

The Use of Noise Perception Index (NPI) For Setting Wind Farm Noise Limits



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Abstract

This paper investigates Noise Perception Index (NPI) as a method for assessing environmental noise from wind farms. NPI is a newly emerging noise assessment tool based on the degree to which pre-existing ambient background sound levels (LA90) are exceeded by the sound under investigation, in this case, wind farm noise.

A practical use of NPI is in the setting of wind farm noise limits. Typically wind farm noise limits of LAeq 40 dB are recommended as an upper limit for wind farm noise received at residential sites by the New Zealand Wind Turbine Acoustic Standard, NZS6808:1998 Acoustics – The Assessment & Measurement Of Sound From Wind Turbine Generators however lower limits may be justified at certain locations, under certain conditions. NPI can assist by identifying sites which exhibit those conditions

This paper describes;

1. NPI values are derived from a comparison of predicted wind farm LAeq or LA90 sound levels and LA90 ambient sound levels for specific wind farm noise receptor sites. The averaged results of this comparison are used to inform whether an alternative, lower noise limit (less than 40 dBA) may be justified based on expected community response;
2. If the overall NPI indicator value for a receiver site exceeds NPI 5, NPI can guide on the decibel amount by which the LA90 40 dB limit should be reduced during quiet periods to provide adequate community protection (based on limiting degree to which predicted wind farm sound will exceed ambient sound levels).

Thus NPI assesses receiver sites based on a comparison of predicted wind farm sound levels and measured ambient sound levels to decide if a noise limit below LA90 40 dB can be justified on the basis of expected community response. As indicated above, the NPI also guides on appropriate decibel limits below 40 dBA, based on a reasonable expectation of community response to the (limited) increase over existing LA90 levels.

Importantly, the NPI method allows sub-40 dBA wind farm noise limits to be set on an objective and consistent basis, taking into account the existing environment and the expected scale of potential wind farm noise effects. If the ambient conditions warrant a lowered noise limit, a suitable wind farm decibel noise limit below LA90 40 dB can be derived based NPI's ability to predict community response in the context of site-specific measured LA90 sound levels. The overall aim is to assist planning to avoid adverse noise effects for proposed wind farm installations in quiet rural areas.

New Zealand Standard For Wind Turbine Noise NZS6808

The current standard for assessing wind farm noise in New Zealand is NZS6808:1998 Acoustics – The Assessment & Measurement Of Sounds From Wind Turbine Generators. This standard was developed specifically for the measurement and assessment of noise from wind turbines (WTG's) and wind farm developments. This 1998 version of this standard was written during the early stages of significant wind farm development in New Zealand.

The 1998 standard has proven to be robust however experience and research over the past decade has brought to light numerous refinements

and enhancements which are being considered within a revised draft version of the Standard, DZ6808:2009 Acoustics- Wind Farm Noise.

Existing Standard NZS6808:1998 allows for Territorial Local Authorities to set noise limits at values below 40 dBA although no guidance is provided.

DZS6808:2009 recommends a “primary” upper limit for wind farm noise of LA90 40 dBA or 5 dB above the background, whichever is the greater. Recommended wind turbine noise limits are specified using the LA90 unit limit rather than LAeq as previously adopted in NZS6808:1998. The “primary” limit is referred to in the standard as follows: ‘In most circumstances the primary noise limit will be adequate to protect health and

some degree of amenity. However, at some locations a secondary noise limit may be desirable to afford a greater degree of protection during evening and night-time. A secondary noise limit should only be considered.’ The 2009 standard recommends that wind farm noise limits should not be set lower than LA90 35 dB.

Table A illustrates diagrammatically the recommended noise limits set out in the 2009 standard.

The NPI method is intended to aid the assessment of secondary noise limits referred to within DZ6808:2009.

40 dBA - Primary Noise Limit

The rationale for the upper limit of

Background Sound Level	Primary Noise Limit (L _{A90})	Secondary Noise Limit (L _{A90})
> 35 dB	background + 5 dB	background + 5 dB 35 dB
30 – 35 dB	40 dB	
< 30 dB		

Table A: DZS6808:2009 Secondary and Primary Noise Limit Summary.

40 dBA recommended within the existing Standard (NZS6808:1998) has been reviewed by the DZ6808:2009 committee in the light of available literature and experience with wind farm noise. Much of the earlier research on which NZS6808:1998 was based is described in the ETSU-R-97 document “The assessment and rating of noise from wind farms”. This document recommends noise from wind farms should be limited to 5 dBA above background noise for both day and night time, with a fixed limit for 43 dBA recommended for night time.

LAeq 40 dB or the average background sound level (whichever is the higher) is adopted as a limit on wind farm within NZS6808:1998. LA90 40 dB or the average background sound level (whichever is the higher) is recommended in DZ6808:2009. Noise limits of this nature are said within these Standards to provide a reasonable level of protection from the adverse effects of wind farm noise, including during quiet night time periods.

There have been several studies examining the annoyance reaction to sound from wind turbines, mostly relying on predicted sound levels rather than measured levels. Due to wind turbine operation mainly during windy periods means there are commonly difficulties in obtaining field measurements of wind farm sound free from the influence of extraneous ambient sound. One of the most recent surveys was conducted within twelve geographical areas in Sweden which surveyed 1095 people in areas with one or more wind turbines with a nominal power of >500 kW. The results summarised in Figure 1 support the idea that wind farm sound received at levels less than LAeq 40 dB do not result in significant proportions of the population expressing high levels of annoyance.

Surveys have purportedly found wind farm noise annoyance higher among people living in more natural environments, i.e. rural versus urban environments, and also among those

who lived in areas where the ambient level was classified as “quiet”. These quiet conditions are the conditions under which elevated NPI values occur.

Annoyance expressed at relatively low levels of received wind turbine sound has been used to justify the idea that possibilities for

“restoration” are reduced or obviated for the noise receivers when noise from wind farm is detectable (Pedersen and Waye 2008). Whether these are effects of any significance within the spectrum of significant health and amenity effects of environmental noise which need to be regulated against has yet to be established. One fact that is emerging is that surveys of response to wind turbine sounds are greatly affected by visual components (making the environment less natural) and may cause subjects to report added noise impact and reduced possibilities for “restoration”.

Summarising the findings, it is clear that some researchers maintain low and moderate stressors such as low level wind turbine noise could have an impact on health, however there appears no compelling evidence that wind turbine noise at levels below 40 dB could cause health problems other than mild annoyance. Thus, 40 dB as an upper limit on wind farm sound appears reasonable for average daily exposure to wind farm sound. Setting limits below 40 dB indicates a desire to address perception effects associated with the audibility of wind farm sounds

Wind Farm Noise Limits Below 40 dBA

Whilst the existing Standard NZS6808:1998 states an upper limit of LAeq 40 dB (or the average background sound level plus 5 dB, whichever is the greater) is adequate to protect people from adverse wind farm noise effects, the Standard allows for lower noise limits to be applied. However no guidance is given.

A number of wind farm projects approved by way of consent orders issued by the Environment Court in New Zealand have included limits of LAeq 35 dB at dwellings. These lower noise limits have been recommended

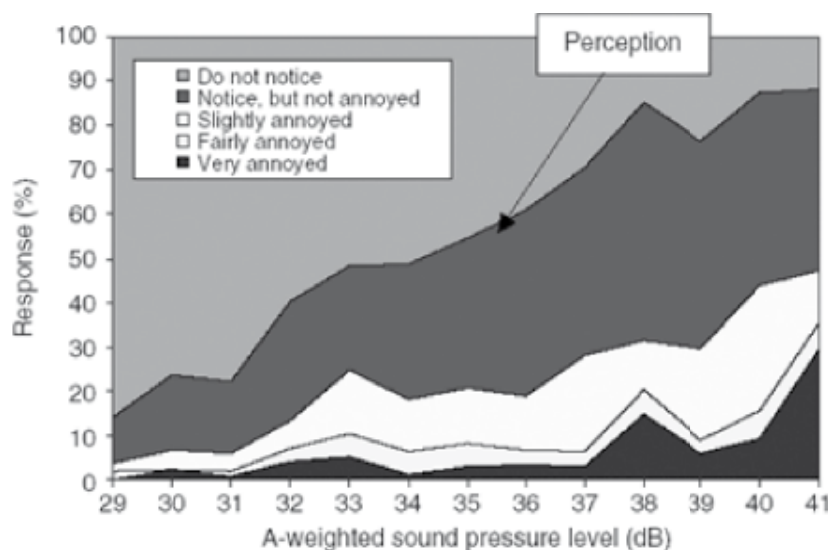


Figure 1 Response to wind turbine noise in relation to A-weighted sound pressure levels outside the dwellings of respondents (n= 1095). E. Pedersen, K. P Waye (2008).

to the court based on assertions that wind farm sounds will be “unduly audible” under low ambient conditions at residential receiver sites, such as when the background sound level (derived from the scattergraph curve of NZS6808) is calculated to be LA90 25 dBA or less. The aim of the lowered noise limit seems to be to avoid times when the wind farm LAeq level may exceed the background sound level (LA90) by 10 dB or more.

A LAeq 35 dB limit is not essential to protect sleep as the established WHO guidelines indicate that negative effects on sleep are avoided when the equivalent indoor sound pressure level does not exceed LAeq 30 dB for continuous noise. This criteria is achieved indoors even with open windows when wind turbine sound is limited to LAeq 35 dB or less outdoors. It appears the lowered limit is intended to address the degree to which wind turbine sounds are audible in the environment. This is a low level noise effect far removed from the usual levels of noise effects at which regulatory authorities act to protect public health and protect amenity.

In New Zealand most land use controls for electricity generation facilities are limited to LA10 or LAeq 40 to 45 dB during the quieter night time periods, which are applied in a consistent manner throughout the quietest night time periods. During calm periods (when wind turbines would not be likely to emit any sound) these typical hydro, thermal or geothermal electricity generation facilities located in similar rural areas may emit sounds (within compliance limits) which exceed ambient LA90 levels by 15 to 20 dB. It seems inconsistent that special treatment is accorded to sound from wind farm electricity generation facilities when ambient sound levels are exceeded generally to a lesser degree than other electricity generating facilities located in rural areas.

The current approach of limiting outdoor wind turbine noise at receiver sites for only some selected wind farms in New Zealand to LAeq 35 dB seems inefficient and leads to inconsistencies. The NPI method set out below indicates when ambient sound levels are sufficiently “low” to warrant the

adoption of a lowered noise limit. Where appropriate, the NPI method can guide on whether the sub-40 dBA limit should be 39, 38, 37, 36, or 35 dB. There appears no technical justification for the tradition of setting wind farm noise limits in 5 dB steps below 40 dB. In fact, considerable flexibility is lost in terms of wind farm design when noise limits are not set a 1 dB steps below 40 dB.

Noise Perception Index (NPI)

NPI is an ambient-based noise assessment tool which is well suited to the task of assessing wind turbine noise on low-ambient receiving sites located in vicinity of wind farms. NPI is based on a concept developed by Hessler and has been promoted based on experience throughout the United States involving

noise sources introduced into green field situations.

NPI is defined as a measure of the true pressure average of the increases above ambient levels due (in this case) to wind farm noise emissions. A minimum of 2,000 ambient 10 minute sound samples is suggested as adequate to measure the temporal trends of ambient sound levels across representative weather conditions (including calm periods < 5 m/sec local wind speeds).

Using information on measured ambient sound levels and predicted (cumulative) wind farm sound levels, NPI is calculated as follows in spreadsheet notation as follows:

$$\text{NPI} = \text{Sum}((10^{\log(10^{\frac{\text{LA90 wind farm sound level}}{10}} + 10^{\frac{\text{LA90}}{10}})} - \text{LA90}))/n \dots\dots\dots \text{Eq 1}$$

LA90 is the measured 10 minute

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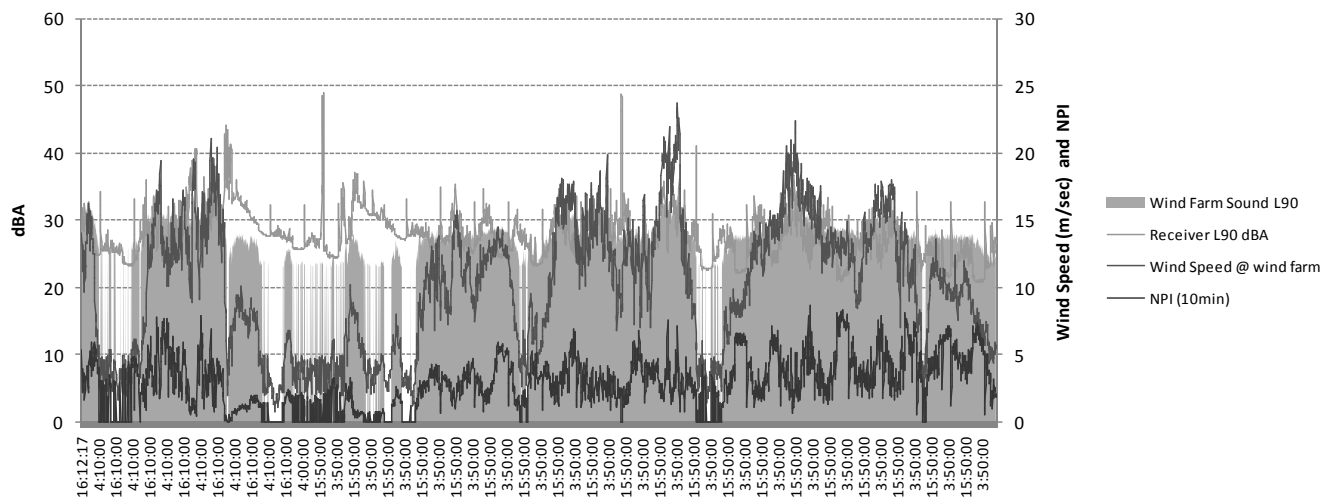


Figure 2: Ambient (dB), wind farm noise level LAeq (dB), wind farm wind speed (m/sec) and calculated NPI(10 min) values for a typical low-ambient receiver site.

existing ambient sound level, wind farm sound level is expressed as LA90, and n = number of 10 minute periods included within the ambient measurement.

An example shown in Figure 2 of NPI values for a sheltered receiver site where modest wind farm sound levels are predicted to be received at levels between 23 and 32. (NPI=4.7). The sample was taken across 30 days of typical weather. Figure 2 depicts the relationship between ambient L90, wind farm noise level LAeq, the wind farm wind speed (m/sec) and calculated NPI(10 min) values for a period of 30 days. This site has a typical average long term NPI value of 4.7.

NPI Values

The NPI rating method returns a single figure NPI value for each measurement site typically 5 or less, but possibly as high as 10 where levels of wind farm sound of 40 dBA or greater are received at very quiet and sheltered receiving sites. Sites with low NPI values are

typically remote from wind farm sites (low received levels of wind farm sound) or are on exposed sites with moderate levels of ambient sound from wind related sources (forests, trees, etc).

In terms of interpreting community response, Hessler (2008) proposes NPI values be assessed on a common basis as shown in Table B.

The main features of NPI when applied to wind farm sound are;

1. The increase over ambient quantified by NPI reflects the degree to which wind farm sound levels exceed background sound levels. This is the basis from which overall estimates of NPI provide an indicator of potential sound intrusiveness or audibility.
2. Wind farm sound levels equal to (or less than) 3 dBA above baseline ambient LA90 is the threshold. Potential adverse noise effects occur above this level, generally at sites where $NPI > 5$. At these site a wind

farm noise limit LA90 <40 dB may be warranted based on the LA90 background sound level, and the expected levels of wind farm sound.

Lowered wind farm noise limits at sites with NPI values of >5 and above can be justified on the basis that the wind farm noise above 35 dBA may cause “Potentially Adverse To Adverse Response”. Table C shows the NPI values derived from calculations performed for a range of typical receiver sites in the vicinity of proposed wind farms, indicating the relationship between NPI and ambient sound levels.

Table C indicates the for the more exposed sites returning a NPI value of 5 or less appear appropriate for the upper noise limit recommended by NZS6808:1998 of LAeq 40 dB or the background sound level plus 5 dBA whichever is the greater.

In terms by how much should the 40 dBA limit be lowered, the guideline dBA values for these wind farm noise limits where a sub 40 dBA limit may be justified as illustrated in Table D provides suggested dBA on the basis of the above NPI analysis.

The NPI tool is particularly useful for identifying sheltered, low ambient receiving sites expected to receive significant wind farm sound. Sites with an average NPI >5, can be considered sites at which an “effects” threshold is exceeded and where a wind farm noise limit of < 40 dBA may be appropriate at times on the basis of the low ambient sound environment and the scale

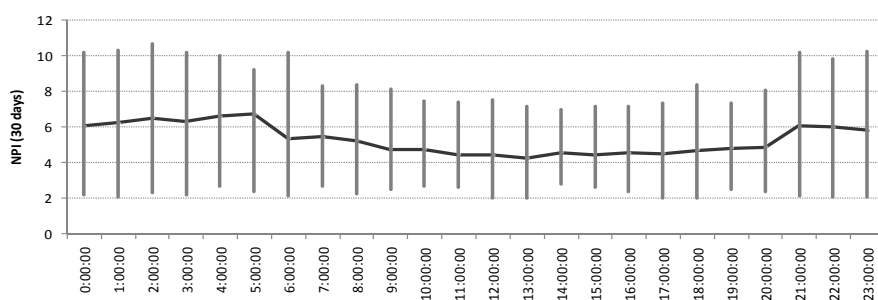


Figure 3: Average hourly NPI (10 min) values across twenty four hours of the day. Higher NPI values occur during times of low ambient LA90.

NPI	PERCEPTION	PREDICTED COMMUNITY RESPONSE
<= 3 dBA	Generally Imperceptible	No Response
3 To 5 dBA	Barely Perceptible To Perceptible	No Response To Potentially Adverse Response
5 To 10 dBA	Perceptible To Noticeable	Potentially Adverse To Adverse Response
> 10 dBA	Readily Noticeable	Adverse Response

Table B: NPI Values vs. Predicted Community Response (after Hessler 2008).

Wind Farm Sound Level(dB) L _{A90}	Ambient Sound Level (dB) L _{A90}			
		HIGH	MEDIUM	LOW
	LOW	NPI <5	NPI 5 to 6	NPI 6 to 8
	MEDIUM	NPI 5 to 6	NPI 6 to 8	NPI 8 to 9
	HIGH	NPI 6 to 8	NPI 8 to 9	NPI >9

Table C. NPI Index values for a range of receiver sites.

Wind Farm Sound Level (dB) L _{A90}	Ambient Sound Level (dB) L _{A90}			
		HIGH	MEDIUM	LOW
	LOW	40 dBA	39 dBA	37 dBA
	MEDIUM	39 dBA	37 dBA	36 dBA
	HIGH	37 dBA	36 dBA	35 dBA

Table D: Recommended wind farm noise limits based on NPI values > 5.

of the potential wind farm sound levels expected for the site. These circumstances may warrant application of a lowered noise limit as per Table D above, indicating a limit up to 5 dBA lower than 40 dBA for sites where the NPI = >9, see Table C.

In all cases, it is recommended any sub-40 dBA wind farm noise limit criteria only be applied during times of low ambient sound, such as when the background sound level (derived from the scatter graph curve of NZS6808) is calculated to be LA90 25 dBA or less. Even for the lowest ambient site the above NPI method does not recommend wind turbine noise limits be set at levels below 35 dB at noise sensitive receiver sites. This is because there is no evidence that that sounds at this low level would result in significant adverse environmental health effects.

That is not to dismiss effects of wind farm sound levels received at low levels. What appears to be emerging is the idea that low level wind farm sounds may cause “restoration” be forgone which is classified as a cause of stress and annoyance. This is also coupled with an identified trend towards preserving

soundscapes in quiet rural areas which do not contain man made sounds.

None of the relevant New Zealand acoustic standards, environmental noise guidelines, or land use planning regimes in place in New Zealand (for example, as implemented through District and Regional Plans) recognise the need to preserve ‘soundscapes’. There are no stated public policies in New Zealand that support the need to entirely avoid the introduction of detectable man-made sound into quiet rural environments.

The planning regime in New Zealand involves significant public input into the rule-setting process. The relevant noise guidelines on New Zealand do allow for noise from introduced sources so long as the amount of introduced sound is not unreasonable and there are acceptable effects on people and the environment.

In summary, recommendations are made with respect to enhancing the approach of DZS6808:2009 to setting sub 40dBA wind farm noise limits in New Zealand. The recommendations are in terms of:

1. Using NPI to define which sites, on

the basis of the expected levels of wind farm sound and the potential exceedance of ambient sound, would be recommended to have a noise limit of LA90 <40 dB.

2. If so, NPI can recommend by how much should the 40 dBA limit be lowered (during specified low-ambient periods) in order to avoid unreasonable wind turbine noise effects during noise sensitive periods.

Conclusions

The “Noise Perception Index” (NPI) offers a workable, objective guide for wind farm noise assessment based on ambient sound levels at receiver sites. The method can be used as a tool to identify low-ambient receiving sites located in vicinity of wind farms that require added protection below the normally applying wind farm noise limit of 40 dBA.

NPI can be used as an aid for setting secondary noise limits under DZ6808 by comparing predicted wind farm sound levels and available data on existing background sound levels. This will identify which sites are recommended to have a sub-40 dBA limit applied; and if so, guiding on how much the 40 dBA limit should be lowered (during specified conditions) in order to avoid unreasonable wind turbine noise effects such as undue audibility.

The method is predicated on the fact that wind farm noise limits of less than 40 dBA can only be justified at receiver sites with demonstrable prevailing low ambient conditions and where future wind farm sound levels are expected to be significant (> 35 to 40 dBA). Such sites exhibit average NPI values of >5.

The recommendations for setting sub-40 dBA wind farm noise limits are designed to avoid “Potentially Adverse To Adverse Response” in the community to the expected level of wind farm noise.

The NPI method is promoted to enhance future wind farm development in New Zealand by ensuring sub 40dBA noise limits are set on an objective and consistent basis taking into account the existing environment and the expected scale of potential wind farm noise effects.

For references see page 36

