



Best Practices in Western Australian Windfarm Assessments

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ABSTRACT

This paper examines the technical and regulatory inconsistencies in wind farm noise impact assessments in Western Australia, arising from trying to comply with both the South Australian Wind Farms Environmental Noise Guidelines and the WA Environmental Protection (Noise) Regulations 1997 at the same time. Through comparative analysis of modelling methodologies and key parameters such as ground absorption, receiver height, and statistical noise metrics, the paper highlights how slight variations in assumptions or approach can significantly affect predicted outcomes. The influences of background noise measurement, seasonal variability, and wind profile conditions are also discussed. Drawing on experience from previous studies, the paper offers practical guidance to acoustic consultants, regulators, and developers to support consistent and technically robust assessments of wind farm projects across Western Australia. Based on the above, a simplified assessment method has been suggested to improve consistency in regulatory decision-making.

1 INTRODUCTION

1.1 Background and aim

Wind energy continues to play a vital role in Australia's transition to a renewable sources of energy, and Western Australia (WA) is home to a growing number of wind farm proposals. Noise emissions from wind farms remain a key consideration in environmental approvals, community engagement, and long-term operational compliance. With increasing scale and complexity near sensitive areas, the need for robust, consistent, and transparent noise impact assessments becomes more important.

In WA, wind farm noise assessments are complicated by the requirement to address two distinct regulatory frameworks: the South Australian Wind Farms Environmental Noise Guidelines (SA Guidelines) and the Environmental Protection (Noise) Regulations 1997 (WA EPNR). While both frameworks aim to protect community amenity, they differ in their modelling methodologies, criteria definitions, and treatment of background noise. This dual requirement has led to inconsistencies in assessment outcomes, with varying interpretations and applications by acoustic consultants, regulators, and planning authorities.

The SA Guidelines provide a relatively prescriptive modelling approach, intended to be conservative, and include provisions for adjusting criteria based on measured background noise. In contrast, the WA EPNR relies on the CONCAWE algorithm and assumptions about worst-case meteorological conditions, which may not accurately reflect the operational characteristics of modern wind farms. The lack of clear guidance on how to reconcile these frameworks has created uncertainty for proponents, regulators, and communities alike.

This paper reviews the technical and regulatory challenges associated with wind farm noise assessments in WA. By comparing common modelling scenarios and analysing the sensitivity of key parameters, the paper aims to support the development of best practice approaches that balance regulatory compliance, technical accuracy, and community expectations.

1.2 Historical context

Wind Farm noise impact assessments are undertaken by desktop assessment, based on manufacturer data (usually tested to a standard), calculation and assessment against criteria (usually state specific). Figure 1 presents a simple flowchart of this process.

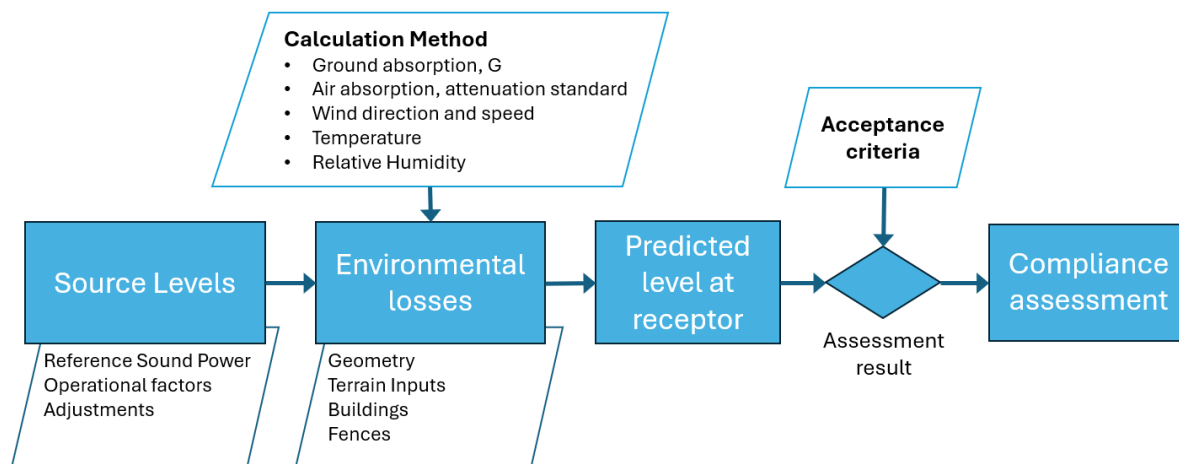


Figure 1: Basic wind farm modelling steps

To achieve consistent assessment outcomes, both the acceptability criteria and the calculation methodology must be clearly defined within regulations or guidelines. When aspects of the assessment process are ambiguous or left open to interpretation, variability in results can arise. In practice, this variability becomes risk of underestimating noise impacts, leading to undesired impacts to community amenity and health, or alternatively risk of overprediction which would potentially limit project viability. Given the significant capital investment required for wind farm developments, proponents rely on a predictable and transparent assessment framework.

In Western Australia, the Environmental Protection (Noise) Regulations 1997 (WA EPNR, the Regulations) are statutory regulations under the Western Australia *Environmental Protection Act 1986*. The Act provides the broad legal framework for noise control, establishing the concept of "unreasonable noise", while the Regulations detail the specific standards and methods for assessing and controlling these emissions. The Regulations do not specifically include or exclude wind farms specifically.

The South Australian Wind Farms Environmental Noise Guidelines were initially published in 2009 and updated in 2021. Like practices in other Australian states and territories, these guidelines have been referenced by Western Australian authorities in the absence of locally specific wind farm noise regulations.

Because the Regulations do not contain provisions specific to wind farm noise characteristics besides tonality or modulation, wind farm noise assessments since 2009 tended to only demonstrate compliance with the South Australian Guidelines. Addressing this, the Department of Planning, Lands and Heritage (DPLH) released the Renewable Energy Position Statement in March 2020, which clarified that application of the Western Australian Environmental Protection (Noise) Regulations 1997 remains mandatory. However, the Renewable Position Statement also recommends assessment under SA Guidelines, specifically referencing the 2009 Guidelines:

Noise emissions from renewable energy facilities, including wind turbines, are required to meet the standards prescribed under the Environmental Protection (Noise) Regulations 1997. The South Australian Environmental Protection Authority – Wind Farms Environmental Noise Guidelines (2009) should also be referenced for assessment purposes.

The SA guidelines were updated in 2021. The revision did not change key modelling parameters affecting predicted noise emissions but did confirm key modelling parameters, including

- Ground absorption $G=0$ (hard ground),
- Predicted emissions are in terms of L_{Aeq} ,
- Alternative algorithms may be used, but should replicate the predictions of ISO 9613-2:1996, and
- Through a 'background plus five' methodology, the criteria at higher wind speeds may be adjusted to exceed an A-weighted base noise level of 35 dB in rural areas.

ISO 9613-2 was updated in 2024 and Appendix D of that standard now provides a dedicated method for assessment of wind farms. The updated standard now has a key deviation from the SA Guidelines, in that there is the option of setting of ground absorption from 'hard' $G=0$ to 'medium' $G=0.5$. Appendix D of ISO 9613-2:2024 notes that

- modelling with $G=0$ with positive adjustments on the source levels (e.g. adding a design or uncertainty 'safety margin') can overstate measured levels;
- modelling with $G=0.5$ without positive adjustments can understate the measured values.

To date there has not been any revision of the SA Guidelines, or any policy or other public guidance from WA regulators regarding the methodology 'option' in Appendix D.

The requirement to assess in accordance with two different methods adds significant complexity and confusion to the assessment of wind farm noise emissions. This complexity is further compounded by informal expectations communicated during reviews by Western Australian authorities since 2020, which are not documented in any publicly available policy or technical guidelines.

2 COMMENTS ON SPECIFIC MODELLING FACTORS

Prior to reviewing some of the wind farm modelling algorithms and methods used for assessment of wind farms in Western Australia, it is useful to discuss the significance of key modelling parameters and baseline wind assessment factors.

Modelling parameters typically discussed in publicly available assessments of wind farms by different consultants include:

- Ground Absorption,
- Receiver height,
- Wind turbine hub height differences,
- Wind turbine sound power tolerances,
- Air absorption model (some acoustic packages / algorithms),
- Statistical variances, and
- where relevant to the application of the South Australian wind farms environmental noise guidelines, the measurement of background noise for receptors surrounding wind farms.

The application of different prediction methods and settings by consultants with varying levels of conservatism results in inconsistent assessment results. These settings are discussed in the following subsections.

2.1 Wind direction

ISO 9613-2 does not provide for wind direction specific predictions. Should wind farm proponents choose to apply noise mitigation modes to specific wind turbines under non-compliant wind directions, there is additional complexity if the modelling method does not allow for input of a specific wind direction. Algorithms such as CONCAWE may therefore need to be used, calibrated to the original predicted noise emission at a specific receptor and informed by weather data. Assessments based on an algorithm that facilitates wind direction specific predictions will allow for more efficient and consistent application of wind turbine noise mitigation modes where required.

2.2 Wind conditions

Published guidelines around the Regulations (Department of Water and Environmental Regulation 2021) nominate the CONCAWE algorithm and inputs for assessment of environmental noise in WA, for comparison with 'Assigned Levels' (criteria defined in the Regulations). These modelling parameters endorsed under the Regulations are based on low wind speed thermal inversion conditions, so do not adequately represent wind farm operations, which typically generate peak noise emissions at higher wind speeds.

This limitation is considered to be one of the reasons why the Renewable Energy Facilities Position Statement recommends referencing the South Australian Wind Farms Environmental Noise Guidelines (2009) for wind farm assessments. In the authors' experience, predictions based on the DWER published guidelines for the Regulations results in lower noise emissions than the SA Guidelines, and therefore will tend to be compliant if the SA Guidelines criteria are met.

Application of the SA Guidelines is known to be conservative, but outcomes are partly offset by criteria adjustments (where applicable) based on the 'background plus five' method.

2.3 Statistical noise measures

The A-weighted equivalent continuous noise level (L_{Aeq}) and A-weighted statistical noise level exceeded 10% of the time (L_{A10}) are common descriptors of environmental noise. Wind turbine noise emissions at a receptor location fluctuate due to long range weather and meteorological effects, such that these descriptors may not be equal. In the experience of the authors', differences between L_{Aeq} and L_{A10} are typically 2 to 2.4 dB at far field locations due to these environmental factors alone. Most acoustic models predict a single number result, which is then interpreted by the acoustic consultant as to what it represents. Based on time varying source profiles and interpretation, adjustments can be applied to the source sound power, or the predicted received values, or be considered to be already accounted for by the modelling methodology such that no additional adjustment is applied.

Generally, assessments under WA Regulations traditionally have been based on use of the CONCAWE algorithm with specified settings for Night and Day scenarios. Although not explicitly stated, the predicted emissions of steady state noise sources (L_{Aeq} equivalent) have been accepted as representing the L_{A10} emission, and therefore directly comparable to the 'Assigned Noise Level' defined in the Regulations.

This may be because the modelling parameters represent a 'worst case' thermal inversion propagation condition discussed above, which is inherently conservative.

There does not appear to be clear policy from WA regulators as to how this methodology is interpreted. If accepted as representing the L_{A10} noise emission, this may reflect a less stringent assessment outcome than historic assessments. Alternatively, an adjustment to the predicted emission may be required to reflect the L_{A10} rather than the L_{Aeq} statistical emission. Opinion is not offered, other than to identify that for technical completeness the issue of statistical parameter should be documented when defining assessment methodology and presenting comparisons with defined criteria.

2.4 Ground absorption

In Western Australia, for general acoustic assessment at distance, there is general acceptance that use of the CONCAWE algorithm with modelling conditions historically defined by DWER, with ground absorption of $G=0.6$ for general topography and $G=0$ for water / hard surfaces represents the L_{A10} noise emission at distance. Monitoring of major projects has generally verified that the modelling methodology is representative.

The application of ISO 9613-2:2024 Appendix D methodology offers the choice of two ground types. Appendix D notes that application of $G=0.5$ for the modelling of wind farms is known to be less conservative than historic assessments using $G=0$, and adjustments (such as wind turbine emission tolerances) should be considered. The predicted difference according to this choice is presented in Section 4 below.

For assessment of wind farm projects in Western Australia under the SA Guidelines, more conservative predictions using ISO 9613-2 with $G=0$ may be offset by 'baseline plus five' adjustments applied when defining the wind speed dependent criteria at receptors.

2.5 Cumulative effects

Wind farm assessments under SA Guidelines are not required to consider the cumulative impacts of other wind farms. Wind farm assessments under the Regulations can be affected by other wind farms, and through the application of Regulation 7 (2) there could be situations where an existing wind farm is required to reduce emissions to a common receptor, particularly where there are high background noise levels.

3 COMMENTS ON BASELINE MONITORING

3.1 Background noise and wind speed

For rural residential receptors, typical assessment criteria involve an outdoor L_{A10} of 35 dB during the 'Night-time' period. There is a strong relationship between measured noise and wind speed (microphone level) for monitoring

near trees (e.g. eucalyptus). in **Figure 2** presents a plot showing typical measured wind speed vs background noise.

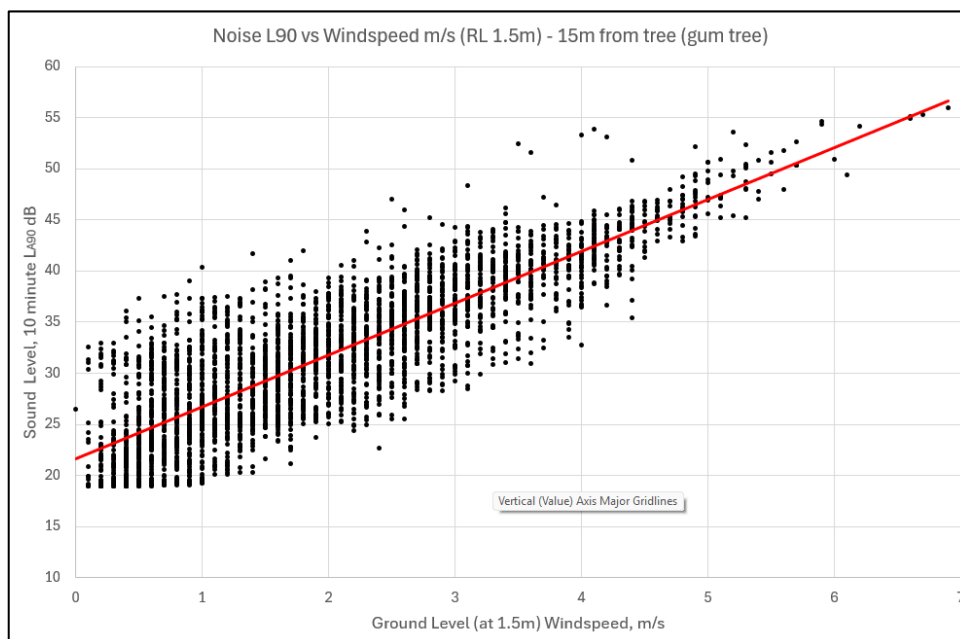


Figure 2: Measured noise level vs wind speed at 1.4m above ground, 15m from trees

The relationship between hub height wind speed and noise can vary for monitoring locations. One cause of variation can be that wind speed at ground level may be related to hub height wind speed when there is full height turbulent mixing, or in other cases, there can be turbulent mixing at hub height and a laminar (almost calm) wind speed at ground level. The latter has been observed for monitoring during clear sky conditions with a thermal inversion (as indicated by met mast temperatures and wind measurements, and weather station at microphone location at microphone elevation).

The classic graph of measured noise level vs hub height wind speed for turbulent mixing shows a clear increase in noise level with hub height wind speed, albeit with significant scatter. Where there are significant periods with a split wind profile, with inversion like laminar conditions near ground, there can be lower noise levels associated with elevated hub height wind speeds. In such cases the calculated 'baseline' noise level can average to not exceed 30 dB. **Figure 3** shows such an example.

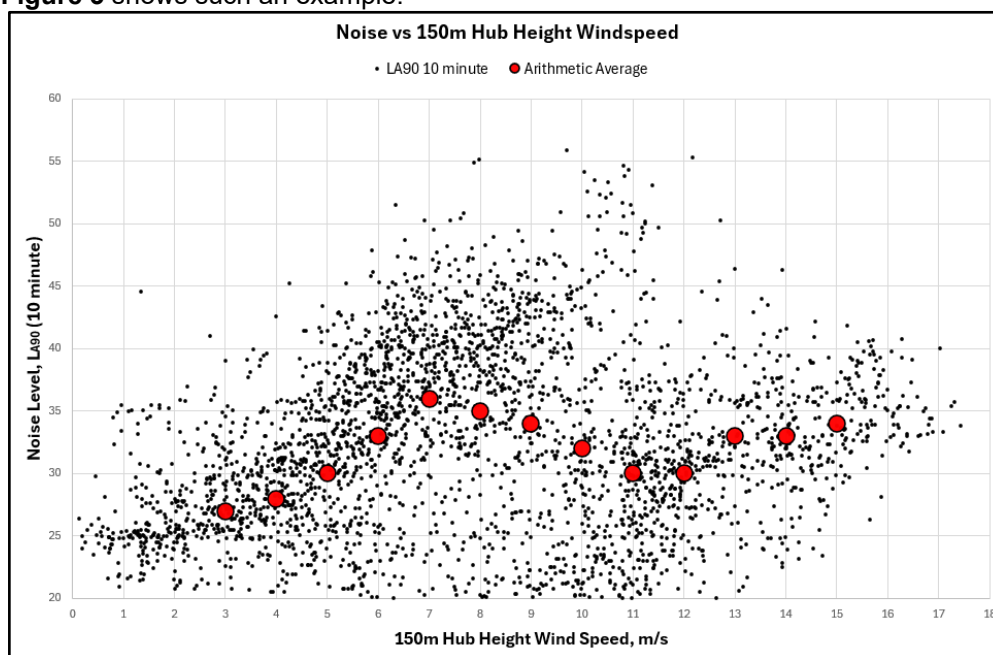


Figure 3: Noise level vs hub height wind speed during thermal inversion conditions

Clear sky thermal inversion conditions are often observed during the April-June months, associated with slow-moving high-pressure cells passing over the state.

3.2 Seasonality

The baseline noise as determined using the method of the SA Guidelines has the potential to be inconsistent, potentially affected by the season when monitoring is undertaken.

If the wind profile varies seasonally (summer vs winter) or with ground surface roughness (cleared fields vs location surrounded by natural bush) then the measured background noise may be dependent on when it is measured, rather than being representative of the receiver location throughout the full year.

Figure 4 shows the percentage of time during the night-time period 7pm – 6am where a thermal inversion of +2 degrees or greater / 100m was measured by met mast for a project located between Badgingarra and Geraldton in Western Australia, by calendar month. The topography is only mildly undulating, with predominantly cleared cropping land.

Figure 4 shows that at this location, monitoring of baseline noise during summer months has the potential to measure a higher average noise level for elevated hub height wind speeds compared to monitoring during winter months.

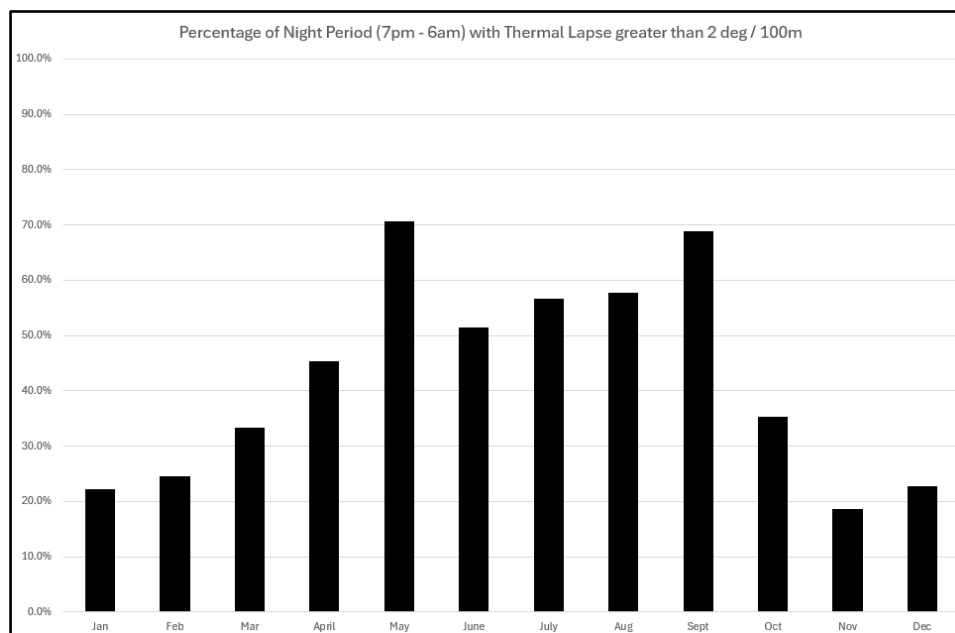


Figure 4: Percentage of inversion lapse rate of 2 degrees/100m condition at night by calendar month

As criteria under SA Wind farm environmental noise guidelines are dependent on measured background noise levels, there is potential for variation in compliance based on when those measurements are taken during the year. On this basis, proponents seeking to maximise wind turbine densities could be selective as to when background noise levels are monitored.

There is potential to check the repeatability and cause of wind conditions associated with wind generated background noise near trees through supplementary measurement of temperature / wind speed at the lower section of existing met masts, extended to cover the full seasonal year. Further studies of existing wind farm assessments may also provide an insight as to the influence of the season during which background noise is measured and the influence of surface roughness surrounding monitoring locations.

There may be opportunity to further investigate and improve understanding of wind and temperature profile near ground in relation to sound propagation conditions.

4 VARIATIONS IN EMISSION PREDICTIONS UNDER TYPICAL CONDITIONS

A simple approach to evaluating the influence of modelling parameters is to simulate a typical scenario at a receiver located at a marginally compliant distance and then observe the magnitude of change in predicted noise levels resulting from variations in input assumptions. The following subsections present the predicted change in results from varying individual factors and using different approaches (combinations of factors).

4.1 Individual factors

Table 1 presents the estimated impact of changing individual parameter values on predicted emissions, in terms of L_{Aeq} . The reference parameter value is bold highlighted for the ISO 9613-2 and CONCAWE algorithms.

Table 1: Predicted differences in A-weighted noise emissions associated with modelling parameter values, dB.

Aspect	ISO 9613-2	1996	2024	CONCAWE	
Reference Level	-	35	35.1	-	33.7
Ground absorption setting, G	0	Reference	Reference	0	6.2
	0.5	-2.1	-2.0	0.5	0.6
Receiver height, R	1.5 m	-0.3	0	0.6	Reference
	4 m	Reference	Reference	1.5	Reference
Hub height, m with R=1.5 m	80	0.4	0	4.0	0
	150	Reference	Reference	80	-0.7
Air absorption standard	-	-	-	ISO 9316-1	Reference
	-	-	-	ISO 3891	-0.5
Upwind	-	-	-	9316-1	-1.4
	-	-	-	ISO 3891	-1.8
Temp T, Relative Humidity, RH	10°C, 80%	-	-	-	-
				15°C, 50%	Reference
Windspeed, Pasquill Stability Class	-	-	-	20°C, 50%	-0.7
				3 m/s, F	Reference
				4 m/s, E	0
				6 m/s, D	0

From this table it can be seen that the ground absorption setting and wind direction can each lead to differences of approximately 2 dB. Differences of 2 dB in emissions associated with the modelling methodology are not in themselves very significant to a receptor who may not be able to detect the difference in sound level by ear. However, in terms of noise impact assessments, the difference can be critical to 'compliance' and ultimately viability, if the capacity of a wind farm project is unnecessarily reduced.

The methodology for application of the SA Guidelines should not be open to interpretation as the key modelling method and parameters are specifically defined. However, several assessments appear to use alternative methods, with discourse to justify the method used, instead of directly applying the reference method. Approvals associated with these assessments, sometimes through planning (Council, DAP, JDAP) indicate acceptance of those methods.

To provide a reference, the parameter interpreted by the author to represent application of the relevant SA Guideline or WA (EPNR) modelling condition is highlighted in bold, with increases in predicted emissions shown as positive.

4.2 Overall approaches

This section attempts to quantify the effects of different modelling approaches typically used.

Two wind turbine data sets were used, as different spectral distribution of sound power leads to variance in predicted emissions at distance. The following results are for wind turbine type A, which has more acoustic energy at higher frequencies than wind turbine type B. Minor adjustments were made to the overall sound power of the source so that the maximum sound power was normalised to a sound power L_{WA} 107 dB for each wind turbine type.

Modelling is based on night conditions for the Regulations which are different for the day period. The default for SA Guidelines is a night condition. The Model receptor is located to the side of a typical multi-turbine wind farm layout in a relatively flat rural farmland area in Western Australia. Modelling carried out for two commercial turbine makes, normalised to a maximum sound power of L_{WA} 107 dB, representative of 6 – 7MW wind turbines.

For the consideration of modelling under the Regulations, the differences in input wind speeds at 10 metres height above ground level (met mast) and at 150 metres (hub height) are calculated using the wind shear method with a factor of 0.2. Comparison with measured met mast wind speed data at differing elevations for several wind farm projects showed that this wind profile model is representative.

The predictions of **Table 2** provide an indication of the influence of modelling methodology applied to wind farm noise impact assessments for each scenario.

Table 2: Comparison of noise modelling predictions for different modelling approaches

Scenario / Approach	A	B	C	D	E	F
Guideline / attenuation standard	SA ISO 9613-2: 1996	SA ISO 9613-2: 2024	SA ISO 9613-2: 2024	WA CONCAWE	WA CONCAWE	WA CONCAWE
Ground absorption setting	G=0	G=0	G=0.5	G=0.6	G=0.6	G=0.6
Receiver height (m)	4	4	4	1.5	1.5	1.5
Temp	10	10	10	50	50	50
Humidity	80	80	80	15 night	15 night	15 night
Wind turbine sound power L_{WA} , dB	107	107	107	102.5	105.6	107
Wind turbine sound power basis	Maximum	Maximum	Maximum	4 m/s at 10m AGL standard, 7 m/s for 150m Hub Height	5 m/s at 10m AGL, 8.6 m/s for 150m Hub Height	Maximum
Modelling windspeed	N/A	N/A	N/A	3 m/s at 10m AGL	6 m/s as turbulent at Hub Height	6 m/s as turbulent at Hub Height
Pasquil Stability Class	-	-	-	F	D	D
LAeq to LA10	Not applied	Not applied	Not applied	Not applied	Not applied	Not applied
WTG tolerances	Not applied	Not applied	Not applied	Not applied	Not applied	Not applied
Wind Direction	N/A	N/A	N/A	All winds / maximum	All winds / maximum	All winds / maximum
Background Noise Adjustment to Criteria (SA Guidelines)	0 – 4 typical	0 – 4 typical	0 – 4 typical	0	0	0
Criteria (WA rural), dB	L_{Aeq} 35 – 39	L_{Aeq} 35 – 39	L_{Aeq} 35 – 39	L_{A10} 35	L_{A10} 35	L_{A10} 35
WTG Type A	35	35.1	33.1	31.6	32.6	33.7
WTG Type B	35	35.5	33.2	29.6	32.7	34.0
(Normalised to 35 dB Scenario A)						
Average increase vs Scenario A, dB	Reference	0.3	-1.9	-4.4	-2.4	-1.2

The methodology of Scenario D may most closely represent the ‘normal’ assessment on noise emissions in Western Australia. This is the application of the CONCAWE predictions using the EPA guideline calculation parameters, but with the daytime 4 m/s (at 10m above ground) wind speed applied. This would be the appropriate method for assessment of project types other than wind farms under WA EPNR, adjusted to consider the higher standard wind modelling condition in recognition of noise source emission being wind speed affected. At least one public

WA wind farm assessment has already documented application of this method for assessment of the emissions under WA EPNR.

It is noted that at the receptor location the predicted emission was 37.1 dB, 2.1 dB higher than for wind turbine type A. Wind turbine type B results have been normalised to 35 dB to allow for comparison of differences associated with calculation methodology.

The inferred reason for the difference between noise emissions of the two different wind turbine types (of the same sound power, L_{WA} 107 dB) is the spectral composition of the sound power emission. The Wind turbine A spectrum contains higher frequency content than wind turbine type B. High frequency sound power is attenuated more at distance due to air and ground absorption effects.

5 SUGGESTED APPROACH

The assessment of wind farm project noise emissions could be simplified through application of a well-defined assessment methodology that is not reliant on measurement of background noise as a means of setting acceptance criteria.

Based on the information and guidance to date, the modelling methodology shown in Scenario E of Table 2 is suggested as a suitable method for the purposes of assessment.

Although predicted emissions under Scenario E are approximately 2 dB lower than those under the SA Guidelines (Scenario A), no background-based criteria adjustment would be applied. This approach is unlikely to misrepresent other noise sources at a wind farm, such as battery energy storage systems (BESS).

Background noise monitoring is still recommended, especially for the purposes of post-construction verification. It is recommended that background noise be measured at a minimum of three locations for a three-week period, once within the April – June months, and additionally during the November – February period at the same locations. Some minor variation to these periods may be warranted based on local climatic activity. This could be a condition prior to commencement of construction, regardless of the submission of a noise impact assessment for approvals. As per SA Guidelines, background noise monitors should be carefully located at a representative distance from trees of the same type as common around residences near the proposed wind farm, so that the measured background noise is representative of the noise at the façade of the typical residences. Background noise should be analysed and reported as per SA Guidelines but not used to set criteria for assessment.

The objective of using a single assessment methodology and defined compliance criteria (EPNR ‘Assigned Levels’) is to provide consistency in assessment and to simplify the process.

6 CONCLUSIONS

There is a need for a consistent approach to the assessment of wind farm projects in Western Australia.

Consistency is required both in terms of assessment criteria and prediction methodology. The method needs to be documented and publicly available, and to be endorsed by government / regulators as the appropriate basis for an acceptable assessment and noise emission outcome.

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REFERENCES

- Department of Planning, Lands and Heritage (DPLH). *Renewable Energy Position Statement*. Government of Western Australia, March 2020.
- Department of Water and Environmental Regulation (2021). *Draft Guideline: Assessment of Environmental Noise Emissions*. Retrieved from <https://consult.dwer.wa.gov.au/regulatory-capability/draft-guideline-assessment-of-environmental-noise/>

- Environmental Protection Authority (EPA). *Environmental Protection (Noise) Regulations 1997*. Government of Western Australia.
- International Organization for Standardization. *ISO 9316-1:1993 – Acoustics — Attenuation of sound during propagation outdoors Part 1: Calculation of the absorption of sound by the atmosphere*. Geneva: ISO, 1993.
- International Organization for Standardization. *ISO 9613-2:1996 – Acoustics – Attenuation of Sound During Propagation Outdoors – Part 2: General Method of Calculation*. Geneva: ISO, 1996.
- International Organization for Standardization. *ISO 9613-2:2024 – Acoustics – Attenuation of Sound During Propagation Outdoors – Part 2: General Method of Calculation*. Geneva: ISO, 2024.
- South Australian Environment Protection Authority (SA EPA). *Wind Farms Environmental Noise Guidelines*. Adelaide: Government of South Australia, 2009 (Revised 2021).
- CONCAWE. *The Propagation of Noise from Petroleum and Petrochemical Complexes to Neighboring Communities*. Report No. 4/81. Brussels: CONCAWE, 1981.