Measuring and calculating sound from wind turbines

Wind turbine operators are obliged to take action if a wind turbine exceeds the maximum noise limits near areas like residential buildings. To this end, the Swedish Environmental Protection Agency provides guidance on the measurement and calculation of sound from wind turbines.

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The operator of a wind turbine is responsible for ensuring that its sound levels do not exceed the permissible sound levels. When a facility receives an operating permit, the terms and conditions of the permit will state the permissible sound levels. If the facility only receives a notification, then the related documents will state the permissible sound levels.

If it becomes necessary to measure sound levels from installed wind turbines, it is important to first carefully consider the purpose of the test so that the measurement results respond to the questions posed. There are two main principles: measuring the sound emitted by the wind turbines (emissions measurement) or determining the sound level at any given point in the surrounding environment (immissions measurement). In many cases, it may be appropriate to combine these measurements. It is important that measurements and planning of any actions take place in consultation with residents and the relevant regulatory authority.

Calculations

A wind speed of 8 m/sec at 10 m above ground level (AGL) with a surface roughness length of 0.05 m is the reference value at which sound power is usually given in accordance with standards. This reference value is used in calculations. It corresponds to a wind speed of 11.5 m/sec at a height of 100 metres.

The computational models are for downwind. For upwind the noise level diminishes, and at great distances substantially. Under certain topographical, meteorological and vegetative conditions, the models used are more uncertain.

The Swedish EPA's report "Ljud från vindkraftverk" (Sound from Wind Turbines), revised edition of report 6241 dated 20 April 2010, describes various models for calculating sound propagation from wind turbines in different situations. **The report is under review.** Read more about the calculations under "Calculations of wind turbine sound" on page 5. Read also about the assessment of sound from wind turbines in the Excel-based calculation application (see the section "More information").

Sound measurements

For emissions measurements at a wind farm, a method is used that is more closely described by the International Electrotechnical Commission (IEC) in its report "Wind turbine generators – Part 11: Acoustic noise measurement techniques", IEC 61 400-11, second edition (Ed 2.1) 2006-11; see also the Swedish version SS-EN 61 400-11.

Immissions measurements should be performed at a hub height wind speed corresponding to the reference conditions (the hub height is the distance

between the ground and the centre line of the turbine rotor). In some cases, it may be appropriate to perform measurements under other conditions as well. Advice and instructions are provided in the report "Mätning av bullerimmission från vindkraftverk" (Measurement of Noise Immission from Wind Turbines; see the section "More information").

Below are examples of wind speed at different heights at reference conditions and a surface roughness length of 0.05 metres:

	Ref. conditions				
Hub height	10 m	80 m	100 m	120 m	150 m
Wind speed, m/sec	8	11.1	11.5	11.8	12.1

An alternative to manned measurements is using long-term noise monitors that are deployed for a longer period of time to capture the sound levels under different meteorological conditions. However, it is difficult to screen out extraneous sounds from the measurement results.

For operations that require registration or a permit, including operations that have been granted permission without a permitting requirement, see the binding provisions of Swedish EPA Regulations (NFS 2000:15) Concerning Measurements and Sampling in Certain Activities (see the section "More information").

Ambient sound can mask the sound from wind turbines

Natural sounds, such as wind in tree crowns or the roar of the water, often mask the sound of wind turbines. Studies suggest that wind turbines will not be heard if they have a sound level that is at least 10 dB(A) lower than the background noise. Typically, natural sources of sound can cause sound to be masked in this way. Natural sources of sound include wind in vegetation or the sound of waves at a beach. Even winds against houses and other buildings can lead to sound levels that can mask the sound originating from wind turbines.

An assessment of whether masking background noise can affect how the sound from wind turbines is perceived usually requires extensive studies that use local measurements or calculations, as well as assessments of the impact of factors such as wind speed, wind direction, season and temperature.

Calculations of wind turbine sound

Sound data should be declared in accordance with IEC TS 61400-14, "Declaration of apparent sound power values and tonality values".

Sound data should be given as Lwd = Lw + K with verification according to IEC 61400-11 and ISO 7574-2.

- Lwd = Lw+ K
- Lwd = declared sound power level dB(A) re:1pW
- Lw = measured sound power level according to IEC 61400-11 reference conditions 8 m/sec. This should be an average of the sound power level determined in accordance with IEC 61400-11 for more than one wind turbine and adjusted to a height of 10 m AGL with a surface roughness length of 0.05 m.
- K = 1.645 x σ, if there are production variations for a production batch of the same type (reference IEC TS 61400-14)
- K = min. 3.8, if the declaration is based on measuring a single turbine using IEC 61400-11 and there is no information about production batch variations (reference SS-EN ISO 4871)
- σ = standard deviation, taking into account measurement uncertainty and production variation

Instructions for calculating σ are given in IEC TS 61400-14.
K = 1.645 x σ reflects a probability of 5% that a measurement result made according to IEC 61400-11 performed at a wind turbine of the production batch exceeds the declared value.

Computational models

The calculations in the Excel sheets (Lundmark Acoustics & Vibration) are based on the computational models presented in the Swedish EPA's report "Ljud från vindkraftverk" (Sound from Wind Turbines), revised edition of report 6241 dated 20 April 2010.

The computational models according to this report are based on free sound propagation in downwind, i.e., when the wind blows from the turbines toward the point of calculation, and when the airborne sound absorption is low (essentially, the worst case). Studies on annoyance levels from wind power noise are based on such calculations.

Sound propagation over land

The computational models for sound propagation over land assume a hemispherical sound propagation (divergence) when calculating the

geometrical spreading attenuation. Airborne sound absorption is also taken into account. Two different computational models are used in the Excel sheets:

For distances up to 1000 m: $LA = LWA - 8 - 20\log(r) - 0.005\,r$

For distances greater than 1000 m: $LA = LWA - 10 - 20\log(r) - \Delta La$

Sound propagation over sea

The computational model for sound propagation over sea assumes a hemispherical sound propagation up to 1000 metres and then cylindrical sound propagation. Airborne sound absorption is also taken into account.

$LA = LWA - 8 - 20\log(r) - \Delta La + 10\log(r/1000)$

Other computational methods

More detailed computational models are also available, such as Nord 2000, which take into account many parameters. But these require more data to be developed for the calculations, which can be cumbersome to obtain and require expertise and experience. It has also been shown that the simpler models typically provide calculation results with good accuracy, at least in the case of installations on land.

The Excel sheets can be downloaded from the Swedish EPA's website (see the section "More information").

Excel sheets: Copyright, idea and development: Lundmark Akustik & Vibration, phone +46 (0)8-751 58 30.

More information

Project report: Upplevd störning av vindkraftsbuller, en jämförande studie av ljud från olika turbiner, K. Bolin, M. Nilsson, G. Bluhm (in Swedish)

Wind Turbine Noise and Natural Sounds: Masking, Propagation and Modeling, PhD thesis of Karl Bolin, KTH

Swedish EPA Regulations Concerning Measurements and Sampling in Certain Activities: NFS 2000:15 (pdf 56 kB, in Swedish)

Mätning av bullerimmission från vindkraftverk. S. Ljunggren, 1998, Elforsk report 98:24 (in Swedish)

Link to Excel sheets (in Swedish)