European Bank
for Reconstruction and Development

Managing the risks of wind power plants to birds and bats

EBRD briefing note

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Contents

Introduction

This briefing note clarifies how bird and bat collision risks and impacts are assessed and managed at wind power plants (WPPs) and with regard to their associated infrastructure, such as overhead power and transmission lines, within the context of the European Bank for Reconstruction and Development's (EBRD) Environmental and Social Requirement 6 (ESR 6).[1] It covers: (i) the appraisal stage of a project, with particular reference to conducting critical habitat assessments (CHAs) for aerial wildlife; and (ii) the construction and operating phases of a WPP, focusing on mitigation, monitoring and adaptive management. It follows the structure of the EBRD guidance note on ESR 6 (2025),[2] which provides broader context for the topics discussed here.

Critical habitat assessment

ESR 6 requires clients to determine whether their project will affect priority biodiversity features or critical habitat. Conducting a CHA for a WPP can be challenging, as the assessment was originally designed to assess project risks associated with a terrestrial or aquatic area. For example, within migratory corridors, large numbers of birds may occupy a particular airspace on a seasonal basis, leading to an intuitive determination that may not align with the established criteria for determining critical habitat. For a WPP, misapplication of the critical habitat concept can have significant effects on the biodiversity resourcing required for lender compliance. For lenders, it can set a precedent that is then misapplied to their wider portfolios. This note clarifies how the designation of critical habitat is not always appropriate in migratory corridors based solely on the seasonal occurrence of large numbers of birds in a given airspace.

1 See EBRD (2024), p.75.

2 See EBRD (2025).

Scope of application

In accordance with EBRD Environmental and Social Requirement 1 (ESR 1),[3] ESR 6 applies to all WPP projects that may pose risks to biodiversity, ecosystems and the services they provide. ESR 6 may apply to projects of any category. The steps taken, as described in this note, should be commensurate with the level of risk posed by the project.

3 See EBRD (2024), p.30.

Requirements

The client's environmental and social management system (ESMS), as described in ESR 1, should set out the fulfilment and monitoring of ESR 6 requirements. A client's environmental and social management plan (ESMP) should further describe how these requirements are to be met in line with the mitigation hierarchy, respecting the limits of the types of impact that can be offset. The ESMP should reference additional plans that may include, but are not limited to, a biodiversity management plan (BMP), species action plans, a biodiversity monitoring and evaluation plan, and a biodiversity offset strategy and/or management plan.

Alternatives assessment and project siting

Prior to finalising the selection of a site for a WPP, alternative sites should be evaluated for their impact on biodiversity, including designs for power collector lines (above or below ground) and transmission lines (routing, distance), among other variables. Where a wind farm is part of a larger plan to develop multiple energy projects, a strategic environmental assessment may be appropriate to evaluate the options for siting the projects and evaluating their impacts.

WPP developers should screen potential wind-farm locations and overhead powerline routes for biodiversity risk and avoid high-risk sites as much as possible. At a minimum, the following features associated with aerial biodiversity impacts should be considered during this screening exercise:[4, 5]

- important bird areas
- legally protected areas
- locations of important migratory bird bottlenecks and stopover sites[6]
- areas that are heavily used by regionally occurring priority bird[7] and bat species[8]
- wetlands, waterbodies and other habitats that are likely to contain high concentrations of bird species that are prone to collisions with wind turbines, powerlines or both.[9]

4 Due to the highly technical nature of many of the screening criteria, it is generally advisable for developers to hire external experts to conduct preliminary biodiversity screenings of candidate wind and overhead powerline sites, particularly if the developer does not have a qualified biodiversity expert on staff.

5 A report generated by the Integrated Biodiversity Assessment Tool will generally be a useful resource to support biodiversity risk screening for most projects, including wind and powerline projects.

6 Whereas migratory "flyways" can include areas with diffuse "broad front" migratory activity, as well as areas in which migration activity is more concentrated, migratory bird "bottlenecks" and major migratory stopover sites include a much more restricted set of flyway areas that support predictable, continentally significant concentrations of migrating birds. BirdLife International and its partner organisations often designate such areas as Important Bird Areas (IBAs) based on their importance as migratory stopover sites and/or bottleneck points, as defined by the International Union for Conservation of Nature's (IUCN) Key Biodiversity Area (KBA) standard (see IUCN, 2016). Location of a wind farm or powerline project within a continentally significant migratory stopover site or bottleneck zone may result in a critical habitat designation for the project, under EBRD critical habitat criterion 4 (see EBRD, 2025, p.16).

7 The eBird database is a source that should be consulted for information on regional occurrences of priority bird species. A broad review should also be conducted for available data on priority bird distributions and concentration areas in the region.

8 For useful guidance on bat sensitivity to wind-farm impacts, see Rodrigues et al. (2014). A broad review should also be conducted for available data on bat distribution and concentration areas in the region.

9 The selection of low-risk sites where bird/bat collision risk is minimised is particularly important for wind-farm projects and for high-voltage power transmission line projects, as projects sited in areas with high collision risk are likely to carry more extensive and expensive requirements for operating-phase impact monitoring and mitigation.

Assessment of risks and impacts, and protection and conservation of biodiversity

Baseline studies

Scoping

Scoping underpins the selection of appropriate baseline study methods. Information collected in the assessment and site selection process for alternatives should be complemented by additional scoping activities, including field reconnaissance and stakeholder consultation, to ensure that baseline studies can be designed to detect bird and bat species of concern and their habitats. In particular, this includes: (i) species listed by the EU Habitats Directive, Birds Directive, Bern Convention or IUCN Red List of Threatened Species with a status of vulnerable, endangered or critically endangered, or listed at a national level using the IUCN Red List methodology; (ii) species with restricted ranges;[10] and (iii) migratory and congregatory species that use the area.

Fieldwork

Aerial wildlife is generally more mobile and dispersed than terrestrial biodiversity, with a propensity for long-distance migration and/or regional-scale seasonal movement. It, therefore, requires specialised survey elements for biodiversity baseline studies.

Baseline survey areas should be defined and justified by the extent of *ground-based features* that support the ecology/habitat requirements of the birds/bats potentially at risk and not be restricted to the direct footprint and airspace of project infrastructure (for example, coastal and topographic features that cause concentrations of flight activity; caves, roosts, forest patches or water sources used by bats; nesting substrates; or feeding/foraging attractors such as cliffs, rubbish dumps, prey-concentration areas and water sources used by vultures, raptors and other large soaring birds). Where such ecological boundaries are not evident, such as large expanses of homogenous habitat, an area of analysis can be defined by the species' local movements (such as daily foraging or commuting).

Baseline surveys for flying wildlife should encompass the full spectrum of seasonal variation at a site, as affected by breeding/wintering activity, movement patterns and migratory patterns (including regional and long-distance patterns). They should also conservatively take into account unknowns in the migratory behaviour of the region's birds and/or bats. Under normal circumstances, this will, at a minimum, entail conducting surveys for a continuous 12-month period for birds and a complete warm season for bats.[11]

Baseline survey methodologies and sampling frameworks should be designed to characterise the most essential spatial elements of potential aerial biodiversity risk as a function of both project infrastructure and the biology of the flying wildlife of the region. At a minimum, this will require the incorporation of the following elements into baseline survey designs:

- Discrimination between the use of "risky" airspace (heights and potential locations of project infrastructure with which birds/bats may collide) and non-risky airspace (altitudes above or below the height of project infrastructure):
    - For bat baseline surveys at wind-farm projects, adequate characterisation of bats' use of risky airspace will generally require the use of ultrasound acoustic survey methodologies[12] rather than mist-netting surveys, as the latter are generally restricted to characterising bat use of non-risky airspace. Furthermore, given the typical

10 For terrestrial vertebrates and plants, restricted-range species are defined as those species that have an extent of occurrence of less than 50,000 square kilometres.

11 In temperate latitudes with a distinct cold season in which bat activity is nearly non-existent, surveys may be restricted to the warm season.

12 The EBRD is generally aligned with the specific methodological guidance of the South African Bat Assessment Association for bat baseline surveys at wind-farm projects. See Sowler et al. (2020) .

heights of wind turbines[13] and the limited detection range of ultrasound detectors,[14] wind-farm baseline studies will generally require the collection of ultrasound data from microphones at rotor-swept altitudes[15] to yield sufficient characterisation of bat activity in risky airspace.[16] Data on environmental variables, such as temperature and wind speed, should be collected concurrently with acoustic monitoring, so that these weather data can be used in the analysis of bat activity levels.

- For baseline surveys of vultures, raptors and other large soaring birds at wind-farm projects, adequate characterisation of birds' use of risky airspace will generally require vantage-point surveys,[17] timed, scaled and tailored to the seasonal and daily activity patterns of priority species occurring in the area.

- The inclusion of spatially explicit baseline data-collection methods[18] that facilitate the development of impact-minimising project layouts and micro-siting (for example, turbine layouts and overhead powerline routes).
- High-voltage power transmission lines do not typically require bat baseline surveys, as bats are not generally susceptible to collisions with this type of infrastructure.
- Low- to mid-voltage power distribution lines require specialised baseline surveys to characterise potential aerial biodiversity impacts only if the lines are aerial and pass through habitats where sensitive species of electrocution-prone birds may occur.[19]

Critical habitat assessment for a WPP incorporating the use of airspace by aerial wildlife

This step uses baseline data to determine whether the study area qualifies as critical habitat as defined by the EBRD.[20] This is an assessment of the terrestrial context of the proposed development, so does not consider specific impacts at this stage. It helps to answer the basic question: "How important is the terrestrial study area for conservation and which ESR 6 mitigation requirements will apply?" For WPPs, risk and mitigation requirements may go beyond those strictly correlated with critical habitat designations.

The CHA methodology draws heavily on the IUCN KBA Standard,[21, 22] which focuses on land and water areas amenable to site-based conservation. Consequently, in the case of birds, the CHA methodology can readily be applied to terrestrial and aquatic areas,[23] such as the migratory stopover points and breeding grounds on which bird concentrations depend. For bats, the same holds for terrestrial areas such as roosting and foraging areas. Birds and bats using key terrestrial and aquatic areas will naturally also use the airspace above and around it. The terrestrial or

13 Installed maximum blade tip heights of 200 metres above ground, with wind turbine technology evolving towards larger and higher turbines over time.

14 Bats can only be reliably detected when they call within 50 metres of an ultrasound microphone due to the rapid attenuation of high-frequency sounds over space.

15 This is most commonly achieved by installing ultrasound acoustic detectors on the meteorological towers, or "met masts", that are typically installed in wind-farm project areas in order to characterise wind speeds within rotor-swept altitudes, prior to project construction (that is, during the baseline study/environmental and social impact assessment (ESIA) preparation phase of project development). See Sowler et al. (2020) for more detail.

16 For wind farms, this is generally referred to as the "rotor-swept zone," defined as the range of altitudes between the lowest and the highest reach of the rotors' blade tips as they are installed on the wind turbines' towers.

17 The EBRD is generally aligned with the specific methodological guidance provided by NatureScot (2025) on vantage-point surveys at wind-farm projects.

18 Widely used and generally advisable methods include flight-path mapping during vantage-point surveys for the highest-priority bird species, surveys and mapping of nest locations, potential nesting substrates, and concentrated feeding/foraging areas for vultures and raptors, as well as surveys and mapping of potential bat concentration areas such as caves, water sources, forest patches or other roosting areas. References that may be useful include Gilbert, Gibbons and Evans (1998) and Hardey et al. (2013).

19 Bird taxa prone to electrocution on power distribution lines include eagles, falcons, other raptors, owls and certain other birds with large body size, as well as those with a tendency to perch and/or nest on powerlines.

20 See EBRD (2025), Table 1.

21 See IUCN (2016).

22 The CHA modifies the KBA Standard by removing the use of political boundaries as a means of delineating sites and simplifying criteria and thresholds to improve the practicality of application.

23 These could be land or water areas that are stopover, breeding or roosting areas, for instance. They may or may not form part of existing KBAs.

aquatic area *and* associated airspace used should, therefore, be considered components of the ecologically appropriate area of analysis (EAAA) for the CHA.

A practical way to consider the inclusion of airspace in the delineation of an EAAA could be as: (i) the airspace above the important terrestrial areas where the species regularly occur; or (ii) the airspace linking two or more nearby terrestrial sites in the same landscape where there is frequent (especially low-altitude) movement of birds. On the former, note that the extent of the airspace (that is, how far it extends outwards from the terrestrial area) would be determined by relevant experts based on the extent of the animal's local movements (that is, daily foraging or commuting as opposed to seasonal or migratory movements) and flight heights. To support practical and consistent application, the airspace is "anchored" to the *terrestrial* area in question. In other words, it is typically considered with respect to the ecological use of terrestrial habitat and not in and of itself.

There may also be cases where the terrestrial area is not necessarily used by the birds in a conventional sense (resting, feeding, nesting and so on), but where topographical or other physical attributes of the ground or sea area contribute to high concentrations of low-flying birds. This might include areas near sea crossings, where the distance between shorelines is shortest and migratory soaring birds concentrate to gain elevation using thermals prior to crossing, or areas of rest after a sea crossing. In such cases, the linkage between airspace with ground and water areas remains, but it is the specific topographic/physical attributes of those areas that affect the birds' patterns of movement and behaviour, making it an important terrestrial area in terms of the occurrence of concentrations of birds. Such sites must be distinct and readily discernible in the landscape, as well as geographically limited in size, to be considered an EAAA, which should be "equivalent in scale to areas mapped for practical site-based conservation management activities".[24]

Under this approach, a CHA will only include airspace where there is an associated important ground or water area and a discernible EAAA, noting that many such sites have already been designated Important Bird Areas.

Impact assessment

As with any project, the biodiversity impact assessment for a WPP is typically produced within an environmental and social impact assessment (ESIA). This integrates all of the information collected during project development (that is, baseline study results and CHA results) and often serves as a key document in project finance negotiations. However, whereas the biodiversity impacts of many development projects tend to occur during construction, when habitat is lost or degraded, the impacts of a WPP can be greater during operation, as WPPs typically involve relatively limited soil disturbance and bird/bat collisions largely occur during operation. This characteristic of the biodiversity risk profile of WPP shapes the structure and content of WPP ESIAs in various ways.

Construction-phase impacts. Habitat loss and degradation are a certainty in undeveloped sites and may also occur in modified grassland habitats (such as pastures) that support wildlife. Habitat loss occurs in the direct footprint of turbines, service roads and associated infrastructure. Habitat degradation can result from human activity at the project site. The addition of tall structures in some grassland environments may reduce habitat quality for grassland-specialised species that are susceptible to predation by raptors, resulting in their displacement to other locations. Related to these impacts is habitat fragmentation, whereby larger continuous areas of habitat are affected by the construction of turbines, roads, transmission lines and associated infrastructure. Large unfragmented areas may be needed by some species for breeding, foraging and sheltering. Habitat fragmentation can generate "edge effects" that create barriers to movement and displacement, as well as nest parasitism and predation.

Operating-phase impacts. Bird and bat mortality from collisions with WPP infrastructure during operation is a major concern. Collision susceptibility in birds and bats is the product of species-specific factors (not all of which are understood) and the ecological and topographical context of the project. In many locations, the risk of bat mortality from collisions with wind turbines may be higher than that of birds, while the risk of collision with overhead transmission lines is generally considered to be significant only for birds, and further limited to certain types of bird.[25] In regions with many wind farms, where bird and bat impacts have been well studied, species-specific patterns of collision susceptibility may

24 See IFC (2019), paragraph GN59.

25 Especially heavy-bodied, non-soaring birds, such as many waterbirds and bustards, and/or birds with poor vision. See Martín Martín et al. (2022).

be fairly well characterised and predictable. In areas with little or no wind energy development, or where few impact studies have been conducted, however, species-specific patterns of collision susceptibility may be difficult to predict, requiring extra precautions in terms of risk management and additional impact assessment. To characterise collision impacts, project-specific impact assessments should synthesise available information on species-specific collision susceptibility with available information on the seasonal abundance patterns of birds and bats at the site. The latter is typically conducted on a broader, regional scale, drawing on information from technical literature and publicly available databases, such as eBird, as well as on a site-specific scale using the results of baseline studies. For wind projects with potential impacts to sensitive species of vulture, eagle, other raptors and/or other large soaring birds, ESIAs are generally required to include species-specific quantitative predictions of annual collision fatality rates, estimated using the collision risk-modelling method developed by William Band and associates[26] and data inputs from the vantage-point surveys,[27] as well as project design and infrastructural elements.

26 See Band (2012). Note that the Band model only assesses collision rate estimates for turbines, not other infrastructure.

27 See NatureScot (2025) on vantage-point survey data requirements for collision risk monitoring.

Mitigation, monitoring and adaptive management

Overview

For EBRD-financed projects, ESR 6 paragraph 11 is clear that biodiversity risks should be managed in accordance with the mitigation hierarchy and good industry practice, and that the client should adopt a precautionary approach and apply adaptive management practices.[28] This applies with or without priority biodiversity features or critical habitat designations, and the EBRD can require the client to achieve no net loss.[29] Because the spatiotemporal patterning, intensity and species composition of adverse impacts of WPP operations are generally harder to predict with precision prior to construction, they require a more flexible biodiversity management paradigm than other types of project, rooted in a disciplined approach to monitoring and adaptive management.

Pre-operating phases

In addition to conventional mitigation for construction impacts already covered by the guidance note on ESR 6,[30] WPPs should consider implementing the following design-stage biodiversity impact minimisation or avoidance measures:

- Turbine micro-siting layout should be adjusted to avoid placing turbines in areas where risks to birds or bats are heavily concentrated, as indicated by baseline study results (for example, in the immediate vicinity of known raptor/vulture nesting substrates, known bat caves or other roosts, and heavily used flight lines, such as along bluff edges).
- Mid-voltage power collection networks should be subterranean rather than aerial wherever possible to avoid a potential source of bird electrocution and powerline collision risk.[31]
- Projects that include overhead powerlines[32] (either low or high voltage) should site such lines at least 500 m from wetlands, waterbodies or other habitats where collision-prone bird species are known to concentrate, in order to avoid avian–powerline collision impacts as much as possible.
- Projects that include overhead powerlines that traverse or come within 500 metres of wetlands, waterbodies or other habitats where collision-prone bird species are known to concentrate should equip the overhead or static wire with bird flight diverters (BFDs) in line with industry standard designs and spacing.[33] Powerlines beyond 500 metres that are on high-risk flight routes in and out of wetlands may also require BFDs.
- Projects that include overhead powerlines passing areas used by electrocution-prone bird species[34] should use "raptor-friendly" designs that minimise electrocution risk on poles, cross-arms, jumper cables and other electrified equipment, in line with good industry practice.[35]

28 See EBRD (2024), p.78.

29 Projects financed by the International Finance Corporation (IFC) would likely apply natural habitat requirements to the bird species using that airspace and follow requirements to achieve no net loss (see IFC, 2019, paragraphs 13-15 and GN43).

30 See EBRD (2025).

31 Use of subterranean cabling may also be a useful mitigation option for some high-voltage power transmission lines, but for engineering reasons, burying high-voltage lines is substantially more difficult and costly than it is for low- or mid-voltage lines. Consequently, the use of subterranean cabling for high-voltage power transmission lines is generally restricted to relatively short spans of very high bird collision risk.

32 When it comes to bird collision risk, high-voltage powerlines (that is, transmission interconnections) are generally riskier than low- or mid-voltage lines (that is, power collector systems). However, both types of overhead powerline may pose avian collision risk and should be evaluated for BFD installation.

33 See Martín Martín et al. (2022).

34 Especially raptors, owls and other bird species of relatively large size, with a behavioural tendency to perch and/or nest on power lines.

35 See Raptor Protection of Slovakia (2021).

- Turbines should be programmed to feather the blades and avoid "freewheeling" rotation when wind speeds are below the cut-in speed at which turbines begin operating and generating electricity. This feature is included automatically as a standard feature in some, but not all, modern wind turbines. Note that this does not lead to operational curtailment, as it applies only in conditions when wind speeds fall below the turbine cut-in speed, so no electricity generation is sacrificed. Feathering the blades to avoid the idle spinning of rotors in low wind conditions has been shown to reduce levels of bat collision fatality substantially in some circumstances.[36]

Operating phase

Although WPP projects may implement all of the above good-practice impact avoidance and minimisation measures at the design and construction stages, there may still be a significant impact on birds and bats on an ongoing basis during operation, especially due to collisions with wind turbines and/or aerial powerlines. The impacts are very difficult to predict prior to project construction. Consequently, a cornerstone of good international industry practice for biodiversity management on WPP projects is a robust operating-phase BMP featuring bird/bat fatality monitoring in line with industry-standard methodologies, rooted in the principle of adaptive management. The EBRD, the International Finance Corporation (IFC) and Germany's Kreditanstalt für Wiederaufbau (KfW) published a Good Practice Handbook in 2023,[37] outlining core concepts and providing comprehensive guidance on how to develop and implement a BMP in the field, as well as analytical and management components. A brief summary of the two core components of an operating-phase BMP for a WPP project is presented below, followed by a brief overview of options for operating-phase impact mitigation available at the time of writing.

Bird and bat fatality monitoring. The foundation of good-practice bird and bat fatality programmes at WPPs is carcass searching. This involves conducting systematic searches for carcasses in predefined areas beneath turbines and/or powerlines at regular intervals, usually on a continuous, year-round basis, generally for at least three years from the commissioning of the WPP. Fieldwork also includes a set of bias-correction experiments, as well as spatial delineation of the carcass search areas, which enable the application of correction factors to account for well-known biases in raw search data. These include searcher efficiency bias (the percentage of carcasses present during searches but not discovered by the searchers), carcass removal bias (the percentage of carcasses removed from the search areas before the next carcass search, that is, by scavengers) and unsearched area bias (the percentage of carcasses estimated to have fallen outside the search areas as a function of search-area size and configuration, and known or theoretical carcass fall spatial distributions). To estimate total (or "corrected") bird and bat fatality rates for the WPP, these raw data are combined with empirically derived bias-correction factors following industry-standard formulae, often using a software package called GenEst,[38] which has been developed and made freely and publicly available by the United States Geological Survey for this purpose. In addition to the characterisation of periodic (annual or semi-annual) total bird and bat fatality rates for WPPs, bird and bat fatality monitoring programmes also serve to characterise the basic spatial, temporal and taxonomic patterning of bird and bat fatalities generated by a WPP during its operating phase, as understanding such patterns is often essential to efficient impact management. Such monitoring programmes for WPPs should be accompanied by explicit periodic reporting requirements to ensure that results can be effectively reviewed and incorporated into management decisions on an ongoing basis.

Adaptive management of bird and bat fatalities. The essential companion of an operating-phase bird and bat fatality monitoring programme at a WPP is the adaptive management plan (AMP), which is typically included in the operating-phase BMP and which governs how the WPP will react or respond to the results of the fatality monitoring. Specifically, the AMP

36 See Good et al. (2012).

37 See IFC, EBRD and KfW (2023).

38 See Dalthorp et al. (2018).

presents numerical thresholds[39] for each priority bird or bat species, which, if exceeded, trigger a requirement to implement additional mitigation in order to achieve no net loss.[40] In addition, AMPs for WPPs typically outline a review and adaptive decision-making process, in which the key stakeholders engage in the periodic review of results from the bird/bat fatality monitoring programme and have an opportunity to evaluate the sufficiency of current biodiversity monitoring and mitigation in light of documented impact patterns. This adaptive review process also serves as a mechanism for designing and implementing efficient, project-specific impact mitigation solutions if needed, for example, because a no-net-loss fatality threshold has been exceeded. It is important to note that the adaptive management of operating-phase impacts must be supported by appropriately precautionary budgetary assumptions. Budgeting for reasonable "worst-case" scenarios will ensure that resources are available to implement additional mitigation measures during operation, should they be necessary.

Operating-phase impact mitigation. On commissioning, depending on the level of bird/bat collision impacts predicted in the ESIA and projected during financing negotiations, a WPP may have chosen to undertake forms of operating-phase impact mitigation beyond specific measures incorporated into the design of the WPP (for example, turbine micro-siting adjustments, the use of subterranean cabling for power collection systems, the installation of BFDs and/or raptor-friendly designs for project-associated powerlines). If significant residual bird and bat risks are anticipated prior to construction and/or if fatalities in excess of no-net-loss thresholds are documented during a project's operating phase, certain bird/bat fatality impact mitigation (minimisation) measures may be implemented on an ongoing basis during the project's operating life. The science and technology for such mitigation is evolving continually and rapidly, and developers are encouraged to consult subject-matter experts and the current technical literature to avail of the latest knowledge and technological options. A brief summary of three of the most prevalent operating-phase collision minimisation measures at the time of writing is presented below.[41]

Elevation of turbine cut-in speed for bat collision impact mitigation

The cut-in speed of a wind turbine is the minimum wind speed at which the turbine produces electricity. Most modern wind turbine models can be programmed to implement a cut-in speed higher than the manufacturer's recommended rate on a selective basis. This practice, generally termed "cut-in speed curtailment", has been shown to be a highly effective way of minimising the collision impacts of some bats.[42] The implementation of cut-in speed curtailment results in some lost electricity generation, as turbines remain idle in certain time periods when winds are suitable for electricity generation. However, it is generally considered a very efficient mitigation measure, as bats are usually most active when winds are lowest. Therefore, foregoing electricity generation at the very lowest wind speeds, when electricity generation potential is lowest, results in a high degree of bat collision impact minimisation (typically 30 per cent to 70 per cent) for a relatively small level of sacrificed generation (generally in the order of 1 per cent). Furthermore, curtailment is typically only undertaken at night and during high-risk periods of the year. Implementation can be further restricted to certain "problem" turbines, to high-risk hours at night or to conditions when high levels of bat activity are detected in the vicinity of the turbines in real time ("smart curtailment").[43]

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39 The key concept of the thresholds in the AMP of WPPs is that they represent the maximum, project-generated fatality levels that can be withstood by the population of the species in question without diminishing the ability of that population to sustain itself, as a function of the demographics and sensitivity of the population, and the level of existing anthropogenic threats to the population from wind energy development and other fatality sources at the national level. Consequently, observed fatality rates below the thresholds are considered to be consistent with the no-net-loss mitigation standard. These thresholds are both species specific and project specific, and are developed using best available scientific information, generally including consultation with region-specific experts. Population viability analysis is a well-established scientific method of generating this type of information, where detailed demographic data on the species of interest are available. When detailed demographic data are not available, there is an alternative methodology for developing these thresholds called "potential biological removal" analysis. This, along with the general concept of developing biologically justified sustainable fatality thresholds for WPP AMP, is further described and referenced in IFC, EBRD and KfW (2023).

40 With the exception of species triggering a critical habitat designation, thereby subject to the "net positive gain" mitigation standard under EBRD ESR 6, bird and bat collision impacts at WPPs are generally managed as priority biodiversity feature impacts and subject to the no-net-loss mitigation standard under EBRD ESR 6.

41 See IFC, EBRD and KfW (2023) for more on this topic.

42 See, for example, Rnjak et al. (2023) and Arnett et al. (2013).

43 See Hayes et al. (2019).

Shut-down-on-demand systems for large bird collision impact mitigation

For WPPs located in areas with globally endangered, critically endangered or otherwise highly sensitive species of large, collision-susceptible birds, especially vultures, eagles and/or other raptors, shut-down-on-demand (SDOD) curtailment systems have proven an effective tool in minimising collision impacts. The two essential components of an SDOD curtailment system are: (i) surveillance to detect when highly sensitive birds are approaching turbines and (ii) a control system to shut down one or more turbines that birds are approaching, once detected and before the bird(s) reach the turbine. SDOD curtailment systems can be further subdivided into those with manual surveillance and control, and those with automated surveillance and control systems. Manual (or "observer-led") SDOD systems require a large amount of local human resources, and one long-term study has shown automated systems to be six times more effective in preventing golden eagle collisions.[44] Key challenges with SDOD systems include cost, minimising missed or late detections of target species, minimising shut-downs in response to detections of non-target species, and fundamental limitations to the type, size and flight speed/behaviour of birds for which SDOD systems are effective.[45] Nonetheless, such systems are considered a useful tool in managing collision impacts in the case of most sensitive large bird species and are in widespread global use at WPPs with the greatest large bird collision risk issues. Similar to cut-in speed curtailment systems for bats, SDOD curtailment systems can achieve very high efficiency levels, producing substantial reductions in large bird collision rates (as much as 90 per cent), with the lost energy yield generally not in excess of 1 per cent and often significantly lower owing to the precision of turbine shut-downs in such systems.

Deterrence of birds and/or bats from approaching wind turbines by broadcasting sound and/or light

The concept of a device that can deter birds and/or bats from approaching wind turbines has long been an attractive idea and the subject of extensive scientific and commercial research and development since at least the early 2000s. Unfortunately, at the time of writing, while a wide variety of bird and/or bat deterrent systems were commercially available, none had proved to be consistently effective at producing biologically meaningful reductions in bird or bat collision rates at single wind turbine scale, let alone for entire WPPs. One of the fundamental challenges in terms of bat deterrence is that ultrasound, which many bats use for echolocation and communication, and which is most frequently broadcast as a bat deterrent, decays very rapidly over distance because of the physical properties of high-frequency sound. Consequently, even if ultrasound is broadcast at extreme volumes from the nacelle of a turbine, it is virtually inaudible to bats as far away as the tip of the blade of a modern wind-turbine rotor. When it comes to bird deterrence, while there is no parallel limitation in terms of the physical properties of visual light or lower-frequency sounds, which have both been used in various systems, a consistently effective bird deterrent device remains elusive.[46]

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44 See McClure, Martinson and Allison (2018), McClure et al. (2021) and McClure et al. (2022).

45 For example, SDOD curtailment systems are generally not viable for small birds or extremely fast-flying birds, as in such cases there is insufficient time after initial detection to implement a turbine shut-down before the bird approaches the turbine. SDOD curtailment systems also have significant limitations in highly complex topography, where at-risk birds may "pop up" from below a cliff, plateau edge or ridge with insufficient time to implement a shut-down before the bird approaches a turbine rotor.

46 Note that painting one of the three blades on wind-turbine rotors was shown to reduce collision rates for all bird species (in aggregate) at a wind farm in Norway, although the study did not produce evidence of effective deterrence of eagles, vultures or other raptors specifically, and further research is needed to understand how widespread and effective this measure is for deterring birds at wind farms (see May et al., 2020). See also IFC, EBRD and KfW (2023).

Conclusion

The risks posed to birds by WPPs may be substantial where the turbine rotor-swept area, any portions of the above-ground collector lines or WPP-associated transmission lines intersect with the airspace used by birds and bats. These risks must be managed.

CHA was not originally designed to manage project risks in airspace not associated with a terrestrial or aquatic area. This note clarifies that the designation of critical habitat is not always appropriate in migratory corridors based solely on the seasonal occurrence of large numbers of birds in a given airspace.

More importantly, however, distinctions as to habitat designation should not cloud the more direct question of whether risks to birds are properly evaluated and managed. Projects that create significant aerial bird collision hazards will always be required to establish biologically based fatality thresholds that are consistent with no net loss. For some threatened species, the annual no-net-loss threshold may be zero. Mitigation and monitoring must be designed to ensure that no net loss is achieved. If this is not possible, it may be necessary to re-think the project and consider whether its location is appropriate.

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Acronyms and abbreviations

AMP	adaptive management plan
BMP	biodiversity management plan
CHA	critical habitat assessment
EAAA	ecologically appropriate area of analysis
EBRD	European Bank for Research and Development
ESIA	environmental and social impact assessment
ESMP	environmental and social management plan
ESMS	environmental and social management system
ESR	Environmental and Social Requirement
IFC	International Finance Corporation
IUCN	International Union for Conservation of Nature
KBA	Key Biodiversity Area
KfW	Kreditanstalt für Wiederaufbau
SDOD	shut down on demand
WPP	wind power plant

1935 Managing the risks of wind power plants to birds and bats – EBRD briefing note

Five Bank Street
London E14 4BG
United Kingdom

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