Statutory Order on Noise from Wind Turbines

Translation of Statutory Order no. 1284 of 15 December 2011

Pursuant to Section 7, subsection 1, no. 1 and 2, Section 7 a, subsection 1, Section 92 and Section 110, subsection 3 of the Danish Environmental Protection Act, cf. Consolidated Act no 879 of 26 June 2010 and Section 33, subsection 1, Section 48, subsection 1, and Section 61, subsection 1 of the Danish Act on Protection of the Marine Environment, cf. Consolidated Act no 929 of 24 September 2009, as amended by Act no 423 of 10 May 2011, the following is hereby established:

Chapter 1
Scope and definitions

SECTION 1. This Statutory Order applies to the installation, modification and operation of wind turbines.

SECTION 2. For the purpose of this Statutory Order the following definitions apply:

1) Small wind turbines: Single wind turbines with a rotor area of 200 m2 or below and with a total height of 25 metres or below, including domestic wind turbines.
2) Prototype wind turbines: The first, non-series-produced wind turbine of a new type.
3) Series 0 wind turbines: The first, small production series of a new type of wind turbine.
4) Test wind turbines: Series 0 wind turbines or wind turbines which are prototype-certified or modified for experimental use pursuant to the Statutory Order on Technical Certification for the Construction, Manufacture, Installation, Maintenance and Service of Wind Turbines.
5) Wind farm: A cluster of three or more wind turbines.
6) Noise impact area around test wind turbines: The largest extent of the area around test wind turbines where total noise level from wind turbines is higher than 37 dB(A) at 6 m/s and 39 dB(A) at 8 m/s, determined in accordance with the guidelines set out in Annex 1.
7) Noise-sensitive land use: Areas that are actually used for or designated in district plans or town planning regulations for residential, institutional, holiday home, camping or allotment purposes or areas designated in district plans or town planning regulations for noise-sensitive recreational activities.
8) Low-frequency noise: Noise in the frequency range from 10 to 160 Hz. Low-frequency noise is characterised by the A-weighted level of noise in one-third octave bands from 10 up to and including 160 Hz, calculated indoors using the method set out in Annex 1.

Chapter 2
Requirements for wind turbines

SECTION 3. Anyone who owns a wind turbine is responsible for installing, operating and maintaining it in such a way as to ensure compliance with this Statutory Order.

SECTION 4. The total noise impact from wind turbines may not exceed the following limit values:

1) At the most noise-exposed point in outdoor living area no more than 15 metres from dwellings in open countryside:
    (a) 44 dB(A) at a wind speed of 8 m/s.
    (b) 42 dB(A) at a wind speed of 6 m/s.
2) At the most noise-exposed point in areas with noise-sensitive land use:
    (a) 39 dB(A) at a wind speed of 8 m/s.
    (b) 37 dB(A) at a wind speed of 6 m/s.

Subsection 2. The total low-frequency noise from wind turbines may not exceed 20 dB at a wind speed of 8 and 6 m/s indoors in dwellings in open countryside or indoors in areas with noise-sensitive land use respectively.
Subsection 3. The limit values laid down in subsections 1 and 2 do not apply to the wind turbine owner's dwelling.

SECTION 5. The noise impact, cf. Section 4, subsections 1 and 2, is determined in accordance with the guidelines in Annex 1 and is stated as the equivalent, corrected, A-weighted noise level at a height of 1.5 metres at wind speeds corrected to a height of 10 metres at 6 and 8 m/s respectively at a roughness length of 0.05 metres.

SECTION 6. Measurements of the source strength of wind turbines and of tone levels in the noise are carried out in accordance with the instructions in Annex 1 as 'Environmental Measurements - External Noise', cf. Statutory Order on Quality Requirements for Environmental Measurements.
Subsection 2. Measurements of wind turbines fitted with several generators must use the noise emission from the wind turbine operating with the noisiest generator as the basis for the noise measurement.

Chapter 3
Test wind turbines

SECTION 7. Dwellings etc that are constructed or converted in existing buildings within a noise impact area around test wind turbines after the date of publication of proposals for the district plan designating the area for the installation of test wind turbines are not included in the assessment of noise from test wind turbines, cf. subsection 2.
Subsection 2. Dwellings etc that are constructed or converted in existing buildings within a noise impact area around offshore test wind turbines after the date of publication of the environmental impact assessment (EIA) are not included in the noise assessment for these wind turbines.
Subsection 3. When wind turbines are to be installed or modified outside an area designated for test wind turbines onshore or outside an offshore area, where the Danish Energy Agency has granted permission for the installation of test wind turbines pursuant to Section 25 of the Danish Promotion of Sustainable Energy Act, the total noise impact from the test wind turbines on which the noise impact area of the wind turbines is based must form the basis of the assessment of whether the noise levels are in compliance with the limits set out in Section 4, subsections 1 and 2. The same applies to inspection of these wind turbines.

Chapter 4
Notifications etc.

SECTION 8. Anyone who wishes to install or modify a wind turbine in a way that may lead to increased noise emission must submit a notification of this to the municipal council. This does not, however, apply to the installation or modification of offshore wind turbines.
Subsection 2. Such notification must include documentation demonstrating that the wind turbines can comply with the noise limits set out in Section 4.
Subsection 3. Documentation must take the form of:
1) A report of measurement of noise emission from one or more specimens of the wind turbine type concerned, cf. Section 6
2) Maps of the area in which the applicant wishes to install the wind turbine(s) concerned. These maps must feature a scale and north arrow as well as accurately indicate the location of the wind

turbine(s) concerned, the location of existing wind turbines and of neighbouring dwellings and the distance to these and to other noise-sensitive land use.
3) The calculation of the noise impact found at the points referred to in Section 4 in accordance with the guidelines in Annex 1.

Subsection 4. For prototype wind turbines such measurements and calculations in accordance with subsection 3, no. 1 must be provided to demonstrate the likelihood of the turbine complying with the noise limits.

SECTION 9. Notification will be regarded as having been submitted when the municipal council has received all the information specified in Section 8, subsection 3. Notification may take place when the required planning basis, land zone permissions, if required, and EIA permit for the wind turbine have been obtained, cf. Statutory Order on the Assessment of the Environmental Impact of Certain Public and Private Facilities.

Subsection 2. If the municipal council has not within four weeks from the date specified in subsection 1 made any objections, the wind turbine may be installed or modified unless this is prevented by other legislation.

Subsection 3. Building and construction work may not commence before the expiry of this four-week time limit unless the municipal council prior to this announces that it will not object to the notification.

Subsection 4. In areas which, according to municipal or district planning, have been reserved for the installation of several wind turbines or designated as wind farms, and where notification of individual wind turbines takes place consecutively, the municipal council may, to ensure that the total noise impact from all the wind turbines in the mentioned areas complies with the noise limits set out in Section 4, set more restrictive requirements for the noise contributed by the individual wind turbine than the noise limits set out in Section 4.

SECTION 10. When a wind turbine is put into operation after installation, the municipal council must be informed of this. This does not, however, apply to offshore wind turbines where the information is to be submitted to the Danish Environmental Protection Agency.

Subsection 2. If a wind turbine has not been put into operation within two years of the expiry of the time limit set out in Section 9, subsection 2 a new notification containing the information specified in Section 8, subsection 3 must be submitted to the municipal council.

Chapter 5
Inspection and orders on noise measurements

SECTION 11. The municipal council supervises compliance with this Statutory Order, cf. subsection 2.

Subsection 2. The Danish Environmental Protection Agency supervises compliance with this Statutory Order for offshore wind turbines.

SECTION 12. The municipal council may order the owner of a wind turbine at his own expense to carry out noise measurements and calculations, cf. Sections 5 and 6,
1) when a wind turbine has been put into operation
2) in conjunction with general statutory supervision, but not more often than once a year, or
3) in conjunction with the processing of neighbours' complaints about noise when the municipal council considers this to be necessary.

Subsection 2. The municipal council may in conjunction with its supervision of small wind turbines decide that noise measurements should not be carried out as 'Environmental Measurement - External Noise' cf. Section 6, subsection 1.
Subsection 3. Subsections 1 and 2 do not apply to offshore wind turbines.

Chapter 6
Complaints and penalties

SECTION 13. With the exception of decisions pursuant to Section 12 and all decisions relating to municipally-owned or municipally-operated wind turbines, decisions taken by the municipal council cannot be appealed to another administrative authority.

SECTION 14. Unless a greater penalty is prescribed in accordance with other legislation, a fine will be imposed on anyone who
1) installs or modifies a wind turbine in a way that may lead to increased noise emission without notification and appropriate documentation, cf. Section 8,
2) commences building and construction work or installs a wind turbine irrespective of objections from the municipal council, cf. Section 9, subsections 2 or 4
3) commences building and construction work in contravention of Section 9, subsection 3,
4) puts a wind turbine into operation in contravention of Section 10, or
5) fails to comply with an order under Section 12.

Subsection 2. The penalty may increase to imprisonment of up to two years if the infringement has been committed intentionally or due to gross negligence and if, as a result of the infringement:
1) damage has been caused to the environment or a risk of this has arisen, or
2) an economic advantage has been obtained or is intended to be obtained for the person concerned or others, including through savings.

Subsection 3. Criminal liability can be imposed on companies etc. (legal entities) in accordance with the rules in Chapter 5 of the Danish Criminal Code.

Chapter 7
Entry into force

SECTION 15. This Statutory Order enters into force on 1 January 2012.
Subsection 2. Section 7 applies to test wind turbines where the EIA report for offshore wind turbines or proposals for district plans designating the area for the installation of test wind turbines have been published on 1 January 2012 or later.
Subsection 3. If a wind turbine has been notified in accordance with regulations applicable prior to 1 January 2012, but has not been put into operation within 2 years of the expiry of the municipal council's objection period, a new notification containing the information specified in Section 8, subsection 3 of this Statutory Order must be submitted to the municipal council. This does not, however, apply to offshore wind turbines.
Subsection 4. Statutory Order no. 1518 of 14 December 2006 on Noise from Wind Turbines is repealed, but continues to apply for wind turbines notified or put into service prior to 1 January 2012.
Subsection 5. Statutory Order no. 304 of 14 May 1991 on Noise from Wind Turbines is repealed, but continues to apply for wind turbines notified or put into operation prior to 1 January 2007.

The Danish Ministry of the Environment
IDA AUKEN

Annex 1

Part 1

1.1. General rules for measurement of noise emission from wind turbines

Measurement position for onshore wind turbines

The noise emission from a wind turbine (sound power level L_{WA} in 1/3 or 1/1 octave bands) is measured at different levels of the electrical power produced by the turbine at a point on the leeward side of the tower. Measurements must be taken at a distance R from the base of the turbine, which must not deviate more than ± 20% from the distance R_0 (see figure 1). The deviation from R_0 must not exceed ± 30 metres. The distance R_0 is the hub height of the wind turbine (h) plus the radius of the rotor (½ d). For a vertical axis wind turbine the distance R_0 is instead the height to the middle of the rotor plus the diameter of the element rotating on the vertical axis; this is not illustrated.

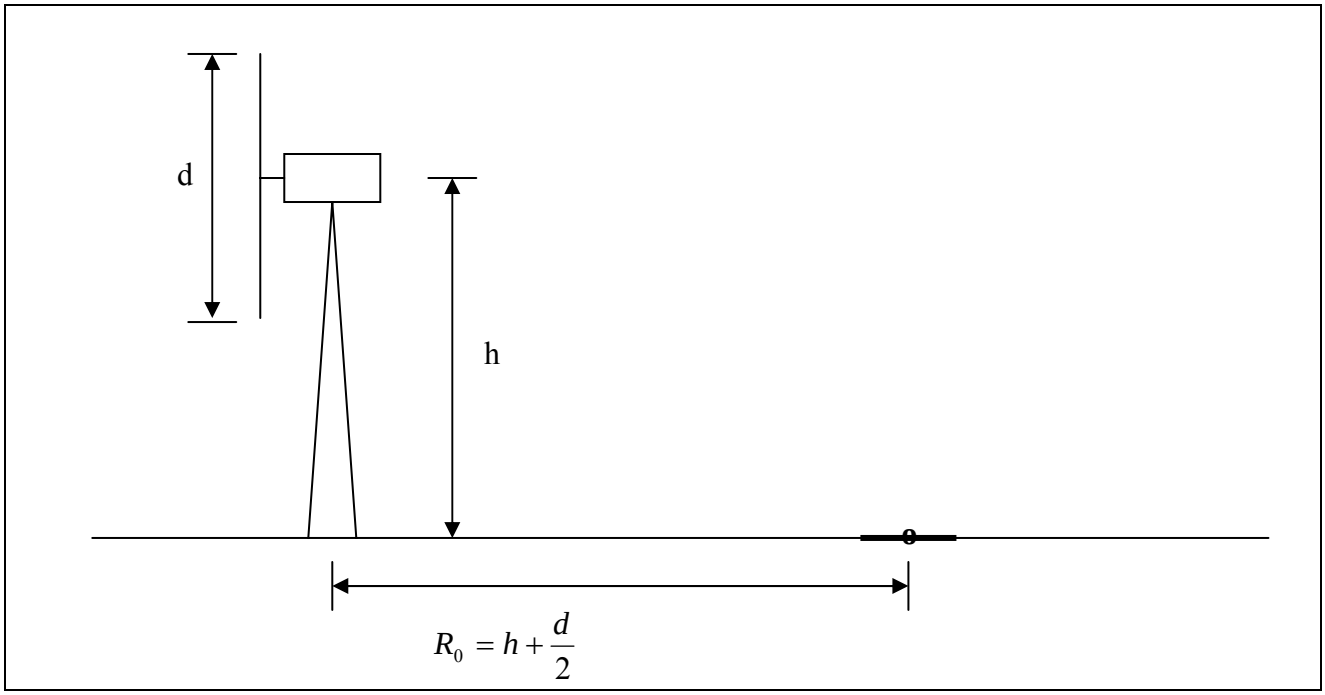

Figure 1.

During the measurement the microphone must be positioned so that the direction from the tower of the turbine to the microphone does not deviate more than ±15° from the wind direction.

Based on the sound measurements, A-weighted reference spectra are determined at wind speeds of 6 and 8 m/s respectively.

One half of a windscreen is affixed to the microphone, which is positioned directly on a reflective board on the ground in order to eliminate wind noise in the microphone as much as possible. The

board must be no smaller than one metre in any direction. The wind may produce too high a level of background noise when measuring noise emissions at low frequencies. This may be counteracted by using a secondary windscreen which is hemispherical, between 40 and 50 cm in diameter or larger and located concentrically above the microphone and the primary windscreen. If a secondary windscreen is used, the attenuation of sound caused by the windscreen must be corrected for. Correction must be made in the 1/3 octave bands.

Measurement of sound spectra and wind speed

The noise from the wind turbine is measured as a number of A-weighted sound spectra per 1/3 octave in a frequency area including, as a minimum, the 1/3 octave bands from 20 to 10,000 Hz. A number of sound spectra must be measured in periods of either 10 or 60 seconds. In the same period, the average electrical power produced by the turbine is registered as well as the wind speed measured with the built-in anemometer in the wind turbine at hub height and with an anemometer erected at a height of at least 10 metres near the wind turbine in a position where neither the wind turbine nor other objects in the area are deemed to affect the wind measurement.

When the average electrical power produced by the wind turbine is less than 0.95 times its nominal power, the wind speed v_h at hub height can be calculated on the basis of the power curve of the wind turbine. The wind speed v_{ref} at a height of 10 metres under reference conditions may then be determined by using Equation 1.1.1. At higher electrical output the wind speed v_h at hub height is determined instead by using the built-in anemometer in the wind turbine at hub height, and the wind speed v_{ref} is determined by using Equation 1.1.1. If in exceptional cases the power curve of the wind turbine is not known, or when the wind turbine has been parked due to background noise being measured, the wind speed is determined by using the anemometer erected at a height of at least 10 metres. The wind speed v_{ref} is then determined by using Equation 1.1.2.

Based on all measurements while the wind turbine is in operation with an average power of less than 0.95 times nominal power, the correlation between the three different wind speed measurements is established as follows: For each measurement period of 10 or 60 seconds the ratio between the wind speed based on the power curve of the wind turbine and the two separately measured wind speeds is determined, and finally the average value of all ratios for each of the two anemometers is determined. These averaged ratios must be multiplied with the readings from the built-in anemometer in the wind turbine at hub height when the average power produced is more than 0.95 times nominal power and with the reading on the anemometer erected at a height of at least 10 metres when the wind turbine has been parked and background noise is measured. This constitutes an *in situ* calibration of the built-in anemometer in the wind turbine and the erected anemometer. Because the power curve of the wind turbine is used to establish the correlation between the power produced and the wind speed, a copy of the power curve must form part of the report on source strength measurements.

For an averaging period of 10 seconds a minimum of 30 spectra must be measured at average electrical power equivalent to the wind speed v_{ref} at a height of 10 metres under reference conditions falling within a range of 5.5 m/s $\leq v_{ref} \leq$ 6.5 m/s and a minimum of 30 spectra where v_{ref} similarly falls within a range of 7.5 m/s $\leq v_{ref} \leq$ 8.5 m/s. For an averaging period of 60 seconds proportionally fewer spectra may be measured in each of the two ranges. Of the above, a minimum of 12 of the spectra (for a period of 10 seconds) must fall within the following four ranges for v_{ref}:

$5.5 \text{ m/s} \leq v_{ref} < 6.0 \text{ m/s}$
$6.0 \text{ m/s} \leq v_{ref} \leq 6.5 \text{ m/s}$
$7.5 \text{ m/s} \leq v_{ref} < 8.0 \text{ m/s}$
$8.0 \text{ m/s} \leq v_{ref} \leq 8.5 \text{ m/s}$

The A-weighted reference spectrum at 6 and 8 m/s respectively for each 1/3 octave bands (or 1/1 octave bands) is then determined as the average energy value of the measured sound pressure spectra for v_{ref} within the specified ranges at around 6 and 8 m/s respectively.

$$v_{ref} = v_h \cdot \frac{\ln \frac{z_{ref}}{z_{0ref}}}{\ln \frac{h}{z_{0ref}}}$$

where:
h = turbine hub height (in metres)
z_{0ref} = reference roughness 0.05 metres (fixed value)
z_{ref} = reference height 10 metres (fixed value)

Equation 1.1.1. Correction of wind speed measured at hub height to a height of 10 metres.

If the wind speed is measured at height z, the correlation between v_{ref} and v_z is shown in Equation 1.1.2.

$$v_{ref} = v_z \cdot \frac{\ln \frac{z_{ref}}{z_{0ref}} \cdot \ln \frac{h}{z_0}}{\ln \frac{h}{z_{0ref}} \cdot \ln \frac{z}{z_0}}$$

where:
z = height of the erected anemometer (in metres)
z_0 is the roughness of the terrain at the measurement location. The roughness of the terrain z_0 is estimated based on Table 1.1.

Equation 1.1.2. Correction of wind speed measured by erected anemometer at height z to 10 metres.

Type of terrain	**Roughness z_0 [metres]**
Water, snow, sand	0,0001
Open, flat land, bare soil, mown grass	0,01
Farmland with some vegetation	0,05
Residential areas, small towns, areas with dense, tall vegetation	0,3

Table 1.1: Roughness for different types of terrain

Correction for background noise, determination of sound power level

With the turbine parked, the background noise is measured as an equivalent number of sound spectra and within the same wind speed ranges as indicated above. The wind speed is measured using an anemometer erected at a height of at least 10 metres, and the wind speed v_{ref} is calculated using Equation 1.1.2.

The average energy value of the measured background noise spectra is determined at 6 and 8 m/s respectively and used to correct the wind turbine's reference spectrum by correcting the sound pressure levels $L_{A,\,ref}$ in each 1/3 octave band (or 1/1 octave band) in the reference spectrum by use of Equation 1.1.3. If the sound pressure level in the reference spectrum is not at least 3 dB higher than the sound pressure level of the background noise, the correction for background noise must be limited to 3 dB.

The total level L_{Aeq} of the averaged background noise must be at least 6 dB lower than the total level L_{Aeq} of the wind turbine noise. If this is not the case, a new measurement must be carried out when the background noise is lower. However, for inspection of noise impact, measurements may be used where the different between total noise and background noise is less than 6 dB provided the calculated noise level after correction for a background noise of -1.3 dB is no higher than the limit values.

$$L_{A,ref,k} = 10 \cdot \log(10^{\frac{L_{A,ref}}{10}} \div 10^{\frac{L_{A,b}}{10}})$$

where:
$L_{A,\,ref,\,k}$ = the corrected reference sound pressure level in 1/3 octave bands (or 1/1 octave bands)
$L_{A,\,b}$ = the sound pressure level of the averaged background noise in 1/3 octave bands (or 1/1 octave bands)

Equation 1.1.3. Correction for background noise

The wind turbine's sound power level $L_{WA,\,ref}$ in 1/3 octave bands (or 1/1 octave bands) can then be calculated using Equation 1.1.4.

$$L_{WA,ref} = L_{A,ref,k} + 10 \cdot \log 4\pi(R^2 + h^2) \div 6dB$$

6 dB is a correction due to measuring close to a reflective board on the ground
R = the current measuring distances between the microphone and the base of the wind turbine.

Equation 1.1.4. The sound power level of the wind turbine

The method described complies with IEC 61400-11, and measurements carried out in accordance with this standard may be used as a basis for the determination of $L_{WA,ref}$.

1.2. Determination of sound pressure level L_{pA}

At a point, e.g. by the nearest neighbour, the wind turbine's sound pressure level in 1/3 octave bands (or 1/1 octave bands) at a height of 1.5 metres can be determined using Equation 1.2.1.

$$L_{pA} = L_{WA,ref} \div 10 \cdot \log(l^2 + h^2) \div 11dB + \Delta L_g \div \Delta L_a$$

where:
l = the distance from the base of the turbine to the calculation point
11 dB = correction for distance, 10 x log 4π
ΔL_g = correction for ground effect (1.5 dB for onshore turbines and 3 dB for offshore turbines)
ΔL_a = air absorption, ($\alpha_a \times \sqrt{l^2 + h^2}$) where the absorption coefficient α_a is shown in Tables 1.2 and 1.3.

Equation 1.2.1. Calculation of sound pressure level in 1/3 octave bands (or 1/1 octave bands)

Calculations are carried out for 1/3 octave bands 50-10,000 Hz or 1/1 octave bands 63-8,000 Hz.

Octave band centre frequency in Hz	**63**	**125**	**250**	**500**	**1000**	**2000**	**4000**	**8000**
α_a in dB/km	0,11	0,38	1,02	2,0	3,6	8,8	29,0	104,5

Table 1.2: Air absorption coefficients per 1/1 octave at a relative air humidity of 80% and an air temperature of 10º C

1/3 octave centre frequency in Hz	**50**	**63**	**80**	**100**	**125**	**160**	**200**	**250**	**315**
α_a in dB/km	0,07	0,11	0,17	0,26	0,38	0,55	0,77	1,02	1,3

1/3 octave centre frequency in Hz	**400**	**500**	**630**	**800**	**1000**	**1250**	**1600**	**2000**
α_a in dB/km	1,6	2,0	2,4	2,9	3,6	4,6	6,3	8,8

1/3 octave centre frequency in Hz	**2500**	**3150**	**4000**	**5000**	**6300**	**8000**	**10000**
α_a in dB/km	12,6	18,8	29,0	43,7	67,2	105	157

Table 1.3: Air absorption coefficients per 1/3 octave at a relative air humidity of 80% and an air temperature of 10º C

A safety margin may be added so that higher numbers for the source strength $L_{WA,ref}$ are used for the calculations than those shown in the measurement report. The total A-weighted sound pressure level $L_{pA,\,tot}$ at the point is then found by adding the sound pressure levels $L_{pA,\,i}$ in each 1/3 octave band (or 1/1 octave band), cf. Equation 1.2.2.

$$L_{pA,tot} = 10 \cdot \log \sum 10^{\frac{L_{pA,i}}{10}}$$

Equation 1.2.2. Total sound pressure level

The uncertainty of the calculated sound pressure level $L_{pA,\,tot}$ by use of this method is ±2 dB.

1.3. Determination of tones and noise exposure level L_r

In order to determine the noise exposure level L_r (noise impact) at a given point, the content of clearly audible tones in the noise is assessed.

The assessment is carried out near the dwelling with the highest noise exposure by means of an objective measurement in accordance with the guidelines contained in Chapter 7 of the Danish Environmental Protection Agency's Guideline on Measuring External Noise, no. 6/1984. The use of this method presupposes that the tones are stationary, i.e. that both the level of the tones and the level of the masking noise are determined by averaging a number of spectra which correspond to an analysis period of at least one minute. The frequency analyses must be carried out on A-weighted spectra.

The noise measurement must be carried out at a representative point close to the nearest dwelling, 1.5 metres above ground and selected in such a way that the wind noise has as little effect as possible on the measurement results.

There must be a tailwind ± 45° from the wind turbine towards the measurement position, and the wind speed measured at 10 metres above ground must be between 6 and 8 m/s. Measurement must take place in a time interval where the tone is most prominent.
In this context, there are no requirements for temperature gradient or cloud cover.

If a frequency analysis of the wind turbine noise measured close to the turbine as described in the procedures for measurement of the A-weighted sound power level shows that no clearly audible tones occur near the turbine, no tones will occur near dwellings either and the assessment at the neighbouring dwelling would be unnecessary.

When processing a notification, the tone content may be determined on the basis of a measurement on the tailwind side of an equivalent turbine at a distance corresponding to the distance to the neighbouring point.

If the noise contains clearly audible tones, L_r is determined as specified in Equation 1.3.1.

$$L_r = L_{pA,tot} + 5dB$$

Equation 1.3.1. Determination of clearly audible tones

1.4. Determination of low-frequency noise from wind turbines

The level of low-frequency noise, e.g. in the nearest dwelling, is determined by use of Equation 1.4.1.

$$L_{pALF} = L_{WA,ref} \div 10 \cdot \log(l^2 + h^2) \div 11dB + \Delta L_{gLF} \div \Delta L_{\sigma} \div \Delta L_a$$

where:
l = the distance from the base of the wind turbine to the calculation point
11 dB = correction for distance, 10 x log 4π
ΔL_{gLF} = correction for ground effect at low frequencies (Table 1.4)
ΔL_{σ} = sound insulation at low frequencies (Table 1.4)
ΔL_a = air absorption, ($\alpha_a \times \sqrt{l^2 + h^2}$) where the absorption coefficient α_a is shown in Table 1.4.

Equation 1.4.1. Calculation of low-frequency noise from wind turbines in 1/3 octave bands

1/3 octave centre frequency in Hz	**10**	**12,5**	**16**	**20**	**25**	**31,5**	**40**
ΔL_{gLF}: ground correction, onshore wind turbine (dB)	6,0	6,0	5,8	5,6	5,4	5,2	5,0
ΔL_{gLF}: ground correction, offshore wind turbine (dB)	6,0	6,0	6,0	6,0	6,0	5,9	5,9
ΔL_{σ}: sound insulation (level difference) (dB)	4,9	5,9	4,6	6,6	8,4	10,8	11,4
α_a in dB/km	0,0	0,0	0,0	0,0	0,02	0,03	0,05

1/3 octave centre frequency in Hz	**50**	**63**	**80**	**100**	**125**	**160**
ΔL_{gLF}: ground correction, onshore wind turbine (dB)	4,7	4,3	3,7	3,0	1,8	0,0
ΔL_{gLF}: ground correction, offshore wind turbine (dB)	5,8	5,7	5,5	5,2	4,7	4,0
ΔL_{σ}: sound insulation (level difference) (dB)	13,0	16,6	19,7	21,2	20,2	21,2
α_a in dB/km	0,07	0,11	0,17	0,26	0,38	0,55

Table 1.4: Terrain correction for low-frequency noise for wind turbines location onshore and offshore respectively, sound insulation (level difference) and air absorption coefficients per 1/3 octave at a relative air humidity of 80% and an air temperature of 10º C

Ground correction for offshore wind turbines is valid for calculation of low-frequency noise in a building close to the coast. If noise is to be calculated in a building which, seen in the direction of the wind turbines, is more than 200 metres inland, the terrain correction for onshore wind turbines is used instead. For buildings located between 0 and 200 metres from the coast linear interpolation between the two values for terrain correction is made.

The total A-weighted sound pressure level $L_{pALF,\,tot}$ in the dwelling is then found by adding the sound pressure levels $L_{pALF,\,i}$ in each 1/3 octave band, cf. Equation 1.4.2.

$$L_{pALF,tot} = 10 \cdot \log \sum 10^{\frac{L_{pALF,i}}{10}}$$

Equation 1.4.2. Total sound pressure level

The uncertainty of the calculated sound pressure level $L_{pALF, tot}$ by use of this method is ±2 dB.

Part 2

Special rules

2.1 Determination of noise from wind farms

In this Statutory Order a wind farm means a cluster of three or more identical wind turbines irrespective of whether these are erected onshore or offshore.

The sound power level $L_{WA, ref}$ in 1/3 octave bands or 1/1 octave bands is determined by measurements of at least three randomly selected wind turbines of the same type. For the other wind farm turbines the average energy value of the three (or more) measured sound power levels is used.

The erected anemometer must, if it is located on the tailwind side of one of the other wind turbines, have a distance to this wind turbine of at least ten times the rotor diameter (d) of the turbine. See Figure 1.

The sound pressure level in 1/3 octave bands or 1/1 octave bands at a point is found by adding the noise contribution from each wind turbine calculated using Equation 1.2.1, as shown in Equation 2.1.

$$L_{total} = 10 \cdot \log(10^{\frac{L_p 1}{10}} + 10^{\frac{L_p 2}{10}} + ...)$$

Equation 2.1. Total sound pressure level from several wind turbines

The same formula is used when the contribution from a new wind turbine needs to be added to the sound pressure level produced by the existing wind turbines around the dwelling concerned.

The total A-weighted sound pressure level $L_{pA, tot}$ at the point is then found by using Equation 1.2.2.

2.2 Measurement of noise emission from offshore wind turbines

A. Microphone mounted on a reflective board on the ship

Compared to measurements for onshore wind turbines, the measurement method is changed so that the reflective board on to which the microphone is placed is affixed to the roof of the pilot house on the measuring vessel or on a correspondingly large surface with an unobstructed view to the wind turbine from the location of the microphone. The roof or board must be no smaller than four metres in any direction.

Otherwise the instructions set out in Chapter 1, Section 1, apply.

B. The microphone mounted off the side of the ship

If the microphone cannot be mounted as specified under Heading A, the microphone must be positioned 3-5 metres above sea level, free from reflective surfaces, etc. and 1-2 metres away from the side of the measurement vessel with an unobstructed view to the wind turbine. A primary windscreen must be affixed to the microphone, and the microphone axis must point in the direction of the hub of the wind turbine.

The noise from the wind turbine is measured as A-weighted spectra for a number of periods in accordance with the guidelines set out in Chapter 1, Section 1 for onshore wind turbines, with simultaneous recording of the power produced by the wind turbine, the wind speed at hub height measured by the built-in anemometer in the wind turbine and the wind speed v_z at a height of at least 10 metres above sea level with the anemometer placed on the same vessel as the microphone. Due to the low roughness value of the surface of the sea, $v_z = v_{ref}$.

If the background noise is too high, its effect may be reduced by increasing the height of the microphone to five metres and reducing the measuring distance.

The turbine's sound power level $L_{WA,\,ref}$ in 1/3 octave bands (or 1/1 octave bands) is then determined as indicated in 2.2.

$$L_{WA,ref} = L_{A,ref,k} + 10 \cdot \log 4\pi(R^2 + h^2) \div 3dB$$

Equation 2.2. Sound power level for offshore wind turbines

The instructions above for the measurement of the noise impact of wind farms also apply to the measurement of the noise impact of offshore wind farms.

2.3 Measurement of noise emission from small wind turbines

For small wind turbines, including domestic turbines, the source strength is determined in accordance with the principles in the method specified in 1.1 with the option of the following deviation:

- During measurement the microphone must be positioned in such a way that the direction from the tower of the turbine to the microphone does not deviate more than ±45° from the wind direction.

Small wind turbines usually do not provide the option of direct reading of the power produced in short time ranges, and the correlation between the noise emission of the wind turbine and the wind speed is, therefore, based on measurements by an anemometer erected at a height of at least 10 metres near the wind turbine in a position where neither the wind turbine nor other objects in the area are deemed to affect the wind measurement.