

ACOUSTIC IMPACT ASSESSMENT OF WIND FARMS IN SPAIN: THE NEW APPROACH OF THE ANDALUSIAN REGULATION

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ABSTRACT

A new regulation about noise management has entered into force recently and it has led to important changes in the acoustic evaluation of wind farms in Andalusia. The Decree 6/2012 approved the Regulations against Acoustic Pollution in the region, establishing new fixed noise limits for all noise sources and activities depending on zoning uses. As the previous regulation defined noise limits based on background noise, the newly regulation represents a different approach for the acoustic impact assessment of wind farms in southern Spain.

In this research paper an analysis of the implications of the new requirements in the acoustic evaluation for wind farms in Andalusia is presented through a case study where background noise measurements were measured at different wind speeds. The noise limits of Andalusian regulations are the compared with other International regulations in order to evaluate its adequacy for wind turbines noise management.

RESUMEN

El Decreto 6/2012 ha introducido importantes cambios en el Reglamento de Protección Acústica de Andalucía, incluyendo la definición de nuevos valores límites en función de la zonificación acústica del territorio. Dado que la anterior normativa establecía límites subjetivos basados en ruido de fondo, el actual reglamento representa una diferente aproximación metodológica de la evaluación acústica de Parques Eólicos.

El presente estudio analiza los requerimientos acústicos para parques eólicos en Andalucía, a través de un caso de estudio donde se evaluó el ruido residual a diferentes velocidades de viento y mediante un análisis comparativo con otras normativas y estándares internacionales.

INTRODUCTION

The new Decree for Acoustic Pollution in Andalusia was approved on the 17th of January 2012 (hereinafter referred as D6/2012). This regulation develops the national law, Royal Decree 1367/07 (RD1367/07), in the Andalusian region and is applied to any infrastructure, installation, machinery, project and private or public activity which could produce acoustic pollution due to noise or vibrations. Therefore, this law is in force for the acoustic assessment of wind farms, including the evaluation of noise levels at the nearest dwellings.

This paper focuses on the evaluation of the Noise Immision Level (NIE, as called in the D6/2012) at the facades of the nearest dwellings to the wind farm under study, considering the acoustic contribution of the wind turbines exclusively. For this purpose, a wind farm is considered as an industrial facility according to the requirements of the Decree 6/2012.

In general, the new Andalusian Regulation includes the legal provisions of the national law, regarding to noise indicators, noise limits, methodology of measurements, and key criteria for evaluation of the Noise Immision Level applied at wind farms. In this sense, the Decree 6/2012 establishes the noise limits for wind farms in the table VII of Chapter II, considering different zoning uses. These noise limits are applied at the façade of the buildings or at the external border of the acoustic areas.

Areas		Noise limits (dBA)		
		L _{kd} Day	L _{ke} Evening	L _{kn} Night
a	Residential areas	55	55	45
b	Industrial areas	65	65	55
c	Recreational and entertainment uses	63	63	53
d	Touristic and tertiary uses (different to area c)	60	60	50
e	Educational, cultural, health activities or any sensitive use that requires a special protection.	50	50	40

Table VII Decree 6/2012. Noise limits for activities and regional port infrastructures (dBA)

To support the implementation of the new regulation, the Andalusian Environmental Agency has published guidelines (CMA, 2012) where the applicability procedure of the regulation to wind farms is clarified:

1. According to the article 29, the Noise Immision Level (NIE) will be evaluated at the façade of the nearest building to the wind farm. For the measurements, the microphone has to be located at 1,5 meter distance and 1,5 meter height to the most exposed façade.
2. The applied noise limits for new wind farms (i.e. those holding a legal authorisation or that have already applied for it before October 24th 2007) will be the values mentioned in table VII. For existing wind farms, the noise limits are less restrictive attending to the increase of emission level of wind turbine due to decline of the installations. In this case, the noise limit of the table VII will be increased in 3 dBA for the evaluation of day, evening and night average and an increment of 5 dBA for short-time evaluation considering the worst scenario (measured in minutes).

The rest of technical issues for the application of the Andalusian Regulation, described in the Technical Annex II, are similar to the methodology of acoustic assessment provided in the National law (described in the Annex IV). Both regulations use the requirements of the standard ISO 1996-2:2007 for noise campaign in wind farm.

MAIN CHANGES INTRODUCED BY THE NOISE REGULATION FOR ANDALUSIAN WIND FARMS

The previous noise regulation, Decree 326/03 (hereinafter referred as D326/2003), was approved in 2003 and was the reference guideline for the acoustic assessment of wind farms until the publication of the Decree 6/2012 on March 6th 2012. The Decree 326/03 defined a different noise indicator in the article 23, called Acoustic Assessment Index (NAE according to Spanish acronym), that established a noise limit based on background noise. The noise indicator NAE was defined as an A-weighted equivalent continuous sound pressure level for a time interval of 10 minutes ($L_{Aeq10min}$).

When Decree 6/2012 entered into force, the control of the noise emission of wind farms changed and the applied noise indicator became the Noise Immision Level (NIE according to Spanish acronym) as it is described in articles 29 and 30. This noise indicator NIE is defined as an A-weighted equivalent continuous sound pressure level (L_{Aeq}), for a time interval of, at least, 5 seconds and with different noise limits considering the urban zoning and the time periods (day, evening and night). The table below describes the main differences between both regulations in order to identify the main changes introduce in the evaluation of wind farm as an industrial facility:

	Acoustic Assessment Index - NAE Decree 326/2003	Noise Immision Level - NIE Decree 6/2012	
Noise indicator	$L_{Aeq10min}$	L_{AeqT}	
Penalties	Up to 5 dBA	Up to 9 dBA	
Adjustment due to reflections	None (open window)	Incident sound	
Time interval	10 minutes	At least 5 seconds	
Number of measurements	At least 1	Three records with a time-lapse of three minutes	
Evaluation of background noise	Same methodology	Same methodology	
Height of microphone	At least 1,2 meters height	1,5 meters	
Location of microphone	Open window	At the facades of the building	
Spatial/time sampling	Worst scenario	Worst scenario	
Time period	Day (7 AM – 11 PM) Night (11 PM – 7 AM)	Day (7 AM – 7 PM) Evening (7 PM – 11 PM) Night (11 PM – 7 AM)	
Noise limits for new wind farms	Background noise + 5 dBA	TABLE VII Day/Evening: 55 dBA Night: 45 dBA	
Noise limits for existing wind farms		TABLE VIII	
		Average Period (+3 dBA)	Short time evaluation (+5 dBA)
		Day/ Evening	58
	Night	48	50

Table 1. Comparison of Requirements of D6/2012 and D326/2003
(Modified from Grilo, 2014)

Based in this table results, the most important changes of Decree 6/2012 are as follows:

1. **Noise limits applicable to Wind Farms:** The main change of the regulation is the criteria used to establish noise limits, replacing the existing noise limits based on background noise for a fixed value of 55 dBA during day/evening and a value of 45 dBA during the night for residential uses.

Obviously, the consequences of this change are highly dependent on the location of the wind farm and the influence of specific noise sources at the surroundings of the wind turbines (road traffic or other industrial noise sources) that could increase the background noise levels. In Andalusia, most of the wind farms are located at open country and quiet areas (Figure 1), where the environmental noise is influenced exclusively by natural sound and the wind-induced noise.



Figure 1. Location of Wind farms in Andalusia (AEE, 2015)

The Acoustic Laboratory of INERCO Acústica has carried out a wind farm noise campaign in South Spain to monitor the background noise at different locations according to ISO 1996-2:2007 during 8 days. In Figure 3 the results obtained from the correlation between the background noise levels, evaluated by $L_{Aeq10min}$, and the wind speed at 10 meters height (w_{10}) for a rural dwelling at open country during the night period are presented. In this particular study, the microphone was situated in an opened window at the ground floor, identified as the most exposed faces of the nearest dwelling from the wind farm.

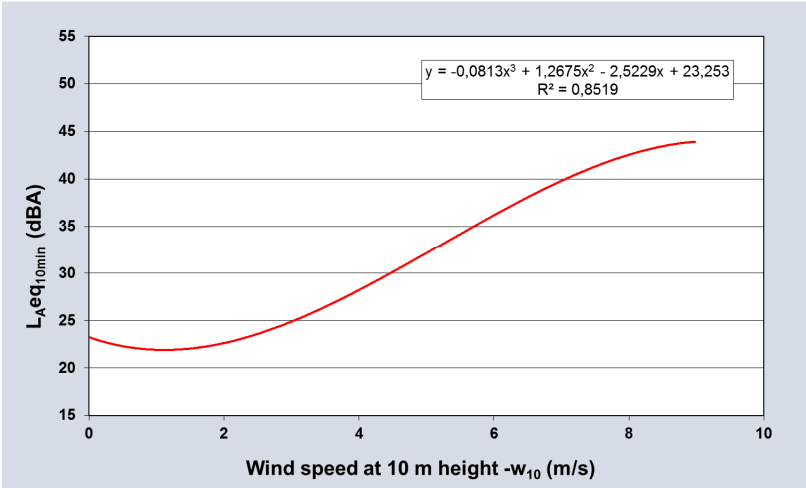


Figure 3. Correlation between the background noise levels and the wind speed at 10 meters height during the night for a studied wind farm.

Taking into account the obtained background noise levels (Figure 3), it is possible to compare noise limits using the previous regulation (D326/2003) and the current applicable limits following the table VII of Decree 6/2012.

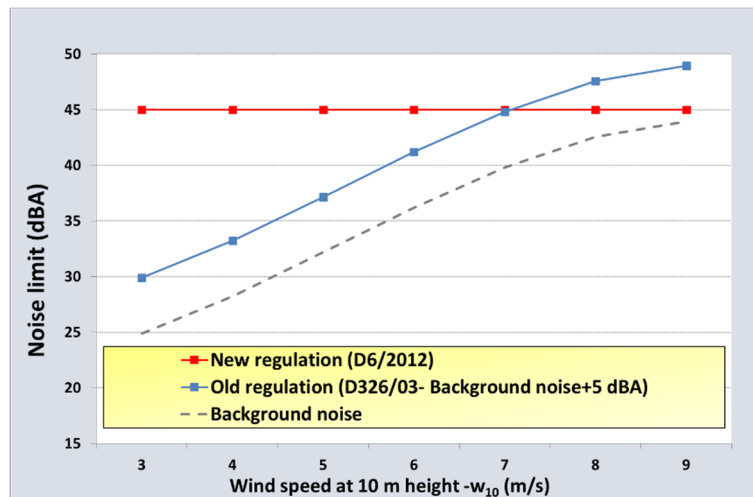


Figure 4. Noise limits of Wind farms for residential uses and night period for a studied wind farm

According to Figure 4 and considering the night period (worst scenario), the new regulation is less restrictive than Decree 326/2003 for wind speed up to 7 m/s. Particularly, at quiet areas, and when the wind speed is below 7 m/s, the background noise appears to be specially low, between 20 dBA and 40 dBA according to our measurements. On the contrary, for the study area, the previous regulation seems to be only more permissive when high wind speeds (more than 8 m/s) are reached and when wind-induced noise exceeds 40 dBA.

As a conclusion, it can be said that for wind farm situated at quiet areas, the noise limit based on background noise (Decree 326/2003) provides a special protection against sound emergence when the environmental noise is low whereas it is more permissive when higher wind speeds are reached and when the wind induced background noise exceeds 40 dBA.

2. **Adjustments due to tonality, impulsiveness, low frequency and low background noise:** Analysing the differences due to the corrections of tonality, impulsiveness, etc. both regulations were compared (table 2). The previous noise regulation included a correction related to low background noise (evaluated by L_{90}) in order to protect the quietness at natural areas. However, this correction was not incorporated to the current regulation, but a new adjustment due to low frequency noise has been included.

	Previous Regulation Decree 326/2003	Current Regulation Decree 6/2012										
Correction due to low background noise (evaluated by $L_{90-10 \text{ min}}$)	<table border="1"> <thead> <tr> <th>L_{90}</th> <th>P</th> </tr> </thead> <tbody> <tr> <td>≤ 24</td> <td>3</td> </tr> <tr> <td>25</td> <td>2</td> </tr> <tr> <td>26</td> <td>1</td> </tr> <tr> <td>≥ 27</td> <td>0</td> </tr> </tbody> </table>	L_{90}	P	≤ 24	3	25	2	26	1	≥ 27	0	Non defined
L_{90}	P											
≤ 24	3											
25	2											
26	1											
≥ 27	0											
Correction due to tonality	5 dBA (if exists)	3 - 6 dBA depending of the range of tonality										
Correction due to impulsiveness	2 - 5 dBA	3 - 6 dBA										
Correction due to low frequency	Non defined	3 - 6 dBA										
Maximum correction	5 dBA	9 dBA										

Table 2. Comparison of Requirements of D6/2012 and D326/2003

There are two differences that can greatly influence the acoustic assessment of wind farms:

- The maximum value of the correction increases until 9 dBA instead of 5 dBA. When the presence of tonality and low frequency is demonstrated at a wind farm, the measured noise

level may be increased up to 9 dBA according to Decree 6/2012, always depending on the characteristics of these components.

- The presence of low frequency at the spectral emission of the wind turbine is penalized by the actual regulation with 3 or 6 dBA, depending on the measured difference between L_{ceq} and L_{Aeq} .

As example, the table 3 shows the calculated correction according to both regulations using data from a noise campaign developed by INERCO Acústica. At the study location, only low frequency correction were identified and the total adjustment according to D6/2012 was 6 dBA versus the null value of D326/2003.

Corrections according to Decree 326/2003					
Wind speed w_{10} (m/s)	6	7	8	9	10
Low background noise correction (P)	0	0	0	0	0
Tonality correction (K1)	0	0	0	0	0
Impulsiveness correction (K2)	0	0	0	0	0
Total adjustment ($A=P+K1+K2 \leq 5$ dBA)	0	0	0	0	0
Corrections according to Decree 6/2012					
Wind speed w_{10} (m/s)	6	7	8	9	10
Tonality correction (Kt)	0	0	0	0	0
Low frequency correction (Kf)	6	6	6	6	6
Impulsiveness correction (Ki)	0	0	0	0	0
Total adjustment ($K=Kt+Kf+Ki \leq 9$ dBA)	6	6	6	6	6

Table 2. Comparison of Requirements of D6/2012 and D326/2003

As the new regulation introduces new adjustments that were not required by the previous legal guidelines, the comparison between the noise limit shown in Figure 5 must be modified considering the correction due low frequency from table 3.

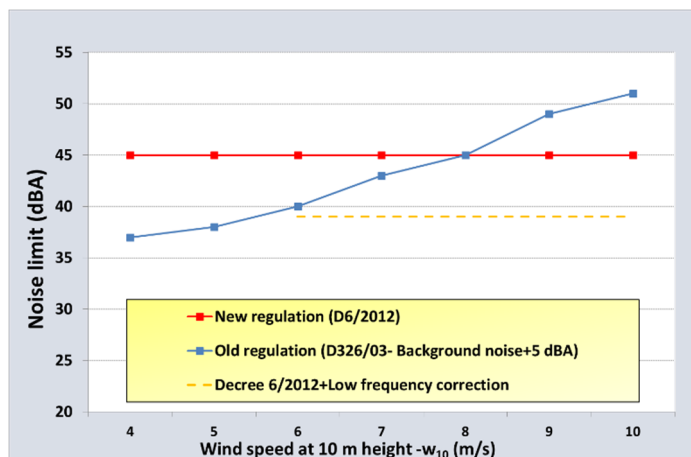


Figure 6. Comparison of Requirements of D6/2012 and D326/2003 considering the application of low frequency correction for a studied wind farm.

The comparison of noise limits from both Regulations, considering the new correction due to low frequency noise, shows that Decree 6/2012 is more restrictive than the former law for all measured wind speeds.

3. **Time interval of the measurements:** Although internationally recommended time interval for wind farms monitoring is 10 minutes (as defined in Decree 326/2003), Decree 6/2012 allows the development of measurement during shorter intervals (at least 5 seconds). In order to get representative samples of the noise immersion levels, 1 minute intervals may be recommended for the evaluation of the noise emission from wind turbines. The total duration of the noise

campaign might be reduced, even improving the relationship between the noise levels and the wind speed, due to the relevant number of 1-minute samples.

Using synchronized sound and meteorological data, different methodologies may be used (polynomial regression, binning method or probability distribution) for the statistical analysis of the measurements. Figure 6 displays the results of the analysis of a monitoring campaign at a wind farm, using the binning method (Asthani & Titus, 2011) applied to 1-minute records.

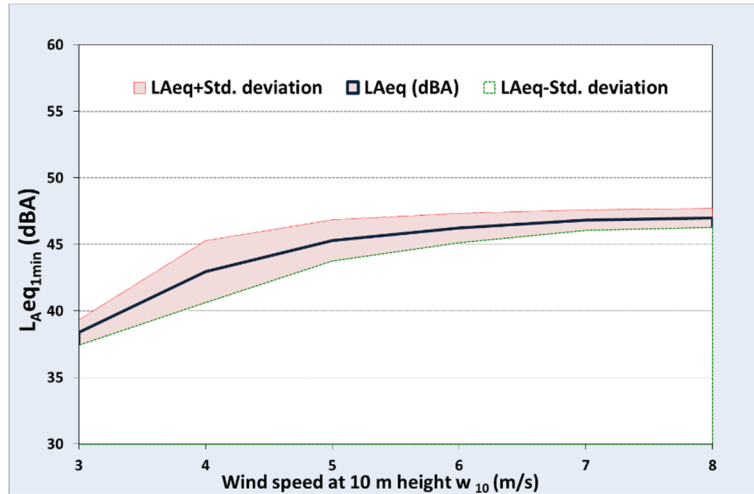


Figure 6. Noise immersion levels analysed by binned wind speeds. The dark line represents the mean $L_{Aeq1min}$ within each bin. The shaded zone represents one standard deviation.

The obtained results were highly representative of the acoustic situation at the nearest dwelling from the studied wind farms, due to a measurement basis of 1 minute interval during 8-days monitoring campaign was set. Thus the calculated deviation error was improved.

- Comparison with International Noise Limits:** The existing guidelines for the acoustic assessment of wind farms consider noise limit based on background noise (e.g. Turkey), based on fixed values (e.g. Spain) or using both of them (e.g. Ontario or France). Comparing the actual noise limits in Andalusia for residential uses and night period, with other guidelines from United States and Europe (figure 6) shows that noise limits of the current regulation in Andalusia are less restrictive than the reviewed standards and the recommendations of other guidelines (IOA, 2013), but according to the World Organization of Health guidelines (WHO, 1999). Furthermore, considering the correction due to low frequency noise (up to 6 dBA), the noise limits for night period become closer to those applied in other countries (39 dBA).

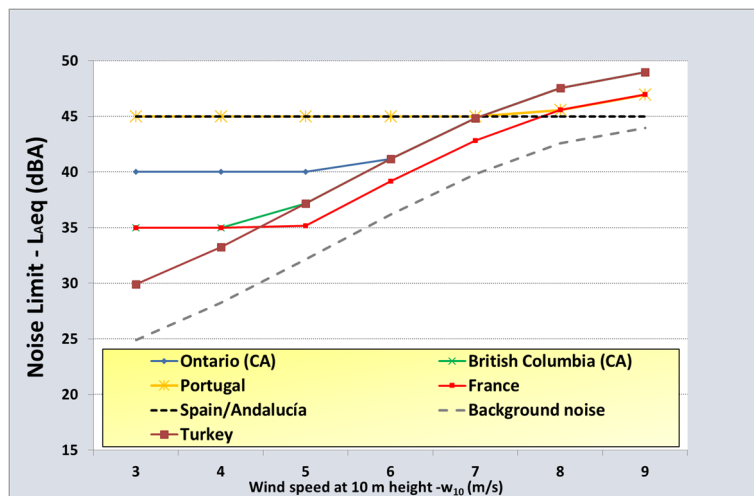


Figure 6. Comparison of Andalusian Noise limits (D6/2012) with other international regulations (Arcadis et al., 2013; Goemé, 2015)

Currently, the main challenge for the acoustic assessment of wind farms in Andalusia is therefore the classification of the noise sensitive receivers when the urban planning is not available. A rural dwelling used as a second residence (usual situation in the region), situated in open country then should be classified as a residential use if the right acoustic quality has to be guaranteed. Otherwise, its classification below any different use (areas b, c or d from Table VII – D6/2012) might prevent the compliance of WHO recommendations.

CONCLUSIONS

The entry into force of a new regulation Decree 6/2012 has led to important changes in the acoustic evaluation of wind farms in Andalusia, establishing new fixed noise limits depending on zoning uses instead of previous limits based on background noise. Despite the fact that some changes in the regulation with respect to the former one might affect residential uses negatively, the noise limits set are more restrictive than the previous ones due to the inclusion of a new correction in low noise frequency, characteristic of noise emission from wind turbines. In this sense, the Decree 6/2012 of Andalusia fulfils the recommendation of the World Organisation of Health for the protection of sensitive uses during the night.

REFERENCES

- AEE. 2015. *Mapa Eólico de Andalucía*. [ONLINE] Available at: <http://www.aeeolica.org/es/map/andalucia/>. [Accessed 30 January 15]
- Arcadis, K. F., Avenue, F., Arcadis, E. K., Box, P. O., and Arnhem, A. G. (2013). *Noise International Legislation and Regulations for Wind Turbine Noise*, Proc. 5th Int. Meet. Wind Turbine Noise. Denver, US. 1–22
- Ashtiani P. and Titus S., 2011. *Analysis of noise immission levels measured from wind turbines*. Proceedings of the 4th International Meeting on Wind Turbine Noise; 2011. Rome, Italy. INCE Europe. ISBN: 978-88-88942-33-9.
- Consejería de Agricultura, Pesca y Medio Ambiente, 2012. *Guía de Contaminación Acústica*. Junta de Andalucía, Noviembre de 2012.
- Decreto 6/2012, de 17 de Enero, *por el que se aprueba el Reglamento de Protección contra la Contaminación Acústica en Andalucía*, Boletín oficial de la Junta de Andalucía, número 24. Pp. 7-37.
- ETSU-R-97, *The assessment and rating of noise from Wind Farms*, Final ETSU-R97 Report for the Department of Trade & Industry. UK Noise Working Group, 1997.
- Goemé, A. (2015). *Comparative analysis of wind turbine noise assessment and rating procedures in the UK, France and the Netherlands*. Proc. 6th Int. Meet. Wind Turbine Noise. Glasgow, Scotland.
- Grilo A, 2014. *Implicaciones del Nuevo Reglamento de Protección contra la Contaminación Acústica en Andalucía sobre las Actividades Industriales Existentes: un Caso Práctico*. Official publication of 45th Spanish Congress on Acoustics. Murcia. Pp. 747-755.
- IOA 2014. *A Good Practice Guide to the Application of ETSU-R-97 for the Assessment and Rating of Wind Turbine Noise*. Institute of Acoustic. Hertfordshire (UK)
- ISO 1996-2:2007 Acoustics: Description, measurement and assessment of environmental noise. Part 2: Determination of environmental noise
- World Health Organization (WHO), 1999. *WHO guidelines for community noise*. Copenhagen.