WENDY aims at unravelling the factors triggering social acceptance of wind farms through an in-depth analysis at three dimensions: social sciences and humanities, environmental sciences and technological engineering.

Handbook of environmental design solutions

Deliverable 3.2

WP3, T3.3

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- Classified R-UE/EU-R – EU RESTRICTED under the Commission Decision No2015/444
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WENDY project's abstract

WENDY aims at unravelling the factors triggering social acceptance of wind farms through an in-depth analysis at three dimensions: social sciences and humanities, environmental sciences, and technological engineering. For that, the project will implement a series of local actions promoting the wider adoption of the project solutions, including guidelines, reports and handbooks which will be created to boost the understanding of wind farms decision making processes and enhance energy citizenship. This will be supported by the spatial multi-criteria WENDY toolbox. A tool able to identify the optimal turbines' siting with the minimum environmental impact and highest social acceptance likelihood. All developed models, methods, guidelines, and tools will be implemented within 10 wind projects spread across 4 countries. These have been selected considering geography (north vs. south Europe), maturity stage (viability phase / planning phase / short-term operation phase / long-term operation phase); type of wind energy (onshore / offshore – floating, fixed-); and co-existence with other activities (agriculture, fisheries, energy communities). In these locations, outreach activities tailored to their specificities will be performed, creating the WENDY Knowledge Hubs which will incorporate citizens, local authorities, business owners and value chain actors of wind energy. WENDY Hubs will serve as a baseline for the WENDY Knowledge Exchange Platform, a forum that will be developed to facilitate the exchange of knowledge between decision makers and key stakeholders within wind farms planning processes. For a successful implementation of the project activities, all the value chain and the best-in-class expertise is involved in the project consortium including 9 partners from 6 European countries: 1 Large Company (EGP), 2 SMEs (WR, Q-PLAN), 1 University (CBS), 2 RTO (CIRCE, NINA), 1 Energy Community (MEC), 2 Non-profit organisations and associations (NOWC, APPA).

List of the WENDY's consortium partners

No	Full name	Short name
1	FUNDACION CIRCE CENTRO DE INVESTIGACION DE RECURSOS Y CONSUMOS ENERGETICOS	CIRCE
2	WHITE RESEARCH SRL	WR
3	STIFTELSEN NORSK INSTITUTT FOR NATURFORSKNING NINA	NINA
4	ENEL GREEN POWER SPA	EGP
5	MARIN ENERGI TESTSENTER AS	NOWC
6	ENERGEIAKI KOINOTITA ANATOLIKIS KRITIS	MEC
7	COPENHAGEN BUSINESS SCHOOL	CBS
8	ASOCIACION DE EMPRESAS DE ENERGIAS RENOVABLES - APPA	APPA
9	Q-PLAN INTERNATIONAL ADVISORS PC	Q-PLAN

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List of abbreviations

Abbreviation	Full name
CA	Consortium Agreement
DoA	Description of Action
EU	European Union
GA	Grant Agreement
WT	Wind Turbine
WTG	Wind Turbine Generator

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Executive summary

The deliverable D3.2 was developed in the frame of Task 3.3, within the second technical Work Package 3 (WP3) of the WENDY project. WP3 is dedicated to carry out an integrated assessment at landscape-level impacts and benefits at technical and environmental level supporting environmental design and energy landscapes.

The aim of D3.2 is to release a handbook with an overview of 'state of art' monitoring systems and viable technological solutions that are currently available and/or in development and can be used as a part of an integrated monitoring program and protection systems to avoid/minimize the potential fatalities of birds and/or bats in the wind farms.

The handbook will deal with relevant features of the systems: capability, applicability in different weather and light circumstance, requirements related to installation, the maturity level, focal target group of species. Most of the systems reported generally include specific algorithms and machine learning techniques that analyses signals produced by different sensors (camera, radar signals, microphones, etc.) controlled by advanced tools.

The purpose of this document is to provide a general overview of what is available, and not a detailed comparison aimed at a ranking or quality comparisons. Only for some solutions are documents and public contributions available that allow evaluations of the performance of the systems, for all other systems only the main features are described. It is a snapshot of the current solutions' ecosystem, but it is important to keep in mind that the technology is evolving rapidly, and development tests are still ongoing for many systems, it is likely that new information on the performance of these devices will be published after this handbook.

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1. Introduction

Wind energy is growing worldwide and is one of the most efficient solutions to reduce emissions in the power sector. But the development of wind energy facilities does not come free of risk of negative impacts on biodiversity.

However, wind farms can have negative impacts on biodiversity, as well as noise and visual impacts for local human communities.

The most important environmental impacts of wind energy systems can be identified in a) Habitat loss and fragmentation impact on wildlife; b) Marine mammals disturbance (offshore); c) Bird and bat collisions (offshore and onshore).

Although all these impacts are of great importance, in this Handbook only technological solutions related to safeguard birds and bats will be collected and described.

The impact on bird and bat species is due to direct collision mortality, barotrauma mortality, displacement from feeding or nesting area, road disturbance, barrier effects to movement, and habitat degradation or loss.

Wildlife mortality from collisions with wind turbines is the most direct, visible, and well-documented impact of wind energy development.

The likelihood of birds and bat collisions depends on factors which may differ between species, season, time of day and even environmental conditions, such as wind speed or temperature.

The best estimates of the number of birds killed by wind turbines in the U.S. each year are based on three studies published in 2013 and 2014, all reporting on data from 2012. These studies show between 140,000 and 500,000 birds die annually [1, 2, 3].

The number of wind farms are rapidly increasing across the world, which makes it is hard to find a measure of the number of birds being killed each year that will still be accurate. The American Bird Conservancy estimated up to a million or more birds a year are killed by turbines in the US for 2021. It is important to highlight that this estimate is far exceeded by collisions with communications towers (6.5 million); power lines, (25 million); windows (up to 1 billion); and cats (1.3 to 4.0 billion) and those lost due to habitat loss, pollution and climate change [4].

To contrast these rising estimates, it is fundamental to design sustainable wind farms, biodiversity-friendly and to adopt mitigation actions if needed.

The mortality of bird and bat species have been used by wind project opponents to stop, downsize, or delay project development and for this reason having technological solutions available that are capable to mitigate the impact of wind turbines on local avifauna is currently of great importance.

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These systems are often based on technological support, most often visual, for the detection of birds and bats (cameras, radar) which, depending on the species and flight behavior, launch deterrents or shut down of the turbine rotor with the aim of minimizing the risk of collision.

Although many operators, authorities and environmental associations have high hopes for these systems, there is still some skepticism towards the use of these technological systems mainly due to doubts about their long-term effectiveness. For instance, in some wind farms where these detection systems with deterrence and shut down are installed, collisions continue to be recorded, which raises the question of the effectiveness of these devices in terms of reducing mortality. Still, it should be emphasized that in general zero-risks are not reachable. Few evaluations and studies on the efficiency of these systems can be found in the literature, and they are often conducted by the system providers themselves or by government agencies or NGOs. However, from these reports it is not easy to draw clear and precise conclusions on the performance of the various systems on the market.

In this Handbook the systems are described from a technical point of view (operating principles) and the areas of application, the degree of maturity of the technology and when possible, the indicative costs are indicated.

Since bird and bat mortality issues and wind turbine designs are largely similar worldwide, the information provided in this document is applicable to all power plants in the world. In theory, many of the systems can be installed for both onshore and offshore wind turbines, as they operate on the same principles. However, in practice, offshore turbines seem to be more difficult to stop quickly, because they are much larger, more powerful, and subject to stronger winds than onshore turbines.

2. System overview

In scientific literature, bird and bat fauna detection systems operating in wind farms are based on different technologies. For bird detection, mainly camera systems are used, but also radar and acoustic systems and occasionally GPS and LiDAR technology. Radar and cameras can also be combined. To detect and record bats' presence the most appropriate systems are based on thermal cameras and an ultrasound acquisition device. In some cases, also visual observations are used to detect risky bird and bat presence that allows to launch temporal shutdown.

Detection combined with the classification of flying objects provides the basis for data and decisions of reactions that reduces the risk of collision. There are mainly two reactions: deterrence (acoustic, visual, electromagnetic) and turbine regulation (shutdown or slowing down the speed of the rotation).
Most of the technology/systems are designed to further the understanding of flight behavior at different scales (micro, meso and macro) or to implement mitigating actions to avoid or minimize the occurrence of collisions.

In addition to reducing the risk of collision, automatic detection systems can be used for other purposes. For example, they can be used to carry out studies that improve the understanding of bird population sizes and trends, including their migration systems and population dynamics during the pre-construction

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phase of a new wind farm. This can be important to obtain more detailed information for the evaluation of environmental impacts, and to inform post-construction studies of bird and bat displacement effects in terms of rate and distance and possible behavioral adaptations to wind farms.
Detection systems have different levels of technological maturity, cost, and potential areas of application.

The following technical aspects are important for the evaluation of systems:

- Degree of automation of detection and/or recognition/classification (real-time acquisition, post-processing, etc.).
- Distance measurement, minimum detectable flying object size, flight path detection.
- Collision risk reduction actions (deterrence and turbine regulation).
- Reliability.

In this handbook are reports also other types of systems that are not based on detection but only on deterrence (acoustic or sonic or visual) to keep bats and birds away from the turbines and a particular bird mitigation solution that consists in painting of turbine blades.

2.1 Detection systems

Current options for continuous monitoring of birds and bats at onshore or offshore wind farms can be categorized as camera-based and radar-based, acoustic-based, LiDAR-based, GPS tracking based or in a combination of two categories.

Radar is best suited for macro and meso scale monitoring, due to its long range and lower resolution and it is very difficult to infer species from radar data alone. Camera-based systems are best for collecting micro- to meso-scale data and for identifying species, although this is still an ongoing area of research. Some camera-based systems include also thermal imaging for nocturnal observations.

Another category of detection systems is that of automated ultrasound detectors (microphones) to estimate the activity and identity of bats in the zone of highest mortality risk at wind turbines.

All detection systems can be useful both for monitoring birds and/or bats presence in a specific area and for mitigating the risk of collision with wind turbines.

2.1.1 Camera systems

Camera systems consist of visual or thermal cameras used to detect bird and bat movement and eventually carry out species identification. They are cost-effective solutions that are more suitable for smaller wind farms. Camera use is more effective at collision monitoring. This is due to the proximity and the number of angles they capture, helping wind farm operators to identify the rate at which collisions occur.

Less used are infrared and thermal imaging to detect bird and bat species since they can’t perform well in adverse weather conditions.

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There are two types of camera systems:

1. **Monoscopic Camera**

In these optical systems the visual is monoscopic and detection and classification are achieved by analyzing pixel variation in the recorded images and classifying in real time whether the detected object is relevant or not, based on its size and/or variation in image size and position. Artificial intelligence algorithms or manually programmed algorithms are used for this purpose. In some cases, a thermal or infrared illumination camera is coupled to these systems to monitor the turbine at night.

2. **Stereoscopic Camera**

In these optical systems the visual is stereoscopic and this technology enables a more accurate assessment of the distance of the detected object and the system uses the trajectory rather than monoscopic optical systems. The direction of the target is determined via the trajectory, and this ensures a more precise analysis of the risk of collision.

Currently, high-resolution cameras coupled in stereoscopic mode may ensure similar distance estimation performance to radar systems. Although the detection range of the vision-based system is limited to 1.0 km. The main advantage of the vision approach over the radar one is its ability to detect a single bird or bat, which then can be followed by their identification.

2.1.2 Radar Systems

This type of detection system is based on radar and can detect any flying object in the monitoring area and estimate the object’s position, velocity and movement. The radar is based on the reflection of radar waves by objects (particularly birds). Radar can usually classify detected birds into size groups, but not yet at the species level directly. Compared to optical detection systems, these have a greater range, but may have poorer coverage at short distances. The detection range depends on several factors including the system frequency band, beam angle and power, and antenna size. Currently, bird detection systems allow observations up to 5 km. The price, the size of the system, the power consumption, and government emissions regulations limiting the beam frequency and power are the main barrier to wide-scale application of radar for bird detection. Radar is especially effective because it can record continuously, regardless of the time of day, over large spatial scales and can operate in most weather conditions. However, radar systems can be affected by clutter due to precipitation, moving turbine blades, vessels and helicopter activity. In addition, radar is not able to reliably detect collisions and the level of taxonomic resolution is imprecise [5]. These latter two issues can be improved by using combinations with other methods such as acoustics and visual technology.

For wind farm operators, radars are powerful tools for conducting risk analysis and environmental impact assessments (EIAs) in the pre-construction and operational phases, and for monitoring bird activity over time.

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Radars can detect and log hundreds of birds at once, including their size, speed, direction, and flight path. This makes them a solution for wind farm sites that operate at a large scale, in addition to their superior range, spanning kilometers of a wide area.

2.1.3 Audio systems

Audio detection systems are devices to monitor the ultrasound echolocation calls of bats and/or acoustic vocalizations of birds. This kind of microphone is useful for species identification and activity monitoring.

2.1.4 Multi sensor systems

Multi sensor systems consist of a combination of two different technologies. Primarily, these two technologies are long-range radar and short-range optical. The advantages of the two technologies are exploited and their respective limitations are overcome.
Another combination being developed is radar technology and microphones to record bird and bat calls around turbines.

3. List of solutions

In this section, a list of solutions identified during the scouting phase is reported. In Figure 1, the identified solutions have been grouped according to four technology groups, which are: camera systems, radar systems and multi-sensor system, audio, and deterrence systems. A total of 15 camera-based solutions, 8 radar-based solutions, 3 multi-sensors and 5 audio sensors were identified, and 5 other different solutions classified “Other sensors” group.

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Figure 1. Explored ecosystem. Solutions identified and broken down by technoly areas

The explored ecosystems consist of the most interesting, promising, and innovative systems, based on our evaluation. All the systems identified are described in detail with the following indicators:

- TRL (TRL low: from 1 to 4, TRL medium from 5 to 7, TRL high from 8 to 9).
- Main characteristics: monitoring, detection, deterrent and shutdown.
- Installation effort;
- Price and Business Model. Price Level: + < 20k€ per system; ++ < 20k€ and< 50k€ per system; +++ > 50k€ and < 100k€ per system; ++++ >100k€ per system.

3.1 Camera system solutions

In Table 1 all camera systems solutions selected for this handbook with main characteristics are reported. In the following paragraphs each solution is described in detail.

TRL 8: system complete and qualified; **TRL 9:** actual system proven in operational environment (competitive manufacturing in the case of key enabling technologies; or in space)

System	Type of Solution	Target	TRL	Price	Applicability and coverage per system	Migration and macro monitoring	Collision monitoring	Detection for reaction	deterrent	Shutdown

SAFEWIND	HD Camera	Birds	9	++	Onshore Offshore 1 WTG	No	Yes	Yes	Yes	Yes
NVBIRD	HD Camera	Birds	8	++	Onshore Offshore 1WTG	No	No	Yes	Yes	Yes
DTBird	HD Camera	Birds	9	++	Onshore Offshore 1 WTG	No	No	Yes	Yes	Yes
BCAS WIND	Thermal Camera	Birds and Bats	9	+++	Onshore Offshore 1 WTG	No	Yes	Yes	Yes	Yes
KONICA MINOLTA	HD Camera	Birds	8	++	Onshore 1 WTG	No	No	Yes	Yes	Yes
DIGISEC	HD Camera	Birds	9	++	Onshore 1 WTG	Yes	No	Yes	Yes	Yes
PROBIRD	2D Camera	Birds	9	NA	Onshore 1 WTG	No	No	Yes	Yes	Yes
SPOOR AI	3D Camera	Birds	8	NA	Onshore Offshore 1 or 2 WTGs	Yes	Yes	Yes	No	Yes
BIOSECO	3D camera	Birds	9	++	Onshore 1 WTG	No	No	Yes	Yes	Yes
IDENTIFLIGHT	3D camera	Eagles	9	+++	Onshore 1 or more WTGs	Yes	No	Yes	No	Yes
3D OBSERVER	3D camera	Birds	8	+++	Onshore 1 or 2/3 WTGs	Yes	No	Yes	No	Yes
U DETECTION SYSTEM	3D camera	Birds	8	++	Onshore 1 WTG	No	No	Yes	Yes	Yes
BCMS VENTURE	3D camera	Birds	8	NA	Onshore More WTGs	Yes	No	Yes	No	Yes
Thermal-Tracker 3D	Thermal camera stereo	Birds and Bats	8	NA	Offshore Onshore 1 WTG	No	No	Yes	No	Yes
B-Finder	Thermal camera	Birds and Bats	8	NA	Onshore Offshore 1 WTG	No	Yes	No	No	No

Table 1. Camera system solutions with relevant characteristics

3.1.1 SAFEWIND

Owner/producer: BIODIV-WIND SAS (France)

<u>General description</u>

- Monoscopic HD cameras system
- Daylight system
- Detect birds in the complete rotor area via real-time-video-monitoring.
- Analyze the collision risk of every flight movement.
- Trigger protection measurements such as acoustic warning signals and reduction of the rotor rotation speed or stopping of the turbine.
- Stops the protection action immediately once the birds move away from the wind turbine to effectively reduce wind energy yield losses.
- Bird species classification (post-processing process)

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TRL Range

- High, commercially available. Since 2015, Biodiv-Wind SAS has equipped nearly 480 wind turbines in western Europe, including France, Germany, Spain, Austria, Belgium and carried out wildlife studies in several other countries (Finland, Iceland…)

INSTALLATION AND HARDWARE

- Non-invasive installation. SafeWind equips the WTGs individually with 8 HD -IP66- cameras and 4 IP 66 horns using stainless steel climbs and Computer Unit installed inside the mast of the WT.

PRICE

- ++ For sale, remote support and flight data analysis fee

DETECTION RATE*

- about 88% for red kite

*Percentage of flying tracks detected by the system out of all the flying tracks within detection range of respective species from field observation data

DETECTION RANGE AROUND THE WT

- 270 m for red kite, and 337 m for eagle

APPLICABILITY

- Onshore

WEB: https://www.biodiv-wind.com/

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Figure 2. Kestrel tracked by SafeWind system

References: [6]

3.1.2 NVBIRD

Owner/producer: NVISIONIST (Greece)

General description

- Monoscopic HD Camera system
- Daylight system (nightvision option with Thermal camera)
- Detect birds in the complete rotor area via real-time-video-monitoring
- Analyze the collision risk of every flight movement
- Trigger protection measurements such as acoustic warning signals and reduction of the rotor rotation speed or stopping of this.
- 360° nacelle speaker for deterrence
- Species Classification: under development

TRL Range

- High, commercially available. Nvisionist has equipped Wind Farms in Europe, including Greece, Austria and Spain.

INSTALLATION AND HARDWARE

- Non-invasive installation of 4HD Cameras and 4 speakers on the WT tower and a speaker on the nacelle. Computer unit inside the WT tower.

DETECTION RATE:

- NA

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DETECTION RANGE

- Up 1 km (declared by supplier)

PRICE

- ++ For sale and remote support fee.

APPLICABILITY: Onshore / Offshore

WEB site: https://nvisionist.com/nvbird-wtg/

References: NA

3.1.3 DTBird

Owner/producer: Liquen Consultoría Ambiental S.L. (Spain)

General description

- Monoscopic HD Cameras system
- Daylight system (nightvision option)
- Detect birds in the complete rotor area via real-time-video-monitoring.
- Analyze the collision risk of every flight movement.
- Trigger protection measurements such as acoustic warning signals and reduction of the rotor rotation speed or stopping of this.
- Record of relevant meteorological data

TRL Range

- High, commercially available. DTBird has equipped 90 onshore /offshore wind farms in 15 countries (Austria, Belgium, China, France, Germany, Greece, Italy, Norway, Poland, Spain, Sweden, Switzerland, The Netherlands, the United Kingdom and the United States). DTBird has been operating since 2009.

INSTALLATION AND HARWDARE

- Non-invasive installation: from 2 to 8 HD cameras and from 2 to 8 speakers per WT using stainless steel climbs. Computer Unit inside WT tower.

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PRICE

- ++ For sale and remote support fee.

DETECTION RATE*

- 80%

*Percentage of flying tracks detected by the system out of all the flying tracks within detection range of respective species from the field observation data.

False positive rate: heavily influenced by air traffic and insects. Harvey et al., (2018) reported a false positive rate of 2.5%

DETECTION RANGE AROUND THE WTG

- Birds between the sizes of 1.9 – 2.25m can be detected up to 320 – 380m away when four cameras are used, and up to 550 - 650m when eight cameras are used. Birds around the size of an Atlantic Puffin (0.47 – 0.63m) can be detected at about 80 – 100m away with four cameras and 130 – 180m with eight cameras. (Data from supplier website).

APPLICABILITY

- Onshore/Offshore

WEB site: https://www.dtbird.com/index.php/

Figure 3. DTBird system installed on a WTG

References: [7,8]

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3.1.4 BCAS WIND

Owner/producer: VOLACOM AD (Bulgaria)

<u>General description</u>

- Thermal imaging sensor (Monoscopic Visual)
- Daylight and nightvision system
- Detect birds and bats in the complete rotor area via real-time-video-monitoring
- Analyze the collision risk of every flight movement
- Trigger protection measurements such as acoustic warning signals and reduction of the rotor rotation speed or stopping of this.
- Deterrence: ASR - acoustic startle reflex

TRL RANGE

- High, commercially available. Volacom has installed over 150 systems in onshore and offshore wind farms in four continents.

INSTALLATION AND HARDWARE

- Non-invasive installation. 2 Thermal sensors and 2 audio module and 1 Control Module per WTG installed on the tower To cover more WTs different configurations are possible. A control module can provide one point of access for all systems installed in a wind farm

PRICE

- +++ For sale and remote support fee.

DETECTION RANGE AROUND THE WTG

- bird size: 25-35 cm max detection range: 170m, bird size: 50-60 cm max detection range: 480m, bird size: 100 cm, max detection range: 650m. (Data from supplier website).

DETECTION RATE*

- 83-91%

*Percentage of flying tracks detected by the system out of all the flying tracks within detection range of respective species from the field observation data.

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APPLICABILITY

- Onshore/Offshore

Web site: https://www.volacom.com/solutions/bcas-wind/

Figure 4. BCAS system

References: [9]

3.1.5 KONICA MINOLTA

Owner/producer: KONICA MINOLTA Business Solutions Spain S.A. (Spain)

General description

- Monoscopic HD camera system
- Daylight system
- Detect birds in the complete rotor area via real-time-video-monitoring.
- Analyze the collision risk of every flight movement.
- Trigger protection measurements such as acoustic warning signals on the tower and on the nacelle and reduction of the rotor rotation speed or stopping of this.
- Species Classification: under development

TRL RANGE

- High, commercially available. Konica Minolta has equipped 2 onshore wind farms in Spain

INSTALLATION AND HARDWARE

- Non-invasive installation: 4 HD cameras and audio module per WT on the tower using stainless steel climbs. The control unit is installed inside the WT tower.

PRICE

- ++ For sale and remote support fee.

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DETECTION RANGE

- up to 700 m

DETECTION RATE
NA

APPLICABILITY: Onshore

WEB Site: https://www.konicaminolta.eu/eu-en

References: NA

3.1.6 BIRD MONITORING SYSTEM DIGISEC

Owner/producer: DIGISEC (Greece)

General description

- Monoscopic HD camera system
- Daylight system (nightvision option)
- Detect birds in the complete rotor area via real-time-video-monitoring
- Analyze the collision risk of every flight movement
- Trigger protection measurements such as acoustic warning signals and reduction of the rotor rotation speed or stopping of this

TRL RANGE

- High, commercially available. DIGISEC has equipped 12 onshore wind farms in Greece.

INSTALLATION AND HARDWARE

- Non-invasive installation. System of more cameras and acoustic module per WT installed on turbine using stainless steel climbs.

PRICE

++ For sale and remote support fee.

DETECTION RANGE

- Up to 1 km (declared by Supplier)

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DETECTION RATE

- NA

APPLICABILITY

- Onshore

WEB site: https://digisec.gr/about-us/

References: NA

3.1.7 PROBIRD

Owner/producer: SENSE OF LIFE (France)

General description

- Monoscopic HD camera system
- Daylight system
- Detect birds in the complete rotor area via real-time-video-monitoring.
- Analyze the collision risk of every flight movement.
- Trigger protection measurements such as acoustic warning signals reduction of the rotor rotation speed or stopping of this.
- Species Classification. From lesser kestrel (65cm) to Eurasian griffon vulture (2.5m).

TRL Range

- High, commercially available. Sense of Life has installed 257 Probird System in Onshore Wind Farms in Europe (France and Spain).

INSTALLATION AND HARDWARE

- Non-invasive installation: 4 HD cameras (25 frames per second) installed on the WT tower using stainless steel climbs. Control module inside the tower. Possibility to install acoustic module on the tower.

PRICE

- NA – Leasing and technical support fee.

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DETECTION RANGE

- Red kite (from 7 to 17 m/s) 600m

DETECTION RATE

- False positive rate: 16%, with new version of ProBird 0,8%; False negative: 2,6% (missed target)

APPLICABILITY

- Onshore

WEB Site: https://sensoflife.com/

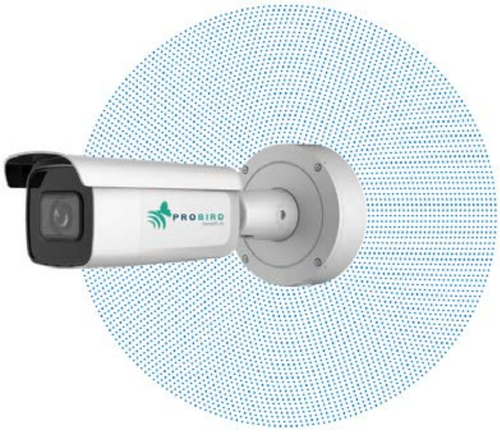

Figure 5. ProBird camera

References: [10]

3.1.8 SPOOR AI

Owner/producer: SPOOR AS (Norway)

General description

- Off-the-shelf cameras and proprietary AI software.
- Daylight system (night vision option with thermal camera).
- Software can detect and track birds up to 2km away using video recording of all flight movements and/or collisions on all monitored WTGs (long range detection).
- Spoor's proprietary model estimates a bird's flight path.
- Analyze the collision risk of every flight movement.
- Statistics on which areas of the wind farms are being used by birds.
- Bird activity data correlated with weather conditions.

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- Trigger protection measurements such as acoustic warning signals, reduction of the rotor rotation speed or stopping of this.
- Species Classification.
- Monitoring of bird abundance and flight altitude.

TRL Range

- High, commercially available. Spoor has installed in some offshore Wind Farms in Norway. Third-party verification test set up in the UK to validate Spoor's performance.

INSTALLATION AND HARDWARE

- Non-invasive installation: off-the-shelf cameras installed on a WT tower to monitor the area around another WT or other mounting options. Possibility that a camera system can cover two WTGs. Control Module, environmental sensors (T, Wind Speed, Humidity).

PRICE

- NA – Supply of the hardware part and annual fee for software license and remote support.

APPLICABILITY

- Onshore and Offshore.

WEB Site: https://spoor.ai/

Figure 6. Spoor Control Module installe dinside a WT tower.

*References: n*o available documents

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3.1.9 BIOSECO BPS Premium

Owner/producer: BIOSECO S.A. (Poland)

General description

- Stereocopic HD camera system
- Daylight system
- Detect birds in the complete rotor area via real-time-video-monitoring
- Analyze the collision risk of every flight movement with evaluation of distance from WTG and trajectory.
- Trigger protection measurements such as acoustic and stroboscopic (visual) warning signals and reduction of the rotor rotation speed or stopping of this.
- Size Classification of bird species in real time in two categories (small and large)

TRL Range

- High, commercially available. Bioseco SA has equipped 17 Wind Farms in Europe, including France, Germany, Spain, Poland.

INSTALLATION AND HARDWARE

- Non-invasive installation: from 4 to 6 modules installed on the WT tower using stainless steel climbs. Control module installed inside the tower. Each module consists of two HD cameras, a doubled strobe deterrence and doubled audio deterrence. Control module.

PRICE

- ++ For sale and remote support fee.

DETECTION RANGE AROUND THE WTG

- 600m for birds with a wingspan of over 1.5m.

DISTANCE ESTIMATION

- 90% accuracy

DETECTION RATE

- False Positive: 10%; False negative: < 1%

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APPLICABILITY

- Onshore, it can be adjusted to the offshore environment.

WEB Site: https://bioseco.com/products/farms

Figure 7. Bioseco system installed on a WT tower.

References: [11]

3.1.10 IDENTIFLIGHT

Owner/producer: Identiflight International (USA)

General description

- Stereoscopic HD camera system
- Daylight system
- Detect birds in the complete rotor area via real-time-video-monitoring
- Analyze the collision risk of every flight movement with evaluation of distance from WTG and trajectory.
- Trigger protection measurements such as reduction of the rotor rotation speed or stopping of this.
- Species Classification
- Network of dedicated autonomous tower-mounted system

TRL Range

- High, commercially available. Identiflight has installed 150 systems in five countries in North America, Europe and Australia.

INSTALLATION AND HARDWARE

- Non-invasive installation: camera module installed on a dedicated tower inside the wind park. The IdentiFlight towers operate as an autonomous system with overlapping aerial coverage for

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detailed viewing. A camera system can monitor more of one WTG based on orography of the area and WTGs layout.

- Camera system consists of a ring of eight fixed Wide Field of View (WFOV) cameras and a High-Resolution Stereo Camera (HRSC) mounted on a Pan and Tilt Unit. The HRSC estimates the line-of-sight distance to the object and takes photographs every 200 ms (5/s). Control module

DETECTION RANGE

- 1000 m for Golden Eagle during optimal weather conditions. During good weather conditions with clear visibility 90% of detections are within a distance of 750 m and during bad weather conditions with partly limited visibility 91% of detections are within a distance of 600 m.

IDENTIFICATION RATE

- The system correctly identified 77% of eagles and 85% of non-eagles.

DETECTION RATE

- False positive rate in curtailment actions: in 5.4% curtailment triggered by a bird, but not by a target species or by a not-flying bird. Only 1% of curtailments by a non-bird.

PRICE

- +++ For sale and remote support fee.

APPLICABILITY

- Onshore, it can be adjusted to the offshore environment.

WEB Site: https://www.identiflight.com/

Figure 8. Identiflight system installed in a wind farm

References: [12, 13]

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3.1.11 3D OBSERVER

Owner/producer: 3D Observer (Spain)

General description

- Stereoscopic HD camera system.
- Daylight system.
- Detect birds in the complete rotor area via real-time-video-monitoring.
- Analyze the collision risk of every flight movement with evaluation of distance from WT and trajectory.
- Trigger protection measurements such as reduction of the rotor rotation speed or stopping of this.
- Species Classification.
- Different mounting options: dedicated autonomous tower-mounted system, on WTs tower. A system can cover more than 1 WT.
- Information on how birds occupy airspace.
- Suitable for pre-construction phase studies.

TRL Range

- High, commercially available. 3D Observer has installed systems in onshore Wind Farms in Spain.

INSTALLATION AND HARDWARE

- Non-invasive installation: 4 HD cameras installed on a dedicated tower inside the wind park or 8 HD cameras installed on WT tower, Environmental Sensors, Control Module. A camera system can monitor more of one WT based on orography of the area and WTs layout

PRICE

- +++ For sale and remote support fee.

DETECTION RANGE

- 900 m (for larger birds as Gyps Fulvus)

APPLICABILITY

- Onshore, it can be adjusted to the offshore environment. Collision monitoring, micro-avoidance behavior monitoring, macro-avoidance behavior monitoring.

WEB SITE: https://3dobserver.com/

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Figure 9. 3D Observer camera system installed in a dedicated tower and on a WT tower

References: NA

3.1.12 U DETECTION SYSTEM

Owner/producer: Artificial Vision (Spain)

<u>General description</u>

- Stereoscopic HD camera system
- Daylight system
- Detect birds in the complete rotor area via real-time-video-monitoring
- Analyze the collision risk of every flight movement with evaluation of distance from WT and trajectory.
- Trigger protection measurements such as acoustic warning signals, reduction of the rotor rotation speed or stopping of this.
- Species Classification

TRL Range

- High, commercially available. Artificial Vision has installed systems in different onshore Wind Farms in Spain.

INSTALLATION AND HARDWARE

- Non-invasive installation: more HD cameras on a dedicated tower inside the wind park or 8 cameras on WT tower. It is possible to connect this module to other Deterrence Module and Windturbine Brake Module.

PRICE

- ++ For sale and remote support fee.

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DETECTION RANGE

- 600 m (for larger birds)

DETECTION RATE

- NA

APPLICABILITY:

- Onshore, it can be adjusted to the offshore environment.

WEB SITE: https://www.artificialvision.es/en/

Figure 10. Artificial Vision system installed on WT tower.

References: NA

3.1.13 BCMS VENTURE

Owner/producer: EDGE Company (Italy)

General description

- Stereoscopic HD Camera system (Stereoscopic Visual)
- Daylight system
- Detect birds in the complete rotor area of a vast area with more WTs via real-time-video-monitoring.
- Analyze the collision risk of every flight movement with evaluation of distance from WT and trajectory.
- Trigger protection measurements such as acoustic warning signals and reduction of the rotor rotation speed or stopping of this.

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- Species Classification
- Different mounting options: dedicated autonomous tower-mounted system, on WTs tower. A camera system can cover a vast area of a wind farms with a group of WTs
- Suitable for pre-construction phase studies.

TRL Range

- High. Under development. EDGE COMPANY has installed the systems in an onshore wind farm in Italy for validation.

INSTALLATION AND HARDWARE

- Non-invasive installation: ultra-HD camera system installed on a dedicated tower inside the wind park or on WTG tower.
- The camera system has IR illuminators with a full 360º continuous rotation pan and 290º tilt control and can monitor an area with more WTs based on orography and WTs layout. Control Module HPC (High Performance Computing). Wireless connection among two modules

PRICE

- NA For sale and remote support fee.

DETECTION RANGE

- 2 km (for larger birds)

DETECTION RATE

- NA

APPLICABILITY

- Onshore, it can be adjusted to the offshore environment. Collision monitoring, micro-avoidance behavior monitoring, macro-avoidance behavior monitoring

WEB SITE: https://www.theedgecompany.net/#deep-tech-solutions

References: NA

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3.1.14 ThermalTracker 3D

Owner/producer: Pacific Northwest National LABORATORY (USA)

General description

- Thermal camera systems
- Stereo vision solution for day and night
- Monitoring of birds and bats
- Three-dimensional flight tracks provide accurate estimates of flight height for risk assessment
- Bird species classification
- Trigger protection measurements (generally shut-down).
- Developed for offshore wind farm.

TRL Range:

- High, under development for nightlight. Tested on-land and in offshore wind farm.

INSTALLATION AND HARDWARE

- Non-invasive installation: a pair of thermal motion cameras installed near the area to monitor. Technology's compact size, which makes it easily integrated with offshore platforms, such as a buoy, substation, or turbine platform. GPS and Computer

DETECTION RANGE

- 500 m

DETECTION RATE

- 81% efficiency. False positive: 17%

PRICE

- NA

APPLICABILITY

- Offshore and Onshore

WEB SITE: https://www.pnnl.gov/available-technologies/thermaltracker-3d

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Figure 11. ThermalTracker 3D camera assembly prototype

References: [14]

3.1.15 B-FINDER

Owner/producer: EMEPKO SA (Poland)

<u>General description</u>

- Thermal Camera system
- Daylight and night vision
- Tool for bat & bird mortality monitoring
- Alert about collision
- Thermal cameras placed at three levels on turbine tower provide 360°coverage around the WT and can detect birds and bats that have collided with blades.

TRL Range

- High, commercially available.

INSTALLATION AND HARDWARE

- Non-invasive installation: 4-12 thermal cameras placed at three levels on turbine tower. Control Module.

PRICE

- NA For sale or leasing monthly and technical support fee.

DETECTION RANGE AND EFFICIENCY

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- 95% efficiency at distances from 50-100m.

APPLICABILITY

- Onshore, it can be adjusted to the offshore environment, but not yet tested. Collision monitoring.

WEB SITE: https://b-finder.eu/#solutions

References: [15]

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3.2 Radar system solutions

In Table 2 all radar system solutions selected for this handbook with main characteristics are reported. In the following paragraphs each solution is described in detail.

TRL 7: system model or prototype demonstration in operational environment; **TRL 8:** system complete and qualified; **TRL 9:** actual system proven in operational environment.

System	Type of Solution	Target	TRL	Price	Applicability	Migration (Macro) monitoring	Collision monitoring	Detection near WTs	deterrent	shutdown
MAX AVIAN RADAR	3D Radar	Birds	9	++++	Onshore/ Offshore	Yes	No	Yes after ~ 10-20 m from rotor swept zone	Yes	Yes
BIRDSCAN MR1	3D Radar	Birds and Bats	9	++++	Onshore/ Offshore	Yes	No	No	No	no
MERLIN E-Series	3D Radar	Birds and Bats	9	++++	Onshore/ Offshore	Yes	No	No	No	No
MERLIN 9090 True3D™ BDR	3D Radar	Birds and Bats	8	++++	Onshore/ Offshore	Yes	No	Yes after ~ 10-20 m from rotor swept zone	Yes	Yes
Accipiter NM1	3D or 2D Radar	Birds and Bats	8	NA	Onshore/ Offshore	Yes	No	NA	Yes	No
BirdTracker	3D or 2D Radar	Birds and Bats	8	NA	Onshore/ Offshore	Yes	No	Yes after ~ 10-20 m from rotor swept zone	No	Yes
AscendXYZ	2D Radar	Birds and Bats	9	NA	Onshore/ Offshore	Yes	No	No	No	No
Zepren solution	3D Radar	Birds and Bats	7	NA	Onshore	Yes	No	Yes	Yes	Yes

Table 2. Radar system solutions with relevant characteristics

3.2.1 MAX AVIAN RADAR

Owner/producer: ROBIN RADAR SOLUTIONS (Netherlands)

General description

- Technology: FMCW, Solid State
- Detection Range: 10 km at 700m altitude
- 360-degree coverage with 60rpm, resulting in track updates every second.
- 3D visualisation of bird flight paths in real-time.
- No species identification, just bird size classification.
- Free standing towers located on wind farm
- Trigger protection measurements such as acoustic warning signals and reduction of the rotor rotation speed or stopping of this.

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TRL Range

High, commercially available

INSTALLATION AND HARDWARE

- Non-invasive installation- Free standing towers located on wind farm. The computer servers can be placed in already existing server rooms, meaning no shelter or housing is required at the radar location itself. All MAX® needs is standard power and ethernet. MAX consists of a radar system including radar antenna, processing station and user interface, breakout box and interconnecting power and network cable.

PRICE

- ++++ For sale or leasing monthly and technical support fee.

DETECTION RANGE

- 10 km at 700m altitude (Bird size: 13 dm2), 3.3 km at 300m altitude (Bird size: 30 dm2)

APPLICABILITY

- Onshore, it can be adjusted to the offshore environment.

WEB SITE: https://www.robinradar.com/max-avian-radar-system

Figure 12. MAX Avian Radar in a wind farm

References: no document available

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3.2.2 BIRDSCAN MR1

Owner/producer: Swiss Birdradar Solution AG (Switzerland)

General description

- Pulse radar - X Band Fixed.
- No species identification, just bird size classification.
- Monitoring day and night bird migrations.
- Suitable for environmental pre-construction phase studies and continuous long-term monitoring.

TRL Range

- High, commercially available.

INSTALLATION AND HARDWARE

- The radar system can be placed as close as 150 m to a turbine with a height of 90 m (hub height + rotor radius).
- BirdScan consists of a transmitter/receiver unit and a computer and analysis unit. The system can be monitored remotely if connected to the internet.

PRICE

- ++++ For sale or for short- or long-term lease and technical support.

DETECTION RATE

- Small birds and bats up to 1000 m distance and large birds (e.g. gulls) up to 2000 m distance.

APPLICABILITY

- Onshore and Offshore

WEB SITE: https://swiss-birdradar.com/systems/radar-birdscan-mr1/

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Figure 13. BirdScan MR1

References: [16, 17, 18, 19, 20]

3.2.3 MERLIN BIRD CONTROL RADAR SYSTEM

Owner/producer: DETECT Inc (USA)

<u>General description</u>

- X- and solid-state S-band Doppler radar sensors in low and high radar power configurations to provide reliable bird detection and deterrent hazing in virtually any terrain, over water and weather conditions, including in fog, rain and snow.
- Detect & deter systems are fully remote controllable.
- No species identification, just bird size classification.
- Suitable for conducting bird and bat surveys, research, mortality risk analysis, habitat and migratory studies, and for long-term and operational monitoring and mitigation of risks.
- Trigger protection measurements such as deterrence and reduction of the rotor rotation speed or stopping of this.
- Single or multi-unit networked fixed, skid-mounted or mobile radar packages.

Versions:

1. MERLIN 7360p True3D™ Bird Detection Radar (BDR) (portable)

   - Full 3D Radar (S-Band) for bird & bat survey & monitoring
   - All weather situational awareness
   - Detection Ranges: Medium-sized Bird/Drone (DJI Phantom): 2.25 km (360°) Large Aircraft: 7 km

2. MERLIN 9090 True3D™ BDR

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- Full 3D Radar S-Band, Pulsed Doppler
- Real-time bird & bat survey and monitoring.
- All weather situational awareness
- Detection range: 15 km

3. E-Series (Environmental)

- Solid State Doppler Horizontal Surveillance Radar and Vertical Scanning Radar.
- Real time bird and bat detection and tracking for quantitative wind farm pre-construction surveys and mortality risk assessment.
- True 3D Tracking: 7.4 Km

TRL Range

- High, commercially available. The MERLIN technology has been tested and proven at installations throughout the U.S., Canada, Europe and Africa and represents the most advanced, proven, widely used avian radar and bird control technology on the market with over 250 MERLIN bird radars delivered worldwide.

INSTALLATION

- System requires a stationary location from which to observe bird activity. For offshore wind farms, this may be a power substation, a Met Mast, or even the shore for near-shore locations. If fiber-optic communication lines can connect the radar sensors to shore, then the processing computer system may be more securely located on shore.

DETECTION RANGE

- It depends on the radar versions.

PRICE

- ++++ – Short-term rental, long-term lease or for sale,

APPLICABILITY

- Onshore and Offshore

WEB Ste: https://detect-inc.com/wind-energy-bird-bat-radars/

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Figure 14. Merlin Radar system in an offshore wind farm

References:[21]

3.2.4 ACCIPITER RADARS

Owner/producer: ACCIPITER RADAR TECHNOLOGIES (USA)

General description

- 2D & 3D radar systems for persistent birds and bat detection and tracking
- Real-time monitoring, automatic alerting, target activity analysis and standardized reporting
- Smart radar activated deterrent activation.
- Tracking bird and bat, 24/7/365 including at night, in the fog
- Generation of temporal and spatial target activity distributions including heat maps, all filtered by time, date, size, speed, heading and altitude.
- No species identification, only size classification

Versions:

1. **Accipiter® NM1-8A Avian Radar System**
   - 2D radar (X or S-Band)
   - Designed to detect and track birds and bats and well suited for use at wind farms for pre-construction assessments and post-construction monitoring.

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- Upgraded with Deterrent Activation Processor
- Additional sensors can be integrated (cameras and weather sensors)

2. **Accipiter® NM1-24D Avian Radar System**
   - 3D volume surveillance radar (X-band)
   - Designed to detect and track birds and bats and well suited for use at wind farms for pre-construction assessments and post-construction monitoring.
   - Additional sensors can be integrated (cameras and weather sensors)

TRL Range

- High, commercially available.

INSTALLATION AND HARDWARE

- Radar system installed in free standing towers located on wind farm. Transmitter/receiver unit and a computer and analysis unit. The system can be monitored remotely if connected to the internet.

PRICE

- NA

DETECTION RATE

- NA

APPLICABILITY

- Onshore and Offshore

WEB Site: https://www.accipiterradar.com/products/safety/bird-strike-prevention/

Figure 15. Accipiter Radar system

References: no available document for Wind farm use case

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3.2.5 BIRDTRACK

Owner/producer: STRIX (Portugal)

General description

- Single and dual radar system
- Bird and bat detection and tracking
- No species identification, just bird size classification.
- Optimized for selective turbine shutdown as a bird mortality mitigation system for wind farms and a bird migration monitoring tool
- Analysis of flight patterns, georeferenced movement parameters, pathways, altitudes, mean traffic rates and other environmental conditions
- Autonomous operation and remote access
- it can be configured for portable and fixed mounted stations

TRL Range

- High, commercially available.
- Test sites:
  - 1 Ecological monitoring at Raposeira Wind Farm (Portugal) during construction phase and first year of post-construction of the wind farm. (2014)
  - 1 Pilot with Radar Assisted Shutdown On Demand (RASOD) and soaring bird monitoring at E.ON's 50MW Barao Sao Joao Wind Farm (Portugal) with a mortality reduction of 100%
  - 1 installation in a Wind Farm in Egypt
  - 1 Pilot for bird and bat monitoring in Offshore Wind farm (2013)

INSTALLATION AND HARDWARE

- Non-invasive installation: radar system for portable and fixed mounted stations. Single and dual radar tracking configurations (2D or 3D) providing large data collection and analysis of long time series. Transmitter/receiver unit and a computer and analysis unit. The system can be monitored remotely if connected to the internet.

DETECTION RANGE

- 15 km

PRICE

- NA

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APPLICABILITY

- Onshore and offshore environment

WEB SITE: https://www.strix.pt/index.php/en/birdtrack

Figure 16. STRIX Radar system in a wind farm

References: [22]

3.2.6 SENS OF LIFE RADAR

Owner/producer: Sens of Life (France)

General description

- Combination of Marine Radar to obtain 3D visualization.
- Detection and tracking flying animals of all size (Birds and bats), over long distances, regardless of visibility conditions.
- Day and night.
- Evaluation of trajectories, measures of distance, speeds and flying altitudes.
- No species identification, just bird size classification.
- Suitable for conducting bird and bat surveys, research, mortality risk analysis, habitat and migratory studies, and for long-term and operational monitoring and mitigation of risks.

TRL Range

- High, commercially available.

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INSTALLATION AND HARDWARE

- Free standing towers located on wind farm. Vertical and Horizontal Marine Radar in combination. Control module.

DETECTION RANGE

- Large birds of prey at 6 km, bats at 2km.

PRICE

- NA. Leasing monthly and technical support fee.

APPLICABILITY

- Onshore and Offshore

WEB: https://sensoflife.com/nos-produits/radar/

Figure 17. Sens of Life Radar

References: no available document for wind farm use case

3.2.7 AVIAN RADAR SYSTEM ASCEND XYZ

Ownwer/Producer: AscendXYZ (Denmark)

General description

- S-Band, Solid State Radar (Marine type).
- 2D Visualization
- Commonly used for bird protection in the airports
- 24/7 Radar detection of birds–that covers up to 150 km2.

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- Real-time monitoring of bird migration
- Pre and post-construction bird activity mapping
- Radar mounted in proximity of turbines, software to process imagery.

TRL Range

- High, commercially available.

INSTALLATION AND HARDWARE

- Radar mounted in proximity of turbines (mobile trailer solution). Furuno (modified by AscendXYZ) Model FAR3000 series Radar and Control Module

DETECTION RANGE

- Large birds (geese) of prey at 10 km, smaller birds at 7 km

PRICE

- NA

APPLICABILITY

- Onshore and Offshore

WEB: https://ascendxyz.com/wind-energy-solutions/

Figure 18. Avian Radar AscendXYZ

References: no available document for Wind farm use case

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3.2.8 EARLYBIRD

Ownwer/Producer: Zepren Solutions (Spain)

General description

- MIMO-FMCW radar system (scheme used in automotive radar today)
- Day and Night
- 360º angular coverage using several (3 to 6) MIMO array blocks with different orientations.
- 3D localization of the flying objects
- Real-time tracking and calculation of the trajectory vector.
- Feature extraction (size, speed, etc.)
- Training a machine learning model for the classification of different species of birds.
- Trigger protection measurements such as acoustic warning signals and reduction of the rotor rotation speed or stopping of this.
- Real-time alarm reporting.
- Suitable for pre-construction phase studies and to detect risk for collision around more WTGs.

TRL Range

- Medium. Under developing.

INSTALLATION AND HARDWARE

- Radar equipment installed on free standing towers located on wind farm. A Radar system can cover more WTGs thanks to a coverage of about 2 km.
- MIMO-FMCW radar in L-Band. Radar equipment has broadcast antenna and 3 or 4 of reception emits between 3,000 and 4,000 pulses per second to detect, identify and calculate the speed of birds.

DETECTION RATE

- Kestrel (Falco tinnunculus) at 1.5 km

PRICE

- NA

APPLICABILITY

- Onshore

WEB: https://zepren.com/

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*Referenc*es: no available document for Wind farm use case

3.3 Audio sensor systems

In Table 3 the audio sensor solutions selected for this handbook with main characteristics are reported. In the following paragraphs each solution is described in detail.

System	Type of Solution	Target	TRL	Price	Applicability and coverage	Migration and macro monitoring	Collision monitoring	Detection for reaction	Deterrent	Shutdown
DTBAT	Ultrasound detector	Bats	9	+	Onshore Offshore 1 WTG	No	No	Yes	No	Yes
PROBAT	Ultrasound detector	Bats	9	+	Onshore Offshore 1 WTG	Yes	No	Yes	No	Yes
AUDIOBAT	Ultrasound detector	Bats	9	+	Onshore 1 WTG	No	No	Yes	No	Yes
ECHOSENSE	Ultrasound detector	Bats	9	+	Onshore 1 WTG	No	No	Yes	No	Yes
ReBAT	Ultrasound detector	Bats	9	NA	Onshore Offshore 1 WTG	No	No	Yes	No	Yes

Table 3. Audio sensor systems with relevant characteristics

3.3.3 3.3.1. DTBAT

Owner/Producer: Liquen Consultoría Ambiental S.L. (Spain)

General description:

- Automatic and real time bat detection with ultrasound recognition
- Sensors: bat detectors installed at WTG height (1-3 units)
- Two modules available: Detection and stop control
- Surveillance area: rotor swept area
- Group species identification from sonogram review
- Stop Control Module (for shutdown when the syst detects bat presence)

TRL

- High. Commercially available. Many DTBat systems installed in different European countries

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INSTALLATION AND HARDWARE

- Non-invasive, 1 or 3 detectors on WTG tower and on nacelle.
  Acoustis sensors, environmental sensors (T, rain, Humidity, Wind Speed), Control Module with Stop control.

PRICE

- + For sale

PRECISION OF REAL TIME DETECTION

- 0.97 (97% of detections are actual bats)

APPLICATION

➢ Onshore and Offshore

WEB: https://dtbat.dtbird.com/

Figure 19. DTBat system installed on WTG

References: no available documents

3.3.2. PROBAT

Owner/Producer: Sens of Life (France)

General Description:

- Automatic and real time bat detection with ultrasound recognition
- Sound capture and post-processing

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- Detection from 1 to 125 kHz, enabling contact with all European species.
- From an hour before sunset to an hour before sunrise
- Stop Control Module (for shutdown when the syst detects bat presence).

TRL

- High Commercially available - 310 Probat systems installed in different Wind farms in Europe

PRICE

- + For sale or Leasing

INSTALLATION AND HARDWARE

- Noninvasive, on the nacelle.
- Acoustic sensors, environmental sensors (T, rain, Humidity, Wind Speed), Control Module with Stop control.

PRECISION OF REAL TIME DETECTION

- 0.90 (90% of detections are actual bats)

APPLICATION

- Onshore and Offshore

WEB: https://sensoflife.com/nos-produits/probat/
Reference: No available.

3.3.4 AUDIOBAT

Owner/Producer: Biodiv Wind (France)

General Description:

- Nocturnal bat detection via microphones
- Sound capture and post-processing
- Regulation module for shut-down on demand

TRL

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- High Commercially available
- Audiobat systems are installed in 3 on-shore Wind farms in France.

INSTALLATION AND HARDWARE

- Non invasive: installation of 3 acoustic units on the tower bottom and on the nacelle to cover 30°C x 240° around it.
- Acoustis sensors and Control Module with Stop control

PRICE

- + For sale

APPLICATION

- Onshore
- WEB Site: https://www.biodiv-wind.com/audiobat/

References: no available documents

3.3.5 ECHOSENSE

Owner/Producer: NATURAL POWER (USA)

General description:

- Detection subsystem - collects bat acoustic and environmental data
- Decision subsystem – processes data against a predetermined rule set and issues commands to curtail or release turbines.
- Curtailment commands are issued to individual turbines.

TRL

- High Commercially available – Echo sense system is tried, tested, installed and operating across numerous sites in North America to protect bats.

INSTALLATION AND HARDWARE

- Non invasive: microphones mounted on brackets on the top of the nacelle, and a bat detector within the nacelle.

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- Acoustics sensors, environmental sensors (T, rain, Humidity, Wind Speed), Control Module with Stop control.

PRICE

- + For sale

APPLICATION

- Onshore

WEB: https://www.naturalpower.com/us

Reference:[23]

3.3.6 ReBAT

Owner/Producer: Normandeau Associates, Inc (USA)

General description:

- Full spectrum bat microphone systems
- Classification of bat calls using a combination of manual expert analysis and SonoBatTM software automated analysis.
- Suitable for long term deployments (pre-and post-construction bird activity mapping)
- Integrable with Turbine Integrated Mortality Reduction system (curtailment launched only when bats are detected to reduce bat-turbine collisions and economic losses.)

TRL

- High, commercially available. Tested on field.

INSTALLATION AND HARDWARE

- Non-invasive: sensors installed on a dedicated tower or on meteorologic tower or on the nacell
- AR125 bat microphone (Binary Acoustic Technology, LLC), environmental sensors (T, rain, Humidity, Wind Speed), Control Module with Stop control.

PRICE

- NA

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APPLICATION

- Onshore and Offshore

WEB: https://www.normandeau.com/environmental-specialists-consultant-rebat-technology/
References: [24]

3.4 Multi sensor solutions

In Table 3 the multi sensor solutions selected for this handbook with main characteristics are reported. In the following paragraphs each solution is described in detail.

System	Type of Solution	Target	TRL	Price	Appicability and coverage	Migration and macro monitoring	Collision monitoring	Detection for reaction	Deterrent	Shutdown
MUSE	2D/3D Radar + stereoscopic cameras	Birds	9	++++	Onshore/ Offshore More WTGs	Yes	Yes	Yes	No	Yes
MINSAIT	3D Radar+ sterescopic cameras	Birds	8	++++	Onshore/ Offshore More WTGs	Yes	Yes	Yes	No	Yes
WT-BIRD	Microphones+ thermal cameras	Birds and Bats	8	NA	Onshore/ Offshore 1 WTGs	No	Yes	No	No	No

Table 4. Multi sensor systems and relevant characteristics

3.4.1 MUSE

Owner/Producer: DHI (Denmark)

<u>General description:</u>

- One high-performance 2D (or 3D) radar coupled to two moving high-definition daylight pan-tilt cameras.
- Species recognition algorithms allow recognition of mitigation responses to the individual focus species.
- Automatically determination of flight height of focus species and 3D flight trajectories.
- Collision detection, meso and micro-scale avoidance monitoring
- Pre-construction studies
- Integration with the wind farm SCADA

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TRL Range

- High, commercially available. DHI’s MUSE solution is validated and well-proven, more of 10 installations in the offshore wind farms worldwide.

PRICE

- ++++ For sale, Leasing and technical support fee.

INSTALLATION AND HARDWARE

- 20’ radar container with server and radar computer, and two 10’ camera container with camera servers. The antenna and gearbox of the FAR- 3000 radar will be installed on the roof of the 20’ container, and the cameras on top of the 10’ container.
- Horizontal (FAR-3000) radar (that can be combined with Vertical radar), two High-definition daylight video cameras or more (based on the configuration and number of WTs to cover). Control Module

DETECTION RANGE

- Radar à 2 km, cameras à from 1 km cover more WTGs for micro-scale avoidance monitoring.

APPLICATION

- Offshore and Onshore

WEB: https://www.dhigroup.com/business-applications/dhi-muse/

Figure 20. MUSE system installed in offshore wind farm

References: [25]

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3.4.2 MINSAIT SYSTEM

Owner/Producer: Minsait - Indra Company

General description:

- 3D radar coupled with one or more PTZ cameras to target the field of view.
- Bird species identification and classification in real-time
- Identification of high-risk situations (Collision probability calculation) and launching of warnings and preventive actions (Shut-down or reduction of rotor speed)
- Radar coverage area of more than 78 km².
- Multi-beam antenna provides a direct measurement of the height of the height of detections and can discard terrestrial targets.
- Multiple target detection Capable of tracking more than 100 targets at a time

TRL

- High. Commercially available

INSTALLATION AND HARDWARE

- Dedicated tower for radar and cameras installation inside the wind farm.
- ART Midrange3D radar (doppler CWLFM, Ku band, 360°), one or more PTZ (pan, tilt and zoom robotic video) cameras. Control module

PRICE

- ++++ For sale more annual technical support

DETECTION RANGE

- Up to about 3 km for medium-sized birds (eagle/kite); More than 4 km for large birds (*Eurasian griffon vulture.)*

WEB: https://www.indracompany.com/en/minsait

References: no available

3.4.3 WT-BIRD

Owner/Producer: TNO (Netherlands Organization for Applied Scientific Research) (Nederland)

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General description:

- Two acoustic detectors per turbine blade, combined optionally with three cameras covering the entire rotor-swept area.
- Bird and bat collision detection in real time.
- Video and audio recordings analysis in order to: check whether a collision took place or not, in case of doubt; identify species; analyze the collision mechanism, e.g. blade position, bird movement before collision; take notice of special circumstances, e.g. weather, other birds passing, etc.

TRL

- High, commercially available.

INSTALLATION AND HARDWARE

- Acoustic devices are installed on the blades and cameras on the tower.
- Acoustic sensors (two for each blade), 3 near IR sensitive cameras per tower and more infrared LED lights and Control Module.

APPLICATION

- Onshore and Offshore.

WEB site: https://www.tno.nl/en/

Figure 21. WTBIRD system installed in a WTG

References: [26, 27, 28, 29]

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3.5 Other systems

In Table 5 the solutions based on different technologies and selected for this handbook are reported. In the following paragraphs each solution is described in detail.

TRL 4 – technology validated in lab; TRL 5 – technology validated in relevant environment (industrially relevant environment in the case of key enabling technologies); **TRL 8:** system complete and qualified; **TRL 9:** actual system proven in operational environment (competitive manufacturing in the case of key enabling technologies; or in space)

System	Type of Solution	Target	TRL	Price	Applicability and coverage	Migration and macro monitoring	Collision monitoring	Detection for reaction	Deterrent	Shutdown
NRG	Ultrasound deterrence	Bats	9	+	Onshore 1 WTG	No	No	No	YES	No
ISU Whistle	Ultrasound deterrence (passive)	Bats	4-5	+	Onshore 1 WTG	No	No	No	YES	No
Fleximaus	Embedded computer technology	Bats	8-9	NA	Onshore 1 WTG	No	No	No	No	Yes
V-Raptor	Drone	Birds	5	NA	Onshore	No	No	No	Yes	No
Airtonomy	Drone	Birds	5	NA	Onshore	No	Yes	No	No	No

Table 5. Deterrence and other systems with relevant characteristics

3.5.1 NRG

Owner/Producer: NRG Systems (USA)

<u>General description</u>

- Bat Deterrent system with ultrasound emissions
- Cover only the rotor swept zone
- No Curtailment
- No Detection
- Installation

TRL

- High, commercially available. Tested on field and Full Field Installations

INSTALLATION AND HARDWARE

- Non invasive: ultrasound speakers mounted on the nacelle and /or on the tower
- Six Ultrasonic Bat Deterrent Units, Deterrent Unit Controller (DUC) ans Wireless modem for communication.

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PRICE

- + for sale

EFFECTIVENESS IN BAT FATALITY REDUCTION

- *Lasiurus cinereus* 78%; *Tadarida brasiliensis* 54%

APPLICATION

- Onshore

WEB site: https://www.nrgsystems.com/products/bat-deterrent-systems/detail/bat-deterrent-systems/

Figure 22. NRG Deterrence Unit installed on the nacelle

References: [30, 31]

3.5.2 ISU WHISTLE

Owner: Iowa State University

General description:

- Passive ultrasonic deterrence
- Bladed mounted driven by blade-relative flow
- Mitigate bat mortality at wind farms with little to no reduction in energy capture
- Under developing technology

TRL

- Medium, under developing.

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INSTALLATION

- Non invasive, mounted on the blades

PRICE

- Unknown, but supposed to be low

APPLICATION

- Onshore

References: [32]

3.5.3 Fleximaus

Owner/producer: Fleximaus GmbH (Germany)

General description:

- Embedded computer technology for the improvement of the switch-off algorithm in wind farms for bat protection.
- Tool for curtailment optimization to reduce energy losses
- Use of wind speed and temperature to do a wind speed calculation over the whole wind farm to reduce the shutdown times
- Possible use of other environmental sensors for humidity and rain to improve the wind calculation
- A server can control more WTGs

TRL

- High, commercially available.

INSTALLATION

- Non invasive: environmental sensors installed on the base of the tower or on a building in the wind farm

HARDWARE

- WT wind speed sensors, other environmental sensors, and Stop control module.

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PRICE

- NA- For sale with annual fee

APPLICATION

- Onshore

WEB Site: https://www.fleximaus.de/solutions/bat-shutdown/?lang=en

References: No available documents

3.5.4 V-Raptor

Owner/Producer: Ventor Innovation (Spain)

General description

- Drone (UAV) for bird deterrence or incognito surveillance.
- V-Raptor is a UAV with the appearance of a bird of prey. Its biomimetic characteristic is key for bird deterrence missions or incognito surveillance.
- Suitable to reduce the Environmental Impact of Wind Farms, avoiding bird mortality.
- It can fly completely autonomously from a programmed flight plan, or semi-automatically by directing it to its position in real time.
- It is especially effective with birds of similar size or smaller.
- V-Raptor specifications:
  Wing Span: 1.600 mm
  Lenght: 725 mm
  Flight Time: 1h 45’
  Range: 50km
  Operation Speed: 40-90 km/h

TRL

- Medium, available for test in Wind Farms

HARWARE

- Drone with biomimetic characteristic

INSTALLATION

- Non invasive. Use of Drone from a programmed flight plan or semi-automatically

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HARWARE

- Drone (UAV) - Unmanned Aerial Vehicle

Price

- NA- For sale or for rent

APPLICATION

- Onshore

WEB site: https://www.ventorinnovations.es/en/v-raptor-bird-control-uav/

Figure 23. V-RAPTOR Drone

References: no available documents

3.5.5 5.AIRTONOMY

Owner: Airtonomy (USA)

General description:

- Drone program to monitor wildlife in the wind farms
- Identification of wind turbine fatalities (bird identification) in a systematic way.
- Currently this technology is under development with use of COTS (Commercial Off The Shelf) drones and exploring bird identification integrating onboard computing.

TRL

- Medium, under development

INSTALLATION

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- Non invasive

PRICE

- NA

APPLICATION

- Onshore

WEB Site: https://thread.one/airtonomy/

Reference: no available documents

3.5 Painting of Turbine Blades

A non-technological technique that can be considered a bird protection solution to apply in wind farms is the painting of turbine blades. A recent study carried out by the Norwegian Institute for Nature Research (NINA) revealed how painting turbine blades black can help birds from colliding with wind turbine blades. This is achieved by reducing motion smear. Motion smear is a visual phenomenon that occurs when an object is moving so fast it appears to the eye like a near-invisible blur. NINA painted a single blade of four turbines black and left four neighbouring turbines unpainted. Bird collision rates were reduced by 70%.

Another 'black blade' pilot project is ongoing in Netherland and is expected to run until the end of 2024. For this pilot test seven of existing turbines in Eemshaven wind farm (with a tip height of 140 metres) have been painted black. The study will also assess aviation safety and the impact of the painted blades on the landscape. This project is an initiative of RWE and Groningen Province in collaboration with other public authorities, the nature sector, and private parties in the wind sector.

More testing is needed to prove the effectiveness of this method conclusively, but the initial results are certainly promising.

The benefits of this solution are:

- Cost-effective solution
- Long-lasting

The critical points are:

- Manual painting of blades

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- Only visible in daylight

References: [33, 34]

4. KPIs for system evaluation

In the literature, there are not many evaluations of the various detection/reaction systems and other bird deterrence, and monitoring systems present on the market. Evaluations are often conducted by the system suppliers themselves or by environmental companies commissioned by wind farm operators or government agencies, but in most of these reports the evaluation protocol is not described precisely.
In Table 6, KPIs are proposed that could be calculated when an evaluation of the effectiveness of primarily detection and response systems were to be conducted with on-site pilot tests.

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DETECTION & DETERRENCE KPIs					
#	**KPI**	**KPI Description**	**KPI Minimum requirements**	**KPI calculation methodology**	**Notes/Clarification**
1	**Detection rates and False Negative**	Proportion (in %) of detected birds (or bats) by systems in relation to the total number of birds near the turbines, as recorded by visual observations. The probability of detection may be calculated for: (A) *3 distances zones* i.e., *Critical zone*, *Normal zone* and *Far zone specified by system type according to their Technical Specification and* (B) Different group species according to the protection status of each region *When this KPI is calculated also **False negative KPI** can be determined (proportion of birds (bats) no detected by systems in relation to the total number of birds near turbines as recorded by visual observations*	a) One year monitoring & calibration program (fieldwork & office work: analysis / spatial comparison of visual observations) b) Functionality of each sub-systems must be known c) The sample size of the visual and the system record must be sufficient to perform statistical analysis	Because the network of the systems aims primarily at detecting and mitigating collisions of birds flying at the altitude of rotor blades, the calculation is suggested to be made for bird flights at all altitude bands, as well as, for bird flights at the altitude of rotor blades, separately	To evaluate the performance of systems the analysis may focus primarily on evaluating the detection and deterrence performance at each wind turbine and each wind farm rather than on the performance of each system. As multiple systems cover different zones of the same wind farm or the same wind turbine it is not objective to evaluate the detectability of individual system in relation to a close distance bird flight because another system of nearby wind turbines could be responsible for detecting any movement to that specific zone of the bird flight. This is also evident from the comparison of the results of the performance analysis per wind farm and per wind turbine in relation to the results of the analysis per system. In general, if looking at individual system, the detection rate may seem low but when assisting detection rate at wind turbines or wind farm their values are considerably higher. If a detection error is found, videos (or other types of detection) can be reviewed and an attempt can be made to classify the detection error (e.g., glare, poor blind spot coverage, etc.). For the case of radar systems where a single system covers more than one wind farm or systems where the detection is done on a matrix basis (the detection systems of each wind farm work as an integrated network), this KPI can evaluate a number of detections occurred in all areas covered done by the field technicians and see what percentage has been detected by the systems.

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2	**Direct Classification of the species**	Dedicated classification per species or group of species (raptors, large predators, large size species, medium size species etc) and type of flight (gliding, hovering, active flight) So that these criteria can be evaluated in these possibilities ((after the revision of videos collected) - % of birds correctly detected - % gliding birds - % large species >1m wingspan % small species <1m wingspan	a) One year monitoring & calibration program (fieldwork & office work: analysis / spatial comparison of visual observations) b) Functionality of each sub-systems must be known c) The sample size of the visual and the system record must be sufficient to perform statistical analysis	Classification of the species based on certain criteria i.e., size, flight behaviour etc. Cross check among specialists' observations with system classification.	Evaluation of the system's ability to classify detected species. If the system can classify by size indicate the percentage of recognition of each size range If the system is capable of recognizing species (even some larger species) Indicate the percentage of recognition of a single species of interest for that site. (Example: % of *Red Kite recognized*)
3	**False Positive (FP) rate**	- The number of false positives detections (over a recommended distance of 500m- 1km) – video sequences or other type of record without birds presence	a) One year monitoring & calibration program b) Functionality of each sub-systems must be known c) The sample size of the visual and the system record must be sufficient to perform statistical analysis	Proportion of false positive system detections (in %) in relation to total system detections, cross check by the ground observations.	False Positives rate can be produced by Helicopters or Airplanes, insects, rain and wild animals (foxes, wolfs etc), the movement of the moving blades, sun-moon contrast, strong prevailing wind etc.

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4	**Deterrence rate**	The number of birds which are visually diverted from the protected zone of the corresponding system.	a) One year monitoring & calibration program (fieldwork & office work: analysis / spatial comparison of visual observations) b) Functionality of each sub-systems must be known c) The sample size of the visual and the system record must be sufficient to perform statistical analysis).	Proportion (in %) of visually detected birds which were diverted from the zones protected by systems. The response to the emitted signal could be verified either visually or by analyzing recorded videos, showing birds changing their flight behavior after sound exposure.	This indicator should be applied when the deterrent signal is launched. Also, can be analyzed how many times the system launches a deterrent signal without a detection or bird nearby.
5	**Number of WT stops due to FP/ Total Number of WT stops**	The proportion of WT stops due to False Positive Detections (in %) in relation to the total number of WTG stops	a) One year monitoring & calibration program (fieldwork & office work: analysis / spatial comparison of visual observations) b) Functionality of each sub-systems must be known c) The sample size of the visual and the system record must be sufficient to perform statistical analysis	As described in KPI 2 False Positive. System's platform must count and calculate the number of total stoppages per day as also the duration of each stop	The wind turbine (WT) False Positive (FP) stops rate can also be calculated as a proportion of FP WT stops against all WT stops per system installed for all wind farms - Some important parameters to take into account for the analysis of this are: Systems where the stop is configurable depending on the distance at which the detection occurs, so it should be a data to take into account. Consider the time it takes the system, from the effective detection with stop until the wind turbine manages to stop
6	**Number of carcasses per WT**	Number off carcasses found under the WTs Rotor Swept Zone	a) Pre - construction bird monitoring b) Monitoring & carcass program with minimum duration of two (2) years	Carcass research according to international practices	Using this KPI we can also estimate the total number of carcasses important species per year/per WF. For new wind farm it is possible to count the carcasses found below a WT. For wind farms in

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					operation already for years with carcasses data before the protection systems were installed, it is possible to see in percentages whether there has been a reduction in fatalities. - To complement the analysis, detectability and predation criteria can be included to make the estimate representative, especially in the case of chiroptera.

Table 6. KPIs proposed to measure the effectiveness of the various systems.

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ANNEX I

Exploitation strategy

	Dimensions	Analysis
1	**Exploitation potential**	Main actors that stand to benefit from the results or findings are the: wind energy farm developers and operators; regulatory authorities and/or government agencies responsible for energy and environmental policies and procedures; NGOs related to issues such as environment, local development, cultural heritage; The added value of the results or findings for WENDY, its partners or external stakeholders is based on the comprehensive overview of technological systems available or under development for environment impact mitigation of onshore and offshore wind farms. Unique features of the deliverable's results that may be attractive: in this handbook the most innovative and promising solutions to monitor and protect birds and bats in wind farms are included and described from a technical point of view (operating principles), the areas of application, the degree of maturity of the technology and indicative costs. The information provided in this document is applicable to all wind plants in the world and can be used as a guide for implementing the most effective solutions for a given mitigation strategy.
2	**Potential exploitation pathways**	Exploitation actions: knowledge transfer activities such as workshops, training webinars to disseminate the findings, publication of the handbook on the Wendy project website.
3	**Partners' plans**	The results and findings are a key information resource for all partners or all partners to get an update on the most innovative mitigation solutions and a guide to choosing the most suitable solution for a given mitigation strategy.

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