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FINAL REPORT (TECHNICAL PART) of project implementation Programme 'Applied Research'				
Report number [1]	4			
Reporting period	**from**	01.04.2021	**to**	30.04.2024

A. PROJECT INFORMATION				
Number of project contract	NOR/POLNOR/Hetman/0073/2019		**Acronym**	Hetman
Duration of project	**from**	01.04.2021	**to**	30.04.2024
Project title	Healthy society-towards optimal management of wind turbines' noise			
Keywords	noise,wind turbines,noise annoyance perception,noise guidelines,health outcomes			
Name of the call	POLNOR 2019 call			

ENTITIES				
Status in project	**Name of entity**	**Short name**	**Type of entity** [2]	**Country**
Project Promoter	Uniwersytet im. Adama Mickiewicza / Adam Mickiewicz University	UAM / AMU	Research unit/institution	Poland
Project Partner 1	Akustix Sp. z o. o. / Akustix Ltd.	Akustix	Micro-enterprise	Poland
Project Partner 2	Akademia Górniczo-Hutnicza im. Stanisława Staszica / AGH University of Science	Akademia Górniczo-Hutnicza im. Stanisława Staszica	Research unit/institution	Poland
Project Partner 3	Stifelsen SINTEF, P.O.	SINTEF	Research unit/institution	Norway
Project Partner 4	Instytut Ochrony Środowiska – Państwowy Instytut Badawczy / Institute of Environmental Protect	Instytut Ochrony Środowiska – Państwowy Instytut Badawczy	Research unit/institution	Poland
Project Partner 5	Główny Instytut Górnictwa - Państwowy Instytut Badawczy/ Central Mining Institute - PIB	Główny Instytut Górnictwa - Państwowy Instytut Badawczy	Research unit/institution	Poland
Project Partner 6	Instytut Medycyny Pracy im. prof. Jerzego Nofera / Nofer Institute of Occupational Medicine	Instytut Medycyny Pracy im. prof. Jerzego Nofera	Research unit/institution	Poland

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Project Partner 7	Polskie Stowarzyszenie Energetyki Wiatrowej / Polish Wind Energy Association	Polskie Stowarzyszenie Energetyki Wiatrowej	Micro-enterprise	Poland

B1. Principal Investigator	
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[1] The successive number of the project report - 1,2,3 etc.
[2] Choose one: research unit/institution, small /medium/ large enterprise, other

C. INFORMATION ON THE IMPLEMENTATION PROGRESS IN THE REPORTING PERIOD

C1-1. Work Package title and number [3]	Noise annoyance and limits - Nr zadania / WP No. 1			
Start date	planned [4]	01.04.2021	actual	01.04.2021
End date	planned	31.03.2024	actual	31.03.2024
Cost of WP (PLN)	planned	1 005 808.86	actual (value at the end of the reporting period)	835 260.28
Implementing entities	UAM / AMU, Akustix, SINTEF, Główny Instytut Górnictwa - Państwowy Instytut Badawczy, Instytut Medycyny Pracy im. prof. Jerzego Nofera, Polskie Stowarzyszenie Energetyki Wiatrowej			
An explanation of the work carried out by the implementing entities (max. 2500 characters with spaces)				

The tasks carried out under WP1 concerned 4 main tasks:

Task 1: Noise annoyance - survey research + noise recordings,

Task 2: Noise annoyance - laboratory experiments,

Task 3: Choice of the appropriate noise indicator,

Task 4: Recommendation limits of noise indicator.

The role of partners in implementing these tasks was as follows:

SINTEF - took an active part in constructing the survey used for field research on noise annoyance (Task 1). SINTEF organized two visits to Norway, in which young scientists working in the project participated. During the first visit, the participants learned about the principles of operation of wind farms in Norway. During the second visit, we worked together on the content of the good practice guide (Task 4).

AkustiX – organized and took an active part in measurement sessions regarding wind turbine noise recordings. AkustiX organized annual monitoring of noise generated at the selected wind farm. This knowledge was used to create limit values for noise levels generated by wind turbines (Task 1 and 4).

GIG took part in recording the noise of wind turbines (Task 1).

IMP-participated in field surveys and in the implementation of joint laboratory experiments regarding the study of the noise annoyance of wind turbines. The same experiment on the potential influence of infrasound components on the perception of wind turbine noise annoyance was conducted by UAM and IMP.

We obtained consistent results suggesting that the presence of low-frequency components in the spectrum of wind turbines does not have a statistically significant impact on the noise annoyance of wind turbines (Task 2 and 3).

PSEW helped us find a suitable wind farm where we could carry out basic noise measurements of wind turbines (Task1).

AGH participated in wind turbine noise measurements and in joint laboratory research on the assessment of wind turbine noise annoyance.

AGH also conducted experiments on the potential impact of infra- and low- frequency components on the perception of the annoyance assessment of wind turbines (Task 1 and 2).

The results of the research conducted in WP1 were presented in the form of 6 deliverables and one completed milestone.

SINTEF, AkustiX. GIG, IMP, PSEW, AGH:

All partners took part in weekly working meetings (online) where we discussed and planned work on the project.

An overview of the progress of work towards the objectives of the project, including achievements, milestones and deliverables identified in the project contract No more than 12 000 characters with spaces for each WP implemented in the reporting period: a description of the results achieved during the reporting period, activities carried out during the reporting period.

The progress of work within the WP1 is included in 6 deliverables and one completed milestone.

D1.1 Selection of the target group for main research (M6)

The beginning of our work in the project meant preparing tools for survey research and measuring wind turbine noise. In WP1, we focused on developing an optimal questionnaire for survey research in the field. At the same time, we had to determine what group of people we would conduct the research on. Based on discussions with all the project partners we decided to select group 4 as the target group, i.e. to study the assessment of the annoyance of wind turbine noise among people who

are exposed to this noise for the first time. This choice will allow us to invite to our laboratory (arranged as a living room) people (recruited for this project for a fee) who will evaluate the annoyance of previously recorded noise generated by wind turbines. The selection of the target group for our research is described in detail in Deliverable 1.

D1.2 Determination of wind turbine noise parameters crucial for annoyance (M12)

Crucial parameters for assessing the noise annoyance of wind turbines were determined on three levels simultaneously. First, we conducted a thorough review of the literature on this issue. Secondly, we conducted 75 field surveys among people living near wind farms. Third, we conducted a laboratory experiment where people rated the noise annoyance of wind turbines recorded in the field.

We have introduced a new element to both survey and laboratory research, which involves teaching research participants how to numerically assess annoyance.

Both the survey and the laboratory study were preceded by training, during which participants assessed the annoyance of previously recorded wind turbine noise samples using numbers. Our preliminary findings suggest that people evaluating annoyance in their homes understand this concept – annoyance - as do people evaluating annoyance in laboratory experiments. Preliminary results were presented in the publication "Evaluation of annoyance due to wind turbine noise based on pre-learned patterns" by J. Felcyn, A. Preis and R. Gogol.

Regarding the parameters relevant to assessing the annoyance of wind turbine noise, the "variability of wind turbine noise" prevails in the surveys. This is a parameter related to the amplitude modulation present in the wind turbine noise.

A good experience was the visit of Polish partners in Trondheim. During a project meeting in Trondheim in June 2022, the Polish partners were introduced to Norwegian policies and how interaction between the wind park owners and the local community built trust and reduced conflicts.

Deliverable D1.2 is included in joint publication “How to determine the annoyance due to wind turbines” by A. Preis and T. Gjestland.

D1.3 The relationship between annoyance and wind turbine noise parameters (chosen from tasks 1.2, 2.1, 2.2 and 2.3) - psychoacoustic model (M24)

Deliverable 1.3 consists of a description of two experiments, one of which was presented at the international conference in Turyn (J. Felcyn, A. Preis, R. Gogol, and M. Emche, Wind turbine's noise annoyance ratings related to the distance and creativity and directivity of a wind turbine, in Proceedings of the 10th Convention of the European Acoustics Association Forum Acusticum 2023, 2023, pp. 3097–3100). The second experiment was conducted jointly by the IMP and AMU partners and is being prepared for publication. Based on the results of these two experiments and additional spectral-time analyzes of the signals assessed in these experiments, the principles of the psychoacoustic model of wind turbine noise were formulated.

In general, for each noise source it is true that the higher the sound level, the greater its annoyance. However, if we compare two noise sources with the same sound level, due to different spectrally and temporal characteristics, the loudness of such noises will not be the same.

In this case, a similar rule should apply: the louder the noise, the greater the annoyance. This rule generally applies to aircraft, car and rail noise, but does not apply to wind turbine noise. Wind turbines, despite their lower loudness value for the same sound level, are always rated as more annoying, both in field and laboratory studies.

The results of our two experiments suggest that the reason for such a high rating of the annoyance of wind turbines is the temporal characteristics of this noise, and in particular the unpredictable, i.e. random, low-frequency change in the noise's amplitude.

This means that there is no basis for adding any additional penalties for this type of noise, because its temporal variability is present and assessed in every signal generated by wind turbines. The nature of this signal is responsible for the high rating of annoyance in both field and laboratory studies.

The results of our second experiment also suggest that the presence of infra and low-frequency components in the noise spectrum of wind turbines do not contribute to the additional annoyance of this type of noise. As we have shown, listeners in a psychoacoustic experiment respond to spectral changes occurring in the frequency range from 125 to 4000 Hz.

The results of our laboratory experiments indicate that at a level of 45 dBA the short-term annoyance rating (5 minutes) is equal to 4 on the ICBEN annoyance scale. An annoyance rating of 4 on the ICBEN scale means little annoyance. In the project, we assumed that we would recommend a level not exceeding rating 4 as the permissible sound level for wind turbines.

D1.4 Masking of wind turbine noise by wind induced noise (M24)

The potential effect of masking of wind turbine noise by wind induced noise, was part of an experiment carried out by WP5. The wind effect is summarized in deliverables D1.4 as follows:

WTN (Wind Turbine Noise) is among the specific noise sources in terms of both spectral and temporal structure. The WTN spectrum is dominated by low-frequency components. While the low masking efficiency of WTN by RTN (Road Traffic Noise) can be attempted to be explained by differences in energy maxima falling at higher frequencies for RTN than for WTN, the insignificant masking effect of WTN by WN (Wind Noise) observed in the present study can be explained primarily based on regular fluctuations in the level of WTN (amplitude modulation), which is not observed in the case of WN.

D1.5 Wind turbine noise – adaptation effect (M27)

We were able to survey the same residents at two different points in time of the wind farm: in June 2022, when the farm was not yet in operation, and in January 2023, when the farm was already in operation from August 2022. Therefore, it was possible to study the potential habituation (adaptation) of residents to the noise of wind turbines

We wanted to find out whether the evaluation of the same acoustic stimuli presented through headphones to the participants of the survey were evaluated the same before and after the launch of the wind farm. In this way, we can indirectly assess whether the operation of wind turbines has affected the evaluation of acoustic stimuli or not.

The comparison of annoyance levels over the past 12 months, both before and after the commencement of operations at the wind farm, indicates no statistically significant variances in mean scores. Given that the wind turbine represents the sole source of sound altering the acoustic landscape within which respondents reside daily, it can be inferred that, on the whole, the turbine's presence does not exacerbate the overall evaluation of the environment several months post-commissioning. However, it cannot be concluded that habituation (better word than adaptation) has occurred, as the expected and literature-reported decrease in annoyance ratings was not observed. The results of this experiment is presented as D1.5.

D1.6 Proposal for new regulations for wind turbine noise – summary

results from WP1 (M30)

Proposals for new legal regulations regarding wind turbine noise limits are presented in D1.6. Participating in these proposals are primarily partners from AkustiX as well as a partner from Norway. Generally, this proposal will also appear as a management proposal in WP7 and as a chapter in the good practice guide prepared by all partners. This guide is deliverable in the WP7 task.

Dose (Exposure) - Response function for wind turbine noise

The milestone has been achieved, but as we noted in the comment in the 2021 interim report this Exposure-Response function for wind turbine noise is obtained based on laboratory experiments.

This means the relationship between the short-term assessment of annoyance (5 minutes) and the average value of the sound level measured during this time LAeq5 minutes.

Traditionally in the literature, this relationship refers to the average annual assessment of the annoyance of a sound source such as a wind turbine and the average annual sound level LDEN.

Generally, all people working in task 1 contributed to the creation of one of the two most important effects of our project, namely the drafting of a document called the Good Practice Guide.

Deliverables [6]
For deliverables that are not in writing (e.g. prototype), the PP must submit a short written description.

Deliverable name	Lead entity	**Deliverable file** (Maximum one file per deliverable, in case of several files, please create a zip and upload that zip)	Comment
D1.1 Selection of the target group for main research (M6)	Uniwersytet im. Adama Mickiewicza / Adam Mickiewicz University	D1.1.zip	This deliverable determines the selection of the target research group.
D1.2 Determination of wind turbine noise parameters crucial for annoyance (M12)	Uniwersytet im. Adama Mickiewicza / Adam Mickiewicz University	D1.2.zip	Included in the joint publication: Preis, A., Gjestland, T. „How to determine the annoyance due to wind turbines” Vibrations in Physical Systems, DOI: 10.21008/j.0860-6897.2022.3.19
D1.3 The relationship between annoyance and wind turbine noise parameters (chosen from tasks 1.2, 2.1, 2.2 and 2.3) - psychoacoustic model (M24)	Uniwersytet im. Adama Mickiewicza / Adam Mickiewicz University	D1.3.zip	Thi deliverable describes the results of two laboratory experiments on the perception of wind turbine noise annoyance.
D1.4 Masking of wind turbine noise by wind induced noise (M24)	Uniwersytet im. Adama Mickiewicza / Adam Mickiewicz University	D1.4.zip	This deliverable describes the potential masking effect of wind on the perception of wind turbine noise.
D1.5 Wind turbine noise – adaptation effect (M27)	Uniwersytet im. Adama Mickiewicza / Adam Mickiewicz University	D1.5.zip	This deliverable describes the potential effect of habituation to wind turbine noise.
D1.6 Proposal for new regulations for wind turbine noise – summary results from WP1 (M30)	Uniwersytet im. Adama Mickiewicza / Adam Mickiewicz University	D1.6.zip	This deliverable describes the proposed limit values for sound levels generated by wind turbines

Milestones [7]						
Number	**Description of milestone**	**Lead entity**	**Planned delivery date (according to project proposal)**	**Achieved (YES/NO)**	**Actual delivery date**	**Comment**
1	Dose-Response function for wind turbine noise	Uniwersytet im. Adama Mickiewicza / Adam Mickiewicz University	31.03.2023	yes	31.03.2023	see below

Description and justification of discrepancies and corrective actions for each WP
If during the reporting period there was a derogation from the contractual provisions (e.g. duration of WP), an explanation should be given: what type of derogation, reasons for the discrepancy, taken or planned corrective actions. (max. 1500 characters with spaces)

The planned milestone was achieved - however, in other manner than it was actually planned, because of several major issues which we encountered during the project. First of all, our sample group is quite small. It was planned to survey around 300 people. However, it was impossible mainly due to the low response rate and no wish of taking part in our project by people living near turbines. Moreover, we did long-term noise monitoring of one wind farm, but the people living nearby did not want to fill in surveys. Another thing is that noise levels we measured were quite limited, without a big span of values. And finally, people who answered our surveys rated wind turbines noise as 7 or higher on ICBEN scale really rarely – thus, the rate of people %HA is very limited.
However, taken into account all our data we have prepared a relation between mean noise annoyance ratings and sound level values. Moreover, this relation - expressed as linear regression model - gives results similar to predictions made in WP2 nad WP7. Thus, we can assume that our results are reliable and can be a basis for further investigation of proposed noise limits values. As this result is in line with our goal - to put a 'noise threshold' around 4 on ICBEN scale - we can tell that the milestone was achieved.

C1-2. Work Package title and number [3]	Monitoring of environment - methodology of wind turbine noise measurement - Nr zadania / WP No. 2			
Start date	planned [4]	01.04.2021	actual	01.04.2021
End date	planned	31.03.2024	actual	31.03.2024
Cost of WP (PLN)	planned	1 063 194.68	actual (value at the end of the reporting period)	851 077.15
Implementing entities	UAM / AMU, Akustix, Akademia Górniczo-Hutnicza im. Stanisława Staszica, SINTEF, Główny Instytut Górnictwa - Państwowy Instytut Badawczy, Polskie Stowarzyszenie Energetyki Wiatrowej			

An explanation of the work carried out by the implementing entities (max. 2500 characters with spaces)

The main aim of WP2 was to prepare methodology for wind turbines noise measurement. Actually, in Poland wind turbines farm, from the viewpoint of type of noise sources are treated like other noise sources. It means that to measure noise from wind turbines farm we have to use methodology which not allowed to measure when the wind speed is higher than 5 m/s, 4-meter above the ground. In this condition wind turbines work in low efficiency and noise from them are not exist. On the other hand, measuring in higher wind speed require solution to counteract wind noise on microphone windshields. During the project, a measurement method was developed which solves these problems. Method of measurement is very simple and possible to use by every accredited measurement laboratory in Poland. Proposed methodology give opportunity to measure the noise for worst situation by measurement in almost all meteorological conditions during few hours. Determining the noise level for the least favourable conditions is necessary because, in accordance with Polish noise protection regulations, permissible noise levels must be met for every day of the year. To determine the noise level for the least favourable conditions based on short measurements in all conditions is possible by appropriate corrections which were determined and should be added to the measured values. The corrections were determined based on short- and long-term measurements carried out as part of the project. First correction is associated with sound power level and its increasing when wind turbines in farm doesn't work on full efficiency. Second one concerns the relationship between the direction of sound propagation and the direction of the wind. As part of the work, research was also carried out to answer the question of how to take into account the influence of the acoustic background in the measurement results. Due to, among other things, the appropriate determination of the acoustic background level, the proposed method of measuring wind turbine noise has two measurement variants - with and without the participation of the wind farm manager.

An overview of the progress of work towards the objectives of the project, including achievements, milestones and deliverables identified in the project contract No more than 12 000 characters with spaces for each WP implemented in the reporting period: a description of the results achieved during the reporting period, activities carried out during the reporting period.

At first, during it was carried out a literature review about some measurement methods for wind turbines noise. Knowledge about various ways of measuring wind turbine noise allowed us to later verify the method prepared as part of this project. Finally, the Danish methodology of measurement was used to verify our measurement method.

In order to develop a simple but accurate measurement method measurements in few wind farms was carried out in different receiving points on 3 different heights (0, 1.5 and 4 meters). Some measurements were long-term measurements. Also, sound power level of wind turbines on these farms was measured. Analysis of the results showed that:

- the best height of the receiving point from the point of view of distance from the background and further use of the results is 1.5 meter above the ground. It also correlates with height of the average observer

· sound level varies depending on the angle between the line connecting the wind turbine to the measurement point and the wind direction. This means that if we want to assess the greatest impact of a wind farm based on the measurement in any situation, the result should be corrected. For this reason, corrections related to wind direction were proposed.

· sound levels depend on the sound power level of wind turbine. Sound power level correlates with the wind speed. If we want adjust measurement results to the worst case, in situations where noise measurements were performed in moderate wind speed some corrections should be added to results. Two methods of correction these results were prepared.

· if we want to properly correct the measurement results for the influence of the acoustic background, we should turn off wind farm partially or totally. In some situations, it is possible not to do it but this may affect the final result.

In addition to field research, tests were carried out about best solution to minimize noise induced by wind on microphone windshield. Recommendation in our methodology is that during wind turbine noise we should use bigger than classical (60 mm) windshields.

The work also described what type of equipment should be used when measuring wind turbines. The proposed choice was dictated by the fact that most laboratories that may be potential users of the wind turbine noise measurement method have such equipment. This means that the proposed method will be as quick as possible to be implemented by this type of entities.

Deliverables [6]
For deliverables that are not in writing (e.g. prototype), the PP must submit a short written description.

Deliverable name	Lead entity	**Deliverable file** (Maximum one file per deliverable, in case of several files, please create a zip and upload that zip)	Comment
D 2.1 Complete methodology of wind turbines' noise measurement which allow to measure both short- and long-term noise indices and their uncertainty, ready to be implemented into state regulation on environmental noise monitoring (M32)	Akustix Sp. z o. o. / Akustix Ltd.	D2.1 (2).docx	--

Milestones [7]

Number	Description of milestone	Lead entity	Planned delivery date (according to project proposal)	Achieved (YES/NO)	Actual delivery date	Comment
1	Description of a new methodology of measurement of the wind turbine noise, which will include specifics of this source. Thanks to that, this methodology will outperform already existing commonly used procedures.	Akustix Sp. z o. o. / Akustix Ltd.	30.11.2023	yes	30.11.2023	--

Description and justification of discrepancies and corrective actions for each WP
If during the reporting period there was a derogation from the contractual provisions (e.g. duration of WP), an explanation should be given: what type of derogation, reasons for the discrepancy, taken or planned corrective actions. (max. 1500 characters with spaces)

not applicable

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C1-3. Work Package title and number [3]	Managing infrasound wind turbine noise - Nr zadania / WP No. 3			
Start date	planned [4]	01.04.2021	actual	01.04.2021
End date	planned	31.03.2024	actual	31.03.2024
Cost of WP (PLN)	planned	654 051.14	actual (value at the end of the reporting period)	587 166.80
Implementing entities	Akademia Górniczo-Hutnicza im. Stanisława Staszica, Główny Instytut Górnictwa - Państwowy Instytut Badawczy, Instytut Medycyny Pracy im. prof. Jerzego Nofera, Polskie Stowarzyszenie Energetyki Wiatrowej			
An explanation of the work carried out by the implementing entities (max. 2500 characters with spaces)				

This WP aimed to develop a comprehensive methodology for assessing the influence of infrasounds generated by wind turbines on human health. This includes determining indicators used in assessing the WTN annoyance, their acceptable values, and methods of measurement and prediction. To gather the necessary data, a measurement site was constructed to research the impact of infrasounds on people. The methodology was designed to be relatively simple, making it accessible to administrative bodies of environmental protection, installation managers, and local communities, enabling them to determine and control the impact of wind turbines on the environment.

During the project, an infrasound measurement method was developed and designed to be as simple as possible for widespread use. This method was verified and refined based on field measurements taken at typical realistic locations and situations. All necessary aspects, such as the influence of other unwanted factors and wind, were carefully analyzed, and an appropriate measurement procedure was developed with guidelines on how to conduct it properly.

Measurement on a board with a secondary wind screen, as in the EN 61400-11 standard, was assumed as the basic protection against wind interference.

Additionally, experiments on the influence of infrasounds on human were conducted using results from in-situ measurements near wind farms. These experiments enabled the verification of the proposed infrasound rating indicators and the establishment of their acceptable values.

A calculation (prediction) method, designed to be as straightforward as possible for widespread use, was also determined. The proposed method was validated based on field measurements similar to those conducted during the in-situ verification. This calculation method involved determining the necessary input parameters and how to estimate/compute them, as well as addressing all aspects related to low-frequency propagation mechanisms and the perception of infrasounds by people.

An overview of the progress of work towards the objectives of the project, including achievements, milestones and deliverables identified in the project contract No more than 12 000 characters with spaces for each WP implemented in the reporting period: a description of the results achieved during the reporting period, activities carried out during the reporting period.

Deliverable 3.1: Complete review of the existing methods and models of infrasounds’ measurement and impact on human health

A literature review was carried out concerning noise sources in wind turbines (particularly regarding the generation of infrasound and low frequency noise), measurement and assessments of infrasound and low frequency, infrasounds’ impact on human health, and modeling infrasound sources.

Deliverable 3.2: The proposal of methodology for infrasounds’ measurements and recording and Milestone 1: Methodology for infrasounds’ measurements

Instrumentation for infrasounds’ measurements of wind turbines is specified. Specifications of equipment for acoustic measurements, including the windshields under consideration, are presented. In addition, requirements for non-acoustic instruments, such as weather measurement equipment, are specified. Acoustic and non-acoustic measurement procedures are described.

Measurement validation of the proposed method was conducted. Based on the measurement results, it can be concluded that the best of the tested variants, in terms of measuring noise from wind turbines in the low-frequency range, is the microphone's position on a board following IEC 61400-11. Thus, using different windshields for the audio and infrasound bands in acoustic measurements of wind turbines is unnecessary. In both cases, measurement on a board with a double windshield works well.

Deliverable 3.3: The proposal of infrasounds' indices used for rating their impact on people

The extra-auditory perception of low-frequency noise or the presence of other (secondary) factors can have an additional impact on its global perception. The problem, however, is the lack of legal regulations in Poland and many other countries regarding the assessment of the noise annoyance of wind turbines. This does not mean, however, that the noise annoyance of wind turbines is not recognized, only that there is a lack of convincing research results. As the part of this task, a review of currently used indicators of infrasound and low-frequency noise was carried out, as well as an experimental verification of the usefulness of selected low-frequency indices.

The measurement results obtained confirm the results reported by many other researchers, namely that wind turbine noise in the infrasound range is well below the hearing threshold curve.

With regard to LFN, it was finally decided that limit values would only be set for infrasound. The higher frequency range of LFN (from 20 Hz to 250 Hz) is covered by A-weighted measurements. For infrasound, the G-weighted equivalent continuous SPL (LGeq,T) has been chosen as the basis for assessing environmental exposure. Short-term (LGeq,D and LGeq,N) and long-term (LDWN(G) and L N(G)) indices have also been proposed. In order to avoid annoyance and other possible harmful effects due to exposure to infrasound regardless of land use, 90 dB was chosen as an acceptable value for LGeq,Dand LDWN(G), and 85 dB for LGeq,N and LN(G)as an acceptable value for the LGeq,D and LDWN(G)levels while 85 dB was adopted for the LGeq,N and LN(G) levels.

Milestone 2: Measure of infrasounds’ impact on people

This study investigated the psychological and physiological effects of wind turbines' infrasound and low-frequency noise (LFN) on human well-being. It involved 129 students and 14 young men exposed to different acoustic conditions, including background noise, synthesized LFN, and wind turbine infrasound. Pre-experiment surveys assessed well-being, mental health, noise sensitivity, and stress levels, while participants performed computerized psychological tests and had their heart rate variability (HRV) monitored.

The results showed no significant differences in test outcomes or HRV parameters across exposure conditions. However, correlations were found between HRV parameters, mental health assessments, and sound levels and performance on specific psychological tests. Perceived annoyance from infrasound did not differ significantly from background noise, but individual baseline conditions influenced post-exposure complaints. The study concludes that while infrasound and LFN do not directly impact cognitive functions or HRV, individual sensitivities and pre-existing conditions are crucial in perceived well-being.

Deliverable 3.4: The comprehensive calculation method, based on results from all tasks of this WP

The performance of three common sound propagation models (ISO 9613-2, CNOSSOS-EU for favourable propagation conditions, Nord2000) in predicting infrasound and low-frequency noise (LFN) generated by wind turbines was tested. The reliability of these models in modelling LFN is generally not validated or guaranteed. The analysis covers octave frequency bands from 4 Hz to 250 Hz and comparisons are made with measurements taken at a wind farm in Poland. Non-parametric statistical tests with a significance level of $\alpha = 0.05$ were used to identify significant differences between measured and predicted results. The findings indicate that the Nord2000 method provides accurate calculations, while the ISO 9613-2 method can be used for simplified assessment of LFN generated by wind turbines during the investment preparation phase.

Milestone 3: The possibly simple method of calculation infrasounds’ noise indices

For the prediction of wind turbine noise emissions in the low-frequency noise range including infrasound, the same calculation methods are used as for the audible noise range. These methods are:

• ISO 9613-2 method - used as a simplified method,

• Nord2000 method - used as a precision method.

The calculation methods proposed for predicting sound levels are divided into a less accurate method (simplified method) and a more accurate method (precision method).

The precision method is appropriate when complete information about the meteorological conditions (roughness length, relative humidity, air pressure, temperature, temperature gradient, standard deviation of temperature gradient, structure parameter of turbulent temperature fluctuations, wind speed and direction, standard deviation of wind speed, structure parameter of turbulent wind speed fluctuations, anemometer height) in the sound propagation path is available. Conversely, the simplified method should be used in the absence of such detailed data.

The construction of the geometric-acoustic model used to predict low-frequency noise, including infrasound, should be analogous to the construction of the model for environmental noise in the audible range.

It must account for all relevant elements affecting noise propagation, such as the terrain model’s accuracy, the location of the receptor, obstacles in the propagation path, tall vegetation, and other pertinent elements.

To predict low-frequency noise, including infrasound, it is necessary to input the sound power level of the source in the frequency range from 1 Hz to

250 Hz.

The sound power level spectrum in 1/3 octave frequency bands is the optimal input for such calculations. If such detailed data are unavailable, the source's sound power level spectrum in the 1/1 octave frequency bands can be used instead.

For the prediction of wind turbine noise in the low-frequency noise range including infrasound, the atmospheric sound attenuation coefficients for each frequency band should be calculated using the equation given in ISO 9613-1.

The standardised values for atmospheric sound attenuation coefficients given in ISO 9613-1 should not be used, as the data presented in this standard are standardised for frequency bands of 50 Hz and above, air temperature at 5°C intervals and relative humidity at 5% and 10% intervals.

Deliverables [6]
For deliverables that are not in writing (e.g. prototype), the PP must submit a short written description.

Deliverable name	**Lead entity**	**Deliverable file** (Maximum one file per deliverable, in case of several files, please create a zip and upload that zip)	**Comment**
D3.1 Complete review of the existing methods and models of infrasounds' measurement and impact on human health (M6).	Akademia Górniczo-Hutnicza im. Stanisława Staszica / AGH University of Science	Deliverable 3_1_ENG.pdf	Deliverable 3_1_ENG ;
D3.2 The proposal of methodology for infrasounds' measurements and recording (M12)	Akademia Górniczo-Hutnicza im. Stanisława Staszica / AGH University of Science	Deliverable 3_2 ver2(final)_ENG.pdf	Deliverable 3_2 ver2(final)_ENG ;
D3.4 The comprehensive calculation method, based on results from all tasks of this WP (M33)	Akademia Górniczo-Hutnicza im. Stanisława Staszica / AGH University of Science	Deliverable 3_4_ENG.pdf	Deliverable 3_4_ENG ;
D3.3. The proposal of infrasounds' indices used for rating their impact on people	Akademia Górniczo-Hutnicza im. Stanisława Staszica / AGH University of Science	Deliverable 3_3_ENG.pdf	Deliverable 3_3_ENG ;

Milestones [7]

Number	**Description of milestone**	**Lead entity**	**Planned delivery date (according to project proposal)**	**Achieved (YES/NO)**	**Actual delivery date**	**Comment**
1	Methodology for infrasounds' measurements	Akademia Górniczo-Hutnicza im. Stanisława Staszica / AGH University of Science	31.03.2022	yes	31.03.2022	--
2	Measure of infrasounds' impact on people	Akademia Górniczo-Hutnicza im. Stanisława Staszica / AGH University of Science	31.10.2023	yes	31.10.2023	--

3	The possibly simple method of calculation infrasounds' noise indices	Akademia Górniczo-Hutnicza im. Stanisława Staszica / AGH University of Science	31.12.2023	yes	31.03.2024	--

Description and justification of discrepancies and corrective actions for each WP If during the reporting period there was a derogation from the contractual provisions (e.g. duration of WP), an explanation should be given: what type of derogation, reasons for the discrepancy, taken or planned corrective actions. (max. 1500 characters with spaces)
not applicable

C1-4. Work Package title and number [3]	Method of wind turbine noise prediction - Nr zadania / WP No. 4			
Start date	planned [4]	01.04.2021	actual	01.04.2021
End date	planned	31.01.2024	actual	31.01.2024
Cost of WP (PLN)	planned	478 613.11	actual (value at the end of the reporting period)	415 363.55
Implementing entities	Akustix, Akademia Górniczo-Hutnicza im. Stanisława Staszica, SINTEF, Polskie Stowarzyszenie Energetyki Wiatrowej			
An explanation of the work carried out by the implementing entities (max. 2500 characters with spaces)				

Several software packages for calculation of outdoor environmental noise are commercially available. However, the calculation module for the sound propagation has typically been developed for source and receiver locations close to the ground, and hence sound propagation also close to the ground. Wind turbines, and especially the new ones in megawatt-size, have their noise sources located high above the ground, typically 100-150 meters. The sound propagation in the vicinity of the turbine is therefore only to a small degree affected by ground properties.

Most software packages for calculation of environmental noise assume ground effects to be prominent for the entire propagation path. This is obviously not the case for wind turbines. An important task in the HETMAN WP 4 was therefore to study the applicability of different propagation modules.

Detailed noise measurements were carried out around several operating wind turbines. Microphones were positioned in four main directions relative to the turbine: upwind ("in front of"), downwind ("behind"), and crosswind ("to the sides parallel to the rotor plane"). The measurement distance was chosen between 150 m and 1500 m, and in each position the microphones were located at three heights: 4 meters, 1,5 meters and one flush to the ground.

The sound from the wind turbine was recorded simultaneously in all these locations. Meteorological conditions were also monitored. The recordings were edited to produce periods of ten to twenty minutes with good signal-to-noise conditions and stable wind speed (stable sound source).

Three candidate calculation methods were selected, one based on the ISO 9613-2 propagation, one based on the EU-favored Cnossos-EU method, and one based on the NORD 2000 propagation algorithms. Sound calculations were conducted using all three methods for all measurement positions and using the meteorological data from measurement campaign. The result was a set of noise predictions (equivalent level for the relevant time period) that could be compared with actual noise measurements. Our conclusion was that the NORD 2000 method gave results that matched the measurement results most closely.

The procedure was reported in a separate paper presented. at Inter-Noise 2023 in Chiba, Japan.

An overview of the progress of work towards the objectives of the project, including achievements, milestones and deliverables identified in the project contract No more than 12 000 characters with spaces for each WP implemented in the reporting period: a description of the results achieved during the reporting period, activities carried out during the reporting period.

This work package is dedicated to the prediction of wind turbine noise. In order to be able to manage WTN in an effective way, it is imperative to have methods for precise noise prediction. The work started by doing a thorough investigation of existing noise prediction programs, and also assessing methods for validating these predictions.

It was determined that the predictions needed to be compared with actual noise measurements. WTN measuring is challenging. Standards for outdoor measurements of environmental noise usually specifies that these must be carried out with little or no wind in order to avoid wind noise generated at the microphone. Recommended maximum wind speed is typically less than a few meters per second. The noise from a wind turbine increases with increasing wind speed up to about 10-12 m/s and the rated noise level is usually specified at certain wind speed. So, the measurements require special techniques to avoid self-generated noise at the microphones.

Different measurement techniques were assessed. The most reliable one was considered to be a microphone mounted on a flat board flush to the ground.

Several measurement campaigns were carried out as part of another work package, and these results were used for comparison with predictions from several existing noise calculation methods. It was concluded that a method based on the NORD 2000 propagation algorithms gave the best over-all results, i.e., the least deviation from the measurements.

Necessary software for noise predictions based on the NORD 2000 method was made available for other partners in the project.

Deliverables [6]
For deliverables that are not in writing (e.g. prototype), the PP must submit a short written description.

Deliverable name	Lead entity	Deliverable file (Maximum one file per deliverable, in case of several files, please create a zip and upload that zip)	Comment
D 4.1 The complete methodology of noise prediction, verified and adapted to wind turbines including specific aspects of generation, propagation and perception, allowing for the determination of both short- and long-term noise indicators, ready to be introduced to state regulation on environmental noise (M30)	Stifelsen SINTEF, P.O.	D4.1.pdf	no
D 4.2 Guidelines for acquisition and assignment of reliable model input data and parameters for a given wind farm (M21)	Stifelsen SINTEF, P.O.	D4.2.pdf	no

Milestones [7]

Number	Description of milestone	Lead entity	Planned delivery date (according to project proposal)	Achieved (YES/NO)	Actual delivery date	Comment
1	Description of a new method of noise prediction in the environment dedicated to wind turbines.	Stifelsen SINTEF, P.O.	30.06.2023	yes	06.12.2022	Revised version: 26.02.2024

Description and justification of discrepancies and corrective actions for each WP If during the reporting period there was a derogation from the contractual provisions (e.g. duration of WP), an explanation should be given: what type of derogation, reasons for the discrepancy, taken or planned corrective actions. (max. 1500 characters with spaces)
not applicable

C1-5. Work Package title and number [3]	Reduction of wind turbines noise - Nr zadania / WP No. 5			
Start date	planned [4]	01.04.2021	actual	01.04.2021
End date	planned	30.04.2024	actual	30.04.2024
Cost of WP (PLN)	planned	393 415.21	actual (value at the end of the reporting period)	317 794.42
Implementing entities	UAM / AMU, Akustix, Akademia Górniczo-Hutnicza im. Stanisława Staszica, Główny Instytut Górnictwa - Państwowy Instytut Badawczy, Polskie Stowarzyszenie Energetyki Wiatrowej			
An explanation of the work carried out by the implementing entities (max. 2500 characters with spaces)				

AMU – During the HETMAN project, WP5 conducted research on "hard" and "soft" methods of noise reduction.

Hard methods are intended for use at the noise source, which is the wind turbine. These methods include solutions that reduce mechanical and aerodynamic noise generated by wind turbines. The aim of using hard noise reduction methods is for the wind farm operator to achieve permissible environmental noise levels without the need to shut down or relocate turbines on the wind farm. The methods described for existing and new wind farms can be applied to the entire farm or individual wind turbines. Only a few organizational solutions require cooperation between turbines to improve acoustic conditions around the farm.

In cases where, despite meeting permissible environmental noise levels, the noise at the immission point is still annoying, WP5 was tasked with proposing at least two "soft" methods aimed at reducing the perception of annoyance. The first method was masking wind turbine noise with another known noise that is less annoying than wind turbine noise. Traffic noise was chosen as the masker. This allows for the placement of turbines along highways, where the noise from moving vehicles can slightly reduce the impact range of wind turbine noise that causes excessive annoyance.

The second "soft" method WP5 examined was the impact of visual factors on the annoyance caused by wind turbine noise. The turbine, along with the generated noise, was presented in a VR environment with scenes showing it partially or completely obscured. Research results indicate a negligible impact of obscuring the noise source on noise annoyance, but it was found that the lack of visibility of the turbine positively affects the overall perception of the environment.

Akustix, AGH, GIG, PSEW – consulting, technical and substantive support.

An overview of the progress of work towards the objectives of the project, including achievements, milestones and deliverables identified in the project contract No more than 12 000 characters with spaces for each WP implemented in the reporting period: a description of the results achieved during the reporting period, activities carried out during the reporting period.

The preparation of the Catalog of wind turbine noise reduction solutions was divided based on the type of methods being developed: "hard" and "soft."

The study of the effectiveness of "hard" methods mainly involved a thorough review of scientific and technical literature, consultations with wind farm managers, manufacturers, and other partners of the HETMAN project. Acoustic measurements were also taken at wind farms, during which recordings of wind turbine noise were made. As a result sufficient data was obtained to create a Catalog that includes all currently used noise reduction methods along with their potential effectiveness.

Two "soft" methods were developed: (1) a method using masking of wind turbine noise with another source, and (2) a method involving the obscuring of the noise source with green objects (trees/bushes) to test the impact of visual factors on the annoyance caused by wind turbine noise.

1. The method of masking wind turbine noise required recording samples of wind turbine noise and masking sounds – from a highway. Wind turbine noise recordings were made during measurements at a wind farm in central Poland. Masking sound recordings were made near the A2 highway near Poznań. Additionally, wind sounds were recorded in a wind tunnel as an extra masking signal. It was essential to obtain sound for airflow with controlled parameters, similar to those present during wind turbine noise measurements.
Using the recorded samples and the Nord2000 methodology to establish the appropriate spectrum and level of sound presentation, psychoacoustic experiments were prepared in the PsychoPy environment, involving several dozen participants. The participants were asked to indicate the distance at which the wind turbine noise amid the masker was as annoying as the masker noise alone. Detection thresholds for annoyance were determined for four masker distances (250, 500, 1000, and 2000 meters). In one experiment, wind recordings were also used as an additional masking factor. Results from 40 participants were analyzed. These findings were presented at the Forum Acousticum 2023 conference in Turin and detailed in Deliverable 5.1.

2. The method of obscuring the noise source to reduce perceived annoyance was tested in a VR environment. VR goggles and an experiment prepared in the Unity game engine were used. Recordings from field measurements were also used for the experiment. The entire experiment was automated and interactive, meaning participants decided when to move to the next stimulus presentation and had unlimited time to rate annoyance on the ICBEN scale. Participants were asked to rate the annoyance of the noise after presentations in an artificially created environment reflecting the field measurement location. The presented turbine was shown at different distances and in three modes of obscuration: none, partial, full. The object obscuring the turbine was trees or bushes placed in the virtual environment. Participants were explicitly instructed to rate the annoyance of the noise caused by the presented turbine. The experiment results were presented at the Winter School of Acoustics and Vibroacoustics 2024 in Szczyrk and detailed in Deliverable 5.1.

Deliverables [6]
For deliverables that are not in writing (e.g. prototype), the PP must submit a short written description.

Deliverable name	**Lead entity**	**Deliverable file** (Maximum one file per deliverable, in case of several files, please create a zip and upload that zip)	**Comment**
D5.1 Catalogue of noise reduction methods either for single turbine or the whole farm. For each method its effectiveness (confirmed empirically) and the conditions of applicability will be provided (M24).	Uniwersytet im. Adama Mickiewicza / Adam Mickiewicz University	D5.1.docx	---

Milestones [7]

Number	**Description of milestone**	**Lead entity**	**Planned delivery date (according to project proposal)**	**Achieved (YES/NO)**	**Actual delivery date**	**Comment**
1	Determination of the real effectiveness of each noise reduction method.	Uniwersytet im. Adama Mickiewicza / Adam Mickiewicz University	31.12.2022	yes	31.12.2022	--
2	Procedures implementing complex noise reduction methods for controlling either emission (close to the source) or immission (at living areas)	Uniwersytet im. Adama Mickiewicza / Adam Mickiewicz University	30.11.2023	yes	30.04.2024	--

Description and justification of discrepancies and corrective actions for each WP If during the reporting period there was a derogation from the contractual provisions (e.g. duration of WP), an explanation should be given: what type of derogation, reasons for the discrepancy, taken or planned corrective actions. (max. 1500 characters with spaces)
Regarding hard methods, after a thorough literature review and consultations with other partners of the HETMAN project, it has been concluded that it is not possible to definitively determine the effectiveness of wind turbine noise reduction methods. The reasons are: - Hard noise reduction methods used on existing and new farms are specific to each Manufacturer of its devices. Their effectiveness is determined by each Manufacturer for their own use. - Presenting the effectiveness of noise reduction solutions from different Manufacturers would expose the HETMAN project to abandoning an objective stance and avoiding favoritism towards any particular Manufacturer. Solutions with the highest effectiveness would point to a specific manufacturer as better compared to its competitors. - Due to the rapid development of technology, the data provided in the Catalog could quickly become outdated. By providing a general overview of available technologies, the Catalog remains a useful tool for longer period. Scientific literature dedicated to noise reduction solutions often focuses on experimental solutions or those that, due to high implementation costs, will never become widely used. - Empirical effectiveness assessment requires the presence of specific solutions in the examined devices. During conducted field measurements no implemented methods were available that could've been studied.

C1-6. Work Package title and number [3]	Managing wind turbines noise - practical implementation of project's results - Nr zadania / WP No. 6			
Start date	planned [4]	01.04.2021	actual	01.04.2021
End date	planned	31.03.2024	actual	31.03.2024
Cost of WP (PLN)	planned	816 898.16	actual (value at the end of the reporting period)	771 278.01
Implementing entities	Akustix, Akademia Górniczo-Hutnicza im. Stanisława Staszica, Polskie Stowarzyszenie Energetyki Wiatrowej			
An explanation of the work carried out by the implementing entities (max. 2500 characters with spaces)				

Task 1: The concept and prototype research of the low-cost wind farm noise measurement system

Within this period an excessive laboratory and field tests of the noise monitoring stations prototype were carried out. During the tests a large number of optimalizations to the software mainly were introduced in order to improve DSP algorithms stability and performance (i.e. minimalization od an CPU load), improve equalizations filters etc.

Also, the monitoring stations management algorithms and communication algorithms were tested and improved. A microphone calibration option with calibration factors stored on the server was added. The software was also developed and improved at the server site.

During this period also a long-term stability in a real environment was tested giving very good results. Also, the parallel long-term measurements with class I Norsonic NOR145 sound analysers placed side by side in the same location were made. The differences were within the measurement uncertainty.

Task 2: The SCADA module - wind farm noise optimizing / management software

The concept of module was prepared and presented to the Hetman Project partners during team meeting in December 2022. The final concept takes into account the conclusions from the discussions and the results of WP1, WP2 and WP4.

Practical implementation of the wind farm operation optimization algorithm was carried out using input data in the form of archived data (long-term noise monitoring - WP2). Many verification tests of the algorithm's operation were also performed using artificial data simulating potential and specific boundary conditions. The ready algorithm was implemented on a wind farm consisting of six turbines and several noise sensitive areas.

The system's operation period lasting many months allowed for the collection of a large database enabling verification and successive introduction of several minor corrections regarding the decision criteria used in the algorithm.

The final prototype of the algorithm is in the form of a code prepared for compilation, taking into account the data exchange format between the SCADA system used by individual wind farm operators (the data format depends on the wind turbine model and the specific topology and security features of the system at given farm) as well as functional parameters including the number of turbines, the number of protected areas, installed receptors or weather forecast sources).

An overview of the progress of work towards the objectives of the project, including achievements, milestones and deliverables identified in the project contract No more than 12 000 characters with spaces for each WP implemented in the reporting period: a description of the results achieved during the reporting period, activities carried out during the reporting period.

TASK 1:

The prototype of low-cost noise measurement system was designed, constructed and tested. In principle, it was not intended to build another accurate class 1 measuring devices but cheaper alternative enabling the assessment the scale of wind farm noise exposure. Considering the low cost of a single noise monitoring station a relatively large monitoring grid can be built around the wind farm. The trade-off between small number of expensive class I monitoring stations and a large number of a little bit less accurate low-cost monitoring units gives an significant improvement in the numerical noise prediction model calibration and in the result calculated noise contours around the wind farm can be calculated with higher accuracy.

The prototype fulfils with the requirements of class 2 sound level meter (according to EN 61672-1:2013 standard: Electroacoustics - Sound level meters - Part 1: Specifications) and even exceeds it. The system is equipped with all-weather ½” microphone kit which is based on MEMS transducer with built -in digital output interface. Whole signal path starting from microphone capsule is in digital domain. The noise floor of the system is 22 dBA, and linear operation range starts from 27 dBA (if class II requirement are concerned) or 28 dBA (if class I requirements are concerned). The system can function as a low-cost wind farm noise monitoring solution affordable to everybody concerned about noise levels, as well as for local or control authorities, e.g. as a preliminary measurement before accurate but more expensive analysis (since the developed monitoring station is not type – approved it cannot be used in the legally regulated area in Poland) and also as the wind farm noise management system – with the same electro-acoustic capabilities. The cost-reducing factors are mainly concerned with limited functionally – not with acoustic performance.

The weather conditions are measured by integrated device with ultrasonic wind speed and direction sensor and temperature / humidity sensors. The core of the system is Raspberry Pi Zero platform single board computer (SBC). It has implemented all the digital signal processing path to serve as a regular sound level meter (SLM) or a 1/3 oct band frequency analyser. The detailed description of the functional characteristic is presented in Deliverable D6.1.

The main functionalities of the developed monitoring system are:

• noise floor 22 dBA

• LAeq linearity range from 27 dBA (according to accuracy grade II defined in EN 61672-1:2013)

• 130 mm wind shield for low wind noise induction

• frequency range covering whole audible range (20 Hz to 20 kHz)

• frequency characteristics meeting class II accuracy grade according to EN 61672-1:2013

• measured acoustic parameters: LAeq,T, LZeq,T, LAmax,F with time history logging step 50 ms

• 1/3 oct band filters meeting class I specification as defined in EN 61260-1:2015

• time history of 1/3 oct frequency spectra (optional feature for wind farm management version)

• measurement of meteorological conditions parameters (wind speed, wind direction, temperature, relative humidity and rainfall) with 30 s logging interval (optional feature for wind farm management version)

• wireless communication – WiFi

• 8 GB of memory on a microSD card (over three months of continuous data logging without network access)

• wireless communication GSN (LTE) – as an option – mainly for wind farm noise management version

• 230V switching power supply (wall socket version) with the 12V DC 1A output – the basic option for individual use

• 230V switching buffering power supply with 12V 15Ah AGM battery with the 12V DC output (optional - version for wind farm noise management purposes)

• SOLAR buffering power supply with 12V 18Ah AGM battery and 100W solar panel with the 12V DC output (optional - version for wind farm noise management purposes

• Linux server with influxDB database for measurement data storage

• measurement data visualization and access based on Grafana tool.

• secure wireless communication and on-line access using ZeroTier VPN solution.

TASK 2:

The aim of this task was to develop a concept and to build prototype system to support the wind farm management with regard to its noise impact. The main idea is to ensure that the operation of the wind farm does not cause noise complaints in residential areas and that, on the other hand, the energy production is as high as possible. Due to the availability of land for wind farms it is also a matter of being able to locate the turbines as close as possible to noise protected areas. Under certain meteorological conditions, individual turbines must be switched off or have to operate in a reduced noise emission mode. This does not apply to all turbines on the wind farm at the same time, as the noise contours around a single wind turbine are not symmetrical. It is due to weather induced refraction of sound waves as well as horizontal noise directivity of the source. In consequence, it results in a dependence of the instantaneous noise levels around the farm on the current wind direction. In addition, there are also situations where, although the noise from the turbines is high, it is not necessarily annoying, due to the masking effect.

To take this into account, it is necessary to know the actual noise level around the wind farm which has two main components the turbines and the background noise. To obtain these data, a multi-point continuous noise monitoring system around the wind farm was built (task 1). The system provides data continuously which combined with noise calculation model fed with instantaneous real-time wind turbine operating parameters as well as weather data. Noise level in the selected direction may be reduced by a few decibels by switching turbines off or switching them into noise reduced mode. Using on-line calibrated noise calculation model this restriction has to be applied only to the selected turbines and only for the selected time period. This active noise management means that turbines can be located closer to noise sensitive areas at the price of temporary energy production restrictions.

The final prototype of the algorithm of wind farm noise optimizing / management software (SCADA module) was designed, developed and tested. The detailed description of the functional characteristic is presented in Deliverable D6.2.

Deliverables [6]
For deliverables that are not in writing (e.g. prototype), the PP must submit a short written description.

Deliverable name	**Lead entity**	**Deliverable file** (Maximum one file per deliverable, in case of several files, please create a zip and upload that zip)	**Comment**
D6.1 Concept and results of prototype research of low-cost wind farms continuous noise controlling system (M24)	Akustix Sp. z o. o. / Akustix Ltd.	D6.1.docx	--

D6.2 Concept and results of prototype research on SCADA module supporting the management of wind farm involving instantaneous noise emission and propagation conditions to keep immission levels (at living areas) below limits (M36)	Akustix Sp. z o. o. / Akustix Ltd.	D6.2.docx	--

Milestones [7]

Number	Description of milestone	Lead entity	Planned delivery date (according to project proposal)	Achieved (YES/NO)	Actual delivery date	Comment
1	Prototype research of the low-cost system of continuous and on-line wind farms noise control	Akustix Sp. z o. o. / Akustix Ltd.	31.03.2023	yes	31.03.2023	--
2	Prototype research of the SCADA module – support for the wind farm management taking into consideration the criterion of the acceptable noise emission and immission levels	Akustix Sp. z o. o. / Akustix Ltd.	31.03.2024	yes	31.03.2024	--

Description and justification of discrepancies and corrective actions for each WP If during the reporting period there was a derogation from the contractual provisions (e.g. duration of WP), an explanation should be given: what type of derogation, reasons for the discrepancy, taken or planned corrective actions. (max. 1500 characters with spaces)
not applicable

C1-7. Work Package title and number [3]	New state regulations and guidance on wind turbines noise management - Nr zadania / WP No. 7			
Start date	planned [4]	01.08.2021	actual	02.08.2021
End date	planned	30.04.2024	actual	30.04.2024
Cost of WP (PLN)	planned	702 842.59	actual (value at the end of the reporting period)	576 045.47
Implementing entities	UAM / AMU, Akustix, Instytut Ochrony Środowiska – Państwowy Instytut Badawczy, Główny Instytut Górnictwa - Państwowy Instytut Badawczy, Instytut Medycyny Pracy im. prof. Jerzego Nofera, Polskie Stowarzyszenie Energetyki Wiatrowej			
An explanation of the work carried out by the implementing entities (max. 2500 characters with spaces)				

Task 7.1 - Dedicated project website was done. It is available on the project website: https://hetmanwind.ios.edu.pl- task completed, the goal has been achieved. Task 7.2 - Basic knowledge and practical aspects collected in the form of a "good practice guide". It contains knowledge covering all aspects of noise management in wind farms- task completed, the goal has been achieved. Task 7.3 - The project results were discussed and assessed by all interested parties during the WINTER SCHOOL workshops on Environmental Acoustics and Vibroacoustics (organized once a year) on February 26 - March 1, 2024, Szczyrk. A number of comments from the winter school participants were discussed and incorporated into the guide and

proposed legal acts. - task completed, the goal has been achieved. Task 7.4 - The results of WP1 and WP3 were used by IOS (with the support of other partners) to prepare a legal act on the permissible noise and infrasound values for wind turbine noise, using the noise indicators selected in the above-mentioned- task completed, the goal has been achieved. Task 7.5 - IOŚ, based on information from partners, including WP1 and WP3, prepared proposals for changes to legal acts regarding noise monitoring, by performing noise measurements in the environment, including determining short- and long-term noise indicators. The document summarizing the project includes a proposal for national reference methods for assessing the acoustic climate in the environment originating from wind turbines, including methods- task completed, the goal has been achieved. Task 7.6 - Results of WP4 were used by IOS to prepare the legal act on noise prediction, which could be a part of the legal act on noise monitoring- task completed, the goal has been achieved.

An overview of the progress of work towards the objectives of the project, including achievements, milestones and deliverables identified in the project contract No more than 12 000 characters with spaces for each WP implemented in the reporting period: a description of the results achieved during the reporting period, activities carried out during the reporting period.

Task 7.1 - Dedicated project website addressed to a wide audience, including administrative authorities, environmental consulting companies, wind farm managers, local communities, etc. The website presents current results and milestones achieved throughout the project, starting from the current state of knowledge (as a result of each Task 1 in WP1 - WP 5). Task 1 - updated during the project. The website contains current information from the Consortium Leader - task completed, the goal has been achieved. Task 7.2 - Basic knowledge and practical aspects collected in the form of a "good practice guide". It contains knowledge covering all aspects of noise management in wind farms- task completed, the goal has been achieved. It presents issues related to the basics of acoustics and psychoacoustics in connection with the introduction of proposed changes in the low frequency range. Methods are presented, proposals for calculation and measurement methods in relation to noise, including low-frequency and infrasonic noise. Based on the results from WP1 to WP6, the following were presented: noise indicators and their limit values, monitoring, forecasting and reduction methods. A standard set of procedures was presented as a 12 K2 - Informacja wewnętrzna (Internal) recommendation for its use by state environmental protection authorities, unifying administrative procedures regarding noise generated by wind farms on a national scale. Task 2 – prepared on the basis of WP 1 – WP 5 A guide whose main goal was to create the basis, methods and tools for reliable assessment, control and management of noise produced by wind farms, taking into account the principle of sustainable development. The basic thematic area concerns health protection and noise-sensitive areas, without unjustifiably limiting the development of wind farms.

The document summarizing the project includes a proposal for national reference methods for assessing the acoustic climate in the environment originating from wind turbines, including methods for in-situ noise measurement, its forecasting at the investment preparation stage, and the assessment of noise associated with the operation of turbines. The project participants were: • UAM-Leader responsible for issues related to shaping the acoustic climate around wind turbines and health indicators; • SINTEF AS; Akustix Sp. z o. o. -responsible partners, among others: for developing the methodology for measuring noise from wind turbines, proposals for noise assessment indicators and permissible levels, and methods for forecasting wind turbine noise; • AGH responsible, among others, for developing the methodology for measuring and calculating lowfrequency noise, including infrasonic noise; • IMP - partner responsible for, among others: for developing proposals for indicators for assessing lowfrequency noise, including infrasound, in the environment; • IOS - partner responsible for, among others, for developing, collecting information from individual partners, presenting draft legal acts containing reference methodologies for measuring noise from wind turbines, including a separate method for low-frequency noise and the administrative procedure in the investment planning and implementation process; • GIG - supporting partner; • PSEW - partner responsible for, among others, for co-developing the administrative procedure in the investment planning and implementation process. Task 7.3 - The project results were discussed and assessed by all interested parties during the WINTER SCHOOL workshops on Environmental Acoustics and Vibroacoustics (organized once a year) on February 26 - March 1, 2024, Szczyrk. A number of comments from the winter school participants were discussed and incorporated into the guide and proposed legal acts. - task completed, the goal has been achieved. Task 7.4 - The results of WP1 and WP3 were used by IOS (with the support of other partners) to prepare a legal act on the permissible noise and infrasound values for wind turbine noise, using the noise indicators selected in the above-mentioned. Packages. Based on information from partners, including WP1 and WP3, IEP prepared proposals for changes to legal acts on the permissible noise and infrasound values for wind turbine noise, using the noise indicators selected in the above-mentioned. packages, i.e. short- and long-term noise indicators - task completed, the goal has been achieved. Task 7.5 - IOŚ, based on information from partners, including WP1 and WP3, prepared proposals for changes to legal acts regarding noise monitoring, by performing noise measurements in the environment, including determining short- and long-term noise indicators. The document summarizing the project includes a proposal for national reference methods for assessing the acoustic climate in the environment originating from wind turbines, including methods- task completed, the goal has been achieved. Task 7.6 - Results of WP4 were used by IOS to prepare the legal act on noise prediction, which could be a part

Deliverables [6]
For deliverables that are not in writing (e.g. prototype), the PP must submit a short written description.

Deliverable name	Lead entity	**Deliverable file** (Maximum one file per deliverable, in case of several files, please create a zip and upload that zip)	Comment
D7.1 Project's website as a widely available database of knowledge (M5)	Instytut Ochrony Środowiska – Państwowy Instytut Badawczy / Institute of Environmental Protect	D7.1.Website.docx	**- task completed.** It is available on the project website: https://hetman-wind.ios.edu.pl**-**
D 7.2 New guidelines on wind turbine noise management (M36)	Instytut Ochrony Środowiska – Państwowy Instytut Badawczy / Institute of Environmental Protect	D7.2-2.GuideEN_v3.zip	**- task completed.**
D 7.3 Legal regulations regarding wind turbine noise (M35)	Instytut Ochrony Środowiska – Państwowy Instytut Badawczy / Institute of Environmental Protect	D7.3-2.Legal_regulationEN.zip	**- task completed.**

Milestones [7]

Number	Description of milestone	Lead entity	Planned delivery date (according to project proposal)	Achieved (YES/NO)	Actual delivery date	Comment
1	Activation of the website devoted to the project	Instytut Ochrony Środowiska – Państwowy Instytut Badawczy / Institute of Environmental Protect	31.08.2021	yes	31.08.2021	--
2	Presentation of the new state regulations on noise: limits, measurements and calculations	Instytut Ochrony Środowiska – Państwowy Instytut Badawczy / Institute of Environmental Protect	29.02.2024	yes	29.02.2024	Digital version
3	Publication of good practice guide on wind turbines noise management	Instytut Ochrony Środowiska – Państwowy Instytut Badawczy / Institute of Environmental Protect	31.03.2024	yes	30.04.2024	Digital version

Description and justification of discrepancies and corrective actions for each WP If during the reporting period there was a derogation from the contractual provisions (e.g. duration of WP), an explanation should be given: what type of derogation, reasons for the discrepancy, taken or planned corrective actions. (max. 1500 characters with spaces)
not applicable

C2. AN OVERVIEW OF THE RESULTS AND THEIR EXPLOITATION AND DISSEMINATION
A short summary (max. 3000 characters with spaces) of the project results for all WPs with putting the results into context, describing the impact of the projects

All project working packages cover different aspect of wind turbine noise and putting them together we get an overall picture of the topic, with more details than was known before. We conducted several laboratory experiments and in situ survey research. Based on them we could establish the relation between noise annoyance ratings and sound level values (WP1). These results were found to be similar to results of WP2 and WP7 – in which, based on real data from the environment, new methods of noise prediction and new noise limits values were proposed.
We analysed thoroughly the problem of infrasounds generated by turbines and their influence on people's well-being and cognitive activity (WP3). No significant relations were found. We have also used several noise models to predict sound levels of noise generated by wind turbines. After calculation, results were compared with real in field values. Based on these analyses we proposed to use both ISO (in basic research) and NORD2000 (in more sophisticated analysis).
Many methods of decreasing noise and its annoyance were also investigated. We have shown that road traffic noise can be a good masker of wind turbines noise, thus it is recommended to locate turbines near highways or other fast roads (WP5).
A special low-cost noise monitoring station was also constructed and programmed (WP6). This type of device can be used both by wind turbines operators – to monitor noise in the field – and by local communities and authorities – to control the noise situation. The device can be accessed via Internet and show all measurements in real-time to give better view into the nature of noise.
Results of the project were also synthesized and put into one large document – good practice guide – which should be used during all administrative procedures regarding wind turbines noise (WP7). This document is prepared in two language versions: English and Polish. The Polish version is intended for immediate implementation into Polish regulations regarding the management of wind turbines in Poland. It is also a good starting point to rethink how the noise limits for this type of noise should be set in Polish law regulations.
All these findings help to better understand the nature of wind turbines noise and control it in more reliable way. Taking into account interests of all sides – operators, local communities and aims of sustainable development – we can responsibly use wind energy in everyday life.

C3. THE CONCLUSIONS ON THE PROJECT
A short description of the conclusions on the project (max. 3000 characters with spaces) for all WPs

The HETMAN project has provided a better understanding of the subjective aspects of wind turbine noise (WTN).
Limits for acceptable exposure levels to WTN are typically defined in terms of Lden. This quantity is a yearly average which is almost impossible to verify through actual measurements, and in those rare cases where the noise is measured for a whole year, any exceeding of the limits can only be assessed after the year-period has expired. In order to achieve a more practical dynamic noise management it is necessary to define short-term limits, typically for a day or parts of the day. Then the noise can be monitored, and corrective measures may be implemented immediately so that the long-term limits are not exceeded.
Such procedures must also be reflected in the noise prediction programs that are being used. Various predictions programs have been assessed. It is recommended to use a method based on the ISO 9613-2 propagation algorithm for simple calculations and the more elaborate NORD2000 method for complex terrain and special meteorological conditions. This will allow the calculation of noise indices used in current Polish legislation.
The HETMAN project did not provide enough data to establish a specific WTN dose-response curve for Poland. However, none of the results seem to contradict the common dose-response curve suggested by Michaud et al. This curve indicates about 10 % prevalence of high annoyance at Lden 45 dB.
Wind turbine noise has anecdotally been associated with special low-frequency and/or infra sound effects. None of the results from the HETMAN project indicate that it is necessary to take extra low-frequency measures other than what is done for other environmental noise sources in general.
Procedures and instrumentation for in situ measurement of WTN has been developed. This can be combined with software that allows active monitoring and control of the noise from a wind farm. If set limits are exceeded nearby wind turbines will be shut down automatically. A prototype of low-cost noise monitoring station was constructed and there are chances to use it more widely in the future.
Several experiments in the HETMAN project seem to indicate that the special annoying effect of WTN is caused by the typical rhythmic fluctuation of the noise level known as amplitude modulation. The modulation frequency is given by the speed of rotor blades. The difference between the maximum and minimum noise level, known as the modulation depth, is closely associated with the annoyance. Increasing modulation depth increases the annoyance.
All our findings are gathered in the good practice guide which cover all aspects of measuring, predicting and controlling noise from wind turbines. This document is prepared in two language versions: English and Polish. The Polish version is intended for immediate implementation into Polish regulations regarding the management of wind turbines in Poland.

C4. A PUBLISHABLE SUMMARY FOR PUBLICATION BY THE PO: SUMMARY OF PROJECT RESULTS

A short summary (max. 2500 characters with spaces) of the project results. The information provided here may be published by the PO on the website of the Programme or transferred to the Donors for publication therefore shall be of a suitable quality to enable direct publication without any additional editing. The summary should answer the following questions: • Why was the project needed? • Which activities were implemented, products delivered, services established, etc.). Why were these activities, products and/or services, etc. important? • What was the main results of the project (including any unintended results)? • What difference has the project made for its end beneficiaries? • How has the situation improved as a result of the project? • What was the importance of the project (make sure to consider expected long-term impact)?
The aim of the HETMAN project was to get better knowledge about wind turbines noise. All aspects about it were carefully analysed, including noise generation, propagation and its influence on people. Several methods of prediction noise were checked and many laboratory experiments were conducted to better understand people's reactions to that type of noise. All these findings can help in providing more precise law regulations regarding wind turbines noise in Poland. The project was conducted by 8 entities, including one Norwegian partner. Project members met online every Wednesday to keep all things clear and synchronized. Together we realized many activities, including: - Short-term and long-term (yearly) noise monitoring near wind farms in Poland - Laboratory experiments aimed to measure noise annoyance evoked by wind turbines noise (including infrasounds) - Study visits – of Polish partners in Norway and of Norwegian partner in Poland - Conference speeches and organizing special sessions during them - Setting up laboratory configurations for experiments and construction of noise measuring prototypes (including programming) All these activities let us to gather data about performance of wind turbines, both objective and subjective. Based on them and results of our experiments we could propose solutions to mitigate noise annoyance and prepare guidelines regarding measuring, monitoring and prediction of wind turbines noise. They are of great interest as the green energy is one of the most important goals of the sustainable world. The project has strengthened relations between partners and develop deeper scientific cooperation – including joined scientific papers and conference lectures. The project also endorsed young researchers – PhD candidates and master students. Project results are gathered in one document, guidelines for measuring and predicting wind turbines noise. This document clean up the knowledge and propose detailed solutions to better control this type of noise. It is a great starting point to change Polish law regarding noise and make wind energy more accessible for the society. In the long-term perspective our findings should let to plan and manage wind turbines noise more reliably and in better cooperation with local authorities and communities.

C5. BILATERAL RESULTS SUMMARY: HOW DID THE BILATERAL PARTNERSHIP CONTRIBUTE TO THE PROJECT'S RESULTS?
• How the project benefited from having a Norwegian partner(s)? Were there any shared results? Did the collaboration lead to improved knowledge and understanding? • Describe the main results from the bilateral level. Has the partnership(s) led to any wider effects? • Are there any plans to continue the bilateral collaboration with Norwegian partner(s)? (max. 2000 characters with spaces)
Discussions with our Norwegian partner gave us a better understanding of the noise generating mechanisms of the wind turbine, and what causes the negative reactions among the exposed population. This joint study of noise annoyance reactions was based on a previous long-term cooperation. The Norwegian partner had good experience in noise propagation prediction and provided free access to Nord2000 calculation algorithms to the Polish partners. One of the Polish project partners and the Norwegian partner are currently members of a consortium that has submitted a proposal for an EU-funded project dealing with the effect of combined exposure to occupational noise and other airborne agents. One of the PhD-students affiliated with the project may have the opportunity to spend some month at our Norwegian partner's facilities working on a wind turbine related project.

C6. HOW DID THE PROJECT CONTRIBUTE TO STRENGTHENING BILATERAL RELATIONS?	
☒	Achieved shared results (e.g. solved a particular issue through sharing experience, knowledge, know - how or working together for joint results)
☒	Improved knowledge and mutual understanding developed between entities involved
☐	The bilateral collaboration generated broader interest in our project from our stakeholders

☒	The bilateral collaboration had wider effects beyond the project (e.g. our results are being used in other contexts, or we are working together on other issues now)
☒	The bilateral collaboration extended to the regional and/or European level (towards EU and its institutions)
☐	The bilateral collaboration led to increased visibility (e.g. media coverage in connection with bilateral activity)
☐	Other

C7. WHAT LEVEL OF INVOLVEMENT DID THE NORWEGIAN PARTNER(S) HAVE IN THE PROJECT?

☒	Attend events in our project
☒	Contribute with presentations and/or input to events
☒	Provide capacity building in our project (in the form of training, etc.)
☒	Work with us to find common solutions to shared challenges in the project
☒	Other

Our Norwegian partner organized a visit of young scientists to Norway twice. One at the beginning of our project and the other at the end. Polish scientists had the opportunity to visit a Norwegian wind farm and learn how cooperation between the people managing the farm and its inhabitants works.

C8. WILL THE COOPERATION WITH THE DONOR PARTNER(S) CONTINUE AFTER THE PROJECT IS COMPLETED?

☐	Yes, a formal cooperation agreement is in place
☐	Yes, continued cooperation is planned
☒	Contact may continue, but no concrete plans for cooperation to date
☐	No, the cooperation will not continue

C9. THE SOCIO-ECONOMIC IMPACT OF THE PROJECT

Gender equality
Please describe the impact of the project on gender equality, actions taken during the project implementation to provide gender balance and other actions which promote gender equality.
(max. 1000 characters with spaces)

The project involved young female researchers, especially two PhD candidates (from AMU and AGH) as well as many other female scientists. Some changes made in project budget were also implemented to extend financing of women in the project. Woman was a principal investigator of the project, also WP7 was lead by female researcher.

Ethical issues
(max. 1000 characters with spaces)

Some ethical issues arised when planning studies in the field, especially noise monitoring. Technically it was possible to put noise meters in the field without a consent from the farm's owner. However, to be totally transparent every time we asked for the permission. Also survey research was conducted in agreement with local authorities. Thanks to these precautions, both sides were satisfied and no misunderstanding were met during the project.
Efforts to involve other actors and to spread awareness (max. 1000 characters with spaces)
Many efforts were undertaken to spread information about the project in mass media. The principal investigator was a guest in radio stations, websites and newspapers. Two special sessions during scientific conferences were organized. There was also an open lecture about wind turbines noise transmitted via Internet. The final meeting of the project was aimed not only to scientists, but also offices' and government's members to inform them about the project results and encourage to use them in their political activities.
The plan for the use and dissemination of foreground (max. 1000 characters with spaces)
All project results are gathered in wind turbines' noise guidelines aimed to discuss all aspects of this type of noise. Based on it we plan to prepare a proposition of law regulation regarding monitoring and prediction of wind turbines' noise. In the long-term perspective, we want to discuss that topic with politicians, government and local authorities to convince them to better control noise generated by wind farms.

C10. DID THE PROJECT SUPPORT YOUNG RESEARCHERS?
☒ YES ☐ NO
If yes, please describe measures taken to support young researchers, facilitate and promote their participation in the project (PI was a young researcher, mentorship activities etc.). Please provide a narrative explaining the contribution of the project to strengthening and facilitating the scientific careers of young researchers. Max. 2000 characters.
In Polish partners many young researchers were emplyed and supported by the project. In UAM one young post-doc was responsible for the experiments in WP1, he also took part in both study visits in Norway as well as in one measurement campaign. Four PhD candidates were hired, they analyzed data from field studies, prepared and conduct experiments in WP5 and also conduct experiments in WP1. Three of them visited Norway and also took part in international conference. In AGH one master thesis was done in the project and PhD thesis is also prepared by a young female researcher (she also took part in the international conferences). The noise calculations at SINTEF was carried out by a young PhD researcher (new employee), and she was also the speaker at the Inter-Noise 2023 conference where the results were presented. All of young researchers were supported by their mentors, met with them regularly and learn ways of cooperation in the international scientific consortium. They are also authors of many conference and journal papers prepared during a project duration.

C11. DID THE PROJECT SUPPORT FEMALE RESEARCHERS?
☒ YES ☐ NO
If yes, please describe measures taken to support female researchers, facilitate and promote their participation in the project (PI was a female researcher, female reserchers going abroad etc.). Please provide a narrative explaining the contribution of the project to strengthening and facilitating the scientific careers of female researchers. Max. 2000 characters.
Overall, 14 female researchers worked in the project. The PI was a female researcher, women were also leaders of WP1 and WP7. The PI was interviewed in many media (see below), she also worked as a mentor for another young PhD female student. Both female PhD students (one from UAM and one from AHG) were supported, including mentor-mentee relation, access to data gathered in experiments and continuous support regarding their conference speeches and journal publications.

[3] Each launched WP in separate table
[4] Planned start date, end date and cost of WP according to the project contract or the last amendment to the project contract (if a project contract was amended).
[6] Please provide basic information about all deliverables produced during the reporting period as they were described in the project proposal (Annex 5 to project contract).
[7] Please provide basic information about all achieved milestones described in the project proposal (Annex 5 to project contract) including their numbers and names as given in Annex 5.

C12. INDICATORS OF THE PROGRAMME								
No.	**Indicator**		**Baseline value**	**Target value**	**Value reached from the last reporting period**	**Value reached from the beginning of the project implementation**	**Progress (%)**	**Description and justification of discrepancies**
1	**Number of peer-reviewed scientific publications submitted** *(please include information about publications in part D1 of the report)*		0	4	6	13	325.00	six more publication have been produced
2	**Number of joint, peer-reviewed scientific publications submitted** *(please include information about publications in part D1 of the report)*		0	3	0	1	33.33	There are two joint peer-reviewed conference papers. The journal publication is prepared.
3	**Number of new products/technologies developed (incl. number of registered applications for Intellectual Property Protection)** *(please include information about new products/technologies developed in part D3 of the report)*		0	2	1	1	50.00	One new product was developed. The reasons why there is 1 not 2 products are explained by people worked in WP6
4	**Number of registered applications for Intellectual Property Protection** *(please include information about applications in part D4 of the report)*		0	0	0	0	n/a	-
5	**Number of Polish researchers supported**	**all**	0	26	23	49	188.46	The number of people increased due to the employment of doctoral students (increased project budget) and PSEW employees
		female	0	8	6	14	175.00	There were also women among the newly employed

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6	**Number of Norwegian researchers supported**	**all**	0	2	1	2	100.00	doctoral student, female, was employed at SINTEF
		female	0	1	1	1	100.00	doctoral student, female, was employed at SINTEF
7	**Number of female researchers going abroad for research**	**female**	0	0	0	0	n/a	-
8	**Number of mentor-mentee relationships established for young researchers**		0	2	2	4	200.00	At least two PhD students working on the project were provided with mentorship
9	**Number of joint applications submitted for further funding** *(please include information about applications in part D5 of the report)*		0	1	0	1	100.00	Because our previous application did not receive funding, it was not possible to apply for another one (no possibility)

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D. DISSEMINATION AND PROMOTION

D1. PUBLICATIONS											
No.	**Title of publication**	**Authors**	**Joint publication (YES/NO)**	**Name of journal**	**IF**	**Date of submission for publication**	**Status of publication**	**Language**	**Open access publication**	**The most representative publications**	**Peer-reviewed scientific publications**
1	Experimental Verification of Windshields in the Measurement of Low Frequency Noise from Wind Turbines	Wszołek, T., Pawlik, P., Kłaczyński, M., Stępień, B., Mleczko, D., Małecki, P., Rozwadowski, K.	no	Energies	3,34	2022-01-01	published	English	gold open access	☐	☒

Link to publication / pdf
https://www.mdpi.com/1996-1073/15/20/7499
Additional information for open access publication: **- DOI (Digital Object identifier)** [8] **- Repository link** [9] **- Date of acceptance** [10]
https://doi.org/10.3390/en15207499
Abstract

Measuring noise from wind turbines is challenging due to significant wind interference, especially in the low-frequency range. In the audible band, particularly A-weighted, wind interference is much less impactful compared to the low-frequency and infrasound bands. Therefore, methods to reduce wind interference in the lowest frequency bands are continually sought. The effectiveness of different windshields was verified under real conditions using LFN source from a salt mine fan station, which operates in windless conditions, allowing noise measurements without wind interference. Signals were recorded in both windless and windy conditions at different wind speeds. An effectiveness analysis was also performed on a wind farm. Research indicates that the best method for measuring wind turbine noise in the low-frequency range is placing the microphone on the board with a double windscreen. At wind speeds below 5 m/s at 1.5 m above the ground, this setup effectively eliminates disturbances above 4 Hz. However, as wind speed exceeds 6 m/s, disturbances increase and their bandwidth expands in the lowest frequencies.											
2	Road,Tram and Aircraft Traffic Noise Annoyance Related to the Number of Noise Events and the Equivalent Sound Level	Felcyn, J., Ptak, P.	no	Archives of Acoustics	0,913	2022-05-21	published	English	gold open access	☐	⊠
Link to publication / pdf											
https://acoustics.ippt.pan.pl/index.php/aa/article/view/3535											
Additional information for open access publication: **- DOI (Digital Object identifier)** [8] **- Repository link** [9] **- Date of acceptance** [10]											
doi:10.24425/aoa.2022.142892											
Abstract											

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Noise mapping is based on long-term noise indicators, such as LN or LDEN. On the other hand, transportation intensity changes during a day (road traffic peak hours) or a year (more flights during holidays) and this variability is not reflected in single sound level values. We wanted to find out whether not only sound level but also the number of noise events is the factor influencing noise annoyance assessment. Ambisonic recordings of real traffic in a city were used. Road, tramway, and aircraft traffic were investigated and two factors were manipulated: the equivalent sound level value and the number of noise events. All stimuli were presented in an anechoic chamber. The results showed that sound level is always a statistically significant parameter while the number of events has an impact only for tramways and airplanes. Moreover, the difference is observed only between one or more subgroups, no matter what the sound level value was. For road traffic this relation was not found to be statistically significant. It was also shown that the existence of tramway bonus or airplane malus is linked with the number of noise events.											
3	Experimental verification of the usefulness of selected infrasound and lowfrequency noise (ILFN) indicators in assessing the noise annoyance of wind turbines	Wszołek, T., Mleczko, D., Pawlik, P., Kłaczyński, M., Małecki, P., Stępień, B.	no	Vibrations in Physical Systems	0,36	2022-07-22	published	English	gold open access	☐	☒
Link to publication / pdf											
https://vibsys.put.poznan.pl/_journal/2022-33-3/articles/vps_2022315.pdf											
Additional information for open access publication: **- DOI (Digital Object identifier) [8]** **- Repository link [9]** **- Date of acceptance [10]**											
10.21008/j.0860-6897.2022.3.15											
Abstract											

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This paper presents an overview of the indices used in evaluating ILFN noise, based on C and G weighting curves and *LC-LA* difference parameter, as well as curves compared to the loudness threshold curve. The research section includes measurement results of wind turbine (WT) noise along with proposed indicators for evaluating this noise in the infrasound and low-frequency bands at distances of 250 m, 500 m and 1000 m from the turbine. The results obtained indicate low noise levels in the infrasound band, lower than the threshold curves from a dozen or so dB in the upper part of this band to nearly 60 dB in the lower part. The *LC-LA* indicator has been shown to be of poor utility for evaluating low-frequency noise, with the *LG* indicator reasonably useful for evaluating infrasound noise.

4	Experimental Research of the AMWG Algorythm for Assessing Amplitude Modulation in Wind Turbine Noise	Czapla, M., Wszołek, T.	no	Vibrations in Physical Systems	0,36	2022-07-22	published	English	gold open access	☐	☒

Link to publication / pdf

https://vibsys.put.poznan.pl/_journal/2022-33-3/articles/vps_2022317.pdf

Additional information for open access publication:
- DOI (Digital Object identifier) [8]
- Repository link [9]
- Date of acceptance [10]

https://doi.org/10.21008/j.0860-6897.2022.3.17

Abstract

The operation of a wind turbine (WT) is characterized by fluctuations in sound pressure amplitude associated with the passage of the propeller blade through the tower. Amplitude Modulation (AM) is one of the factors that contributes to the increased annoyance of wind turbine noise. The phenomenon of AM is currently the subject of research in many research centers around the world in the context of a parametric assessment of its impact on annoyance. Despite the development of many methods to measure the AM of a WT noise, there is no commonly accepted method. This paper discusses the most crucial factors that stimulate the phenomenon of AM and the implementation in the MATLAB environment of the algorithm to find the frequency and depth of AM proposed by the Amplitude Modulation Working Group (AMWG). The results of verification of the developed algorithm as well as the measurement results of the frequency and depth of modulation for two measurement samples of a 2 MW wind turbine are presented.

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5	Evaluation of annoyance due to wind turbine noise based on prelearned patterns	Felcyn, J. , Preis, A., Gogol, R.	no	Vibrations in Physical Systems	0,36	2022-07-22	published	English	gold open access	☐	⊠
Link to publication / pdf											
https://vibsys.put.poznan.pl/vibrations-in-physical-systems-2022-vol-33-no-3/											
Additional information for open access publication: **- DOI (Digital Object identifier)** [8] **- Repository link** [9] **- Date of acceptance** [10]											
DOI: 10.21008/j.0860-6897.2022.3.10											
Abstract											
Annoyance due to wind turbine noise is usually assessed on the basis of surveys conducted among people living in the vicinity of turbines or in the laboratory conditions. Due to the fact that the latter are very different from natural conditions, we propose a solution to reduce this difference. Prior to the surveys, 50 participants were asked to familiarize themselves with 5 environmental signals. They were informed about the annoyance rating assigned to each signal (obtained earlier in laboratory conditions), expressed as a number between 0 (not annoying signal) and 10 (extremely annoying signal). Participants were then presented with new environmental sounds and asked to rate the annoyance caused by each sound, in accordance with the previously learned method. The analysis of our results shows that the variability of answers given by respondents at their homes is similar to those obtained earlier in laboratory conditions.											
6	How to determine the annoyance due to wind turbines	Preis, A., Gjestland, T.	yes	Vibrations in Physical Systems	0,36	2022-07-22	published	English	gold open access	⊠	⊠
Link to publication / pdf											

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https://vibsys.put.poznan.pl/vibrations-in-physical-systems-2022-vol-33-no-3/
Additional information for open access publication: **- DOI (Digital Object identifier)** [8] **- Repository link** [9] **- Date of acceptance** [10]
DOI: 10.21008/j.0860-6897.2022.3.19
Abstract
In the study of annoyance due to wind turbines, the dominant approach takes into account only the noise generated by these sound sources. However, there are studies which show that such value alone is not enough to explain why for the majority of people living near wind turbines their noise is extremely annoying, despite the fact that the measured sound level values are relatively low. One way of solving this problem is to introduce a correction to the one-factor noise index. This has been already done by taking into account the time variability (amplitude modulation) of the sound generated by wind turbines. Another proposal is to establish a multifactorial noise index which includes not only the noise parameters, but also non-acoustic characteristics (mainly visual), which are supposed to influence the overall perception of the annoyance associated with wind turbines. These two approaches will be discussed in this paper.

7	Review of evaluation criteria for infrasound and low frequency noise in the general environment	Pawlaczyk-Łuszczyńska, M., Dudarewicz, A	no	Digital Monogragh (In New techniques and methods for noise and vibration measuring, assessing and reducing)	0	2022-01-01	published	English	gold open access	☐	☒

Link to publication / pdf
https://www.ciop.pl/CIOPPortalWAR/file/95674/2022111512226&R_3_Article_Pawlaczyk_Review_OK.pdf

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Additional information for open access publication: **- DOI (Digital Object identifier)** [8] **- Repository link** [9] **- Date of acceptance** [10]											
https://www.ciop.pl/CIOPPortalWAR/file/95674/2022111512226&R_3_Article_Pawlaczyk_Review_OK.pdf											
Abstract											
It has been suggested that infrasound (IS) and low frequency noise (LFN) may be responsible for adverse health effects in people living in the vicinity of wind farms. Many studies have indicated that the basic noise measure − an A-weighted sound pressure level (SPL) − is a less suitable descriptor for assessing the effects of IS and/or LFN. Thus, this paper reviews existing or proposed methods for evaluating infrasound and LFN in residential areas with regard with their impact on human health and wellbeing.											
8	Impact of infrasound and low frequency noise on human health and well-being. Part I: Review of experimental studies	Pawlaczyk-Łuszczyńska, M., Dudarewicz, A., Myshchenko, I., Bortkiewicz, A.	no	Medycyna Pracy. Workers' Health and Safety	0,8	2023-02-14	published	English	gold open access	☐	⊠
Link to publication / pdf											
https://medpr.imp.lodz.pl/Wplyw-infradzwiekow-i-halasu-niskoczestotliwosciowego-na-zdrowie-i-samopoczucie-czlowieka,172195,0,2.html											
Additional information for open access publication: **- DOI (Digital Object identifier)** [8] **- Repository link** [9] **- Date of acceptance** [10]											

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DOI: https://doi.org/10.13075/mp.5893.01354											
Abstract											
This paper summarizes the currently available knowledge on the impact of infrasound and low frequency noise (LFN) on human health and well-being. This narrative review of the literature data was based on the selected, mostly, peer-reviewed research papers, review articles, and meta-analyses that were published in 1973–2022. It has been focused on infrasound perception, annoyance attributed to infrasound and low-frequency noise, as well as their effects on the cardiovascular system and sleep disorders. Particular attention was also paid to the latest research results and specific sources of infrasound and LFN, i.e., wind turbines. Med Pr Work Health Saf. 2023;74(4):317–32.											
9	Impact of infrasound and low frequency noise on human health and well-being. Part II: Review of epidemiological studies.	Pawlaczyk-Łuszczyńska, M., Dudarewicz, A., Myshchenko, I., Bortkiewicz, A.	no	Medycyna Pracy. Workers' Health and Safety	0,8	2023-05-15	published	English	gold open access	☐	☒
Link to publication / pdf											
https://medpr.imp.lodz.pl/pdf-172194-97838?filename=Impact%20of%20infrasound%20and.pdf											
Additional information for open access publication: **- DOI (Digital Object identifier)** [8] **- Repository link** [9] **- Date of acceptance** [10]											
DOI: https://doi.org/10.13075/mp.5893.01390											
Abstract											

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This paper summarizes the currently available knowledge on the impact of infrasound (IS) and low frequency noise (LFN) on human health and well-being. This narrative review of the literature data was based on the selected, mostly, peer-reviewed research papers, review articles, and meta-analyses that were published in 1971-2022. It has been focused on the results of epidemiological studies concerning the annoyance related to infrasound and low frequency noise, as well as their impact on the cardiovascular system and sleep disorders. Particular attention was also paid to the latest research results and specific sources of IS and LFN, i.e., wind turbines. Med Pr Work Health Saf. 2023;74(5):409-23.											
10	Does Stochastic and Modulated Wind Turbine Infrasound Affect Human Mental Performance Compared to Steady Signals without Modulation?	Małecki, P., Pawlaczyk-Łuszczyńska, M., Wszołek, T., Preis, A., Kłaczyński, M., Dudarewicz, A., Pawlik, P., Stępień, B. and Mleczko, D.	no	International Journal of Environmental Research and Public Health	4,61	2022-11-29	published	English	gold open access	⊠	⊠
Link to publication / pdf											
https://www.mdpi.com/1660-4601/20/3/2223											
Additional information for open access publication: **- DOI (Digital Object identifier)** [8] **- Repository link** [9] **- Date of acceptance** [10]											
https://doi.org/10.3390/ijerph20032223											
Abstract											

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Wind turbines (WT) are a specific type of noise source, with unique characteristics, such as amplitude modulation (AM) and tonality, infrasonic and low frequency (LF) components. The present study investigates the influence of wind turbine infrasound and low frequency noise (LFN) on human well-being. In the between-subjects study design, 129 students performed a cognitive test evaluating attention and filled out questionnaires in three various exposure conditions, including background noise, synthesized LFN (reference noise) and registered WT infrasound (stimulus). No significant differences in test results or in the number of reported post-exposure feelings and ailments in various exposure conditions were found when analyzing them in males and females, separately. However, a significant association between pre-exposure well-being and reported post-exposure complaints was noted and explained by in-depth statistical analysis.											
11	Should limit values be set for infrasound caused by wind turbines?	Pawlaczyk-Łuszczyńska, M., Dudarewicz, A., Wszołek, T., Małecki, P., Bortkiewicz, A.	no	International Journal of Occupational Medicine and Environmental Health	1,4	2024-03-21	submitted	English	gold open access	☐	☒
Link to publication / pdf											
not applicable											
Additional information for open access publication: **- DOI (Digital Object identifier) [8]** **- Repository link [9]** **- Date of acceptance [10]**											
submitted											
Abstract											
According to the results of previous studies, human tolerance to infrasound is defined by the hearing threshold. Infrasound that cannot be heard (or felt) is not annoying and is not thought to have any other adverse health effects. Recent research largely confirms the earlier findings. This paper presents the current state of knowledge on infrasound generated by wind turbines and discusses the measurement methods and assessment criteria. It also includes proposals for limit values for infrasound in the environment caused by wind turbines, expressed as short-term indicators (LGeq,D and LGeq,N) and long-term indicators (LDWN(G) and LN(G)). Irrespective of land use, the G-weighted equivalent continuous sound pressure level was set at 90 dB for a reference time T=16 h during the day and 85 dB for a reference time T=8 h during the night. Similarly, the following values were adopted as acceptable values for long-term indicators, irrespective of land use: 90 dB - for ?LDWN(G) and 85 dB - for LN(G).											

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12	Suitability analysis of selected methods for modelling infrasound and low-frequency noise from wind turbines	Stępień, B., Wszołek, T., Mleczko, D., Małecki, P., Pawlik, P., Kłaczyński, M., Czapla, M.	no	Energies	3,0	2024-02-17	published	English	gold open access	☐	☒

Link to publication / pdf
https://www.mdpi.com/1996-1073/17/12/2832
Additional information for open access publication: **- DOI (Digital Object identifier)** [8] **- Repository link** [9] **- Date of acceptance** [10]
https://doi.org/10.3390/en17122832
Abstract
Wind turbines emit infrasound and low-frequency noise (ILFN), which can be annoying for people living near wind farms. To assess the acoustic impact of wind turbines on the environment, it is essential to model ILFN propagation during the forecasting stage. This study assesses the effectiveness of three commonly used sound propagation models (ISO 9613-2, CNOSSOS-EU for favourable propagation conditions, Nord2000) in predicting ILFN generated by wind turbines. The performance of these models in modelling ILFN is generally not validated or guaranteed. The analysis covers octave frequency bands ranging from 4 Hz to 250 Hz, and comparisons are made against measurements conducted at a wind farm in Poland. Non-parametric statistical tests were used with a significance level of ;????=0.05 ;to determine significant differences between measured and predicted results. The results show that the Nord2000 method provides accurate calculations, while the ISO 9613-2 method can be used for simplified assessments of ILFN generated by wind turbines during the investment preparation phase.

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13	No Impact of Wind Turbine Noise on Various Cognitive Functions	Agnieszka Rosciszewska, Maciej Buszkiewicz, Gabriela Dobrzynska-Kobylec, Anna Klichowska, Tomasz Przybyla, Blanka B. Nagy, Andrzej Wicher, Michal Klichowski	no	Humanities and Social Sciences Communications	3,5	2024-07-01	submitted	English	gold open access	⊠	⊠

Link to publication / pdf
not applicable
Additional information for open access publication: **- DOI (Digital Object identifier)** [8] **- Repository link** [9] **- Date of acceptance** [10]
not applicable
Abstract
Despite their alignment with sustainable development principles, wind farms often provoke controversy and misinformation, particularly regarding the noise they produce and their potential impact on human functioning. Concerns have been raised about the possible effects of this noise on irritation levels and various cognitive functions. Yet, these concerns have not been substantiated by controlled, comprehensive laboratory studies. Here, we used recordings from an actual wind turbine to investigate its impact on the dynamics of brain waves crucial for complex cognitive tasks, as well as on sustained attention and inductive reasoning. We also tested the subjective evaluation of the stress induced by wind turbine noise and the annoyance it causes. Our findings reveal that exposure to wind turbine noise with a sound pressure level corresponding to the real-world situation does not adversely affect any of the examined cognitive functions and is not perceived as more stressful or bothersome than road traffic noise. Furthermore, we utilized various psychological scales and found that even tendencies towards rumination or reduced capacity for reflection and ambiguity tolerance did not lead to maladaptive perceptions of wind turbine noise and, therefore, to a state that might indirectly influence cognitive functioning. These results contribute to an objective understanding of wind farm noise's influence on human life and counteract misleading narratives about it.

D2. CONFERENCES AND SEMINARS

No.	Title of presented work	Authors	Name of the conference / seminar	Date and place	Type	Presentation / poster / other (specify)
1	Towards optimal management of wind turbines' noise Hetman	Preis, A., Gjestland, T., Kokowski, P., Wszołek, T., Chacińska, P., Kompała, J., Pawlaczyk-Łuszczyńska, M., Klera, M.	1 st Conference on Sound Perception (CSP)	2021-09-03 Faculty of Physics A. Mickiewicz University in Poznań	international	presentation
LINK						
https://csp2023.syskonf.pl/						
2	Review of methods for predicting, measuring and assessing infra- and low-frequency noise from wind turbines	Wszołek, T	Seminar organized by Department of Acoustics -AMU university Poznań	2021-12-14 Department of Acoustics (on-line mode)	national	presentation
LINK						
https://hetman-wind.ios.edu.pl/14-12-2021/						
3	Corrections used in the assessment of the nuisance of noise sources	Wszołek, T.	Open Seminar on Acoustics 2021 (OSA)	2021-09-14 National OSA2021 conference organized by Polish Acoustical Society, Krakow Division	national	presentation
LINK						
http://www.osa2021.ptakrakow.pl/						

4	How to determine the annoyance due to wind turbines	Preis, A., Gjestland, T	Open Seminar on Acoustics (OSA)	2022-09-12 Rzeszów-Solina, 12 -16.09.2022	national	presentation
LINK						
https://pta.ur.edu.pl/?page_id=218						
5	Evaluation of wind turbine noise annoyance based on pre- learned patterns	Felcyn, J. Preis, A., Gogol, R.	Open Seminar on Acoustics (OSA)	2022-09-12 Rzeszów-Solina, 12 -16.09.2022.	national	presentation
LINK						
https://pta.ur.edu.pl/?page_id=218						
6	Experimental Research of the AMWG Algorithm for Assessing Amplitude Modulation in Wind Turbine Noise	Czapla M., Wszołek T.	Open Seminar on Acoustics (OSA)	2022-09-12 Rzeszów-Solina, 12 -16.09.2022	national	presentation
LINK						
https://pta.ur.edu.pl/?page_id=218						
7	Proposal of infra and low frequency noise (ILFN) indicators and verification of their usefulness in the assessment of noise annoyance of wind turbines	Wszołek T., Kłaczyński M., Małecki P., Pawlik P., Stępień B., Mleczko D.	Open Seminar on Acoustics (OSA)	2022-09-12 Rzeszów-Solina, 12 -16.09.2022.	national	presentation
LINK						

https://pta.ur.edu.pl/?page_id=218						
8	Comparison Analysis of Noise Generated by Wind Turbines with Other Noise Sources in Outdoor Environment	Staniek, A., Kompała, J., Bramorska, A., Bartmański, C.	Open Seminar on Acoustics (OSA)	2022-09-12 Rzeszów-Solina, 12 -16.09.2022	national	presentation
LINK						
https://pta.ur.edu.pl/?page_id=218						
9	Road traffic noise influence on wind turbine noise detection	Buszkiewicz, M., Wicher, A., Gołębiewski, R., Pyffel, R.	Open Seminar on Acoustics (OSA)	2022-09-12 Rzeszów-Solina, 12 -16.09.2022	national	presentation
LINK						
https://pta.ur.edu.pl/?page_id=218						
10	Review of evaluation criteria for infrasound and low-frequency noise in the general environment	Pawlaczyk-Łuszczyńska, M., Dudarewicz, A.	XIX International Conference NOISE CONTROL 2022	2022-06-26 Lidzbark Warmiński, 26-29 June 2022	international	presentation
LINK						
https://www.ciop.pl/CIOPPortalWAR/file/94840/2022061581235&NoiseControl2022_program_pl_en.pdf						
11	Proposal measurement method to assess the annoyance of infra and low frequency noise (ILFN) from wind turbines	Wszołek, T., Kłaczyński, M., Pawlik, P., Mleczko, D., Małecki P., Stępień, B.	XIX International Conference NOISE CONTROL 2022	2022-06-26 Lidzbark Warmiński, 26-29 June 2022	international	presentation

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LINK						
https://www.ciop.pl/CIOPPortalWAR/file/94840/2022061581235&NoiseControl2022_program_pl_en.pdf						
12	Research on wind turbine noise perception	Małecki, P., Wszołek, T., Mleczko, D., Pawlik P., Kłaczyński, M., Stępień, B., Preis, A., Pawlaczyk-Łuszczyńska, M.	XIX International Conference NOISE CONTROL 2022	2022-06-26 Lidzbark Warmiński, 26-29 June 2022	international	presentation
LINK						
https://www.ciop.pl/CIOPPortalWAR/file/94840/2022061581235&NoiseControl2022_program_pl_en.pdf						
13	Analysis of the application of different windscreens for lowfrequency noise measurements	Pawlik, P., Wszołek, T., Kłaczyński, M., Stępień, B., Małecki, P., Mleczko, D.	XIX International Conference NOISE CONTROL 2022	2022-06-26 Lidzbark Warmiński, 26-29 June 2022	international	presentation
LINK						
https://www.ciop.pl/CIOPPortalWAR/file/94840/2022061581235&NoiseControl2022_program_pl_en.pdf						
14	Application of common computational methods for modelling low-frequencynoise of wind turbines	Stępień, B., Wszołek, T., Mleczko, D., Małecki, P., Kłaczyński, M., Pawlik, P.	XIX International Conference NOISE CONTROL 2022	2022-06-26 Lidzbark Warmiński, 26-29 June 2022	international	presentation
LINK						
https://www.ciop.pl/CIOPPortalWAR/file/94840/2022061581235&NoiseControl2022_program_pl_en.pdf						

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15	Does self-assessment of sleep quality reflect exposure to wind turbine noise? A case study	Pawlaczyk-Łuszczyńska, M., Dudarewicz, A.Bortkiewicz A.	The 29Th International Congress on sound and vibration, (ICSV29)	2023-07-09 2023-07-09 - 2023-07-13, Prague, Czech Republic	international	presentation
LINK						
https://icsv29.org/index.php?va=viewpage&vaid=175#						
16	Prediction of wind turbine noise. Comparison of three standardized prediction methods	Evensen, K.B., Gjestland, T., Kokowski, P., Libiszewski, P., Kaczmarek, T., Gałuszka, M.	The 52nd International Congress Inter-Noise 2023	2023-08-20 Chiba, Greater Tokyo 20-23 August 2023	international	presentation
LINK						
https://www.inceusa.org/publications/ince-digital-library						
17	Wind turbine's noise annoyance ratings related to the distance and creativity and directivity of a wind turbine	Felcyn, J., Preis, A., Gogol, R., Emche, M.	10th Convention of the European Acoustics Association Forum Acusticum 2023	2023-09-11 Torino, Italy September 11-15, 2023	international	presentation
LINK						
https://dael.euracoustics.org/confs/fa2023/data/index.html						
18	Noise annoyance studied in different situations: a comparison of results obtained in situ and laboratory conditions	Felcyn, J., Emche, M., Preis, A.	10th Convention of the European Acoustics Association Forum Acusticum 2023	2023-09-11 Torino, Italy September 11-15, 2023	international	presentation
LINK						

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https://dael.euracoustics.org/confs/fa2023/data/index.html						
19	Modelling Low-Frequency Noise of Wind Turbines	Stępień, B., Wszołęk, T., Mleczko, D., Małecki, P., Kłaczyński, M., Pawlik, P.	10th Convention of the European Acoustics Association Forum Acusticum 2023	2023-09-11 Torino, Italy September 11-15, 2023	international	presentation
LINK						
https://dael.euracoustics.org/confs/fa2023/data/index.html						
20	Analysis of wind turbine acoustic signals in terms of detecting amplitude modulation and frequency deviation	Czapla, M., Wszołek, T.	10th Convention of the European Acoustics Association Forum Acusticum 2023	2023-09-11 Torino, Italy September 11-15, 2023	international	presentation
LINK						
https://dael.euracoustics.org/confs/fa2023/data/index.html						
21	On-line wind farm noise control	Kokowski, P,. Libiszewski, P., Kaczmarek, T., Gałuszka, M., Pękala, P, Gjestland, T.	10th Convention of the European Acoustics Association Forum Acusticum 2023	2023-09-11 Torino, Italy September 11-15, 2023	international	presentation
LINK						
https://dael.euracoustics.org/confs/fa2023/data/index.html						

22	Analiza zjawisk wibroakustycznych generowanych przez turbiny wiatrowe i ich oddziaływanie na środowisko	Wszołek, T., Kłaczyński, M., Stępień, B., Małecki,P.,	"Badania naukowe na Wydziale Inżynierii Mechanicznej i Robotyki" z okazji 70 lecia WYdziału Inzynierii Mechanicznej i Robotyki Akademii Górniczo-Hutniczej w Krakowie.	2022-05-26 Akademia Górniczo-Hutnicza w Krakowie	national	presentation
LINK						
http://krim.agh.edu.pl/badanie-naukowe-na-wydziale-inzynierii-mechanicznej-i-robotyki-materialy-konferencyjne-praca-zbiorowa/						
23	Experimental studies of the impact of amplitude modulation (AM) and tonality on the annoyance of wind turbine noise in the low frequency (LF) range	Wszołek,T., Pawlik, P., Małecki, M., Kłaczyński, M. Mleczko, D., Czapla, M., Stępień, B.	The 52nd International Congress Inter-Noise 2023	2023-08-20 Chiba, Greater Tokyo 20-23 August 2023	international	presentation
LINK						
https://www.inceusa.org/publications/ince-digital-library						
24	Tests of windshields for wind turbines noise measurements	Wszołek, T., Kłaczyński, M., Pawlik, P. Stępień, B., Małecki, P., Mleczko, D.,	69th Open Seminar of Acoustics OSA2023 and 5th Polish-German Structured Conference on Acoustics PGSCA 2023	2023-09-26 Karpacz, Polska, 25-29.09.2023	national	presentation
LINK						
https://acoustics.org.pl/wp-content/uploads/2023/09/OSA2023-Book-of-abstract.pdf						
25	Infrasound and well-being: a study of wind turbine impact,	Małecki, P., Pawlaczyk-Łuszczyńska, M., Wszołek, T., Drzymała, B.	69th Open Seminar of Acoustics OSA2023 and 5th Polish-German Structured Conference on Acoustics PGSCA 2023	2023-09-26 Karpacz, Polska, 25-29.09.2023	national	presentation

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LINK						
https://acoustics.org.pl/wp-content/uploads/2023/09/OSA2023-Book-of-abstract.pdf						
26	Propozycja oceny hałasu niskoczęstotliwościowego od turbin wiatrowych (Proposal for assessing low-frequency noise from wind turbines)	Wszołek, T., Pawlaczyk-Łuszczyńska, M.	LI Szkoła Zimowa Akustyki Środowiska i Wibroakustyki (LI Winter School of Environmental Acoustics and Vibroacoustics)	2024-02-27 Szczyrk, Polska, 26.02-01.03.204	national	presentation
LINK						
https://ogpta.pl/images/SZASIW/Program-SZ-ASiW-2024-p.pdf						
27	Badanie wpływu hałasu turbin wiatrowych w zakresie małych częstotliwości na zdrowie i samopoczucie człowieka: badanie akustyczne w środowisku kontrolowanym (Studying the impact of low-frequency wind turbine noise on human health and well-being: an acoustic study in a controlled environment)	Małecki, P., Pawlaczyk-Łuszczyńska, M., Wszołek T., Bortkiewicz, A., Dudarewicz, A., Kłaczyński, M., Pyda, G., Stępień, B., Pawlik, P., Mleczko, D.	LI Szkoła Zimowa Akustyki Środowiska i Wibroakustyki (LI Winter School of Environmental Acoustics and Vibroacoustics)	2024-02-27 Szczyrk, Polska, 26.02-01.03.204	national	presentation
LINK						
https://ogpta.pl/images/SZASIW/Program-SZ-ASiW-2024-p.pdf						
28	The influence of wind turbine infrasound on human cognitive performance	Małecki, P., Pawlaczyk-Łuszczyńska, M.. Wszołek, T.	CSP 2023 2nd Conference on Sound Perception	2023-09-01 Poznań, Poland, 01-03.09.2023	international	presentation
LINK						

https://csp2023.syskonf.pl/conf-data/csp2023/files/CSP%202023%20–%203%20kor.pdf						
29	Wybrane metody modelowania hałasu infradźwiękowego i niskoczęstotliwościowego generowanego przez turbiny wiatrowe (Selected methods for modeling infrasound and low-frequency noise generated by wind turbines)	Stępień, B., Wszołek, T., Mleczko, D., Małecki, P., Kłaczyński, M., Pawlik, P., Czapla, M.	LI Szkoła Zimowa Akustyki Środowiska i Wibroakustyki	2024-02-07 Szczyrk, Polska, 26.02-01.03.204	national	presentation
LINK						
https://ogpta.pl/images/SZASIW/Program-SZ-ASiW-2024-p.pdf						
30	Hałas turbin wiatrowych - modelowanie ILFN (Wind turbine noise - ILFN modeling)	Stępień, B., Wszołek, T., Mleczko, D., Małecki, P.,	50. ogólnopolskie sympozjum Diagnostyka Maszyn	2024-03-03 Wisła, Polska, 3 - 7.03.2024 r.	national	presentation
LINK						
http://ptdt.pl/index.php?page=156						
31	The Impact of Wind Turbine Noise on Human Health in A Controlled Study	Małecki, P., Pawlaczyk-Łuszczyńska, M., Wszołek, T., Bortkiewicz, A., Dudarewicz, A., Kłaczyński, M., Pyda, G., Stępień B., Pawlik, P., Mleczko, D.	DAGA 2024 - 50. JAHRESTAGUNG FÜR AKUSTIK	2024-03-20 Hannover, Germany, 18-21.04.2024	international	poster
LINK						
https://app2024.daga-tagung.de/konferenz?session=134						

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32	Psychoakustyczna analiza dźwięku generowanego przez turbinę wiatrową (Psychoacoustic analysis of sound generated by a wind turbine)	Preis, A., Felcyn, J.	LI Szkoła Zimowa Akustyki Środowiska i Wibroakustyki	2024-02-27 Szczyrk, Polska 26.02 – 01.03.2024	national	presentation
LINK						
https://ogpta.pl/index.php/sz-asiw2						
33	Detekcja hałasu turbin wiatrowych – czy zmodulowany hałas stacjonarny innych źródeł jest postrzegany jako turbina wiatrowa? (Wind turbine noise detection - is the modulated stationary noise of other sources perceived as a wind turbine?)	Felcyn, J., Emche, M.	LI Szkoła Zimowa Akustyki Środowiska i Wibroakustyki	2024-02-27 Szczyrk, Polska 26.02 – 01.03.2024	national	presentation
LINK						
https://ogpta.pl/index.php/sz-asiw2						
34	Wpływ filtracji górno- i dolnoprzepustowej na ocenę dokuczliwości hałasu turbin wiatrowych (Effect of high-pass and low-pass filtering on the assessment of wind turbine noise annoyance)	Kozłowski, E., Gogol, R., Felcyn, J., Pawlaczyk- Łuszczyńska, M.	LI Szkoła Zimowa Akustyki Środowiska i Wibroakustyki	2024-02-27 Szczyrk, Polska 26.02 – 01.03.2024	national	presentation
LINK						
https://ogpta.pl/index.php/sz-asiw2						
35	Ocena dokuczliwości turbin wiatrowych – badania terenowe (Evaluation of the annoyance of wind turbines - field studies)	Pastusiak, A., Gogol, R.	LI Szkoła Zimowa Akustyki Środowiska i Wibroakustyki	2024-02-27 Szczyrk, Polska 26.02 – 01.03.2024	national	presentation

LINK						
https://ogpta.pl/index.php/sz-asiw2						
36	Propozycja metody pomiaru hałasu turbin wiatrowych (Proposal for a method of measuring wind turbine noise)	Kaczmarek, T., Gałuszka, M., Pękala, P., Libiszewski, P., Kokowski, P.	LI Szkoła Zimowa Akustyki Środowiska i Wibroakustyki	2024-02-27 Szczyrk, Polska 26.02 – 01.03.2024	national	presentation
LINK						
https://ogpta.pl/index.php/sz-asiw2						
37	Efekt maskowania jako narzędzie do redukcji dokuczliwości hałasu turbiny wiatrowej (Masking effect as a tool to reduce wind turbine noise annoyance)	Wicher, A., Buszkiewicz, M., Maćkowiak, J.	LI Szkoła Zimowa Akustyki Środowiska i Wibroakustyki	2024-02-27 Szczyrk, Polska 26.02 – 01.03.2024	national	presentation
LINK						
https://ogpta.pl/index.php/sz-asiw2						
38	Udział czynników wzrokowych w ocenie dokuczliwości hałasu turbiny wiatrowej (Contribution of visual factors in the evaluation of wind turbine noise annoyance)	Wicher, A., Buszkiewicz, M., Pastusiak, A.	LI Szkoła Zimowa Akustyki Środowiska i Wibroakustyki	2024-02-27 Szczyrk, Polska 26.02 – 01.03.2024	national	presentation
LINK						
https://ogpta.pl/index.php/sz-asiw2						

39	Wsparcie systemu zarządzania farmą wiatrową minimalizujące na bieżąco ryzyko wystąpienia skarg na hałas (Support of the wind farm management system to minimize the risk of noise complaints on an ongoing basis)	Kokowski, P., Libiszewski, P., Kaczmarek, T., Gałuszka, M., Pękala, P.	LI Szkoła Zimowa Akustyki Środowiska i Wibroakustyki	2024-02-27 Szczyrk, Polska 26.02 – 01.03.2024	national	presentation
LINK						
https://ogpta.pl/index.php/sz-asiw2						
40	Planowanie lokalizacji farm wiatrowych a normy hałasowe (Wind farm site planning and noise standards)	Kupczyk, W.	LI Szkoła Zimowa Akustyki Środowiska i Wibroakustyki	2024-02-27 Szczyrk, Polska 26.02 – 01.03.2024	national	presentation
LINK						
https://ogpta.pl/index.php/sz-asiw2						
41	Hałas turbin wiatrowych w kontekście uregulowań prawnych – aspekty planistyczne (Wind turbine noise in the context of regulations - planning aspects)	Chacińska, P., Świat, P.	LI Szkoła Zimowa Akustyki Środowiska i Wibroakustyki	2024-02-27 Szczyrk, Polska 26.02 – 01.03.2024	national	presentation
LINK						
https://ogpta.pl/index.php/sz-asiw2						
42	Hałas od turbin wiatrowych w kontekście uregulowań prawnych – pomiary hałasu w środowisku (Noise from wind turbines in the context of regulations - environmental noise measurements)	Książka, P., Bukowska, J.	LI Szkoła Zimowa Akustyki Środowiska i Wibroakustyki	2024-02-27 Szczyrk, Polska 26.02 – 01.03.2024	national	presentation

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Norway grants

LINK
https://ogpta.pl/index.php/sz-asiw2

D3. NEW PRODUCTS/TECHNOLOGIES DEVELOPED
(A single product (good or service) or single technology developed or significantly improved as a result of EEA and Norway Grants 2014-2021 support)

No.	Name	Description	Project Partners	Registered applications for intellectual property protection (IPR)
1	not applicable	not applicable	not applicable	☐ YES ☒ NO

D4. REGISTERED APPLICATIONS FOR INTELLECTUAL PROPERTY PROTECTION (IPR)

No.	Name	Type of IP Rights	Application reference / number	Date of the application	Official title of the application	Patent office	Jointly registered applications for Intellectual Property Protection	Applicant(s)	Has the IPR protection been awarded?	If available, official publication number of award of protection

If the project doesn't have any application for IPR, please check the box.
☒ This project does not have any application for IPR

D5. APPLICATIONS FOR FURTHER FUNDING

No.	Title of the project	Project partners	Joint application	Funding source (applied for)	Funding source (applied for) - name of the programme	Status of the application (under preparation / submitted / funded / rejected)	Project budget (EUR) [11]

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1	Specially amplitude modulated high noise from wind turbines	SINTEF, AMU	☒ YES ☐ NO	International source (non-EU)	Bilateral initiative proposal within EEA Financial Machanism and Norwegian Financial Mechanism 2014-2021 Bilateral Fund	rejected	86 150.00

[8] this is a unique string of characters allocated to a website, file, or other piece of digital information
[9] Link to to the Open Access repository or to any other repository where a copy of the published version or the author's accepted manuscript has been deposited, or to a page within that repository providing access to the deposited version (possible after the end of an embargo period, where applicable). This is not a link to the publication on the journal/publisher website, and itis NOT a link to a personal or institutional homepage where the publication may have been posted.
[10] The date that the Open Access repository has accepted the publication

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D6. OTHER
D6.1 Link to the project website or social media profile
https://hetman-wind.ios.edu.pl/
D6.2 Indication of the website featuring the database providing free access to raw research data
The data is not publicly accessible now.
D6.3 Organization of information events on progress, achievements and results in the project, such as a seminar/workshop or a conference with stakeholders, a press conference or press event, including a launch activity and/or a closing activity for the project
The project was launched in the 'late COVID-19 pandemic', thus at the beginning we met only online. However, finally the situation improved and many meetings were organized. We had two special sessions at conferences: at Open Seminar on Acoustics in 2022 and at Winter School on Environmental Acoustics and Vibroacoustics 2024. Polish partners visited the Norwegian partner twice and two meetings of all partners were organized (once in Krakow and once in Poznan). In March 2024 we also organized an open final meeting (the invitation was sent to media, politicians and local activists), at which we presented all results and organized a formal dinner.
D6.4 Media library (links to visuals)
https://hetman-wind.ios.edu.pl/knowledge-base/
D6.5 Media coverage about the project (links)
https://audycje.tokfm.pl/podcast/156994,-Nie-da-sie-okreslic-dokuczliwosci-halasu-turbin-wiatrowych-na-podstawie-odleglosci-Jak-zrobic-to-profesjonalnie https://audycje.tokfm.pl/podcast/117258,Czy-wiatraki-wytwarzajace-prad-stwarzaja-zagrozenie-dla-mieszkajacych-w-ich-poblizu-ludzi https://audycje.tokfm.pl/podcast/132158,Jak-brzmi-wiatrak https://codziennypoznan.pl/artykul/2024-03-16/halas-turbin-wiatrowych-pod-kontrola-naukowcy-z-uam-opublikuja-najnowsze-wyniki-badan/ https://www.youtube.com/watch?v=Mqzp86GNRzc https://uniwersyteckie.pl/nauka/turbiny-pod-kontrola https://www.bankier.pl/wiadomosc/Turbiny-wiatrowe-postawione-na-glowie-Nikt-nie-mierzy-halasu-tak-jak-w-Polsce-8728006.html https://www.portalsamorzadowy.pl/ochrona-srodowiska/potrzebne-sa-regulacje-dot-norm-i-zasad-halasu-turbin-wiatrowych,537283.html https://wyborcza.pl/7,75400,30292664,akustyczka-sprawdzam-jak-halas-skraca-zycie.html
D6.6 Promotional materials
https://hetman-wind.ios.edu.pl/baza-wiedzy/
D6.7 Training materials, educational materials
https://hetman-wind.ios.edu.pl/infradzwieki-wskazniki-i-kryteria-oceny-infradzwiekow-oraz-halasu/ https://hetman-wind.ios.edu.pl/halas-turbin-wiatrowych-i-jego-percepcja/
D6.8 Master thesis, PhD thesis
"The influence of temporal and spectral structure on the perception of wind turbine noise annoyance" – Martyna Emche, Master Thesis, defended 1.02.2024, UAM, Poznań "Weryfikacja doświadczalna i analiza czynników wpływających na dokuczliwość hałasu turbin wiatrowych"- Dominika Muzyk, Bachelor, Engineering work, defended in 2023, AGH, Kraków
D6.9 Do the project results include free software or software with an open access licence?
☐ YES ☒ NO

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D7. RISK MANAGEMENT IN THE PROJECT
Foreseen risks Please, refer to the risks described in the Annex 2 to the Proposal Manual: PROJECT PROPOSAL FORM - Implementation and Management (annex to the submitted project proposal). Information about materialised risks and applied risk mitigation measures.
As it was reported a year ago, some delays were met in noise monitoring. However, after initial problems the procedure ran smoothly and now we have results of almost 16 months of the continuously monitoring. Moreover, we also managed to receive additional data from wind turbines hubs from different owners. Thanks to that, the procedure of establishing new noise limits was easier and more reliable. Unfortunately, there was no changes regarding people’s willingness to fill in surveys. However, we managed to ask several people once again (they are living near a newly built wind farm). It let us see that for this type of noise there is no adaptation effect.
Unforeseen risks Provide description of new risks identified in the project and information about planned risk mitigation measures. Please, include also information about unforeseen risks that have been already mitigated (during the reporting period).
One minor – but unforeseen risk – was that the project website was down several days because of the changes made to the Internet infrastructure of the partner. However, it was repaired and the website is still online. The biggest challenge of the last period of the project is the preparation of a good practice guide. It turned out that it is far more difficult than we thought. The online preparation of the document is not possible – as partners use different software and also formatting of figures or equations in online document does not work well. Another problem is to use a proper language – to be enough precise, but not to be too specialised as the guide should be used by people who do not work with noise everyday. However, despite many small challenges met each day, the guide is almost finished.

E. PLAN FOR COMMERCIALIZATION OF RESEARCH RESULTS AFTER PROJECT COMPLETION
E1. DESCRIPTION OF POSSIBILITIES OF COMMERCIALIZATION AND IMPLEMENTATION, APPLICATION, PRACTICAL USAGE OF THE PROJECT RESEARCH RESULTS Please include plans for commercialisation (e.g. using the research results in the business activity of the Project Promoter or partners, sale of research results, licensing, creasing spin-off, transfer of IPR to the enterprise) or implementation, application and practical usage of research results.
Possibilities of commercialization (max. 1500 characters with spaces)
Noise monitoring stations designed in the project have proved its performance in the field measurements including data collection, transmission and further processing of noise data while preserving low assembly costs and high measurement accuracy. This is very promising in terms of possible commercialization of these devices as well as a whole noise monitoring system.
Possibilities of implementation, application and practical usage (max. 1500 characters with spaces)
Prediction methods and algorithms (eg. modulation detection, immission optimisation, etc.) developed within the project can be included in a real-life wind farm (WF) noise management system. The communication protocol is easy to implement with just little effort from the WF manager/owner. Another possible application is to acquire acoustic and meteorological data to further extend the prediction accuracy or optimisation algorithms. The low-cost noise monitoring system prototyped within a scope of the project can be used to actual controlling of noise in residential areas around a WF. They can be used both as a remotely controlled system with independent noise monitoring stations connected to cloud-based database and standalone simpler detectors with sufficient accuracy and durability to be able of long term noise data acquisition.

E2. MARKET RESEARCH
Please describe market analyses of the product/technology/service that is a result of the project. Please include: competitive and substitute products/technologies/services, estimation of production costs, planned sale price, demand for the product/technology service (Max. 1500 characters with spaces)

Existing systems for wind turbine (WT) noise monitoring are generally based on commercially available noise monitoring stations (eg. Norsonic, B&K, Larson Davis, Svantek, Sonopan and so on). They are well established on the market, however the price of such a system is at least one order of magnitude higher than an expected sale price of low-cost stations prototyped within the project.
These stations are based on MEMS digital microphones and BCM2837 chip which is sufficient for the noise monitoring task and all base components are also widely available, durable and cheap. It’s design and functionality are optimised on the basis of the conclusions of HETMAN project and dedicated specifically for WT noise measurements. Planned sale price ranges between 300-1000 EUR depending on configuration.
The emerging era of renewable energy sources - including wind turbines - will enforce the location of such devices closer to the residential areas. This gives a special importance of proper WT noise monitoring and optimisation on a large scale systems consisting of dozens of noise monitoring devices. It can be predicted, that such a low-cost noise monitoring system capable of not only collecting acoustic data but also reducing (via SCADA) noise emissions while still preserving the most possible energy production will be of great importance for sustainable use of a WT.

F. PLAN FOR ENSURING THE SUSTAINABILITY OF THE PROJECT RESULTS [12]
Please include plans for continuing the research after the project is concluded (including possible sources of financing the project in the future), using the products/technologies developed in the project after the project end, plans to disseminate the project results in the future. Which factors contributed to the sustainability of results and which worked against sustainability?
Max. 3000 characters

The hardware and software parts of the noise monitoring system needs to be optimised in order to prepare production versions over the prototypes built in the project. The optimisation needs to be done e.g. in the following areas: algorithms for on-board noise data analysis in order to decrease amount of data to be transferred via GSM network, data presentation variants based on a database contents, automation of database and VPN deployment, web service and interface for customisation of noise monitoring station parameters and for in depth data presentation, cost optimisation of various PCBs and its components before production, and so on.
Noise monitoring stations for the controlling of noise from the WF will also require type approval certificate from the corresponding authority in the EU before their commercialisation.
SCADA interface will always (even after commercial system deployment) need customisation to each particular WF solutions.
We also plan to extend the list of available communication interfaces to at least LoRa and Starlink or their mix (eg. LoRa within a WF and a single Starling bridge in a selected location, and so on).
It is also necessary to conduct a market research in order to get a wider understanding of potential customer expectations and demands, optimal sales strategies, implementation schedule and more.
Future research could be financed from the application grants or own funds depending on the market situation and demand. We do not plan at the moment cooperative financing of the future releases of the noise monitoring system with WF owners/managers or noise measurement solutions manufacturers in order to keep non-biased development of the system.
The presently available prototypes of noise monitoring stations will be used for long-term testing in changing atmospheric conditions on different locations in Poland.
It is planned to reach a wider audience of the noise monitoring stations by various presentations on conferences, industry magazines and popular, widely accessible social media, etc.
In our opinion, the main factor determining the sustainability of the project results, and in particular the further development of noise monitoring stations, will be the situation on the renewable energy market. As shown during the pandemic (which caused severe delays in our project due to limited availability of electronic components and substantial price change) it is very hard to predict the real final outcome of the project in changing economic environment.

G. EQUIPMENT - LIST OF THE EQUIPMENT DEPRECIATED AND/OR PRODUCED WITHIN THE PROJECT
Please provide information about equipment used within the project implementation by adding it in the appropriate part of the table (depending on the form in which expenditures were considered as eligible (depreciation cost, purchase - in the case of small equipment; payable use of equipment – leasing, rent)

Equipment purchased within the project

No.	Name of the equipment	Cost (PLN)	Year of purchase	How will the equipment be used after completion of the project?

☒ Not applicable

Equipment produced within the project

No.	Name of the equipment	Cost (PLN)	Year of production	How will the equipment be used after completion of the project?

☒ Not applicable

Equipment depreciated within the project

No.	Name of the equipment	Cost (PLN)	Year of deprecation	How will the equipment be used after completion of the project?
1	Signal recorder MODEL EXPERT 35120-EV 16	12383.91	2022	The measurement system will be used to non-commercial research.
2	Measuring set consisting of infrasound microphone and preamplifier	36449.18	2022	The measuring set consisting of infrasound microphone and preamplifier will be used to non-commercial research.
3	Laptop PROBOOK 455 G7	4483.01	2022	The laptop will be used to non-commercial research
4	Devices for testing the impact of infrasound on humans (subwoofers, speakers, multichannel recorder, closed and open reference headphones, complete set of cables and stands)	52530.84	2022	The equipment acquired for this project will be utilized for ongoing scientific research in the field of acoustics, specifically focusing on the impact of infrasound on humans. Post-project, the subwoofers, speakers, multichannel recorder, and reference headphones will be employed in experimental setups to further investigate the physiological and psychological effects of infrasound. The complete set of cables and stands will support various configurations necessary for precise measurements and data collection. Additionally, this equipment will be available for collaborative research with other institutions, fostering advancements in acoustic science. It will also serve as an educational tool for training students and researchers in advanced acoustic measurement techniques.
5	Laptop, Audio equipment (USB Audiointerface BabyFace Pro FS, two povered Studio monitors LS 5, Yamaha, powered subwoofer DX12 MK, Yamaha)	7743.18	2023	The devices remain in the research unit after the project is completed and will be used in research projects and to disseminate theirs results also these of the current project.
6	Laptop, Audio equipment (USB Audiointerface BabyFace Pro FS, two povered Studio monitors LS 5, Yamaha, powered subwoofer DX12 MK, Yamaha)	598.57	2024	The devices remain in the research unit after the project is completed and will be used in research projects and to disseminate theirs results also these of the current project.
7	*Noise monitoring stations (2)*	60943.88	2024	*Will be used in the field. The devices remain in the research unit after the project is completed*
8	Laptop with software (1 unit)	5200.00	2021	Noise data collection and analysis, field measurements, access to database, data visualization
9	Laser distancemeter (1 unit)	1979.00	2022	Field measurements
10	Extra tall microphone masts (2 units)	4428.00	2022	Field measurements, long-term noise monitorin
11	Meteo stations (2 units)	12546.00	2022	Field measurements, long-term noise monitoring
12	Noise monitoring stations (2 units)	77434.92	2024	Field measurements, long-term noise monitoring, data acquisition

13	Maintaince upgrade and expansion of Matlab environment (1 unit)	56230.69	2024	Further development and testing of software tools for noise data collection and analysis, database communication, and presentation of the results

Payable use of the equipment within the project

No.	Name of the equipment	Cost (PLN)	Year of usage	How will the equipment be used after completion of the project?

☒ Not applicable

H. INFORMATION ON AUDITS/ON-THE-SPOT VERIFICATIONS AND IMPLEMENTATION OF AUDIT RECOMMENDATIONS

No.	Type of audit	The entity carrying out the audit	Date	Recommendations	Compliance with the audit recommendations	To what extent the audit recommendations have not been applied and reasons for not applying the recommendations
1	Scheduled inspection.	National Centre for Research and Development.	2022-03-10 - 2022-03-11	As a result of the inspection, no ineligible costs were found. As a result of the inspection, no other irregularities or shortcomings were found.	Not applicable.	Not applicable.
2	Scheduled inspection.	National Centre for Research and Development.	2022-11-17 - 2022-11-17	As a result of the inspection, no irregularities or shortcomings were detected in the period covered by the inspection, i.e. from January 1, 2021. until October 31, 2022	Not applicable.	Not applicable.
3	Planned control - audit at the end of the project.	Idea Audit Financial Audit	2024-04-01 - 2024-05-31	As a result of the inspection, no irregularities or shortcomings were detected in the period covered by the inspection, i.e. from January 1, 2021. until April 31, 2024	Not applicable	Not applicable

I. HAS THE PROJECT CONTRACT BEEN TERMINATED BEFORE THE DATE OF THE PROJECT COMPLETION SPECIFIED IN THE PROJECT CONTRACT?
IF **YES**, PROVIDE THE REASONS FOR TERMINATION AND A DESCRIPTION OF THE CURRENT LEGAL SITUATION, INCLUDING THE STATUS OF THE CONSORTIUM AGREEMENT.

Has the project been terminated before the date of the project completion specified in the project contract?	Reasons (if applicable)
☐ YES ☒ NO	-

Person responsible for preparing the final report (technical part)	**Name and last name:**	Anna Preis
	Phone number:	501 132320
	E-mail:	apraton@amu.edu.pl

[11] In case of the application having budget in other currency than EUR, please use the exchange rate from the date of submission of proposal. For proposals under preparation, please use the current exchange date (date of preparing the final report).
[12] OECD DAC definition of sustainability (2019) "the extent to which the net benefits of the intervention continue or are likely to".