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Mitigation measures to reduce impact of onshore wind power projects

The mitigation hierarchy provides developers with a logical framework to address the negative impacts of development on biodiversity and ecosystem services. It is applicable to projects in any sector, including renewable energy, and is based on the sequential and iterative application of four actions: avoid, minimise, restore and offset. There are several existing mitigation measures that can be applied across all the phases of a onshore wind power project. The IUCN ***Mitigating biodiversity impacts associated with solar and wind energy development Guidelines for project developers*** details recommendations for addressing the impacts of onshore wind power projects on nature across four phases: project design, constructions, operational, and end-of-life.

Table 5-3 Selected examples of automated image detection and radar technologies for shutdown-on-demand*

Technology	Application	Demonstrated use & effectiveness
Camera technology		
DTBird Uses a suite of daylight and/or thermal imaging cameras mounted on individual turbines or similar structures	**Birds only** Once targets are identified, the system can issue a warning sound or automatically shut down turbines, based on preset criteria (e.g. distance from turbine). Detection distance is related to bird size. Best-case scenario for a golden eagle (*Aquila chrysaetos)* is ~600 m during the day and ~200 m at night.	Detectability was shown to be >80% at a test site in California, USA.[1] Warning sounds reduced flights in the collision risk zone in trials in Sweden and Switzerland by 38-60%.[2]
IdentiFlight Uses a suite of daylight and/or thermal imaging cameras mounted on individual turbines or similar structures	**Birds only** Imaging is linked to an algorithm to classify objects; has the potential to be species-specific. Fully integrated with Supervisory Control And Data Acquisition (SCADA) for automated shut down; no need for human involvement. Has an operational range of 1,000 m.	Has a 96% detection rate (i.e. missed 4% of all bird flights) with a false negative rate of 6% (classifying eagles as non-eagles) and false positive rate of 28% during trials in Wyoming, USA.[3] Installed at wind farm sites in Australia (for wedge-tailed and white-tailed sea eagles), northern Germany (for red kites) and multiple USA sites.
Radar technology		
Robin Radar Max © Uses radar to provide real-time detection and 3D tracking of birds	**Birds only** Has a ~15 km maximum detection distance with unrestricted line of sight. Shut down can be fully automated using predefined rules, and has the potential to be species-specific. Expensive to purchase, at ~ >US$ 500,000. Use may be restricted by national military or aviation regulations.	Deployed at the Tahkoluoto offshore wind farm in Finland, to prevent collisions from white-tailed sea eagles and black-backed gull.[4] Operational at the Kavarna wind farms in Bulgaria, where it automatically shuts down turbines for priority species, particularly migratory species.
STRIX BirdTrack A radar system to automatically detect and track individual birds or bats	**Birds and bats** Cannot identify individual species – can detect size class only. Has a detection range of up to 12 km, depending on target size. Shut down can be fully automated using predefined rules or manually controlled. Radar use may be restricted by national military or aviation regulations. Has not been used in isolation, always in combination with observers.	BirdTrack was used at the Barão de São João wind farm (Annex 2, case study 13) with zero fatalities over five years (note: radar was used in combination with observers). Deployment in Egypt has resulted in fatality levels held at 5–7 fatalities, from around 370,000 birds passing through the wind farm each season.[5]

** Note: This list is not exhaustive. Other technologies are available and in the process of development.*

1 H.T. Harvey & Associates (2018).
2 Riopérez et al. (2016).
3 McClure et al. (2018).
4 Södersved (2018).
5 Tomé et al. (2018).

Table 5-4 Bird flight diverter designs

Design	Practical and ecological considerations	Evidence of effectiveness
Flappers (mobile)	Come in a wide variety of sizes and configurations – all of which have similar levels of effect. Very visible because they can pivot over 360° when windy, and some contain reflective panels or iridescent components making them visible at night. May malfunction (either break or fall off) in locations with sustained high wind speeds or extreme temperature conditions. Can be installed on operational transmission lines using drones, or from the ground using a hot stick.	In California, installation of flappers on spans reduced avian collisions by 60% when compared with non-marked spans.[6] In Nebraska, installation of flappers resulted in >50% reduction in sandhill crane deaths compared to spans without flappers.[7]
Spirals (static)	Come in a variety of dimensions for different line widths. Likely the most durable option, with no moving parts, but may be less visible to some species for the same reason. Very challenging to install once transmission line is operational, and installation is labour-intensive. Not recommended for installation on transmission lines >230 kV due to corona effects.	In Indiana, waterfowl collisions were reduced by 73% and 37.5% for small and large spirals, respectively, on marked versus unmarked lines.[8] In the UK, installation of large spirals reduced average springtime collisions from c. 15 to <1 mute swan between years.[9]
Night-lit devices	Important where at-risk species move by night. New technology which has only been trialled in a limited number of sites for a few species; effectiveness unknown for other species or locations.	Installation of near-ultraviolet lighting that shines on powerlines in Nebraska, USA reduced sandhill crane (*Antigone canadensis*) collisions by 98%.[10] In South Africa and Botswana bird flapper and flight diverters fitted with Light Emitting Diodes (LED) have been installed to reduce flamingo (*Phoenicopterus roseus* and *P. minor*) and blue crane (*Anthropoides paradiseus*) collisions. Anecdotal evidence points to the effectiveness of this mitigation measure.[11]
Aviation balls	May not be suitable for areas where ice or high winds are expected, due to increased stress on the line. Visually more obvious than other options. More costly per unit than other options, but greater spacing means overall costs may not be more costly. Labour-intensive to install on existing line. Use may be limited by aviation regulations.	Installation of 30 cm diameter yellow balls with a black stripe on spans in Nebraska reduced collisions of sandhill cranes by 66% compared with unmarked spans.[12] In South Carolina, there was a 53% reduction in all species' collision mortalities at spans with yellow balls compared with unmarked spans.[13]
Increasing wire thickness	Much more expensive than standard diameter wire, and requires heavier-duty supporting infrastructure. Extremely durable, with quoted life-spans of >40 years.	Anecdotal evidence of effectiveness, but unproven in rigorous field trials.

6 Yee (2008).
7 Murphy et al. (2009).
8 Crowder (2000).
9 Frost (2008).
10 Dwyer et al. (2019).
11 Smallie (2008); van Rooyen & Froneman (2013).
12 Morkill & Anderson (1991).
13 Savereno et al. (1996).

Table 5-5 Summary of mitigation approaches for onshore wind farm development

Project phase	Mitigation Hierarchy	Mitigation approaches include:
Project design phase	Avoidance and Minimisation	Micro-siting: changing the layout of project infrastructure to avoid sensitive habitats or areas used by sensitive species Re-routing, marking or burying onshore powerlines to avoid collision risk
Construction phase	Avoidance	Scheduling: changing the timing of construction activities to avoid disturbing biodiversity during sensitive periods
	Minimisation	Abatement controls to reduce emissions and pollutants (noise, erosion, waste) Operational controls to manage and regulate contractor activity (e.g. exclusion fencing around sensitive areas, designated machinery and lay-down areas)
	Restoration and rehabilitation	Revegetation of temporary use areas as they come available, using top soil and indigenous plants from the site where possible
Operational phase	Minimisation	Physical controls: modification to infrastructure, or its operation, to reduce impacts (e.g. shutdown on demand to minimise collision risk, installation of Bird Flight Diverters on transmission lines) Abatement controls (e.g. restricting vehicle movements when sensitive species are present, waste management) Operational controls to make sites less suitable for sensitive species (e.g. habitat modification, removal of carcasses for scavengers)
End-of-life	Avoidance	Scheduling: changing the timing of decommissioning activities to avoid disturbing biodiversity during sensitive periods (e.g. during breeding seasons)
	Minimisation	Abatement controls to reduce emissions and pollutants (e.g. noise, erosion, waste) created during decommissioning Operational controls to manage and regulate contractor activity (e.g. exclusion fencing around sensitive areas, designated machinery and lay-down areas)
	Restoration and rehabilitation	Revegetation of disturbed areas as they become available, using top soil and indigenous plants from the site where possible. Reinstatement of original vegetation, as far as feasible, after decommissioning Consider (if legislation allows) if leaving infrastructure would provide benefits to sensitive species