INTERNATIONAL ACOUSTICS RESEARCH ORGANIZATION

The Acoustic Impact of Wind Power Plants on Neighbouring Residents

A Scientific Response to Section 4.6 “Impact on Human Health and Well-Being”, Subsection 4.6.1 “Noise”, as submitted in the Report on Phase 1 of “Strategic Environmental Assessment for Dedicated Spatial Plan of Wind Power Plants, including Pre-selected Locations in Põhja-Pärnu Municipality”, Estonia (Job No. 2021-256, September 2024).

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International Acoustics Research Organization

IARO is an international group of researchers with a mission to investigate acoustical environments, especially with respect to features that affect humans and animals, and to publish the results. IARO holds the ethics approval for the CSI-ACHE, the Citizen Science Initiative into Acoustical Characterisation of Human Environments, the results of which are publicly disseminated.

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CONTENTS

EXECUTIVE SUMMARY

1. In December 2024, IARO scientists were contacted by *For Nature and People*, based in Estonia, and were requested to provide a review of the Section 4.6 "Impact on Human Health and Well-Being", Subsection 4.6.1 "Noise," contained in "Report on Phase 1 of Strategic Environmental Assessment for Dedicated Spatial Plan of Wind Power Plants, including Pre-selected Locations in Põhja-Pärnu Municipality," prepared by Kobras OÜ and submitted to the Local Government of the North-Pärnu, in Estonia.

2. The Kobras Report has followed the protocols stipulated by the Strategic Environmental Assessment (SEA) Directive, as required by EU standards.

3. By doing so, profound scientific flaws are introduced into the prediction of the impact of Wind Power Plants (WPPs) on the health and well-being of neighbouring residents and livestock.

4. These profound scientific flaws are ingrained into SEA protocols which, in turn, profoundly misinform, mislead and deceive governmental officials, decision-making hierarchies and the general public, regarding the health effects caused by the acoustic output of WPPs on neighbouring residents and livestock.

5. The scientific basis for the above statement is provided in this report with the aim of educating laypersons.

6. Computer modelling techniques for evaluating the noise emitted by WPPs only consider deafness as a consequence of exposure, because all numerical data is expressed in A- weighted decibels (dBA), meaning, only audible noise is considered.

7. The most important acoustic outputs of WPPs, which are harmful to human health, are contained within the infrasonic and lower frequency components of the acoustical spectrum (exposure to which does not cause deafness), and this is not taken into consideration by the computer modelling techniques, nor by SEA directives.

8. Recommendations are suggested for the second phase of this strategic planning project, assuming that the health of the general public and that of livestock are considered factors worth protecting.

A. INTRODUCTION

I. Background

9. In December 2024, IARO scientists were contacted by *For Nature and People* [MTÜ Looduse ja Inimeste Eest], a not-for-profit organization based in Estonia. It was requested that IARO provide a review of the Section 4.6 "Impact on Human Health and Well-Being", Subsection 4.6.1 "Noise," contained in the Report prepared by Kobras OÜ and submitted to the Local Government of the North-Pärnu, in Estonia: "Report on Phase 1 of Strategic Environmental Assessment for Dedicated Spatial Plan of Wind Power Plants, including Pre-selected Locations in Põhja-Pärnu Municipality" [Põhja-Pärnumaa valla tuuleparkide eriplaneeringu asukoha eelvalik ja keskkonnamõju strateegilise hindamise I etapi aruanne] (Job No. 2021-256, September 2024).

10. The English translation of Subsection 4.6.1. of the above mentioned Kobras Report (pp. 146-162) that was received by IARO scientists, is provided in Annex A.

II. Goal

11. To provide a scientific review of Section 4.6.1 of the Kobras Report, regarding the acoustic output (i.e. noise) of wind power plants and its effects on human and animal health.

III. Disclaimer

a. The report provided herein has one, and only one, agenda; that of pure scientific inquiry.

b. The authors of this report are not party to anti-technology sentiments and do not harbour anti-wind-energy sentiments.

c. In no way can or should this scientific review be construed as a document arguing for or against the implementation of wind power plants, or any other type of infrastructure or industrial complexes that generate acoustic pollution.

d. IARO members and authors of this report hold no financial interest in the SAM Technology.

IV. International Acoustics Research Organization, IARO

12. The International Acoustics Research Organization represents a group of scientists who, collectively, hold over 200 years of scientific experience in the field of infrasound and low frequency noise, and its effects of human health. Since 2016, IARO researchers have been recording and analysing acoustical data in and near homes located in the vicinity of onshore wind power plants, in the following countries (alphabetical): Australia, Canada, Denmark, England, France, Germany, Ireland, New Zealand, Northern Ireland, Portugal, Scotland, Slovenia, and The Netherlands. Prior to 2016, all IARO scientists were already working either in acoustics alone or in acoustics and health. All research conducted by IARO is part of the Citizen Science Initiative for Acoustic Characterization of Human Environments (CSI-ACHE).

V. Acronyms and Variables Used in IARO Reports

13. Table 1 lists the acronyms and variables used in IARO Reports.

Table 1. Acronyms and Variables that may appear in IARO Reports

dB	Decibel unweighted	(measure of sound pressure level)
dBA	Decibel A-weighted	(measure of sound pressure level)
Hz	Hertz	(measure of frequency)
ILFN	Infrasound and Low Frequency Noise	
IWT	Industrial Wind Turbine	
SEA	Strategic Environmental Assessment	
SPL	Sound Pressure Level	
WHO	World Health Organization	
WPP	Wind Power Plant	
WTAS	Wind Turbine Acoustic Signature	

B. SUBSECTIONS 4.6.1–3 OF THE KOBRAS REPORT

14. Section 4 of the Kobras Report is dedicated to the Strategic Environmental Assessment (SEA), with Section 4.6 covering the overall "Impacts on Human Health and Well-Being". This, in turn, is divided into Subsection 4.6.1, covering "Construction Noise," Subsection 4.6.2 covering "Operational Noise," and Subsection 4.6.3 covering "Low Frequency Noise."

15. It is understood that:

- **a.** The authors of the Kobras Report are constrained by the SEA protocols that have been previously established.
- **b.** SEA protocols impose specific methodologies for the environmental assessment of this agent of disease, i.e., "noise."
- **c.** The authors of the Kobras Report have duly complied with SEA protocols.
- **d.** The authors of Kobras Report may have limited knowledge regarding the type of "noise" emitted by Wind Power Plants (WPPs, also known as "wind farms").
- **e.** Even if the authors of the Kobras Report *had* proper scientific knowledge on acoustics in general, and on the acoustic output of WPPs in particular, they would be unable to implement this knowledge in their report, as it would be mostly incompatible with, and irrelevant to, SEA directives.

16. The dire consequence of this situation is that governmental officials, decision-making hierarchies and the general public are ill-informed and greatly misled regarding the noise output from WPPs and its effects on the surrounding human and animal populations.

17. It is the purpose of this IARO Report to scientifically inform governmental officials, decision-making hierarchies and the general public regarding the acoustic output of WPPs.

C. WHAT DO NUMBERS EXPRESSED IN A-WEIGHTED DECIBELS MEAN?

I. Target Values

18. On page 147 of the Kobras Report, it is stated:

> *For residential areas, the noise limit value for industrial noise is 60 dBA during the day and 45 dBA at night. The target value is 50 dBA during the day and 40 dBA at night.*

19. It is understood that these numerical values are imposed by pre-existing directives from the Estonian government, including a 2016 Supreme Court ruling demanding that WPPs comply with "target" values rather than with the Ministry of Environment's noise limit values.

20. Scientifically, however, there are significant flaws with this type of noise characterization, and these become blatantly obvious (and a serious health concern) when WPPs are the noise source.

21. Since acoustics is a complex topic, IARO scientists have often used graphs to explain the meaning of these numerical values to laypersons (i.e., governmental officials, decision-making hierarchies and the general public). The same will be done here.

II. Target Values expressed in dBA

22. The "A" in the dBA metric refers to the application of the A frequency-weighting filter. This filter has been applied to the measurement of noise levels for almost a century because it simulates sensitivity of human hearing. When noise levels are measured directly, without A-weighting, they are expressed in dB units, and not in dBA units.[1]

[1] For further understanding of this issue, please see: Alves-Pereira M, Rapley B, Bakker H, Summers R. (2019) Acoustics and Biological Structures. In: Abiddine Fellah ZE, Ogam E. (Eds) *Acoustics of Materials.* IntechOpen: London. DOI: 10.5772/intechopen.82761.

23. Figure 1 compares two acoustic environments, one with a measured value of 36 dBA and the other of 38 dBA, i.e., within the target value.[2, 3]

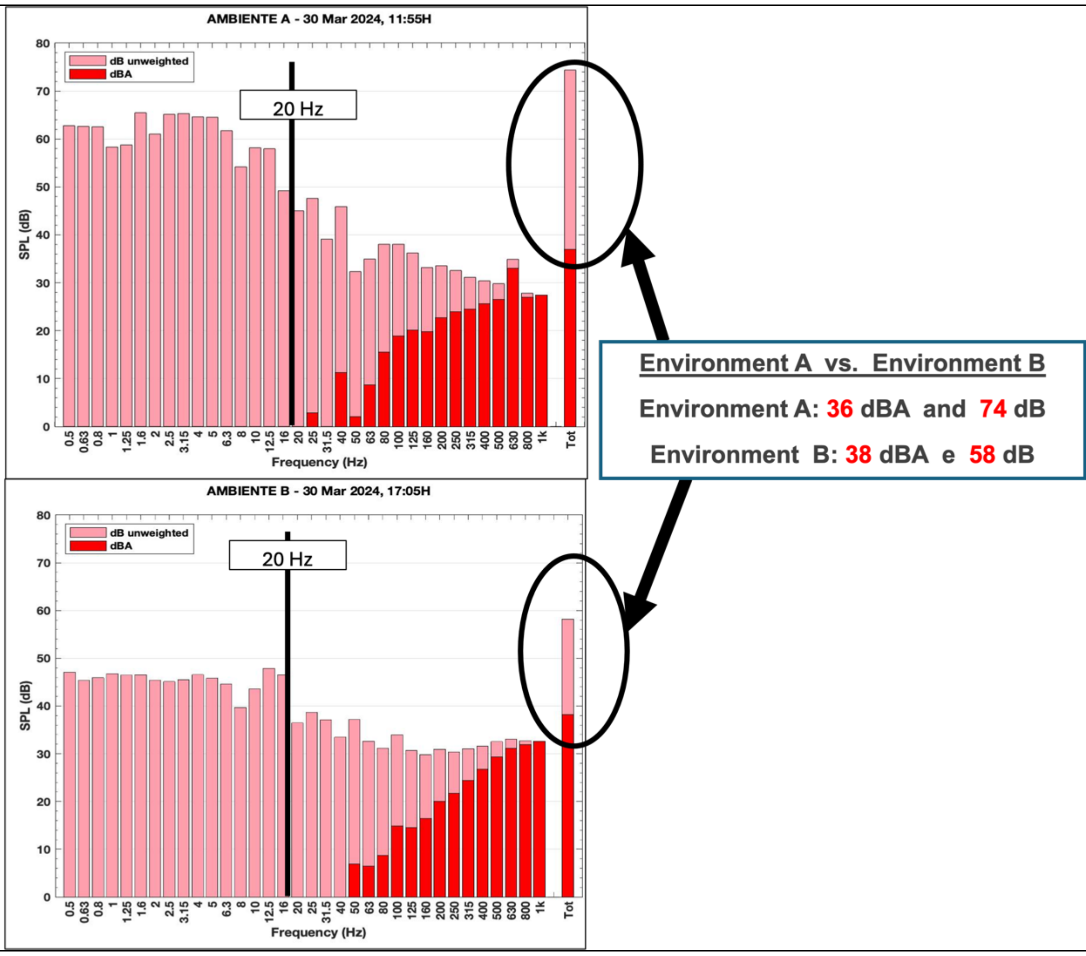

Figure 1. Frequency distribution of two acoustic environments, represented as 10-minute averages. Both were measured in the same location (see text) at different times of day: Environment A at 11:55H and Environment B at 17:05H. The last bar on the right side of either graph (in black circles) represent the overall noise level as expressed in dBA (red bar) and in dB unweighted (pink bar). The similarity of values when expressed in dBA leads most mainstream scientists to the belief that these are acoustically comparable environments. In reality, however, they are significantly different as shown by their sound levels in unweighted dB: 74 vs 58 dB.

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[2] The use of logarithm scale to define the acoustic decibel (referenced to 20 micropascal) means that the amplitude of the sound doubles every 6 dB.

[3] The acoustical data presented in this report are reproduced from a paper previously published in a Portuguese Technical Journal: Sousa-Pereira P, Bakker HHC, Alves-Pereira M. (2024) [The dose-response relationship in occupational noise exposures.] *Revista Segurança*, 271: 13-18. This work was awarded the best e-poster prize by the III Symposium on Occupational Health, organized by the School of Medicine of the University of Porto, Portugal (23 September 2024).

24. Please note that these numerical values are based on field measurements, and not computer modelling techniques. The measurement location was in the animal shed of a livestock farm located near WPPs (For more information on this case, see[4].).

25. Figure 2 is an educational representation of Figure 1, pointing out the portions of the graph that are relevant for understanding the matter at hand.

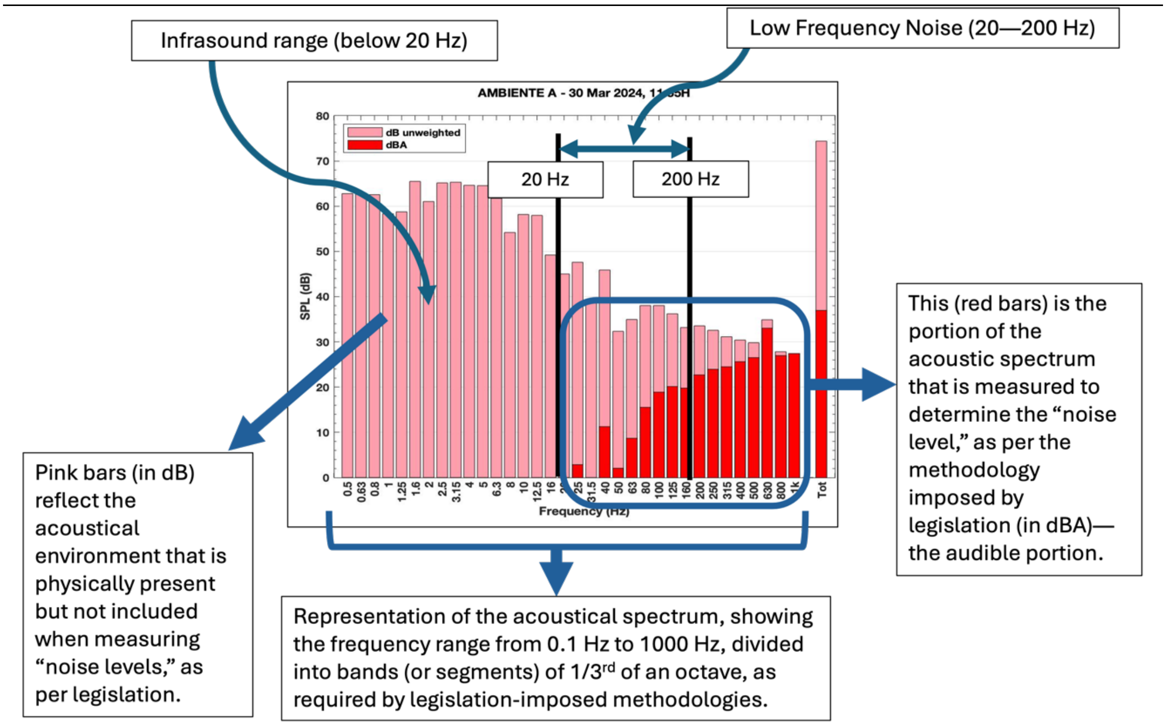

Figure 2. Educational representation of Figure 1, pointing out portions of the graph that are relevant for understanding the matter at hand. This is a representation of the distribution of acoustic energy over frequency in an environment, based on the average of a 10-minute measurement. Infrasound (below 20 Hz) and low frequency noise (20–200 Hz) correspond to the frequency ranges as indicated. The red bars indicate that noise level that is measured after the application of the A frequency-weighting filter (dBA), as required by legislation.[5] The pink bars reflect the acoustical environment that is physically present, as measured with no filters applied (dB unweighted, or dB Linear, or dBZ), but this is not required by legislation.

[4] Bakker HHC, Alves-Pereira M, Mann R, Summers R, Dickinson P. (2023) Infrasound exposure: High resolution measurements near wind power plants. In: Suhanek M, Kevin Summers J. (Eds) *Management of Noise Pollution*. IntechOpen: London. DOI: 10.5772/intechopen.109047

[5] Only the range 0.5–1000 Hz is shown here because above 1000 Hz, A-weighted sound levels and unweighted sound levels are essentially equal.

26. As shown in Figure 1, when noise levels are measured after applying A-weighting, and expressed in dBA (red bars), a large portion of the soundscape is not taken into consideration (pink bars).

27. Mainstream scientists assume that "what you can't hear won't hurt you" (see Section F-I below), presuming that the only impact of sound on human health is mediated through auditory pathways and, therefore, the only health consequence is hearing impairment or deafness.

28. This (erroneous) notion justifies why a large portion of the soundscape (pink bars) is not considered within the context of human health.

29. Instead, this portion of the soundscape (pink bars) is considered inaudible to humans and, therefore, irrelevant to human health.

30. More importantly, Figure 1 shows that expressing noise levels in dBA does not differentiate between two, significantly different, acoustical environments (74 vs. 58 dB).

31. Therefore, determining a target value of 40 dBA for residential areas surrounding WPPs is merely protecting the human hearing function from becoming impaired due to continuous noise exposure.

32. The proposed target value will not protect any other aspect of human health with the exception of hearing impairment (See Section D-II below) and, possibly, speech intelligibility and overall auditory fatigue.

33. Establishing a target value of 40 dBA for residential areas surrounding WPPs <u>does not</u> guarantee the protection of health in human (and livestock) populations.

D. ANNOYANCE AND THE PURPOSE OF NOISE STANDARDS

> *It should also be noted that there is a distinction between noise levels exceeding regulatory limits and noise levels causing annoyance. Noise standards are designed to ensure noise levels do not harm human health. This does not mean that the noise source will be inaudible. In the case of annoyance, the noise source is audible and may be unpleasant, but it does not constitute a health-threatening situation. The perceived annoyance of noise depends significantly on individual perception. Various studies have proposed 35 dB as the annoyance threshold for WPP noise (Schmidt et al., 2014). However, as mentioned, individual sensitivity to wind turbine noise varies.* (Kobras Report, pp. 147)

I. Annoyance

34. The paragraph transcribed above illustrates a generalized idea which has practically zero scientific veracity, rendering it essentially irrelevant to the matter at hand.

35. "Annoyance" is not a scientifically valid medical or clinical endpoint.

36. In fact, the term "annoyance" does not appear in the 2017 edition of Mosby's Medical Dictionary,[6] nor does it appear in the 2018 edition of the Medical Dictionary published by the British Medical Association.[7] In the 2020 edition of the Oxford Medical Dictionary, one single entry is found for this word:

> *Glare n. the undesirable effects of scattered stray light on the retina, causing reduced contrast and visual performance as well as* ***annoyance*** *and discomfort.*[8]

37. In accordance with the World Health Organization (WHO):

> *An adverse effect of noise is defined as a change in the morphology and physiology of an organism that results in impairment of functional capacity, or an impairment of capacity to compensate for additional stress, or*

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[6] O'Toole MT et al. (Eds). (2017) Mosby's Medical Dictionary. 10th Ed. Elsevier: St Louis, MI, USA.

[7] British Medical Association. (2018) Medical Dictionary. 4th Edition. Dorling Kindersley: London, UK.

[8] Martin E, Law J. (Eds) (2020) Concise Colour Medical Dictionary. 7th Ed. Oxford University Press: Oxford, UK.

increases the susceptibility of an organism to the harmful effects of other environmental influences.[9]

38. Clearly, the concept of "annoyance" does not comply with this WHO definition.

39. "The perceived annoyance of noise depends significantly on individual perception." This is the classical definition of a ***subjective parameter***.

40. Annoyance is commonly studied within the realm of Psychoacoustics, and not within the realm of Clinical/Medical Sciences, where ***objective medical endpoints*** are required to properly assess a medical situation.

41. "Individual sensitivity to wind turbine noise varies" because, individually, prior exposures to infrasound and low frequency noise (ILFN) also vary, oftentimes significantly.

42. Sensitivity to wind turbine noise increases with increasing exposures to (any type of) ILFN due to the physiological damage to the mechanisms involved in hearing. These prior exposures can be occupational, residential or recreational in nature. The time-profile over which these exposures occur are variable, depending on the nature and location of the source. For more detailed information on this topic, see [10,11,12].

II. Noise standards

43. "Noise standards are designed to ensure noise levels do not harm human health." This is not entirely accurate.

44. Current noise standards in the European Union are designed to ensure that noise levels, ultimately, ***do not cause hearing impairment or deafness***.

45. The assumption that these noise standards have been designed to protect "human health" is quite erroneous; they only protect human hearing and hearing-related issues.

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[9] World Health Organization. (1999) Guidelines for community noise. Stockholm University & Karolinska Institute: Stockholm, Sweden. pp. 21. https://www.who.int/publications/i/item/a68672

[10] IARO. (2024) Health Report on Arnicle Farm, Glenbarr, Tarbert, Argyll, Scotland. Document No. IARO24-C1. Redacted version available at: IARO.org.nz.

[11] Alves-Pereira M, Rapley B, Bakker H, Summers R. (2019) Acoustics and Biological Structures. In: Abiddine Fellah ZE, Ogam E. (Eds) *Acoustics of Materials*. IntechOpen: London. DOI: 10.5772/intechopen.82761.

[12] Stepanov V. (2001) Biological effects of low frequency acoustic oscillations and their hygienic regulation. State Research Center of Russia, Moscow. https://archive.org/details/DTIC_ADA423963

46. This is plainly visible in Figure 1. "Noise standards" only demand that the audible part of the acoustic environment be measured by mandating A-weighting (in dBA, red bars). All other possible impacts to human health via acoustical phenomena are ignored.

47. If "human health" had been a concern when designing these standards, infrasound and low frequency noise would not have been excluded from consideration, i.e., the pink bars in Figure1 would have been taken into account.

48. In the Russian Federation, for example, noise standards were indeed designed to protect human health because they also considered limiting values for infrasonic exposures, as shown in Figure 3.

Premise	Sound pressure levels, dB, in octaval bands of averaged geometric frequencies, Hz				General sound pressure level dB "Lin"
	2	4	8	16	
Different jobs inside industrial premises and production areas:					
- Different physical intensity jobs	100	95	90	85	100
- Different intellectual emotional tension jobs	95	90	85	80	95
Populated area	90	85	80	75	90
Living and public premises	75	70	65	60	75

Figure 3. Permissible exposure levels for infrasonic exposures in the Russian Federation.[13] Notably, a) the infrasonic range has been segmented into one-octave bands at 2, 4, 8 and 16 Hz, each with different values for exposure limits, b) noise levels are expressed in dB "Lin," meaning, unweighted dB, and c) permissible exposure levels are provided for two different types of occupational environments and two different types of environmental exposures.

49. Note that the numerical values shown in Figure 3 were established before the advent of WPPs, and therefore refer to tonal noise, and not pulsed trains of acoustic pressure waves, as are emitted from WPPs (See Section E-III below).

[13] Reproduced from: Stepanov V. (2001) Biological effects of low frequency acoustic oscillations and their hygienic regulation. State Research Center of Russia, Moscow. https://archive.org/details/DTIC_ADA423963

E. NOISE FROM WIND POWER PLANTS

The noise sources in WPP's can be divided into two categories:

-- Mechanical noise generated by the gearbox, motor, and other mechanisms of the wind turbine.

-- Aerodynamic noise created by the rotor blades moving through the air.

Modern wind turbines have been designed with considerable attention to noise reduction. Mechanical noise has been significantly minimized through the use of various insulation materials and technical solutions. Similarly, technical measures have been implemented to reduce aerodynamic noise. However, since these are large technical devices, some level of noise emission is inherent during the operation of wind turbines. (Kobras Report, pp. 146)

I. Audible Noise

50. "Mechanical noise," as described above, usually occurs within the audible range. With the current noise standards (including tonal analyses), this category of acoustic disturbance can be mitigated or even eliminated in a relatively easy manner.

51. Computer modelling programs that are used worldwide for predicting the acoustic output of WPPs are based on the current noise standards. As has been shown, these do not protect human health, they merely protect human hearing.

52. All the images presented in the Kobras Report (Figure 76, pp. 153 through Figure 85, pp. 159) are based on this type of computer modelling.

53. The conclusion is, therefore, that none of these WPPs pose a risk for classical hearing impairment (as measured through audiograms) among the residents in the surrounding areas.

II. Aerodynamic Noise

54. "Aerodynamic noise," however, is an entirely different matter, because most of its acoustical energy resides in the infrasonic and lower-frequency part of the acoustic spectrum.[14]

55. Therefore, even when "technical measures [are] implemented to reduce aerodynamic noise," these fall short of protecting the health of the general public.

> *The noise generated by turbines depends on wind strength. With weaker winds, the rotational speed of the turbine is lower, resulting in a lower noise level. As wind speed increases, the rotational speed rises, but natural ambient noise also increases, partially masking the turbine noise.* (Kobras Report, pp. 147)

56. While wind speed is an obvious factor in the amount of aerodynamic noise produced by a rotating industrial wind turbine (IWT), blade size is another very important factor.

57. Aerodynamic noise is related to the amount of air that is pushed by the blade. The larger the area of the blade, the larger the amount of air that is displaced during rotation.

58. Therefore, the statement contained in the above-cited paragraph, "The noise generated by turbines depends on wind strength," is incomplete. It depends on wind strength ***and blade size***.

59. Regarding the last statement in the above paragraph, it is pertinent to transcribe the emails exchanged between RES (Renewable Energy Systems) and residents of Arnicle Farm in Argyle, Scotland, regarding the Blary Hill Wind Power Plant, owned and operated by RES, and installed in November/December 2021.[15,16]

60. On 14 June 2022, Arnicle Farm Resident (EM) questioned RES as to:

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[14] As the size of the wind turbine increases more and more of the sound energy moves to the lower-frequency and infrasonic region.

[15] IARO. (2024) Health Report on Arnicle Farm, Glenbarr, Tarbert, Argyll, Scotland. Document No. IARO24-C1. Redacted version available at: IARO.org.nz.

[16] IARO. (2023) Report on the High-Resolution Infrasonic and Low-Frequency Sound Recordings conducted at Arnicle Farm, Glenbarr, Tarbert, Argyll, Scotland in 2022 and 2023. Document No. IARO23-C1. Redacted version available at: IARO.org.nz.

> *Why are the five turbines that are supposed to be stopped, turning slowly? We are experiencing more disturbance at Arnicle since they started, also disturbed sleep.*[17]

61. Response from RES employee:

> *The turbines are currently under automatic curtailment. This automatic curtailment this [sic.] is below the normal speed of rotation and there will be no generation from the turbines. My colleagues continue to look into the issues you reported starting on Friday night and we will certainly investigate if anything has recently changed with the turbine operation, but I can't see anything from the data I am looking at.*[18]

62. Apparently, it is believed that "no generation" of electricity is synonymous with "no generation" of noise,[19] not understanding that it is the displacement of air by rotating blades that is causing disturbance. Arnicle Farm Resident EM's response less than one hour later:

> *Take my word for it, there is more disturbance here, my husband has just gone back to bed ......which is unheard of.......as he has had a very disturbed night and is exhausted.*[20]

63. On 07 July 2022, Arnicle Farm Resident EM wrote to Argyll & Bute Council:

> *The disturbance from Blary Hill Windfarm is affecting us really badly since RES changed the front five turbines from being completely off to freewheeling. We have requested a few times that they keep them at a standstill, but they refuse saying that there is no change. (…) We are finding it very hard to carry on living at Arnicle and have to go away most days for a few hours to get some relief from the windfarm.*[21]

64. On 27 September 2022, Arnicle Farm Resident (EM) again wrote to RES: "If today is a taste of what's to come with all the turbines turning, you will drive us from our homes if this continues;"[22] And again, on the following day:

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[17] Email from Arnicle Farm Resident (EM) to RES (MG) on 14 June 2022, at 10:31.

[18] Email from RES (MG) to Arnicle Farm Resident (EM) on 14 June 2022, at 10:49.

[19] This might even be true if only A-frequency weighted sound pressure levels were to be exclusively considered, see Figure 1.

[20] Email from Arnicle Farm Resident (EM) to RES (MG) on 14 June 2022, at 11:24.

[21] Email from Arnicle Farm Resident (EM) to Argyll & Bute Council (Senior Planning Officer AK) on 07 July 2022, at 15:12.

[22] Email from Arnicle Farm Resident (EM) to RES (MG) on 27 September 2022, at 13:58.

Why are you ignoring our request to monitor the low frequency noise, as that is what is causing the disturbance in the atmosphere at Arnicle not the audible noise that you are monitoring? [23]

65. On 29 September 2022, RES insisted:

Our monitoring has shown a vast improvement in the noise performance of these turbines following this remedial work and we have decided to restart three machines so far.[24]

66. The response came from the husband of Arnicle Farm Resident (EM) and was unsurprising:

In reply to your email of 29th September I do not appreciate either myself or [EM] being called a liar.[25]

67. This short transcription of email exchanges shows the position taken by acousticians who are working for wind-industry related companies.

68. A "vast improvement of the noise performance" was considered to have occurred, but this appears to have translated into an aggravated acoustic disturbance for the residents.

69. This situation occurs because industry-employed acousticians, following legislated guidelines, base their noise levels solely on values expressed in dBA.

70. These acousticians, as well as the authors of the Kobras Report, are gravely misinformed on the topic of health and noise exposure.

71. The consequence of relying solely on SEA protocols for the evaluation of the acoustic output of WPPs is the severe health deterioration of human and animal populations that reside in the neighbouring areas.

The noise level is not directly dependent on the size of the turbine. Rather, for turbines with the same noise emission, the noise level reaching residential areas is somewhat lower for taller turbines, as the distance is greater. (Kobras Report, pp.148-9)

72. If this "noise level" refers to the audible noise, generated by gearboxes and mechanical components of the IWT, then, indeed, with taller IWT, these devices are theoretically (slightly) further away from residences.

[23] Email from Arnicle Farm Resident (EM) to RES (MG) on 28 September 2022, at 15:43.

[24] Email from RES (MG) to Arnicle Farm Resident (EM) on 29 September 2022 at 17:02.

[25] Email from Arnicle Farm Resident (DM) to RES (MG) on 30 September 2022, at 09:27.

73. If this "noise level" is supposed to refer to aerodynamic noise as well, then this statement is a profound scientific fallacy.

74. Not only do taller IWTs produce much more infrasonic energy, the taller the IWT, the further and stronger the infrasonic components will propagate.[26]

III. Wind Turbine Acoustic Signatures (WTAS)

75. Figure 1 is representative of the methodology imposed by legislation for the measurement of noise levels: temporal resolution of 10-minute averages, spectral resolution of 1/3rd of an octave, and sound pressure levels expressed in dBA.[27]

76. Scientists, however, are not constrained or restricted by these oversimplistic and antiquated methodologies.

77. Herein, acoustic environments are studied with a temporal resolution of 1 second and a spectral resolution of 1/36th of an octave.

78. For the layperson, one could say that IARO scientists are examining an acoustical environment with a microscope rather than a magnifying glass. That is, the resolution (temporal and spectral) is greatly increased.

79. Using new techniques to analyse recorded soundscapes,[28] the significant differences detected in Environment A and Environment B (See Figure 1) become understandable.

80. Figure 4 shows the same frequency distribution in Environment A and Environment B, but with the above-mentioned increased spectral resolution: 1/36th of an octave instead of the 1/3rd of an octave as shown in Figure 1.

81. Figure 5 shows an educational representation of this same Figure 4.

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[26] Moller H, Pedersen CS. (2011) Low frequency noise from large wind turbines. *Journal of the Acoustical Society of America*, 129(6):3727-44. doi: 10.1121/1.3543957.

[27] It should be noted that these technical specifications are derived from the abilities of the best measuring instruments that existed almost a century ago.

[28] Bakker HHC, Rapley BI, Summers SR, Alves-Pereira M, Dickinson PJ. (2017). An Affordable Recording Instrument for the Acoustical Characterisation of Human Environments. Paper presented at *ICBEN-(International Commission for the Biological Effects of Noise)-2017*, Zurich, Switzerland (Paper No. 3654). https://www.icben.org/2017/ICBEN%202017%20Papers/SubjectArea05_Bakker_P40_3654.pdf.

** The authors of this IARO Report hold no financial interest in the SAM technology.

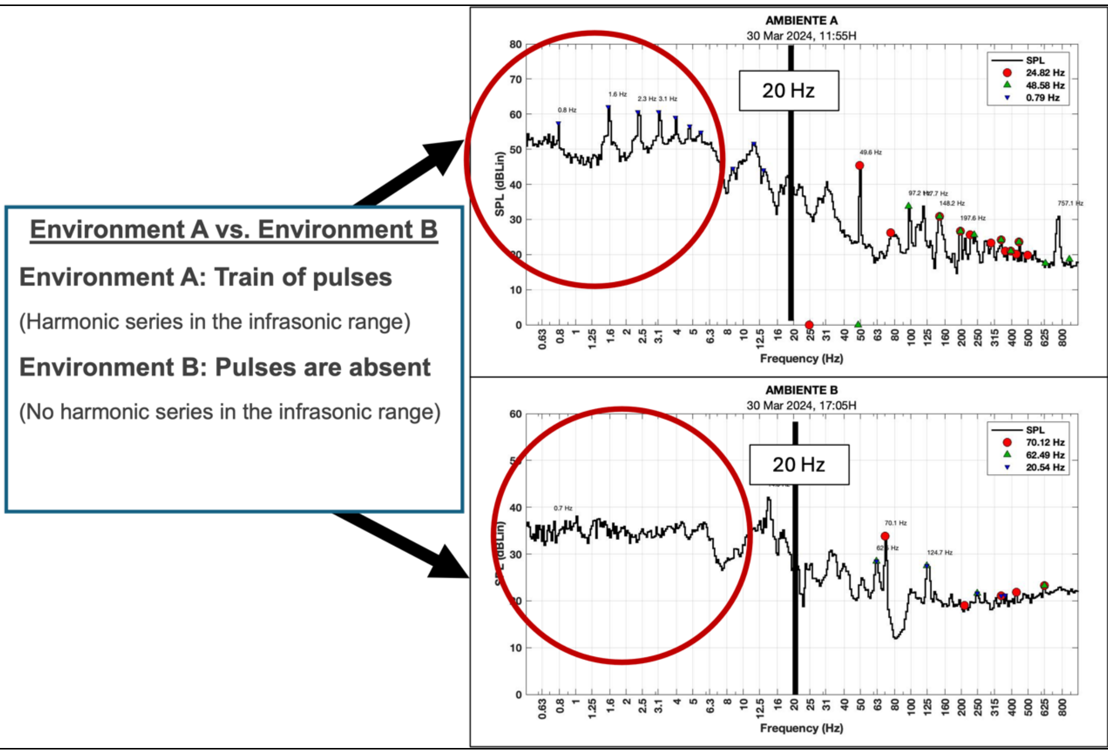

Figure 4. Frequency distribution of the same two environments shown in Figure 1, but with increased spectral resolution—1/36th of an octave instead of 1/3rd of an octave— and increased temporal resolution—1-second averages instead of 10-minute averages. Noticeably, Environment A presents with a series of peaks indicating a harmonic series (indicative of a train of pulses in the signal), while in Environment B this acoustic phenomenon is absent. It is pertinent to recall that both these environments have comparable "noise levels" as expressed in dBA (36 vs. 38 dBA) (See Figure 1).

82. It is pertinent to recall that the characterization of the two Environments, A and B, are the result of direct, scientific-grade field-measurements (not computer modelling) and

- **a.** have similar noise levels as expressed in dBA (36 vs. 38 dBA),
- **b.** have noise levels below the Target Value of 40 dBA, and,
- **c.** are acoustically significantly different (74 vs. 58 dB-unweighted).

Figure 4 shows the presence of an acoustic phenomenon in Environment A which is absent in Environment B, namely, a train of pulses.

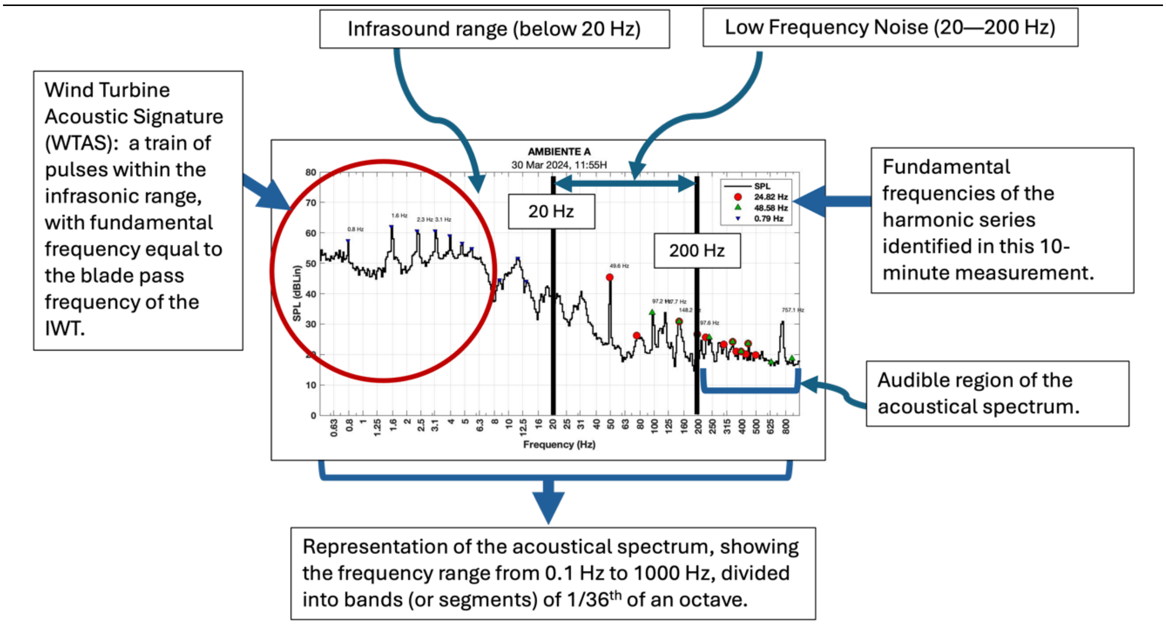

Figure 5. Educational representation of Figure 3, pointing out portions of the graph that are relevant for understanding the matter at hand. This is the representation of the distribution of acoustic energy in an environment over frequency, based on the average of a 600-second (10-min) measurement. Infrasound (below 20 Hz) and low frequency noise (20–200 Hz) correspond to the frequency ranges as indicated. The noise level is expressed in dB on the Y axis. The red circle shows the spectral components of a train of pulses as a harmonic series with a fundamental frequency of 0.8 Hz, as indicated by the blue inverted triangles. They are generated by an IWT with a blade-pass frequency of 0.8 Hz.

83. For mathematical reasons, entirely explained in other scientific and peer-reviewed publications,[29,30] these trains of pulses are representative of the acoustic output of IWTs, referred to as Wind Turbine Acoustic Signature (WTAS).

84. The existence of WTAS in Environment A is responsible for the significantly higher noise level in A (74 dB) when compared to Environment B (58 dB).

85. However, as can be seen in the comparative Figure 1, if the temporal and spectral resolution imposed by legislation is maintained—10-minute averages and 1/3rd octave

[29] Bakker HHC, Alves-Pereira M, Mann R, Summers R, Dickinson P. (2023) Infrasound exposure: High resolution measurements near wind power plants. In: Suhanek M, Kevin Summers J. (Eds) *Management of Noise Pollution*. IntechOpen: London. DOI: 10.5772/intechopen.109047,

[30] Alves-Pereira M, Krough C, Bakker HHC, Summers R, Rapley B. (2019) Infrasound and low frequency noise guidelines – Antiquated and irrelevant for protecting populations. *Proceedings of the 26th International Congress on Sound & Vibration*, Montreal, Canada, July 7-11, No. 682. (Peer-Reviewed Conference Paper).

band segmentation—then this type of information is not captured, and Environments A and B are (erroneously) considered comparable.

86. WTAS is deemed irrelevant to human health because it occurs, mainly, within the infrasonic range, which is considered to be inaudible to humans and, consequently, have no impact on human health.[31]

87. If WTASs are considered to be important enough to be quantified within the context of human health, the currently legislated noise-measurement methodologies would make this quantification impossible.

88. In a peer-reviewed scientific paper published in 2022, WTAS was specifically (strongly) correlated with sleep disturbance: When present the residents did not sleep, when absent they slept peacefully.[32]

[31] Using 'Light' as an analogy, this is equivalent to believing that electromagnetic radiation that is not perceived through the eyes (such as x-rays, microwaves, ultraviolet) are irrelevant to human health because they cannot be seen as light through the eyes. Moreover recent studies have shown that infrasonic signals can be processed by the brain but not conducted through the classical auditory pathways. See: Weichenberger M, Bauer M, Ku¨hler R, Hensel J, Forlim CG, Ihlenfeld A, et al. (2017) Altered cortical and subcortical connectivity due to infrasound administered near the hearing threshold: Evidence from fMRI. *PLoS ONE*, 12(4): e0174420. https://doi.org/10.1371/journal.pone.0174420.

[32] Bakker HHC, Alves-Pereira M, Mann R, Summers R, Dickinson P. (2023) Infrasound exposure: High resolution measurements near wind power plants. In: Suhanek M, Kevin Summers J. (Eds) *Management of Noise Pollution*. IntechOpen: London. DOI: 10.5772/intechopen.109047,

F. BRIEF REVIEW OF THE HEALTH EFFECTS CAUSED BY EXPOSURE TO INFRASOUND AND LOW FREQUENCY NOISE

I. "What you can't hear won't hurt you"

> *The human hearing threshold begins at medium frequencies (500–4000 Hz) with a sound pressure level of 0–20 dB. For low-frequency ranges (0–200 Hz), the sound pressure must be significantly higher for the sound to be perceived—around 80 dB near 20 Hz and about 107 dB at 4 Hz. This principle must be considered when discussing the low-frequency noise impact of WPP's.* (Kobras Report, pp. 161)

89. There are several inaccuracies in the above paragraph, transcribed from the Kobras Report.

90. The most profound flaw is the assumption that health effects due to infrasound and low frequency noise exposures are only related to acoustic energy audible through the hearing function, i.e., "what you can't hear won't hurt you."

91. This idea was shown to be a scientific fallacy as early as 1978, when it was proved that genetically deaf mice were greatly affected by infrasound exposures.[33]

92. More recently, it has been shown that the brain processes infrasound signals that are not relayed by the classical auditory pathways.[34]

93. The "principle [that] must be considered when discussing the low-frequency noise impact of WPP's," in the opinion of the authors of the Kobras Report is, in reality, a false issue.

94. Where WPPs are concerned, and contrary to the foundational precepts of Medical Sciences, great emphasis is placed on the question of *perception* or *non-perception* of

[33] Busnel RG, Lehmann AG (1978). Infrasound and sound: Differentiation of their psychophysiological effects through use of genetically deaf animals. *Journal of the Acoustical Society of America*, 63(3):974-977. https://pubmed.ncbi.nlm.nih.gov/670562/

[34] Weichenberger M, Bauer M, Kühler R, Hensel J, Forlim CG, Ihlenfeld A, et al. (2017) Altered cortical and subcortical connectivity due to infrasound administered near the hearing threshold: Evidence from fMRI. *PLoS ONE*, 12(4): e0174420. https://doi.org/10.1371/journal.pone.0174420.

the "noise," insinuating that, if the "noise" is not perceived through the auditory pathways, then it is not harmful.[35]

95. This notion is, of course, absurd (see Footnote 31).

96. Therefore, while the statement "For low-frequency ranges (0–200 Hz), the sound pressure must be significantly higher for the sound to be perceived—around 80 dB near 20 Hz and about 107 dB at 4 Hz" may be true, it has no relevance to health effects other than the hearing function.

II. Sources of Infrasound and Low Frequency Noise

> *Low-frequency components are present in most sounds, caused by both human-made sources (e.g., traffic) and natural sources (e.g., wind). For low-frequency sound to be disruptive or harmful to health, its sound pressure level is crucial.* (Kobras Report, pp. 161)

97. Here, again, several inaccuracies are insinuated.

98. While it is true that "[l]ow-frequency components are present in most sounds, caused by both human-made sources (e.g., traffic) and natural sources (e.g., wind)," it is misleading to insinuate that these sources are similar or comparable. Indeed, they are significantly different. "[M]ost sounds" do not contain pulse trains, or even tonality, in this range.

99. The time profile over which acoustic events occur is of fundamental importance to determine health effects caused by this type of physical agent of disease (noise)—not merely the average level of sound pressure.

100. When statements such as "[f]or low-frequency sound to be disruptive or harmful to health, its sound pressure level is crucial" are provided, it misleads government officials and laypersons into believing that the sound level pressure is the most important factor (if not the only one) that matters when evaluating the health effects of ILFN exposures.

101. As shown in Figure 1, the generally used sound pressure level (expressed in dBA), does not differentiate between two significantly different acoustic environments.

> *Wind turbines, like many other sound sources, produce low-frequency sounds. However, current measurements and studies conducted at WPP's*

[35] The word **noise** is here presented with quotes due to semantics: If the acoustical event is non-audible to humans, and noise is defined as unwanted sound, then the noise that can be perceived but not heard must be presented as "noise."

have not detected low-frequency sounds at levels where they would be audible or cause health effects. (Kobras Report, pp.161)

102. Here, again, the scientific fallacies are shown to be deeply ingrained into SEA protocols:

103. "Current measurements… have not detected low-frequency sounds at levels where they would be audible..." Again, classical audibility of sound is deemed to be all-important, to the exclusion of all else. It is insinuated that action is necessary if, and only if, the low-frequency sound measurements are at levels considered audible. This perpetuates the notion "what you can't hear won't hurt you."

104. "Current measurements… have not detected low-frequency sounds at levels where they would…. cause health effects." This is not a scientifically proven, or provable, statement. The fact that some studies have found no health effects cannot be taken to prove that no health effects exist, especially when other studies disagree. See Annex B for an example of this situation.

Studies to date indicate that the low-frequency sounds caused by wind turbines are at a level comparable to ordinary environmental background noise (Leventhall, 2006). (Kobras Report, pp.161)

105. The average level of sound pressure may be comparable to ordinary background noise when using analyses with a spectral resolution of 1/3rd of an octave and a temporal resolution of 10-minute averages and, under these circumstances, could mask any differences in the character of the noise.

106. Yet, this is an antiquated methodology that is still in practice today (as imposed by legislative documents and guidelines), even though technology and analytical techniques have existed for many decades that permit a more scientific analysis of acoustic environments, with higher resolution.

107. Figure 6 shows the same two environments, A and B, as in Figure 1 and Figure 4, but here the data is presented in the form of Sonograms. Spectral resolution is 1/36th of an octave while the temporal resolution is 1-second, for a duration of 600 seconds (10 minutes).

108. Figure 7 is an educational representation of Figure 6.

109. Figure 6 shows, in each successive second, what SPL (in unweighted dB, given by the colour-scale) was present at each 1/36th octave band of the frequency spectrum.

110. The difference between the environmental background noise with and without the presence of a WTAS can be seen by any layperson.

111. The train of pulses of the WTAS, seen as the peaks of a harmonic series, in Figure 4 are manifested as the unbroken, horizontal lines seen in the corresponding sonogram

(Environment A). That is, the peaks of energy seen in Figure 4 are present in each successive second, creating the horizontal lines.

112. These horizontal lines are absent in Environment B, as can be seen in the corresponding sonogram.

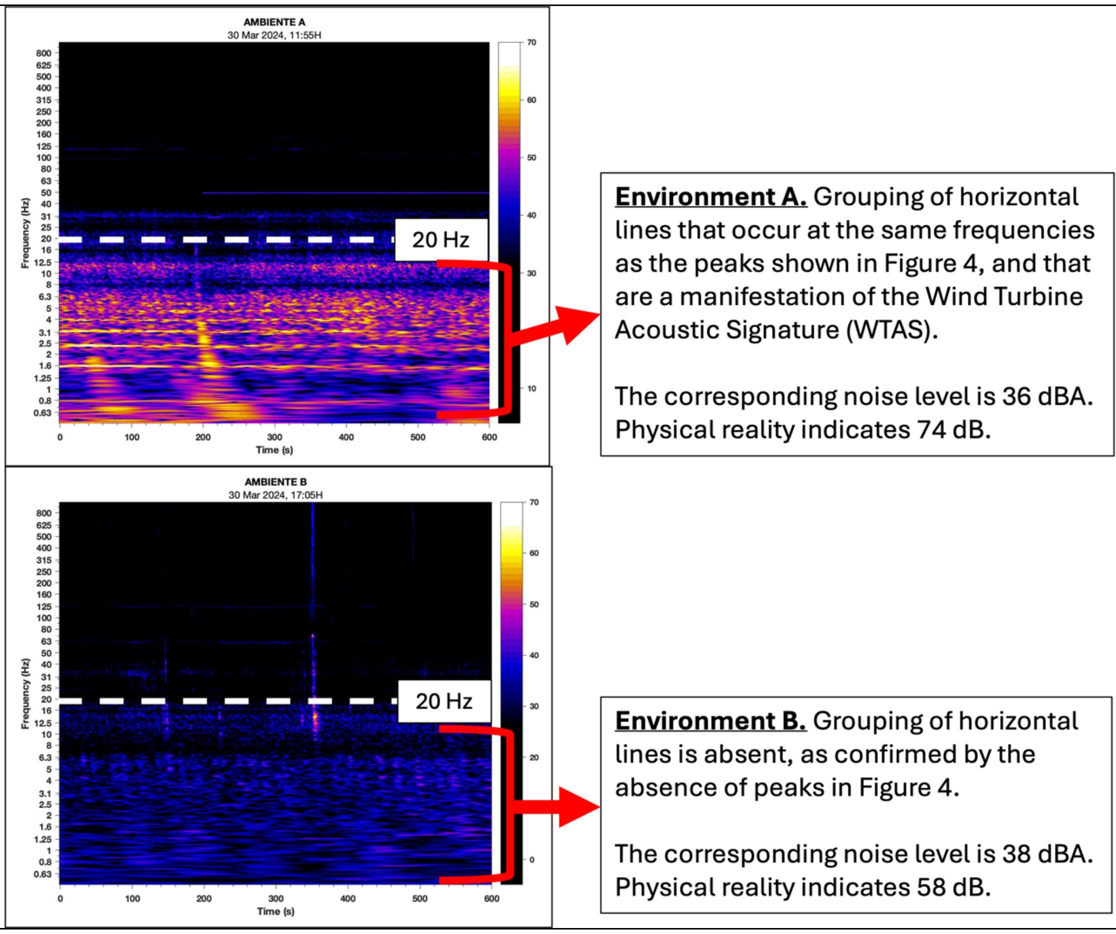

Figure 6. Sonograms of Environment A (**top**) and Environment B (**bottom**). The significant difference between these two acoustical environments is visually evidenced.

113. With these types of scientific-grade analyses, where the observation of the acoustic environment is accomplished with a higher temporal and spectral resolution of measurements —from magnifying glass to microscope—natural background noise can be clearly differentiated from human-made noise. Nature does not generally produce acoustic events in straight lines (harmonic series) over such an extended period of time.

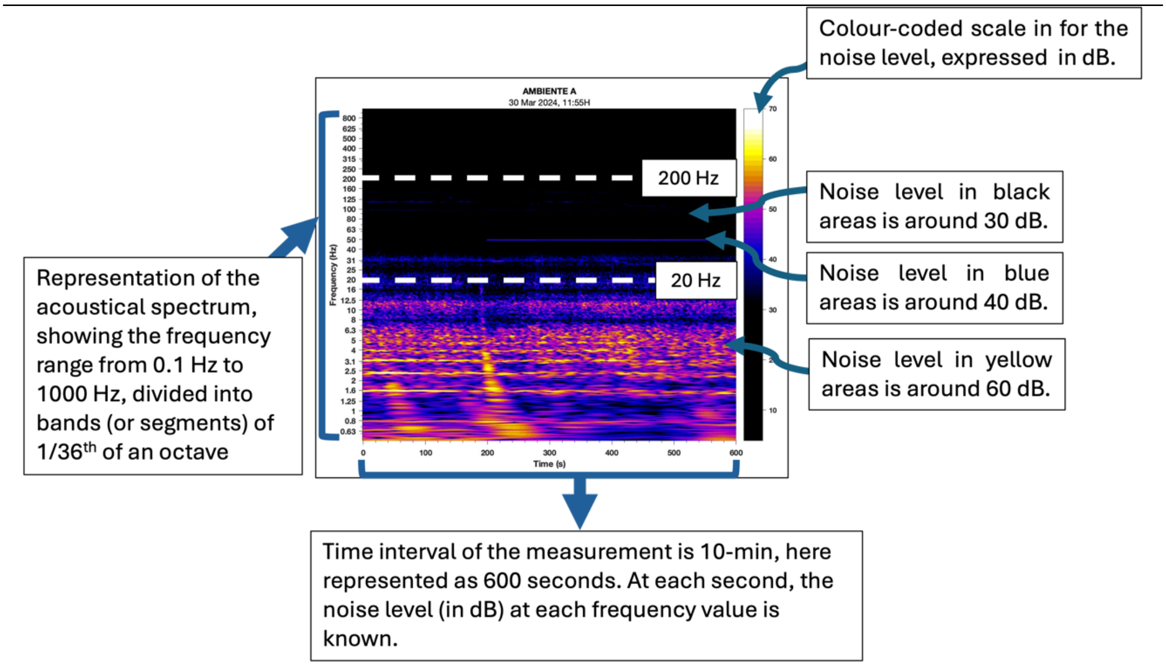

Figure 7. Educational representation of Figure 6, pointing out portions of the graph that are relevant for understanding the matter at hand. This is the representation of the frequency distribution of an environment, based on the average of a 600-second (10-min) measurement. The regions corresponding to Infrasound (below 20 Hz) and low frequency noise (20-200 Hz) are indicated. Examples of SPLs as read with the colour-coded scale are given.

III. Studies cited by the Kobras Report

114. The Kobras Report refers to two studies in order to substantiate their position that noise emanating from WPPs has no impact on health (unless it is audible).

115. These studies are:

a. *Maijala P, Turunen A, Kurki I, Vainio L, Pakarinen S, et al. (2020) Infrasound does not explain symptoms related to wind turbines. Publications of the Finnish Government's Analysis, Assessment and Research Activities, 2020:34. Prime Minister's Office: Helsinki*.[36] (Kobras Report, pp. 161), and

b. *Marshall N, Cho G, Toelle BG, Tonin R, Bartlett DJ, et al. (2023) The Health Effects of 72 Hours of Simulated Wind Turbine Infrasound: A Double-Blind Randomised*

[36] https://julkaisut.valtioneuvosto.fi/handle/10024/162329

Crossover Study in Noise-Sensitive, Health Adults. Environmental Health Perspectives, 131(3): 1-10.[37] (Kobras Report, pp. 162)

116. IARO scientists have already performed a critical analysis of these (and other) studies. Regrettably, in the opinion of IARO scientists, these two studies have profound methodological flaws which fully invalidate the reported conclusions.

117. In Annex B, an excerpt of the 2024 IARO Arnicle Health Report is provided, where the critical analyses of these two studies are put forth, and the reasons why their conclusions <u>are not based</u> on the foundational principles of the Scientific Method are explained.

[37] https://pubmed.ncbi.nlm.nih.gov/36946580/

G. CONCLUSIONS

118. It is fully recognized by IARO scientists that Governments worldwide have been informed of the perceived economic benefits that WPPs might bring to their nations.

119. As demonstrated herein, these perceived economic benefits are accompanied by a substantial cost that is associated with the significant reduction in the health of human and animal population living in and around the vicinity of WPPs.

120. The Kobras Report submitted to the local government officials in Estonia, because of its good compliance with SEA Directives, perpetuates flawed and archaic methodologies regarding noise assessments for the prevention of harmful effects to health.

121. These flawed and archaic methodologies are used to justify conclusions that are, oftentimes, outright scientific fallacies.

122. This is particularly true for the health impacts induced by the acoustic output of WPPs.

123. Because Subsection 4.6.1 of the Kobras Report appears to be in good compliance with Estonian governmental legislation and EU SEA Directives, it continues to propagate the scientific fallacy that "what you can't hear, can't hurt you."

124. It is hoped that the relevant authorities and the general public will take the following Recommendations under consideration.

H. RECOMMENDATIONS

125. The Kobras Report states that a second phase for this project, proposing the installation of multiple WPPs throughout the Estonian countryside, might be undertaken.

126. If a second planning phase is undertaken, the following recommendations are suggested for decision-makers, governmental officials and the general public (as applicable):

I. Acoustics

127. Baseline noise recordings should be conducted prior to any initial construction of any WPP and must include the infrasonic region of the acoustic spectrum.

128. Analysis of these recordings must include low-resolution averages expressed in dB unweighted and must include high-resolution samples over the infrasonic and low-frequency regions.

129. This means that noise measurement protocols cannot be exclusively dictated by current legislation, but rather, by proper scientific practices.

130. These noise measurements cannot be substituted by computer modelling techniques.

131. After the installation of WPPs, these noise recordings and analyses should be regularly performed for a minimum of five years (assuming that all approved WPPs will be fully installed and operational within the next five years).

132. As the propagation of WTAS is directional, the recordings and analyses should include the full range of wind directions and weather conditions present over all seasons.

133. These actions should be taken under the auspices of the Estonian governmental agency responsible for Public Health. In their absence, these actions should be taken by individual citizens under Citizens' Science Initiatives.

II. Public Health

134. Prior to the installation of any WPP, neighbouring residents (up to 20 km away from the proposed WPPs) should be interviewed to ascertain their a) extent of prior ILFN exposures, b) current clinical situation, and c) past medical histories.

135. During and after the installation of WPPs, residents should be monitored as to pertinent and relevant clinical and reproductive outcomes (and not merely for subjective, psychoacoustic parameters) for a minimum of five years.

136. These actions should be taken under the auspices of the Estonian governmental agency responsible for Public Health. In their absence, these actions should be taken by individual citizens under Citizens' Science Initiatives.

III. Livestock Health

137. Detailed reports should be prepared by livestock owners regarding mortality, birth rates and sickness among their animals ***before*** the installation of any WPP.

138. Monitoring of these parameters must be maintained for a minimum of 5 years after the installation of the WPPs.

139. These actions should be taken under the auspices of the Estonian governmental agency responsible for Animal & Livestock Health. In their absence, these actions should be taken by individual citizens, under Citizens' Science Initiatives.