# The Nexus between Wind Energy, Biodiversity Protection and Social Acceptance: Evidence of Good Practices from Greece, Latvia and Poland

Christos Bouras, Eirini Stergiou, Charitini Karakostaki, Vasileios Tzanos, Vasileios Kokkinos



***Abstract*—**Wind power represents a major pathway to curtailing greenhouse gas emissions and thus reducing the rate of climate change. A wind turbine runs practically emission-free for 20 years, representing one of the most environmentally sustainable sources of energy. Nevertheless, environmental and biodiversity concerns can often slow down or halt the deployment of wind farms due to local public opposition. This opposition is often fuelled by poor relationships between wind energy stakeholders and civil society, which in many cases led to conflictual protests and property damage. In this context, addressing these concerns is essential in order to facilitate the proliferation of wind farms in Europe and the phase-out of fossil fuels from the energy mix. The aim of this study is to identify a number of good practices and cases to avoid increasing biodiversity protection at all stages of wind farms' lifecycle in three participating countries, namely Greece, Latvia, and Poland. The results indicate that although available technological solutions are already being exploited worldwide, in these countries, there is still room for improvement. To address this gap, a set of policy recommendations is proposed to accomplish the wind energy targets in the near future while simultaneously mitigating the pertinent biodiversity risks.

***Keywords*—**Biodiversity protection, environmental impact, social acceptance, wind energy

## I. Introduction

ACCELARATING the deployment of wind farms across Europe is necessary to deliver the Green Deal and achieve carbon neutrality by 2050. To meet the EU target of reducing emissions by 55% by 2030, the European Commission has set a goal for the overall energy mix to comprise at least 40% renewables, which means that around 68% of Europe's electricity should come from renewables [13]. This necessitates a massive scale-up of renewable energy production, including wind energy production, which has the highest potential in EU. Nevertheless, reaching this objective imposes an increase in public acceptance for wind energy projects and rebuilding trust within local communities.

A key issue for the wind power sector, with significant implications for the expansion of the wind energy capacity, is the risk that wind turbines will adversely impact wildlife both directly, through collisions with birds and bats, and indirectly through noise pollution, habitat disruption and reduced survival or reproduction rates of the animals in the local ecosystems.

In this context, protecting biodiversity and alleviating social concerns while maintaining the economic viability of wind farms remains a key challenge for the wind energy industry. Although mandatory environmental impact assessments have made biodiversity considerations an important part of the permitting process, the possibility of cumulative effects on vulnerable species is likely to increase, particularly in countries where clusters of wind projects are located near to areas of importance for threatened bird and bat populations. Energy planning has yet a long way to go before defining a standardized European framework for biodiversity risk mitigation that would be highly beneficial for both the deployment of wind farms and the protection of local ecosystems.

The present study aims to enhance the knowledge-base of public authorities, environmental agencies and NGOs, regarding current biodiversity risk mitigation measures and good practices in order to promote biodiversity protection in wind farms projects. For the purpose of the research, a survey was carried out in three EU countries, namely Greece, Poland and Latvia, followed by a qualitative approach that aimed to assess the good practices and their economic impact on operational wind farms.

The remainder of the paper is structured as follows: Section II describes the wind farm's impact on biodiversity, Section III the good practices and technologies for increased biodiversity protection and Section IV the cases to avoid. In Section V, the methodology for the data collection is analysed; whereas the main findings are discussed in Section VI. Lastly, Section VII develops some policy recommendations addressed to public authorities, wind farm private stakeholders and the scientific community, and discusses possible future directions that could follow this work.

## II. Wind Farm's Impact on Biodiversity

### *A. Impact of Onshore and Offshore Wind Turbines on Bird and Bat Population*

There are several types of risks that could affect and impact the bird and bat population [1]. However, certain species are more vulnerable than others to collisions, particularly raptors (i.e., hawks, eagles, falcons), as they tend to spend more time

C. Bouras is with the Computer Engineering & Informatics Department, University of Patras, GR26501, Patras, Greece (corresponding author, phone: +30 2610996952; e-mail: bouras@upatras.gr).
E. Stergiou is with the Department of Economics, University of Patras, GR26501, Patras, Greece (e-mail: e.stergiou@upnet.gr).
C. Karakostaki and V. Tzanos are with the Hellenic Society for the Promotion of Research and Development Methodologies, GR15232, Athens, Greece (e-mail: karakostaki@promea.gr, tzanos@promea.gr).
V. Kokkinos is with the Computer Engineering & Informatics Department, University of Patras, GR26501, Patras, Greece (e-mail: kokkinos@cti.gr).

in the air looking for prey and even flying well above ground level puts them within the rotor swept area of an average wind turbine [2], [3]. Since raptors have in general lower reproduction rates, even a small number of casualties can cause problems both to the raptors' population and the health of the ecosystem. For the case of bats, most fatalities are caused by bats colliding with rotating blades of wind turbines, whereas it has been observed that mortality of bats at wind turbines is highly seasonal. Fatalities are highest during autumn migration (August-September) and on nights with low wind speeds [4].

Moreover, wind farms can affect wildlife species through changes in the habitat quantity, quality and connectivity. Empirical studies have shown that soaring birds tend to change their flight trajectories to avoid turbines and that their numbers decrease in the close proximity of wind turbines [5]. These avoidance behaviours suggest that birds are to some extent able to cope with the presence of wind turbines to avoid collisions but as a result their trajectories become more scattered. In addition, empirical evidence has shown that the presence of wind turbines can cause functional habitat loss (i.e., loss of airways in travel corridors) [14]. Wind farms occupy and transform relatively small percentages of the land; however, the land clearing necessary for the wind turbine operation and the roads required for the installation and maintenance of the wind turbines add to the total habitat fragmentation, potentially severely impacting wildlife in the area. In particular, the amount and the location of habitat patches remaining in a landscape can have strong effects on overall species abundance, behaviour and conservation through edge effects, and other ecological processes.

### B. Impact of Offshore Wind Turbines on Marine Mammals

Most whales and seals, and even some invertebrates such as squid, rely on acoustic signals for a great number of basic activities, including communication, mate selection, location of prey, protection against predators and navigation. A change in ambient noise can have a negative impact on the biological fitness of individual animals or even entire populations. Consequently, the main risk affecting marine mammals is communication disturbance and behavioural change from the underwater noise during construction (e.g., drilling), as well as boat and helicopter traffic. Thus, they can be affected during the implementation and operation phases of offshore wind farms [1]. In addition, even though the noise of operating turbines does not appear to damage the hearing organs of marine animals, it is known to affect the animal behaviour when they are in the proximity of the turbines. Although the sound level is moderate, it is permanent (until decommissioning) and can impact mammals that depend on their hearing systems for communication, orientation, hunting and echolocation [6], [7].

In monopile installations, the noise from the drilling rigs during construction drives away several marine species (such as marine mammals that are sensitive to noise) from the area, whereas the disturbance of the seabed also affects other micro-organisms. On the other hand, this problem (i.e., adversely impacting wildlife during the construction phase) can be avoided with the use of floating turbines. These represent a technological solution with a considerably lower impact on the environment and biodiversity, although they have not yet reached the same technological maturity as fixed foundation turbines.

## III. Good Practices and Novel Technologies for Increased Biodiversity Protection Throughout Wind Farm's Lifestyle

### A. Good Practices during Wind Farm Planning

Experience has shown that it is highly important to address ecological and biodiversity issues already during the site selection process. Incorporating the 'screening' of projects and plans at the preliminary stages of the licensing process allows an early assessment of biodiversity risks and the overall environmental impact and enables the adoption of case-sensitive mitigation strategies.

The most common and effective way to reduce potential environmental impacts, such as bird and bat habitat loss and deterioration, is through a suitable selection of the installation site based on a set of predefined criteria (e.g., minimum distances from nests of sensitive bird species as well as from habitats associated with high bat activity such as migratory or transit routes). This requires a detailed and scientifically documented environmental impact study.

Another widespread practice is public consultation with experts, local communities and civil society. This allows the expression of biodiversity concerns by both local communities and civil society organizations (such as the Hellenic Ornithological Society which is actively working for the protection of many bird species) and is taken into account by wind energy companies.

### B. Good Practices during the Construction Phase

Floating wind turbines are a relatively new technological development that exhibit considerable environmental advantages over traditional fixed-foundation turbines that involve drilling to the sea floor to install the turbine foundation. Floating wind turbines are mounted on a floating structure and their installation generates significantly less underwater noise. However, despite its lower environmental impact this technology is still not widely applied.

Furthermore, interventions on the landscape through the use of deterrence methods could prevent birds from entering the wind farm area. Superficially tilling the soil around the base of turbines in order to reduce the amount of vegetation and, consequently, the abundance of potential prey constitutes an indicative example of this practice [8].

### C. Good Practices during the Operation of the Wind Farm

Good practices during the wind farm operation are particularly important as they concern the phase with the greatest risks to biodiversity.

Curtailment is a simple but very popular and efficient practice. It consists of shutting down turbines when they are likely to harm birds or bats, reducing only slightly and momentarily the electricity generation. More recent technologies use a mix of Artificial Intelligence, machine learning and high precision optics to efficiently curtail the electricity production. The system automatically curtails the turbine when an eagle (or eagle-like flying object) is detected. By detecting a bird as far as one kilometre away and classifying it as a protected species (such as an eagle) in real time, the system arms wind farm operators with critical visual and quantitative data needed to reduce or avoid collisions. In that way, protected birds are conserved, and energy production loss is minimized [9]. This technology is already widely used in wind farms in Germany, the Netherlands and in Spain. Similar curtailment techniques are also adopted to protect bats at times of peak activity such as during the autumn migration and swarming [10]. Several wind farms in Germany use curtailment algorithms to stop the turbines at times of high predicted collision risk at the expense of lower energy production.

A second widespread good practice is the employment of black rotor blades, which due to their colour are easier to be distinguished by birds [11]. A Norwegian study, carried out in the Smøla wind power plant, compared bird mortality rates before and after painting a single wind turbine blade black in four out of 68 turbines. The study showed that this technique reduced fatalities by 72% and that it was most effective at reducing collision deaths for birds of prey, such as white-tailed eagles (*Haliaeetus albicilla*) [12]. A similar study in Eemshaven in Netherlands goes beyond the results of the aforementioned study and explores different factors such as flight safety and aesthetics issues [11].

### *D.Good Practices at the Decommission Phase*

Decommissioning is the process whereby all or part of the wind farm infrastructure is removed, and the habitat is restored to the condition stipulated by the competent national authority. It can cause noise pollution in both onshore and offshore wind turbines and vibrations, bottom disturbance and turbidity in the offshore. Moreover, risks of chemical pollution are increased during removal activities. All these aspects can potentially cause an ecological impact on present ecosystems. To this day, only a few wind farms have been decommissioned.

The removal of actual turbines and related structures might have negative effects in terms of the reef effect in offshore projects. Coral reefs provide habitat for numerous marine species. Therefore, upon decommissioning there needs to be a balanced consideration of the advantages and disadvantages of leaving in place certain infrastructure, such as wind-turbine foundation bases and rock armours, which may confer benefits to marine mammals.

Usually, new, more modern and more productive wind turbines will be installed on the same site, so that clean energy production can continue, making use of existing infrastructure (e.g., grid). Consideration should be given however to carrying out decommissioning at a time of year that minimizes disturbance to bats and their habitats [8]. This requires local knowledge about the bat species present in the area, knowledge of the presence of hibernacula and maternity roosts and then understanding of their annual life-cycle point. A typical year in the life of bats in Europe involves a period when they are active and a period when they are in hibernation. In central Europe generally, bats are active from April to October, and they are usually less active or in hibernation from November to March. However, in the warmer South and in the maritime climate of the West, hibernation only occurs from mid-December to February; whereas in some mild winters some populations do not hibernate at all. In order to mitigate the environmental impact on local bat populations, the choice of the least sensitive time for decommissioning operations is therefore a very important aspect to consider.

## IV. Cases to Avoid

Identifying cases to avoid are particularly important, since they could be used to identify lessons learnt and hinder similar mistakes. Some of these include unsuitable wind turbines placement (e.g., in areas with endangered bird species), and extensive or unneeded deforestation, all of which can have serious consequences for wildlife. Requiring a wind power project to obtain environmental licensing in the planning phase usually prevents such mistakes.

First of all, the lack of sufficient monitoring of the wind turbines' impact on wildlife can potentially have severe consequences for endangered species and impede the adoption of suitable mitigation measures. To address this issue, surveys and intensive monitoring of short- and long-term effects on bird and bat populations are necessary in order to assess the extent of wind farm impacts on bird populations and define appropriate mitigation measures to reduce those impacts.

Moreover, the improper and incomplete collection of wind farm turbines can have a significant impact on the environment and consequently on the flora and fauna of the area, thus damaging biodiversity. If wind turbines and their blades are not properly collected after the wind farm reaches its end of life, but instead lie on the ground, they will create waste, with many possible harmful consequences. The blades are disintegrating and filling the area with microplastics. As a result, some birds who feed from the local flora are inevitably ingesting plastic and possibly other materials, such as aluminium, which can be proven fatal.

## V.Data Collection and Methodology

The methodology and good practices/cases to avoid that are presented in Sections V and VI are part of the project "Wind4Bio - Increasing the Social Acceptance of Wind Energy" of the European Climate Initiative (EUKI) programme. The project involves partners from three EU countries, namely Greece, Latvia and Poland. Partners carried out a survey in their respective territories in order to identify and collect good practices on biodiversity protection in onshore and offshore wind farms, as well as cases to avoid.

The survey followed a qualitative research approach that aimed to gain a comprehensive understanding of the measures implemented so far in existing wind farm projects or will be implemented in planned projects. To guarantee that all results are documented in a consistent and clearly structured manner, a common approach was used to collect the required data. In particular, a questionnaire was developed to facilitate the research, addressed to the three partners, namely, University of Patras (UPAT) from Greece, Green Liberty from Latvia and Foundation Warsaw Institute for Economic and European Studies (WiseEuropa) from Poland.

The survey was conducted through two sub-questionnaires, both hosted on the EU surveys platform. The first sub-questionnaire was dedicated to the identification of good practices, model examples and novel technologies for increased biodiversity protection and their impact assessment. The identification section included general information about the good practice, such as the:

- Title
- Location (Onshore; Offshore)
- Implementer and its legal status (Company/Private initiative; Regional/National authority; Grassroot initiative/Community; NGO; Other)
- Type (Technology; Model of civic participation; Management/Governance; Monitoring; Other)
- Phase (Planning; Construction; Operation; Decommissioning)

In the impact assessment section, partners were requested to evaluate the effectiveness of the identified good practices with regards to three criteria: a) capacity to mitigate biodiversity risks, b) impact on wind farm's economic activity, and c) transferability potential. Each criterion included a number of sub-criteria that were evaluated on a basis of 0 to 3, taking into consideration any available quantitative data measuring impact (e.g., bird casualties before and after the application of the 'good practice', energy generation loss due to turbines shut-down, duplication rate of the good practice in other regions). The second sub-questionnaire focused on cases to avoid.

## VI. Results

All partners contributed to data collection with cases from their own territory, demonstrating a high level of commitment and reaching the collection targets set in the Methodology Section. A total of 14 good practices were identified by the partners, providing illustrative and practical examples that have been proven to be successful. In addition, four cases to avoid were reported. In Appendix, Tables I and II present the collected good practices and cases to avoid.

### A. Overall Findings

As Fig. 1 displays, out of the 14 identified practices, six are located in Greece, four in Poland and four in Latvia. Conversely, two cases to avoid are identified in Greece, and one in both Poland and Latvia.

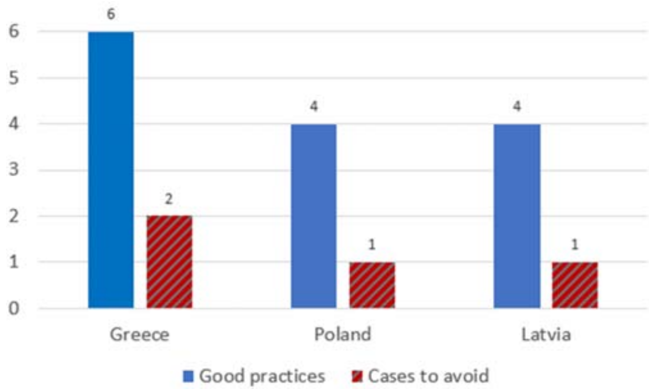


Fig. 1 Geographical distribution of identified good practices and cases to avoid

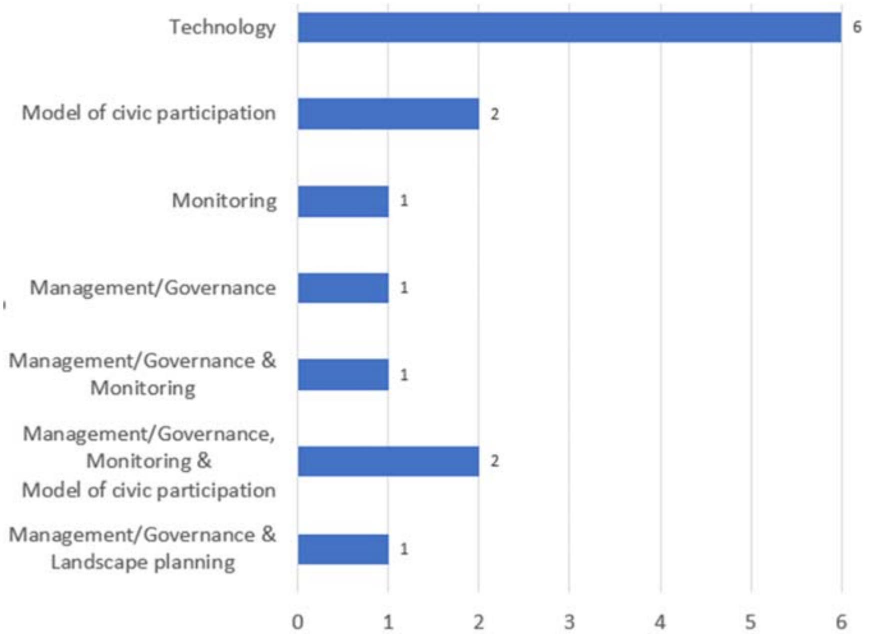


Fig. 2 Distribution of good practices' type

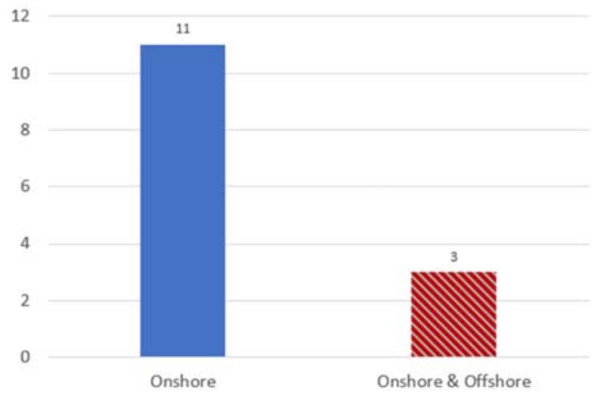


Fig. 3 Distribution of good practices' location

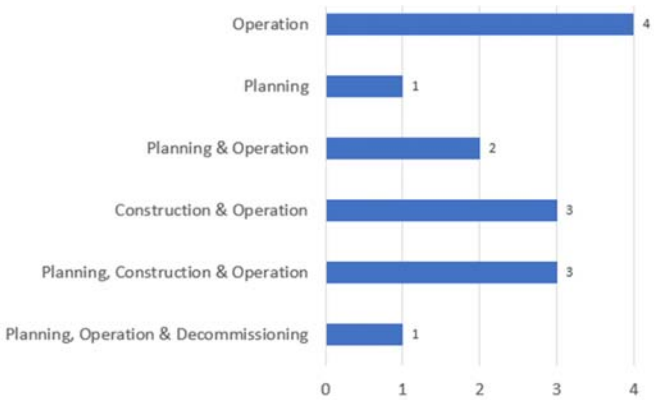


Fig. 4 Distribution of good practices' phase

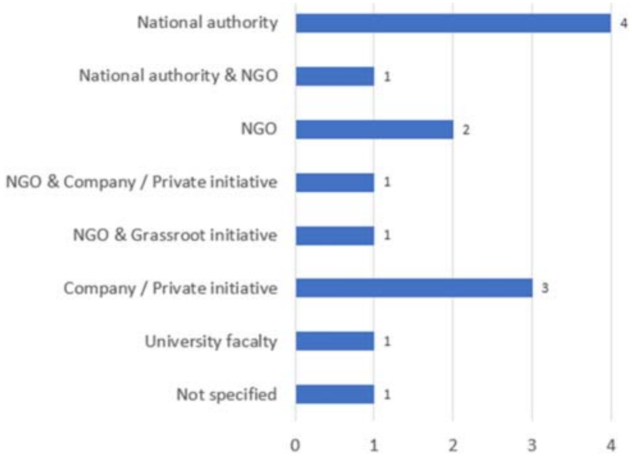


Fig. 5 Distribution of the implementer's legal status

Regarding the type distribution of the identified good practices, as presented in Fig. 2, six good practices relate to 'Technology', two relate to a 'Model of civic participation', one to 'Monitoring' and 'Management/governance', and the remaining to a combination of the available types.

Fig. 3 shows the classification of good practices based on their location. Out of the 14 practices, 11 are specific to onshore wind farms, whereas three have potential applications in both onshore and offshore wind farms. No good practice is identified to specifically mitigate biodiversity risks in offshore wind farms.

As to the phase of the wind farm's lifecycle, as shown in Fig. 4, four good practices are employed during the operation phase, one during the planning phase, two during both planning and operation, three during both construction and operation, three across all planning, construction and operation phases and one good practice during planning, operation and decommissioning phases.

Finally, as depicted in Fig. 5, regarding the legal status of the implementer, five practices involve a national authority (4 of which are implemented solely by a national authority whereas one involves a mix of national authority and an NGO); four involve an NGO (2 of them are exclusively implemented by an NGO, whereas the other two refer to a combination of private initiative and an NGO as well as a combination of a grassroot initiative and an NGO); three practices involve a company or private initiative, one involves a university faculty and one implementer is not specified.

*B. Good Practice Assessment*

As mentioned in Section V, after identifying good practices, the partners were asked to evaluate them based on the following three criteria: (i) effectiveness in mitigating biodiversity risks (Positive impact), (ii) lack of impact on the economic activity of the wind farm (Negative impact), and (iii) transferability potential, namely their potential for being replicated or adopted to other contexts (Positive impact).

For the second criterion, which refers to the negative impact, a reverse scoring is applied, i.e., the highest score is assigned to the lowest economic impact. This allows for the scores to be aggregated and presented as a single, uniform evaluation, assessing only positive impacts. Figs. 6-8 present the (normalized to 100) score for the three criteria of each good practice, where 100 refers to the maximum score.

Fig. 6 highlights that good practices provided by the UPAT show a relatively low effectiveness in mitigating biodiversity risks. This may be due to the wide variation in the individual biodiversity threats (i.e., the sub-criteria) that were put up for evaluation in the questionnaire. A low or medium score does not necessarily reflect a poor performance. A good practice may appear to lag behind in individual threats but be very good at addressing a single one, resulting in a low score. Alternatively, a practice may be moderately effective in all areas, leading to a higher score, but not exceptionally good at addressing particular threats. Therefore, this cumulative score should be evaluated in conjunction with the individual sub-criteria.

Another observation is that as the effectiveness increases, the practice's impact on the wind farm's economic activity also grows. This suggests that there is a trade-off between effectively mitigating threats to biodiversity and avoiding any impact on wind farm's operations, which further complicates policy making. The sixth good practice highlights this issue, as its effectiveness in mitigating biodiversity risks would lead to a significant reduction of the available wind farm sites. So, whereas it is reasonable for selected areas (e.g., Natura areas) it is not a practice that could be broadly transferred to other areas.

Fig. 7 illustrates that identified good practices have moderate or low efficiency but at the same time high economic impact. The seventh practice in particular, which seems to have a significantly higher effectiveness may not be an attractive option as it seems to have a crucial negative impact on the economic activity of the wind farm.

In Fig. 8, the twelfth practice seems to score very highly. Nevertheless, it is not a good practice by definition as it concerns future targeting and not an established practice. It is however included here as it was recorded by the partner who collected it and is being considered to the extent that it could be a recommendation for the future.

In Figs. 6-8 overall, there is a slight preference for procedural over technological good practices. That is, although technologies are those that actually enable monitoring and help to predict and avoid the risk of bird and bat casualties, which is the most important and immediate of threats to biodiversity, procedures, rules and generally the existence and adherence to a protocol or regulatory framework are considered to be the most important.

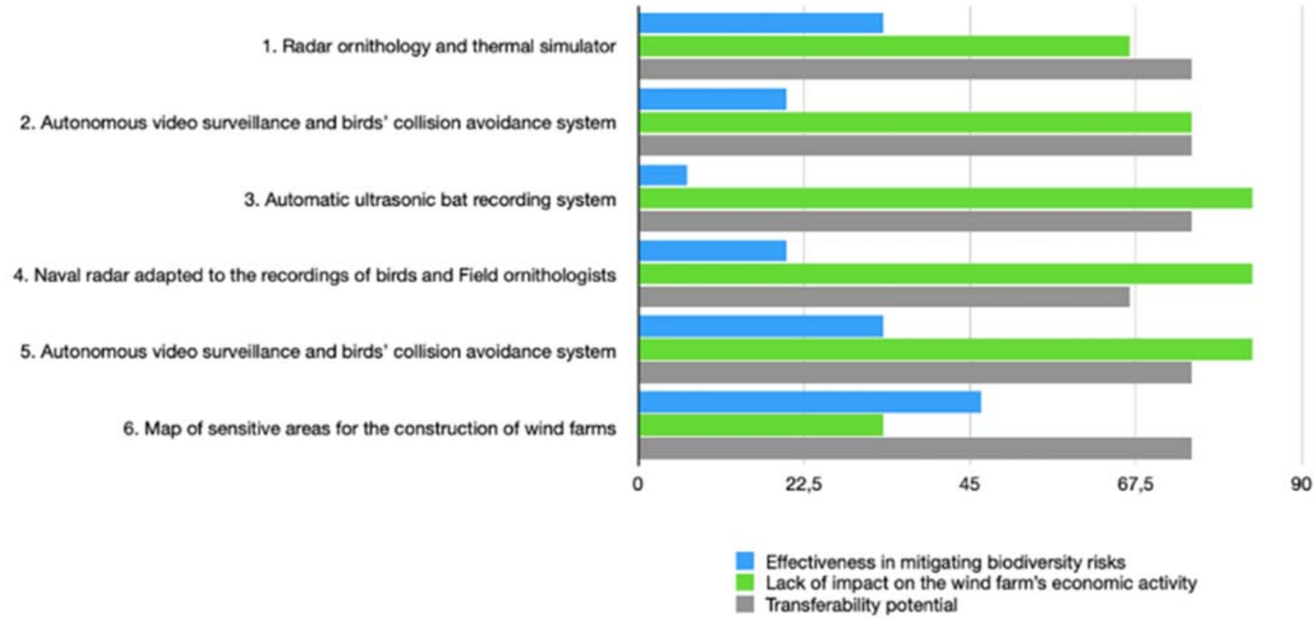


Fig. 6 Overall impact assessment per criterion: Good practice comparison in Greece

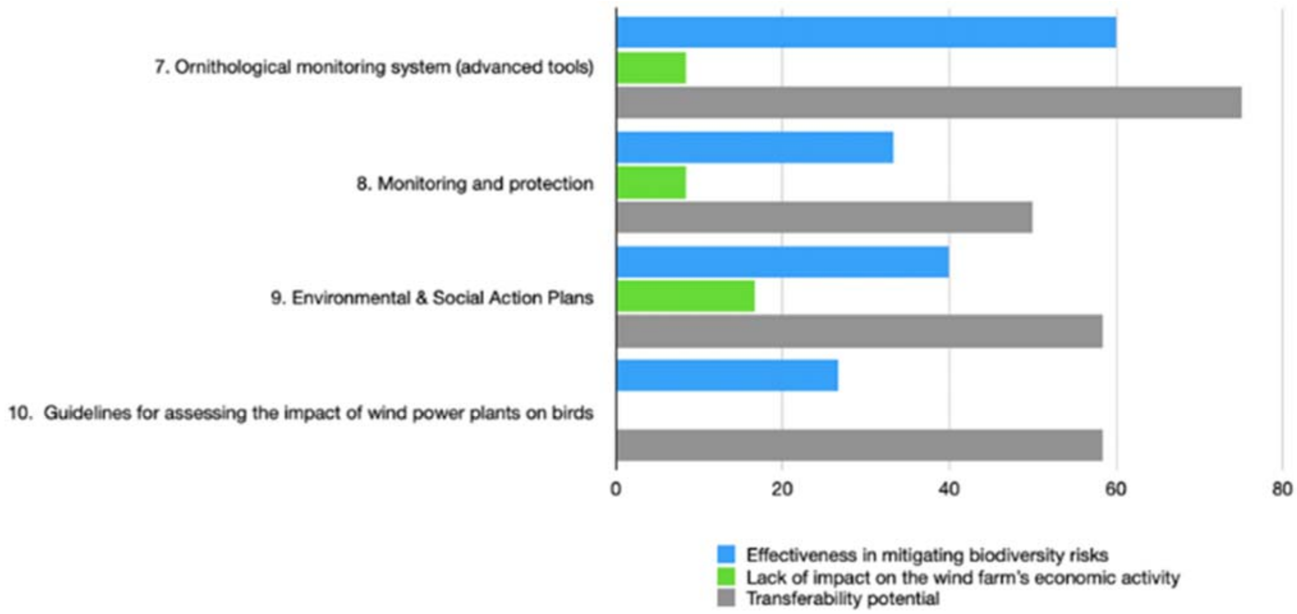


Fig. 7 Overall impact assessment per criterion: Good practice comparison in Poland

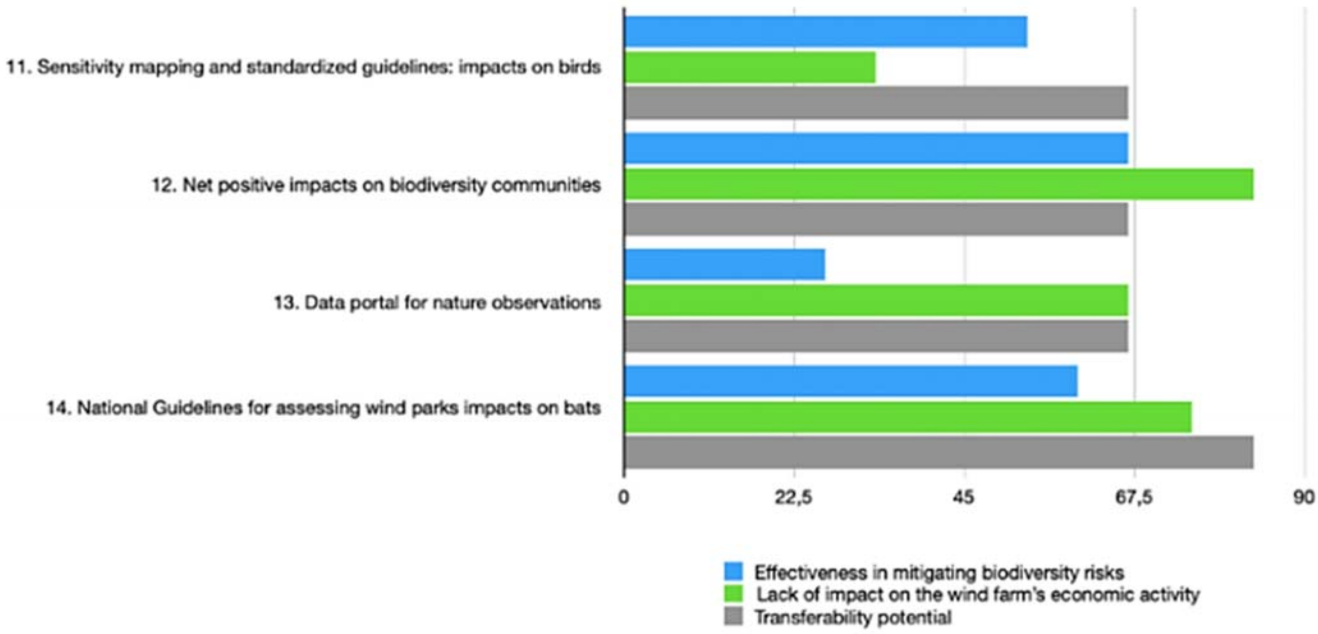


Fig. 8 Overall impact assessment per criterion: Good practice comparison in Latvia

Overall, the findings of the study highlight the importance of rules and regulatory frameworks in mitigating biodiversity risks associated with wind farm projects. This is evident in both identified good practices and cases to avoid, where the presence/absence of regulations can make a significant difference in the effectiveness of biodiversity risk mitigation measures. While technologies such as monitoring systems and bird and bat collision avoidance systems are essential, partners judged that procedures, guidelines and rules are more effective in achieving biodiversity risk mitigation goals. Thus, all partners concur that biodiversity risk mitigation should start as early as the planning and permitting phase. The case of Latvia's legislative framework is particularly interesting, as it prohibits wind farms in intensive agricultural areas designated as "farmlands of national importance." Whereas this regulation aims to protect these areas and the interests of farmers and rural economic activity, it also limits wind park planning to mixed-cover or forest landscapes where biodiversity risks are much higher. This, in turn, demonstrates the need for a more nuanced approach to regulations that balances economic considerations with biodiversity conservation goals.

## VII. Conclusion

Current status of biodiversity risk reduction efforts is concentrated on technologies such as monitoring systems and bird/bat collision avoidance systems, and also procedures such as systematic impact monitoring, casualty assessment, and regulatory frameworks that mandate and encourage pre-emptive measures and precautionary principles for biodiversity risk mitigation. Nevertheless, even though there is variation in the implementation and effectiveness of these practices, there are several new technologies currently being tested or used in Europe but have not yet been employed in the partner countries.

In addition, the study revealed a significant dearth of quantitative data related to both biodiversity risk mitigation - such as measuring bird and bat mortality before and after the implementation of good practices - and economic impact of such practices on costs and energy production at operational wind farms. It is moreover remarkable, that no good practices that exclusively concern offshore wind farms were identified and no good practices that focus on the decommissioning phases were recorded. This general lack of data highlights the need for improved and more comprehensive monitoring and assessment throughout all stages of the wind farm's lifecycle, necessitating the involvement of public energy agencies, private companies operating the farms and the scientific community.

Based on these findings, some policy recommendations can be disclosed. One possible solution to enhance the status of biodiversity risk mitigation is to incentivize (e.g., providing grants and other financial incentives) for the adoption of new technologies that are currently available in Europe but have not yet been adopted in the participating countries due to high costs or other constraints. This approach is also recommended in a good practice from Latvia, which emphasizes the need for the introduction of innovative practices and technologies to the national context. Furthermore, establishing a culture of collaboration among public authorities, private entities and the scientific community is essential for the implementation of permanent monitoring and continuous impact assessment practices. This entails defining clear procedures for measuring and analysing quantitative and qualitative data and fostering knowledge sharing with the ultimate goal of enhancing the effectiveness and sustainability of wind farms.

Particular attention should also be paid to the regulatory framework governing the development of wind farms. With wind power expected to scale-up in the coming years it is important to strike a balance between the interests of energy producers, landowners, and the state, and in that way prevent unnecessary hindrance or unnecessary cost to wind farm operations. Finally, it is imperative to prioritize informed site selection from the outset to avoid the need for expensive, energy-intensive mitigation measures in the future. This should involve conducting comprehensive biodiversity risk assessment to identify areas of high biodiversity value and avoid locating wind farms in such areas.

Future research is to valorise the results of this study and develop a biodiversity risk management framework that will be addressed to public administration and energy and environmental agencies. More specifically, it will give information on how to (a) assess biodiversity sensitivity in wind farms, (b) identify the potential impact to biodiversity by throughout wind farms' lifecycle, (c) pinpoint suitable mitigation measures, and (d) deploy tools and processes to monitor the effectiveness of any mitigation measures to be instituted.

## Appendix

TABLE I
COMPILATION OF GOOD PRACTICES

| Good practice | Type [a] | Implementer | Location | Phase [b] | Description |
|---|---|---|---|---|---|
| 1. Radar ornithology and thermal simulator | T | Not specified | Florina, Greece, (Onshore) | O | During the 06/2013-08/2014 period, ornithological recordings were made to investigate the use of space by the birds (especially silver pelicans and rose pelicans) and the reaction of the birds to the deterrent sounds while a model of thermal simulation of the area was developed to estimate the use of space from the birds. The system was installed on nine wind turbines, covering the entire wind park in order to warn, prevent and immobilize the wind turbines when necessary. |
| 2. Autonomous video surveillance and birds' collision avoidance system | T | Centre for Renewable Energy Sources & Saving (CRES) & Nature Conservation Consultants (NCC) (National Authority) | Keratea, Attica, Greece, (Onshore) | O | The system detects and records flight of flyers objects in the area in real time, evaluates them and makes decisions about activating methods to prevent bird collisions (emission of sounds, immobilization of wind turbine), depending on the risk. The warning sound for birds approaching the wind turbine was activated 30% of flights, the repelling sound 30% of flights and the wind turbine shutdown routine 17% of flights. |
| 3. Automatic ultrasonic bat recording system | T | Centre for Renewable Energy Sources & Saving (CRES) & Nature Conservation Consultants (NCC) (National Authority) | Keratea, Attica, Greece, (Onshore) | O | Three different models of bat detectors were installed in order to examine the recording of the activity of bats and determine the necessity of adjusting the wind turbines in case of significant risk of collision. The microphone of each system was placed at the base of the spindle of the wind turbines. |
| 4. Naval radar adapted to the recordings of birds and Field ornithologists | T | Centre for Renewable Energy Sources & Saving (CRES) & Nature Conservation Consultants (NCC) (National Authority) | Keratea, Attica, Greece, (Onshore) | P, O | The radar system is used to locate birds and track their flight paths, while field ornithologists visually determine the species of birds and their flight height. |
| 5. Autonomous video surveillance and birds' collision avoidance system | T | Centre for Renewable Energy Sources & Saving (CRES) & Nature Conservation Consultants (NCC) (National Authority) | Thrace, Greece, (Onshore) | O | The video surveillance system automatically monitors the daily movements of the birds near the wind turbine with four (4) high-definition cameras, while ten loudspeakers emit warning and deterrent sounds when birds are detected near the wind turbine in order to reduce the risk of collision. |
| 6. Map of sensitive areas for the construction of wind farms | CP | WWF Greece (NGO/Non-profit organization) | Thrace, Greece (Onshore) | P | The site selection proposal includes a map of sensitive areas with updraft birds, which divides the region into two distinct categories based on the distribution of highly vulnerable bird species: "exclusion zones" (the installation of wind parks should be prohibited) and "enhanced protection zones"(parks could be installed with the appropriate mitigation measures in place). |
| 7. Ornithological monitoring system (advanced tools) | T | PGE Polska Grupa Energetyczna (Polish Energy Group) and BIOSECO (Company/ Private initiative) | Kisielice and Lotnisko, Poland, (Onshore) | C, O | Designed by Bioseco, the monitoring system is made up of software that works with 24 HD cameras mounted in eight modules on the windmill tower. It can detect birds approaching the turbine within two seconds, and then automatically selects an adequate action to minimize the risk of collision. This can be a warning light signal, an audible signal or an automatic stop of the turbine. |
| 8. Monitoring and protection | M | Polenergia (Company/Private initiative) | Montagu's harrier, Lower Silesia, Poland, (Onshore) | C, O | Polenergia partnered with the Environmental Protection Department and hired an ornithologist to perform monitoring. A long-term contract was concluded with him, which provides for observations of wind farm areas and neighboring areas during the breeding season in order to locate and protect bird nests. Birds were ringed, protective pens for bird nests were installed, repellents (safe to humans, animals, and the environment) were used to protect the birds from potential predators. |
| 9. Environmental & Social Action Plans | MG, M | Polenergia (Company/ Private initiative) | Szymankowo and Dębsk, Poland, (Onshore) | C, O | Polenergia conducted environmental supervision on the site and in the vicinity of two wind farms, which included: training on environmental and nature protection carried out by naturalists during ground works, training on how to install herpetological fences and the principles of handling trapped amphibians and other protected animals, ongoing field supervision. |

| Good practice | Type [a] | Implementer | Location | Phase [b] | Description |
|---|---|---|---|---|---|
| 10. Guidelines for assessing the impact of wind power plants on birds | CP, MG, M | Polish Wind Energy Association, Polish Society for the Protection of Birds (NGO/ Non-profit organization) | Poland, National level (Onshore & Offshore) | P, O, D | Guidelines for environmental monitoring and investment preparation of wind farms to provide actors with the appropriate tools for the assessment of the impact of wind farms on the environment. |
| 11. Sensitivity mapping and standardized guidelines: impacts on birds | MG | University of Latvia, Faculty of Biology (Other) | Latvia, National level, (Onshore) | P, C, O | Ornithologists from the University of Latvia are developing standardized methodology for experts working on new wind park assessments – the goal is to define thresholds of significance and anticipate cumulative effects. The study will also present the first risk zoning of Latvia – a map of sensitivity areas for different bird species. It should improve the decision making for both public authorities and developers. The draft will be discussed with a wider expert community in autumn 2023. |
| 12. Net positive impacts on biodiversity communities | MG, LPM | International wind park developers (Vattenfall, Orsted), Company/ Private initiative (NGO/Non-profit organization) | Baltic Sea Region, Latvia, (Onshore & Offshore) | P, C, O | As Latvia's wind parks are still few, it will be expected that the companies introduce new practices to the national context. In addition to the principles of mitigation hierarchy in siting, several international developers have adopted commitments to invest in measures that contribute to broader ecological values of wind park landscapes (Vattenfall and Orsted in the Nordics). Efforts to restore or enhance ecosystems coupled with offsets should result in net positive impacts on biodiversity. |
| 13. Data portal for nature observations | CP | Latvian Fund for Nature, Grassroot initiative/ Community (NGO/Non-profit organization) | Latvia, National level, (Onshore) | P, C, O | Nature data portal dabasdati.lv collects observations from experts and wider public. ~80% of observations are about birds. Dabasdati.lv is a key data source for environmental assessments about the occurrence of different bird species in different regions. It is especially relevant for understanding the patterns of migratory routes where data from the official platforms is lacking. The portal will be upgraded in 2023 based on Ornitho platform (already in use in several other countries). |
| 14. National Guidelines for assessing wind parks impacts on bats | MG, M | Bat Research Society of Latvia, National authority (NGO/Non-profit organization) | Latvia, National level, (Onshore & Offshore) | P, O | In 2022, Nature Conservation Agency and Bat Research Society published the national guidelines to standardize experts' assessments of wind parks' impacts on bats. Their goal was to provide a common reference for data collection, species-specific siting decisions and threshold values for mortality. The authors concluded that most wind parks in forested areas will require temporary operational curtailment to prevent high bat mortality and recommended how to design effective monitoring systems. |

[a] T = Technology, CP = Civil Participation, M = Monitoring, MG = Management/Governance, LPM = Landscape Planning and Management
[b] O = Operation, P = Planning, C = Construction, D = Decommissioning

TABLE II
COMPILATION OF CASES TO AVOID

| Country | Cases to avoid | Implementer | Location | Phase[c] | Description |
|---|---|---|---|---|---|
| Greece (UPAT) | 1. Lack of monitoring | Not specified | Thrace, Onshore | O | Wind turbines can be threatening for endangered species when there is lack of sufficient monitoring. During the 2009-2010 period, in Thrace, three out of the five birds of prey species found dead were listed as "endangered" (Black Vulture), "vulnerable" (Western Marsh Harrier) or "near threatened" (Short-toed Eagle) in the Red Data Book of Threatened Animals of Greece. Thus, the nonexistence of proper monitoring had a serious impact on the biodiversity of the area.<br>Lessons learnt: Surveys and intensive monitoring of effects on bird/bat population and the implementation of different technology measures to mitigate the collisions and deaths should be firstly considered during the operation phase of wind turbines. |
| | 2. Failure to comply with the Habitats Directive for Natura 2000 areas | Ministry of Environment | Onshore | P | WWF has petitioned the European Commission on the basis that Greece's Environment Ministry has made inadequate progress toward the protection of threatened species in designated areas. The European Commission has sent a reasoned opinion to Greece over alleged failures to comply with the Habitats Directive when authorizing the construction of wind farms affecting Natura 2000 areas without accompanying impact assessment.<br>Lessons learnt: Greece, or any other country, should be working on a new framework for the special planning of renewables projects by taking into consideration the necessity to halt biodiversity loss and protect as much as possible any Natura 2000 area. |
| Poland (Wise Europa) | Non-compliance of municipal authorities in Poland regarding guidelines and regulations related to the development of wind farms (specifically, their locations) | Public (municipal) authorities | Onshore | P | Municipal authorities may sometimes place wind farms in areas that are off-limits according to regulations designed to protect biodiversity. This action puts biodiversity at risk and indicates that the authorities have not taken sufficient measures to safeguard it.<br>Lessons learnt: Wind farm regulation should be more strictly enforced by tighter monitoring and anti-corruption measures (in many cases, the municipal authorities were bribed by wind farm operators in less or more direct ways). Moreover, wind farm regulation must be unambiguous, as leaving room for interpretation may lead to decreased biodiversity protection. |
| Latvia (Green Liberty) | Prohibition of wind farms in intensive agricultural areas | Ministry of Agriculture | Zemgale region, Onshore | P | "Farmland of national importance" is a land use category characterized by high soil fertility and large field size (>50 ha) located in Zemgale region, Latvia. The regulation prohibits wind park development in these areas despite the fact that there is grid infrastructure and |

| Country | Cases to avoid | Implementer | Location | Phase[c] | Description |
|---|---|---|---|---|---|
| | | | | | protected nature sites are mostly absent. This restriction redirects wind park planning to mixed-cover or forest landscapes where biodiversity risks are higher.<br>Lessons learnt: The wind park restriction in large-scale farmlands is currently being revised at the Ministry of Agriculture. The government has considered proposals from environmental organizations and wind industry. The case is not unique for Latvia, there have been similar restrictions in other countries (Romania). There has not been major opposition from farmers' associations. This formal restriction explains why developers explore forested areas when other economic uses pose barriers in open landscapes. |

[c] O = Operation, P = Planning

## ACKNOWLEDGMENT

This research has been financed by the German Federal Ministry for Economic Affairs and Climate Action (BMWK) through the European Climate Initiative (EUKI) programme (Project Agreement Number: 81293039).

## REFERENCES

[1] C. Lago, A. Prades, Y. Lechón, C. Oltra, A. Pullen, and H. Auer, "Wind energy - the facts: Part V - Environmental Issues," pp. 307-410, Mar. 2009.
[2] M. Premalatha, T. Abbasi, and S. A. Abbasi, "Wind energy: Increasing deployment, rising environmental concerns," *Renewable and Sustainable Energy Reviews,* vol. 31, pp. 270-288, Mar. 2014.
[3] W. Grainger Hunt, et al., "Quantifying the demographic cost of human-related mortality to a raptor population," *PLoS One*, vol. 12, no. 2, Feb. 2017.
[4] S. Z. Goldenberg, P. M. Cryan, P. M. Gorresen, and L. J. Fingersh, "Behavioral patterns of bats at a wind turbine confirm seasonality of fatality risk," *Ecology and Evolution*, vol. 11, no. 9, pp. 4843-4853, Mar. 2021.
[5] R. Villegas-Patraca, S. A. Cabrera-Cruz, and L. Herrera-Alsina, "Soaring migratory birds avoid wind farm in the Isthmus of Tehuantepec, southern Mexico," *PLoS One*, vol. 9, no.3, Mar. 2014.
[6] P. T. Madsen, M. Wahlberg, J. Tougaard, K. Lucke, and P. Tyack, "Wind turbine underwater noise and marine mammals: implications of current knowledge and data needs," *Marine ecology progress series*, vol. 309, pp. 279-295, Mar. 2006.
[7] J. K. Kaldellis, D. Apostolou, M. Kapsali, and E. Kondili, "Environmental and social footprint of offshore wind energy. Comparison with onshore counterpart. ," *Renewable Energy*, vol. 92,pp. 543-556, July 2016.
[8] M. Pescador, J. I. G. Ramírez, and S. J. Peris, "Effectiveness of a mitigation measure for the lesser kestrel (Falco naumanni) in wind farms in Spain," *Journal of Environmental Management*, vol. 231, pp. 919-925, Feb. 2019.
[9] J. W. McClure, et al., "Eagle fatalities are reduced by automated curtailment of wind turbines," *Journal of Applied Ecology*, vol. 58, no. 3, pp. 446-452, Mar. 2021.
[10] L. Rodriguez, et al., *Guidelines for consideration of bats in wind farm projects*, (Report No. Publication Series No. 6). Report by EUROBATS, Jan. 2015.
[11] RWE Renewables GmbH, "Research into the effects of black rotor blades on bird protection is in full swing," pp. 1-3, Sep. 2022
[12] R. May, et al., "Paint it black: Efficacy of increased wind turbine rotor blade visibility to reduce avian fatalities," *Ecology and Evolution,* vol. 10, no.16, pp. 8927-8935, Aug. 2020.
[13] European Commission, "Directive (EU) 2023/2413 of the European Parliament and of the Council of 18 October 2023 amending Directive (EU) 2018/2001, Regulation (EU) 2018/1999 and Directive 98/70/EC as regards the promotion of energy from renewable sources, and repealing Council Directive (EU) 2015/652", pp. 1-77, Oct. 2023.
[14] A. T. Marques, C.D. Santos, F. Hanssen, A.R. Muñoz, A. Onrubia, M. Wikelski, F. Moreira, J. M. Palmeirim, and J. P. Silva, "Wind turbines cause functional habitat loss for migratory soaring birds." *Journal of Animal Ecology*, vol. 89, no. 1, pp. 93-103, Jan. 2020.