DIGEST

BIODIVERSITY AND *ONSHORE* WIND POWER

Measure effectiveness and recommendations for minimizing the impact of onshore wind power on biodiversity

Onshore wind power provides an alternative to fossil fuels. It contributes to the reduction of national energy dependence and to the diversification of energy sources. Despite these advantages, onshore wind power poses environmental challenges and generates opposition because of its impact on biodiversity.

This "Digest" summarizes a study identifying, from the scientific literature, the measures that are effective in mitigating the risks to flying animals, i.e. birds, bats, and insects. It provides recommendations to the scientific community, developers and operators, and nation states for reducing these impacts. This work is in line with target 8 of the Global Biodiversity Framework, which aims to: "minimize the impact of climate change and ocean acidification on biodiversity and increase its resilience through mitigation, adaptation, and disaster risk reduction actions, including through nature-based solution and/or ecosustem-based approaches, while minimizing negative and fostering positive impacts of climate action on biodiversity".

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SUR LA BIODIVERSITÉ

What do we mean by the impact of *onshore* wind power ?

With the current climate crisis, switching to renewable energy sources has become essential to limit greenhouse gas emissions. Onshore wind power is a rapidly growing sector and plays an important part in this transition. However, its rapid development poses a number of environmental problems, including its negative impact on flying species. These impacts include the collision of birds, bats, and insects with wind turbines, changes in animal behaviour, and disruption of local ecosystems. (*see sheet: "**Biodiversity and onshore wind power**"*).
Among the most worrying impacts is the collision of birds and bats with rotor blades and turbine masts, resulting in high mortality rates. Scientists have shown that collision risk varies with:

geographical location | **bird and bat population density** | **local environmental conditions** | **species' flight behaviour** | **wind turbine and wind farm type**

The measures described below have shown a certain effectiveness in specific studies restricted to particular contexts and species..

FOCUS ON THE KEY ELEMENTS OF THIS REVIEW

- Studies were primarily carried out in North America (around 70 %) and Western Europe (more than 25 %), while other parts of the world were underrepresented.
- Only one document from the reference list came from France.
- Insects are clearly underrepresented, being studied in only 5.6 % of the references.
- For bats, the most studied measures were ultrasonic acoustic deterrence and increasing the turbine cut-in speed.
- For birds, the most frequently studied measures involved adjusting turbine curtailment strategies and painting the turbines.
- Studies focused mainly on two types of results: the activity and mortality of affected species.
- Results related to mortality were the most frequently reported.

REGULATORY FRAMEWORKS AND TECHNICAL GUIDELINES

A number of guidelines and recommendations have been published covering different aspects of wind power project planning, development and delivery. These documents clarify the legal framework and offer detailed technical advice. They help developers apply **the avoid-reduce-compensate sequence** and integrate environmental considerations into the planning and management process.

Wind farms, being Classified Installations for the Protection of the Environment, are subject to specific environmental obligations. The planning and regulation framework for minimizing the environmental impact of wind power projects in France aims to guarantee the harmonious coexistence of renewable energy development and biodiversity conservation.

One of the main tools of this framework is the **Strategic Environmental Assessment (SEA)**, which is required for projects that have a significant impact on the environment.

FOCUS ON

The "avoid-reduce-compensate" sequence: a fundamental approach for managing the environmental impact of onshore wind farms.

Avoid At the start of the process, spatial planning plays a crucial role to ensure that wind farms are not built in sensitive areas for biodiversity, such as nesting grounds or migration corridors. By avoiding sensitive areas, developers can significantly reduce the risk of collision and habitat disturbance. **However, in France, specific spatial planning for the development of onshore wind power has never really been implemented. Only recently has it been seriously envisaged to include these considerations in future projects.**

Reduce When impacts cannot be avoided entirely, mitigation strategies are put in place.

Compensate When negative impacts persist despite the implementation of mitigation measures, compensation measures are taken. This can include the restoration of degraded habitats elsewhere, the creation of new habitats, or funding conservation programmes for the affected species. These measures tend to compensate for biodiversity loss by improving the state of habitats and populations elsewhere.

MEASURES TO MITIGATE THE IMPACT OF WIND TURBINES ON FLYING SPECIES

Assess the effectiveness of the solutions and measures that have been recommended for minimizing the impact of onshore wind power on flying species.

The solutions presented in this publication have shown a certain effectiveness in specific studies restricted to particular contexts and species. Additional research is needed to ascertain their generalizability.

Légende :

- Operationality of the solution (green arrow)
- Evidence-based effectiveness of the solution (blue arrow)

PREDICTING THE MORTALITY RATES OF FLYING SPECIES

Predicting mortality rates using models developed to assess bird collision risk with wind turbines.

- Operationality: The use of predictive models can be effective to anticipate and mitigate the impact of wind farms on bird populations. The integration of such tools in environmental impact assessments is thus an approach that can minimize the environmental risk posed by wind farms.
- Effectiveness: The effectiveness of this measure may be context-dependent. It is necessary to test it under local conditions. In terms of research, additional empirical studies are required to consolidate these results and refine the models, for instance by testing them on a wider range of species and environmental conditions.

Micro-siting and **macro-siting**, *i.e.* the process of determining the optimal location of wind turbines within a defined area, taking into account local factors such as landscape, wind direction and environmental impacts to maximize energy production and minimize disturbances.

- Operationality: The geographical location of wind turbines can significantly influence the mortality rates of birds and bats. Strategic choices in terms of location thus contribute to the mitigation of their environmental impact.
- Effectiveness: This measure has been shown to be effective, but requires the intervention of ecologists with specialist knowledge of the species to be conserved.

CURTAILMENT STRATEGIES

Adjusting the blade angle (feathering) below a minimal wind speed (the cut-in speed). This slows down or stops blade rotation, thus reducing the collision risk of flying animals. Under normal operation, turbine blades are always perpendicular to the wind to maximize their energy efficiency.

- Operationality: Adjusting the cut-in speed and blade feathering are effective measures, reducing bat mortality by more than 50 % in most cases while having a limited impact on energy production.
- Effectiveness: An effective measure. It would be worth assessing the long-term effects on bat populations, as well as the seasonal changes in effectiveness.

Selective turbine shutdown when an at risk situation for a medium to large bird is detected.

- Operationality: Selective turbine shutdown, based on the detection in real time of species at risk of collision, seems promising for reducing the mortality of flying animals, especially large birds. Studies show a significant decrease in mortality (up to 92.8 % for griffon vultures), and a negligible impact on energy production (< 0.51 % decrease).
- Effectiveness: An effective measure for large birds that would also be worth implementing for smaller species.

Curtailment using new technologies that allow adjustments to be made in real time.

- Operationality: Smart technology, such as real-time acoustic detection systems and automated algorithms, are innovative solutions for reducing wildlife fatalities on wind farms. Studies show that these systems can significantly reduce mortality, by up to 84.5 % for bats and 63 % for eagles, and at the same time optimize energy production.
- Effectiveness: An interesting approach, but not sufficiently standardized. The cost-effectiveness of these technologies is also worth assessing. Some methodological biases have been pointed out.

Increasing the cut-in speed at different times of night or depending on temperature, or **complete turbine shutdown** during migration periods or below certain wind speeds.

- Integrating parameters such temperature, migration period, and the time of night, optimizes these results while limiting losses in energy production. Adjusting these parameters significantly reduces bat mortality, sometimes by 100 %.
- An effective measure.

DETERRENT DEVICES

Deterrent devices disturb the orientation of flying animals and deter them from approaching collision risk areas.

Ultrasonic acoustic deterrence that aims to disrupt the bats' echolocation.

- Studies have shown a significant reduction in bat activity and mortality (up to 91 %), depending on the species and the configuration of the device.
- An effective measure that warrants additional research to standardize protocols, assess the long-term impact on different species, and validate these devices in different environments.

Mid-frequency acoustic deterrence by the exposure to different types of acoustic signals.

- Studies have shown that sound treatments caused birds to maintain a greater distance from hazards and adjust their flight trajectories before coming close to obstacles. No statistical differences were observed between the different sound treatments, but consistent trends within the data suggest that the 4-6 kHz frequency-modulated oscillating signal elicited the strongest avoidance behaviours.
- An effective measure for birds that warrants additional research, especially on the different sound treatments.

Radar deterrence by the emission of electromagnetic fields.

- Studies have shown a significant reduction in bat activity in areas exposed to the radar's electromagnetic field.
- A measure that has been shown to be effective for bats, and which would warrant additional research on a larger scale.

Light deterrence by the emission of UV light from or towards the turbines, in order to exploit birds' and bats' sensitivity to these wavelengths and thus make the obstacles more visible to them.

- UV light reduced bird and bat activity around wind turbines, and thus decreased the collision risk.
- The effectiveness of this measure is context-dependent. *In situ* assessments are necessary to ascertain its cost-effectiveness.

STRUCTURAL MODIFICATION OF WIND TURBINES

Wind farm repowering by replacing one-bladed or vertical-axis turbines with fewer three-bladed turbines.

- Wind farm repowering with newer turbines significantly reduces the impact on biodiversity and increases energy production.
- An effective measure. To maximize the environmental benefits, repowering projects require pre-invervention environmental assessments, post-intervention monitoring, and the integration of other conservation measures.

Altering the turbine rotor diameter by decreasing or increasing blade size.

- A reduction in rotor diameter seems to be associated with a decrease in mortality, in particular in birds and bats; however these differences are not always statistically significant.
- The precise effect of rotor size on collision risk remains unclear, and further research is needed to clarify this relationship.

Applying paints, such as black paint, UV-reflective paint, or colour paint on turbine blades or at the base of the tower.

- Applying black paint or specific motifs on turbines seems to be a very promising method for reducing bird collisions, especially for vulnerable species such as raptors and ptarmigans. Colours, however, must be chosen carefully to minimize insect attraction and avoid indirect ecological effects.
- An effective measure for certain species. The effect of natural backgrounds on the reduction in collision risk warrants additional research.

Replacing the smooth surfaces of turbines with textured surfaces.

- Applying a textured coating to reduce bat attraction to wind turbines is not proven scientifically.
- The effectiveness of this measure has not been demonstrated.

FOCUS ON TWO SEEMINGLY GOOD IDEAS THAT MAY BE DOING MORE HARM THAN GOOD

Removal of attractive ecological factors by superficially tilling the soil and thus eliminate the natural vegetation around turbines to reduce rodent populations, by the regular clearing of ground vegetation above 10 cm, or by using biocides.

- The removal of ecological factors that attract animals to wind farms are mixed in terms of their effectiveness in mitigating the impact of wind turbines on wildlife and often have substantial negative ecological consequences, such as a reduction in biodiversity and the disturbance of ecosystems.

Install aviation warning lights to improve the safety of nocturnal flights.

- Although aviation warning lights can potentially reduce nocturnal bird and bat fatalities, they can also have a negative impact on biodiversity, and assessments need to be carried out before they are used. Indeed, they can impact the navigation and migratory behaviour of flying animals. These effects can lead to exhaustion and lower survival rates.

RECOMMENDATIONS TO MITIGATE THE RISK TO BIODIVERSITY

FOR THE SCIENTIFIC COMMUNITY

The scientific community studying the impacts of onshore wind power on flying species can contribute to the development and improvement of risk reduction technologies. The recommendations below will increase knowledge and thus the effectiveness of the implemented measures.

Recommendation		Specific research to be carried out
Mitigation technology research and development	Optimization of acoustic devices for bat deterrence	Fine-tune acoustic deterrence methods and assess the negative impact of long-term use.
	Development of multimodal methods and the use of radars	Test the effectiveness of radars as a means of deterrence. Combine acoustic signals with other methods to improve effectiveness.
	New ways of using UV lighting	Improve UV lighting systems by conducting more research. Assess the possible ecological impacts, such as attracting insects.
	Improve turbine visibility with paints	Assess the effectiveness of paints (colour, motifs, where to apply on the turbine).
	Texturing turbine towers	Improve the type of texture used.
	Rotor diameter	Assess the impact on increasing rotor diameter on birds, insects, and bats.

Studies on the impacts on biodiversity and ecosystems	Research on insects	Determine the direct and indirect impact of mitigation measures on insects. Develop measures that minimize the impact of wind power on insects.
	Impact of wind farm repowering	Assess the impact of wind farm repowering on wildlife over the long term.
	Environmental rehabilitation of wind power sites	Develop optimal practices for the rehabilitation of decommissioned sites. Assess the effectiveness of restoration measures on biodiversity.
Modelling, prediction and decision-making tools	Develop models for predicting risk	Create and improve collision risk models, and use the results in the decision-making process
	Project planning tools	Design tools for planning projects that are less harmful to biodiversity. Work with regulators to include these models in the planning process.
Standardized methods and data sharing	Develops standard protocols	Standardize study protocols to allow the comparison of data.
	Promote data sharing and accessibility	Foster data sharing in the scientific community. Use standardized databases to make it easier to carry out global analyses.
International and Interdisciplinary collaboration	Strengthen interdisciplinary collaborations	Foster interdisciplinary research projects.
	International partnerships	Collaborate with scientists from parts of the world where there are less studies. Share knowledge to fill local knowledge gaps.
	Interact with operators and policy-makers	Work with operators to implement scientific recommendations. Assist the science-to-policy process by being members of committees and working groups.

New methods and technology	Develop new research methods	Create new methods for assessing impact (drones, AI, advanced sensors).
	Integrate new technology	Test new technologies designed to mitigate the impact of wind turbines.
Awareness and training	Knowledge dissemination	Organize events to present recent advances and advise on best practices.
	Training of scientists	Hire scientists to work in the field of renewable energy. Offer interdisciplinary educational programmes to train people to become experts with a broad knowledge base

FOR DEVELOPERS AND OPERATORS

Like the rest of the private sector, wind farm developers and operators must assess, monitor, and regularly and transparently disclose their biodiversity risks, dependencies, and impacts, over the entire supply and value chains, and provide consumers with the necessary information to promote sustainable modes of energy consumption; progressively reduce the negative impacts on biodiversity; increase the positive impacts; reduce the risks to biodiversity and provide consumers with the necessary information to promote sustainable modes of energy consumption. The recommendations below will help move towards these objectives.

Recommendation		Specific actions
Planning and ecological design	Planning and ecological design	Consider all potential impacts at the start of the planning process to choose sites that cause the least ecological disturbance. Develop innovative designs to reduce the visual and acoustic impact of wind turbines.
	Use predictive models	Use models that predict collision risk during the planning stage.

Integration of mitigation technology and innovations	Use combined strategies	Combine curtailment and other measures to maximize the reduction of bird and bat mortality.
	Adopt new technology	Adopt technologies and specific systems such as curtailment, deterrence, AI-powered detection systems.
	Specific paints and textures	Test the application of specific paints on turbines to improve visibility and reduce bird collision risk. Test the application of specific textures on towers to reduce the risk to bats.
	Integrated systems of environmental management	Put systems in place for adjusting turbine operation in real time, in response to environmental conditions.
Environmental management and monitoring	Management of environmental factors	Implement measures that are tailored to local conditions, taking into account their potential impact on local ecosystems. Prefer integrated and sustainable solutions to preserve the integrity of local ecosystems.
	Monitoring and assessment	Put post-installation environmental monitoring programmes in place to assess and adjust mitigation measures. Homogenize monitoring protocols to ensure that data are comparable across different contexts.
Support collaborations	Collaboration and data sharing	Promote the sharing of research data and retrospective experience reports. Contribute to the development of a standardized database where all reports and data can be deposited, in order to make it easier to conduct global analyses. Publish data on impact and effectiveness with abstracts and keywords in English. Collaborate with researchers and government agencies to improve practices.
Community involvement	Consult and mediate with local communities	Involve local communities in the planning stage. Be transparent in your communication, and promote the active participation of communities in both project planning and postinstallation environmental monitoring.

FOR STATES AND GOVERNMENT AGENCIES

Nation states, and more generally public authorities, must ensure that operators and developers meet their obligations in relation to biodiversity in order to protect the species and ecosystems on which our quality of life depends. The following recommendations converge towards this objective.

Recommendation		Specific actions
Clear and coordinated regulations	Strengthen the regulation and governance framework	Clarify regulations concerning onshore wind power. Improve coordination between different levels of government and regulatory agencies.
Science funding	Financial support for research and development	Use subsidies and tax incentives to promote mitigation technology research and development. Fund research in France and in underrepresented regions (South-East Asia, Sub-Saharan Africa, South America).
	Standardized methods and data sharing	Support the development of standardized protocols for data gathering and reporting. Facilitate the creation of data sharing platforms.
Community involvement	Public participation and community involvement	Establish a legal framework for the involvement of local communities in the project development process.
Support collaborations	Support collaborations within the sector	Foster partnerships between the wind power sector, scientists, and local communities.
Environmental monitoring and continuous assessment	Monitoring and assessment	Impose the implementation of post-installation environmental monitoring programmes to assess the effectiveness of the mitigation measures in place.

Biodiversity is a common good that benefits us all. Protecting it is essential to preserve a high quality of life, for all living beings. Nation states, citizens, the private sector, and scientists must all contribute towards the objective of the Convention on Biological Diversity: “to live in harmny with nature”. However, being aware of the reality of the biodiversity crisis and its impact on the present and future habitability of our planet is not enough. We must be convinced that biodiversity conservation is one our priorities, just like the fight against climate change or the conservation of natural resources.

Mitigating the impact of climate change solutions, and finding operational solutions with demonstrated effectiveness is also essential. This is the focus of the present study. Technological solutions such as wind turbines always affect wildlife, be it by their occupation of space, the collisions they cause, the chemical, sound, and electromagnetic pollution they generate, or by transforming the landscape. It is the responsiblity of operators, spatial planners, governments and developers to understand these impacts, mitigate them, and communicate on their biodiversity risks and dependencies. The support of the Mirova Research Center has allowed the FRB to examine this subject and update our knowledge on the effectiveness of proposed solutions for reducing the impact of onshore wind power on biodiversity.

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Read the full publication :

Reference : Quinard A., Dupuis L., Hette-Tronquart N., Besnard A., Jactel H and Langridge J. (2024) The Effectiveness of Measures and Good Practices in Place for Minimizing the Impact of Onshore Wind Power on Biodiversity. Knowledge Synthesis. Paris, France : French Foundation for Biodiversity Research (FRB).

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