at a set distance, these data highlight the inadequacy of using 'distance to the nearest turbine' as a proxy for wind turbine noise exposure as has been done in recent studies by Shepherd et al (2011) and Nissenbaum et al. (2012). Likewise, we believe that these data highlight the value of noise-based rather than distance-based wind turbine setback guidelines for minimizing community noise exposure.

3.2 Predicted noise levels for 'participating receptors'

Of the 8123 individual receptor locations considered in this study, 522 represent 'participating receptors' (i.e., locations for which the property owners have entered into a legal agreement with the wind farm developer to permit the installation and operation of wind turbines or related equipment on their property). The predicted noise levels at these 'participating receptor' locations were generally higher than those predicted for non-participating receptors (Figure 1). However, roughly 73% of these receptor locations were still predicted to experience wind turbine related noise levels in compliance with the WHO (2009) recommended night time community noise value (40dB(A)). Roughly 25% were expected to encounter noise in the 41-45 dB(A) range and less than 1.5% in the >45 dB(A) range.

In previous studies, it has been shown that participating receptors who receive an economic benefit from the presence of wind turbines are significantly less likely to be annoyed by wind turbine noise than those who do not receive an economic benefit, even though they tend to experience higher levels of wind turbine related sound and to notice the sound of wind turbines more often (Bakker et al. 2012; Janssen et al. 2011; Pedersen et al. 2009). For this reason, participating receptors are generally excluded from the development of dose-response modelling linking wind turbine noise to annoyance (Bakker et al. 2012; Janssen et al. 2011). Therefore, we did not include these receptors in the predictions of wind farm noise related annoyance in Ontario. However, it is anticipated that the levels of annoyance for participating receptors in Ontario will be very low (or not at all) as has been observed in previous studies (Bakker et al. 2012; Pedersen et al. 2009).

3.3 Noise levels and predicted rates of annoyance for 'non-participating receptors'

By combining the values in Figure 1 with the self-reported rates of annoyance for non-participants in both outdoor and indoor scenarios from Pedersen et al. (2009) and Bakker et al. (2012), it was possible to predict potential levels of outdoor (Figure 2) and indoor (Figure 3) annoyance related to wind turbine noise for non-participants in Ontario with respect to distance.

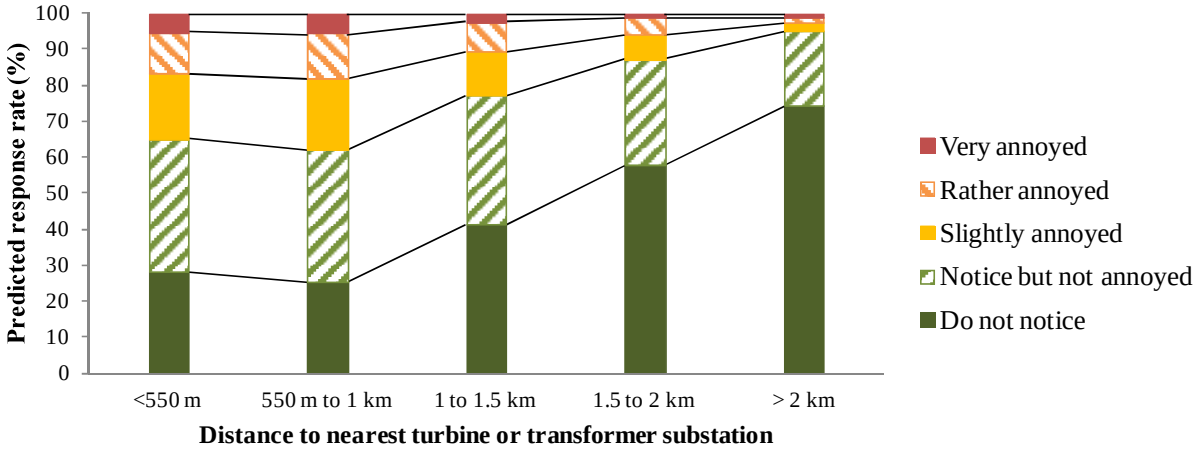

Fig. 2. Predicted levels of outdoor annoyance (%) from wind turbine associated noise for non-participants based on distance from nearest wind turbine noise source (turbine or transformer substation).

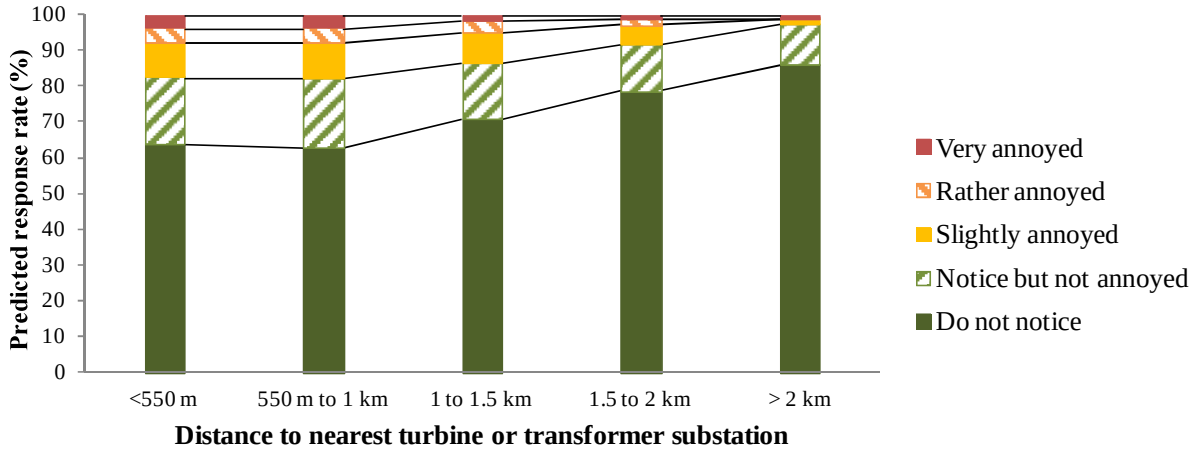

Fig. 3. Predicted levels of indoor annoyance (%) for non-participants based on distance from nearest wind turbine noise source (turbine or transformer substation).

It is interesting to note that even in the categories expected to experience the highest noise exposure (i.e., less than 1 km to nearest noise source and outdoors), over 60% of receptors were predicted to be 'not annoyed' and an additional 18 to 19% were predicted to be 'slightly annoyed', while the remaining 17 to 18% were predicted to be 'rather' or 'very' annoyed (Figure 2). The level of annoyance predicted indoors for the same receptors (i.e., less than 1 km to nearest noise source) was further reduced, with approximately 7% predicted to be 'rather' or 'very' annoyed by wind turbine noise based on these results (Figure 3). Further reductions in the predicted rates of annoyance were observed as distance from the nearest wind turbine noise source increased.

The proportions of receptors predicted to be ‘rather’ or ‘very’ annoyed (when indoors) due to wind turbine and related noise, range from 1.2 to 7.3% depending on distance to the nearest noise source (Figure 3). These proportions are comparable to or lower than rates of noise-related annoyance reported for other more common noise sources such as traffic noise. For example, in two nation-wide telephone surveys of more than 2500 Canadian adults each, approximately 8% of respondents reported being either “very or extremely bothered, disturbed, or annoyed” by noise in general when they were at home and 6.7% of respondents indicated they were either “very or extremely annoyed” by traffic noise specifically (Michaud et al. 2005). Furthermore, Michaud et al. (2005) were able to subdivide their results between large communities (> 100 000 residents) and small communities (< 5000 residents) and in small communities that are typically associated with low background noise levels, 11% of respondents were moderately to extremely annoyed by traffic noise. Similarly, a national survey in the UK in 1999/2000 (Grimwood et al. 2002) found that 8% of the general population reported that they were ‘very’ or ‘extremely’ annoyed by noise (specifically traffic noise). These results suggest that the predicted levels of wind turbine noise related annoyance (indoors) shown in Figure 3 are at levels less than or equal to levels of noise related annoyance identified by people in Canada and elsewhere from other, more common, sources of noise.

3.4 Limitations of this study

The main limitation of this study is that survey results from the Netherlands were used to predict rates of annoyance for residents of Ontario, Canada. Certainly there may be cultural issues that influence rates of annoyance differently in these locations. In light of this uncertainty, it is encouraging that some researchers, including Health Canada (see http://www.hc-sc.gc.ca/ewh-semt/consult/_2013/wind_turbine-eoliennes/research_recherche-eng.php), have initiated studies to compare measured and self-reported indicators of health to measured and predicted noise levels associated with wind turbine installations at residences in Canada. It is hoped that these studies may lead to a more definitive answer on annoyance levels in Canadians and whether any linkages to health issues exist.

4. Conclusions

We investigated the impact of the current Ontario noise limits by comparing the noise assessment results from 13 currently planned wind power developments in Ontario (for a more than 8000 receptor locations) with survey results from the Netherlands regarding annoyance and wind turbine related noise. For non-participating receptors it was predicted that the rates of noise-related annoyance (when indoors) would not exceed 8%, with further reductions in the rates of annoyance at increased distances (i.e., > 1 km). As noted by Verheijen et al. (2011) noise limits for wind turbines represent “a trade-off between the need for protection against noise annoyance and the feasibility of national targets for renewable energy”. Based on this trade-off, Verheijen et al. (2011) recommended a wind turbine noise limit of Lden = 45 dB(A) for the Netherlands, a value that is consistent with the 40 dB(A) limit currently used in Ontario. This level of noise-related annoyance is well within the range of common existing levels of community

noise related annoyance in Canada (including traffic noise in small rural communities in Canada) and elsewhere from a variety of noise sources. Therefore, we conclude that the current noise restrictions in Ontario that determine the siting of wind turbines and associated transformer substations are likely sufficient to limit community exposure to wind turbine related noise in such a way that levels of annoyance will not exceed those commonly experienced for non-wind turbine related noise sources. Furthermore, this comparison highlights the fact that noise and annoyance are not issues that are unique to wind turbines and we suggest that their impacts should be evaluated no differently regardless of their source.

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