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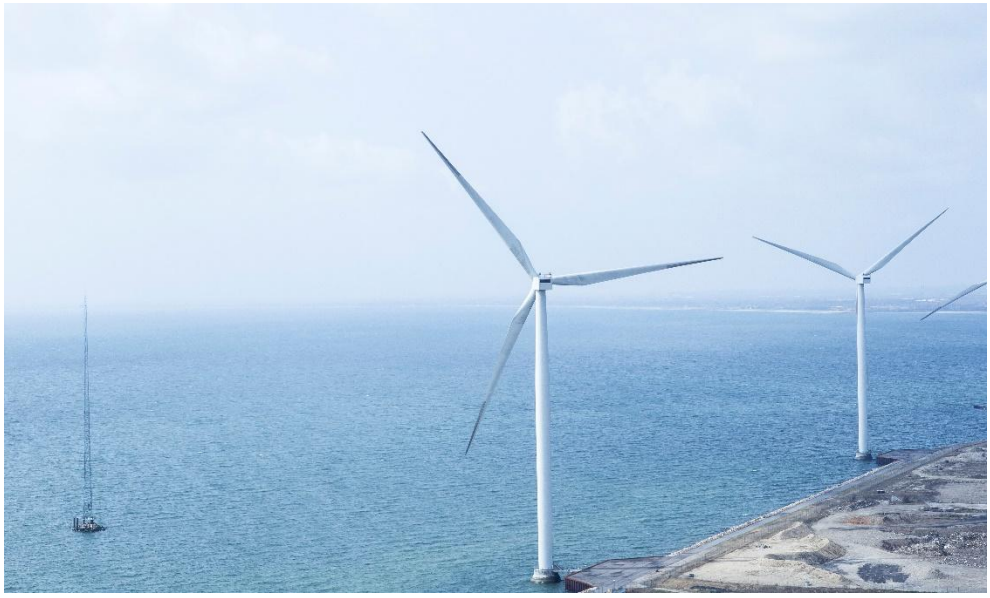
NORTH WEST ESTONIA OFFSHORE WIND FARM, ESTONIA

LOW FREQUENCY NOISE AND INFRASOUND SURVEY



RAMBØLL

NORTH WEST ESTONIA OFFSHORE WIND FARM, ESTONIA
LOW FREQUENCY NOISE AND INFRASOUND SURVEY

Date	8.12.2022
Made by	Ville Virtanen
Checked by	Jari Hosiokangas
Description	Low frequency noise and infrasound survey for the operation of Enefit Green AS North West Estonia offshore wind farm, Estonia

Ref	1510055015-001

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Annex

1. FOREWORD

Enefit Green AS is planning a wind farm to be located north from Hiiumaa, Estonia. Ramboll made a calculation low frequency noise and impact assessment of infrasound. The objective of this noise survey project was to assess the impact of low frequency noise and infrasound by calculating the noise levels to the closest reference points on the coast of the Hiiumaa Island and on three points on the sea with 4 different turbine and coordinate alternatives.

The project was assigned to Ramboll by Enefit Green AS, the contact person was Karmo Kõrvek. Project manager in Ramboll was Jari Hosiokangas, the noise modelling was conducted by Ville Virtanen.

2. NOISE LIMIT VALUES

2.1 Environmental noise

Estonian national environmental noise level standards are established in Minister of the Environment 16.12.2016 regulation no 71 “Normative levels of environmental noise and methods for measurement, determination and assessment of noise levels”. Clause 4 “Industrial noise” states: *For the purposes of this Regulation, industrial noise is noise emitted by stationary noise sources, including wind turbines and ports*.

Estonian national noise indicators are L_d and L_n that respectively describe average equivalent noise levels during the daytime (7:00-23:00) and during the night-time (23:00-7:00). Indicator L_d includes evening period (19:00-23:00) which includes additional 5 dB.

Table 1. Noise limit values for industrial and traffic noise stated in Minister of Environment Regulation No 71

Category	Time of day	Limit values $L_{pA,eq,T}$		Target values $L_{pA,eq,T}$	
		Traffic noise	Industrial noise	Traffic noise	Industrial noise
I recreational areas, quiet areas	day (L_d) night (L_n)	55 50	55 40	50 40	45 35
II educational, health care, social welfare, residential and green areas;	day (L_d) night (L_n)	60 (65[1]) 55 (60[1])	60 45	55 50	50 40
III/IV mixed use, central areas/ areas of public buildings	day (L_d) night (L_n)	65 (70[1]) 55 (60[1])	65 50	60 50	55 45

[1)] permitted on the side of the roads (railway) of noise-sensitive buildings
If there tonal or impulse component, respective correction shall be applied.

For wind turbines target values for Category II shall be used.

2.2 Indoor noise

Estonian national noise level standards for infrasound are established in Minister of Social Affairs 6.5.2002 regulation no 75 “Limits for ultrasonic and infrasonic sound pressure levels and measurement of ultrasonic and infrasonic sound pressure levels”. Limit values for infrasound are stated in § 4:

> *§4 Limit value for infrasound sound pressure level*
>
> *The limit value for the G-weighted sound pressure level L_{pG} of the constant level infrasound or the G-weighted equivalent sound pressure level $L_{pG,eq,T}$ of the variable level infrasound is 85 dB.*

The Minister of Social Affairs Regulation No 42 of 4 March 2002 establishes the 1/3 octave band indoor recommended noise levels in residential and recreational areas and residential buildings. The recommended sound pressure levels for low frequency noise annoyance assessment for residential living and sleeping rooms are shown in Table 2. 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

There are no limit values or recommendations for outdoor Low Frequency Noise or Infrasound in Estonia.

3. INFRASOUND FROM WIND TURBINES IN GENERAL

Infrasound is usually determined as sound below a frequency of 20 Hz. Infrasound is produced 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 range (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 1 shows different hearing thresholds suggested. The results vary but are parallel: humans 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.

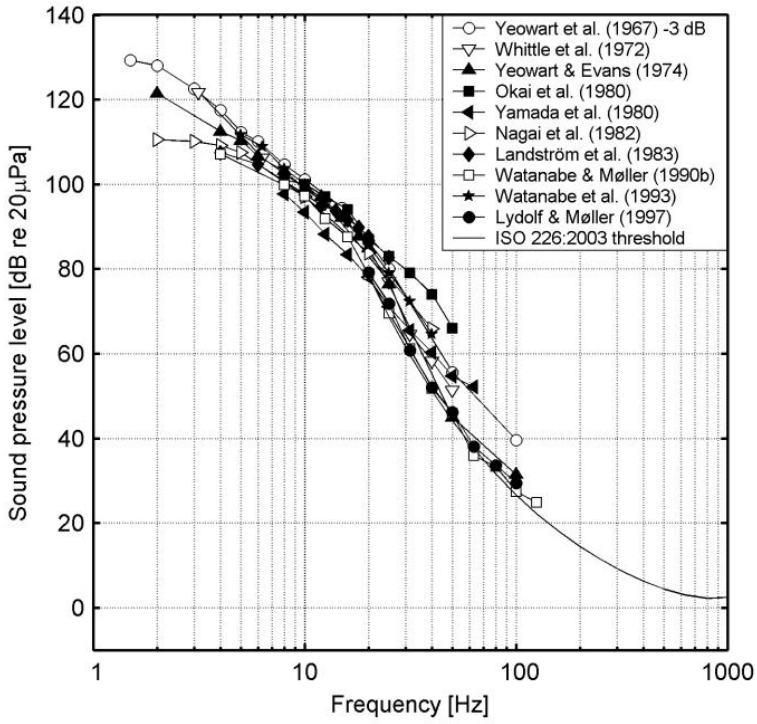


Figure 1. Different hearing thresholds suggested. (Hearing at low and infrasound frequencies, Møller et al, 2004)

3.1 Infrasound measurement results in literature

There are numerous research reports available worldwide including results of Wind Turbine Noise measurements, but only limited number of research reports including Infrasound measurements for Wind Turbines. Those measurements have been conducted mainly for onshore Wind Turbines and the number of measured turbines has been smaller than in case of Hiiumaa Wind project. Also, the distances between measurement locations and nearest Wind Turbines have been smaller than in the case of Hiiumaa Wind project. Bearing this in mind, the results of those measurements may still be used for reference and comparison.

Field measurements were made in a Japanese research project in the noise immission areas around several wind farms across Japan. Figure 2 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.

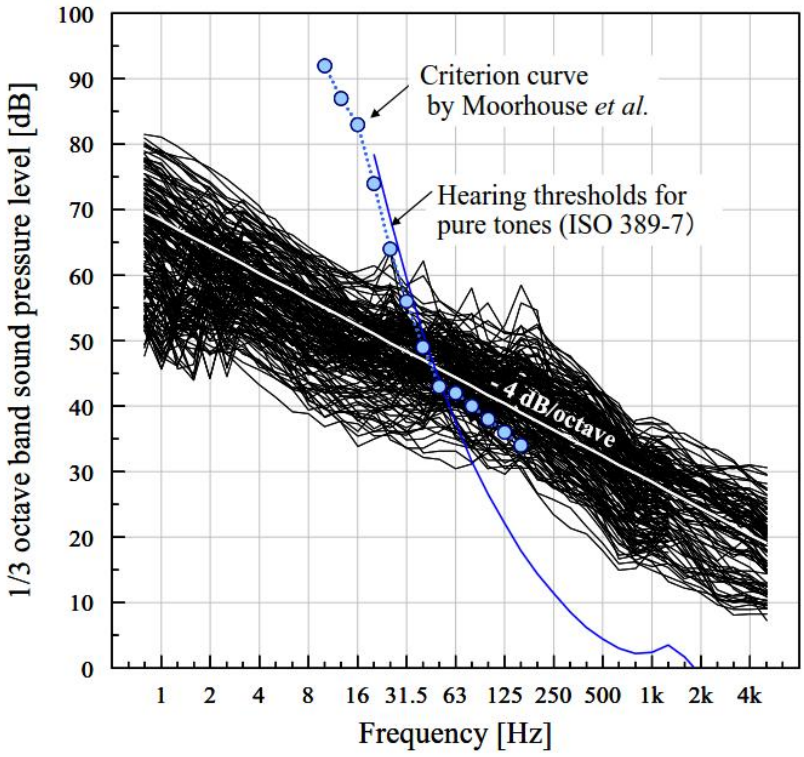
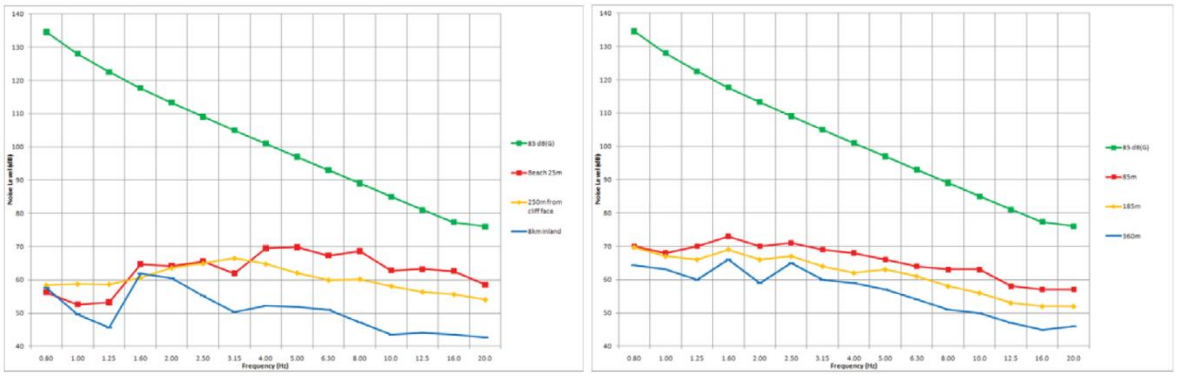


Figure 2. Measurement results at 164 points around 29 wind farms in Japan. (Assessment of wind turbine noise in immission areas, H. Tachibana et al, 2013)

Figure 3 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 3. 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)

Infrasound from wind turbines was measured in Finland as a part of the research on Health effects of Infrasound from Wind Turbines, funded by the Finnish Council of State. Measurements took place in two locations nearby two different Wind power plants. The other location was in the vicinity of Santavuori wind power plant (17 Vestas V126 3.3 MW turbines) in Ilmajoki, Finland, nearest turbine at 1585 m from measurement location. The other location was in the vicinity of Kopsa wind power plant (7 Siemens SWT-3.0-DD 3.0 MW turbines and 10 Vestas V126 3.3 MW turbines) in Raahe, Finland, nearest turbine at 1,5 km from measurement location. Figures 4 and

5 show infrasound measurement results for noise caused by wind farm and other sources (natural sources, road traffic and agricultural activities).

Conclusions of the measurement campaign were that the infrasound levels in the vicinity of wind power plants were higher than in an area with only natural infrasound sources. However, the infrasound levels were not higher than levels measured in urban surroundings.

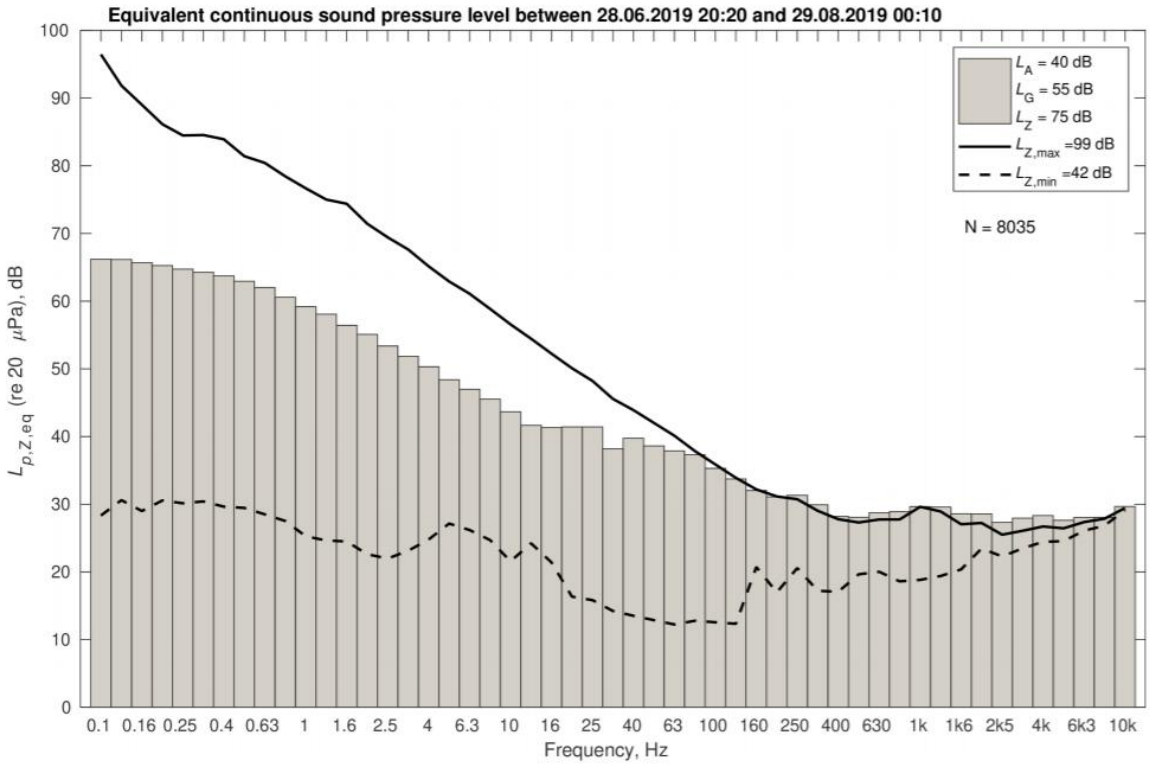


Figure 4. Measured outdoor levels of sound (0.1 Hz to 10 kHz) at Raahe, Finland. Third octave bands for all the validated data based on 600 seconds equivalent sound pressure levels. Also, the minimum and maximum L_Z curves are shown. (Infrasound Does Not Explain Symptoms Related to Wind Turbines, Maijala et al, 2020)

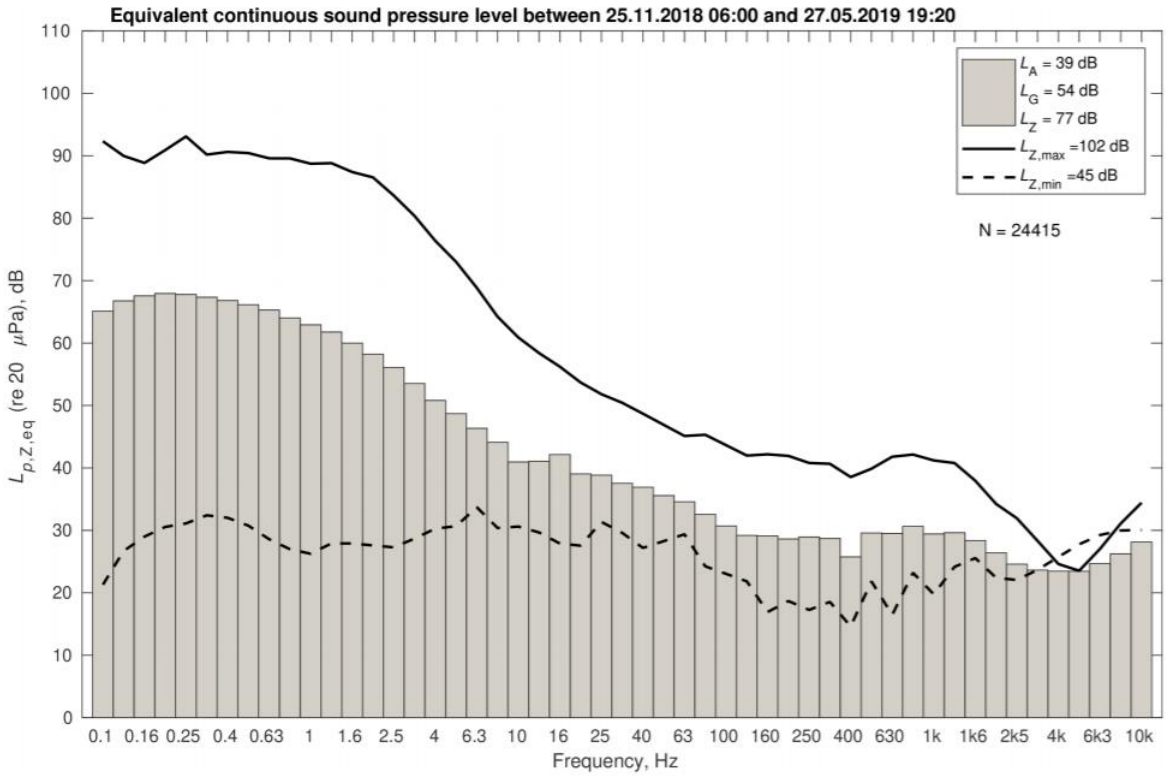


Figure 5. Measured outdoor levels of sound (0.1 Hz to 10 kHz) at Ilmajoki, Finland. Third octave bands for all the validated data based on 600 seconds equivalent sound pressure levels. Also, the minimum and maximum L_Z curves are shown. (Infrasound Does Not Explain Symptoms Related to Wind Turbines, Maijala et al, 2020)

3.2 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.

Council of State in Finland assigned in 2019 a research group aimed to assess whether wind turbine infrasound has harmful effects on human health. Research consisted of a questionnaire study, sound measurements and provocation experiments. Measured infrasound levels were found to be similar to the levels occurring typically in urban environments. In the questionnaire study, symptoms that were intuitively associated with wind turbine infrasound were relatively common within 2,5 km from the closest wind turbine. In that response group the symptom spectrum was broad. Many of the symptomatic respondents associated their symptoms also with vibration or electromagnetic field from wind turbines. From the measurements the captured sound samples with the highest infrasound levels and amplitude modulation values were selected and used in the double blinded provocation experiments. The experiment group consisted of respondents that had reported symptoms intuitively associated with wind turbine infrasound and also respondents that had not reported such symptoms. In the research it was shown that wind turbine infrasound exposure did not cause physiological responses in either participant group. The participants who had previously reported wind turbine infrasound related symptoms were not able to perceive infrasound in the noise samples and did not find samples with infrasound more annoying than those without previous wind turbine infrasound related symptoms. The conclusion of the research project was that infrasound does not explain symptoms related to wind turbines.

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 and with 1238 respondents it is currently the most extensive research about health effects of wind turbines. 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 Wind Turbine Noise is not audible there are no health effects.

4. NOISE MODELLING

4.1 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 Figures 9-12. The calculations were made to 9 (A-I) immission 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 residential buildings façades that are stated in Keränen et. al research “The sound insulation of façades at frequencies 5–5000 Hz” (Table. The insulation values are based on the sound insulation measurements conducted several residential buildings in Finland. The measurements and the insulation values are reported in the “The sound insulation of façades at frequencies 5–5000 Hz, Keränen et. al” article in “Building and Environment Volume 156, June 2019, Pages 12-20”.

Table 3. Airborne sound insulation values for residential buildings façades

Frequency band, Hz	10	12,5	16	20	25	31,5	40	50	63	80	100	125	160	200
Insulation (level difference outdoor-indoor),dB	6,2	6,6	7,1	7,6	8,3	9,2	10,3	11,5	13	14,8	16,8	18,8	21,1	22,8

Those sound insulation values are the best information available, as there is no equivalent information available from Estonia. Compared to Finland the building types and materials may be little different in Estonia, but the differences are considered to be small enough that the insulation values can be applied for this assessment.

4.2 Wind turbine information

Alternatives 1 and 2:

For alternatives 1 and 2 the noise was modelled using SG 7.0-167 DD (hub height of 110 metres) and GE Haliade-X - 50/60 Hz turbine models (hub height of 134 metres).

The noise data of SG 7.0-167 DD Wind Turbine was obtained by Kajaja Acoustics OÜ (Marko Ründva) on the basis of document “Acoustic Emission, SG 8.0-167 DD, Rev. 1” and provided to Ramboll by Enefit Green (email Hallik-Ristolainen 9.10.2020). According to the provided data, safety margin of +2dB was added to the noise emission.

Noise data of SG 7.0-167 DD Wind Turbine contained 1/3-octave bands noise emission levels between 10 - 160 Hz. The band of 200 Hz was calculated by extrapolation. According to the manufacturer’s data provided, the For SG 7.0-167 DD with standard setting produces a total sound power level of 111,2 dB on wind speed of 8 m/s and maximum 115,0 dB on wind speed above 10 m/s at 10 m reference height. Maximum sound power level was used in calculations.

Figure 6 shows the one-third octave band sound power levels produced by the SG 7.0-167 DD used in the noise modelling.

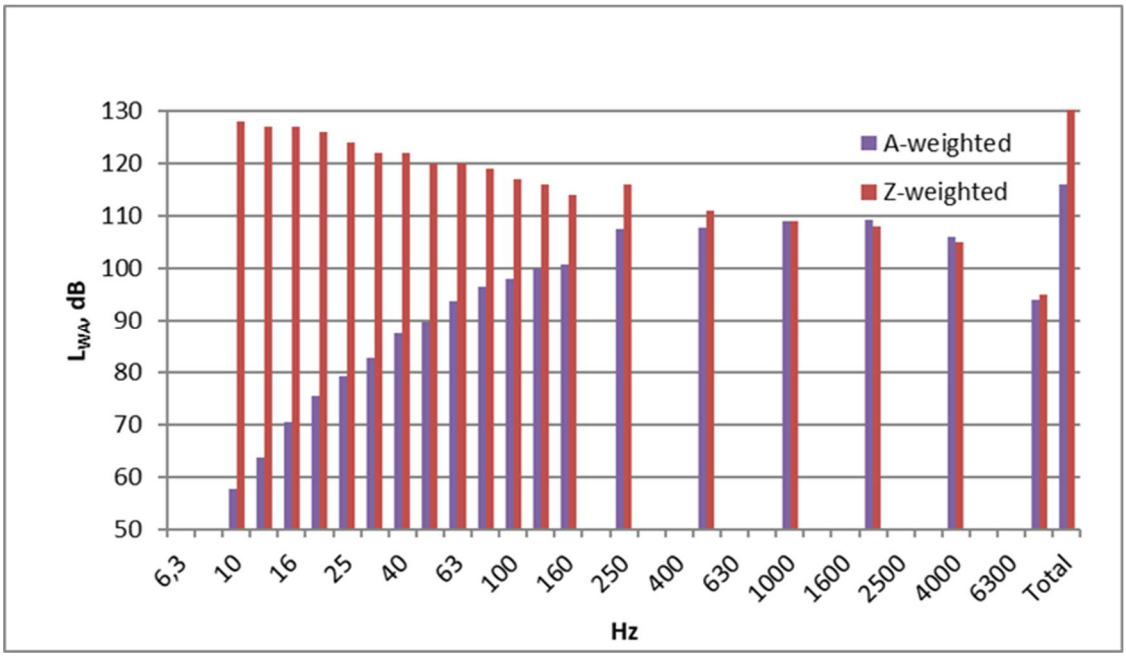


Figure 6. One-third octave band sound power levels of SG 7.0-167 DD Wind Turbine (incl. +2dB safety margin)

The noise data of GE Haliade-X - 50/60 Hz Wind Turbine was obtained from document “Technical Documentation, Wind Turbine Generator Systems, Haliade-X - 50/60 Hz, Noise Emission, RDS-PP Code 17_054 = Gxxx & EWA201, Rev. 02”.

Noise data of GE Haliade-X - 50/60 Hz Wind Turbine contained 1/3-octave bands noise emission levels between 12,5 – 10 000 Hz. According to the manufacturer’s data provided, the GE Haliade-X - 50/60 Hz Wind Turbine with standard setting produces a total sound power level of 115,0 dB on wind speed of 10 m/s at hub height. According to the documentation, the data is not guaranteed, so safety margin of +2dB was added to the noise emissions before modelling.

Figure 7 shows the one-third octave band sound power levels produced by the GE Haliade-X - 50/60 Hz used in the noise modelling.

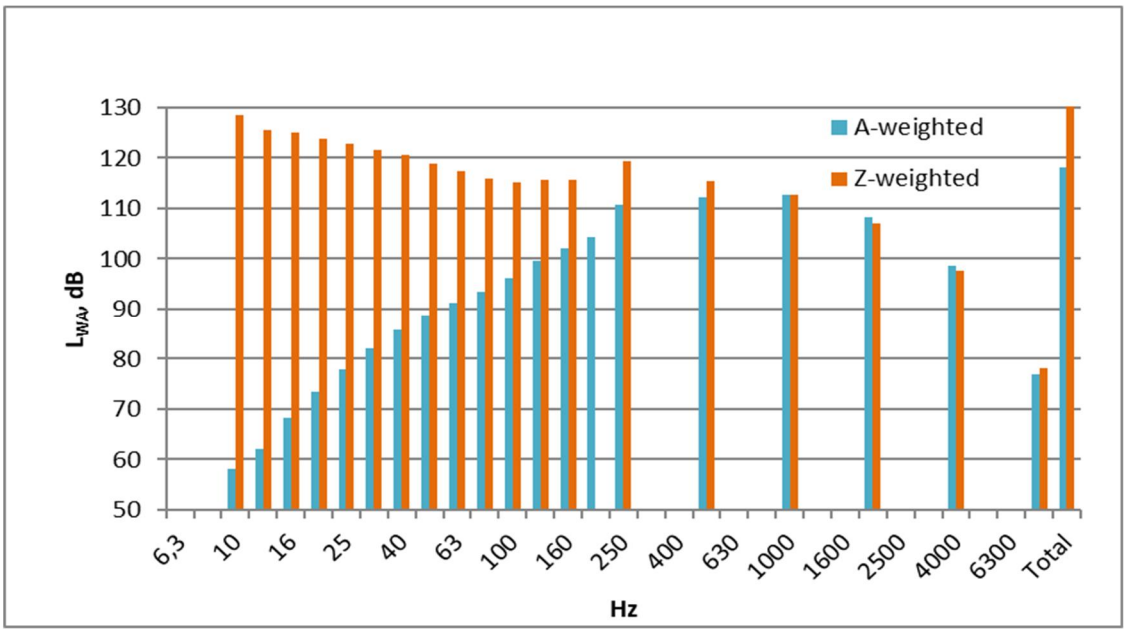


Figure 7. One-third octave band sound power levels of GE Haliade-X - 50/60 Hz Wind Turbine (incl. +2dB safety margin)

Alternatives 3 and 4:

For alternatives 3 and 4 the noise was modelled using Vestas V236-15MW noise data (hub height of 146 metres for the 15MW turbine and 162m for the 20MW turbine).

The noise data of V236-15MW Wind Turbine is based on a document "V236-15 MW Third octave noise emission, DMS 0105-2594_00, Date 2021-04-14". According to the documentation, the data is not guaranteed, so safety margin of +2dB was added to the noise emissions before modelling.

According to the manufacturer's data provided, the Vestas V236-15MW turbine with standard setting produces a total sound power level of 118,0 dB on wind speed of 11 m/s at 10 m reference height. Figure 8 shows the one-third octave band sound power levels of Vestas V236-15MW (incl. +2dB safety margin).

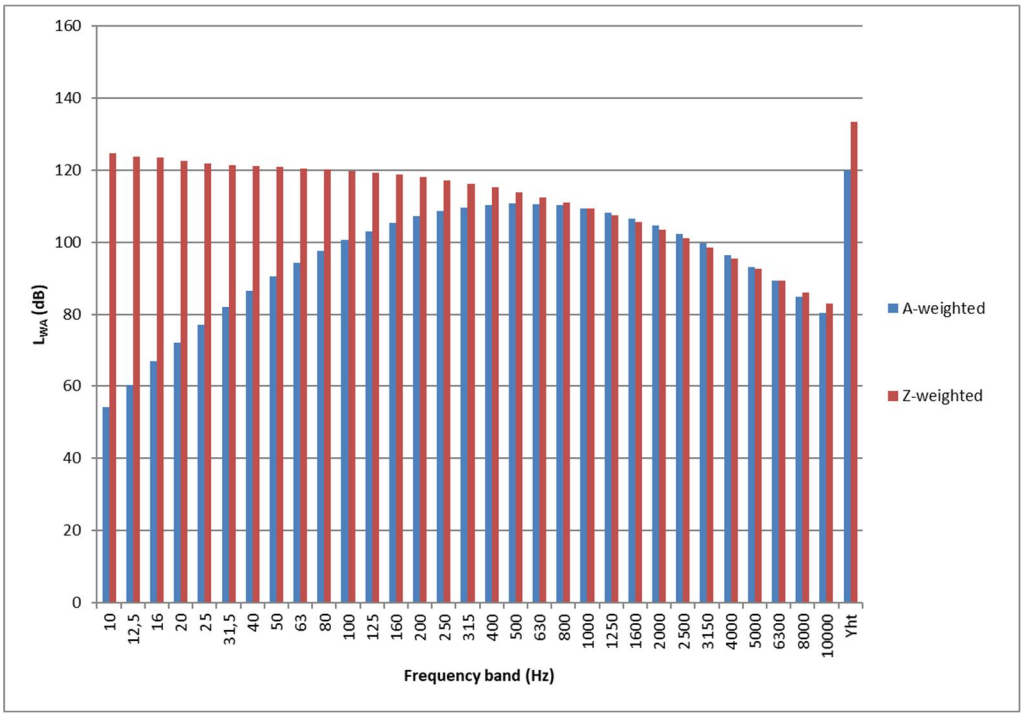


Figure 8. One-third octave band sound power levels of Vestas V236-15MW Wind Turbine (incl. +2dB safety margin)

For the 20MW turbine type there is no noise data available, thus the calculations were made by using 15 MW turbine noise emission data, and searching then the maximum allowable dB addition on it so that there will not be exceedances of recommended indoor sound pressure levels of low frequency noise (stated in Minister of Social Affairs Regulation No 42) at onshore receiver points A-I.

As a result, 9,6 dB was calculated as a maximum addition when LFN recommendation levels are not exceeded at any onshore receiver A-I with the studied coordinates and number of turbines. The restrictive receiver was receiver F, where the 50 Hz band noise is (after 9,6 dB addition) at level of L_{eq} 43 dB which equals to the LFN recommendation level at this frequency band.

4.3 Modeled alternatives

In this survey the noise from four alternative lay-outs and noise levels of Wind Turbines were calculated. The alternatives are:

1. 157 pcs of SG 7.0-167 DD Wind Turbines, L_{WA} 115,0 + 2 dB(Uc), (hub height of 110 metres)
2. 37 pcs of SG 7.0-167 DD Wind Turbines, L_{WA} 115,0 + 2 dB(Uc), (hub height of 110 metres) and 70 pcs of GE Haliade-X - 50/60 Hz Wind Turbines, L_{WA} 115,0 + 2 dB(Uc), (hub height of 134 metres), all together 107 Wind Turbines
3. 73 pcs of V236-15MW Wind Turbines, L_{WA} 118,0 + 2 dB(Uc), (hub height of 146 metres)
4. 55 pcs of V236-20MW Wind Turbines, L_{WA} 118,0 + 2 dB(Uc) + 9,6 dB to frequency bands of V236-15MW (hub height of 162 metres)

The lay-outs are presented in Figures 9-12. The coordinates of the wind turbines are presented in Annexes 5-8.

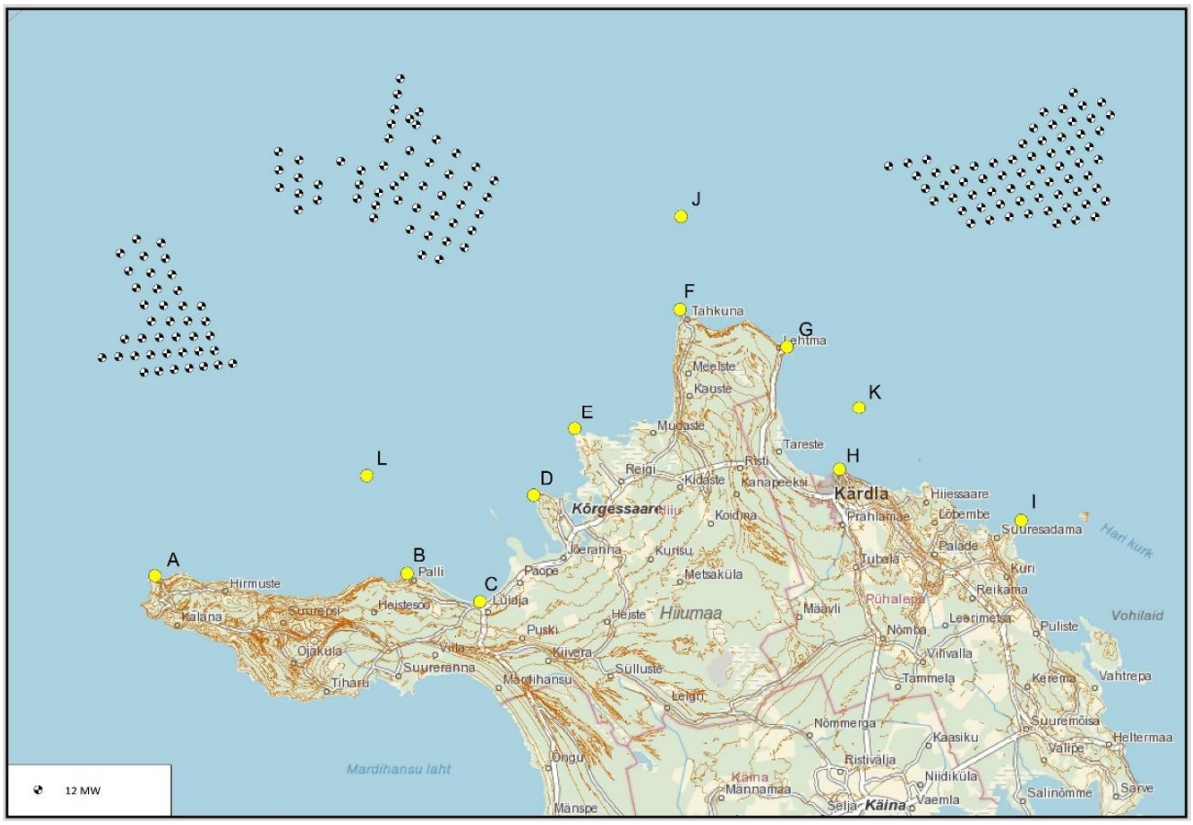


Figure 9. Alternative 1, receiver point locations and the Wind Turbine areas (157 turbines)

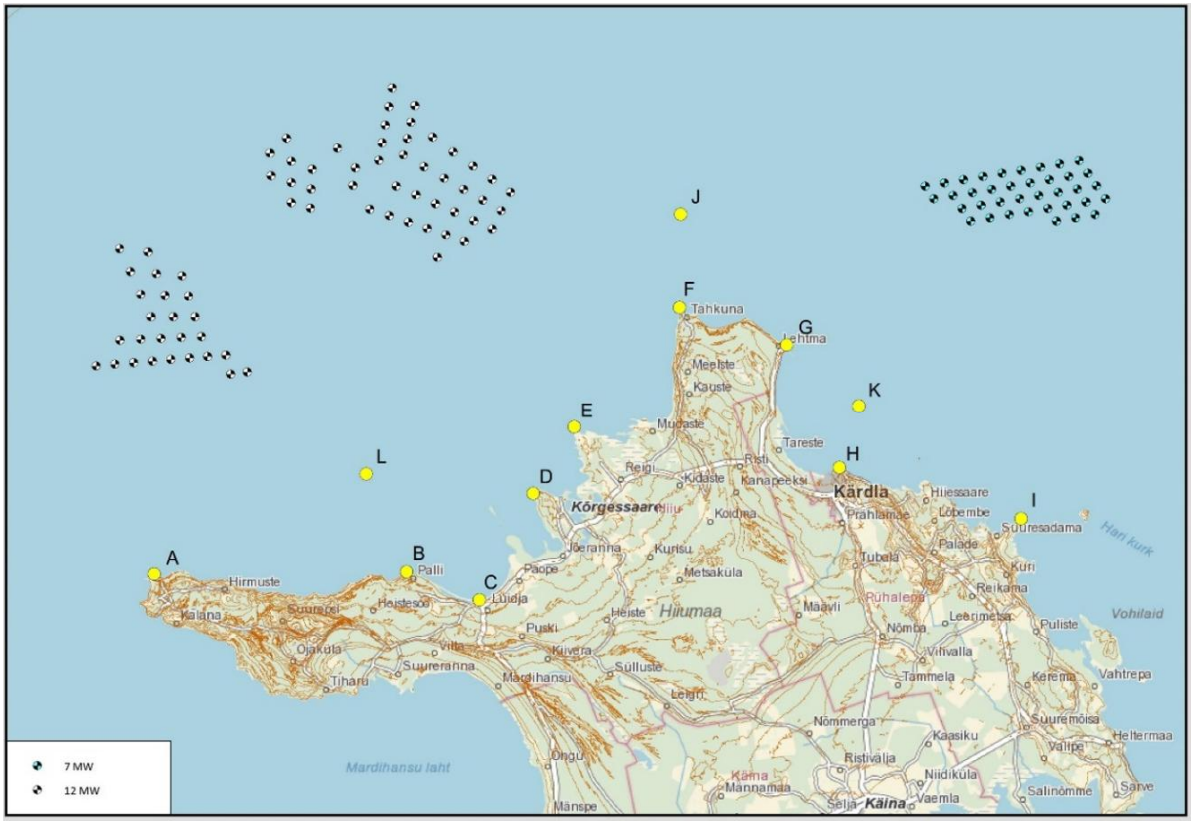


Figure 10. Alternative 2, receiver point locations and the Wind Turbine areas (107 turbines)

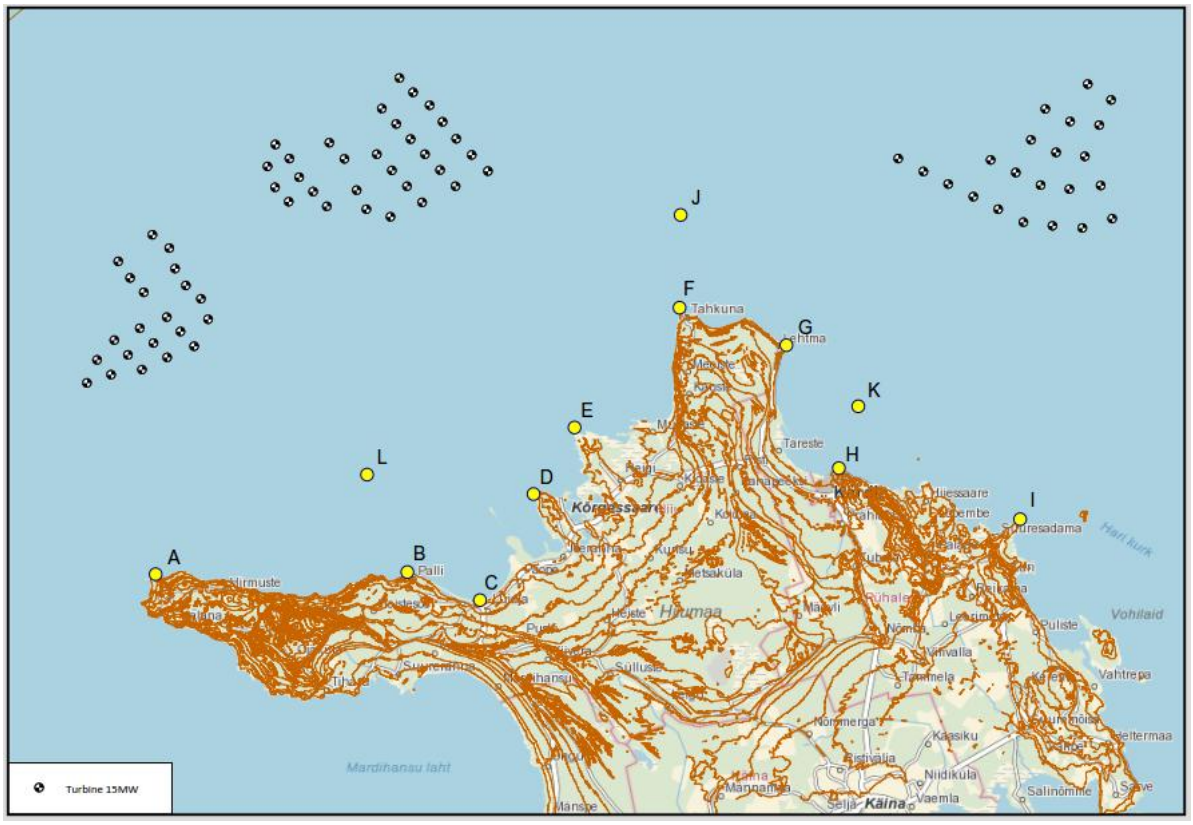


Figure 11. Alternative 3, receiver point locations and the Wind Turbine areas, 15MW

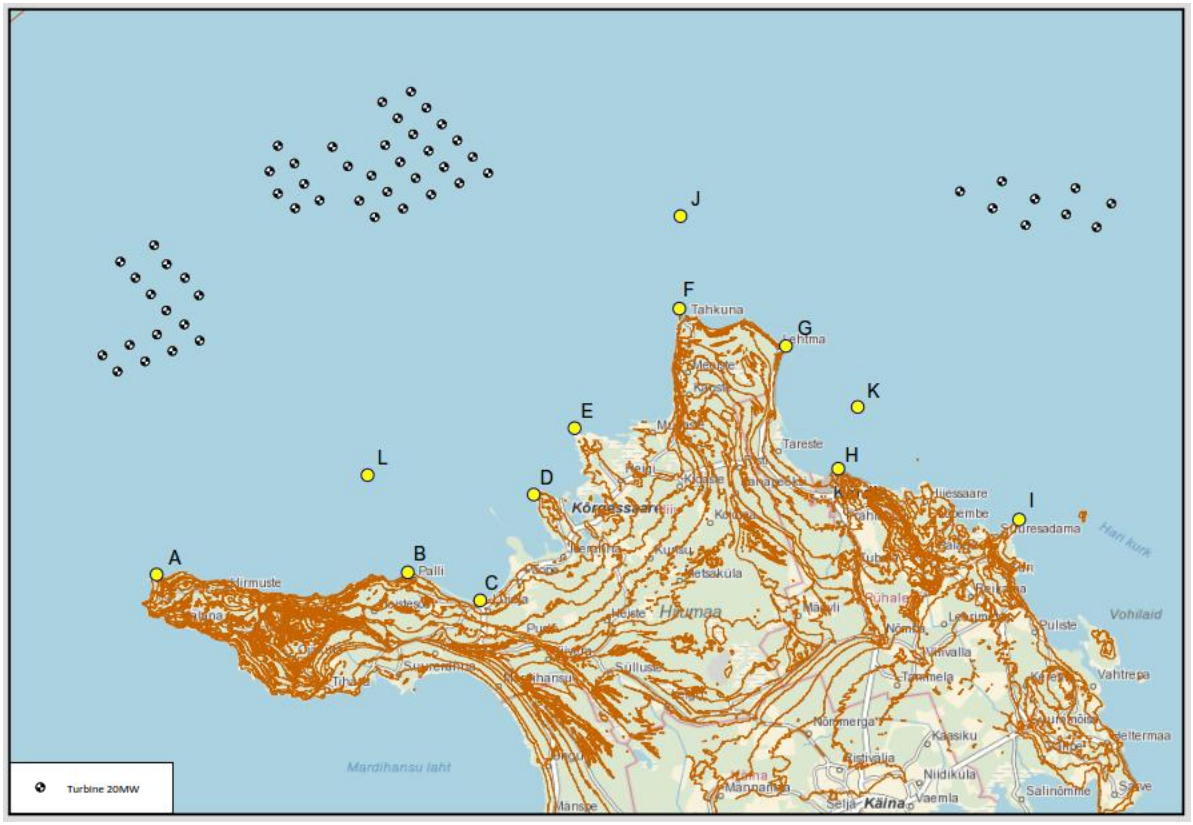


Figure 12. Alternative 4, receiver point locations and the Wind Turbine areas, 20MW

5. RESULTS

The onshore receiver points are set along the shoreline of Hiiumaa on multiple locations. As the nearest actual residential buildings are located more inland, the noise levels there are probably slightly lower than calculated levels onshore.

5.1 Infrasound and low frequency noise

Alternatives 1 and 2, G-weighted noise levels:

G-weighted results are presented in the tables in Annex 1 and Annex 2.

G-weighted indoor noise levels at receiver locations A-I (located on the shore of Hiiumaa) are 60-63 dB(G) for Alternative 1 and 57-60 dB(G) for Alternative 2. Calculated G-weighted indoor noise levels at receiver locations J-L (offshore) are given for information, although there are no buildings at those points. Calculated indoor noise levels at receiver locations J-L (offshore) are 62-63 dB(G) for Alternative 1 and 60-61 dB(G) for Alternative 2. The results show the calculated G-weighted noise levels for both alternative lay-outs are below the limit value ($L_{pG,eq}$ 85 dB) at all receiver locations.

G-weighted outdoor noise levels at receiver locations A-I (located on the shore of Hiiumaa) are 63-70 dB(G) for Alternative 1 and 60-68 dB(G) for Alternative 2. G-weighted outdoor noise levels at receiver locations J-L (offshore) are 69-71 dB(G) for Alternative 1 and 67-68 dB(G) for Alternative 2.

Alternatives 1 and 2, low frequency noise 10 – 200 Hz:

Indoor and outdoor results for 10-200 Hz unweighted 1/3 octave band sound pressure levels are presented in the figures 13-16 and in tables in Annex 1 and Annex 2.

The calculated indoor noise levels (the sound insulation of the building taken into account) were below the recommended indoor 10-200 Hz noise level guidelines at all receiver locations A-I located on the shore of Hiiumaa (Figures 13 and 15).

The outdoor results indicate that the low frequency noise from wind turbines may be audible outside the buildings at certain weather conditions in frequencies between 40…125 Hz, but as mentioned, the indoor noise levels are estimated to stay below guidelines.

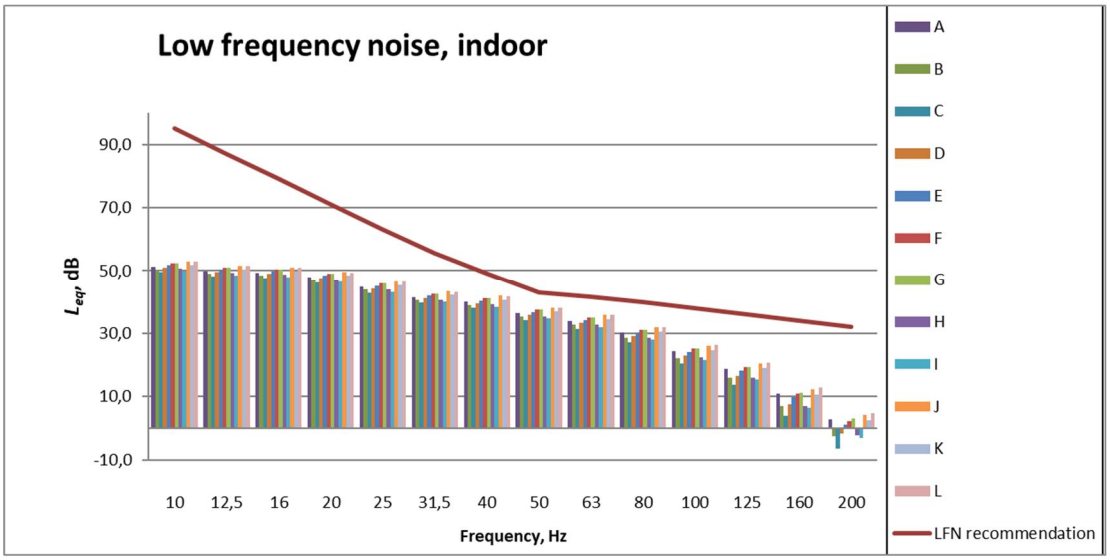


Figure 13. One-third octave band sound indoor levels at receiver points for Alternative 1 (157 Wind Turbines)

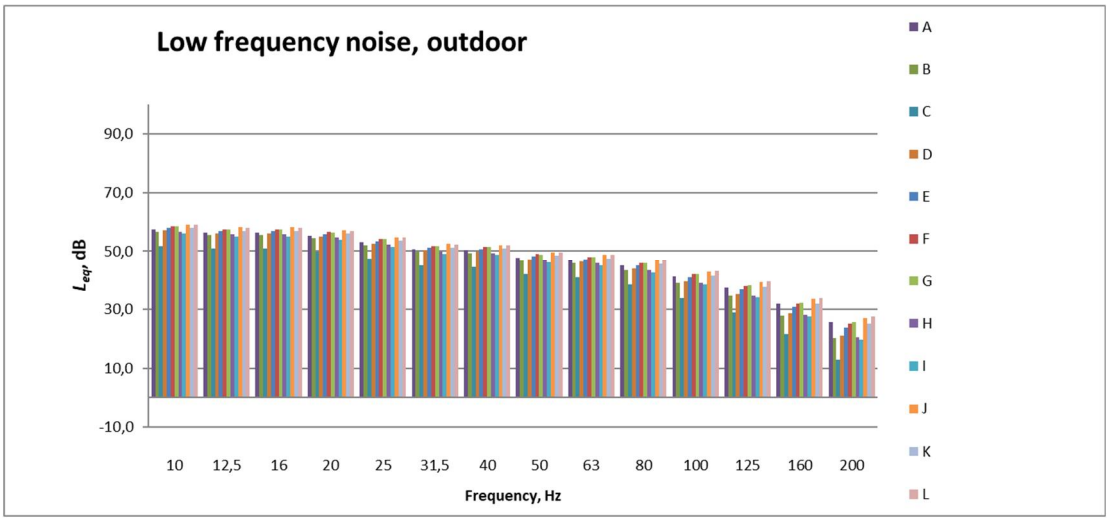


Figure 14. One-third octave band sound outdoor levels at receiver points for Alternative 1 (157 Wind Turbines)

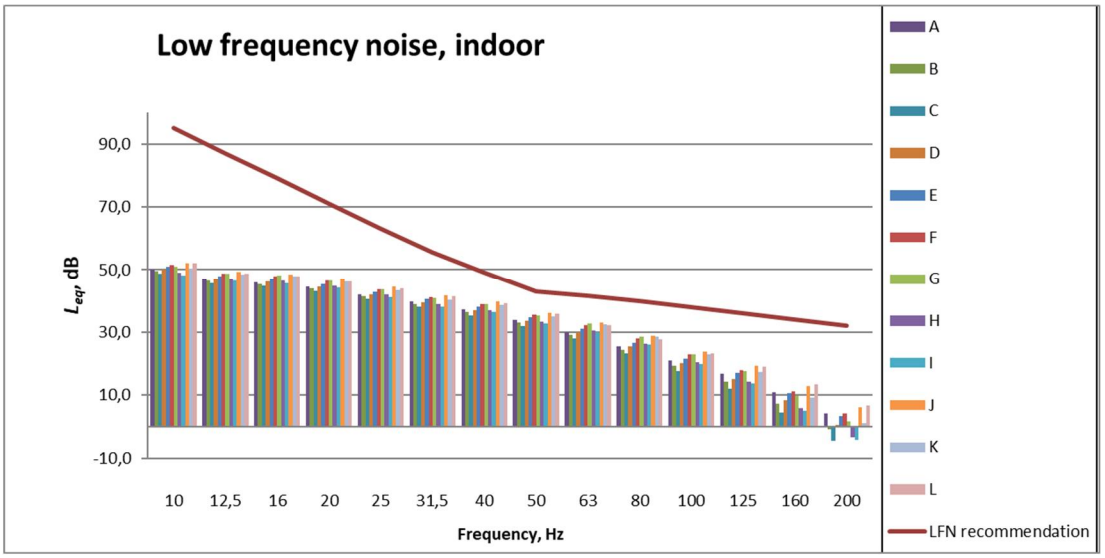


Figure 15. One-third octave band sound indoor levels at receiver points for Alternative 2 (107 Wind Turbines)

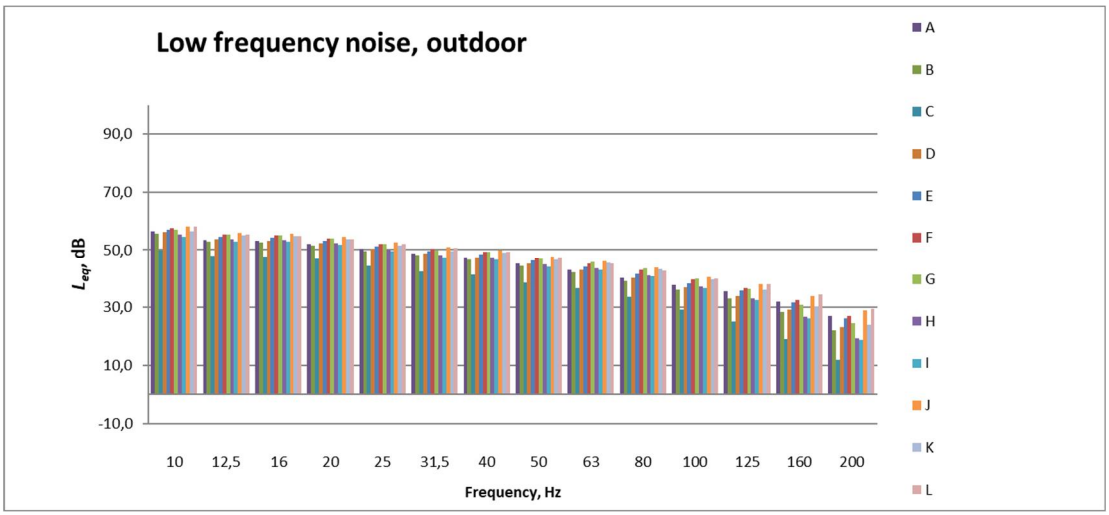


Figure 16. One-third octave band sound outdoor levels at receiver points for Alternative 2 (107 Wind Turbines)

Alternatives 3 and 4, G-weighted noise levels:

G-weighted results are presented in the tables in Annex 3 and Annex 4.

G-weighted indoor noise levels at receiver locations A-I (located on the shore of Hiiumaa) are 53-56 dB(G) for Alternative 3 and 60-64 dB(G) for Alternative 4.

Calculated G-weighted indoor noise levels at receiver locations J-L (offshore) are given for information, although there are no buildings at those points. Calculated indoor noise levels at receiver locations J-L (offshore) are 54-56 dB(G) for Alternative 3 and 62-65 dB(G) for Alternative 4. The results show the calculated G-weighted noise levels for both alternative lay-outs are below the limit value ($L_{pG,eq}$ 85 dB) at all receiver locations.

G-weighted outdoor noise levels at receiver locations A-I (located on the shore of Hiiumaa) are 58-63 dB(G) for Alternative 3 and 67-71 dB(G) for Alternative 4.

G-weighted outdoor noise levels at receiver locations J-L (offshore) are 62-64 dB(G) for Alternative 3 and 69-73 dB(G) for Alternative 4.

Alternatives 3 and 4, low frequency noise 10 – 200 Hz:

Indoor and outdoor results for 10-200 Hz unweighted 1/3 octave band sound pressure levels are presented in the figures 17-20 and in tables in Annex 3 and Annex 4.

The calculated indoor noise levels (the sound insulation of the building taken into account) were below or at the recommended indoor 10-200 Hz noise level guidelines at all receiver locations A-I located on the shore of Hiiumaa. In alternative 4, where 9,6 dB addition was applied to 15 MW turbine noise levels, the indoor noise level at receiver F is 43 dB in 50 Hz frequency band, which equals to the LFN recommendation level at this frequency band. All other receivers are below the recommended values.

The results also show that the low frequency noise from wind turbines may be audible outside the buildings at certain weather conditions in frequencies between 31,5…200 Hz, but as mentioned, the indoor noise levels are estimated to stay within guidelines.

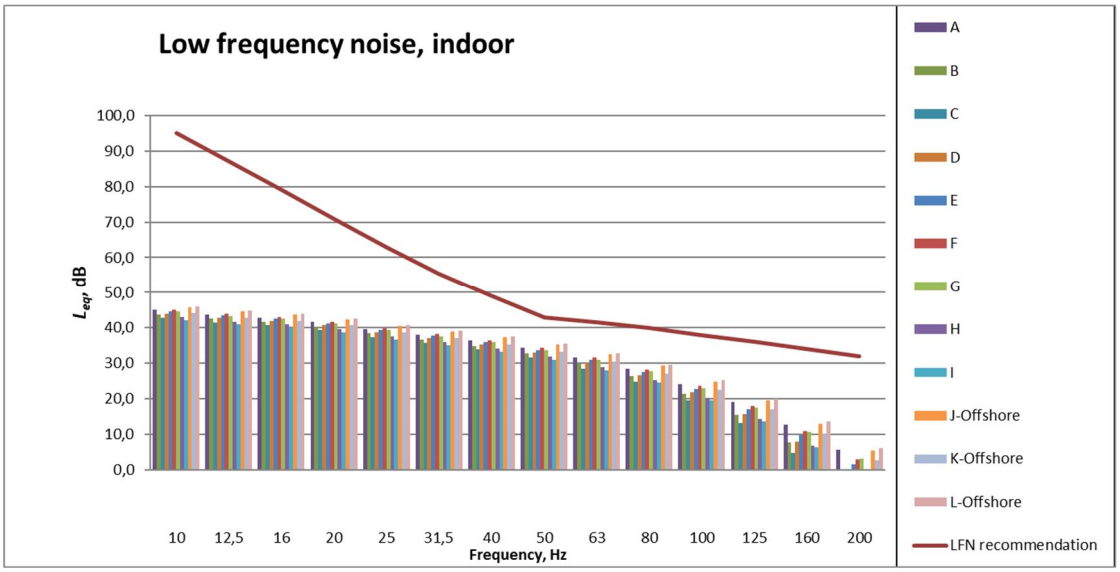


Figure 17. One-third octave band sound indoor levels at receiver points for Alternative 3, 15MW (73 Wind Turbines)

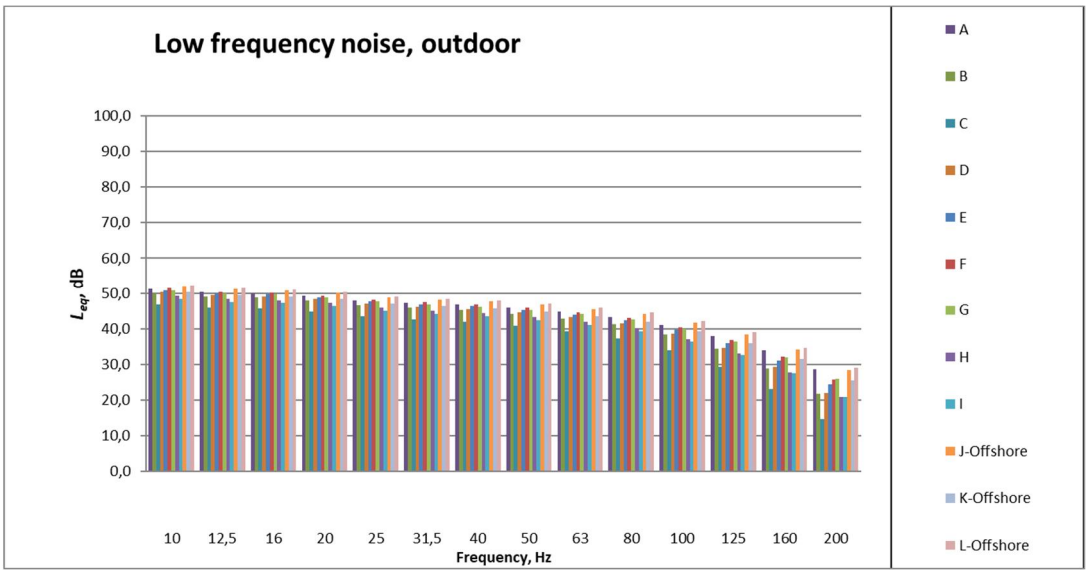


Figure 18. One-third octave band sound outdoor levels at receiver points for Alternative 3, 15MW (73 Wind Turbines)

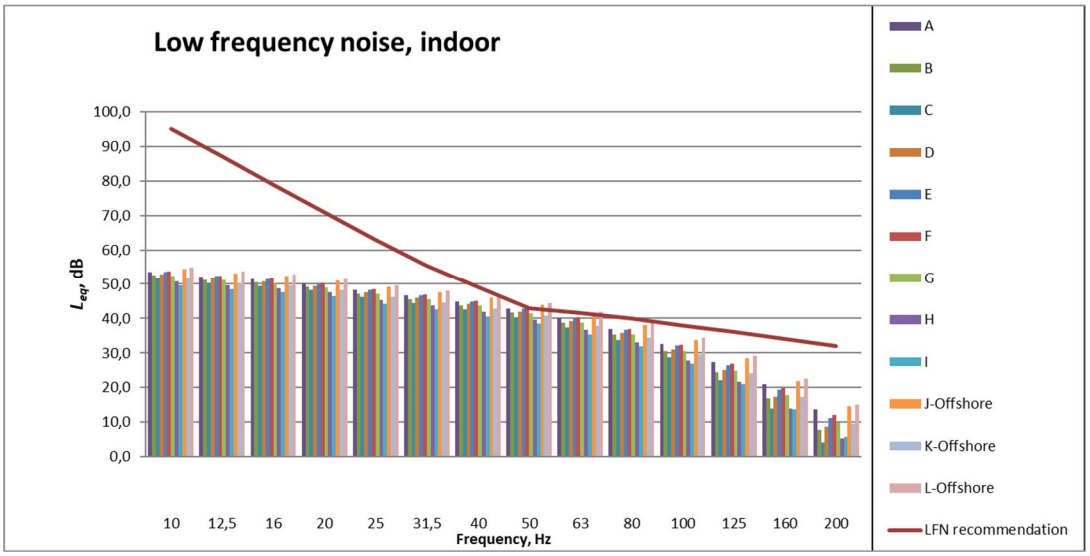


Figure 19. One-third octave band sound indoor levels at receiver points for Alternative 4, 20MW (55 Wind Turbines)

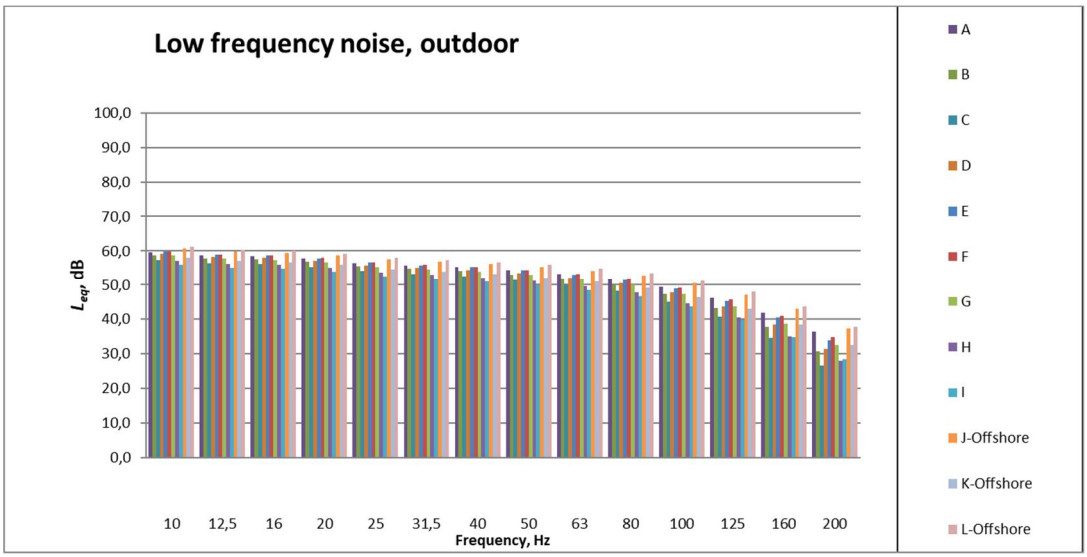


Figure 20. One-third octave band sound outdoor levels at receiver points for Alternative 4, 20MW (55 Wind Turbines)

5.2 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 reliably be estimated only 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.

5.3 Hiiumaa results compared to current knowledge of low frequency and infrasound from wind turbines

In current studies, presented earlier in the report, measurements have been made for wind turbines with a lower nominal power than wind turbines in the Hiiumaa wind farm project. However, the measurements, e.g. regarding publication of “Infrasound Does Not Explain Symptoms Related to Wind Turbines” in Finland, have been made closer distance to existing wind farms than the distance between the Hiiumaa wind farm and the Baltic coast. Although the sound power levels of offshore wind turbines are typically higher than onshore wind turbines, the distance to settlement is correspondingly much longer. In the impact assessment it is important to consider the noise levels in the settlement rather than the magnitude of the wind turbine sound power levels.

The modelled infrasound levels (10-25 Hz) are below the hearing threshold and according to existing research data, if wind turbine noise is not audible there are no health effects.

According to the modelling, low frequency noise (31.5-200 Hz) may be audible (results compared to hearing threshold) outside the buildings in certain frequency bands and under certain operating and weather conditions, but the indoor results are below the recommended values.

6. CONCLUSIONS

Alternatives 1 and 2

According to noise modelling the calculated G-weighted noise levels for both alternative 1 and 2 lay-outs are below the limit value ($L_{pG,eq}$ 85 dB) at all receiver locations.

The 10-200 Hz noise levels inside buildings are well below the recommended indoor noise levels and limit values on the shore of Hiiumaa. As the nearest actual residential buildings are located more inland, the noise levels there are probably slightly lower than calculated levels onshore.

Alternative 3, 15 MW turbines

According to noise modelling the calculated G-weighted noise levels are below the limit value ($L_{pG,eq}$ 85 dB) at all receiver locations.

The 10-200 Hz noise levels inside buildings are well below the recommended indoor noise levels and limit values on the shore of Hiiumaa. As the nearest actual residential buildings are located more inland, the noise levels there are probably slightly lower than calculated levels onshore.

Alternative 4, 20 MW turbines

Noise modelling of 20 MW turbines is based on 15 MW turbine noise data, by adding 9,6 dB (and 2 dB(Uc)) to its sound emission levels (constantly to all frequency bands). This is not an estimate of real emission value of 20 MW turbine but represents maximum allowed noise emission to keep the low frequency noise levels within recommended indoor low frequency noise levels set by Minister of Social Affairs Regulation No 42. The restrictive receiver was F, where the 50 Hz band noise is at level of Leq 43 dB (=the same as recommendation), when 9,6 dB addition is applied. It must bear in mind, that there may be differences in noise spectrums of 15 MW and 20 MW turbines. Calculations are then strongly recommended to revise when actual noise data is available for 20 MW turbines.

Remarks

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. The infrasound exists in urban and natural environments at similar levels to the infrasound measured close to wind turbines. However, the level of infrasound caused by wind turbines is in nearly all occasions well below the audibility threshold. According to the latest research infrasound does not cause health effects

below levels of hearing or perception threshold. This means that if Low Frequency Noise or Infrasound from Wind Turbines is not audible there are no health effects.

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RAMBOLL FINLAND

8th of December, 2022

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team manager

Ville Virtanen
project manager

Annex 1 Results, layout alternative 1 157 pcs of SG 7.0-167 DD Wind Turbines (hh 110 m)

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	$L_{pG,eq}$
A	57,4	56,4	56,4	55,4	53,0	50,7	50,3	47,8	47,0	44,9	41,1	37,5	31,9	25,6	68,8
B	56,6	55,6	55,6	54,6	52,1	49,8	49,3	46,7	45,7	43,3	39,0	34,7	28,0	20,2	68,0
C	51,9	50,9	50,9	49,9	47,4	45,0	44,5	41,9	40,8	38,3	33,8	29,0	21,7	13,0	63,2
D	57,1	56,1	56,1	55,1	52,6	50,3	49,8	47,3	46,2	43,9	39,6	35,3	28,7	21,1	68,5
E	57,9	56,9	56,9	55,9	53,5	51,1	50,7	48,2	47,3	45,0	40,9	36,9	30,8	23,9	69,2
F	58,6	57,6	57,6	56,6	54,2	51,8	51,4	49,0	48,1	45,9	41,9	38,0	31,9	25,0	69,9
G	58,5	57,5	57,5	56,5	54,1	51,8	51,4	48,9	48,0	45,9	42,0	38,2	32,3	25,7	69,8
H	56,7	55,7	55,7	54,7	52,3	49,9	49,4	46,8	45,8	43,4	39,1	34,8	28,1	20,4	68,1
I	56,0	55,0	55,0	54,0	51,5	49,2	48,7	46,1	45,0	42,6	38,3	34,1	27,4	19,8	67,4
J (offshore receptor)	59,2	58,2	58,2	57,2	54,8	52,5	52,1	49,7	48,9	46,8	42,9	39,2	33,4	26,9	70,5
K (offshore receptor)	58,0	57,0	57,0	56,0	53,6	51,3	50,9	48,4	47,5	45,4	41,5	37,7	31,8	25,2	69,4
L (offshore receptor)	59,0	58,0	58,0	57,0	54,6	52,3	52,0	49,5	48,8	46,7	43,0	39,5	33,9	27,6	70,3

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	$L_{pG,eq}$
A	51,2	49,8	49,3	47,8	44,7	41,5	40,0	36,3	34,0	30,1	24,3	18,7	10,8	2,8	61,5
B	50,4	49,0	48,5	47,0	43,8	40,6	39,0	35,2	32,7	28,5	22,2	15,9	6,9	-2,6	60,8
C	49,5	48,1	47,6	46,1	42,9	39,6	37,9	34,1	31,4	27,1	20,4	13,6	3,9	-6,4	59,9
D	50,9	49,5	49,0	47,5	44,3	41,1	39,5	35,8	33,2	29,1	22,8	16,5	7,6	-1,7	61,2
E	51,7	50,3	49,8	48,3	45,2	41,9	40,4	36,7	34,3	30,2	24,1	18,1	9,7	1,1	62,0
F	52,4	51,0	50,5	49,0	45,9	42,6	41,1	37,5	35,1	31,1	25,1	19,2	10,8	2,2	62,7
G	52,3	50,9	50,4	48,9	45,8	42,6	41,1	37,4	35,0	31,1	25,2	19,4	11,2	2,9	62,6
H	50,5	49,1	48,6	47,1	44,0	40,7	39,1	35,3	32,8	28,6	22,3	16,0	7,0	-2,4	60,9
I	49,8	48,4	47,9	46,4	43,2	40,0	38,4	34,6	32,0	27,8	21,5	15,3	6,3	-3,0	60,2
J (offshore receptor)	53,0	51,6	51,1	49,6	46,5	43,3	41,8	38,2	35,9	32,0	26,1	20,4	12,3	4,1	63,3
K (offshore receptor)	51,8	50,4	49,9	48,4	45,3	42,1	40,6	36,9	34,5	30,6	24,7	18,9	10,7	2,4	62,2
L (offshore receptor)	52,8	51,4	50,9	49,4	46,3	43,1	41,7	38,0	35,8	31,9	26,2	20,7	12,8	4,8	63,1
LFN recommendation	95	87	79	71	63	55,5	49	43	41,5	40	38	36	34	32	

Annex 2 Results, layout alternative 2

37 pcs of SG 7.0-167 DD Wind Turbines (hh 110 m)
70 pcs of GE Haliade-X - 50/60 Hz Wind Turbines (hh 134 m)
all together 107 Wind Turbines

Outdoor noise levels, dB

	1/3 frequency band / Hz													
Receptor	10	12,5	16	20	25	31,5	40	50	63	80	100	125	160	200	$L_{pG,eq}$
A	56,4	53,5	53,1	52,0	50,3	48,8	47,4	45,3	43,1	40,3	37,7	35,5	31,9	27,0	65,7
B	55,7	53,0	52,6	51,5	49,7	48,1	46,7	44,4	42,1	39,2	36,1	33,1	28,4	22,0	65,2
C	49,9	48,0	47,8	46,7	44,4	42,4	41,2	38,7	36,6	33,5	29,1	25,0	19,2	11,9	60,2
D	56,3	53,6	53,3	52,2	50,3	48,7	47,4	45,1	43,0	40,2	36,9	34,0	29,4	23,2	65,9
E	57,1	54,5	54,1	53,1	51,2	49,7	48,4	46,2	44,1	41,5	38,4	35,7	31,6	26,2	66,7
F	57,6	55,3	55,0	53,9	52,0	50,3	49,2	47,0	45,3	42,8	39,6	36,7	32,4	27,0	67,5
G	57,0	55,3	55,1	54,1	51,9	50,0	49,2	46,9	45,7	43,5	39,8	36,4	30,9	24,5	67,6
H	55,3	53,6	53,4	52,4	50,2	48,1	47,3	44,9	43,5	41,1	37,1	33,1	26,8	19,3	65,9
I	54,4	52,9	52,9	51,8	49,5	47,3	46,7	44,2	43,0	40,7	36,6	32,5	26,1	18,6	65,3
J (offshore receptor)	58,2	55,9	55,6	54,6	52,7	51,0	49,9	47,7	46,1	43,7	40,6	38,0	33,9	28,9	68,2
K (offshore receptor)	56,5	55,0	54,8	53,8	51,6	49,5	48,9	46,5	45,4	43,3	39,6	36,1	30,4	23,9	67,3
L (offshore receptor)	58,2	55,3	54,9	53,8	52,2	50,7	49,3	47,3	45,2	42,6	40,0	37,9	34,4	29,6	67,5

Indoor noise levels, dB

	1/3 frequency band / Hz													
Receptor	10	12,5	16	20	25	31,5	40	50	63	80	100	125	160	200	$L_{pG,eq}$
A	50,2	46,9	46,0	44,4	42,0	39,6	37,1	33,8	30,1	25,5	20,9	16,7	10,8	4,2	58,6
B	49,5	46,4	45,5	43,9	41,4	38,9	36,4	32,9	29,1	24,4	19,3	14,3	7,3	-0,8	58,0
C	48,6	45,6	44,7	43,1	40,5	37,9	35,4	31,9	28,0	23,2	17,6	12,1	4,4	-4,6	57,2
D	50,1	47,0	46,2	44,6	42,0	39,5	37,1	33,6	30,0	25,4	20,1	15,2	8,3	0,4	58,7
E	50,9	47,9	47,0	45,5	42,9	40,5	38,1	34,7	31,1	26,7	21,6	16,9	10,5	3,4	59,6
F	51,4	48,7	47,9	46,3	43,7	41,1	38,9	35,5	32,3	28,0	22,8	17,9	11,3	4,2	60,4
G	50,8	48,7	48,0	46,5	43,6	40,8	38,9	35,4	32,7	28,7	23,0	17,6	9,8	1,7	60,4
H	49,1	47,0	46,3	44,8	41,9	38,9	37,0	33,4	30,5	26,3	20,3	14,3	5,7	-3,5	58,7
I	48,2	46,3	45,8	44,2	41,2	38,1	36,4	32,7	30,0	25,9	19,8	13,7	5,0	-4,2	58,1
J (offshore receptor)	52,0	49,3	48,5	47,0	44,4	41,8	39,6	36,2	33,1	28,9	23,8	19,2	12,8	6,1	61,0
K (offshore receptor)	50,3	48,4	47,7	46,2	43,3	40,3	38,6	35,0	32,4	28,5	22,8	17,3	9,3	1,1	60,1
L (offshore receptor)	52,0	48,7	47,8	46,2	43,9	41,5	39,0	35,8	32,2	27,8	23,2	19,1	13,3	6,8	60,4
LFN recommendation	95	87	79	71	63	55,5	49	43	41,5	40	38	36	34	32	

Annex 3 Results, layout alternative 3 73 pcs of Vestas V236-15MW Wind Turbines (hh 146 m)
LWA 118 + 2 dB(Uc)

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	$L_{pG,eq}$
A	51,2	50,3	50,0	49,2	48,0	47,3	46,7	45,8	44,7	43,3	41,0	37,9	33,9	28,6	62,6
B	50,0	49,1	48,8	48,0	46,7	45,9	45,2	44,2	42,9	41,2	38,3	34,3	29,0	21,8	61,4
C	46,8	45,9	45,6	44,8	43,4	42,6	41,8	40,7	39,2	37,2	33,9	29,3	23,1	14,8	58,2
D	50,2	49,3	49,0	48,2	47,0	46,2	45,5	44,5	43,2	41,5	38,6	34,6	29,2	22,0	61,6
E	50,9	50,0	49,7	48,9	47,6	46,9	46,3	45,3	44,0	42,4	39,7	35,9	31,0	24,3	62,3
F	51,3	50,4	50,1	49,3	48,1	47,4	46,8	45,8	44,6	43,1	40,4	36,9	32,1	25,8	62,7
G	50,8	49,9	49,6	48,8	47,6	46,9	46,2	45,3	44,0	42,5	39,9	36,4	31,9	26,0	62,2
H	49,2	48,3	48,0	47,2	45,9	45,1	44,4	43,3	41,9	40,1	37,1	33,1	27,8	20,9	60,6
I	48,4	47,5	47,2	46,4	45,0	44,2	43,5	42,5	41,0	39,3	36,4	32,6	27,6	20,9	59,8
J (offshore receptor)	52,0	51,1	50,8	50,0	48,9	48,2	47,6	46,7	45,5	44,1	41,7	38,4	34,1	28,4	63,5
K (offshore receptor)	50,3	49,4	49,1	48,3	47,0	46,3	45,6	44,7	43,4	41,9	39,3	35,8	31,4	25,5	61,7
L (offshore receptor)	52,3	51,4	51,1	50,3	49,1	48,4	47,8	47,0	45,9	44,5	42,1	38,9	34,7	29,0	63,7

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	$L_{pG,eq}$
A	45,0	43,7	42,9	41,6	39,7	38,1	36,4	34,3	31,7	28,5	24,2	19,1	12,8	5,8	55,4
B	43,8	42,5	41,7	40,4	38,4	36,7	34,9	32,7	29,9	26,4	21,5	15,5	7,9	-1,0	54,1
C	42,8	41,5	40,7	39,4	37,4	35,7	33,8	31,6	28,5	24,9	19,6	13,2	4,8	-5,0	53,2
D	44,0	42,7	41,9	40,6	38,7	37,0	35,2	33,0	30,2	26,7	21,8	15,8	8,1	-0,8	54,4
E	44,7	43,4	42,6	41,3	39,3	37,7	36,0	33,8	31,0	27,6	22,9	17,1	9,9	1,5	55,1
F	45,1	43,8	43,0	41,7	39,8	38,2	36,5	34,3	31,6	28,3	23,6	18,1	11,0	3,0	55,5
G	44,6	43,3	42,5	41,2	39,3	37,7	35,9	33,8	31,0	27,7	23,1	17,6	10,8	3,2	55,0
H	43,0	41,7	40,9	39,6	37,6	35,9	34,1	31,8	28,9	25,3	20,3	14,3	6,7	-1,9	53,4
I	42,2	40,9	40,1	38,8	36,7	35,0	33,2	31,0	28,0	24,5	19,6	13,8	6,5	-1,9	52,5
J (offshore receptor)	45,8	44,5	43,7	42,4	40,6	39,0	37,3	35,2	32,5	29,3	24,9	19,6	13,0	5,6	56,2
K (offshore receptor)	44,1	42,8	42,0	40,7	38,7	37,1	35,3	33,2	30,4	27,1	22,5	17,0	10,3	2,7	54,4
L (offshore receptor)	46,1	44,8	44,0	42,7	40,8	39,2	37,5	35,5	32,9	29,7	25,3	20,1	13,6	6,2	56,4
LFN recommendation	95	87	79	71	63	55,5	49	43	41,5	40	38	36	34	32	

Annex 4 Results, layout alternative 4 55 pcs of Vestas V236-20MW Wind Turbines (hh 162 m)
LWA 118 + 2 dB(Uc) + 9,6 dB addition

Outdoor noise levels, dB

	1/3 frequency band / Hz													
Receptor	10	12,5	16	20	25	31,5	40	50	63	80	100	125	160	200	$L_{pG,eq}$
A	59,7	58,8	58,5	57,7	56,5	55,8	55,2	54,3	53,2	51,8	49,3	46,1	42,0	36,5	71,1
B	58,8	57,9	57,6	56,8	55,5	54,8	54,1	53,1	51,8	50,1	47,2	43,3	37,9	30,6	70,2
C	57,4	56,5	56,2	55,4	54,1	53,3	52,6	51,5	50,0	48,2	45,0	40,6	34,6	26,5	68,8
D	59,1	58,2	57,9	57,1	55,9	55,1	54,5	53,5	52,2	50,6	47,7	43,8	38,5	31,4	70,5
E	59,8	58,9	58,6	57,8	56,6	55,9	55,3	54,3	53,1	51,5	48,9	45,3	40,4	33,9	71,2
F	60,0	59,1	58,8	58,0	56,7	56,0	55,4	54,5	53,3	51,8	49,2	45,7	41,0	34,8	71,4
G	58,7	57,8	57,5	56,7	55,4	54,7	54,0	53,0	51,7	50,1	47,3	43,6	38,8	32,5	70,1
H	57,1	56,2	55,9	55,1	53,7	52,9	52,2	51,1	49,6	47,8	44,7	40,5	35,1	28,0	68,5
I	56,0	55,1	54,8	54,0	52,6	51,8	51,0	49,9	48,4	46,6	43,6	39,8	34,9	28,4	67,4
J (offshore receptor)	60,7	59,8	59,5	58,7	57,5	56,8	56,2	55,4	54,2	52,8	50,4	47,2	43,0	37,3	72,1
K (offshore receptor)	57,9	57,0	56,7	55,9	54,6	53,9	53,2	52,2	50,9	49,2	46,5	42,9	38,4	32,5	69,3
L (offshore receptor)	61,2	60,3	60,0	59,2	58,0	57,3	56,8	55,9	54,8	53,5	51,1	47,9	43,6	37,8	72,6

Indoor noise levels, dB

	1/3 frequency band / Hz													
Receptor	10	12,5	16	20	25	31,5	40	50	63	80	100	125	160	200	$L_{pG,eq}$
A	53,5	52,2	51,4	50,1	48,2	46,6	44,9	42,8	40,2	37,0	32,5	27,3	20,9	13,7	63,9
B	52,6	51,3	50,5	49,2	47,2	45,6	43,8	41,6	38,8	35,3	30,4	24,5	16,8	7,8	63,0
C	51,6	50,3	49,5	48,2	46,2	44,5	42,7	40,4	37,4	33,8	28,6	22,2	13,9	4,1	62,0
D	52,9	51,6	50,8	49,5	47,6	45,9	44,2	42,0	39,2	35,8	30,9	25,0	17,4	8,6	63,3
E	53,6	52,3	51,5	50,2	48,3	46,7	45,0	42,8	40,1	36,7	32,1	26,5	19,3	11,1	64,0
F	53,8	52,5	51,7	50,4	48,4	46,8	45,1	43,0	40,3	37,0	32,4	26,9	19,9	12,0	64,1
G	52,5	51,2	50,4	49,1	47,1	45,5	43,7	41,5	38,7	35,3	30,5	24,8	17,7	9,7	62,8
H	50,9	49,6	48,8	47,5	45,4	43,7	41,9	39,6	36,6	33,0	27,9	21,7	14,0	5,2	61,3
I	49,8	48,5	47,7	46,4	44,3	42,6	40,7	38,4	35,4	31,8	26,8	21,0	13,8	5,6	60,1
J (offshore receptor)	54,5	53,2	52,4	51,1	49,2	47,6	45,9	43,9	41,2	38,0	33,6	28,4	21,9	14,5	64,9
K (offshore receptor)	51,7	50,4	49,6	48,3	46,3	44,7	42,9	40,7	37,9	34,4	29,7	24,1	17,3	9,7	62,1
L (offshore receptor)	55,0	53,7	52,9	51,6	49,7	48,1	46,5	44,4	41,8	38,7	34,3	29,1	22,5	15,0	65,4
LFN recommendation	95	87	79	71	63	55,5	49	43	41,5	40	38	36	34	32	

Coordinates of the Wind Turbines
Alternative 1

Annex 5

E / lon	N / lat	Z	hh	WT type	E / lon	N / lat	Z	hh	WT type
402410	6564762	0	110	SG 7.0	390969	6550485	0	110	SG 7.0
406844	6559569	0	110	SG 7.0	391215	6549627	0	110	SG 7.0
405700	6560383	0	110	SG 7.0	390245	6549578	0	110	SG 7.0
404535	6561184	0	110	SG 7.0	389238	6549568	0	110	SG 7.0
404133	6559821	0	110	SG 7.0	388231	6549524	0	110	SG 7.0
405278	6559134	0	110	SG 7.0	387224	6549482	0	110	SG 7.0
406383	6558442	0	110	SG 7.0	386205	6549446	0	110	SG 7.0
403765	6558446	0	110	SG 7.0	386788	6548446	0	110	SG 7.0
404866	6557906	0	110	SG 7.0	385840	6548393	0	110	SG 7.0
405988	6557359	0	110	SG 7.0	384867	6548335	0	110	SG 7.0
404439	6556715	0	110	SG 7.0	388675	6548583	0	110	SG 7.0
405545	6556264	0	110	SG 7.0	387724	6548508	0	110	SG 7.0
403681	6554387	0	110	SG 7.0	389603	6548652	0	110	SG 7.0
404699	6554118	0	110	SG 7.0	390563	6548711	0	110	SG 7.0
405124	6555192	0	110	SG 7.0	391468	6548770	0	110	SG 7.0
404068	6555528	0	110	SG 7.0	392569	6547993	0	110	SG 7.0
402998	6555881	0	110	SG 7.0	391704	6547915	0	110	SG 7.0
403372	6557163	0	110	SG 7.0	390844	6547826	0	110	SG 7.0
402621	6559031	0	110	SG 7.0	389987	6547723	0	110	SG 7.0
402973	6560524	0	110	SG 7.0	397591	6558533	0	110	SG 7.0
401732	6561257	0	110	SG 7.0	396439	6558000	0	110	SG 7.0
401894	6562102	0	110	SG 7.0	395311	6558351	0	110	SG 7.0
402081	6562962	0	110	SG 7.0	395281	6559375	0	110	SG 7.0
402252	6563867	0	110	SG 7.0	395258	6560465	0	110	SG 7.0
403526	6562824	0	110	SG 7.0	396450	6559981	0	110	SG 7.0
402961	6562387	0	110	SG 7.0	396416	6558943	0	110	SG 7.0
403344	6562058	0	110	SG 7.0	431145	6559615	0	110	SG 7.0
400841	6556573	0	110	SG 7.0	433823	6557554	0	110	SG 7.0
402294	6557607	0	110	SG 7.0	433308	6558304	0	110	SG 7.0
402053	6558445	0	110	SG 7.0	432792	6559054	0	110	SG 7.0
401446	6559629	0	110	SG 7.0	432277	6559804	0	110	SG 7.0
401142	6558059	0	110	SG 7.0	435986	6556242	0	110	SG 7.0
400984	6557298	0	110	SG 7.0	435470	6556992	0	110	SG 7.0
399864	6557705	0	110	SG 7.0	434954	6557742	0	110	SG 7.0
399994	6558534	0	110	SG 7.0	434438	6558492	0	110	SG 7.0
400103	6559364	0	110	SG 7.0	433922	6559242	0	110	SG 7.0
398920	6559895	0	110	SG 7.0	433407	6559992	0	110	SG 7.0
386907	6555316	0	110	SG 7.0	436601	6557180	0	110	SG 7.0
388329	6555100	0	110	SG 7.0	436085	6557930	0	110	SG 7.0
388594	6554196	0	110	SG 7.0	435569	6558680	0	110	SG 7.0
385939	6554484	0	110	SG 7.0	435053	6559430	0	110	SG 7.0
387323	6554310	0	110	SG 7.0	437732	6557369	0	110	SG 7.0
388978	6553234	0	110	SG 7.0	437216	6558119	0	110	SG 7.0
387716	6553336	0	110	SG 7.0	436700	6558868	0	110	SG 7.0
386431	6553454	0	110	SG 7.0	436183	6559618	0	110	SG 7.0
386886	6552441	0	110	SG 7.0	438864	6557558	0	110	SG 7.0
388111	6552381	0	110	SG 7.0	438347	6558307	0	110	SG 7.0
389307	6552299	0	110	SG 7.0	437831	6559057	0	110	SG 7.0
390720	6551359	0	110	SG 7.0	437314	6559806	0	110	SG 7.0
389621	6551398	0	110	SG 7.0	439995	6557747	0	110	SG 7.0
388493	6551421	0	110	SG 7.0	439478	6558496	0	110	SG 7.0
387346	6551447	0	110	SG 7.0	438962	6559245	0	110	SG 7.0
387773	6550482	0	110	SG 7.0	438445	6559995	0	110	SG 7.0
388865	6550485	0	110	SG 7.0	441127	6557936	0	110	SG 7.0
389917	6550492	0	110	SG 7.0	440610	6558685	0	110	SG 7.0

E / lon	N / lat	Z	hh	WT type
440093	6559434	0	110	SG 7.0
439576	6560183	0	110	SG 7.0
439059	6560932	0	110	SG 7.0
442259	6558125	0	110	SG 7.0
441742	6558874	0	110	SG 7.0
441225	6559623	0	110	SG 7.0
440708	6560372	0	110	SG 7.0
440191	6561121	0	110	SG 7.0
439673	6561870	0	110	SG 7.0
443391	6558314	0	110	SG 7.0
442874	6559063	0	110	SG 7.0
442357	6559812	0	110	SG 7.0
441839	6560561	0	110	SG 7.0
441322	6561310	0	110	SG 7.0
440805	6562059	0	110	SG 7.0
440288	6562808	0	110	SG 7.0
443488	6560001	0	110	SG 7.0
442971	6560750	0	110	SG 7.0
442454	6561499	0	110	SG 7.0
441937	6562248	0	110	SG 7.0
441419	6562997	0	110	SG 7.0
443585	6561687	0	110	SG 7.0
443068	6562436	0	110	SG 7.0
442551	6563185	0	110	SG 7.0
442033	6563934	0	110	SG 7.0
444199	6562625	0	110	SG 7.0
443682	6563374	0	110	SG 7.0
443908	6557565	0	110	SG 7.0
437117	6556431	0	110	SG 7.0
438248	6556620	0	110	SG 7.0
439380	6556808	0	110	SG 7.0
441029	6556248	0	110	SG 7.0
440512	6556997	0	110	SG 7.0
442161	6556437	0	110	SG 7.0
441644	6557187	0	110	SG 7.0
443293	6556627	0	110	SG 7.0
442776	6557376	0	110	SG 7.0
407941	6558766	0	110	SG 7.0
406639	6555820	0	110	SG 7.0
407523	6557803	0	110	SG 7.0
407055	6556796	0	110	SG 7.0
406196	6554817	0	110	SG 7.0
396422	6557045	0	110	SG 7.0
397542	6557635	0	110	SG 7.0
389095	6547660	0	110	SG 7.0
388206	6547561	0	110	SG 7.0
387336	6547476	0	110	SG 7.0

Coordinates of the Wind Turbines
Alternative 2

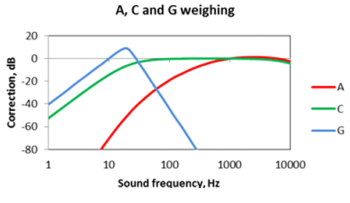
Annex 6

E / lon	N / lat	Z	hh	WT type	E / lon	N / lat	Z	hh	WT type
404619	6554132	0	134	GE	384566	6547748	0	134	GE
397167	6557006	0	134	GE	390753	6549458	0	134	GE
396046	6557329	0	134	GE	389577	6549410	0	134	GE
406220	6555068	0	134	GE	388388	6549360	0	134	GE
394791	6560264	0	134	GE	387184	6549310	0	134	GE
407843	6555783	0	134	GE	385967	6549259	0	134	GE
406756	6556271	0	134	GE	401776	6562967	0	134	GE
405649	6556768	0	134	GE	403314	6563041	0	134	GE
404522	6557274	0	134	GE	401980	6564073	0	134	GE
403375	6557789	0	134	GE	395750	6561107	0	134	GE
396034	6559776	0	134	GE	398753	6560558	0	134	GE
397261	6559294	0	134	GE	393460	6547390	0	134	GE
399663	6558350	0	134	GE	392478	6547266	0	134	GE
394857	6558925	0	134	GE	392198	6548384	0	134	GE
396040	6558524	0	134	GE	391126	6548295	0	134	GE
402918	6556189	0	134	GE	390048	6548205	0	134	GE
405130	6555438	0	134	GE	402635	6560139	0	134	GE
404029	6555812	0	134	GE	401386	6560849	0	134	GE
401798	6556569	0	134	GE	402856	6561083	0	134	GE
400668	6556953	0	134	GE	401578	6561892	0	134	GE
397213	6558125	0	134	GE	408930	6557948	0	134	GE
390376	6550636	0	134	GE	407844	6558710	0	134	GE
389098	6550636	0	134	GE	406718	6559500	0	134	GE
387798	6550635	0	134	GE	405550	6560319	0	134	GE
389995	6551827	0	134	GE	404339	6561169	0	134	GE
388611	6551882	0	134	GE	403082	6562050	0	134	GE
387194	6551939	0	134	GE	402207	6558313	0	134	GE
389609	6553032	0	134	GE	399804	6559391	0	134	GE
388115	6553151	0	134	GE	401199	6559834	0	134	GE
386576	6553274	0	134	GE	408387	6556866	0	134	GE
387610	6554442	0	134	GE	407298	6557485	0	134	GE
388964	6548115	0	134	GE	406179	6558122	0	134	GE
387874	6548024	0	134	GE	405029	6558776	0	134	GE
386777	6547932	0	134	GE	403848	6559448	0	134	GE
385674	6547841	0	134	GE	385944	6554641	0	134	GE

E / lon	N / lat	Z	hh	WT type
433823	6557554	0	110	SG 7.0
433308	6558304	0	110	SG 7.0
435986	6556242	0	110	SG 7.0
435470	6556992	0	110	SG 7.0
434954	6557742	0	110	SG 7.0
434438	6558492	0	110	SG 7.0
437117	6556431	0	110	SG 7.0
436601	6557180	0	110	SG 7.0
436085	6557930	0	110	SG 7.0
435569	6558680	0	110	SG 7.0
438248	6556620	0	110	SG 7.0
437732	6557369	0	110	SG 7.0
437216	6558119	0	110	SG 7.0
439380	6556808	0	110	SG 7.0
438864	6557558	0	110	SG 7.0
438347	6558307	0	110	SG 7.0
441029	6556248	0	110	SG 7.0
440512	6556997	0	110	SG 7.0
439995	6557747	0	110	SG 7.0
439478	6558496	0	110	SG 7.0
438962	6559245	0	110	SG 7.0
442161	6556437	0	110	SG 7.0
441644	6557187	0	110	SG 7.0
441127	6557936	0	110	SG 7.0
440610	6558685	0	110	SG 7.0
440093	6559434	0	110	SG 7.0
443293	6556627	0	110	SG 7.0
442776	6557376	0	110	SG 7.0
442259	6558125	0	110	SG 7.0
441742	6558874	0	110	SG 7.0
441225	6559623	0	110	SG 7.0
443908	6557565	0	110	SG 7.0
443391	6558314	0	110	SG 7.0
442874	6559063	0	110	SG 7.0
442357	6559812	0	110	SG 7.0
436700	6558868	0	110	SG 7.0
437831	6559057	0	110	SG 7.0

Table 4
The expected level difference, DL_{σ}, as a function of frequency, f. The value is based on our results from 26 façades and it is expected to be exceeded in 84% of Finnish dwellings. The second row involves the expected level difference, ΔL_{σ}, suggested by Ref. [3].

f [Hz]	5	6.3	8	10	12	16	20	25	31.5	40	50	63	80	100	125	160	200
DL_{σ} [dB]	5.5	5.7	5.9	6.2	6.6	7.1	7.6	8.3	9.2	10.3	11.5	13.0	14.8	16.8	18.8	21.1	22.8
ΔL_{σ} [dB]				4.9	5.9	4.6	6.6	8.4	10.8	11.4	13.0	16.6	19.7	21.2	20.2	21.2	



Coordinates of the Wind Turbines
Alternative 3, 15MW

Label	E / lon	N / lat	Z	hh	WT type	Label	E / lon	N / lat	Z	hh	WT type
TP1.01	431767	6559971	0	110	V236-15MW	TP2.20	404144	6563106	0	110	V236-15MW
TP1.02	433240	6559222	0	110	V236-15MW	TP2.21	403158	6563880	0	110	V236-15MW
TP1.03	434713	6558474	0	110	V236-15MW	TP2.22	402347	6564737	0	110	V236-15MW
TP1.04	436187	6557726	0	110	V236-15MW	TP3.01	398064	6557164	0	110	V236-15MW
TP1.05	437661	6556979	0	110	V236-15MW	TP3.02	395826	6557430	0	110	V236-15MW
TP1.06	439134	6556232	0	110	V236-15MW	TP3.03	397257	6558024	0	110	V236-15MW
TP1.07	440859	6556012	0	110	V236-15MW	TP3.04	395014	6558286	0	110	V236-15MW
TP1.08	442616	6555896	0	110	V236-15MW	TP3.05	396445	6558885	0	110	V236-15MW
TP1.09	444378	6556445	0	110	V236-15MW	TP3.06	394576	6559505	0	110	V236-15MW
TP1.10	437217	6559893	0	110	V236-15MW	TP3.07	395877	6559976	0	110	V236-15MW
TP1.11	438690	6559146	0	110	V236-15MW	TP3.08	395039	6560798	0	110	V236-15MW
TP1.12	440165	6558399	0	110	V236-15MW	TP4.01	387171	6547538	0	110	V236-15MW
TP1.13	441866	6558170	0	110	V236-15MW	TP4.02	388668	6548243	0	110	V236-15MW
TP1.14	443701	6558391	0	110	V236-15MW	TP4.03	390245	6548912	0	110	V236-15MW
TP1.15	439595	6561086	0	110	V236-15MW	TP4.04	383935	6546750	0	110	V236-15MW
TP1.16	441069	6560340	0	110	V236-15MW	TP4.05	385339	6547236	0	110	V236-15MW
TP1.17	442780	6560105	0	110	V236-15MW	TP4.06	386355	6548395	0	110	V236-15MW
TP1.18	440435	6562914	0	110	V236-15MW	TP4.07	387859	6549103	0	110	V236-15MW
TP1.19	441909	6562168	0	110	V236-15MW	TP4.08	389437	6549772	0	110	V236-15MW
TP1.20	443622	6561945	0	110	V236-15MW	TP4.09	391077	6550494	0	110	V236-15MW
TP1.21	442945	6564378	0	110	V236-15MW	TP4.10	384532	6548096	0	110	V236-15MW
TP1.22	444316	6563429	0	110	V236-15MW	TP4.11	385542	6549265	0	110	V236-15MW
TP2.01	401833	6556553	0	110	V236-15MW	TP4.12	387051	6549963	0	110	V236-15MW
TP2.02	400412	6556985	0	110	V236-15MW	TP4.13	388628	6550632	0	110	V236-15MW
TP2.03	399839	6558116	0	110	V236-15MW	TP4.14	390658	6551717	0	110	V236-15MW
TP2.04	399117	6559959	0	110	V236-15MW	TP4.15	389757	6552489	0	110	V236-15MW
TP2.05	398211	6560920	0	110	V236-15MW	TP4.16	387272	6552088	0	110	V236-15MW
TP2.06	403701	6557392	0	110	V236-15MW	TP4.17	389117	6553500	0	110	V236-15MW
TP2.07	402794	6558350	0	110	V236-15MW	TP4.18	386464	6552949	0	110	V236-15MW
TP2.08	401903	6559288	0	110	V236-15MW	TP4.19	388777	6554688	0	110	V236-15MW
TP2.09	401018	6560230	0	110	V236-15MW	TP4.20	385768	6553914	0	110	V236-15MW
TP2.10	405656	6558345	0	110	V236-15MW	TP4.21	387798	6555493	0	110	V236-15MW
TP2.11	404743	6559297	0	110	V236-15MW						
TP2.12	403870	6560234	0	110	V236-15MW						
TP2.13	403015	6561122	0	110	V236-15MW						
TP2.14	402175	6562010	0	110	V236-15MW						
TP2.15	401311	6562922	0	110	V236-15MW						
TP2.16	407567	6559231	0	110	V236-15MW						
TP2.17	406620	6560192	0	110	V236-15MW						
TP2.18	405702	6561154	0	110	V236-15MW						
TP2.19	404904	6562148	0	110	V236-15MW						

Coordinates of the Wind Turbines
Alternative 4, 20MW

Annex 8

Label	E / lon	N / lat	Z	hh	WT type
TP1.01	435457	6558106	0	110	V236-20MW
TP1.02	437386	6557123	0	110	V236-20MW
TP1.03	439344	6556118	0	110	V236-20MW
TP1.04	437932	6558703	0	110	V236-20MW
TP1.05	439890	6557669	0	110	V236-20MW
TP1.06	441723	6556758	0	110	V236-20MW
TP1.07	443541	6555990	0	110	V236-20MW
TP1.08	442276	6558309	0	110	V236-20MW
TP1.09	444407	6557385	0	110	V236-20MW
TP2.01	400863	6556588	0	110	V236-20MW
TP2.02	402542	6557095	0	110	V236-20MW
TP2.03	404204	6557931	0	110	V236-20MW
TP2.04	405876	6558590	0	110	V236-20MW
TP2.05	407577	6559195	0	110	V236-20MW
TP2.06	399952	6557551	0	110	V236-20MW
TP2.07	401612	6558083	0	110	V236-20MW
TP2.08	403292	6558893	0	110	V236-20MW
TP2.09	404964	6559552	0	110	V236-20MW
TP2.10	406665	6560157	0	110	V236-20MW
TP2.11	400688	6559040	0	110	V236-20MW
TP2.12	402376	6559855	0	110	V236-20MW
TP2.13	404053	6560514	0	110	V236-20MW
TP2.14	405754	6561119	0	110	V236-20MW
TP2.15	399278	6559604	0	110	V236-20MW
TP2.16	401491	6560843	0	110	V236-20MW
TP2.17	403142	6561477	0	110	V236-20MW
TP2.18	404842	6562081	0	110	V236-20MW
TP2.19	398363	6560739	0	110	V236-20MW
TP2.20	402231	6562440	0	110	V236-20MW
TP2.21	403931	6563043	0	110	V236-20MW
TP2.22	401320	6563402	0	110	V236-20MW
TP2.23	403019	6564005	0	110	V236-20MW
TP3.01	396159	6557112	0	110	V236-20MW
TP3.02	397613	6557587	0	110	V236-20MW
TP3.03	395145	6557985	0	110	V236-20MW
TP3.04	396699	6558553	0	110	V236-20MW
TP3.05	394651	6559299	0	110	V236-20MW
TP3.06	396118	6559771	0	110	V236-20MW
TP3.07	395137	6560801	0	110	V236-20MW
TP4.01	385676	6547465	0	110	V236-20MW
TP4.02	387291	6548072	0	110	V236-20MW
TP4.03	388906	6548679	0	110	V236-20MW
TP4.04	390522	6549288	0	110	V236-20MW
TP4.05	384769	6548432	0	110	V236-20MW
TP4.06	386383	6549038	0	110	V236-20MW
TP4.07	387998	6549645	0	110	V236-20MW
TP4.08	389614	6550253	0	110	V236-20MW
TP4.09	388555	6551070	0	110	V236-20MW
TP4.10	390479	6551970	0	110	V236-20MW
TP4.11	387645	6552035	0	110	V236-20MW
TP4.12	389652	6553007	0	110	V236-20MW
TP4.13	386733	6553002	0	110	V236-20MW
TP4.14	388577	6553816	0	110	V236-20MW
TP4.15	385828	6553963	0	110	V236-20MW
TP4.16	387834	6554931	0	110	V236-20MW