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PERIODIC REPORT (TECHNICAL PART) of project implementation Programme 'Applied Research'				
Report number [1]	2			
Reporting period	**from**	01.01.2022	**to**	31.12.2022

A. PROJECT INFORMATION				
Number of project contract	NOR/POLNOR/Hetman/0073/2019		**Acronym**	Hetman
Duration of project	**from**	01.04.2021	**to**	01.04.2024
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 / Central Mining Institute	Główny Instytut Górnictwa	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

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

B1. Principal Investigator	
First and last name, academic degree/title	Anna Preis, profesor zwyczajny
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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	30.09.2023	actual [5]	in progress
Cost of WP (PLN)	planned	890 524.11	actual (value at the end of the reporting period)	312 745.09
Implementing entities	UAM / AMU, Akustix, SINTEF, Główny Instytut Górnictwa , 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 specific tasks to be carried out in the reporting period were Task 1.2: Online annoyance assessment will be conducted in chosen localization and Task2: Noise annoyance - laboratory experiments.

The purpose of Task 1.2 was to determine the wind turbine noise parameters crucial for annoyance (modulation depth, LAeqT, S/N ratio, conditions under which turbines are not audible) in several houses at different distances from the turbines. This task was conducted parallel with the Task 2 from WP2.

Regarding Task 1.2, we were able to conduct 75 surveys (face to face) in the following locations: Farm A- Lodz Province (15), Farm B- Lubuskie Province (10), Farm C- Greater Poland Province (25), Farm F- Lubuskie Province (25). In the survey audio examples were included which were presented to residents via headphones.

Regarding Task 2.1, the noise samples recorded in the field are assessed to get the exact relationship between annoyance ratings and wind turbine noise parameters (chosen from task 1.1 and 1.2). ICBEN scale is used in annoyance noise assessment. This experiment is still going on.

Task 2.2 is carried out within the framework of the tasks envisaged in WP5, determined jointly with the researchers carrying out tasks under WP1. The exact determination of parameters such as threshold wind speed at which turbines are inaudible (masked by wind induced noise) will be determined. The analysis will be performed to determine whether and how often occurs such conditions. This experiment is still going on.

Regarding task 2.3, 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. 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. We are currently in the process of analyzing these results.

SINTEF, Akustix, GIG, IMP, PSEW:

Participation in weekly discussions and planning of progress of 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 this period.

During the reporting period, the tasks to be carried out were **Tasks 1.2 and 2**. As part of **Task 1.2**, we had to: conduct online annoyance assessment in chosen localization. The purpose was to determine the wind turbine noise parameters crucial for annoyance (modulation depth, LAeqT, S/N ratio, conditions under which turbines are not audible) in several houses at different distances from the turbines. This task was conducted parallel with the Task 2 from WP2. It has been done (75 surveys) in 4 localizations using the face to face method. 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. We plan to continue conducting further surveys at the site where annual wind turbine measurements are conducted in accordance with task 2 in WP2. Our preliminary findings suggest that people evaluating annoyance in their homes understand this concept – annoyance - as do people evaluating annoyance in laboratory experiments. Regarding the parameters relevant to assessing the annoyance of wind turbine noise, the "variability of wind turbine noise" prevails in past surveys. This is a parameter related to the amplitude modulation present in this noise. To date, for most of those surveyed, wind turbine noise is not audible at home. They hear the noise when they are outside their homes. These conclusions need to be confirmed for more surveys - the target is 300.

The analysis of previous surveys (**Task 1.2**) as well as a review of recent literature (**Deliverables D1.2 and D4.1**) led us to the conclusion that crucial wind turbine noise parameters worth investigating in laboratory experiments on a selected target group (**Deliverable D1.1**) are: the distance (which directly relates to LAeqT) of the listener from the wind turbine, the variation of wind turbine noise amplitude measured by modulation depth, and visual effects affecting the annoyance of the noise under study.

Task 2 „Noise annoyance - laboratory experiments" consists of **3 subtasks: 2.1, 2.2, 2.3** under which we were to do:

Within **Task 2.1** to perform **3 experiments**. In the **first one** participants have to assess the noise samples recorded in the field to get the exact relationship between annoyance ratings and the distance of the wind turbine from the listener. The results of this experiment will be presented at the "Forum Acusticum" conference in September 2023 in Torino. This experiment is being conducted as part of student Martina Emche's master's thesis.

In the **second one** the participants have to assess the effect of visual information on the perception of wind turbine noise annoyance. This experiment is being conducted as part of the master's thesis of Mikołaj Kryszak.

Finally, in the **third experiment part** the participants have to assess the effect of modulation depth on the noise annoyance generated by the wind turbine. All three experiments will be completed according to the project schedule.

Within **Task 2.2** the masking effect is studied together with partners form WP5. This laboratory experiment determines what level of noise generated by another sound source , in this case a highway, is able to mask the noise of a wind turbine. In addition, the wind speed at which the noise generated by the wind turbine itself is inaudible will be determined.

Within **Task 2.3** the adaptation effect is studied. We decided to study the effect of adaptation to wind turbine noise at two time points: when the wind turbines were not yet operating (April 2022) and when they had already been operating for 6 months (January 2023). The annoyance of the same sound stimuli was evaluated by people in their places of residence (presentation of five recordings of wind turbines through headphones). A comparison of the ratings of annoyance made by the same survey participants will allow us to answer the question of whether there is any difference in these ratings or not. There is a chance that we will still be able to get evaluations from the same research participants after a year of wind turbine operation.

Deliverable D1.2: Determination of wind turbine noise parameters crucial for annoyance (M12) is included in joint publication "How to determine the annoyance due to wind turbines" by A. Preis and T. Gjestland.

With a view to further tasks for WP1 (**Tasks 3 and 4**) a good experience was the visit of Polish partners in Trondheim. During a project meeting in Trondheim in June, 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.

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**
D1.2 Determination of wind turbine noise parameters crucial for annoyance (M12)	UAM / AMU	D1.2.zip	It can be made ; available on the project website: https://hetman-wind.ios.edu.pl

Milestones [7]

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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	UAM / AMU	31.03.2023	yes	31.03.2023	The milestone was planned to be achieved in the 2023, not 2022 (and this year is raported in this report). Thus, the details about it will be discussed in the next report, however, as the report is filled in in May of 2023, we can confirm that this milestone was achieved in 2023 with no delays.

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 to determine impact on further implementation of the project and achievement of planned results of the project. (max. 1500 characters with spaces)
not applicable

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	30.11.2023	actual [5]	in progress
Cost of WP (PLN)	planned	1 133 687.50	actual (value at the end of the reporting period)	344 384.55
Implementing entities	UAM / AMU, Akustix, Akademia Górniczo-Hutnicza im. Stanisława Staszica, SINTEF, Główny Instytut Górnictwa , Polskie Stowarzyszenie Energetyki Wiatrowej			
An explanation of the work carried out by the implementing entities (max. 2500 characters with spaces)				

AKUSTIX:

Task 2 – Verification of the of the method prepared in Task 1 by extended field measurements; data delivery to WP4, WP5 and WP 6.

The main noise measurements and recordings necessary to develop final measurement method were conducted in real working wind farm conditions (Głuchów wind Farm, Lodz Province, referred in the text as Farm A). Wind farm A was selected as main research site due to good cooperation with the wind farm manager.

In cooperation with wind farm manager data measurement were conducted during operation of all turbines, then they were switched off sequentially until only one of them was operating. Finally, when all turbines were turned off background noise was recorded for several wind speeds.

Recordings were conducted simultaneously at several locations around central wind turbine at different microphone heights. For the position at ground (on the plate) different microphone orientations and wind screens were used (see Task 3).

The dataset contains data for experiments covering scenarios ranging from one turbine to the entire farm. Data analysis of this stage is still in progress along with the field study data analyses of Task 4. It is because this data are being used many times for different topics (tasks in WP 2 – WP

6), depending on specific demand such as testing the influence of microphone height and wind induced noise on the measurement result, determination of amplitude modulation depth, wind turbine directivity as well as validation of prediction methods.

Verification of the proposed noise monitoring will be conducted in real life conditions on the data from wind farm Lubno, Lubuskie municipality, referred as Farm B. As the second site for verification/tuning of the method wind farm Kuślin (3,3 MW turbines VESTAS V126), Greater Poland Province, was selected, referred as Farm C. Field measurements are planned for 2023 after the start-up phase of installation.

Task 3 –Technical specification of requirements for the measurement set-up dedicated to wind turbine noise monitoring based on results of Task 1, corrected if necessary during Task 2

Measurement campaigns were conducted in laboratory test conditions of aerodynamic tunnel on the efficiency of existing and available windscreen solutions as well as different types of double layered windscreens designed in our laboratory for the purposes of this task. Tests were made at different wind speeds in order to choose optimal solution for a real life wind speeds in the field. The key part of the noise monitoring methodology being prepared for the delivery (Deliverable 2.1, M32) is the wind speed range to access wind turbine noise (WTN) in real life monitoring.

In the next step, set of experiments was prepared to validate the results of aerodynamic tunnel tests in real wind conditions. The above mentioned different types of windscreens, including prototypes with a larger diameter than those tested in a tunnel, where exposed to outdoor (low background) noise environment in different wind speeds.

Data analysis of this stage is in progress (it was not finished by the end of 2022 due to starting WP 2 initial delay (as reported in 2021).

Task 4 – Complete methodology of noise monitoring ready for WP7 Task 7.5; data delivery to WP4, WP5 and WP6.

We have built 5 monitoring stations (based on Norsonic type Nor 145 sound level meters) dedicated for long term noise monitoring in the field. Test site was arranged with "ENEA Nowa Enegria sp. z o.o." wind farm operator (partnership agreement of 1st April 2022). These monitoring stations were then located on the Farm B and start working since January 2023.

Noise monitoring stations provide instantaneous noise levels and audio recordings. These data are correlated with wind turbines operating parameters and weather conditions and will be used for validation / verification and further tunning of initially proposed noise monitoring methodology.

SINTEF:

Discussions and planning of WTN measurements. Preparation of guidelines (based on SINTEF experience on WTN measurements) on additional microphone location (close to and perpendicular to the ground) tests as an extension of Task 1 outcomes. Measurements will be used for validation of WTN prediction method in WP4.

UAM, AGH, GIG:

Discussions and planning of WTN measurements. Participation in measurement campaign at wind farm A (stuff and equipment), Task 2.2. Finally, resources of project partners allowed for the construction of measurement facility composed of 20 noise measurement stations.

Measurements are being used for validation of WTN prediction method in WP3.

Long term monitoring of Task 4 is accompanied by wind turbine sound recordings (wav files) which provide samples to WP 1 experiments, especially in AM threshold detection.

Activities due to WP 2 in Hetman Project:

During project meeting in Trondheim, June 2022, the Polish partners were introduced to Norwegian policies on WTN management, including noise monitoring procedures and how interaction between the wind park owners and the local community built trust and reduced conflicts.

Participation in weekly discussions and planning of progress of the project.

Presentation of current WP2 results on annual Hetman Project meeting in December 2022.

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 this period.

Task 2 – Verification of the of the method prepared in Task 1 by extended field measurements; data delivery to WP4, WP5 and WP 6.

Data were collected for 2 MW turbines VESTAS V90 (wind farm A) at distances: 150 m, 250 m, 500 m, 750 m, 1000 m, 1500 m in two directions: downwind and crosswind at three microphone heights: 0 m, 1.5 m and 4.0 m. Measurements were carried out simultaneously in all locations. During measurements 1/3 octave instantaneous RMS and audio signals – at 1.5 m height were recorded. These data are correlated with wind turbines operating parameters (feedback from farm operator) and weather conditions monitored either at wind turbine hub height (feedback from farm operator) or at 4 m and 10 m (AkustiX weather station).

At 0 m height microphone position (onboard measurements) we tested three types of wind screens and two microphone orientations (horizontal one and – due to SINTEF proposal - vertical one, with microphone facing downwards).

Measurement sessions with one turbine turned on (all others turned off) provides data for basic experiments with one source (necessary to validate noise monitoring procedure, delivery D 2.1, and general noise prediction method, see WP 4, as well as to assess the accuracy of short-term Leq predictions based on instantaneous weather conditions, i.e. wind: direction, speed and vertical profile, see WP 6 Task 2).

Wind speed profiles were taken from accompanying weather measurements conducted at three heights (hub height, 10 m and 4 m).

Data from measurement sessions with more than one working turbine have been prepared for the stage of the proposed methods for noise monitoring as well as for noise prediction of the whole wind farm. This process is in progress.

Wind noise recordings taken during time intervals with all turbines turned off were used as a contribution to database of different type wind shields efficiency (see Task 3).

For the purposes of method verification initial measurements were made on farm B (2,35 MW ENERCON E92 turbines). Measurements for this purpose will be continued at this farm.

The results obtained so far:

· clearly shows the directivity of wind turbine noise radiation in crosswind direction of the order of 2 – 3 dB in the range of distances 150 m – 1000 m,

· shows amplitude modulation depth of SPL in the range up to 5 – 7 dB recorded in cross-wind direction at point closest to turbine (150 m) is decreasing with distance.

Analyses of the measurement results preformed so far in relation to the microphone height recommends for the delivery D 2.1 standard measurement height of 1.5 m above ground. Data shows 0 – 3 dB lower background level compared to 4 m along with a much lower difference compared to 0 m on board measurements. This is a compromise, supported by two technical arguments. Mounting microphone for 1.5 m measurement is simplest (especially compared to 0 m position set-up requirements, albeit with the least wind induced noise). On the other hand, accuracy of examined prediction methods, including Nord 2000 (WP 4) is better with increasing height of the observer.

Task 3 –Technical specification of requirements for the measurement set-up dedicated to wind turbine noise monitoring based on results of Task 1, corrected if necessary during Task 2

The idea is to develop relatively simple wind turbine noise measurement procedure ready to implement to the state regulation on environmental noise monitoring, so that it would be accessible to administrative bodies of environmental protection, installation managers and local communities to measure (control) the actual impact of wind turbines. The main issue in wind turbine noise measurements is the reduction of wind induced noise by a wind shield. To comply with the assumption of simplicity dedicated windscreen should be easily accessible and cheap.

In Task 3 we have made a set of laboratory tests (in aerodynamic tunnel at Instytut Techniki Cieplnej in Łódź) of an existing windscreen solutions as well as designed in our laboratory different prototypes of double layered windscreens. The following configurations were tested: standard 45 mm windscreen both in position parallel and perpendicular to the inflow, the above with hairy cover (“deadcat”), Svantek SV297, Norsonic NOR 1217, prototypes: single/double layer of material, two densities of materials, in parallel/perpendicular position. The tests were made at different wind speeds, from 3 m/s to 11 m/s, in order to choose optimal solution for a real life wind speeds in the field. RMS in 1/3 octave bands of wind induced noise (result of interaction of wind flow and windscreen) was measured. Then comparative analyses were conducted.

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It showed that:

· windscreen SV279 induces lower noise levels than either standard 45mm or NOR 1217 ones,

· prototypes with outer layer of diameter 20 cm give in general lower noise levels than standard 45mm windscreens, but it did not give better results than SV279 which is simpler in construction,

· the larger the diameter the lower is wind induced noise level which explains best results of SV279,

· adding second layer improves the result.

Next step of the research was planned to expand the set of tested windscreen configurations. Prototype solution is based on either standard 45 mm windscreen or SV279 with second layer of greater diameter (30, 35, 40 cm). In this stage windscreens are tested in the field exposed to real winds. This part of the task is in progress.

Task 4 – Complete methodology of noise monitoring ready for WP7 Task 7.5; data delivery to WP4, WP5 and WP6.

Facility composed of 5 monitoring stations designed for long term wind farm noise monitoring in real outdoor environment was prepared. We have selected the wind farm with typical (at the time of Hetman Project) 8 wind turbines each of 2,35 MW power, located far away from potential sources of extraneous noise (wind farm B). Partnership agreement with the farm operator provide us full synchronization of noise data with instantaneous operating parameters of turbines (rotation speed, pitch angle, wind direction, wind speed, humidity and temperature at hub height). Except that, weather data are recorded at heights of 10 m and 4 m by our station accompanying one of noise monitoring stations. For these stations we select locations at distances of 500 m to 800 m to the nearest turbine. They are situated in four directions relative to the centre of the wind farm. The 5th station is located close to the in centre wind turbine to always have information on actual emission level. We got agreements with land owners and built power supply and data transmission infrastructure. Data are collected in dedicated database and are used by other WP's.

This experiment is planned for 12 months.

Distribution of monitoring stations around wind farm gives information on noise levels at several angles to the wind direction at a time. It allows for the validation of calculation methods (WP 4, WP 6 Task 2) either for different propagation conditions or source directivity. These two factors depend on either actual wind direction or location of the observation point in relation to the position of the source.

First results will be presented in 2023 as a two conference papers:

· validation of prediction methods (WP 4) at Inter Noise (Tokio, August 2023) – paper by SINTEF and AkustiX

application of prediction methods to wind farm noise management (WP 6 Task 2) at Forum Acusticum (Torino, September 2023) – paper by AkustiX and SINTEF.

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
No record			

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	30.11.2023	no	-	Proposing a new research methodology requires an adequate amount of measurement data collected and verified. This is how the work accutally proceeds.

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 to determine impact on further implementation of the project and achievement of planned results of the project. (max. 1500 characters with spaces)

During 2021 and 2022 due to Covid restrictions it was not possible to arrange noise monitoring campaign in Norway for the types of wind turbines which are not represented in Poland for the time being (as planned in Task 2). To fill this gap, with the efforts of PSEW and SINTEF as well as by literature review we are trying to gather existing data of noise measurements carried out by other laboratories, available with necessary supplementary data (wind turbine operating parameters, weather data).

Task 2 and Task 3 were not finished by September 2022 mainly due to the initial delay of starting WP 2 what was reported in 2021. But also farm managers were uncooperative due to low energy production for a large part of the year but mostly reluctant to share operating data. That's why data are still been collected. Results will be available in 2023 without negative impact either on other tasks of the project or its planned deliverables.
Wind farm C - field measurement site for tunning of the proposed noise monitoring method – will be available in 2023, after start-up phase of the farm.

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	31.12.2023	actual [5]	in progress
Cost of WP (PLN)	planned	529 182.14	actual (value at the end of the reporting period)	281 514.44
Implementing entities	Akademia Górniczo-Hutnicza im. Stanisława Staszica, Główny Instytut Górnictwa , 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)				

During the period described, the tasks to be performed were **D3.2, D3.3** and **D3.4**. Task **D3.2** involved developing the proposal of methodology for infrasounds' measurements and recording. The first aim was to determine the suitability of various wind shields for use in infrasound and low-frequency noise (ILFN) measurements. The second aim was to determine the method of taking measurements (on the ground or on a tripod at different heights above the ground). For this purpose, it was necessary to make sound pressure measurements by an infrasound-generating source. The ventilation shaft "Kosciuszko" belonging to the Wieliczka Salt Mine (Małopolskie Province) was chosen for the measurements. The unquestionable advantage of this noise source is that it works regardless of weather conditions, that is, both in windless weather and during intense winds. Next, measurements were made already in real conditions at Farm D - Podkarpackie Province. Based on the analysis of the measurements taken, the best way to take measurements was determined.

Under D3.3, it was necessary to provide proposals for ILFN indicators useful in assessing the impact of this noise on annoyance. Based on **D3.1**, useful indicators were preliminarily identified. In addition, a study was performed on a control group of 129 students to determine the impact of ILFN, accompanying the operation of wind turbines in Poland, on human well-being. The subjects completed a cognitive test assessing attention under three exposure conditions (background noise, synthesized LFN (reference noise) and recorded wind turbine infrasound (stimulus)). It also tested whether the modulated signal could have a negative effect on mental performance. Work on **D3.3** is still in progress.

As part of **D3.4**, an acoustic model of Farm A- Lodz Province had to be made. SoundPLAN software was used to build the model. Based on acoustic measurements taken in March 2022, the acoustic power of the turbine (necessary for building the model) and the environmental noise level (for tuning the model) were determined. ILFN noise propagation was calculated using two computational models for comparison with the measurement results. Work on **D3.4** is still in progress, and the next step will be to use the NORD 2000 method to calculate ILFN propagation in the environment.

GIG, IMP, PSEW:

Participation in weekly discussions and planning of progress of 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 this period.

During the reporting period, the tasks to be carried out were **Deliverables D3.2, D3.3** and **D3.4.**

In **Deriverable D3.2**, the proposal of methodology for infrasounds' measurements and recording was developed.

In order to verify the suitability of wind shields in application to low-frequency noise measurements, the sound pressure generated by the "Kościuszko" ventilation shaft belonging to The "Wieliczka" Salt Mine, Małopolska, Poland, was measured. This source was chosen because it generates sound covering the low-frequency band regardless of wind conditions. This made it possible to determine the effect of wind on the measurement result using various methods: 1) 4m tripod with classic wind shield; 2) 1.5m tripod with classic wind shield; 3) Board at ground level with half windscreen (primary windscreen IEC 61400-11); 4) Board at ground level with double wind shield (IEC 61400-11); 5) 1m tripod with classic wind shield placed in the tent functioning as a second shield.

As expected, the most significant interference in the low-frequency range was registered at microphones placed on tripods with a single traditional wind shield. Marked interference was also registered on the board, but with a single wind shield, as in the case with a microphone placed in a tent. The best results were obtained for the measurement on the double-shielded board (IEC 61400-11).

The measurement set was tested under real conditions at a Farm D – Podkarpackie Province. The measure was realized at a distance of 130 m from the turbine.

For measurements made with an average wind speed of 2.1 m/s with gusts up to 4.5 m/s, the best results were obtained for measurement on a board with a double wind shield and measurement in a tent. However, for higher wind speeds (average speed of 3.5 m/s with gusts up to 6.7 m/s), the measurement on a board with a double wind shield proved to be the best, which is indicated by the lowest dispersion of results.

In summary, it can be stated 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, it is not necessary to use different wind shields for the audio and infrasound bands in acoustic measurements of wind turbines. In both cases, measurement on a board with a double wind shield works well.

Milestone 1 was based on **Deliverable D3.2**.

Deliverable D3.3 proposes ILFN indices useful in assessing the impact of this noise on annoyance. Available studies indicate that ILFN, especially in the infrasound band, is more annoying than noise in the audible band of similar loudness. The reasons for this effect include a greater dispersion of the perception threshold in the low frequency range as well as the influence of non-acoustic factors that "inform" about possible infrasound, including sounds with higher frequencies (higher harmonics) of sounds from the infrasound band, as well as perceived vibrations. The above makes it difficult to indicate universal indicators that will be well correlated with the perception of sound in the low frequency range, on the other hand, they are easy to measure. As a result of the analysis of literature studies, single-number indicators - differences in LC-LA levels and G level as well as indicators based on hearing threshold curves - Moller & Pedersen, Watanabe & Moller, DEFRA and the G86 spectrum (SPL levels in 1/3 octave bands, corresponding to the level of LG=96 dB) were indicated as potentially useful. The usefulness of the LG level in the assessment of infrasound noise and the levels corresponding to the G86 threshold curve have been shown to be quite good. More details and analyzes of infrasound indicators can be found in publication 3 (point D1).

Within the research related to ILFN assessment, the influence of acoustic conditions and gender on the level of human mental performance, as well as that of the feelings and ailments associated with the exposure conditions, were analyzed. 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). The main aim of the experiment was to investigate whether the IS and

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LFN accompanying the operation of wind turbines in Poland affect human well-being. In particular, an attempt has been made to answer the question of whether modulated IS and LFN can negatively affect mental performance compared to signals without modulation.

The main, but not straightforward, conclusion of the work is that there were no statistically significant differences in response rates between subjects exposed to infrasound of WT origin and steady infrasound without AM modulation. However, small but significance differences were visible between people exposed to WT infrasound and people without exposure. Generally, the latter subgroup less frequently reported feeling pressure changes in the head, experience of physical or mental discomfort and the perception of any changes in exposure conditions. The second output should be especially robust due to its potential prominence; therefore, several other factors have been carefully examined.

There were also significant differences between females and males. Generally, a greater proportion of males perceived changes due to exposure conditions, while females more often felt worse after classes. However, no significant impact of exposure conditions was observed when analyzing the proportions of answers to the post-exposure questionnaire in men and women separately.

There were no significant differences in the self-assessment of well-being before classes between subjects performing the psychometric test in various exposure conditions. Basically, with one exception, neither exposure conditions nor gender had a significant impact on the self-assessment of subjects' well-being before classes. In addition, there were no significant associations between the performance level of the psychometric test and the self-assessment of students' well-being before classes. Generally, subjects well rested before classes felt better after their end. Additionally, no significant differences in performance levels of the work under stress simulator test in various exposure conditions were found in males and females analyzed separately. Similar results were obtained when analyzing the total number of feelings and ailments subjectively related to exposure conditions during classes.

As part of **Deliverable D3.4**, a geometric and acoustic model of the wind farm under study (Farm A- Lodz Province) was built in SounPlan software. Based on the measurements, the sound power level of the wind turbine in the tertiary frequency bands between 1 Hz and 8 kHz was determined in accordance with EN 61400-11:2013/A1:2018, which was used to model the propagation of ILFN in the environment.

ILFN noise measurements were also carried out at various distances (250 m, 500 m, 1000 m, 1500 m) from the wind turbine, which were used to verify the computational models. Measurements were taken for two microphone locations: on a plate located on the ground and at 4 m above ground level. The propagation of ILFN noise generated by the wind turbine was calculated using two calculation methods, namely ISO 9613-2 and CNOSSOS-EU in the frequency range from 1 Hz to 250 Hz. The calculations were made for two receiver locations, the same as during the measurements. The ISO 9613-2 and CNOSSOS-EU methods allow calculations in the frequency range from 63 Hz to 8000 Hz, so the same propagation parameters have been assumed for frequency bands below 63 Hz as for the 63 Hz band. The results of the calculations were compared with the results of the measurements.

Subsequent work under **Deliverable D3.4** will involve the use of the NORD 2000 method to calculate ILFN propagation in the environment. As a result, the results of the calculations obtained using the three aforementioned methods will be compared with the results of the measurements carried out around the wind farm.

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**
D3.2 The proposal of methodology for infrasounds' measurements and recording	Akademia Górniczo-Hutnicza im. Stanisława Staszica	D3.2.zip	It can be made available on the project website: https://hetman-wind.ios.edu.pl

Milestones [7]

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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	31.03.2022	yes	31.03.2023	It can be made available on the project website: https://hetman-wind.ios.edu.pl
2	Measure of infrasounds' impact on people	Akademia Górniczo-Hutnicza im. Stanisława Staszica	31.10.2023	no	-	Laboratory studies are currently being conducted on the effects of infrasound on the human body.
3	The possibly simple method of calculation infrasounds' noise indices	Akademia Górniczo-Hutnicza im. Stanisława Staszica	31.12.2023	no	-	Reaching this milestone will be possible after completion of laboratory testing

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 to determine impact on further implementation of the project and achievement of planned results of the project. (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	30.09.2023	actual [5]	in progress
Cost of WP (PLN)	planned	483 475.00	actual (value at the end of the reporting period)	128 053.13
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)				

SINTEF: It has been decided to use the Nord2000 sound propagation module. Necessary software has been transferred to Akustix so they can do own calculations. Calculations will be made using the ISO9613 and the CnossosEU propagation modules in addition to Nord2000 and compare the prediction results with actual field measurements.

Akustix, AGH, PSEW: Participation in weekly discussions.

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 this period.

A number of noise prediction programs are available commercially. The programs differ both with respect to input and output parameters. Some programs will only calculate worst case scenarios and assume very simple meteorological conditions (down-wind in all directions) and with the yearly average noise level, Lden, as the only output. Other programs rely on detailed meteorological data and will calculate the noise level in given positions under actual weather conditions.

The useful frequency range also varies. Some prediction programs have output values in dBA only, whereas others will present results for the full frequency range down to infrasound. The most sophisticated programs require detailed input parameters (meteorological data and ground surface characterization). These programs are not intended for use by the general practitioner but require specialist operators.

It has been decided to use the Nord2000 sound propagation module for noise predictions in the project. Software has been made available for Akustix and preparations have been made to do parallel calculations using different propagation modules, and to compare the predictions with actual field measurements. Work is currently being done to compare predicted noise level using different propagation modules with actual field measurements at a wind farm A.

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 4.2 Guidelines for acquisition and assignment of reliable model input data and parameters for a given wind farm	SINTEF	D4.2.zip	Included in SINTEF report 2022:00637 Noise from wind turbines: Physics and psychology

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.	SINTEF	30.06.2023	no	-	All partners are included in discussions on choosing the best method to predict noise generated by wind turbines to the environment.

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 to determine impact on further implementation of the project and achievement of planned results of the project. (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	31.03.2023	actual [5]	in progress
Cost of WP (PLN)	planned	354 943.75	actual (value at the end of the reporting period)	137 247.00
Implementing entities	UAM / AMU, Akustix, Akademia Górniczo-Hutnicza im. Stanisława Staszica, Główny Instytut Górnictwa , Polskie Stowarzyszenie Energetyki Wiatrowej			
An explanation of the work carried out by the implementing entities (max. 2500 characters with spaces)				

AMU: Preparation and execution of 3 psychoacoustic experiments: (1) determination of wind turbine noise detection threshold amid road-traffic masking noise, (2) determination of “annoyance threshold” of wind turbine noise aid road-traffic masking noise and (3) determination of “annoyance threshold” amid maskers of combined road-traffic noise and wind sounds. All experiments determined threshold as a function of level and distance from the source (wind turbine). Term “annoyance threshold” refers to distance/level of presentation at which subjects consequently pointed at samples with wind turbine noise as more annoying than samples without wind turbine noise.

Preparation of psychoacoustic experiment of audio-visual annoyance of wind turbine noise/view using VR technology. Execution of the experiment has not began in 2022.

Conducting noise measurements and recordings of: (a) road traffic noise near A2 highway at different distances; (b) wind sounds at constant wind speed corresponding to wind speeds at site of wind turbine noise measurements.

Modelling of the propagation distances of wind farm noise with/without present “hard” reductions methods – methods of sound pressure level reduction. Modelling was undertaken using SoundPLAN software.

Akustix, AGH, PSEW: Participation in weekly discussions.

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 this period.

In 2022, the Work Package 5 research team focused on preparing and conducting psychoacoustic experiments testing the "soft" methods of wind turbine noise reduction proposed during the implementation of Task 1. Psychoacoustic experiments were conducted on the basis of recordings and measurements of wind turbine noise, which took place in 2021. Masking wind turbines with sounds commonly found in the vicinity of wind farms - road noise - was adopted as a reduction method. Samples of highway sounds that later became masking sounds were prepared on the basis of acoustic measurements. An experiment was also prepared using a natural masking sound - wind.

Real recordings were used for the experiments, which were filtered through a transfer function based on the Nord2000 methodology. This methodology was adopted in the Hetman project to conduct noise modelling and calculations due to the function that takes into account the noise spectrum in 1/3 octave bands. In the case of wind turbine noise and noise perception research, this is an extremely important element, because it is impossible to conduct a detailed sound analysis based on a single-number indicator (which is the result of commonly used methodologies: ISO 9613 or CNOSSOS-EU). A set of samples for experiments reflecting sounds at different distances from the source was created from a source sample recorded at a distance of 150m from the turbine. The source sample was filtered through a transfer function that changed the spectrum of the recording in one-third octaves in the range of 20 - 10,000 Hz. Samples were generated for distances from 150m to 2150m in steps of 10m.

The aim of the prepared experiments was to determine the limit of perception of wind turbine noise against the background of masking sounds (motorway noise) and the level ratio between the turbine and motorway signal (signal to noise ratio - SNR). The effectiveness of masking the sounds of wind turbines was to be determined by testing the detection (recognition) of wind turbine sounds against the noise of the highway, and the obtained perception threshold - expressed in the level of the sample at which the sound of the turbine just stopped being heard, or by the distance corresponding to this sample at the detection threshold which defined the criterion for the implementation of this "soft" noise reduction method.

The research was conducted on a group of subjects with normal hearing. The first experiment investigated the noise detection threshold of wind turbines. The subjects had to listen to 2 sound samples, both of which contained masking sounds, but only one in randomly order presented sample contained the sound of a wind turbine, and indicated which one contained the turbine noise. The 2AFC method was used, which forces a decision to be made even if the subject does not know which answer is correct (which sample contains wind turbine noise). When the answer was correct, the experiment procedure made it difficult to hear the turbine against the background of the masker by reproducing a sample corresponding to the greater distance of the sound source from the subject. If the answer was wrong, the experiment became easier by reproducing sounds corresponding to the closer distance of the source from the subject. The experiment was repeated for three distances of presentation of the masking noise, and in each of them the detection thresholds for the noise of wind turbines against the background of the motorway were determined. The results of the first experiment showed that if the subjects know the source of the sound or what sound they are supposed to "search for", they mostly indicate the correct sample even with a very negative SNR < -20dB. For this reason, in the next experiment, the test procedure was changed so that it better reflects the real conditions of exposure to wind turbine noise, which is usually part of the acoustic background, and not a sound source consciously listened to. The results of the first experiment were presented at the Open Seminar on Acoustics 2022 in Solina.

The second experiment was based on the same research procedure as the first one, but this time the subjects were not informed about the sound sources they would be listening for. The task of the subjects was to indicate the sample that seemed to them more annoying. It was assumed that samples containing wind turbine sounds would be more annoying, and their indication would be treated as a correct answer. In addition, the subjects were asked about the factors that influenced their answers. The experiment was repeated for four different distances of masking sound from the observer.

The results of the second experiment made it possible to determine the thresholds for masking wind turbine noise, which is perceived "in the background", and not as the dominant sound. Masking thresholds expressed as the distance of the wind turbine sound source from the subject in relation to the distance of the masker from the subject were compared with the actual locations of wind farms on expressways/motorways in Poland.

The third experiment, using the developed measurement procedure with highway masking sounds, additionally takes into account recordings of wind, which is always present during the operation of the wind turbine and can serve as a natural masking sound. Wind noise was recorded in the wind tunnel at the Institute of Power Engineering in Łódź. The wind speed was controlled during the measurements and corresponded to the speed of the wind blowing during recordings of sound samples from wind turbines in 2021. The experiment is in progress, but the first results show that the detection thresholds decrease when subjects are asked to recognize a wind turbine against the background of a motorway and wind.

As part of the development of "soft" methods of noise reduction of wind turbines, it is planned to conduct experiments using the VR environment. Unfortunately, due to delays in the delivery of equipment for the presentation of scenes in virtual reality, the experiments could not start until early 2023. The experiment has been prepared, the research will start in the near future.

Determination of the effectiveness of hard methods, i.e. those that reduce the noise level at the point of emission and immission, is carried out using computer modelling in the SoundPLAN environment based on the Nord2000 methodology. Full verification of their effectiveness will be possible after obtaining the appropriate amount of data from long-term measurements carried out as part of Work Package 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
D5.1 Catalogue of noise reduction methods either for a single turbine or the whole fam1. For each method its effectiveness (confirmed empirically) and the conditions of applicability will be provided (M24)	UAM / AMU	D5.1.zip	Catalogue of wind turbine noise reduction methods will be available on the project website: https://hetman-wind.ios.edu.pl

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.	UAM / AMU	31.12.2022	yes	31.12.2022	Milestone has been achieved. However, the work is being continued in order to obtain more detailed results of the reduction efficiency of the selected methods.
2	Procedures implementing complex noise reduction methods for controlling either emission (close to the source) or immission (at living areas)	UAM / AMU	31.03.2023	yes	31.03.2023	The milestone was planned to be achieved in the 2023, not 2022 (and this year is raported in this report). Thus, the details about it will be discussed in the next report, however, as the report is filled in in May of 2023, we can confirm that this milestone was achieved in 2023 with no delays.

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 to determine impact on further implementation of the project and achievement of planned results of the project. (max. 1500 characters with spaces)
The completion date for this deliverable was initially set for March 31, 2023. Unfortunately, the task's execution has been prolonged due to numerous difficulties, including unfavorable weather conditions at wind farms and challenges in obtaining permissions for measurements. The lack of satisfactory measurement data and acoustic recordings has caused delays in the preparation and commencement of psychoacoustic studies on wind turbine noise masking and audiovisual annoyance. The recruitment and examination process of participants itself is highly time-consuming and cannot be expedited. Deliverable 5.1 will be completed by **June 30, 2023 - WP5 has been extended by the decision of the Rector of UAM to this date**. Currently, psychoacoustic research is being conducted simultaneously in three experiments. Based on literature and technical data, calculations (computer modeling) are underway to assess the effectiveness of selected noise reduction methods. Additional time is required to complete Deliverable 5.1 to finalize the experimental studies (approximately half of the target group has been examined so far), analyze the results, and draft the catalog of noise reduction methods along with implementation guidelines.

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 [5]	in progress
Cost of WP (PLN)	planned	759 293.75	actual (value at the end of the reporting period)	212 630.05
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)				

Within a reporting period the following task have been realized:

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

The initial concept of the hardware part of the noise control system have been defined taking into account the results from the other WPs, especially

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from WP 1 (dependence of amplitude modulation, AM, depth on annoyance) and from WP 2 (field measurements of background noise levels on real wind farms, wind induced noise and observed actual AM depths). Main functional modules of the system are: noise gathering/processing/recording unit, bidirectional communication unit, general control unit, weather station, power supply unit (main power and PV panel). Different available solutions have been taken into account as well as genuine hardware platform based on own construction.

We are now in the process of testing several possible candidate prototypes in order to choose the best possible solutions (keeping in mind the price-quality ratio).

Task 2: The concept of SCADA module optimizing turbine's performance to minimize the risk of wind farm annoyance due to noise

The concept of module was prepared and presented to the Hetman Project partners during team meeting in December 2022. The main idea is to minimize wind farm noise impact by turbines' operating parameters optimization in real time. Wherein minimalization of noise impact is understood as a minimalization of the risk of noise complaints, so keeping noise levels below permissible levels is not key issue. In some conditions (which are defined in the algorithm, see below) it may happen that there are no complains even if they are exceeded. Measures related to noise annoyance are applied here. It is based on continuous multipoint noise measurements (using the system developed in Task 1). Real time assessment is conducted based on current noise dose (which is a combination of several factors, outcomes of WP 1) and noise prediction based on short-term weather forecast. For the noise prediction Nord 2000 method was preliminary selected (result of WP 4). It is being validated (based on the data from WP2 Task 4) with the version of the method sensitive to instantaneous vertical wind speed profile. The issue of required heights of wind speed measurement close to the ground has not yet been determined (the lower the easier to access).

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 this period.

TASK 1: General philosophy behind the prototyped control (measurement) system is to provide low-cost solution for preliminary wind farm noise assessment of acceptable accuracy (ca. 2 dB) without costly noise monitoring (regulated by legal acts) with class 1 measurement systems.

It was decided that system will be based on MEMS microphones with measuring range from 30 dBA up.

Although general purpose and expected functionality of the module was previously defined, several practical aspects have changed after some findings in the project. Such an example is method of detecting amplitude modulation proposed by AGH. This method required high calculation power of DSP. We are now testing our own algorithm based on 50 ms 1/3 octave band RMS spectrum which detects AM efficiently in case of good S/N ratio. On the other hand, in low S/N ratio conditions annoyance due to AM seem not to be a problem (WP 1). Then such information is enough for Task 2 purposes and by the way it reduces the DSP required calculation power. Moreover, thanks to this solution it may appear that large data transfers will not be required (50 ms RMS 1/3 octave band spectra instead of wav files).

We are also during tests of different preselected sensors (temperature, humidity, wind speed, precipitation, microphones) due to its stability in different weather conditions and power consumption. We also test own design of ½ inch capsule for MEMS microphone which allow for acoustic (standard) calibration and wind screen mounting (resulting from WP 2).

TASK 2: Based on results from WP 2 numerical experiments are being conducted to determine minimal required number of measurement sensors located on the wind farm and in the built-up area to get satisfactory accuracy of Nord 2000 predictions. Sensors located closer to wind turbines are used as a calibration point to increase the accuracy of prediction in sensitive area (residential areas). Procedure is based on 15 minutes A-weighted time-averaged sound pressure levels (LAeq).

The potential of wind farm noise impact management lies in that noise contours of LAeq around one wind turbine, WT, are not symmetrical (due to wind direction, directivity of WT, other propagation conditions). This is why sound levels in the noise protected (residential) areas around wind farm are not the same. Observed directivity (outcomes of WP 2 Task 2) is of the order of 3 dB.

What is more, LAeq may be reduced by a few decibels by switching WT into noise reduced mode. This applies to a selected WT influencing sound levels at a given area where current conditions might cause noise complaints (while the other WTs can operate in a normal mode). We are during numerical experiments to access quantitative effect of this action for the real wind farms scenarios.

Making use of WP 1 outcomes we now are implementing to the algorithm other factors influencing annoyance.

There are factors that increase the probability of noise complaints, such as amplitude modulation (AM), as well as decrease this probability, such as masking effect of wind induced noise, high ambient noise or rain. Setting the current operation mode of WTs must also take into account noise level forecast for the next few hours (based on short-term weather forecast) in order not to exceed the noise dose causing complaints for the reference (daily/weekly) period of assessment (which is not determined yet).

Results will be presented to the public in 2023 as a conference paper – "On-line wind farm noise control" at Forum Acusticum (Torino, September 2023) – paper by AkustiX and SINTEF

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 The concept and prototype research of the low-cost wind farm noise measurement system (M24)	Akustix	D6.1.pdf	It is available on the project website: https://hetman-wind.ios.edu.pl

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	31.03.2023	yes	31.03.2023	The milestone was planned to be achieved in the 2023, not 2022 (and this year is raported in this report). Thus, the details about it will be discussed in the next report, however, as the report is filled in in May of 2023, we can confirm that this milestone was achieved in 2023 with no delays.
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	31.03.2024	no	-	Preparatory work is underway.

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 to determine impact on further implementation of the project and achievement of planned results of the project. (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	01.08.2021
End date	planned	31.03.2024	actual [5]	in progress
Cost of WP (PLN)	planned	648 405.00	actual (value at the end of the reporting period)	41 184.51
Implementing entities	UAM / AMU, Akustix, Instytut Ochrony Środowiska – Państwowy Instytut Badawczy, Główny Instytut Górnictwa , 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 1 - A dedicated project's website addressed to the wide audience including administrative authorities, environmental consulting companies, wind farms managers, local communities, etc. The website will present ongoing results and milestones achieved during the whole project, starting with current state of knowledge (as a result of each Task 1 in WP1 - WP 5). Task 1 - updated during the project - **task started.**

Task 2 - Basic knowledge and practical aspects will be published in the form of "good practices guide". It will cover all aspects of wind farms' noise management, depending on: the stage of the investment (planning, exploitation, control of noise limits etc.), the question arose (how to predict, reduce noise, etc.), the problem to solve (what should be done at the stage of wind farm planning, what to do if noise limits are exceeded, etc.). Based on results from WP1 to WP6 will be presented: noise indicators and its limits, methods of monitoring, prediction and abatement. Making use of SINTEF and IOS experience, the guide is planned to be a standard set of procedures recommended by state environmental authorities, unifying administrative procedures dealing with wind farms' noise countrywide. Task 2 - prepared on the basis of WP 1 - WP 5 – **task not started.**

Task 3 - Results of the project will be discussed and rated by all interested parties during workshops (organized once per year) in the formula similar to the workshop which was held this year during the 66th Open Seminar on Acoustics (https://osa2019.pl/ index.php?menu=9&lang=EN). Once a year; presentation and ongoing evaluation of results up to date Task 4 - law regulation on noise limits based on WP 1 Task 4 and WP 3 Task 2 Task 5 - law regulation on noise measurement method based on WP 2 Task 6 - law regulation on noise prediction method based on WP 4 - **task not started.**

Task 4 - Results of WP1 and WP3 will be used by IOS (with support of other partners) to prepare the legal act

on noise and infrasound noise limits for wind turbine noise, using noise indices chosen in the abovementioned packages - **task not started.**

Task 5 - WP2 results will be used by IOS to prepare the legal act on noise monitoring, including determination of short- and long-term noise indices (as indicated in WP1 Task 3) - **task not started.**

Task 6 - Results of WP4 will be used by ISO to prepare the legal act on noise prediction, which will probably be a part of the legal act on noise monitoring - **task not started.**

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 this period.

Tasks related to WP7 task 4, task 5 and task 6 packages are planned to be launched and implemented in parallel in the second half of 2023. The works envisaged in the application are to be implemented based on the results of WP1 and WP3. In the first half of 2023, a preliminary table of contents for the operating guide program related to environmental noise protection for wind farms was defined. Preliminary preparatory activities have started. In the current reporting period:

· - the task related to updating the website was carried out,

· - a working meeting was attended to discuss detailed works in Krakow (December 2022),

· - issues related to the project were presented during the presentation at the 50th Winter School of Environmental Acoustics and Vibroacoustics (February 2023). Information on the needs of professional persons regarding the guide was obtained behind the scenes. https://www.polsl.pl/en/ps_aktualnosci/50th-winter-school-of-environmental-acoustics-and-vibroacoustics/

D 7.1 Project’s website as a widely available database of knowledge (M5) a website design was made, containing information about the project https://hetman-wind.ios.edu.pl/aktualnosci/.

D 7.2 New guidelines on wind turbine noise management (M36) and **D 7.3** Legal regulations regarding wind turbine noise (M35) at the moment it is expected that the task will be implemented as planned

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
No record			

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	31.08.2021	yes	31.08.2021	https://hetman-wind.ios.edu.pl
2	Presentation of the new state regulations on noise: limits, measurements and calculations	Instytut Ochrony Środowiska – Państwowy Instytut Badawczy	29.02.2024	no	-	Preparatory work is underway. All project partners are taking part in discussions regarding this milstone

3	Publication of good practice guide on wind turbines noise management	Instytut Ochrony Środowiska – Państwowy Instytut Badawczy	31.03.2024	no	-	Preparatory work is underway. All project partners are taking part in discussions regarding this milstone

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 to determine impact on further implementation of the project and achievement of planned results of the project. (max. 1500 characters with spaces)

not applicable

C2. A publishable summary of the progress of work
A short summary (max. 1500 characters with spaces) for all WPs of the total work performed on the project during the reporting period. 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.

Many of the planned results from the HETMAN project are based on listening tests using real samples of WTN as stimuli. Measurements and recordings of WTN in the audible range and in the infra sound range have been carried out. Various techniques comprising microphone positions and mountings, and the use of windscreens of diverse constructions have been tested.
The measurements will be used to verify our choice of noise prediction method, Nord2000. The noise propagation algorithms for Nord2000 have been transferred to AkustiX and implemented in their prediction programs.
The recordings have been used for listening tests to determine lower limits for WTN identification and for studying possible masking by other noises (wind noise and road traffic noise).
A management system for the operation of a wind farm close to people's residences is being planned. A combination of input from field sensors and prediction software will determine when critical noise limits are about to be exceeded. This system will provide feedback to the wind farm operator.
A comprehensive report describing the basics of WTN: "Noise from wind turbines. Physics and psychology" have been published and is available on the project web site.

[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).
[5] If WP was not completed during the reporting period, use the phrase "in progress"
[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.

C3. INDICATORS OF THE PROGRAMME							
No.	**Indicator**		**Baseline value**	**Target value**	**Value reached in the reporting period**	**Value reached from the beginning of the project implementation**	**Progress (%)**
1	**Number of peer-reviewed scientific publications submitted** *(please include information about publications in part D1 of the report)*		0	4	7	7	175.00
2	**Number of joint, peer-reviewed scientific publications submitted** *(please include information about publications in part D1 of the report)*		0	3	1	1	33.33
3	**Number of new products/technologies developed**		0	2	0	0	0.00
4	**Number of registered applications for Intellectual Property Protection** *(please include information about applications in part D3 of the report)*		0	0	0	0	n/a
5	**Number of Polish researchers supported**	**all**	0	26	2	26	100.00
		female	0	8	0	8	100.00
6	**Number of Norwegian researchers supported**	**all**	0	2	0	1	50.00
		female	0	1	0	0	0.00
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	0	2	100.00
9	**Number of joint applications submitted for further funding** *(please include information about applications in part D4 of the report)*		0	1	1	1	100.00

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D. DISSEMINATION AND PROMOTION

D1. PUBLICATIONS

No.	**Title of publication**	**Authors (names and surnames of authors)**	**Joint publication** *publication that is authored by researchers from at least one Polish and one Norwegian entity* **(YES/NO)**	**Name of journal**	**IF**	**Date of submission for publication** year of publication	**Status of publication** (under preparation/ submitted/ published / rejected)	**Language**	**Open access publication** (YES/NO)
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	3,34300	2022-01-01	published	English	yes

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

https://doi.org/10.3390/en15207499, Gold open access.

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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	,91300	2022-05-21	published	English	yes
Additional information for open access publication: - DOI (Digital Object identifier) [8] - Repository link [9] - Date of acceptance [10]									
doi:10.24425/aoa.2022.142892, Gold open access.									
3	Experimental verification of the usefulness of selected infrasound and low-frequency 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	,360	2022-07-22	published	English	yes
Additional information for open access publication: - DOI (Digital Object identifier) [8] - Repository link [9] - Date of acceptance [10]									
DOI: 10.21008/j.0860-6897.2022.3.15, Gold open access.									
4	Experimental Research of the AMWG Algorythm for Assessing Amplitude Modulation in Wind Turbine Noise	Czapla, M., Wszołek, T.	no	Vibrations in Physical Systems	,360	2022-07-22	published	English	yes

Additional information for open access publication: **- DOI (Digital Object identifier)** [8] **- Repository link** [9] **- Date of acceptance** [10]									
DOI: 10.21008/j.0860-6897.2022.3.17, Gold open access.									
5	Evaluation of annoyance due to wind turbine noise based on pre-learned patterns	Felcyn, J. , Preis, A., Gogol, R.	no	Vibrations in Physical Systems	0,36000	2022-07-22	published	English	yes
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, Gold open access.									
6	How to determine the annoyance due to wind turbines	Preis, A., Gjestland, T.	yes	Vibrations in Physical Systems	,360	2022-07-22	published	English	yes
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, Gold open access.									

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	yes

Additional information for open access publication: **- DOI (Digital Object identifier) [8]** **- Repository link [9]** **- Date of acceptance [10]**
https://www.ciop.pl/CIOPPortalWAR/file/95668/2022111512226&Monograph_NOISE_CONTROL_2022.pdf, Gold open access.

D2. CONFERENCES AND SEMINARS

No.	Title of presented work	Authors (names and surnames of authors)	Name of the conference / seminar	Date and place	Type (international / national)	Presentation / poster / other (specify)
1	How to determine the annoyance due to wind turbines	Preis, A., Gjestland, T.	Otwarte Seminarium z Akustyki	2022-09-12 Rzeszów-Solina, 12 -16.09.2022.	national	Plenary paper

Link to the presentation or conference / seminar agenda
https://pta.ur.edu.pl/?page_id=218

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2	Evaluation of wind turbine noise annoyance	Felcyn, J. Preis, A., Gogol, R.	Otwarte Seminarium z Akustyki	2022-09-12 Rzeszów-Solina, 12 -16.09.2022.	national	Session paper
Link to the presentation or conference / seminar agenda						
https://pta.ur.edu.pl/?page_id=218						
3	Experimental Research of the AMWG Algorithm for Assessing Amplitude Modulation in Wind Turbine Noise	Czapla M., Wszołek T.	Otwarte Seminarium z Akustyki	2022-09-12 Rzeszów-Solina, 12 -16.09.2022.	national	session paper
Link to the presentation or conference / seminar agenda						
https://pta.ur.edu.pl/?page_id=218						
4	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.	Otwarte Seminarium z Akustyki	2022-09-12 Rzeszów-Solina, 12 -16.09.2022.	national	Session paper
Link to the presentation or conference / seminar agenda						
https://pta.ur.edu.pl/?page_id=218						
5	Road traffic noise influence on wind turbine noise detection	Buszkiewicz, M., Wicher, A., Gołębiewski, R., Pyffel, R.	Otwarte Seminarium z Akustyki	2022-09-12 Rzeszów-Solina 12 -16.09.2022	national	Session paper
Link to the presentation or conference / seminar agenda						

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https://pta.ur.edu.pl/?page_id=218						
6	Comparison Analysis of Noise Generated by Wind Turbines with Other Noise Sources in Outdoor Environment	Staniek, A., Kompała, J., Bramorska, A., Bartmański, C.	Otwarte Seminarium z Akustyki	2022-09-12 Rzeszów-Solina, 12-16.09.2022	national	Session paper
Link to the presentation or conference / seminar agenda						
https://pta.ur.edu.pl/?page_id=218						
7	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	2022-07-26 Lidzbark Warmiński, 26-29 June 2022	international	Plenary paper
Link to the presentation or conference / seminar agenda						
https://www.ciop.pl/CIOPPortalWAR/file/94840/2022061581235&NoiseControl2022_program_pl_en.pdf						
8	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	Plenary paper
Link to the presentation or conference / seminar agenda						
https://www.ciop.pl/CIOPPortalWAR/file/94840/2022061581235&NoiseControl2022_program_pl_en.pdf						
9	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	Session paper

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Link to the presentation or conference / seminar agenda						
https://www.ciop.pl/CIOPPortalWAR/file/94840/2022061581235&NoiseControl2022_program_pl_en.pdf						
10	Analysis of the application of different windscreensfor low-frequency 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	Session paper
Link to the presentation or conference / seminar agenda						
https://www.ciop.pl/CIOPPortalWAR/file/94840/2022061581235&NoiseControl2022_program_pl_en.pdf						
11	Application of common computational methods for modellinglow-frequency noise 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	Session paper
Link to the presentation or conference / seminar agenda						
https://www.ciop.pl/CIOPPortalWAR/file/94840/2022061581235&NoiseControl2022_program_pl_en.pdf						

D3. REGISTERED APPLICATIONS FOR INTELLECTUAL PROPERTY PROTECTION (IPR)

No.	Type of IP Rights (Patent/ Trademark/ Registered design/ Utility model/ Other)	Application reference/ number	Date of the application	Official title of the application	Applicant(s)	Has the IPR protection been awarded? (YES/NO)	If available, official publication number of award of protection

If the project currently doesn't have any application for IPR, please check the box.

☒ This project does not currently have any application for IPR

D4. APPLICATIONS FOR FURTHER FUNDING						
No.	**Title of the project**	**Project partners**	**Joint application** *a continuation of existing collaboration supported within the project, including at least 1 researcher from the supported Norwegian partner and 1 researcher from the supported Polish partner.* **(YES/NO)**	**Source of financing, name of the programme**	**Status of the application (under preparation / submitted / funded / rejected)**	**Project budget (EUR)** [11]
1	Specially amplitude modulated high noise from wind turbines' submitted November 8, 2022	SINTEF i UAM	yes	Bilateral initiative proposal within EEA Financial Mechanism and Norwegian Financial Mechanism 2014-2021 Bilateral Fund (submitted November 8,2022)	submitted	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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D5. OTHER (not mentioned above e.g. promotional materials, training materials, educational materials, master thesis, PhD thesis, organization of workshops, conferences etc.)
2 master thesis, 1 PhD thesis, organization of a special session in OSA 2022 conference

D6. 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.
In the past year we continued to meet online every week. Moreover, because of the better pandemic situation, we had also two stationary meetings – one in Norway and one in Krakow in Poland. Both these meetings were a great opportunity to share our experiences, doubts and discuss potential problems. In this year several papers were published and many conferences were attended. As we predicted, some delays are in the experimental part – mainly because of the need of careful planning the whole procedure. However, several experiments are now conducted and their results are expected to be obtained in the upcoming months. The most crucial delay in the previous year was the start of the long-term noise monitoring. Unfortunately it turned out, that more formal agreements were required. Luckily, all documents were signed and right now (in the beginning of 2023) noise monitoring is already carried out. The data is collected weekly, so there will be soon enough information to model noise using proposed methods and compare its results with the real noise level values. Moreover, gathering data in field conditions is difficult. People are not willing to fill in a survey, negotiations with wind farms' managers are also very long. However, we succeeded with gathering data in one place before and after launching of the new wind farm. Hopefully more data will be gathered in this year.
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).
The year passed brought in Poland very high inflation which directly influenced prices on market, not only of devices but also of services. Thus, we have to carefully analyse our budget and cut some spending. Moreover, while planning experiments, new ideas showed, but we do not have money to pay listeners for their participation. All these problems led us to write a proposal for increasing the budget. Another delay is observed for WP3 which was aimed to be ended in the end of 2022. However, the end date was postponed due to the delay in buying the necessary equipment and need to further investigate the influence of infrasounds in laboratory experiments with people. In addition, it is still difficult to collect data in the field. People are reluctant to fill in a survey, and negotiations with wind farm managers are very long. However, we have managed to collect data in one place before and after the new wind farm was commissioned. Hopefully more data will be collected this year, but it is likely that we will not be able to collect as much data as we planned in the project proposal. However, to mitigate this problem, we have also prepared an online version of the survey. It will be used among people living near wind farms, and we also plan to launch a social media campaign to collect more data. There are also some minor issues with wind shields for measurement microphones of the future measuring system. Laboratory tests did not show sufficient efficiency for high wind speeds, so the designing process is still on. Fortunately, the construction of the main device does not require these shields to be already ready, so the development process is not violated.

Person responsible for preparing the periodic report (technical part)	**Name and last name:**	Anna Preis
	Phone number:	501 132 320
	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 prepating the periodic report).