Modern technologies for the mitigation of impacts of wind farms on biodiversity

Technical Brochure

WindFarms & Wildlife

LIFE12 BIO/GR/000554

ΚΑΠΕ CRES

The LIFE+ Biodiversity project entitled "Demonstration of good practices to minimize impacts of wind farms on biodiversity in Greece" (LIFE12 BIO/GR/000554) is implemented by the Center for Renewable Energy Sources and Saving (CRES), in collaboration with the Nature Conservation Consultants Ltd (NCC), with the financial support of the European Union LIFE Instrument and the Green Fund.

The objectives of the project are the demonstration of modern methods and approaches to minimize the impacts of wind farms on biodiversity in Greece, to improve the compatibility of wind farm development with the EU's biodiversity conservation objectives and to develop standards and guidelines that will enable stakeholders in Greece to better design, implement and evaluate methods to reduce the potential impacts of wind energy projects on biodiversity.

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Introduction

According to international reports, climate change and its impacts are becoming more and more evident, making its mitigation and the conservation of the natural environment and biodiversity the key priorities of the European Union (EU) and the international community.

According to the latest data from the International Energy Agency (IEA), in 2017, after three years of stagnation, the global energy-related level of CO_2 increased by 1.4%, reaching the highest level of all time. In 2017, the global electricity demand increased by 3%, with China and India accounting for 70% of this increase [1].

The development of Renewable Energy Sources (RES), and especially of wind energy, is crucial for meeting the growing demand for energy in the most sustainable way and to address climate change. According to the IEA forecasts (2018), the capacity of onshore wind farms is expected to increase by 323 GW in the next 5 years, reaching almost 839 GW by 2023. In addition, the capacity of offshore wind farms is expected to reach 52 GW by 2023, from 18 GW in 2017, with electricity generated being of the order of 55 TWh. Nevertheless, the rapid increase of wind energy production creates challenges regarding its potential impact on nature and wildlife, which cannot be ignored due to the predicted scale of growth. The potential impacts of wind energy projects on biodiversity are:

1. Risk of collision with the wind turbine blades or barotrauma, leading to direct mortality or injury of birds and bats.
2. Disturbance and/or displacement of sensitive species, through indirect loss of habitat due to avoidance of the wind farm site by birds.
3. Habitat loss or degradation, through wind farm construction.
4. Barrier effects, causing changes in flight patterns.
5. Indirect effects on species habitats and prey.

The potential impacts of a wind farm on biodiversity can be estimated, prevented or even mitigated by recording the presence and movements of the flying fauna. Flying fauna monitoring allows for better siting of the wind farm or its parts, as well as for the application of appropriate measures in order to mitigate the impacts of its operation.

During recent years, there have been considerable advances in technology concerning monitoring and recording of flying fauna. In relation to the conventional recording methods, the commercially available modern systems and methods allow for the collection of important information, concerning the movements and the use of airspace by flying fauna, with considerably greater data quality and quantity, as well as for an automated data recording and activation of measures for mitigation of wind farm impacts on biodiversity.

The present brochure provides a review of these modern technologies for monitoring, recording and early warning/prevention of collision of flying fauna, accompanied by examples and references.

Modern Technologies for the mitigation of wind farm impacts on biodiversity

The available tools for the mitigation of potential impacts of wind farms on flying fauna refer to the monitoring before and after the construction of a wind farm and the application of measures, if required, to mitigate and/or prevent negative impacts on the flying fauna.

Modern technologies, such as radars, video surveillance systems, bats detectors, and thermal cameras are key tools for wind farm consultants and investors during the design, siting and operation phase of a wind farm project.

Monitoring of the flying fauna in the area of interest, as well as prevention and avoidance measures, if considered necessary, are the key for proper siting and operation of a wind energy project.

Monitoring

Monitoring concerns the recording, processing and evaluation of data on the movement of the flying fauna in the airspace of a wind farm and its area use, as well as on the potential impacts of the project on the flying fauna. Monitoring can be carried out by:

- field researchers in the area of the wind farm and the combined use of modern technologies and conventional monitoring methods; and

- the use of automated or conventional flying fauna monitoring technologies (such as radar, video surveillance, night vision, thermal imaging and bioacoustic systems), where the collected data are subsequently processed by experts.

The efficiency of each technology applied for the site monitoring, especially that of the automated ones, has to be evaluated by simultaneous recordings with the use of conventional methods.

Mitigation / Prevention of Impacts

The mitigation and prevention of the negative impacts of wind farms on flying fauna with the use of modern technologies concern the reduction and/or avoidance of injuries and loss of individuals and can be accomplished by the following methods.

Conventional methods of mitigation/prevention. Techniques for the prevention of flying fauna, such as dissuasion through acoustic stimuli.

Modern technologies for early warning/collision avoidance of flying fauna.

These technologies primarily aim at:

- monitoring of flying fauna in the area of interest by early warning systems, such as radar or video surveillance,

- monitoring of bats by bat detectors,

- dissuassion of flying fauna and change of its flight routes in order to avoid collisions with wind turbine(s). Prevention is mainly achieved through emission of sounds.

- shutdown/stopping of wind turbine operation in real time via the SCADA system, based on the information on the presence of the flying fauna and its movements towards wind turbine(s) within high collision risk area.

- setting of wind turbine operation specifications under specific temperature/wind conditions or periods of the year, when the presence of bats and the risk of collission/barotrauma is increased.

The “shut down on demand” of one or more wind turbines can be automatically performed in real time either by the early warning and collision avoidance systems, such as the video surveillance systems or radar, or by field researchers, mainly during specific periods of the year, such as migration season.

Any mitigation or dissuasion method needs to be monitored and evaluated for its efficiency by searches for injured or dead individuals of flying fauna.


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Source: ©NCC


Source: ©NCC

Application of the modern technologies at wind energy projects

A. Ornithological radar

An ornithological radar has the ability to scan the threedimensional airspace around its location and record: (a) birds crossing the area, (b) their flight altitude, and (c) their flight routes.
Radar systems vary and may be either marine surveillance radars, scanning parts of the airspace of the wind farm, or automated marine-type radars or meteorological radar systems or a combination of two or more radars in a system, to scan the entire airspace.

Flying fauna: Birds / Bats


Source: ©NCC

Siting /Operation:

An ornithological radar is placed at a specific location in a wind farm, in order to provide the best coverage of its airspace. It may be necessary to use more than one system at sites with highly uneven terrain relief or in large wind farms.

Its power supply may be autonomous, for limited periods of time, or connected to the wind farm, for the provision of power for longer periods. Its operation may be continuous. The data recorded by non-automated radar systems needs to be analysed by an expert in order to identify flying biological targets and their routes. There are radar systems with automated identification and recording of data, however the identification of species by visual ornithological observations is required for both, automated and non-automated types of radar systems.

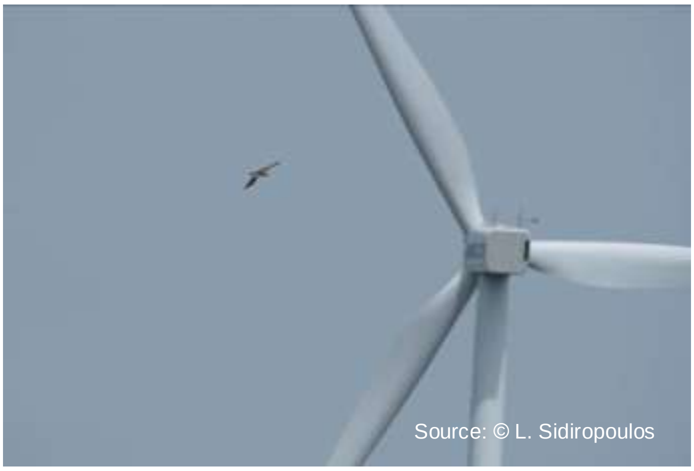
Monitoring:

The system allows continuous and simultaneous observation of a large number of birds at long distances and under conditions of low or no visibility. In addition, it allows the estimation of the vertical profiles of bird and bat movements, that is particularly useful in estimating nocturnal bird migration, for which the radar is the most powerful available tool. Radar monitoring can be achieved through the use of:

- An automated recording system, with subsequent data evaluation and processing by experts. Species identification is carried out simultaneously with the radar recording by visual field observations.
- A non-automated recording system, where experts process and record data in real-time. Species identification is carried out simultaneously with the radar recording by visual field observations.
- A combination of ornithological radar and a network of field researchers, where the system operates complementary to the visual observations. The radar provides a full coverage of the area and guides the observers in the directions of located birds.

Mitigation:

In the case of an ornithological radar the mitigation of the impacts directly refers to the shuting down ('shut down of demand') of one or more wind turbines, for which, based on the radar information, there is a high collission risk. This requires real time flying fauna movement surveillance and wind turbine shut down decision-making.



Radar collision mitigation can be implemented with the use of :

- An automated ornithological radar system, equipped with a decision-making software, which is connected with the SCADA, that activates wind turbine "shut down on demand" command in cases of birds detected on collision route.

- A non-automated ornithological radar system, where recording and real-time decision making are done by field researchers. They directly communicate with the wind farm operator at the control center to activate the "shut-down on demand" command.

Results from the use of the radar system in Greece:

Marine surveillance radar was used in the project LIFE12 BIO/GR/000554 to monitor and record flying fauna in the areas of interest. This system has been successfully applied in insular, hilly and mountainous areas with limited and low vegetation, as well as in lowland areas around large wetlands. However, in areas with abundant high vegetation, such as forests or/and highly uneven terrain relief, such as multiple nearby tops or ridges of hills and mountains, the radar "blind areas" can make effective monitoring of the airspace of the area of interest infeasible.

In areas where the use of the marine surveillance radar was feasible, the system has proven to be especially effective in detecting birds at large ranges, i.e. from distances of 1 km to 1,5 km for small-sized birds (e.g., passerines) to distances up to 6 km for large species (e.g. pelicans, swans).

In comparison with the conventional visual recording of birds, the radar recorded 5 to 10 times more birds, due to its larger detection radius and monitoring of 360° around the radar location. Additionally, the radar is the only tool for the monitoring of nocturnal migration in large radius of up to 2 km.

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• Simultaneous recording of numerous bird movements at large distance and altitude ranges. • Monitoring under conditions of low or no visibility. • Ideal complementary tool to conventional visual recordings for specific limited periods, such as migration. • Ideal for cases of nocturnal bird migration.	• Not suitable for areas with highly uneven terrain relief and high vegetation. • In some cases a series of recording systems is required for an effective complete coverage of the wind farm site. • Visual species identification is required. • High operational cost for prolonged operation. • High cost of an automated radar system.

During the pre-construction phase of a wind farm, radars are used as a reliable and long-term recording tool, collecting scientific data on bird movements and migration in the area (see Figure 1). They can detect and automatically record hundreds of birds simultaneously, including their size, speed, direction and flight path. A non-exhaustive list of companies that provide automated or non-automated radar systems is provided in the Annex.

B. Optical systems

Optical systems are based on the analysis of high definition images and identification of targets. These systems can visually cover the entire airspace around the wind turbines on which they are installed (see Annex).

Flying fauna: Birds

Siting/Operation:

Optical systems can be installed on the wind turbine tower without any interference with it. The high definition cameras cover a monitoring area of 360° around the wind turbine. These systems have a detection range from several dozens to few hundred meters, depending on the size of the monitored bird species. A single system can usually cover from one to three wind turbines, depending on the siting of the wind farm and the type of wind turbines. The system's operation is continuous, with a power supply provided at the wind turbine.

Monitoring:

The system allows the monitoring of the airspace within the range it covers during the day and under good visibility conditions. The detectability of the flying fauna can be improved by adapting detection criteria in accordance with additional information for each site. The system allows monitoring of the bird aerial activity in the vicinity of wind turbines and can therefore be a complementary method to the GPS telemetry and the ornithological radar, to determine the space use by flying fauna at wind farms. The monitoring is carried out with the use of an automated recording system and the subsequent manual evaluation - processing of the recorded videos, for both, species identification and discarding of other flying targets, such as aircrafts and insects. The system can also record collision incidents, which however need to be confirmed on site.

Mitigation:

Mitigation of impacts with the use of an optical system involves the dissuasion of birds and/or shuting down of one or more wind turbines, in cases of potential collision risk. The mitigation requires real time monitoring of the flying fauna movements and decision making. This is achieved by using a decision-making software which is directly connected to the SCADA system for the activation of the shut down command of the wind turbine, while the dissuasion command activates a system of speakers emitting sounds of varying intensity according to the estimated collision risk.

Results from the use of optical systems in Greece:

The system can be used successfully at all types of land reliefs, under conditions of sufficient visibility. In addition, in areas with high traffic of other flying targets, such as aircrafts, special adjustments need to be made in order to avoid false positives. When there is sufficient number of operational optical systems, they record more birds than conventional visual bird monitoring, due to better visual coverage of the area of interest.

During the demonstrative operation of the optical system in the framework of the LIFE project the estimated energy loss due to shut-down on demand of the wind turbine varied between 0.12% and 0.24% of the total annual energy output of the wind turbine. The wind turbine shutdown commands were activated on the average 0.6 times per day with a duration of approximately 1.5 minutes.

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• Continuous diurnal recording of bird movements within the monitoring zone. • Relatively low installation and operational costs. • Monitoring can focus on areas with confirmed bird activity.	• In cases of large wind farms, a series of recording systems is required to ensure sufficient coverage. • Unable to detect targets under conditions of low visibility or during the night. • Limited bird detection range (suitable for large- or medium-sized birds).

Source: CRES

Source: CRES

Installation of a video surveillance system at a 750 kW wind turbine (w/t), with tower height of 45 m, in the framework of the project LIFE12 BIO/GR/000554

4 high definition (HD) cameras were installed at a height of 4m, and 4 sound emission speakers at a height of 13 m from the base of the wind turbine.

Special magnets were used for the installation of the equipment.

The system includes a small cabinet containing the monitoring and control system that was placed internally at the base of the w/t tower.

Installation of a video surveillance system at a 2 MW wind turbine (w/t), with tower height of 80 m, in the framework of the project LIFE12 BIO/GR/000554

4 high definition (HD) cameras were installed at a height of 15 m from the base of the w/t and 10 sound emission speakers, 6 at a height of 25 m and 4 at a height of 65 m from the base of the wind turbine.

Special magnets were used for the installation of the equipment.

The system includes a small cabinet containing the monitoring and control system that was placed internally at the base of the w/t tower.

C. Bioacoustic systems

The bioacoustic systems (bat detectors) are based on ultrasound detection. A bioacoustic system or a bat detector is a device used for detecting the presence of bats, recording their presence/activity and identifying species, based on the ultrasounds they emit.

Flying fauna: Bats

Siting/Operation:

The systems are usually installed on the wind turbine with the microphone mounted at the base of the nacelle and the data recording system placed inside the wind turbine. Their operation is continuous with power supply provided at the wind turbine. Before the construction of a wind farm, bat detectors can be installed on meteorological masts, or can be used as portable devices. All bioacoustic systems require subsequent data processing by a bat expert, for the identification of the species.

Monitoring:

The system allows a 24-hour per day monitoring of bat activity near the wind turbine rotor, while its operation can be adjusted to record only during periods of the day when bats are active. Monitoring is carried out by using an automated recording system, followed by the evaluation and processing of the collected data by experts using specialized bat ultrasound processing software.

Mitigation:

The mitigation of the impacts with the use of bioacoustic systems is directly related to the adjustements of wind turbine operation under specific temperature/wind conditions and periods of the year. These may involve temporary shut down of specific wind turbines during particular periods of the year, when the bat presence is increased, or potentially the adjustment of the cut-in speed, if this is technically feasible. The wind turbine manufacturer must be informed and provide consent for any intervention in the operation of the wind turbine.

Results from the use of bat detectors in Greece:

The results of the demonstration of bioacoustic systems in the framework of the LIFE project show that the bats were active at temperatures above 15˚C and at low wind speeds (during spring ≤ 3m/s, while during autumn ≤ 5m/s), with the most intense bat activity taking place from May until October.

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• Allow recording of bat activity at rotor height, where bat collision or barotraumas risk is the highest. • Allow continuous data recording.	• Require time consuming data processing. • Due to short detection range real time mitigation of collision or barotrauma is not feasible.

Phase 1. Design – Siting of the wind farm

(a) The use of a radar system in cases of expected significant nocturnal passage of small migratory birds and crossing of large-sized sensitive bird species on migration or in local movement corridors.

(b) The use of ultrasound receivers or/and thermal imaging in areas with expected increased presence of bats or bat migration corridors. Additionally, the presence of bats may be monitored by an automated ultrasound recording system mounted at nacelle height (e.g. on a meteorological mast) for a better assessment of collision or barotrauma risks.

Phase 2. Operation of the wind farm

(a) An automated visual monitoring system of the wind farm, combined with ornithological monitoring programs and searches for dead or injured birds can contribute to the mitigation of the collision risk in areas with resident or migratory large-sized sensitive bird species. In case the range of the optical system is not sufficient, it may be replaced by a non-automated radar system.

(b) A network of observers guided by a non-automated marine radar for early warning and in direct contact with the wind farm control system for the shut-down of the wind turbine(s) can be used in areas with a significant migration of large-sized birds. This method can be applied for limited time periods.

(c) The recording of bats with the use of bioacoustic systems and their analysis, in conjunction with wind and meteorological data at the wind farm site, can provide important information on the activity of bats under specific temperature/wind/season conditions.

Figure 1. Recommended applications of modern technologies for the reduction of the impact of wind energy projects during their design and operation phases.

Conclusions - Recommendations

Based on the experience gained through the LIFE project, as well as the literature international experience [3,4,5,6,10,11,12], modern technologies for monitoring/recording and early warning/collision prevention of flying fauna provide important tools for reducing the impact of wind energy projects on biodiversity both during planning/siting and operation phase of wind energy projects.

If the basic principle of proper siting of the wind energy project has been met, the use of modern technologies and the evaluation of the data collected, as well as the application of measures/modern technologies, wherever required, can greatly contribute to the reduction of the impacts of wind farms on biodiversity.

The application of modern technologies should be considered on a case-by-case basis and taking into account on the one hand the characteristics of the wind energy project, and on the other hand the sensitivity of the area, the composition of the sensitive fauna and its ecological requirements, as well as the potentials and limitations of each technology. The monitoring and the evaluation of the efficiency of the selected applied technologies are required during the entire wind farm operation phase.
The involvement of qualified experts for the proper selection and siting of the modern technologies, as well as for the evaluation of their efficiency is necessary at all stages of the design, operation and monitoring of a wind farm project.

A comparison and evaluation of the data collected before the construction of the wind farm and during its operation are important factors in the assessment of the potential impacts of a wind energy project on biodiversity.

A continuous evolution of these systems will help optimize their operation in terms of the detection range and the performance of the functions and services they provide, the cost reduction, the minimum possible interference in the operation of the wind turbines and the optimal performance for the protection of flying fauna.

Annex

Company / Website	Automated real time radar monitoring	Non-automated marine or meteorological radar	Radar data analysis software	Automated real time video surveillance	Non-automated night vision or thermal imaging system	Thermal Imaging data analysis software	Automated bat monitoring	Ultrasound recording analysis software	Collision Monitoring	Bird dissuasion	SCADA / automated shut down on demand
Accipiter Radar www.accipiterradar.com	X									X	
Avisoft Bioacoustics www.avisoft.com							X				
Bat Bio Acoustic Technology GmbH www.bioacoustictechnology.de							X				
Biodiversity Research Institute / HiDef Aerial Surveying Limited www.briloon.org				X					X		
Biotope www.biotope.fr								X			X
BirdsVision Ltd www.birdsvision-solutions.com				X						X	X
Boulder Imaging www.boulderimaging.com				X							X
Bushnell www.bushnell.com					X						
Calidris www.calidris.fr									X		
Carbon Trust www.carbontrust.com					X				X		
DeTech Inteligent Sensors www.detect-inc.com	X		X							X	X
DHI www.dhigroup.com		X									
ECN www.ecn.nl				X					X		
ecoObs GmbH www.ecoobs.com							X	X			
Elekon AG www.batlogger.com							X	X			
FLIR Systems www.flir.com					X	X					
Furuno www.furuno.com		X									
IfAÖ - Institute for Applied Ecosystem Research www.ifaoe.de				X							

Company / Website	Automated real time radar monitoring	Non-automated marine or meteorological radar	Radar data analysis software	Automated real time video surveillance	Non-automated night vision or thermal imaging system	Thermal Imaging data analysis software	Automated bat monitoring	Ultrasound recording analysis software	Collision Monitoring	Bird dissuasion	SCADA / automated shut down on demand
Liquen Consultoría Ambiental www.dtbird.com				X			X			X	X
Normandeaus Associates Inc. www.normandeau.com					X		X				
Pettersson Elektronik www.batsound.com							X				
Pulsar www.pulsar-nv.com					X						
radR project www.radr-project.org			X								
Robin Radar Systems www.robinradar.com	X		X								X
Sonobat www.sonobat.com								X			
Strix www.strix.pt	X		X								X
Swiss BirdRadar Solution AG www.swiss-birdradar.com	X		X								
Titley Scientific www.titley-scientific.com							X	X			
Wildlife Acoustics Inc. www.wildlifeacoustics.com							X	X			
WindBat www.windbat.techfak.fau.de											X
Yukon Advanced Optics Worldwide www.yukonopticsglobal.com					X						

The list is indicative and has emerged from literature and internet research. Exclusion of any relevant equipment/system manufacturer from the list is purely accidental and by no means intentional. The list includes prototypes and commercially available systems and technologies. System-specific information was derived from manufacturers' websites and the reports of their use.

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