Title: **Making Wind Power More Biodiversity-Friendly: The Role of Environmental Assessment**
Concurrent Thematic Session (Renewable Energy): Recent Wind Power Developments to Reduce Impacts
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Overview:

Wind power today is widely regarded as a key component of an environmentally sustainable, low-carbon energy future because it is renewable, requires almost no fresh water, and generates near-zero emissions of greenhouse gases and other pollutants.[2] In many parts of the world, wind power has the potential to reduce greenhouse gas emissions from electric power generation, thereby helping to limit the severe social and environmental consequences of human-induced climate change. Notwithstanding these key benefits, wind power poses its own special environmental concerns. These include visual impacts, noise, radar and telecommunications interference, aviation hazards, and a variety of land acquisition, benefits-sharing, and other socio-economic and cultural issues. However, from a biodiversity conservation standpoint, the impacts of wind power on birds, bats, and natural habitats are of greatest concern. **This paper summarizes (i) the main biodiversity-related impacts associated with wind power and (ii) how Strategic Environmental Assessments, along with project-specific Environmental Impact Assessments, can effectively address these impacts in the planning, construction, and operation of wind projects.** The focus here is mainly on land-based wind power, which is still preferred (for economic reasons) in most developing countries; offshore wind development poses its own particular impacts (positive and negative) involving marine life (EEA 2009).

Biodiversity Impacts:

There is growing scientific consensus that human-induced global climate change poses serious, even catastrophic, risks to the long-term survival of many animal and plant species (IPCC 2007). Thus, to the extent that increased use of wind power could appreciably reduce the severity of global climate change by reducing net greenhouse gas emissions, the cumulative impact of wind power worldwide might provide a net benefit for biodiversity conservation. Nonetheless, the project-specific impacts of certain wind power facilities—wind farms, transmission lines, and access roads--can be decidedly negative from a biodiversity standpoint. Accordingly--as with any type of infrastructure or energy development project--it is important to acknowledge, assess, and mitigate these negative impacts.

Birds are killed by collisions with wind turbines, masts (meteorological towers) with guy wires, and transmission lines, sometimes in significant numbers from a conservation standpoint. Athough modern large turbine blades appear (from a distance) to rotate slowly, the blade tip speed is actually very fast (around 270 km/hour), such that the birds are struck by surprise. For all birds taken together as a group, wind power is still a very small proportion of all human-caused mortality--wind farms kill far fewer birds in the aggregate than collisions with glass windows, vehicles, telecommunications towers, outdoor domestic cats, pesticides, or hunting (Erickson *et al.* 2005). Nonetheless, bird mortality at wind farms can be of significant concern when considered at the species level. In particular, large raptors (birds of prey) are long-lived and slow to reproduce, but some species collide with wind turbines at unsustainably high rates, as has been found with Golden Eagles in California (Smallwood and Thelander 2009), White-tailed Eagles in Norway and Eurasian Griffon Vultures in Spain (EEA 2009), and White-tailed Hawks in Mexico (INECOL 2009). For species such as these, wind turbine mortality can be a high proportion of total human-caused mortality. Also of conservation concern are the potential cumulative impacts of many future wind farms that (in the absence of

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[2] The greenhouse gas emissions are marginally higher when forests are cleared to install wind farms and access roads.

adequate environmental planning) are likely to be located within key bird migration pathways. If adequate mitigation measures (such as those recommended in this paper) are not broadly adopted, then the expected large-scale expansion of wind power capacity in many countries (by 1-2 orders of magnitude) is likely to lead to corresponding increases in aggregate bird mortality. Electrical transmission lines, which are a necessary element of wind projects (along with other types of power generation), can pose significant collision risks for large-bodied flying birds (De La Zerda and Rosselli 2003, Jenkins and Smallie 2009) and electrocution risks for raptors (APLIC 2006). For some scarce, open-country birds (such as various species of prairie grouse), the main conservation threat posed by wind power development is not collisions, but displacement from their habitat because the birds instinctively stay far away from wind turbines, transmission towers, and any other tall structures (Molvar 2008); large, shy wild mammals can also be displaced by the regular presence of wind farm employees.

Bats are even more vulnerable to wind turbine mortality than most birds. Bats tend to be killed by wind turbines at significantly higher rates than birds, except at those sites where bats are naturally scarce or absent. The significantly higher mortality for bats is largely because (i) for reasons that are still poorly understood, bats appear to be attracted to wind turbines (rather than simply encountering them by chance, as birds do) and (ii) bats (unlike birds) can be killed just by closely approaching an operating wind turbine without even touching it, due to lung damage from rapid decompression, known as barotrauma (Arnett *et al.* 2008). Unlike birds, bats almost never collide with transmission lines, masts, or other non-turbine structures. Data from North America, Europe, and Mexico suggest that migratory, tree-roosting bat species tend to be the most frequent casualties, although resident (non-migratory) species are also killed in substantial numbers, especially in forested areas (Ledec *et al.* 2011). Because bats are long-lived and have low reproductive rates, they (like raptors) tend to be more vulnerable to the added mortality from wind turbines than most (faster reproducing) small bird species. Without careful site selection and other mitigation measures, large-scale wind power expansion could potentially threaten the future survival of some bat species.

In specific cases, wind power development can affect biodiversity besides birds and bats. For example, wooded mountain ridge-tops (particularly in the tropics) often harbor unique plant and animal species, due in part to their wind-swept micro-climate. Long rows of turbines with inter-connecting roads along such ridge-tops can disproportionately affect scarce, highly-localized species. More generally, the construction of access roads to previously remote wind farm sites can lead to the loss or degradation of **natural habitats**, either (i) directly, though road construction and resulting erosion or (ii) indirectly, through increased land clearing, wood cutting, informal mining, hunting, or other human activities facilitated by improved access.

Environmental Assessment Tools:

During project planning, the single most important measure for managing biodiversity (along with most other environmental impacts) is **careful site selection** of wind power facilities, including wind farms, transmission lines, and access roads. From a biodiversity standpoint, the higher-risk (more likely problematic) sites for locating wind farms tend to include existing and proposed protected areas, critical natural habitats (including Important Bird Areas), wildlife migration corridors, forests and woodlands, wetlands, shorelines, small islands, native grasslands or shrub-steppes, and near caves. Conversely, lower-risk sites tend to have low bird and bat numbers year-round and do not harbor species or ecosystems of conservation concern; they include most (though not all) cultivated lands, non-native pastures, and deserts (away from coastlines and oases) (Ledec *et al*. 2011).

Strategic Environmental Assessments (SEAs) are a key planning tool for optimizing the site selection of wind power facilities from an environmental standpoint. Since most countries still have the majority of their potential wind power resources untapped, they typically have multiple options regarding where to locate new wind farms, for connection to a national or regional electricity grid. Although SEAs can vary greatly in their scope and approach, a fundamental output of any wind power SEA is **sensitivity maps** that show where the zones of high wind power potential (based mainly on wind speeds and proximity to the power transmission grid) are located in relation to the areas of major environmental concern. In addition to showing these areas of overlap (and potential conflict), some SEAs also produce **zoning maps** for prospective wind power development, recommending, for example (i) “Red” Exclusion Zones, where wind farms or transmission lines would be prohibited; (ii) “Yellow” Precaution Zones, where wind farm development would need to follow special precautions based on the specific natural or cultural resource(s) of concern; and (iii) “Green” Promotion Zones, where wind farm development could be actively promoted, subject to the standard environmental due diligence--or perhaps even pre-screened for expedited environmental approval. An interesting example of such an SEA with zoning maps has recently been produced for the state of Wyoming, USA (Molvar 2008).

Project-specific Environmental Impact Assessments (EIAs) serve as a key tool during the planning, construction, and operation of wind power facilities. EIA reports should document and explain the process used (ideally involving SEA) to select the project site, including the environmental and other criteria by which alternative sites were evaluated. As part of the project-level EIA process, it might also be important to carry out specialized, site-specific studies of particular bird or bat species, species groups, or natural habitat areas that could be of special concern in the context of the proposed new wind project. As the environmental (including biodiversity) impacts of wind power development become better known, more governments are likely to require EIA studies for wind projects.

Once the general site for a new wind farm has been selected, a project-specific EIA can provide the information needed to adjust the **location of turbine rows or individual turbines**. Bird collisions can be substantially reduced by locating turbines a fairly short distance away from specific areas of high bird use, such as shorelines, canyon rims, and mountain passes (consistent with the presence of favorable wind conditions). Specific turbines can also be located within a wind farm so as to minimize the number and length of new roads, thereby reducing the loss and fragmentation of natural habitats.

Project-specific EIAs can also provide useful technical input to the selection of **wind power equipment**, so as to reduce adverse impacts. On a per-MW basis, larger wind turbines are often less risky for birds (and perhaps also for bats) than smaller turbines; their advantages include (i) wider spaces between each turbine in a row; (ii) a rotor-swept area (RSA) higher off the ground, enabling more birds to safely pass underneath; and (iii) a smaller total number of turbines, which may reduce overall bird and bat collision risks. A smaller number of larger turbines also results in a smaller footprint of disturbed land for turbine platforms, as well as generally reduced visual impacts. Besides turbine size, wind power equipment tends to be more bird-friendly when (i) the number of masts is minimized once the wind farm is operational; (ii) aircraft warning lights atop turbine nacelles are white strobe lights (rather than solid or slowly pulsating red or white lights); (iii) ground-level lighting around the wind farm is minimized (consistent with operational security and worker safety); (iv) turbines have the fewest possible external structures on which birds could easily perch (consistent with operational needs and worker safety); (v) transmission lines that connect the wind farm with the electric grid are marked with bird flight diverters, when crossing wetlands or other areas of high bird use; and (vi) power poles have raptor-friendly cross-beam and wire configurations. There is also evidence that painting the bottom 3-5 meters of turbine towers a dark color could reduce collisions from birds flying near the ground, since they would not mistake broad, white tower bases to be open sky (Ledec *et al.* 2011).

All EIA reports for wind power projects should include some type of **Environmental Management Plan** (EMP), specifying the environmental mitigation or enhancement (including monitoring) actions to be taken, along with an implementation schedule, institutional responsibilities, budget, and funding source(s). To minimize adverse impacts (including upon biodiversity) during **project construction**, the EMP needs to prescribe good environmental practices during the installation of wind turbines, access roads, and transmission lines. These good practices include: (i) minimizing any clearing of natural vegetation during turbine installation; (ii) locating worker camps, storage sheds, parking lots, and other construction-related facilities so as to avoid or minimize the removal of natural vegetation, opting instead to use previously cleared or degraded lands; (iii) installing sufficient drainage works under all access roads, to avoid flooding land and damaging streams; (iv) implementing adequate measures to control soil erosion and runoff; (v) ensuring proper disposal of all solid and liquid wastes; (vi) refraining from washing of vehicles or changing of lubricants in waterways or wetlands; (vii) ensuring that locally obtained construction materials (such as gravel, sand, and wood) come from legal and environmentally sustainable sources; (viii) following chance finds procedures if archaeological, historical, or other relics are unearthed during project construction; (ix) restoring cleared areas where feasible to minimize the wind project's environmental footprint, although the area around each turbine should typically have minimal or short ground cover for the duration of post-construction monitoring of bird and bat mortality; and (x) enforcing good behavior by construction workers, including prohibition of hunting, fishing, wildlife capture, bushmeat purchase, plant collection, unauthorized vegetation burning, speeding, off-road driving, firearms possession (except by security personnel), or inappropriate interactions with local people. As with any large-scale civil works, environmental rules for contractors need to be specified—not just in the EMP but also in bidding documents and contracts. To help ensure that results will match expectations, adequate field supervision by qualified personnel is needed, as are transparent penalties for non-compliance.

The EMP should also specify the key biodiversity-related measures to be carried out during **project operation**, including post-construction monitoring, operational curtailment (where needed), and wind farm maintenance. **Post-construction monitoring** of bird and bat mortality is an essential part of proper environmental management for any wind power project. This type of monitoring is indispensable for (i) knowing whether or not a significant bird or bat mortality problem exists at any given wind farm, since pre-construction studies cannot definitively determine this; (ii) predicting the biodiversity-related impacts of scaling-up development within a particular wind resource area; (iii) adaptive management of wind farm operation to reduce bird or bat mortality; and (iv) advancing scientific knowledge in a field that still faces a steep learning curve. Such monitoring, which involves searching for bird and bat carcasses around turbines (also masts and transmission lines), should be carried out for at least the first two years of wind farm operation and continued for longer if significant mortality is found, so that mitigation measures can be tested and implemented. The data collected from each wind project should ideally be (i) presented in a readily understood form, (ii) publicly disclosed, and (iii) collaboratively shared with international scientific research networks and partnerships.

In bird and bat monitoring, there is a very real--and sometimes very large--difference between real mortality and observed mortality at wind farms. **Correction factors** need to be used to account for (i) areas not searched, (ii) searcher efficiency, and (iii) scavenger removal of carcasses. For very large birds (eagles, vultures, storks, pelicans, etc.), the difference between real and observed mortality is likely to be rather small. However, for small birds and bats, this difference can be very large—perhaps as high as 50-fold at some projects (Ledec *et al.* 2011).

Operational curtailment, involving specific changes in how wind turbines are operated, can substantially reduce bat or bird mortality, sometimes in a cost-effective manner. For bats, the most important type of operational curtailment appears to be a modest **increase in cut-in speed**. This is the lowest wind speed at which the rotor blades are spinning and generating electricity for the grid. Recent research at wind farms in Pennsylvania, USA; Alberta, Canada; and Germany shows impressive results: Increasing the cut-in speed from the usual 3.5-4.0 meters/second to about 6 m/s reduces bat mortality by 44-93%, while reducing power generation by 1% or less (Arnett *et al.* 2010). Such remarkable findings are explained by both biology and physics: Bats fly around mostly at low wind speeds and mainly at night (and, at higher latitudes, during only a portion of the year), while higher wind speeds contain much more energy that turbines can usefully convert into electricity. Accordingly, wind power projects can readily become more bat-friendly by (i) conducting their own research trials, monitoring the effects on bat mortality, and then choosing a cut-in speed that optimizes between bat conservation and power generation or (ii) presumptively choosing to operate at a higher cut-in speed (such as 6 m/sec) at night, with the expectation that bat mortality will be lower.

For migratory birds, the most useful type of operational curtailment can be **short-term shutdowns**, in which the rotor blades do not turn during peak migration events. These shutdowns can be cost-effective in preventing large-scale mortality of migratory birds, when the species of special concern pass through the wind farm area for only a few weeks per year (and then only during a portion of each day). Shutdowns can be scheduled in advance on a precautionary basis, if the normal dates of peak bird passage through the wind farm area are known. They can also be on-demand in real time, if radar and/or human spotters show sizable flocks headed towards the wind farm; this approach has been effectively demonstrated at the World Bank-supported La Venta II Project in Mexico.

Wind farm **maintenance practices** can be an important tool for managing biodiversity and other environmental impacts. Proper maintenance of wind power equipment can help prevent unnecessary bird mortality or other environmental damage. For example, capping holes in turbine nacelles will keep birds and bats from entering turbines to nest or roost inside (at their great peril, due to the proximity to the spinning rotors). **Landscape management** at wind farms needs to consider different (sometimes conflicting) objectives, including (i) maintaining pre-existing land uses; (ii) conserving and restoring natural habitats; (iii) managing land for species of conservation interest; (iv) deterring bird or bat use, as a means of reducing mortality; and (iv) facilitating post-construction monitoring. For best results, vegetation management at wind farms should be carefully planned in advance, discussed with stakeholders, and recorded within the project's Environmental Management Plan. **Managing public access** to wind power facilities should seek to optimize between different objectives, including (i) maintaining previous land uses; (ii) ensuring public safety; (iii) minimizing the risk of sabotage or theft of wind power equipment; (iv) protecting vulnerable species and ecosystems; and (v) promoting local tourism and recreation. In areas where hunting is inadequately controlled, wind projects can have a positive biodiversity impact by effectively prohibiting hunting and shooting within the wind farm area.

Conservation offsets can be a useful tool for mitigating biodiversity-related damage from a wind project and enhancing the project's overall conservation outcome. Off-site (away from the wind farm) conservation options include financial and other support by the wind project sponsors for the improved protection and management of (i) natural habitats of similar or greater conservation value than those affected by the wind project and (ii) particular bird, bat, or other species of conservation interest. To succeed, these compensatory conservation investments need to be carefully planned and executed, with clear implementation responsibilities and adequate, up-front funding commitments as part of the overall wind power project. Conservation offsets can be designed at the level of individual wind projects, using the project-specific EIA process; they can also be planned using SEAs to address the cumulative impacts of multiple wind farms over a larger area.

Conclusions:

Avoiding significant harm to biodiversity—specifically birds, bats, and natural habitats--has emerged as a key environmental challenge for scaling-up wind power development. Wind power development can become considerably more biodiversity-friendly by systematically adopting the good practices that are available for wind project planning, construction, and operation. SEAs are a key planning tool for site selection of wind projects, while project-specific EIAs and their EMPs are needed to address biodiversity and other environmental issues throughout project planning, construction, and operation. Effectively addressing biodiversity and other environmental concerns will enable wind power to more fully live up to its image as a "clean" and "green" energy source.

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