Intended for
Nelja Energia AS

Document type
Report

Date
15/11/2016

Reference
1510023010

Madalsagedusliku ning infraheli uuringu tõlge asub KMH aruande ptk-s 5.11.2 „Infraheli ja madalsageduslik müra"

HIIUMAA OFFSHORE WINDFARM, ESTONIA
LOW FREQUENCY NOISE AND INFRASOUND SURVEY

HIIUMAA OFFSHORE WINDFARM, ESTONIA
LOW FREQUENCY NOISE AND INFRASOUND SURVEY

Date	15/11/2016
Made by	Ville Virtanen, Veli-Matti Yli-Kätkä
Checked by	Janne Ristolainen
Description	Low frequency noise and infrasound survey for the operation of Nelja Energia AS offshore wind farm in Hiiumaa, Estonia

Ref 1510023010

Ramboll
Niemenkatu 73
FI-15140 LAHTI
T +358 20 755 611
F +358 20 755 7801
www.ramboll.fi

CONTENTS

1. FOREWORD

Nelja Energia AS is planning a wind farm to be located north from Hiiumaa, Estonia. Ramboll made a noise calculation for low frequency noise and infra sound. The objective of this noise survey project was to investigate the effects of low frequency noise and infra sound to the closest reference points on the coast of the Hiiumaa Island and on three points on the sea.

The project was assigned to Ramboll by Nelja Energia AS, the contact person was Siim Paist. Ramboll Project manager was Janne Ristolainen; the noise modelling has been conducted by Ville Virtanen and Veli-Matti Yli-Kätkä.

2. NOISE LIMIT VALUES

The Minister of Social Affairs Regulation No 42 of 4 March 2002 establishes the noise limit values in residential and recreational areas and residential buildings. The limit values are applied in land use, traffic and construction planning and building permitting.

Table 1. Noise limit values for industrial sources stated in Minister of Social Affairs Regulation No 42

	Existing areas, Application level L_{Aeq}		Planned new areas, Application level L_{Aeq}	
Outdoors	Daytime (07–23)	Night time (23–07)	Daytime (07–23)	Night time (23–07)
Category I: Natural recreation areas and National parks, recreation and health authorities recreation areas	50 dB	40 dB[1)]	45	35
Category II: Educational and day care institutions, health care and social welfare institutions, residential and recreational areas and parks in cities or towns	55 dB	40 dB [1)]	50	40
Category III: Mixed area (residential and public buildings, commercial buildings, service and manufacturing companies)	60 dB	45 dB [2)]	55	45
Category IV: Brownfield	65	55	65	55
Indoors				
Living and sleeping quarters	30 dB L_{Aeq}	25 dB L_{Aeq} 40 dB L_{max}	30 dB L_{Aeq}	25 dB L_{Aeq} 35 dB L_{max}

Low frequency noise is assessed if the overall noise level is very close to levels in Table 1 (but not exceeding it). The 1/3 octave band indoor noise levels are compared to recommended levels shown in Table 2 (recommended sound pressure levels for low frequency noise annoyance assessment for residential living and sleeping rooms). It is used for evaluation of low frequency noise in living rooms or other indoor spaces caused by heating systems, music in entertainment facilities or other low frequency noise sources.

Table 2. Recommended (unweighted) indoor sound pressure levels of low frequency noise stated in Minister of Social Affairs Regulation No 42

1/3 frequency band / Hz	10	12,5	16	20	25	31,5	40	50	63	80	100	125	160	200
Night time L_{eq}, dB	95	87	79	71	63	55,5	49	43	41,5	40	38	36	34	32

3. NOISE MODELLING

3.1 Method

Low frequency noise survey was conducted as set out in Finnish ministry of environments guidelines. The recommended values for low frequency noise in this project are as it is stated in The Minister of Social Affairs Regulation No 42.

Low frequency noise levels emitted from wind turbines were calculated at the potentially most relevant immission points shown in Figure 4. The calculations were made to 9 (A-I) immisson points that are located by the shore of Hiiumaa and 3 (J-L) of which are located in the Baltic Sea ~5 km from the shore. Low frequency noise inside buildings was estimated using airborne sound insulation values for buildings of residence façades that are stated in DSO 1284 calculation method. The insulation values stated in DSO 1284 calculation method are based on the sound insulation measurements conducted several residential buildings in Denmark 2008. The measurements and the insulation values are reported in the DELTA report *Measurements of Sound Insulation of Facades*. Sound insulation values stated in DSO 1284 are the best information available, as there is no equivalent information available from Estonia. Compared to Denmark the building types and materials may be different in Estonia, but the differences are considered to be small enough that the insulation values can be applied for this assessment.

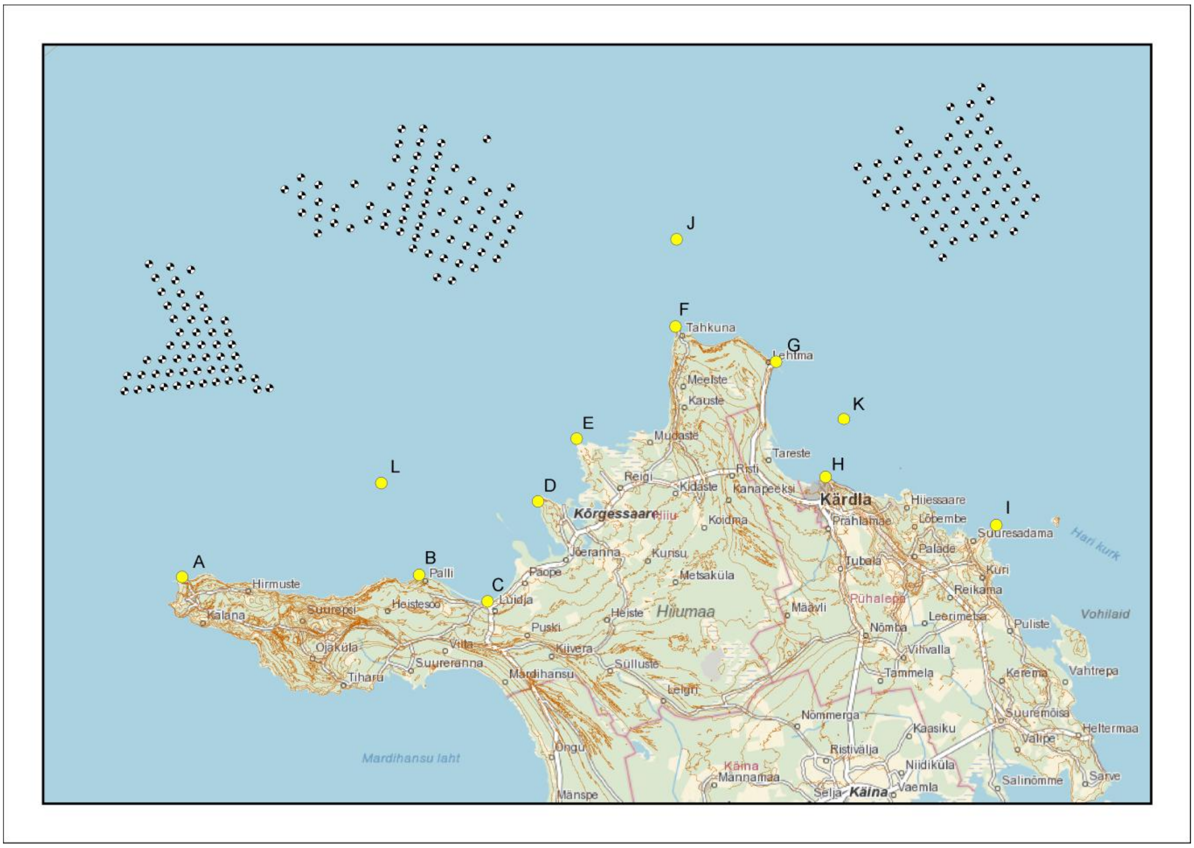


Figure 1. Receiver point locations

3.2 Wind turbine information

The Hiiumaa wind farm was modelled using Siemens SWT-4,0-130 turbine model with a hub height of 110 metres.

For Siemens SWT-4,0-130 turbine model 1/3-octave bands noise emission data's between 10 - 160 Hz were used as provided by Siemens. The band of 200 Hz was calculated by extrapolation. According to the manufacturer's data provided, the Siemens SWT-4,0-130 with standard setting produces a total sound power level of 110.0 dB on wind speed of 8 m/s at 10 m reference height.

Lower sound power levels can be achieved with the SWT-4.0-130 wind turbine by controlling the turbine in noise restricted operation (noise modes from “Setting -1 dB” to “Setting -6 dB”).

Figure 3 shows the one-third octave band sound power levels produced by the turbine model used in the noise modelling.

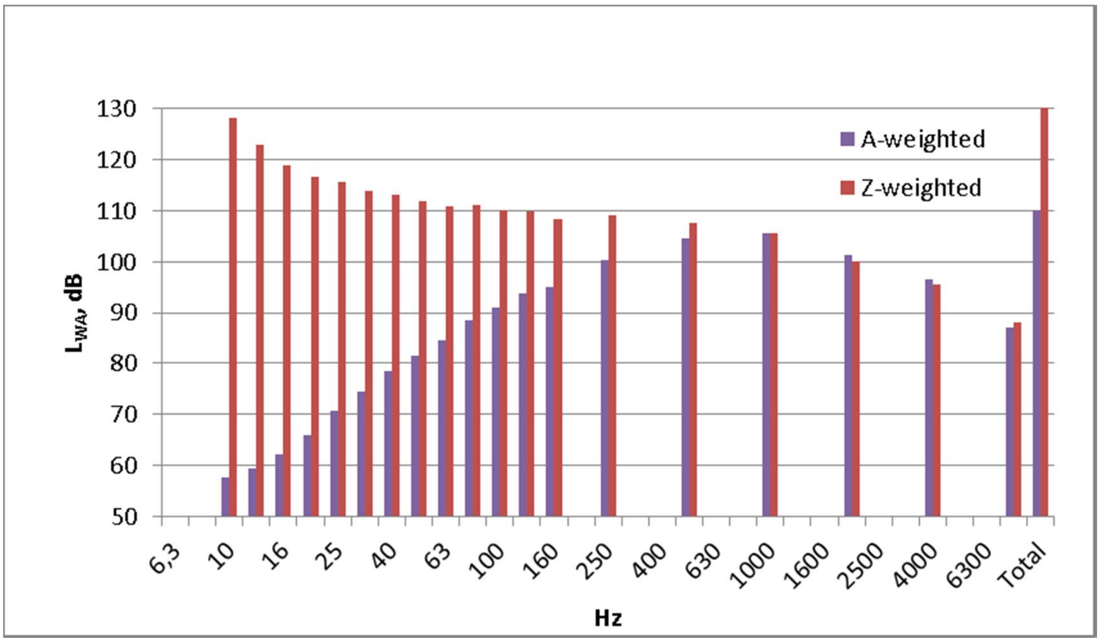


Figure 2. One-third octave band sound power levels of Siemens SWT-4.0-130 Wind Turbine

The noise data was obtained from documents “Contract Acoustic Emission, SWT-4.0-130, Rev. 0, Hub Height 90.0 m. Document ID: E W EN OEN DES TLS, Bo Schou NeIsen / 2014.08.04” and “Standard Acoustic Emission, SWT-4.0-130, rev. 0, Hub Height 110.0 m. Document ID: E W EN OEN DES TLS 7-10-0000-0885-00, Melek Sarigötz / 2013.04.05”

4. RESULTS

The calculated low frequency indoor noise levels (the sound insulation of the building taken into account) were below the recommended indoor low frequency noise levels at all receiver locations.

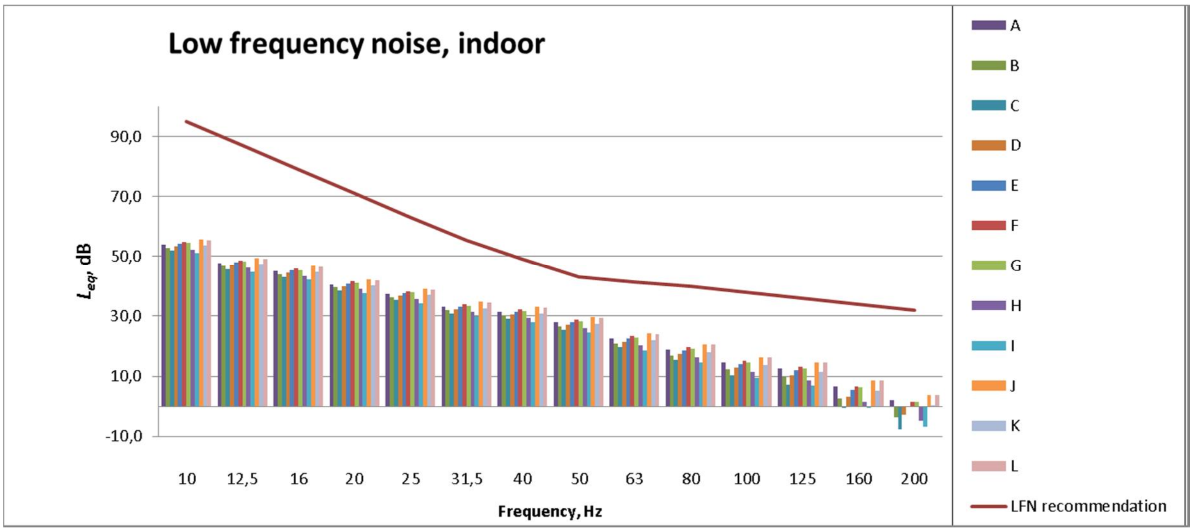


Figure 3.One-third octave band sound indoor levels at receiver points

The results are shown also in tables in Annex 1.

The results show that the low frequency noise from wind turbines can be audible at certain weather conditions, but that the levels are well below the recommended values at the shore of Hiiumaa.

4.1 Penalties due to tonality, amplitude modulation and impulsivity

According to the document “Environmental Administration Guidelines 2 | 2014 Modelling of wind turbine noise” published by Finnish Ministry of the Environment, the effects of impulsivity and amplitude modulation are already included into the warranted level given by the wind turbine manufacturer. However, if it is known that the turbine model produced tonal noise and it can be estimated that these characteristics are audible in the immission points, the penalty for the tonality (e.g. 5 dB) can be added to the sound power level reported by the manufacturer. The tonality is estimated according to the guideline given by the Finnish Ministry of the Environment (Environmental Administration Guidelines 4 | 2014 Measurement of wind turbine noise levels in exposed areas).

As the wind turbine manufacturers of the turbine models used in this survey have not reported that their turbines produce tonal noise, the sanction for tonality is not applied in the results. The tonality can only be estimated after the wind farm has been build and the possible penalty for the tonality can be added into the sound pressure levels used in the modelling. However, according to the information available the penalties due to tonality are unlikely.

5. INFRASOUND FROM WIND TURBINES

Infrasound is usually determined as sound below a frequency of 20 Hz. Infrasound is excited by a wide range of natural sound sources such as wind, waterfalls and waves on the coastline. Human activity also causes infrasound and the sound sources vary from vehicles and industrial processes to air conditioning and wind farms.

The hearing threshold is standardized between 20 and 20 000 Hz but not for infrasound (frequencies below 20 Hz). This may have caused the common incorrect assumption that human hearing is incapable to sense infrasound.

There have been many studies on the low frequency threshold of human hearing. These studies have determined the lowest levels which are audible to an average person with normal hearing all the way down to 1.5 Hz. Figure 2 shows different hearing thresholds suggested. The results vary but are parallel: We are capable to hear infrasound if the sound pressure level is high enough. Tonality is lost below around 16-18 Hz and consequently a key element of perception is lost.

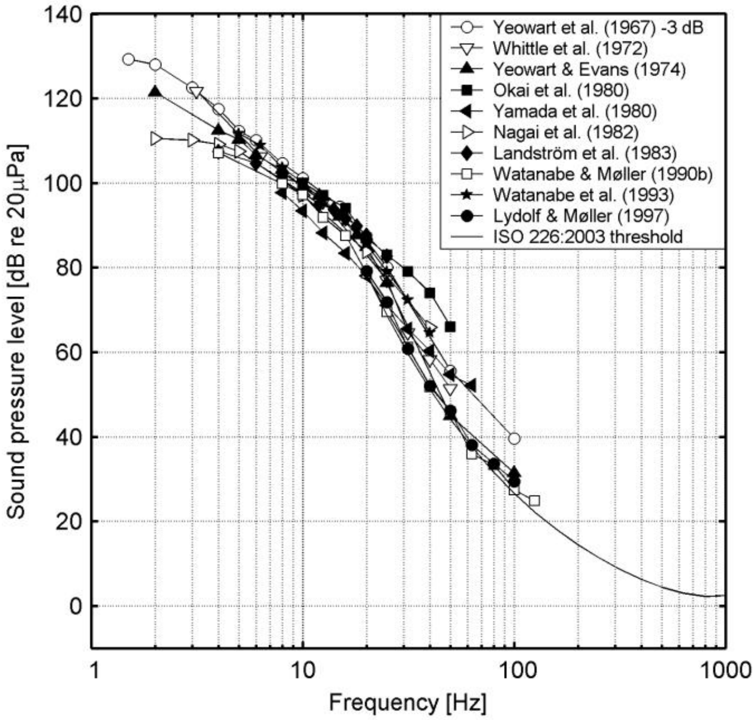


Figure 5. Different hearing thresholds suggested. (Hearing at low and infrasound frequencies, Møller et al, 2004)

5.1 Infrasound measurement results in literature

Field measurements were made in a Japanese research project in the noise immission areas around several wind farms across Japan. Figure 6 shows a composition of these results. It is seen from the results that the frequency components below 20 Hz of almost all measuring points are much lower than the hearing or sensation thresholds.

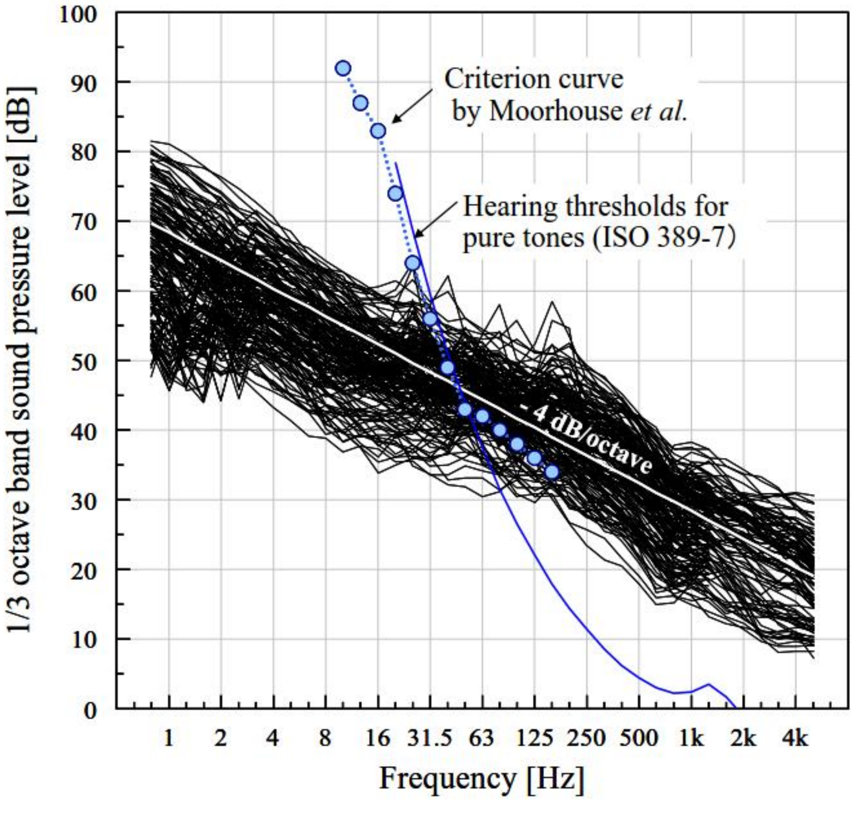
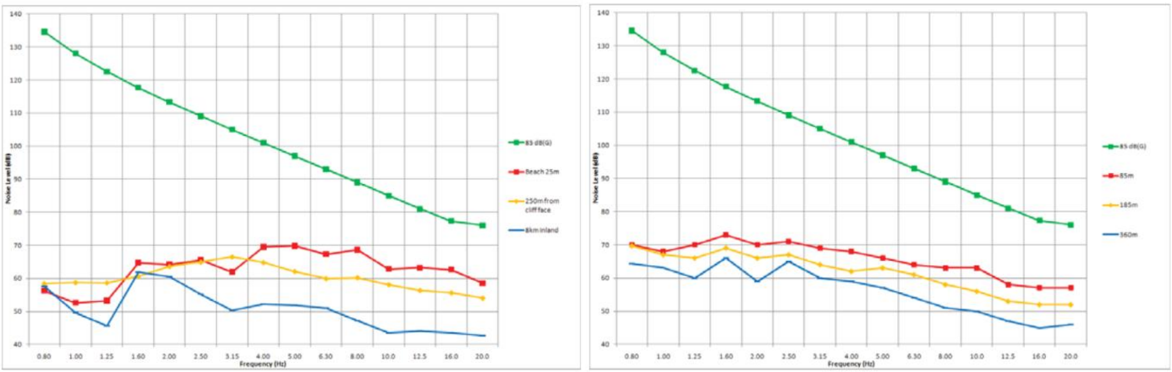


Figure 6. Measurement results at 164 points around 29 wind farms in Japan. (Assessment of wind turbine noise in immission areas, H. Tachibana et al, 2013)

Figure 7 shows infrasound measurement results for noise caused by natural sources and wind farm. The wind farm consists of 29 wind turbines with rated capacity of 2.1 MW (model REpower MM82). The green line in the pictures is the infrasound level of 85 dB(G) that is a common audibility threshold limit for infrasound. Figure shows that the infrasound caused by wind farm was slightly higher than the levels created by natural sources. However, all the measured levels from different sources were well below the hearing threshold.



LEFT FIGURE	Natural sources	RIGHT FIGURE	Cape Bridgewater Wind Farm
RED LINE	Beach 25 m	RED LINE	85 m
ORANGE LINE	250 from cliff face	ORANGE LINE	185 m
BLUE LINE	8 km inland	BLUE LINE	360 m

Figure 7. Measured levels of infrasound (0.8 Hz to 20 Hz) from different sound sources. (Measurement and level of infrasound from wind farms and other sources, C. Turnbull et al, 2012)

5.2 Health effects

The health effects of environmental noise are transmitted through sense of hearing. Other health effects are mainly a result of noise annoyance or sleep disturbance. In other words, if the noise is not audible there are no effects. Often in the public debate it is only spoken about the presence of infrasound and the low levels are forgotten or ignored.

Health Canada initiated in 2012 a cross-sectional epidemiological study to investigate the prevalence of health effects or health indicators among a sample of Canadians exposed to wind turbine noise using both self-reported and objectively measured health outcomes. The results were published in 2015. No association of measured or self-reported health effects and wind turbine noise was observed. Statistically significant exposure-response relationships were observed between increasing wind turbine noise levels and an increase in the prevalence of long term high annoyance towards several wind turbine features, including: noise, shadow-flicker, visual impacts, blinking lights and vibrations. This also suggests that if the noise is not audible there are no effects.

6. CONCLUSIONS

According to noise modelling, the low frequency noise from wind turbines can be audible at certain weather conditions, but that the levels are well below the recommended values at the shore of Hiiumaa. The measurements conducted in the surroundings of Finnish wind turbine areas and the estimation of the noise calculation error suggest that approximately two times out of three the calculations give values greater than what would be achieved with noise measurements.

Wind turbines are one of many sources of infrasound around us. However, the level of infrasound caused by wind turbines is in nearly all occasions well below the audibility threshold. The infrasound exists in urban and natural environments at similar levels to the infrasound measured close to wind turbines.

7. REFERENCES

DSO 1284 “Statutory Order on Noise from Wind Turbines”

Measurements of Sound Insulation of Facades. DELTA AV 1097/08, 30. April 2008

A review of published research on low frequency noise and its effects, G. Leventhall, 2003

Hearing at low and infrasound frequencies, Møller et al, 2004

Measurement and level of infrasound from wind farms and other sources, C. Turnbull et al, 2012

What is infrasound? G. Leventhall, 2007

Assessment of wind turbine noise in immission areas, H. Tachibana et al, 2013

Wind Turbine Noise and Health Study, Michaud et. al, Health Canada, 2015

Annex 1

Outdoor noise levels, dB

	1/3 frequency band / Hz													
Receptor	10	12,5	16	20	25	32	40	50	63	80	100	125	160	200
A	58,8	53,6	49,6	47,2	45,8	43,8	42,8	40,9	39,1	38,4	35,6	32,8	27,8	23,2
B	57,8	52,6	48,6	46,2	44,7	42,7	41,5	39,6	37,6	36,6	33,4	29,8	23,7	17,5
C	50,8	45,6	41,6	39,2	37,7	35,6	34,3	32,3	30,0	28,9	25,1	20,8	13,6	6,1
D	58,3	53,1	49,1	46,7	45,2	43,2	42,0	40,1	38,1	37,2	33,9	30,4	24,3	18,3
E	59,1	53,9	49,9	47,5	46,1	44,1	42,9	41,0	39,1	38,4	35,3	32,1	26,5	21,2
F	59,8	54,6	50,6	48,2	46,8	44,8	43,7	41,8	40,0	39,3	36,4	33,3	27,9	22,7
G	59,3	54,1	50,1	47,7	46,3	44,3	43,2	41,3	39,5	38,8	35,9	32,8	27,6	22,5
H	57,3	52,1	48,1	45,7	44,2	42,1	40,9	38,9	36,8	35,9	32,5	28,8	22,6	16,4
I	56,0	50,8	46,8	44,4	42,8	40,7	39,5	37,4	35,3	34,2	30,7	27,0	20,7	14,3
J (offshore receptor)	60,5	55,3	51,3	48,9	47,6	45,6	44,6	42,7	41,0	40,4	37,6	34,8	29,8	25,0
K (offshore receptor)	58,5	53,3	49,3	46,9	45,5	43,5	42,3	40,4	38,5	37,8	34,8	31,7	26,4	21,3
L (offshore receptor)	60,3	55,1	51,1	48,7	47,3	45,4	44,3	42,5	40,7	40,1	37,4	34,6	29,6	25,0

Indoor noise levels, dB

	1/3 frequency band / Hz													
Receptor	10	12,5	16	20	25	32	40	50	63	80	100	125	160	200
A	53,9	47,7	45,0	40,6	37,4	33,0	31,4	27,9	22,5	18,7	14,4	12,6	6,6	2,0
B	52,9	46,7	44,0	39,6	36,3	31,9	30,1	26,6	21,0	16,9	12,2	9,6	2,5	-3,7
C	52,0	45,8	43,1	38,7	35,3	30,9	29,0	25,4	19,6	15,4	10,3	7,3	-0,6	-7,7
D	53,4	47,2	44,5	40,1	36,8	32,4	30,6	27,1	21,5	17,5	12,7	10,2	3,1	-2,9
E	54,2	48,0	45,3	40,9	37,7	33,3	31,5	28,0	22,5	18,7	14,1	11,9	5,3	0,0
F	54,9	48,7	46,0	41,6	38,4	34,0	32,3	28,8	23,4	19,6	15,2	13,1	6,7	1,5
G	54,4	48,2	45,5	41,1	37,9	33,5	31,8	28,3	22,9	19,1	14,7	12,6	6,4	1,3
H	52,4	46,2	43,5	39,1	35,8	31,3	29,5	25,9	20,2	16,2	11,3	8,6	1,4	-4,8
I	51,1	44,9	42,2	37,8	34,4	29,9	28,1	24,4	18,7	14,5	9,5	6,8	-0,5	-6,9
J (offshore receptor)	-	-	-	-	-	-	-	-	-	-	-	-	-	-
K (offshore receptor)	-	-	-	-	-	-	-	-	-	-	-	-	-	-
L (offshore receptor)	-	-	-	-	-	-	-	-	-	-	-	-	-	-
LFN recommendation	95	87	79	71	63	55,5	49	43	41,5	40	38	36	34	32

Coordinates of the Wind Turbines

Annex 2

Siemens SWT-4,0-130

E / lon	N / lat	Z	hh	E / lon	N / lat	Z	hh
431440	6559524	0	110	440146	6559050	0	110
432019	6558679	0	110	440727	6558206	0	110
430860	6560368	0	110	437915	6564311	0	110
435598	6555506	0	110	438497	6563468	0	110
430281	6561213	0	110	437334	6565155	0	110
385899	6555103	0	110	438009	6566199	0	110
387567	6554083	0	110	438590	6565356	0	110
386692	6553355	0	110	439078	6562625	0	110
386299	6554223	0	110	441404	6559253	0	110
387232	6554923	0	110	436077	6564953	0	110
388528	6554749	0	110	440823	6560096	0	110
436275	6556552	0	110	439660	6561782	0	110
431537	6561414	0	110	440241	6560939	0	110
435695	6557396	0	110	437725	6560534	0	110
434534	6559084	0	110	434630	6560973	0	110
435114	6558240	0	110	435211	6560129	0	110
432117	6560570	0	110	434050	6561817	0	110
434437	6557193	0	110	432889	6563505	0	110
435018	6556350	0	110	433469	6562661	0	110
433857	6558038	0	110	435791	6559286	0	110
432697	6559726	0	110	432793	6561615	0	110
433277	6558882	0	110	433373	6560771	0	110
387897	6553253	0	110	437533	6556755	0	110
389182	6550027	0	110	436372	6558442	0	110
390142	6550045	0	110	436953	6557598	0	110
388212	6550009	0	110	440050	6557160	0	110
390876	6550804	0	110	435306	6562019	0	110
387231	6549991	0	110	439469	6558004	0	110
391090	6550062	0	110	438307	6559690	0	110
388578	6549202	0	110	438888	6558847	0	110
389494	6549243	0	110	435887	6561175	0	110
387655	6549160	0	110	438211	6557801	0	110
385782	6549076	0	110	438792	6556957	0	110
386722	6549118	0	110	437630	6558644	0	110
389345	6552366	0	110	436468	6560331	0	110
387463	6551658	0	110	437049	6559488	0	110
388224	6552433	0	110	400778	6558307	0	110
389075	6553154	0	110	401803	6557883	0	110
387081	6552500	0	110	399739	6558738	0	110
388547	6551621	0	110	395435	6560520	0	110
388867	6550819	0	110	396533	6560065	0	110
389879	6550811	0	110	402816	6557463	0	110
387840	6550827	0	110	406730	6555843	0	110
389613	6551586	0	110	394398	6559793	0	110
390661	6551550	0	110	405770	6556240	0	110
433954	6559928	0	110	403813	6557050	0	110
438402	6561579	0	110	404799	6556642	0	110
438983	6560736	0	110	403197	6558896	0	110
437821	6562423	0	110	404225	6558370	0	110
436658	6564109	0	110	402148	6559433	0	110
437239	6563266	0	110	403393	6559629	0	110
439565	6559893	0	110	401077	6559981	0	110
436563	6562220	0	110	405232	6557854	0	110
437144	6561377	0	110	401973	6558649	0	110
435982	6563064	0	110	403005	6558173	0	110

E / lon	N / lat	Z	hh
398774	6560127	0	110
406219	6557348	0	110
407187	6556853	0	110
395464	6559401	0	110
406276	6554840	0	110
396492	6557023	0	110
405327	6555147	0	110
403413	6555766	0	110
404374	6555455	0	110
403954	6554281	0	110
408139	6556365	0	110
407678	6555450	0	110
408599	6557280	0	110
404888	6554061	0	110
409059	6558195	0	110
400633	6557499	0	110
401636	6557130	0	110
399621	6557872	0	110
396519	6559013	0	110
397563	6558628	0	110
402629	6556765	0	110
398512	6557351	0	110
402446	6556079	0	110
397512	6557675	0	110
395492	6558328	0	110
396505	6558001	0	110
402325	6560231	0	110
386845	6547379	0	110
387664	6547460	0	110
386023	6547298	0	110
384374	6547136	0	110
385200	6547217	0	110
388482	6547540	0	110
391726	6547860	0	110
392532	6547939	0	110
390919	6547780	0	110
389296	6547620	0	110
390109	6547700	0	110
385436	6548155	0	110
386320	6548218	0	110
384548	6548091	0	110
390403	6549284	0	110
391303	6549324	0	110
387197	6548281	0	110
390662	6548529	0	110
391515	6548590	0	110
389803	6548467	0	110
388072	6548343	0	110
388940	6548405	0	110
392699	6547228	0	110
403794	6561135	0	110
401392	6561737	0	110
402691	6561880	0	110
408110	6558892	0	110
401554	6562647	0	110
402507	6561048	0	110
406673	6558471	0	110
407647	6557869	0	110
405674	6559089	0	110
403592	6560376	0	110

E / lon	N / lat	Z	hh
404647	6559724	0	110
403074	6563599	0	110
404210	6562694	0	110
408576	6559921	0	110
393461	6547325	0	110
407055	6562948	0	110
401722	6563582	0	110
406125	6560349	0	110
407134	6559609	0	110
405081	6561116	0	110
402881	6562731	0	110
404001	6561909	0	110