The full text

Statutory Order on noise from wind turbines

Pursuant to section 7(1), no. 1 and 2, section 7a(1), section 92 and section 110(3) and (4) of the Danish Environmental Protection Act, cf. Consolidation Act No 753 of 25 August 2001, as amended by Act No 475 of 7 June 2001, Act No 385 of 25 May 2005, Act No 569 of 24 June 2005 and Act No 244 of 27 March 2006, the following is laid down:

Part 1

Scope

Section 1. This Executive Order shall apply to the installation, modification and operation of wind turbines.

Part 2

Requirements for wind turbines

Section 2. Anyone who owns a wind turbine is responsible for it being installed, operated and maintained in such a way that the provisions of this Executive Order are complied with.

Section 3. The noise impact from wind turbines may not exceed the following limit values:

1) At the most noise-exposed point in outdoor residential areas, no more than 15 metres from the neighbouring dwelling 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 outdoor residential areas, in areas for 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.

(2) For the purposes of this Executive Order, the following definitions shall apply:

1) Neighbouring dwelling: any other dwelling than the wind turbine owner's private dwelling.

2) Noise-sensitive land use: areas which are used for or in district plans or town planning regulations have been assigned for residential, institutional, holiday home or allotment purposes or as recreational areas.

Section 4. The noise impact is determined in accordance with the guidelines in Annex 1 and is stated as the equivalent, 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.

(2) Measurements are carried out as "Environmental measurements – external noise", cf. Executive Order on quality requirements for environmental measurements carried out by accredited laboratories, certified individuals, etc.

(3) Measurements of wind turbines which are fitted with several generators shall use the noise emitted from the noisiest generator as the basis for the noise measurement.

Part 3

Notifications etc.

Section 5. Anyone who wishes to install or modify a wind turbine shall submit notification to the municipal council of this.

(2) The notification shall include documentation that the wind turbines can comply with the noise limits in section 3.

(3) Documentation shall take the form of:

1) A report of the noise emission readings from one or more specimens of the notified wind turbine type.

2) Maps of the area in which the applicant wishes to install the notified wind turbine(s). The maps shall feature a scale and North arrow as well as accurately indicate the location of the notified wind turbine(s), the location of existing wind turbines and of neighbouring dwellings and the distance to these and another noise-sensitive land use.

3) The calculation of the noise impact found at the points referred to in section 3 in accordance with the guidelines in Annex 1.

(4) For prototype turbines there shall be measurements and calculations under section 3(1) so that the likelihood of the turbine complying with the noise limits can be worked out.

Section 6. The notification is considered to have been submitted when the municipal council has received all the information specified in section 5(3).

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

(3) Building and construction work may not commence before the expiry of this four-week deadline unless the municipal council announces before then that it will not object to the notification.

(4) In areas which, according to municipal or district land-use planning, are reserved for the installation of several wind turbines or assigned to be wind farms, and where notification of individual wind turbines takes place consecutively, the municipal council may on the basis of the calculations of the noise from the individual wind turbine set more extensive requirements for the noise contributed by the individual wind turbine than the noise limits set out in section 3, so that the total noise contribution from the wind turbines in the area can comply with the noise limits in section 3.

Section 7. When a wind turbine is put into operation the municipal council shall be informed of this.

(2) If a notified wind turbine is not put into operation within two years of the expiry of the deadline in section 6(2), a new notification containing the information specified in section 5(3) shall be submitted to the municipal council.

Part 4

Orders on noise measurements

Section 8. The municipal council may order the owner of a wind turbine to carry out noise measurements at their own expense, cf. section 4:

1) when a notified wind turbine is put into operation;

2) in connection with general statutory supervision, however no more than once a year; or

3) in connection with the processing of neighbours' complaints about noise, when the municipal council considers this to be necessary.

Part 5

Appeals and penalties

Section 9. With the exception of decisions pursuant to section 8 and all decisions relating to municipally-owned or municipally-operated wind turbines, decisions taken by the municipal council may not be appealed to another administrative authority.

Section 10. Unless a higher penalty is prescribed under other legislation, a fine shall be imposed on anyone who:

1) installs or modifies a wind turbine without notification or proper documentation, cf. section 5;

2) commences building and construction work or installs a wind turbine irrespective of any objections from the municipal council, cf. section 6(2) or (4);

3) commences building and construction work in contravention of section 6(3);

4) puts a wind turbine into operation in contravention of section 7; or

5) fails to comply with an order under section 8.

(2) The penalty may be increased to a prison sentence of up to two years should the infringement be committed intentionally or through gross negligence and if the infringement has

1) caused damage to the environment or resulted in the risk thereof, or

2) achieved, or was intended to achieve, financial gain for the person concerned or for others, including as a result of savings made.

(3) Criminal liability may be imposed on companies etc. (legal persons) under the rules of Part 5 of the Danish Penal Code.

Part 6

Entry into force and transitional provisions

Section 11. This Executive Order shall enter into force on 1 January 2007 and shall be repealed automatically on 31 December 2012, unless otherwise determined before this date, cf. the Danish Ministry of Justice's letter dated 28 February 2002 relating to a pilot scheme for the application of automatic expiration clauses in certain executive orders covering environmental and working environment issues.

(2) Section 6(4) also applies to areas which, according to district land-use planning, are reserved for the installation of several wind turbines or assigned as a wind farm, until this planning is changed or repealed, cf. section 3(1), (2) or (4) of Act No 571 of 24 June 2005 on amending the Danish Planning Act.

(3) Executive Order No 304 of 14 May 1991 on noise from wind turbines is repealed but shall still apply to wind turbines which have been notified or put into operation before 1 January 2007.

(4) If a wind turbine is notified before 1 January 2007 but not put into operation within two years of the municipal council's deadline for objections expiring, a new notification containing the information specified in section 5(3) shall be submitted to the municipal council in accordance with this Executive Order.

The Danish Ministry of the Environment, 14 December 2006

Connie Hedegaard

/Karsten Skov

Annex 1

Part 1

1. General rules for measuring noise emission from a wind turbine

The method in sections A-C generally complies with IEC 61400-11 (2002). Measurements carried out in accordance with this standard can be used as the basis for the determination of $L_{WA,ref}$.

A. Land-based turbines

A turbine's noise emission (sound power level L_{WA} in 1/1 octave band) 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).

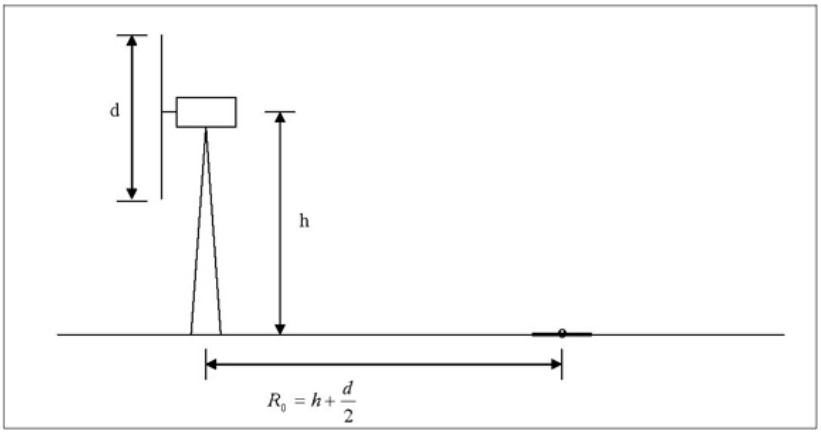

Figure 1

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.

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

Half a wind protector is affixed to the microphone, which is positioned directly above a reflective plate on the ground in order to eliminate wind noise in the microphone as much as possible. The plate must not be smaller than one metre in any direction.

The noise from the turbine is measured as a number of A-weighted 1/1 octave sound spectra from 63 to 8,000 Hz, each determined over at least a one minute period. For each spectrum the average electrical power produced in the same period is measured, and the corresponding wind speed v_h at the turbine's hub height h can then be read from the turbine's power curve.

At least five spectra are measured at average electrical power, corresponding to the wind speed v_{ref} at a height of 10 metres under reference conditions in the range 5.5 m/s ≤ v_{ref} < 6.5 m/s, and at least five spectra where v_{ref} corresponds to the range 7.5 m/s ≤ v_{ref} < 8.5 m/s and where the relationship between v_{ref} and v_h is given in equation 1.1.1 (below).

There should be at least one of the abovementioned spectra for each of the following four ranges for v_{ref}:

5.5 m/s ≤ v_{ref} < 6.0 m/s

6.0 m/s ≤ v_{ref} < 6.5 m/s

7.5 m/s ≤ v_{ref} < 8.0 m/s

8.0 m/s ≤ v_{ref} < 8.5 m/s

The A-weighted reference spectrum at 6 and 8 m/s respectively is then determined as the average energy value of the measured sound pressure spectra for v_{ref} situated in the specified intervals at around 6 and 8 m/s respectively.

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

h = the turbine's hub height in metres

z_{0ref} = reference roughness 0.05 metres (fixed value)

z_{reff} = reference height 10 metres (fixed value)

Equation 1.1.1. Correction of wind speed for turbines with known power curve

B. Turbines without known power curve

If in exceptional cases the turbine's power curve is unknown and v_h can therefore not be determined, the wind speed at the location can be measured at a representative, freely sited position on the turbine's headwind side at a height of at least 10 metres.

The distance between the anemometer and the tower of the turbine must be within two and four times the turbine's rotor diameter d, just as the perpendicular distance between the anemometer and the vertical plane on which the rotor's axis of rotation is situated must be no greater than d.

The measurements must be carried out at the same time as the noise measurements.

If the wind speed is measured at the height z, the relationship between v_{ref} and v_z is given using equation 1.1.2:

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

The roughness of the terrain z_0 is estimated on the basis of table 1.

Equation 1.1.2. Correction of wind speed for turbines without known power curve

Type of terrain	**Roughness z0 [metres]**
Water, snow, sand	0.0001
Flat open countryside, bare soil, cut lawns	0.01
Agricultural areas with vegetation	0.05
Residential areas, small towns, areas of dense, tall vegetation	0.3

Table 1: Roughness for various types of terrain

C. Correction for background noise

With the turbine stopped, the background noise is measured off for at least five A-weighted 1/1 octave sound spectra, each of one minute's duration at wind speeds v_z, corresponding to v_{ref} being in the range 5.5 m/s ≤ v_{ref} < 6.5 m/s, and for at least five spectra when wind speeds v_z correspond to v_{ref} being in the interval 7.5 m/s ≤ v_{ref} < 8.5 m/s.

The relationship between v_z and v_{ref} is given in equation 1.1.2.

The value v_z is measured at the same time as the background measurements in a freely located position as described above.

The average energy value of the measured background noise spectra is determined at 6 and 8 m/s respectively and used to correct the turbine's reference spectrum, where the sound pressure levels $L_{A,\,ref}$ of each octave band in the reference spectrum are corrected in accordance with equation 1.1.3.

The total level $L_{A,\,eq}$ of the averaged background noise must be at least 6 dB lower than the total level $L_{A,\,eq}$ of the turbine noise. If this is not the case, a new measurement must be carried out when the background noise is lower. In connection with the checking of noise impact, measurements may, however, be used where the difference between total noise and background noise is less than 6 dB, provided that the calculated noise level after a background noise correction 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 1/1 octave band

$L_{A,\,b}$ = the averaged background sound pressure level in 1/1 octave band

Equation 1.1.3. Correction for background noise

The turbine's sound power level $L_{WA,\,ref}$ in 1/1 octave band is then found 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 plate on the ground

R = the actual measuring distance in metres between the microphone and the base of the turbine.

Equation 1.1.4. The turbine's sound power level

2. Determination of sound pressure level L_{pA}

At a point, e.g. by the nearest neighbour, the turbine's sound pressure level in 1/1 octave band at a height of 1.5 metres can be determined using equation 1.2.1:

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

where

l = the distance in metres from the base of the turbine to the calculation point

11 dB = correction for distance, 10 x log 4π

ΔL_g = correction for the terrain (1.5 dB for land-based turbines and 3 dB for offshore turbines)

ΔL_a = luftabsorption ($\alpha_a \sqrt{(l^2 + h^2)}$), hvor dæmpningskoefficienten α_a fremgår af tabel 2.

Equation 1.2.1. Sound pressure level in 1/1 octave band

Octave band centre frequency in Hz	63	125	250	500	1000	2000	4000	8000
a_a in dB/m	0.0001	0.0004	0.001	0.002	0.0036	0.0088	0.029	0.1045

Table 2: Air absorption coefficients at a relative air humidity of 80% and an air temperature of 10ºC

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 the individual octave bands, 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 $L_{pA,\,tot}$ when using this method is ±2 dB.

3. Determination of tones and noise exposure L_r

In order to determine the noise impact L_r at a given point, the noise's content of clearly audible tones is assessed.

This assessment is carried out at the dwelling with the most noise exposure by objectively measuring in accordance with the guidelines in part 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 time of at least one minute.

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

There must be a tailwind ±45° from the wind turbine towards the measuring point, and the wind speed measured 10 metres above the terrain must be between 6 and 8 m/s. Measurement must take place in a time interval where the tone is clearest.

In this context there are no requirements for temperature gradient or cloud cover.

If a frequency analysis of the turbine noise measured close to the turbine as described in the procedures for measuring the A-weighted sound power level shows that no clearly audible tones occur near the turbine, the assessment at the neighbouring dwelling is unnecessary.

When processing a notification, the tone content can be determined on the basis of a measurement in the tailwind side of an equivalent turbine at a distance corresponding to the actual distance to the neighbour 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

Part 2

Special rules

1. Measuring noise from turbine groups

A turbine group is taken to mean a collection or three or more identical turbines, irrespective of whether these are installed on land or as offshore turbines.

The sound power level $L_{WA,\,ref}$ in 1/1 octave band is determined by measurements for at least three randomly selected turbines. The deviation between L_{WA} can typically be expected to be ±2-3 dB when the turbines are identical. For the other turbines in the group the average energy value of the three measured sound power levels is used.

The sound power level in 1/1 octave band at a point is found by adding the noise contributions from the individual turbines, calculated according to equation 1.2.1, as specified in equation 2.1

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

Equation 2.1. Total sound pressure level from turbine groups

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

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

If the wind speed must be measured during a noise measurement because it is not possible to measure the power produced by the turbine, the distance to this turbine from the anemometer, if it is placed on the tailwind side of the other turbines, must be at least 10 times the turbine's rotor diameter (d), see figure 1.

2. Measuring noise from offshore turbines

A. Microphone mounted on a reflective plate on the ship

Compared to measurements for land-based turbines, the measuring method is changed so that the reflective plate on to which the microphone must be directly affixed is positioned on the roof of the pilot house on the measuring ship or on some correspondingly large surface with an unobstructed view of the wind turbine from the microphone's location. The roof or surface must not be smaller than 4 metres in any direction.

The instructions in part 1.1 apply otherwise.

B. Microphone mounted on the ship without using a reflective plate

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 out from the edge of the measuring ship with an unobstructed view of the wind turbine.

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).

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.

Measurements must then be taken as follows:

A wind protector should be affixed to the microphone and the microphone axis must point towards the hub of the turbine.

The noise from the turbine should be measured as a number of A-weighted 1/1-octave sound spectra from 63 to 8,000 Hz, each determined over at least a one minute period. For each spectrum the average electrical power produced in the same period is measured, and the corresponding wind speed (v_h) at the turbine's hub height (h) can then be read from the turbine's power curve.

At least five spectra are measured at average electrical power, corresponding to the wind speed v_{ref} at a height of 10 metres under reference conditions in the range 5.5 m/s ≤ v_{ref} < 6.5 m/s, and at least five spectra where v_{ref} corresponds to the range 7.5 m/s ≤ v_{ref} < 8.5 m/s and where the relationship between v_{ref} and v_h is given in equation 1.1.1.

There should then be at least one spectrum for each of the following four ranges for v_{ref}:

5.5 m/s ≤ v_{ref} < 6.0 m/s

6.0 m/s ≤ v_{ref} < 6.5 m/s

7.5 m/s ≤ v_{ref} < 8.0 m/s

8.0 m/s ≤ v_{ref} < 8.5 m/s

The A-weighted reference spectrum at 6 and 8 m/s respectively is then determined as the average energy value of the measured sound pressure spectra for v_{ref} situated in the specified intervals at around 6 and 8 m/s respectively.

When measuring the background noise, a measurement should also be taken of the wind speed v_z at a height of 10 metres above sea level with the anemometer positioned on the same vessel as the microphone.

Due to the sea level's low roughness value, $v_z = v_{ref}$.

With the turbine stopped, at least five A-weighted 1/1 octave band sound spectra of the background noise are measured, with v_z in the same two intervals as v_{ref}, before the A-weighted reference spectrum is then corrected as described for the measurements on land-based turbines.

The total level $L_{A,\,eq}$, of the averaged background noise must be at least 6 dB lower than the total level $L_{A,\,eq}$ of the turbine noise. If this is not the case, even when using the smallest possible measuring distance and largest possible microphone height, a new measurement must be carried out when the background noise is lower. In connection with the checking of noise impact, measurements may, however, be used where the difference between total noise and background noise is less than 6 dB, provided that the calculated noise level after a background noise correction of -1.3 dB is no higher than the limit values.

The turbine's sound power level $L_{WA,\,ref}$ in 1/1 octave band is then found using equation 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 an offshore turbine