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New environmental regulation for wind turbines in Flanders (Belgium)

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Summary

Wind energy is an important pillar in the ambition of the Flemish government to realize a substantial part of the Belgian target of 13% renewable energy by 2020.

Due to the lack of sufficient environmental standards for wind turbines within the existing environmental policy and the lack of clear, unambiguous and sufficiently binding noise guidelines in the evaluation framework (circular EME/2006/01-RO/2006/02), a technical actualization of the environmental standards for wind turbines was needed. For Flanders, which is a densely populated area with very few open areas, this provides a challenge.

In the development of the new environmental noise policy, the principles of existing environmental policy were applied.

This resulted in a new environmental regulation, which was approved by the end of 2011 by the Flemish government. The regulation sets conditions related to sound, together with safety and shadow flicker and a transitional regulation. The noise of wind turbines is now regulated by noise levels that extend beyond the distance of 250 meters between wind turbines and the people living near them. In addition, this regulation is more strict for residential areas than for industrial areas.

As a result, the new policy provides legal certainty for both people living near wind turbines, wind developers and permitting authorities for the siting and exploitation of large wind turbines in Flanders.

After being evaluated and checked with international policies, the new environmental noise policy for wind turbines in Flanders sets the conditions for both existing and new wind turbines.

1. Introduction

Due to the lack of sufficient environmental standards for wind turbines within the existing environmental policy and the lack of clear, unambiguous and sufficiently binding noise guidelines in the evaluation framework (circular EME/2006/01-RO/2006/02 (Vlaamse overheid 2006)), a technical actualization of the environmental standards for wind turbines was needed.

The Flemish government has chosen to develop and implement these noise standards within the existing sectoral environmental legislation (VLAREM). This provides legal certainty for both people living near wind turbines, wind developers and permitting authorities for the siting and exploitation of large wind turbines in Flanders.

These standards set up a status quo between the annoyance which should be reduced to a minimum level for people living near wind turbines on one hand and the renewable energy targets on the other hand.

1.1 Sound of wind turbines

Sound of wind turbines is mainly generated by the movement of rotor blades through the air at high speed. The aerodynamic noise is caused by turbulence at imperfections of the rotor blades, at the edge of the blade where areas of under- and overpressure are mixed, and at the wingtips (AFFSET 2008). These three effects have a different spectral composition. Combined these cause a noise-like, repetitive sound.

Aerodynamic noise is directed by a vectorial component, which implicates that the sound of wind turbines mainly originates at the edges of downward moving rotor blades. Due to the distance between receiver and the wind turbines, it may seem for an observer that the sound originates by the passage of the rotor blades at the tower. However, detailed sound measurements of Oerlemans (Oerlemans 2009), show that this is not the case (Fig. 1).

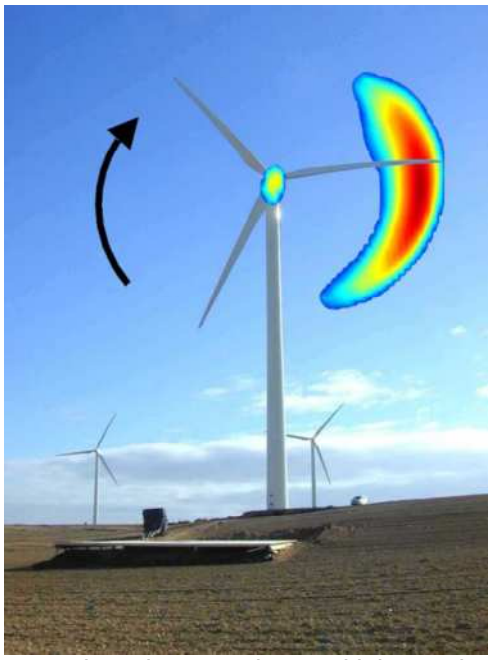

Figure 1: sound sources in the rotor plane (averaged on multiple rotations) projected on the image after measurements of microphones in an array setup (Oerlemans, 2009).

The spectral composition of about thirty types of wind turbines was compared in a Dutch study (Rijksuniversiteit Groningen 2008) including some of the most commonly used turbines. When presenting the spectra as octave bands, scaled relative to the total sound power level of the

wind turbine, it shows that most wind turbines have a more or less similar spectrum, with maxima in the octave bands of 250, 500 or 1000 Hz (Fig. 2).

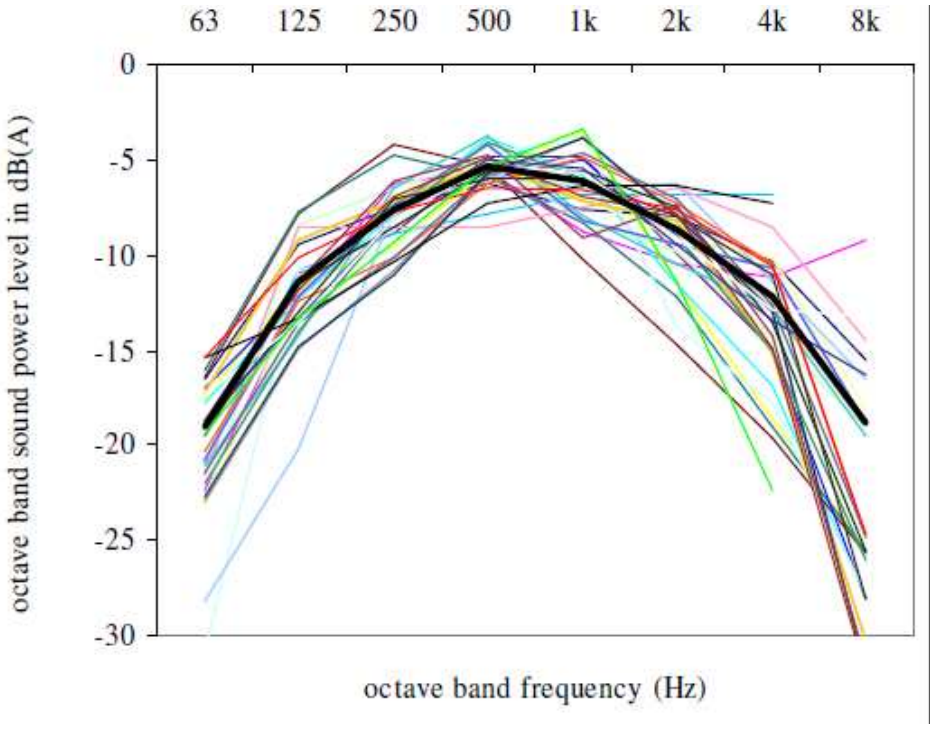

Figure 2: octave band spectra of different types of wind turbines. The average sound spectrum is shown as the bold line.

Apart from aerodynamic noise, mechanical noise can be a contributing factor as well, that can be particularly significant in older wind turbines. All components in the nacelle can cause mechanical noise with the gearbox (if present) and subunits of the generator, e.g. cooling units, being the most important source. The presence of rubber elements, isolation materials and sound dampers on ventilation systems make modern wind turbines acoustically better suited.

1.2 Annoyance of the sound of wind turbines

Sound of wind turbines is perceived as annoying. As such, it has been subject of several studies, with main contribution of Dutch and Swedish authors. Three of these studies were combined by TNO, the Dutch organization for applied scientific research, in a report commissioned by the Dutch government (TNO 2008). By using questionnaires the self-reported annoyance of wind turbine sound of people living near wind turbines was assessed. To complete the survey, multiple other parameters, such as the sensitivity to sound in general, the co-ownership of wind turbines, the visibility and possible sleep disturbance, were included. In Sweden and The Netherlands 3770 inhabitants were asked to complete the survey, with a 49% response rate. The results were correlated with the calculated sound imission levels at each participant and based on L_{den} as measure, which was derived from the maximum sound imission levels of the wind turbines ($L_{p\ 8m/s,\ at\ 10m\ height}$) using the ISO 9613-2 propagation model. These imission levels were converted to the yearly averaged sound dose measure L_{den} by incorporating the meteorological data, the location and the characteristics of the wind turbine. It was concluded that the L_{den} level corresponded with the $L_{sp\ 8\ m/s}$ level plus a correlation factor (Δ) of +4,7 dB(A).

The study concluded that the level of annoyance can be predicted by regression analysis of the calculated L_{den} value and the reported annoyance.

Compared to other sources of noise, such as from road traffic, rail traffic and air traffic, noise of wind turbines is perceived as more annoying, although perceived at the same imission level (L_{den}). (Fig. 4).

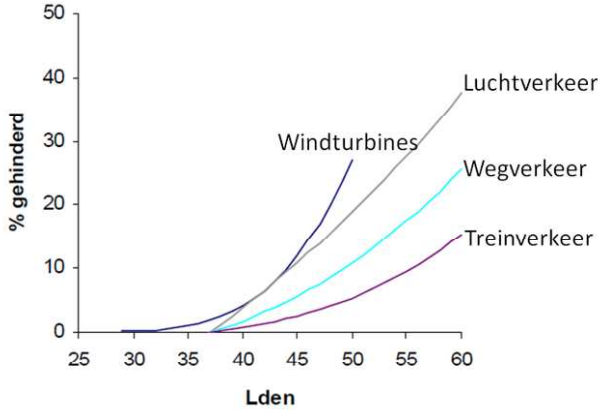

Figure 3: Annoyance of wind turbines in comparison to other noise sources (adjusted from TNO, 2008)

Traffic noise might mask the sound of wind turbines. Using the extensive WINDFARM perception research of the Dutch government (Rijksuniversiteit Groningen 2008), Pedersen and colleagues assessed this masking effect of road traffic on wind turbines showing that wind turbine noise is, however, not easily masked by road traffic noise (Pedersen *et al.* 2010). Only in case that the sound of road traffic is more than 20 dB L_{den} higher than the sound of wind turbines (L_{den}), a strong reduction of the reported annoyance was observed. In addition, wind turbine noise is not fully spectrally masked by road traffic noise. The different day- night relation of the sound source can also be part of the explanation. Where road traffic noise is often strongly reduced at night, this is not the case for wind turbines. The repetitive character of wind turbine noise also plays an important role, as this implicates a higher audibility.

1.3 Reduction of annoyance of wind turbine noise

Annoyance is partially a subjective parameter which can be influenced in several ways, by altering the perception of the wind turbine or by masking the wind turbine noise. Finally, wind turbine noise can be reduced by reducing the sound power level of the wind turbine.

1.4 Previous legislation for wind turbines in Flanders

The circular EME/2006/01-RO/2006/02 provided noise limits for wind turbines from May 2006 until March 2012. For the siting of wind turbines, it was stated that, if the closest house or residential area was located at a distance fewer than 250 to the wind turbine tower, the sound imission level of the wind turbine must be lower than the limit values in open air as listed in the circular, or 5 dB(A) lower than the background noise (L_{A95}). If the distance was more than 250 m, the circular stated that the noise level was acceptable in any case.

Indeed, experience with the circular EME/2006/01-RO/2006/02, indicated that this framework did not provide a sufficient basis to evaluate and limit the annoyance of people living near wind turbines. In addition, a circular has by definition a limited legal strength. It is a legal guideline of which the government states it will impress on itself. As a result, a more binding environmental legislation for wind turbines was needed.

On the other hand, for industrial noise in general, the current environmental legislation (VLAREM) sets the environmental conditions. VLAREM states that the specific sound of an installation or set of installations, must be limited to a certain maximum noise level, irrespective of the distance. The limit of this noise level depends on the period of the day (day, evening, night), the area destination, if it encompasses an existing or new installation and the existing acoustical quality of the area.

Article 5.20.5.1 of title II of VLAREM stated that in contrary to the legal provision of chapter 4.5 (general environmental noise legislation), the noise limits of VLAREM were not applicable for

wind turbines. Furthermore, it stated that specific sound emission levels can be determined in the environmental permit in relation to the local environmental conditions.

2. Experimental design

In the design of the new noise standards, the principles of the current environmental legislation were considered:

- unacceptable annoyance of people living near the wind turbines cannot be allowed;
- differentiation of the environmental conditions by area destination: the noise standards in for example industrial areas should be higher than those in residential areas;
- the possibility to take the background noise into account.

To provide legal certainty for both people living near wind turbines, wind developers and permitting authorities, it was chosen to insert these noise standard in the sectoral environmental legislation (VLAREM).

3 Preliminary results

The new environmental regulation, which was approved by the end of 2011 by the Flemish government and effective from April 2012, sets conditions related to sound, together with safety and shadow flicker and a transitional regulation (Vlaamse Regering 2011).

3.1 New noise levels for wind turbines

The noise of wind turbines is now regulated by noise levels that extend beyond the distance of 250 meters between wind turbines and the people living near them. Similar to the general industrial noise legislation, this regulation is differentiated per destination area and per period (day, evening, night). The new noise levels for wind turbines are given in table 1. These levels are defined as noise levels in dB(A).

Table 1: noise levels for wind turbines (annex 5.20.6.1 of VLAREM)

Area	Noise level in dB(A) in open air		
	day 7u-19u	evening 19u-22u	night 22u-7u
1°a Residential recreation areas	44	39	39
2°a Areas or parts of areas, other than residential areas, at a distance of less than 500 m of industrial areas	50	45	45
2°b Residential areas or part of residential areas, at a distance of less than 500 m of industrial areas	48	43	43
3°a Areas or parts of areas, other than residential areas or parts of residential areas, at a distance of less than 500 m of areas for small and medium-size companies, areas for the provision of services or excavation areas, during the excavation	48	43	43
3°b Residential areas or parts of residential areas at a distance of less than 500 m of areas for small and medium-size companies, areas for the provision of services or of land use areas, during the excavation	44	39	39
4° Residential areas	44	39	39
5° Industrial areas, areas for the provision of services and public utilities and land use areas, during the	60	55	55

excavation			
5bis° Rural areas	48	43	43
6° Recreation areas, other than residential recreation areas	48	43	43
7° All other areas, other than buffer areas, military areas and areas where in specific decisions noise levels are determined	44	39	39
8° Buffer areas	55	50	50
9° Areas or parts of areas at less than 500 m of gravel excavation areas, during the excavation	48	43	43

Note: if an area is covered by two or more area descriptions of the table, the highest noise level is applied.

During the evening or night, the noise levels are more strict then during the daytime. The difference between the night/evening and day level is set to 5 dB(A) for any given area.

In general, residential areas now have a high level of protection. The noise level of 39 dB(A) at night is similar to the previous framework of the circular. Residential recreation areas receive the same level of protection. Rural areas have a noise limit of 43 dB(A), just like recreation areas. At industrial areas and in buffer areas, a level of 55 dB(A) and 50 dB(A) respectively results in a less strict noise level. These noise levels do not limit the exploitation and development of wind turbines in large industrial areas (such as the Port of Antwerp) as such.

In order to sufficiently protect residential areas near existing industrial infrastructure, a more differentiated legislation is applied near smaller industrial areas and areas for small and medium-size companies. At less than 500 m of industrial area, a noise level of 45 dB(A) at night is applied, on the condition there is no residential area present at this distance. If there do is a residential area at less than 500 m of an industrial area, the presence of a high number of houses requires a more strict noise level. On the other hand, the presence of industry probably causes a high background noise level. In addition, in the existing industrial noise legislation these areas receive a more flexible noise limit. A noise limit value of 43 dB(A) was chosen, comparable to the noise limit in rural areas. This also comes close to the current environmental legislation for industrial installations (noise limit 40-45 dB(A), depending on the level of the background noise) and taking into account the annoyance of the sound of wind turbines.
Areas at less than 500 m of areas for small and medium-size companies, areas for the provision of services or excavation areas, during the excavation, receive a similar approach. For residential areas at less than 500 m of the aforementioned area, a noise limit of 39 dB(A) is applied (similar to the noise level for residential areas for wind turbines). If no residential area is present at less than 500 m, a noise level of 43 dB(A) is applied (similar to the noise level for rural areas for wind turbines).
Areas for small and medium-size companies often cause fewer noise annoyance than industrial areas. This is especially true at night, when the activities seize and there is a need to limit the sound imission levels of wind turbines to an acceptable level.

3.2 The use of background noise as noise limit

The audibility and annoyance of wind turbines is at least partly determined by the level of the residual background noise (L_{A95}). This residual background noise is a parameter that can be taken into account in the current environmental legislation for industry.

The residual background noise can vary greatly depending on the time and location. As a result, if the residual background noise level is used, it must be determined at the most critical house or houses. These are the houses that have the highest sound imission level of wind

turbines according to the prognosis of the accredited sound expert, at maximal operation of the wind turbines.

The measuring of background noise has to be done at a sufficiently long period. The aim of the measurement is to develop a representative long-term average of the residual background noise, given as $L_{A95,1h}$ per period (day, evening, night). As an absolute minimum, a measurement of 14 days is required. In bad or unrepresentative weather conditions, a longer measurement is required.

Only if the measured level of the background noise (L_{A95}) is higher than the applicable noise limits for wind turbines (L_{Aeq}), this background noise level can be used as noise limit. For example, if the noise limit in a given area is 44 dB(A) according to the annex and the background noise level is assessed at 45 dB(A), the value of the background noise can be used in that period. To prevent wind turbine developers to site the wind turbines very close (for example 150 m) to houses at areas with high residual noise levels, an additional condition was set. If the developer wishes to use the background noise as noise limit, the legislation requires a minimum distance between the wind turbines and the houses of more than three times the rotor diameter. This provides sufficient level of protection for the inhabitants.

3.3 Calculation of wind turbine noise

A calculation of the sound imission levels conform ISO 9613-2 or equivalent is now mandatory when applying for an environmental permit. This calculation must to be performed by a sound expert, accredited by the Flemish Government. Furthermore, the expert must state the parameters used in the calculation.

The sound power level used in the calculation, must be determined according to the IEC-61400-11 standard (95% of rated power).

The new legislation allows the use of common international software, on the condition they use the extensive method of the ISO 9613-2:1996 standard. By consulting accredited sound experts the parameters a calculation must meet were define and the following conditions were determined:

a) wind turbines need to be modeled as point source at hub height;
b) the sound needs to be calculated in 1/3 octave bands (or as octave bands if 1/3 octave band are not available) starting at 50 Hz (or 63 Hz at 1/3 octave bands);
c) the receiver height is 4 m, unless the specific situation requires a different receiver height. In the latter case a motivation must be given;
d) reflections are not to be calculated, unless it is required by the local conditions;
e) standard conditions for the atmospheric parameters are a temperature of 10 °C, and an air humidity of 70%. Every imission point is calculated with minor downwind conditions, implied in the ISO 9613-2 calculation;
f) within the ISO-9613-2:1996-standard, the frequency-dependent formula for ground attenuation is used;
g) the meteo correction term (Cmeteo) is set to 0;
h) the ground attenuation factor G = 1 is used for porous ground, and the ground attenuation factor G = 1 is used in conditions of absolute reflection. In a rural area, the default ground attenuation factor is set to G = 0.8. In conditions with lots of hard ground, it is set as G = 0.2. $A_{foliage}$ is not used, because it contains not permanent and alterable elements. Other values for the ground attenuation factor can only be used if a motivation is given;
i) if the imission level at a house differs less than 3 dB(A) from the sound limit, a detailed calculation is given (including the ground attenuation factors);

j) the presence of individual houses or other buildings is not taken into account, unless a significant influence is expected. In that case, reflections of the first order are used;
k) only if height differences are relevant in relation to the source height, they are to be taken into account;
l) tonality is treated with respect to the general environmental legislation.

4 Conclusions

In the development of the new environmental noise policy, the principles of existing environmental policy were applied.

This resulted in a new environmental regulation, which was approved by the end of 2011 by the Flemish government and effective by April 2012. The regulation sets conditions related to sound, together with safety and shadow flicker and a transitional regulation. The noise of wind turbines is now regulated by noise levels that extend beyond the distance of 250 meters between wind turbines and the people living near them. In addition, this regulation is more strict for residential areas than for industrial areas.

Recently TNO researched the dose-effect relation for wind turbine noise. Although these imission levels are presented as L_{den}, they are in fact based on the sound imission level calculated in standard acoustical studies (calculation of L_p at 8 m/s), with addition of a correction factor of +4,7 dB(A). As such, the results of this TNO-report can also be applied to wind turbines and acoustical studies in Flanders, keeping in mind that this derived dose-effect relation has a greater uncertainty than those for road traffic, as it is based on only a limited number of studies.

Furthermore, these results can be compared with other sources of environmental annoyance. Studies show that more than 400.000 Flemings are exposed to road traffic noise exceeding 55 dB(A) L_{den} (LNE 2009). The new environmental legislation for wind turbines has in most cases a lower impact on individuals than these doses of traffic noise.

Compared with international legislation, such as the new Dutch legislation of 2010, with the L_{den} limit of 47 dB(A) and the L_{night} limit of 41 dB(A), which correlates with the imission level of 43 dB(A) L_p in Flanders, it can be noted that the Flemish legislation is in some instances more strict than the Dutch legislation.

In the following table (table 2) the noise limits are compared with the previous framework (circular) and the general noise levels for industrial installations (VLAREM) (red = new noise policy is more strict). It can be concluded that in most instances, the new noise levels for wind turbines are more strict than the circular and more flexible than the noise limits of VLAREM.

Table 2: comparison of new noise limits with the existing or previous noise policy

Area	Noise level in dB(A) in open air				circular	VLAREM
	day 7u-19u	evening 19u-22u	night 22u-7u		night	night
1°a Residential recreation areas	44	39	39		39	30
2°a Areas or parts of areas, other than residential areas, at a distance of less than 500 m of industrial areas	50	45	45		49	45
2°b Residential areas or part of residential areas, at a distance of less than 500 m of industrial areas	48	43	43		49	45

3°a Areas or parts of areas, other than residential areas or parts of residential areas, at a distance of less than 500 m of areas for small and medium-size companies, areas for the provision of services or excavation areas, during the excavation	48	43	43		44	40
3°b Residential areas or parts of residential areas at a distance of less than 500 m of areas for small and medium-size companies, areas for the provision of services or of land use areas, during the excavation	44	39	39		44	40
4° Residential areas	44	39	39		39	35
5° Industrial areas, areas for the provision of services and public utilities and land use areas, during the excavation	60	55	55		59	55
5bis° Rural areas	48	43	43		39	35
6° Recreation areas, other than residential recreation areas	48	43	43		44	40
7° All other areas, other than buffer areas, military areas and areas where in specific decisions noise levels are determined	44	39	39		39	35
8° Buffer areas	55	50	50		54	50
9° Areas or parts of areas at less than 500 m of gravel excavation areas, during the excavation	48	43	43		49	45

The new environmental noise policy for wind turbines in Flanders sets the conditions for both existing and new wind turbines.

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