Minimization of impacts of wind farms on biodiversity in Greece – A Summary of LIFE12BIO/GR/000554 project results

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Summary
Wind energy's ability to produce electricity without carbon emissions is expected to reduce the risk of potentially disastrous effects to wildlife from the climate change, as well as to offer several environmental benefits. Despite the benefits of wind energy, the siting and operation of wind farms, mainly in sensitive ecological areas, continues to be a source of concern for biodiversity. The extent and severity of the possible impacts of wind farms on the biodiversity greatly depends on the proper wind farm siting, on the relevant environmental permits, on the mitigation measures adopted, and in extreme cases on the effectiveness of compensation measures applied. The project "Demonstration of good practices to minimize impacts of wind farms on biodiversity in Greece, LIFE12BIO/GR/000554" mainly aims to provide solutions for the reconciliation of wind energy and biodiversity. The project targets at the demonstrative implementation of integrated approaches for the mitigation of impacts on the biodiversity during the operation of wind farms in accordance with the EU guidance document "Wind energy development and Natura 2000", and on the basis of available modern methods and technologies. Modern technologies, or the so-called "early warning systems", and best practices can help to avoid and/or to reduce to a tolerable level the impacts of the wind farms on biodiversity during their design, construction and operation. Successful examples and case studies verify that the adaptation of the modern technologies, in several cases, can reduce the impacts of the wind farms on biodiversity, whilst maintaining the power output.

1. Introduction

EU has adopted an ambitious plan of increasing the proportion of renewable energy to 20% of the total energy production by 2020. The wind energy is one of the main renewable energy sources to achieve this objective. In Greece despite the continuous increase of the installed wind farms, Greek wind energy will have to increase significantly in order to reach the target of 7.5 GW by 2020 set by the National Renewable Energy Action Plan. At the end of 2017 the total installed capacity of wind farms in Greece was about 2.65 GW, meaning that for the period of 2018-2020 more than 3.5 GW new wind farms should be installed. In parallel, the EU has adopted the Biodiversity Strategy aiming in halting the loss of biodiversity and ecosystem services in the EU and help stop global biodiversity loss by 2020. The rapid development of wind projects raises concerns about possible impacts on nature and wildlife that cannot be ignored due to the predicted scale of growth. It is important to ensure that such rapid growth is sustainable in all respects and is accomplished in accordance with EU environmental legislation, including Habitats and Birds Directives, [1], and the targets set by the EU Biodiversity strategy.

The LIFE+Biodiversity Project "Demonstration of good practices to minimize impacts of wind farms on biodiversity in Greece", LIFE12 BIO/GR/000554, (www.windfarms-wildlife.gr) is implemented by CRES, in collaboration with NCC Ltd, in Greece. The project aims in the pilot demonstration and evaluation of modern technologies, including radar, infrared cameras, high resolution cameras and bat detectors, as well as on the demonstration of good practices, for the minimization of the impacts of wind farms on the biodiversity of Greece. The project is implemented at CRES Demonstration Wind Farm - Park of Energy Awareness PENA, at Keratea-Attica, and at other areas of Greece where wind farms have been installed. Most of the data presented in this article is part of the Good Practice Guide (GPG) for the mitigation of wind farm impacts on biodiversity with the use of modern technologies and methods, produced by the project. The Progress of Wind Energy in Europe and Greece

The contribution of RES to the total energy production in EU countries is increasing rapidly, with the significant contribution of wind power. In 2017 a total of 336 TWh of electricity was generated from wind farms in the EU-28, which covered an average of 11.6% of the total electricity consumption, (see Table 1), [2]. At the same time, wind energy accounts for 18% of all installed power generation capacity in the EU-28 with a total installed capacity of 169 GW (153 GW

onshore and 15.8 GW offshore wind farms), taking the second place as energy producer, approaching natural gas.
Moreover, the evolution of wind turbine technology over the last 20 years is important and is also the main reason for the rapid development of wind power. In addition, the power of onshore wind turbines has increased from less than 50 kW in the 1980s to more than 3 MW today. In general, in new wind farms the rated power of wind turbines ranges from 1.5 MW to 3 MW with a tower height of 80-100 meters. Thus, fewer wind turbines are needed for a specific wind power.

Table 1. Installed Wind Power capacity in EU-28, [2].

Total EU Electricity Consumption (TWh)	Onshore Wind Energy Production (TWh)	Offshore Energy Production (TWh)	Total Wind Energy Production (TWh)	Share of EU Consumption met by Wind Energy
2,906	292	43	336	11.6%

In Greece, during the last decade, there is a significant increase in wind energy with a rate of 8.3% of average annual electricity demand being covered by wind, (Figure 1).

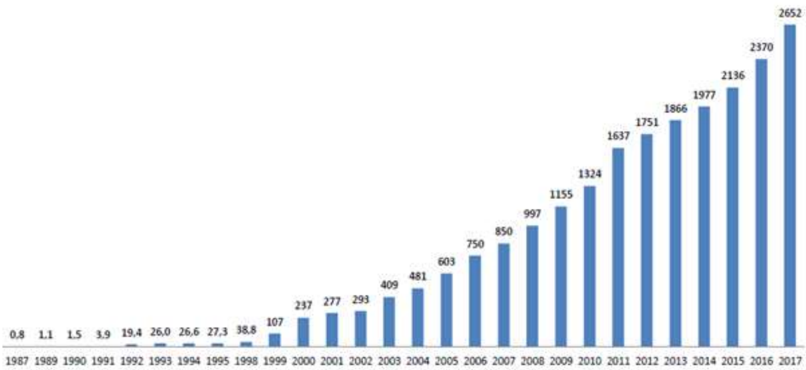


Figure 1. Wind energy development progress in Greece [3].

At the end of 2017 the total installed capacity of wind farms in Greece reached the 2,652 MW, with most of the facilities being installed in Central Greece (33%) and in the region of Peloponnese (19%), (Figure 2), [3].

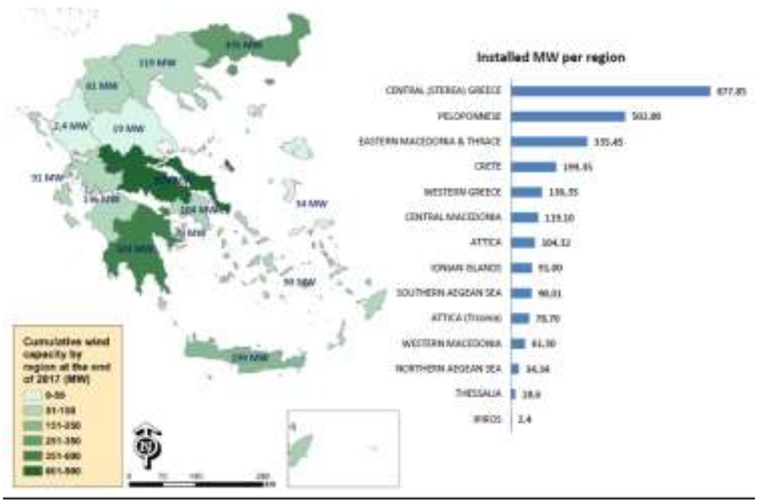


Figure 2. Cumulative wind capacity by region in Greece at the end of 2017 [3].

2. Legislation Framework for Wind Energy and Biodiversity

As the number of wind farm installations is expected to grow at a significant rate in the short to medium term in Europe, it is important to ensure that its growth is sustainable in all respects and is achieved without damage to the Europe's natural heritage and to the natural environment.

The Birds Directive (2009/147/EC on the conservation of wild birds) and Habitats Directive (92/43/EEC on the conservation of natural habitats and of wild fauna and flora) is the base of the EU's biodiversity policy. Specifically, in Article 6 of Directive 92/43/EEC it is well defined that plans and projects, including those for wind energy production, in or nearby to Natura 2000 sites, are not excluded in advance, but should be assessed on a case-by-case basis, as well as those outside Natura 2000 sites and inside protected species natural distribution range. Possible impacts on specific areas can be avoided and minimized by carefully designing and siting of projects, or can be mitigated or compensated.

The Directive 2001/42/EC on the assessment of the effects of certain plans and programmes on the environment, aims to provide for a high level of protection of the environment and to contribute to the integration of environmental considerations into the preparation and adoption of plans and programmes with a view to promoting sustainable development, by ensuring that, in accordance with this Directive, an environmental assessment is carried out for certain plans and programmes which are likely to have significant effects on the environment.

The Directive 2011/92/EU as amending by the Directive 2014/52/EU on the assessment of the impact of certain public and private projects on the environment describes the requirements for this assessment.

In Greece the above EU Directives have been adapted in legislation with several National Laws and Ministerial Decisions. According to Law 4014/2011, an Environmental Impact Assessment (EIA) is required for Category A[1] (A1, A2) projects, i.e. those whose construction is likely to have significant effects on the environment, to impose specific conditions and restrictions for the protection of the environment. According to Law 4014/2011, in the case of projects and activities taking place in protected areas of the Natura network, environmental licensing is carried out on the basis of the relevant provisions of more specific presidential decrees and ministerial protection decrees. In the absence of the relevant provisions: (a) for Category B projects, (those whose construction is likely to have local and insignificant effects on the environment), an Appropriate Assessment (AA) is required, while for Category A projects, the Appropriate Assessment is an integral part of the EIA.

3. Possible Impacts of the wind farms to biodiversity

Currently available evidence shows that well-designed and properly sited wind farms are not a serious threat to wildlife and are characterized by no or only limited and largely insignificant impacts on biodiversity as written in the EU Guidance Document "Wind energy developments and Natura 2000".

The siting or location of a wind farm seems to be the most important aspect contributing to the risk of bird and bat fatalities, though wind farm design and layout also have contribute. Predicting and assessing the siting impact is seen to be the most important management tool.

Moreover, there are cases where the development of a wind farm has brought benefits to biodiversity, especially in areas where the natural environment has been degraded. An example is the case of the Black Law, in the Lanarkshire area of Scotland, a mountainous area where before the installation of the wind farm it was degraded with mining signs. The investor, with environmental consultants, designed and implemented a habitats management plan for the area in which planting crops for winter bird feed, creation of a shallow wetland, and more; were included. Its implementation benefited a wide range of wildlife species such as owl species, wild boar, etc.

However, there is a wide range of possible interactions between the wind farms and biodiversity, including their associated infrastructure (e.g. access roads, power lines, meteorological masts, etc.), which may lead to significant impacts to wildlife. The types of impacts that might occur from wind farms to biodiversity are as follows:

- Collision risk, leading to direct mortality
- Disturbance and/or displacement of sensitive species

[1] The categorization of wind energy projects and other RES projects (Group 10), is based on the MD 2307/2018, which is the last amendment of a series of Ministerial Decision.

- Habitat loss or degradation
- Barrier effects, causing changes in flight patterns
- Indirect effects on species habitats and prey species

The above impacts may be significantly enhanced due to cumulative impacts of multiple wind farms or other developments or human activities within the same area. The type and degree of wind farm impact to the biodiversity is greatly dependent upon a range of factors, such as location and the type of species present, wind farm size, etc.

The impacts of each project vary significantly among different projects, therefore should be assessed individually, as well as, in conjunction with other projects and activities in the area, in order to adapt the project plan and design accordingly.

The assessment of impacts should consider the factors on which the significance of impacts depends. Biological information required for the assessment of impacts within the framework of the Appropriate Assessment includes the best available scientific knowledge on the qualifying species and habitats for Natura 2000 sites, in specific:

- Area, representatively and conservation status of priority and non-priority habitats in the site
- Population size and density, conservation status, degree of isolation of the species of Annex II of the Habitats Directive, Annex I of the Birds Directive, and regularly occurring migratory species not listed in Annex I Birds Directive present in the site.
- Conservation objectives of the site: (a) ecological requirements, (b) conservation status on national and EU level, (c) threats and (d) national and EU importance of the of site's qualifying species and habitats for Natura 2000 sites, as well as (e) role of the site within the broader biogeographical region and in the coherence of the Natura 2000 network
- Conservation status of Natura 2000 qualifying species and habitats
- Favorable Reference values
- Main threats and pressures
- Ecological structure and function
- Evolution of the site without the proposed project

One of the key issues of the EIA process, and AA when required, is the assessment of the significance of impacts, which play a critical role in whether or how the development project will proceed. Proper research, based on the best scientific knowledge and appropriate consultation from the very start of the development planning allows for a smoother project decision making process.

Moreover, there is a variety of best practice methods for predicting the impacts and the assessment of their significance [4]. Some of the commonly used methods of predicting impacts are as follows:

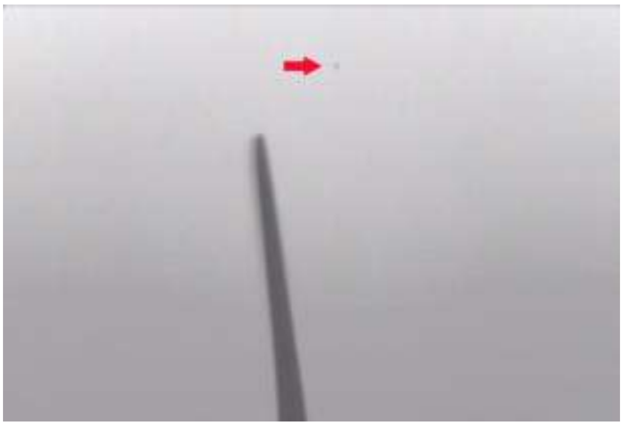
- Direct measurements
- Checklists or matrices
- Flow charts, networks and systems diagrams
- Quantitative predictive models
- Geographical Information Systems (GIS) overlays
- Information from previous similar projects
- Expert opinion and judgment
- Description and correlation
- Carrying capacity analysis
- Ecosystem analysis

The proper design of wind farms and their accompanying projects (e.g. access roads, electricity transmission cables, meteorological webs), especially for ecological sensitive areas, can, in the main, reduce the likelihood of adverse effects on biodiversity. If potentially significant impacts are identified, these should be minimized or avoided altogether, especially when affecting rare and endangered species and habitats of Community importance. The use of modern methods and technologies to prevent collision and recording in wind farms can play an important role.

5. Measures for the reduction of possible impacts of wind farms to the biodiversity - Modern methods and technologies

The use of modern methods and technologies for recording of avifauna and bats and preventing collision in wind farms can play an important role. Various advanced technologies have been developed during recent years that greatly expand survey capabilities and efficiency. These methods and technologies might be used during the planning-design, and operation of a wind farm. These methods and technologies include amongst others:

- Ornithological Radar - Radar surveys have a wide range of applications both, onshore and offshore, for flying fauna, due to the ability to continuously detect and record flights and flight heights at large distances and under conditions of no or low visibility. It is usually associated with direct visual observations or flight call recordings to allow species identification. Radar data may be utilized for the assessment of displacement, barrier effects and collision risks.
- Bat detectors are the essential tool for recording the distribution and abundance of bat species and may be applied either at specific locations (e.g. wind turbine nacelle) or record bats along line transects in the area of interest. They have limited range, therefore may be applied in association with other telemetry techniques, e.g. thermal imagery or radar. Similarly, flight call recordings and microphone registration for the identification of bird species provide complementary information to visual observation or telemetry methods (e.g. radar, thermal imagery). The data collected by thermal imagery (Figure 3), provide information on avoidance behavior, collisions, flock size and flock altitude of flying fauna in close vicinity of wind turbines at night, when other visual observations are not feasible.



Source: NCC

Figure 3. View of the use of thermal camera at CRES Demonstration Wind Farm-PENA.

- High Definition (HD) Surveillance Video Cameras provide an automated alternative to visual observations. Video cameras can be used either in aerial surveys or as land based surveillance systems in order to estimate collision risks. Additionally, commercially available automated on-demand shutdown radar and HD camera systems are available that automatically control the operation of wind farms or individual turbines to reduce collision rates.

Modern technologies allow the collection of significantly greater quantity and quality of data concerning flying fauna movements and use of space in comparison with conventional recording methods. This feature can be used both in the design phase of wind farms, by integrating of biological data into their technical design and operation, and their operation phase, by reducing impacts with particular emphasis on mitigation of collisions, as well as the regulation of wind turbine operation in order to minimize this risk. However, no technological solution can substitute the benefits of a good environmental assessment and appropriate siting of a project.
The option of using modern technologies to prevent the adverse effects of wind turbines on flying fauna should always be considered on a case-by-case basis, taking into account both the characteristics of the wind farm and the sensitivity of each area, the composition of the fauna sensitive to them, as well as the possibilities and limitations of each method or technology and the financial cost of its implementation. Whenever it is considered appropriate or necessary to use modern technologies, it is advisable to explore the combination of existing available conventional

and modern methods and technologies and to assess the cost and environmental benefits of each combination in order to determine the best method to ensure the most efficient mitigation of expected or confirmed impacts on flying fauna, as well as its economically feasible implementation. It should also be stressed that no technology, as advanced and automated as it may be, can operate without the human factor at the design, assessment, monitoring and control stages of its implementation.

6. Case Studies of the application of modern technologies within LIFE project

6.1. The use of ornithological radar at CRES Demonstration Wind Farm-PENA and other areas

In the context of the LIFE Windfarms and Wildlife project, a combination of a marine radar adapted to bird surveillance in conjunction with field ornithologists has been used to record bird species, their abundance and their pathways in both the PENA wind farm of CRES (see Figure 4), and other wind farms of interest located in mountainous areas with both minimal and abundant high vegetation or near large wetlands. The radar system is used to detect birds and to monitor their flight routes and patterns, while field ornithologists visually identify the species of birds and their flight height. The data collected can be used both during the wind farm design phase, to determine the use of the airspace by birds, and its operational phase, to identify birds in a wind turbine collision course and in cases of temporary stopping of specific wind turbines in order to avoid bird collisions.

This system has been successfully used in 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, e.g. forests, or even intense relief, e.g. with many nearby hill or mountain tops or ridges, radar blind areas can significantly limit an effective monitoring of the airspace around the area of interest. In areas where radar use is feasible, this system has proven to be very effective in detecting birds in long-range, from 1-1.5 km for small birds (e.g., passerines) up to 6 km for large species (e.g. pelicans, swans). Compared to the conventional bird's visual monitoring, radar recorded 5 to 10 times more birds due to larger detection and continuous monitoring angle of 360° around the radar position. Furthermore, the radar is also the only means for nocturnal migration monitoring over long ranges of up to 2 km.

Source: NCC

Source: NCC

Figure 4. (a), (b) Views of the use of the ornithological radar system at CRES Demonstration Wind Farm-PENA.

6.2 Use of automatic ultrasound recording systems to record the activity of bats at rotor height at CRES Demonstration Wind Farm-PENA

A pilot installation of three different models of automated ultrasound recording systems on two wind turbines of CRES Wind farm (V47/660, NM48/750) was carried out, in order to examine their ability to record bat activity at the rotor height and to determine the possible need for curtailment of the wind turbine operation in the event of a significant risk to bats (Figure 5). For this purpose, the microphone of each system was mounted on wind turbine nacelles. The results of the ultrasound recording systems pilot operation reveal similar ultrasound detection and recording capabilities for all three different systems. Single or multiple bats were recorded, with 86-781 recordings per month per wind turbine, with the majority of recordings occurring between May and October

Up to 178 bats have been recorded per night. In spring, 94% of the bat activity was at wind speeds less than 3m/s. In autumn, bats were active at higher wind speeds with 50%, 80% and 95% of bat activity been recorded at wind speeds of less than 3m/s, 4m/s and 5m/s, respectively. Nearly the whole bat activity (> 99%) was recorded at an average daily temperature above 15°C. In total, 6 species or groups of species were recorded, out of 34 bat species present in Greece.

Source: CRES

Source: CRES

Figure 5. (a), (b) Views of the use of a bat detector at CRES Demonstration Wind Farm-PENA.

In the particular wind farm and for the period from spring until autumn, the bat activity at rotor height is highest at low wind speeds, less than the wind turbine cut-in speed, and temperatures above 15°C. Therefore, the risk of collision or barotrauma at the wind farm is low, as evidenced by the fact that no dead or injured bats were found throughout the project period.

6.3 Use of HD video surveilance system at CRES Demonstration Wind Farm-PENA

An autonomous image-based bird monitoring and mortality mitigation system was installed for demonstration purposes in the NM48/750 kW wind turbine of CRES Wind Farm (see Figure 6). This system autonomously monitors bird’s daily movements in the vicinity of the wind turbine, with the use of 4 high-definition cameras installed on the wind turbine, and emits warning and discouraging sounds by 4 speakers, when birds are detected to approach the wind turbine, in order to reduce collision risk. The system detects/records movements of flying objects in the area, assesses them and makes decisions to trigger bird collision mitigation measures (sound emission, wind turbine stopping) in real time depending on the risk of impact. The system has been in operation since March 2016 and analyzes of its operation and recordings is carried out, as well as simultaneous bird movements monitoring by field workers to assess the levels of bird detection by the system.

During the first year of its operation, 2,500 birds have been recorded, while the system activations due to false positives were within the manufacturer specifications at 2 per day. The warning sound for birds approaching the wind turbine has been activated 720 times (30% of the flights), in 700 cases (30% of the flights), subsequently the dissuasion sound was activated, while in 400 cases (17% of flights) the wind turbine virtual stop control module was activated.

For the period April 2016 to January 2017, the total time during which the wind turbine virtual stop module would be activated for speeds higher than the cut-in speed of the wind turbine (>3m/s), was 4.75 hours. The corresponding energy loss would be 0.24% of the total energy produced during this period.

6.4 Use of HD video surveilance system at a wind farm at Thrace, North Greece

An autonomous image-based bird monitoring and mortality mitigation system was installed in spring 2018, for demonstration purposes, at a V90/2MW wind turbine at a private wind farm in North Greece, (Figures 7, 8). The system autonomously monitors bird daily movements in the vicinity of the wind turbine by 4 high-definition cameras installed on the tower of the wind turbine, and emits warning and discouraging sounds by 4 and 6 speakers at two different heights of the tower, when birds are detected to approach the wind turbine in order to reduce collision risk.

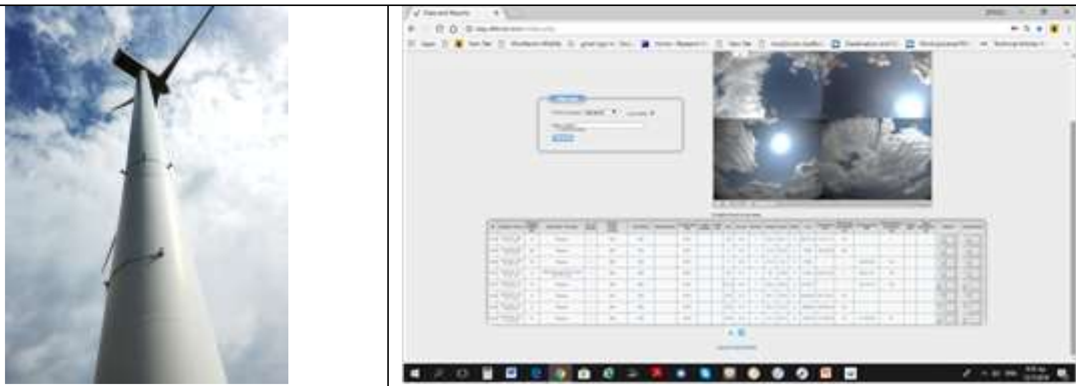
Source: CRES | Source: CRES

Figure 6. (a), (b) Views from the installation of the video surveillance system at CRES Demonstration Wind Farm-PENA.

During 49 days of system's operation in spring and early summer 2018 a total of 275 video records have been recorded, consisting of 151 bird flights involving 164 birds and 124 false positives. A vast majority of bird records consisted of large and medium sized birds. The false positives were primarily due to wind turbine blades, insects and airplanes. The warning and discouraging sounds which were activated when birds were detected to enter the Moderate Collision Area and High Collision Area, respectively, were triggered on 90 (59.6% of bird flights) and 61 (40.4% of bird flights) occasions. The average number of warning and discouraging per day were, 1.84 and 1.23 triggers per day, respectively, with the average trigger duration of 27.8s and 35s, respectively.
The frequency of false positive warning and discoursing sound triggers was 0.42 triggers per day. No collisions were detected by the video records as well by carcass searches carried out around the wind turbine. The monitoring of the operation of the system was carried out by visual observations using telescope and binoculars for a total of 43 observation hours during seven days. The observation point was located 1km from the wind turbine with the installed system aiming to record birds which approach within a 500m radius of the wind turbine. A total of forty five (45) bird flights have been recorded within observation survey area, including primarily large and medium size raptors and storks. The area is used by bird primarily for local movements by soaring, gliding or active flight (80% of flights) while other types of behavior include foraging (11%), social interactions (7%) and takeoff/landing (2%). Among these twenty three (23) bird flights were recorded within the system maximum detection area (200m). Among these the system detected and recorded 15 flights. The other eight (8) flights were not detected because they were outside the maximum detection range for the bird species' size (e.g. 100m for buzzard-sized birds) or were flying close to the ground.
These results indicate that all birds recorded by visual observations were recorded within the distance ranges identified by the manufacturer, i.e. birds with wingspan of >150cm, 75-150cm and 25-75cm were detected at distances of 180-200m, 100-140m and 70-80m respectively.
On the other hand, during the period of simultaneous video surveillance system and visual observation recording, the video surveillance system recorded additional three (3) bird flights which were not detected by the observer, due to small bird size and long distance from the observation point (>1km).
Warning or discouraging sounds were activated by the system in case of all fifteen (15) flights recorded by the video surveillance system and visual observations. In twelve (12) cases (80%) there was an immediate sudden change of flight direction away from the wind turbine, while in other three (3) cases (20%) there were no visible bird reactions to the systems sounds.

Source: CRES Source: CRES

Figure 7. (a), (b) Views of the installation of HD video surveillance system at the wind turbine in North Greece.



Source: NCC Source: CRES reported by LIQUEN

Figure 8. (a) View of the HD video surveillance system of CRES at Thrace, (b) View of the screen shot data of the video surveillance system.

7. Conclusions

The development of wind power offers the promise of contributing to renewable energy portfolios to reduce greenhouse gas emissions from carbon-based sources, which contribute to accelerating climate change. Given the projected growth of wind power generation, it is crucial that future analysis of the impacts of wind energy development, especially in sensitive ecological areas, take into account population effects for wildlife, which is considered sensitive to impacts of wind farms. These impacts can be avoided first of all with proper siting of the wind farms. When properly sited, the impacts that might occur can be further reduced with the use of early warning systems and mitigation measures, when these measures are required.

The so-called “early warning systems”, such as ornithological radars, video surveillance systems, thermal cameras and bio-acoustic monitoring systems along with traditional methods of data collection (e.g. optical observations), and the information on the responses of the flying fauna to wind turbines, can help to reduce the impact on biodiversity during the operation stage, as well as significantly improve the biodiversity data on the space use within a planned wind farm site during the planning stage.

Acknowledgment

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