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ENVIRONMENTAL, HEALTH, AND SAFETY GUIDELINES FOR WIND ENERGY

INTRODUCTION

1. The Environmental, Health, and Safety (EHS) Guidelines are technical reference documents with general and industry-specific examples of Good International Industry Practice (GIIP).[1] When one or more members of the World Bank Group are involved in a project, these EHS Guidelines are applied as required by their respective policies and standards. These industry sector EHS Guidelines are designed to be used together with the **General EHS Guidelines** document, which provides guidance to users on common EHS issues potentially applicable to all industry sectors. For complex projects, use of multiple industry sector guidelines may be necessary. A complete list of industry sector guidelines can be found at www.ifc.org/ehsguidelines.

2. The EHS Guidelines contain the performance levels and measures that are generally considered to be achievable in new facilities by existing technology at reasonable costs. Application of the EHS Guidelines to existing facilities may involve the establishment of site-specific targets, with an appropriate timetable for achieving them.

3. The applicability of the EHS Guidelines should be tailored to the hazards and risks established for each project on the basis of the results of an environmental assessment in which site-specific variables, such as host country context, assimilative capacity of the environment, and other project factors, are taken into account. The applicability of specific technical recommendations should be based on the professional opinion of qualified and experienced persons.

4. When host country regulations differ from the levels and measures presented in the EHS Guidelines, projects are expected to achieve whichever are more stringent. If less stringent levels or measures than those provided in these EHS Guidelines are appropriate, in view of specific project circumstances, a full and detailed justification for any proposed alternatives is needed as part of the site-specific environmental assessment. This justification should demonstrate that the choice for any alternate performance levels is protective of human health and the environment.

APPLICABILITY

5. The EHS Guidelines for wind energy include information relevant to environmental, health, and safety aspects of onshore and offshore wind energy facilities. It should be applied to wind energy facilities from the earliest feasibility assessments, as well as from the time of the environmental impact assessment, and continue to be applied throughout the construction and operational phases. Annex A contains a full description of industry activities for this sector. EHS issues associated with the construction

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[1] Defined as the exercise of professional skill, diligence, prudence, and foresight that would be reasonably expected from skilled and experienced professionals engaged in the same type of undertaking under the same or similar circumstances globally. The circumstances that skilled and experienced professionals may find when evaluating the range of pollution prevention and control techniques available to a project may include, but are not limited to, varying levels of environmental degradation and environmental assimilative capacity, as well as varying levels of financial and technical feasibility.

and operation of transmission lines are addressed in the **EHS Guidelines for Electric Transmission and Distribution**.

This document is organized in the following manner:

1. INDUSTRY-SPECIFIC IMPACTS AND MANAGEMENT

6. The following section provides a summary of EHS issues associated with wind energy facilities, along with recommendations for their management. As described in the introduction to the **General EHS Guidelines**, the general approach to the management of EHS issues should consider potential impacts as early as possible in the project cycle, including the incorporation of EHS considerations into the site selection, in order to maximize the range of options available to avoid and minimize potential adverse impacts. Importantly, many EHS impacts associated with wind energy facilities may be avoided by careful site selection.

1.1 Environment

7. Construction activities for wind energy facilities typically include land clearing for site preparation and access routes; excavation, blasting, and filling; transportation of supply materials and fuels; construction of foundations involving excavations and placement of concrete; operating cranes for unloading and installation of equipment; construction and installation of associated infrastructure;[2] installation of overhead conductors or cable routes (above ground and underground); and commissioning of new equipment. Decommissioning activities may include removal of project infrastructure and site rehabilitation.

8. Environmental impacts associated with the construction, operation, and decommissioning of wind energy facilities activities may include, among others, impacts on the physical environment (such as noise or visual impact) and biodiversity (affecting birds and bats, for instance). Due to the typically remote location of wind energy facilities, the transport of equipment and materials during construction and decommissioning may present logistical challenges (e.g., transportation of long, rigid structures such as blades, and heavy tower sections). Recommendations for the management of such EHS issues are provided in the construction and decommissioning section of the **General EHS Guidelines**. The construction of access roads for the siting of wind facilities in remote locations may result in additional risks, including adverse impacts on biodiversity and induced access to relatively inaccessible areas. The

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[2] As presented in Annex A.

Toll Roads EHS Guideline provides additional guidance on prevention and control of impacts associated with the construction and operation of road infrastructure.

9. Environmental issues specific to the construction, operation, and decommissioning of wind energy projects and facilities include the following:

- Landscape, Seascape, and Visual impacts
- Noise
- Biodiversity
- Shadow Flicker
- Water Quality

10. Due to the nature of wind energy facilities and, this sector may be particularly associated with cumulative environmental and social impacts. If no relevant country-specific guidance is available in relation to cumulative impacts assessment, international sources of good practice guidance on this topic should serve as references.[3] Cumulative impacts assessments are especially warranted when multiple wind energy facilities are sited in close proximity to sensitive receptors such as areas of high biodiversity value.

1.1.1 Landscape, Seascape, and Visual Impacts

11. Depending on the location, a wind energy facility may have an impact on viewscapes, especially if visible from or located near residential areas or tourism sites. Visual impacts associated with wind energy projects typically concern the installed and operational turbines themselves (e.g., color, height, and number of turbines).

12. Impacts may also arise in relation to operational wind facilities' interaction with the character of the surrounding landscape and/or seascape. Impacts on Legally Protected and Internationally Recognized Areas of importance to biodiversity[4] and cultural heritage features[5] are also a consideration. Preparing zone of visual influence maps and preparing wire-frame images and photomontages from key viewpoints is recommended to inform both the assessment and the consultation processes.

13. Avoidance and minimization measures to address landscape, seascape, and visual impacts are largely associated with the siting and layout of wind turbines and associated infrastructure, such as meteorological towers, onshore access tracks, and substations.

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[3] Guidance documents include: International Finance Corporation (IFC), *Good Practice Handbook on Cumulative Impact Assessment and Management: Guidance for the Private Sector in Emerging Markets* (2013); Canadian Wind Energy Association (CanWEA), An Introduction to Wind Energy Development in Canada (2011); Scottish Natural Heritage (SNH), Assessing the Cumulative Impact of Onshore Wind Energy Developments (2012).

[4] See paragraph 20 in IFC Performance Standard 6 (IFC, 2012) for the definition of "Legally Protected and Internationally Recognized Areas."

[5] Sites with archaeological, paleontological, historical, cultural, artistic, and religious values.

14. Consideration should be given to turbine layout, size, and scale in relation to the surrounding landscape and seascape character and surrounding visual receptors (e.g., residential properties, users of recreational areas/routes).

15. Consideration should also be given to the proximity of turbines to settlements, residential areas, and other visual receptors to minimize visual impacts and impacts on residential amenity, where possible. All relevant viewing angles should be considered when considering turbine locations, including viewpoints from nearby settlements.

16. Other factors can be considered in relation to minimizing visual impacts:

- Incorporate community input into wind energy facility layout and siting.
- Maintain a uniform size and design of turbines (e.g., type of turbine and tower, as well as height).
- Adhere to country-specific standards for marking turbines, including aviation/navigational and environmental requirements (see Community Health and Safety section below), where available.
- Minimize presence of ancillary structures on the site by minimizing site infrastructure, including the number of roads, as well as by burying collector system power lines, avoiding stockpiling of excavated material or construction debris, and removing inoperative turbines.
- Erosion measures should be implemented and cleared land should be promptly re-vegetated with local seed stock of native species.

1.1.2 Noise

Construction Noise

17. Onshore construction noise should be limited to protect people living nearby. Noise-producing activities include blasting, piling, construction of roads and turbine foundations, and the erection of the turbines themselves. Guidance on acceptable levels can be found in the **General EHS Guidelines**.

18. Underwater noise and vibration from offshore construction—e.g., from piling activity—may adversely impact marine life, including fish, marine mammals, and sea turtles. Environmental parameters that determine sound propagation in the sea are site-specific, and marine species could be impacted differently depending on their sensitivity to underwater sound frequencies. Assessments should be conducted to identify where and/or when underwater noise has the potential to impact marine life significantly and to identify appropriate mitigation measures.

Operational Noise

19. Wind turbines produce noise through a number of different mechanisms, which can be roughly grouped into mechanical and aerodynamic sources.[6] The major mechanical components include the gearbox, generator, and yaw motors, each of which produce their own characteristic sounds. Other mechanical systems, such as fans and hydraulic motors, can also contribute to the overall acoustic emissions. Mechanical noise is radiated by the surface of the turbine and by openings in the nacelle

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[6] Generally, wind turbines radiate more noise as the wind speed increases.

housing. The interaction of air and the turbine blades produces aerodynamic noise through a variety of processes as air passes over and past the blades.[7]

20. Noise impact should be assessed in accordance with the following principles:

- Receptors should be chosen according to their environmental sensitivity (human, livestock, or wildlife).
- Preliminary modeling should be carried out to determine whether more detailed investigation is warranted. The preliminary modeling can be as simple as assuming hemispherical propagation (i.e., the radiation of sound, in all directions, from a source point). Preliminary modeling should focus on sensitive receptors within 2,000 meters (m) of any of the turbines in a wind energy facility.
- If the preliminary model suggests that turbine noise at all sensitive receptors is likely to be below an LA90[8] of 35 decibels (dB) (A) at a wind speed of 10 meters/second (m/s) at 10 m height during day and night times, then this preliminary modeling is likely to be sufficient to assess noise impact[9]; otherwise it is recommended that more detailed modeling be carried out, which may include background ambient noise measurements.
- All modeling should take account of the cumulative noise from all wind energy facilities in the vicinity having the potential to increase noise levels.
- If noise criteria based on ambient noise are to be used, it is necessary to measure the background noise in the absence of any wind turbines. This should be done at one or more noise-sensitive receptors. Often the critical receptors will be those closest to the wind energy facility, but if the nearest receptor is also close to other significant noise sources, an alternative receptor may need to be chosen.
- The background noise should be measured at 10 m height over a series of 10-minute intervals, using appropriate wind screens. At least five of these 10-minute measurements should be taken for each integer wind speed from cut-in speed to 12 m/s.[10, 11]

Noise Mitigation Measures

21. Measures to prevent and control noise are mainly related to engineering design standards and turbine siting. With modern turbines, mechanical noise is usually significantly lower than aerodynamic noise, and continuous improvement in airfoil design is reducing the latter.[12]

22. Additional recommended noise management measures might include:

- Operating turbines in reduced noise mode.

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[7] B. Howe *et al*., *Wind Turbines and Sound: Review and Best Practice Guidelines* (2007).

[8] Noise level exceeded for 90 percent of the measurement period, A-weighted.

[9] ETSU, Report ETSU-R-97, “The Assessment and Rating of Noise from Wind Farms” (1997).

[10] Institute of Acoustics (IOA), “A Good Practice Guide to the Application of ETSU-R-97 for the Assessment and Rating of Wind Turbine Noise” (2013).

[11] D. McLaughlin, “Wind Shear and Its Effect on Wind Turbine Noise Assessment,” *Acoustics Bulletin*, July/August 2012, 39-42 (2012).

[12] Idem.

- Building walls/appropriate noise barriers around potentially affected buildings (only an option in hilly terrain, due to the height of turbines).
- Curtailing turbine operations above the wind speed at which turbine noise becomes unacceptable in the project-specific circumstances.

23. See section below for noise-related mitigation options with respect to offshore ecological receptors.

1.1.3 Biodiversity

24. Wind energy facilities have the potential for direct and indirect adverse impacts on both onshore and offshore biodiversity during construction, operation and maintenance, and decommissioning.[13,14] Examples of impacts include bird and bat collision-related fatalities; bat fatalities due to the potential impact of pulmonary barotrauma;[15] displacement of wildlife; habitat conversion/degradation;[16,17,18] and noise to marine mammals with respect to offshore facilities. In offshore environments, benthic disturbance and new structures may also impact existing habitats and attract new habitat-forming species, such as shellfish, corals, and underwater vegetation.[19] The location of operational turbines may disrupt the daily movements of bats and birds (e.g., from feeding to roosting or breeding grounds), and may potentially represent a barrier to the migratory patterns of certain wildlife.[20,21] Adverse impacts can also result from associated infrastructure, particularly overhead transmission lines, meteorological masts, substations, underwater cables, roads, lighting, and boat-based maintenance traffic.

25. Site selection is critical to avoiding and minimizing potential adverse impacts on biodiversity. Site selection should include the following:

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[13] D. Strickland *et al.*, "Comprehensive Guide to Studying Wind Energy/Wildlife Interactions," (Washington, D.C.: National Wind Coordinating Collaborative, 2011).

[14] G. C. Ledec *et al.*, *Greening the Wind: Environmental and Social Considerations for Wind Power Development*, (Washington, D.C.: World Bank, 2011).

[15] Note that evidence suggests that adverse impacts on bats related to barotrauma may have been overestimated. The following literature and others should be duly considered: E. F. Baerwald *et al.*, "Barotrauma Is a Significant Cause of Bat Fatalities at Wind Turbines," *Current Biology* 18:R695-R696 (2008); D. Houck *et al.*, "A Computational and Analytical Study of Bats Flying near Wind Turbines: Implications Regarding Barotrauma," Oral presentation given at the National Wind Coordinating Committee, Wind-Wildlife Research Meeting IX, November 27–30, 2012, Denver, CO, USA (2012); K. E. Rollins *et al.*, "A Forensic Investigation into the Etiology of Bat Mortality at a Wind Farm: Barotrauma or Traumatic Injury?" *Veterinary Pathology* 49:362-371 (2012).

[16] Hötker *et al.*, "Impacts on Biodiversity of Exploitation of Renewable Energy Sources: The Example of Birds and Bats – Facts, Gaps in Knowledge, Demands for Further Research, and Ornithological Guidelines for the Development of Renewable Energy Exploitation" (Bergenhusen: Michael-Otto-Institut im NABU, 2006).

[17] J. M. Pearce-Higgins, "Distribution of Breeding Birds around Upland Wind Farms," *Journal of Applied Ecology* (2009).

[18] Due to the limited footprint of wind energy facilities, habitat conversation/degradation is more likely a consideration in high-value habitats, especially in forested habitats that are more likely to incur impacts related to habitat fragmentation.

[19] J. Köller *et al.* (Eds.), *Offshore Wind Energy: Research on Environmental Impacts*, (Berlin, 2006).

[20] A. L. Drewitt and H. W. Langston, "Assessing the Impacts of Wind Farms on Birds," *Ibis* 148, (2006): 29–42.

[21] Masden *et al.*, "Barriers to Movements: Impacts of Wind Farms on Migrating Birds," *ICES Journal of Marine Science* 66 (2009): 746–753.

- Consideration of the proximity of the proposed wind energy facility to sites of high biodiversity value in the region (including those located across national boundaries). Early screening can improve macro-level project site selection and the scoping of priorities for further assessment, thus reducing unnecessary biodiversity impacts and costs in the future. Sites of local, regional, and international importance may include: national and international protected areas (including marine protected areas), Important Bird Areas (IBA), Key Biodiversity Areas (KBAs), Alliance for Zero Extinction (AZE) sites, Ramsar sites (Wetlands of International Importance), known congregatory sites, and unique or threatened ecosystems. These sites may be known to be important migration routes, wetlands, or staging, foraging, or breeding areas; they may house bat hibernation areas and roosts; or they may contain important topographical features, including ridges, river valleys, shorelines, and riparian areas. Useful site selection tools can include: (i) strategic environmental assessments that compare the biodiversity and other environmental sensitivity of different wind resource areas; (ii) sensitivity (overlay) maps;[22] (iii) digital resources that display areas of high biodiversity value;[23,24,25] and (iv) zoning maps.
- With respect to offshore facilities, siting would include a review of areas of importance to the life history of marine life, notably fish, marine mammals, and sea turtles (e.g., feeding, breeding, calving, and spawning areas) or other habitats, such as juvenile/nursery habitats, mussel/oyster beds, reefs, or sea grass and kelp beds. Siting would also include a review of productive fishing areas.
- Consultation with relevant national and/or international conservation organizations also helps to inform site selection for both onshore and offshore facilities.

Pre-construction assessments

26. Following a scoping and desktop study, appropriate site-specific baseline biodiversity information may be needed to inform the Environmental & Social Impact Assessment (ESIA). Baseline biodiversity surveys, where required, should occur as early as possible (e.g., when wind meteorological masts are erected) and should consider seasonality. A tiered approach to biodiversity surveys could be useful in terms of designing a survey effort commensurate with the stage of project development, also considering the existing biodiversity value of the area.[26, 27]

27. Guidelines have been developed that detail the scope and extent of biodiversity surveys for onshore[28,29,30,31]and offshore[32,33,34,35,36,37]wind energy facilities. Where robust in-country guidelines are not

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[22] For example, the migratory soaring bird project available at http://migratorysoaringbirds.undp.birdlife.org/en

[23] Tools, such as the Integrated Biodiversity Assessment Tool (IBAT), can facilitate access to key international data sets. See www.ibat-alliance.org.

[24] See http://www.protectedplanet.net/

[25] European Commission (EC) Guidance Document, “Wind Energy Developments and Natura 2000,” (2011).

[26] A. R. Jenkins *et al.*, Best Practice Guidelines for Avian Monitoring and Impact Mitigation at Proposed Wind Energy Development Sites in Southern Africa (2011).

[27] U.S. Fish and Wildlife Service, “Land-based Wind Energy Guidelines” (2012).

[28] Scottish Natural Heritage (SNH), *Visual Assessment of Windfarms: Best Practice* (2014).

[29] U.S. Fish and Wildlife Service 2012.

[30] L. Rodrigues. *et al*., “Guidelines for Consideration of Bats in Wind Farm Projects,” EUROBATS Publication Series No. 6 (Bonn: UNEP/EUROBATS, 2014).

yet developed, international guidelines should be used and should always consider the need for surveys to be site-, species-, and season-specific. Generic risk assessments and mitigation plans are unlikely to be useful or easily transferable between species and locations. Surveys should consider the following:

- Site-specific issues: consideration of habitats, geographical location, topography, and vicinity of the wind energy facility to sites of high biodiversity value.
- Species-specific issues: surveys should be targeted to species of flora and fauna of high biodiversity value, those with a special international or national conservation status, endemic species, and species that are at elevated risk of impact from wind energy facilities. For example, species with a relatively high collision risk include certain soaring, aerial-displaying, and/or migratory birds and flocking birds, as well as birds of prey; and migratory, tree-roosting, and insectivorous bats. Species with a relatively high risk of visual disturbance include open-country species that instinctively avoid tall structures.[38] Some species may be attracted to wind energy facilities as perches or feeding areas, which could further increase potential for collision. Species at risk of collision with associated transmission lines include relatively heavy-bodied birds with limited maneuverability (e.g., vultures, bustards, waterfowl, cranes, storks, pelicans, herons, flamingoes), as well as flocking bird species. Species at risk of electrocution from associated transmission lines include various raptors, vultures, owls, and certain storks and other birds with large wingspans, and with behavioral tendencies to perch frequently on power lines and associated structures. Species with a relatively high risk of disturbance from underwater noise (at offshore wind facilities) include marine mammals (especially cetaceans) and certain pelagic schooling fish species (e.g., herrings). These impacts and potential mitigation options should be assessed on a species-by-species basis.
- Season-specific issues: surveys should take into consideration certain periods during the year when the project site may have a greater or different ecological function or value (e.g., migration, breeding season, or winter seasons). Surveys should usually be conducted for at least one year when at-risk wildlife is identified. Longer surveys may sometimes be necessary in areas with exceptional aggregations of at-risk migratory birds and where existing biodiversity data are limited. This would be determined on a project-by-project basis.

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[31] L. Hundt, Bat Surveys: Good Practice Guidelines, (Bat Conservation Trust, 2012).

[32] K. Camphuysen, Towards Standardized Seabirds at Sea Census Techniques in Connection with Environmental Impact Assessments for Offshore Wind Farms in the U.K. (Collaborative for Offshore Wind Research into the Environment (COWRIE), 2004).

[33] R. J. Walls *et al*., “Revised Best Practice Guidance for the Use of Remote Techniques for Ornithological Monitoring at Offshore Windfarms,” (COWRIE, 2009).

[34] I. M. D. Maclean *et al*., “A Review of Assessment Methodologies for Offshore Windfarms,” (British Trust for Ornithology Report, Commissioned by COWRIE, 2009).

[35] C. B. Thaxter and N. H. K. Burton, “High Definition Imagery for Surveying Seabirds and Marine Mammals: A Review of Recent Trials and Development of Protocols,” (British Trust for Ornithology Report, Commissioned by COWRIE, 2009).

[36] I. M. D. Maclean *et al*., “Use of Aerial Surveys to Detect Bird Displacement by Offshore Windfarms,” BTO Research Report No. 446 to COWRIE (Thetford: BTO).

[37] D. Jackson and P. Whitfield, “Guidance on Survey and Monitoring in Relation to Marine Renewables Deployments in Scotland,” *Birds* Volume 4. (2011).

[38] Strickland *et al.* 2011.

28. Surveys should be designed and implemented to adequately guide the micro-siting of turbines (and turbine selection) to minimize collision risks to birds and bats. This is normally expected to entail gathering relatively precise information on the spatial patterns of site utilization by at-risk wildlife species, as well as consideration of the locations of certain topographic, ecological, or other landscape features that may attract or otherwise concentrate the activity of flying wildlife within the project area and its surrounding landscape.[39] Specific data-gathering methods and study designs should be selected based on site- and species-specific considerations, guided by technical experts, and may include vantage point surveys,[40,41] point count surveys, ultrasound acoustic methods, remote-sensing data-gathering techniques, and/or other techniques to understand movement patterns, as appropriate. The extent of data collection should be commensurate with the biodiversity risk at the wind energy facility.

29. The use and effectiveness of radar and/or other remote-sensing technologies in pre-construction studies should be evaluated on a project-by-project basis and may be appropriate to supplement observer-based surveys, depending on the circumstances.[42] Remote-sensing technologies are particularly useful at offshore wind facilities, as observer-based studies are more difficult and expensive in the offshore environment.

30. Surveys for bats could include an assessment of feeding and/or roosting habitats both within the project area and in its vicinity, activity surveys (transects) using hand-held ultrasound bat detectors, trapping and release surveys, and deployment of static ultrasound detectors (particularly at turbine locations). It is preferable for static detectors to be deployed at height and could be attached to meteorological masts.

31. Depending on the location of the wind energy facility and on species-specific considerations, Collision Risk Modeling (CRM) may be also appropriate, especially when wind energy facilities are located close to areas of high biodiversity value.[43,44] The utility of CRM is to be evaluated on a project-by-project basis with qualified experts. CRM is particularly useful at offshore wind farm facilities where empirical tools are limited.[45]

32. Where multiple wind farm facilities are located in the same geographical area and near areas of high biodiversity value, wind project developers are encouraged to implement a coordinated approach to surveys and monitoring. This approach is cost-effective, as surveys could be jointly planned and implemented with costs shared between developers. A common survey methodology and approach also lends itself to cumulative impact assessment, as data collection methods and the level of effort could be standardized. Cumulative impact assessments should be undertaken in cases where multiple wind farms

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[39] G. D. Johnson *et al*., Wildlife Monitoring Studies, Seawest Windpower Plant, Carbon County, Wyoming, 1995-1999. Final report prepared for SeaWest Energy Corporation, San Diego, California, and the Bureau of Land Management, Rawlins, Wyoming, (Cheyenne: Western EcoSystems Technology, Inc. (WEST), 2000).

[40] SNH 2014.

[41] Strickland *et al.* 2011.

[42] Walls *et al*. 2009.

[43] SNH, "Guidance: Wind Farms and Birds – Calculating Theoretical Collision Risk Assuming No Avoiding Action," (2000).

[44]. B. Band, "Using a Collision Risk Model to Assess Bird Collision Risks for Offshore Wind Farms," (British Trust for Ornithology, 2012).

[45] SNH (2000).

are located near areas of high biodiversity value.

Mitigation Measures (Onshore)

33. Careful site selection and layout should reduce adverse impacts on biodiversity. Any significant residual adverse impacts will need appropriate mitigation,[46] which could include the following:

- Modify the number and size of turbines and their layout in accordance with site-, species-, and season-specific risks and impacts. Fewer taller towers may reduce the collision risk for most birds and reduce vegetation clearing for construction. The location of associated infrastructure—such as transmission lines, substations, and access roads—should also be accordingly informed by biodiversity risk and impact assessments.
- If the wind energy facility is located close to areas of high biodiversity value, active turbine management such as curtailment and shut-down on-demand procedures should be considered as part of the mitigation strategy, and factored into financial modeling and sensitivities at an early stage. This method of mitigation should be adaptive and guided by a well-developed post-construction monitoring program. Curtailment and shut-down on-demand measures should be first conducted as an experiment, with control turbines that are not curtailed and with both sets carefully monitored, to determine whether or not the curtailment is producing the desired fatality reduction. Technology-led turbine shut-down should be considered in certain cases, although any such system should be subject to a period of observer-led ground truthing and evaluation through a process of adaptive management.
- Avoid artificially creating features in the environment that could attract birds and bats to the wind energy facility,[47] such as water bodies, perching or nesting areas, novel feeding areas, and staging or roosting habitats. Capping or fixing any cavities in walls or buildings helps to remove potential bat roosting sites.
- Avoid attracting birds to predictable food sources, such as on-site or off-site waste disposal areas, or landfills; this is especially relevant when vultures or other carrion-eating birds are present. These types of mitigation measures may also need to be carried out in the surroundings of the wind energy facility in order to be effective.
- Consider adjustments of cut-in wind speeds to reduce potential bat collisions. The feasibility of this measure should be informed by species- and site-specific data. A slight increase in cut-in wind speed may have the potential to achieve significant reductions in bat fatalities,[48,49] with minimal reduction in generation or financial returns.
- Eliminate “free-wheeling” (free spinning of rotors under low wind conditions when turbines are not generating power).
- Avoid artificial light sources where possible. White, steady lights in particular attract prey (e.g., insects), which in turn attracts predators. If lights are used, red or white blinking or pulsing

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[46] National Wind Coordinating Collaborative, *Mitigation Toolbox,* (2007).

[47] It is understood that, in the case of bats, the turbines themselves are an attractant.

[48] E. B. Arnett, “Altering Turbine Speed Reduces Bat Mortality at Wind-Energy Facilities,” *Frontiers in Ecology and the Environment* 9(4): 209–214, (2011).

[49] R. E. Good *et al*., “Bat Monitoring Studies at the Fowler Ridge Wind Farm, Benton County, Indiana,” Final Report: April 1–October 31, 2011, Prepared for Fowler Ridge Wind Farm (Bloomington: Western EcoSystems Technology, Inc., 2012).

lights[50,51] are best. Steady or slow blinking lights are to be avoided. Timers, motion sensors, or downward-hooded lights help to reduce light pollution.

- Bury on-site transmission lines.
- Install bird flight diverters on transmission lines and guy wires from meteorological masts to reduce bird collisions when located in or near areas of high biodiversity value and/or where birds of high biodiversity value are at risk of collision.[52,53]
- Use “raptor safe” designs for power line poles to reduce electrocution risk.[54]
- Assess the current state of the art of bird and bat deterrence technology, and consider implementing any proven effective technologies where appropriate.

Mitigation Measures (Offshore)

34. Biodiversity-related mitigation measures for offshore facilities, including noise-related mitigation, may include the following:

- If species of high biodiversity value are associated with the site, plan construction activities to avoid sensitive times of the year (e.g., migration and breeding seasons) and to coincide with less productive times of year for fish.
- Employ a “soft start” procedure for pile-driving activities to help prevent exposure of marine life to damaging underwater noise and vibration levels and provide them with an opportunity to leave the area. The use of bubble curtains during pile driving is also recommended.[55]
- Employ auger piling or other means of fixing wind turbine generators to reduce conventional pile-driving disturbance.
- Use a monopole turbine foundation in shallower water, which results in less seabed disturbance than other foundation types.[56] In deeper water, alternative foundations such as jacket type may be more appropriate.
- Use acoustic deterrent devices that emit sounds to deter marine life from the area during construction activities.
- If species of high biodiversity value, such as marine mammals or sea turtles, are anticipated in the area, appoint observers prior to the commencement of construction. Construction should take place at least 500 meters away.

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[50] J. L. Gehring, *et al*., “Communication Towers, Lights, and Birds: Successful Methods of Reducing the Frequency of Avian Collisions,” *Ecological Applications* 19: 505–514 (2009).

[51] P. Kerlinger *et al*., “Night Migrant Fatalities and Obstruction Lighting at Wind Turbines in North America,” *The Wilson Journal of Ornithology* 122: 744–754 (2010).

[52] Avian Power Line Interaction Committee (APLIC), *Reducing Avian Collisions with Power Lines: The State of the Art in 2012*, (Washington, D.C.: Edison Electric Institute and APLIC, 2012).

[53] APLIC 2012.

[54] Idem.

[55] J. Nedwell *et al*., “Assessment of Sub-Sea Acoustic Noise and Vibration from Offshore Wind Turbines and Its Impact on Marine Wildlife; Initial Measurements of Underwater Noise during Construction of Offshore Wind Farm, and Comparison with Background Noise,” COWRIE Report 544 R 0424, (Southampton, UK: Subacoustech Ltd., 2003).

[56] Cape Wind Associates, LLC (CWA), “Cape Wind Energy Project Draft Environmental Impact Statement” (2004).

- Use hydraulic jet plowing technology or other less environmentally damaging technologies for the installation of cables.
- Where electrically or magnetically sensitive species are present within the study area, mitigation measures include appropriate choice of cable types, separation, and burial depths for the cables.

1.1.4 Shadow Flicker

35. Shadow flicker occurs when the sun passes behind the wind turbine and casts a shadow. As the rotor blades rotate, shadows pass over the same point causing an effect termed shadow flicker. Shadow flicker may become a problem when potentially sensitive receptors (e.g., residential properties, workplaces, learning and/or health care spaces/facilities) are located nearby, or have a specific orientation to the wind energy facility.

36. Shadow flicker is not typically considered to be a significant issue for offshore wind energy facilities, given the distances involved between wind turbines and potential receptors located onshore.

37. Potential shadow flicker issues are likely to be more important in higher latitudes, where the sun is lower in the sky and therefore casts longer shadows that will extend the radius within which potentially significant shadow flicker impact will be experienced.

38. Where there are nearby receptors, commercially available software can be used to model shadow flicker in order to identify the distance to which potential shadow flicker effects may extend. The same software can typically also be used to predict the duration and timing of shadow flicker occurrence under real weather conditions at specific receptors located within the zone of potential shadow flicker impact.

39. If it is not possible to locate the wind energy facility/turbines such that neighboring receptors experience no shadow flicker effects, it is recommended that the predicted duration of shadow flicker effects experienced at a sensitive receptor not exceed 30 hours per year and 30 minutes per day on the worst affected day, based on a worst-case scenario. [57,58,59,60]

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[57] In order to assess compliance with the recommended limits, shadow flicker should be modeled and predicted based on an astronomical worst-case scenario, which is defined as follows:

- There is continual sunshine and permanently cloudless skies from sunrise to sunset.
- There is sufficient wind for continually rotating turbine blades.
- Rotor is perpendicular to the incident direction of the sunlight.
- Sun angles less than 3 degrees above the horizon level are disregarded (due to likelihood for vegetation and building screening).
- Distances between the rotor plane and the tower axis are negligible.
- Light refraction in the atmosphere is not considered.

[58] Federal States Committee for Pollution Control, Hinweise zur Ermittlung und Beurteilung der optischen Immissionen von Windenergieanlagen [Information on Identifying and Assessing the Optical Emissions from Wind Turbines], (2002).

[59] French Decree of 26 August 2011 relating to electricity production facilities using mechanical wind energy (facility subject to authorization) (Arrêté du 26 août 2011 relatif aux installations de production d’électricité utilisant l’énergie mécanique du vent au sein d’une installation soumise à autorisation au titre de la rubrique 2980 de la législation des installations classées pour la protection de l’environnement.)

[60] Canadian Wind Energy Association (CanWEA), “An Introduction to Wind Energy Development in Canada,” (2011).

40. Prevention and control measures to avoid significant shadow flicker impacts include the following:

- Site wind turbines appropriately to avoid shadow flicker being experienced or to meet limits placed on the duration of shadow flicker occurrence, as set out in the paragraph above.
- Wind turbines can be programmed to shut down at times when shadow flicker limits are exceeded.

41. Previously, blade or tower glint, which could occur when the sun reflects off a rotor blade or the tower at a particular orientation, was considered to have a potential impact on communities. However, provided that wind turbines are painted with a matt, non-reflective finish, as is typical with modern wind turbines, blade or tower glint is no longer considered to be a significant issue.

1.1.5 Water Quality

Onshore

42. The installation of turbine foundations, underground cables, access roads, and other ancillary infrastructure may result in increased erosion, soil compaction, increased run-off, and sedimentation of surface waters. Measures to prevent and control these issues are discussed in the **General EHS Guidelines** and in the **Toll Roads EHS Guideline**.

Offshore

43. The installation of the turbine foundations and subsurface cables may disturb the marine seabed and may temporarily increase suspended sediments in the water column, thereby decreasing water quality and potentially adversely affecting marine species and commercial or recreational fisheries. Furthermore, the installation of the offshore structures may result in localized seabed erosion due to changes in water movements. Additional guidance is provided in the **Ports, Harbors, and Terminals EHS Guideline**.

44. Other prevention and control measures to address the impacts on water quality include the following:

- Conduct a site selection process that considers the potential for interference of the project's structural components with commercial or recreational fisheries and marine species habitats.
- Plan the construction, installation, and removal of structural components, taking into account sensitive lifecycle periods.
- Control the use of jetting, bubble curtains, and sediment traps; undertake such activities in slack water (or on a tide that moves material away from the sensitive location).

1.2 Occupational Health and Safety

45. Occupational health and safety hazards during the construction, operation, and decommissioning of onshore and offshore wind energy facilities are generally similar to those of most large industrial facilities and infrastructure projects. They may include physical hazards, such as working at heights, working in confined spaces, working with rotating machinery, and falling objects. Prevention and control of these and other physical, chemical, biological, and radiological hazards are discussed in the **General EHS Guidelines**.

46. Occupational health and safety hazards specific to wind energy facilities and activities primarily include the following:[61]

- Working at Height
- Working over Water
- Working in Remote Locations
- Lifting Operations

1.2.1 Working at Height and Protection from Falling Objects

47. Working at height occurs frequently throughout all phases of operation at any wind energy facility, and is especially relevant for maintenance purposes. The main focus when managing working at height should be the prevention of a fall. However, additional hazards that may also need to be considered include: falling objects and adverse weather conditions (wind speed, extreme temperatures, humidity, and wetness). Managing working at height activities requires suitable planning and the allocation of sufficient resources. Preferred mitigation methods may include, in this order:

- Eliminate or reduce the requirement to work at height. During the planning and design phases of an installation, specific tasks should be assessed with the aim of removing the need to work at height, if practicable. Examples of this would include assembling structures and carrying out ancillary works at ground level, then lifting the complete structure into position to the extent that is feasible and cost effective.
- If working at height cannot be eliminated, use work equipment or other methods to prevent a fall from occurring. Collective protection systems, such as edge protection or guardrails, should be implemented before resorting to individual fall arrest equipment. In addition, safety nets or airbags can be used to minimize the consequences of a fall should it occur.

48. In addition to the above hierarchy, the following points should be considered as methods of preventing working-at-height and falling-object incidents:

- Ensure all structures are designed and built to the appropriate standards,[62] and have the appropriate means of working-at-height systems fitted.
- Suitable exclusion zones should be established and maintained underneath any working-at-height activities, where possible, to protect workers from falling objects.
- Ensure all employees working at height are trained and competent in the use of all working-at-height and rescue systems in place.
- Provide workers with a suitable work-positioning device; also ensure the connectors on positioning systems are compatible with the tower components to which they are attached.
- Ensure that hoisting equipment is properly rated and maintained and that hoist operators are properly trained.

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[61] A comprehensive set of guidelines for safe working procedures during construction and operation and maintenance of offshore wind turbines is available from British Wind Energy Association (BWEA), “BWEA Briefing Sheet: Offshore Wind,” (2005c).

[62] E.g., International Electrochemical Commission (IEC), “IEC 61400”.

- When working at height, all tools and equipment should be fitted with a lanyard, where possible, and capture netting should be used if practicable.
- Signs and other obstructions should be removed from poles or structures prior to undertaking work.
- An approved tool bag should be used for raising or lowering tools or materials to workers on elevated structures.
- Avoid conducting tower installation or maintenance work during poor weather conditions and especially where there is a risk of lightning strikes.
- An emergency rescue plan should be in place detailing the methods to be used to rescue operatives should they become stranded or incapacitated while at height.

1.2.2 Working over Water

49. Prevention and control measures associated with working over open water include the basic principles described for working at height, as above, in addition to the following:

- Complete a risk assessment in order to develop a safe system of work for all working-over-water tasks and allocate appropriate resources to mitigate the hazards.
- Ensure all operatives are trained and competent in all tasks they are expected to undertake and in using all equipment, including Personal Protective Equipment (PPE) they are expected to operate.
- In addition to standard PPE, as noted above, use approved buoyancy equipment[63] (e.g., life jackets, vests, floating lines, ring buoys) when workers are over, or adjacent to, water where there is a drowning hazard.
- Where exposure to low water temperatures is likely to lead to the onset of hypothermia, control measures such as survival suits must be implemented.
- When buoyancy equipment is being used with working-at-height fall-arrest equipment, these systems should be compatible.
- Train workers to avoid salt spray and contact with waves.
- Allow the provision of appropriate rescue vessels with qualified operators and emergency personnel, if required.

1.2.3 Working in Remote Locations

50. Planning is vital in ensuring the safety, health, and welfare of employees when operating in remote locations, especially in offshore sites. Areas to consider when planning for remote working include:

- Suitability of communication equipment available for the work crew.
- The training and competence of personnel working remotely and the readiness of all necessary safety equipment in the location.

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[63] E.g., ISO 12402 Personal flotation devices.

- Supervision by competent personnel empowered to make decisions based on events and conditions at the work location.
- Means for managers to track the exact location of the working crew.
- Local emergency plan in place.
- Provision of suitably qualified first-aid-trained personnel in the work crew.

51. Additional information on Lone and Isolated workers can be found in the **General EHS Guidelines**.

1.2.4 Lifting Operations

52. Lifting operations are an integral component of the construction of any wind energy facility. During the construction phase, components are typically assembled and transported to the site where assembly will take place. This involves using large, complex pieces of lifting equipment to lift loads of varying dimensions and weights numerous times.

53. The lifting requirements during the construction of an onshore wind facility are similar to those of any other construction project, however when lifting operations are required in an offshore environment the lifts can become a very complex operation, involving multiple vessels and cranes. This can create a number of additional hazards, including: sea states that can affect the stability of the lifting platforms, a marine environment that can accelerate the degradation of lifting points on components, and communication problems between multinational crews on separate vessels carrying out the lift.

54. The management of lifting operations requires the use of competent personnel, thorough planning, effective communication, and a high level of supervision when carrying out a lift. Consideration should be given to the following areas:

- Ensure all relevant information is known about the load, e.g., the size, weight, method of slinging, and attachment points.
- Ensure all lifting equipment (including load attachment points) is suitable, capable of supporting the load, in good condition, and in receipt of any statutory inspections required.
- Ensure all supervisors, equipment operators, and slingers are trained and competent in the lifting equipment and intended lifting techniques.
- Where possible, exclusion zones are to be established and maintained in order to prevent any unauthorized access to lifting areas.
- When lifting large loads, ensure weather conditions are favorable for the task. Heavy lifting equipment typically has safe operating parameters included in its operating manual and these parameters should not be exceeded at any time. Additional information on severe weather can be found in the **General EHS Guidelines**.

55. A planning meeting between all parties involved in the lift should be carried out and should include: the details of the lift, the roles of each party involved in the lift, and the methods used to communicate instructions among the parties.

1.3 Community Health and Safety

56. Community health and safety hazards during the construction, operation, and decommissioning of onshore and offshore wind energy facilities are similar to those of most large industrial facilities and infrastructure projects. These hazards may apply to the structural safety of project infrastructure, life and fire safety, public accessibility, and emergency situations. Their management is discussed in the **General EHS Guidelines**.

57. Community health and safety hazards specific to wind energy facilities primarily include the following:

- Blade and Ice Throw
- Aviation
- Marine Navigation and Safety
- Electromagnetic Interference and Radiation
- Public Access
- Abnormal Load Transportation

1.3.1 Blade/Ice Throw

58. A failure of the rotor blade can result in the "throwing" of a rotor blade, or part thereof, which may affect public safety. The overall risk of blade throw is extremely low.[64] If ice accretion occurs on blades, which can happen in certain weather conditions in cold climates, then pieces of ice can be thrown from the rotor during operation, or dropped from it if the turbine is idling.

59. Turbines must be sited at an acceptable distance ("setback") between wind turbines and adjacent sensitive receptors to maintain public safety in the event of ice throw or blade failure.

60. Blade throw risk management strategies include:[65]

- Establish setback distances between turbines and populated locations. The minimum setback distance is 1.5 x turbine height (tower + rotor radius), although modeling suggests that the theoretical blade throw distance can vary with the size, shape, weight, and speed of the blades, and the height of the turbine.[66] It is therefore recommended that the minimum setback distances required to meet noise and shadow flicker limits be maintained with respect to sensitive residential receptors to provide further protection.
- Minimize the probability of a blade failure by selecting wind turbines that have been subject to independent design verification/certification (e.g., IEC 61400-1), and surveillance of manufacturing quality.
- Ensure that lightning protection systems are properly installed and maintained.

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[64] Health and Safety Executive (HSE), "Study and Development of a Methodology for the Estimation of the Risk and Harm to Persons from Wind Turbines," Research Report RR968, (2013).

[65] CanWEA 2011.

[66] Rogers *et al*. 2011.

- Carry out periodic blade inspections and repair any defects that could affect blade integrity.
- Equip wind turbines with vibration sensors that can react to any imbalance in the rotor blades and shut down the turbine if necessary.

61. Ice throw risk-management strategies include:

- Establish setback distance.[67]
- Curtail wind turbine operations in weather conditions that can lead to ice accretion.
- Equip turbines with ice detectors that shut down the turbine to an idling state when ice is present.
- Post warning signs at least one rotor diameter from the wind turbine in all directions, if turbines are required to operate in icing conditions, and are in a remote location where people are unlikely to be put at risk.
- Equip turbines with ice detectors to control blade-heating systems, which are designed to release ice from the blade surface, thereby maintaining the efficiency of the turbine; the blade surface finish may also affect the efficiency of heating systems.
- Post warning signs at entrance points to the wind energy facility.
- Ensure that working procedures include precautions such as shutting down wind turbines before maintenance personnel access the site in icing conditions.

62. In addition to the health and safety implications of operation in cold climates, it is important that turbines be of suitable specification to achieve reliable and long-lasting operation.

1.3.2 Aviation

Aircraft Safety

63. Wind turbine blade tips, at their highest point, can reach up to 200 meters and in the future may exceed this height as the technology evolves. If located near airports, military low-flying areas, or known flight paths, a wind energy facility (including anemometer mast) may impact aircraft safety directly through potential collision or alteration of flight paths.

64. Prevention and control measures to address these impacts include the following:

- Consult with the relevant aviation authorities before installation, in accordance with air traffic safety regulations.
- When feasible, avoid siting wind energy facilities close to airports and within known low-flying areas or flight paths. Cumulative impacts associated with the number of existing wind energy facilities within, or in close proximity to, low-flying areas or flight paths should be a consideration in siting turbines.

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[67] International Energy Agency, “Wind Expert Group Study on Recommended Practices: 13,”Wind Energy Projects in Cold Climates, 1st Edition, (2011).

- Use anti-collision lighting and marking systems on towers and/or blades and consult with the relevant aviation authorities to determine appropriate lighting and marking requirements in line with national standards. In the absence of national standards, refer to good practice guidance.[68]

Aviation Radar

65. Wind energy facilities located near radar may impact the operation of aviation radar by causing signal distortion, which may cause loss of signal, masking real targets and/or erroneous signals on the radar screen, creating flight safety issues.[69] These effects are caused by the physical structures of the tower/turbine and the rotating blades.[70] Proximity to existing energy facilities should also be considered in relation to cumulative impacts on radar.

66. Prevention and control measures to address these impacts include the following:

- Consider wind energy facility design options, including geometric layout, location of turbines, and changes to air traffic routes.
- Consider radar design alterations, including relocation of the affected radar, radar blanking of the affected area, or use of alternative radar systems to cover the affected area.[71]
- Consultation should be undertaken with the relevant aviation authorities to determine prevention and control measures.

1.3.3 Marine Navigation and Safety

Marine Safety

67. As with aviation safety, if located near ports, harbors, or known shipping lanes, an offshore wind turbine may impact shipping safety through collision or alteration of vessel traffic. Additional vessel traffic during construction can increase these risks. This may result in damage to turbines and/or vessels, as well as pollution risk associated with collisions.

68. Offshore turbines, cable routes, and other associated infrastructure require careful consideration in terms of siting to take into account factors such as anchorage areas, seabed conditions, archaeology sites, existing cable or pipeline routes, and fishing grounds, and to minimize impacts where possible.

69. Offshore wind turbine generators can interfere with radar operation used for shipping navigation, preventing vessels from being detected, with the potential to impact normal and shipping operations.

70. Prevention and control measures to address these impacts include the following:

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[68] International Civil Aviation Organization (ICAO) 2012; CAA 2013; American Wind Energy Association (AWEA) 2008; CanWEA 2011.

[69] Radio Advisory Board of Canada (RABC) & CanWEA (undated), “Technical Information and Coordination Process between Wind Turbines and Radio Communication and Radar Systems.”

[70] Idem.

[71] Civil Aviation Authority (CAA), “Policy and Guidelines on Wind Turbines” (CAP 764, 2013).

- Consult with marine regulatory traffic authorities before installation, in accordance with marine traffic safety regulations.
- When feasible, avoid siting wind energy facilities close to ports and within known shipping lanes.
- Use anti-collision lighting and marking systems on turbines and all other hazards. Use of guard vessels should also be considered. Lighting and marking should be determined with relevant marine authorities.
- Safety zones can be established around each turbine and construction vessel during the construction phase in order to minimize disruption to other sea users.
- Use reference buoys to aid navigation.

1.3.4 Electromagnetic Interference

71. Wind turbines could potentially cause electromagnetic interference with telecommunication systems (e.g., microwave, television, and radio). This interference could be caused by path obstruction, shadowing, reflection, scattering, or re-radiation.[72] The nature of the potential impacts depends primarily on the location of the wind turbine relative to the transmitter and receiver, characteristics of the rotor blades, signal frequency receiver characteristics, and radio wave propagation characteristics in the local atmosphere.[73]

Telecommunication Systems

72. Impacts on telecommunications systems can include those on broadcast-type systems and those on point-to-point systems. Prevention and control measures to address impacts to telecommunications systems include the following:

- Modify placement of wind turbines to avoid direct physical interference of point-to-point communication systems; consultation with relevant operators can assist in establishing the location of telecommunication links and relevant buffers to be applied in order to minimize impacts.
- Install a directional antenna.
- Modify the existing aerial.
- Install an amplifier to boost the signal.[74]

Television

73. Prevention and control measures to address impacts to television broadcast include the following:

- Site the turbine away from the line-of-sight of the broadcaster transmitter.
- If interference is detected during operation, install higher-quality or directional antenna.

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[72] RABC & CanWEA (undated).

[73] D. Sengupta and T. Senior, "Large Wind Turbine Siting Handbook: Television Interference Assessment, Final Subcontract Report," (1983).

[74] URS Australia Pty. Ltd, "Woodlawn Wind Farm Environmental Impact Statement," (2004).

- Direct the antenna toward an alternative broadcast transmitter
- Install digital television.
- Install an amplifier.
- Relocate the antenna.

1.3.5 Public Access

74. Safety issues may arise with public access to wind turbines (e.g., unauthorized climbing of the turbine) or to the wind energy facility substation. Any public rights of way located within and close to the wind energy facility site should be identified prior to construction in an effort to establish any measures that may be required to ensure the safety of their users.[75]

75. Prevention and control measures to manage public access issues include:

- Use gates on access roads.
- Where public access is not promoted to the site and/or there are no current rights of way across the site, consider fencing the wind energy facility site, or individual turbines, to prohibit public access to the turbines.
- Provide fencing of an appropriate standard around the substation with anti-climb paint and warning signs.
- Prevent access to turbine tower ladders.
- Post information boards about public safety hazards and emergency contact information.

1.3.6 Abnormal Load Transportation

76. Traffic and transportation issues to consider in siting wind energy facilities are largely covered within the **General EHS Guidelines** and the **Toll Roads EHS Guideline.** The main challenge with respect to wind energy facilities lies with the transportation of oversized or heavy wind turbine components (blades, turbine tower sections, nacelle, and transformers) and cranes to the site. The logistics, traffic, and transportation study should assess impacts on existing offsite roadways, bridges, crossings over culverts, overpasses/underpasses, turning radii, and utilities, as well as whether surface replacements, upgrades, or resettlements will be required. To reduce delays to other road users and the potential for other effects on local communities in the vicinity of the proposed route, schedule deliveries outside of peak hours, use only approved access routes, provide traffic management to stop other traffic where needed (for example, at pinch-point locations), and provide police escorts where required.

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[75] European Union, “European Best Practise Guidelines for Wind Energy Development,” (2002).

2. PERFORMANCE INDICATORS MONITORING

2.1 Environment

2.1.1 Emissions and Effluent Guidelines

77. Wind energy facilities do not normally generate process emissions and effluents during their operation. Guideline values for process emissions and effluents in this sector are indicative of good international industry practice, as reflected in relevant standards of countries with recognized regulatory frameworks. Air emissions, wastewater discharges, and solid wastes related to construction and decommissioning activities are discussed in the **General EHS Guidelines**.

2.1.2 Noise Monitoring

78. Noise impacts should not exceed the levels presented in the **General EHS Guidelines**.

79. Noise generated from wind energy facilities tends to increase with the speed of the wind, as does overall background noise due to the friction of air over existing landscape features. Increased wind speeds may also mask the noise emitted by the wind energy facility itself, and wind speed and direction may affect the direction and extent of noise propagation. The application of noise guideline values and the assessment of background levels should therefore take these factors into consideration. It is considered good practice to undertake noise compliance testing when the project becomes operational to verify the modeled noise levels at nearby properties and confirm the appropriateness of any mitigation applied.[76]

80. Additional consideration may be required to address the nuisance factor associated with impulsive or tonal (sound of a specific frequency) characteristics of noise emitted from some wind energy facilities' configurations.[77]

2.1.3 Environmental Monitoring

81. Environmental monitoring programs for this sector should be implemented to address all activities that have been identified to have potentially significant impacts on the environment, during both normal operations and upset conditions. Environmental monitoring activities should be based on direct or indirect indicators of emissions, effluents, and resource use applicable to the particular project.

82. Monitoring should be conducted by qualified individuals following monitoring and record-keeping procedures and using properly calibrated and maintained equipment. Additional guidance on applicable sampling and analytical methods for emissions and effluents is provided in the **General EHS Guidelines**.

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[76] For measurement procedures, see International Electrochemical Commission (IEC), "IEC 61400-11 Wind Turbines – Part 11: Acoustic Noise Measurement Techniques," (2012).

[77] Some jurisdictions apply a "penalty" of 5 dB(A) that is added to the predicted levels.

2.1.4 Operation Phase Biodiversity Monitoring

83. Operation phase biodiversity monitoring (post-construction monitoring) is essential for (i) confirming the predicted bird or bat mortality and recording unexpected mortality; (ii) enabling adaptive management of the wind energy facility; (iii) better predicting the impacts of additional turbines in the same geographical area; and (iv) advancing scientific knowledge for future wind energy developments. The extent and design of operation phase biodiversity monitoring programs should be informed by site-specific, species-specific, and season-specific risks, as identified during baseline surveys, impact assessments, and/or collision risk assessments.

84. Monitoring programs should be designed to measure the rate and the taxonomic composition of bird and bat fatalities that are occurring at the facility and the effectiveness of mitigation measures, most notably curtailment strategies and on-demand shut-down procedures, and other experimental mitigation measures. Following an adaptive management paradigm, the implementation of mitigation measures may be augmented, diminished, or eliminated, depending on their demonstrated effectiveness. Monitoring programs should be focused on species of heightened concern as defined by the pre-construction assessment[78].

85. Assessment of collision-related impacts to bats and birds at land-based wind energy facilities is normally expected to include post-construction carcass searches. Depending on the type and extent of biodiversity risk at the wind energy facility, such searches should be conducted for a minimum of one to three years subsequent to the initiation of wind farm operation, and may be extended to longer durations in high-risk environments, if necessary.

86. Post-construction carcass searches and evaluation should incorporate current scientific design elements[79,80,81] to ensure that the resulting estimates of bird and bat fatality rates at the facility are accurate and robust, such as the following: 1) correction for searcher efficiency (carcass detection) bias; 2) correction for carcass removal by scavengers; 3) correction for unsearched areas; 4) selection of appropriate carcass search frequency based on expected fatality and carcass scavenging rates;[82] 5) selection of subsample of turbines to be searched, as appropriate, depending on size of project and expected fatality rates; 6) selection of search area size and configuration at searched turbines depending on substrate searchability and analytical considerations.

87. In certain circumstances, post-construction monitoring may also include further surveys of the use and movement patterns of birds and bats through the project area to supplement data gathered by carcass searches.

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[78] See second bullet of paragraph 27.

[79] See Ledec (2011), Appendix D.

[80] F. Korner-Nievergelt *et al*., "Estimating Bat and Bird Mortality Occurring at Wind Energy Turbines from Covariates and Carcass Searches Using Mixture Models," *PLoS One* 8(7): e67997.doi:10.1371/journal.pone.0067997, (2013).

[81] M. M. P. Huso, and D. Dalthorp, "Accounting for Unsearched Areas in Estimating Wind Turbine-caused Fatality," *Journal of Wildlife Management* 78:347-358 (2014).

[82] Á. Camiña, "Bat Fatalities at Wind Farms in Northern Spain — Lessons to Be Learned," Museum and Institute of Zoology, *Acta chiropterologica* 4(1): 205–212 (2012).

88. Where multiple wind farm facilities are located in the same geographical area and close to areas of high biodiversity value, wind project developers are encouraged to implement common post-construction monitoring procedures so that results can be assessed cumulatively. A common data-sharing and reporting mechanism would facilitate this process.

89. Wind farm developers are also encouraged to make post-construction monitoring results available to relevant stakeholders.

90. Offshore wind energy facilities should be monitored both temporally and spatially for parameters, including benthic organisms, mammals, and fish. Parameters may include infauna (sediment and infaunal communities); hard substrate habitat; fish; sand eel (indicator species of changes to sediment characteristics); birds and bats; and marine mammals.

2.2 Occupational Health and Safety

2.2.1 Occupational Health and Safety Guidelines

91. Occupational health and safety performance should be evaluated against internationally published incident statistics, if they are available. Typical methods to assess an organization's performance include:

- Recording all incidents that occur over the course of project implementation.
- Recording near-miss (also known as near-hit) data during a project in order to identify trends and implement improvements.
- Carrying out workplace and worker auditing to assess the effectiveness of risk management systems and workplace safety culture.
- Conducting worker consultation and feedback via questionnaires or periodic safety meetings.
- Comparing organizational data with released industry-specific data, if available.

2.2.2 Accident and Fatality Rates

92. Project management should aim to reduce the number of accidents among project workers (whether directly employed or subcontracted) to zero, especially accidents that could result in lost work time, different levels of disability, or even fatalities. Accident rates may be benchmarked against the performance of similar facilities in this sector in developed countries through consultation with published sources.

2.2.3 Occupational Health and Safety Monitoring

93. The working environment should be continually monitored for occupational hazards relevant to the specific project. Monitoring should be designed and implemented by accredited professionals[83] as part of an occupational health and safety-monitoring program. Facilities should also maintain a record of occupational accidents and diseases, as well as dangerous occurrences and accidents. Additional

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[83] Accredited professionals may include certified industrial hygienists, registered occupational hygienists, or certified safety professionals or their equivalent.

guidance on occupational health and safety monitoring programs is provided in the **General EHS Guidelines**.

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ANNEX A. GENERAL DESCRIPTION OF INDUSTRY ACTIVITIES

94. Wind energy facilities are based on harnessing natural wind and converting it into electrical energy. These facilities are located in both onshore and offshore locations. The primary factor in determining a site's feasibility and viability as a proposed wind energy facility is the presence of a good wind resource. An energy yield assessment is conducted to assess predicted energy generation and consequent revenues. Other significant factors in determining whether a site is appropriate for a wind energy project include environmental and social impacts, the cost of construction and operation, reaching agreement on the sale of electricity at a commercially appropriate price, and access to a grid connection with adequate capacity.

95. As with other industry sectors, the life cycle of a wind energy project consists of a wind resource assessment, environmental and social impact assessment, construction, operation, maintenance, and decommissioning phases. Activities typically associated with the construction phase include access road construction or upgrade, site preparation (such as construction of access tracks and turbine foundations), and transport of as well as installation of project components (e.g., anemometers, wind turbines, transformers, substations). Decommissioning activities depend on the proposed subsequent use of the site, but typically consist of removal of infrastructure (e.g., turbines, substations, roads) and reinstatement of the project site to its pre-project condition. The following section provides a description of the facilities and activities common to the construction and operation of onshore and offshore wind energy facilities.

A.1 Facilities and Activities Common to Onshore and Offshore Wind Energy Facilities

96. Structural elements of a wind energy project include wind turbines, transformers, underground or aboveground collector transmission cables between the wind turbines, substations, and aboveground transmission lines to connect to an existing power grid and access roads (figure A-2). Wind turbines are spaced to maximize energy yield while minimizing land use.

97. The wind turbine generator is the fundamental component of a wind energy project and is responsible for harnessing wind energy and converting it into useful electrical energy. Increases in rotor diameter and tower height have led to an increase in generating capacity and efficiency.

98. The turbine consists of a foundation, tower, nacelle, rotor blades, rotor hub, and lights (Figure A-1).

99. The turbine towers are primarily a tapered cylinder shape and are usually made of steel. They are typically painted white or off-white, but they can have different painted markings for air traffic and marine safety (offshore), depending on country-specific requirements.

Figure A-1: Typical Structural Components of a Wind Turbine

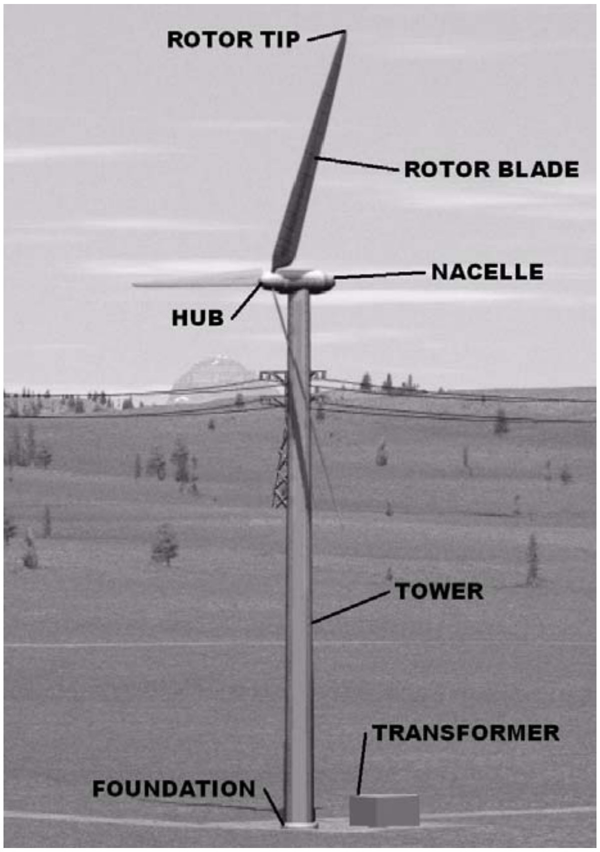
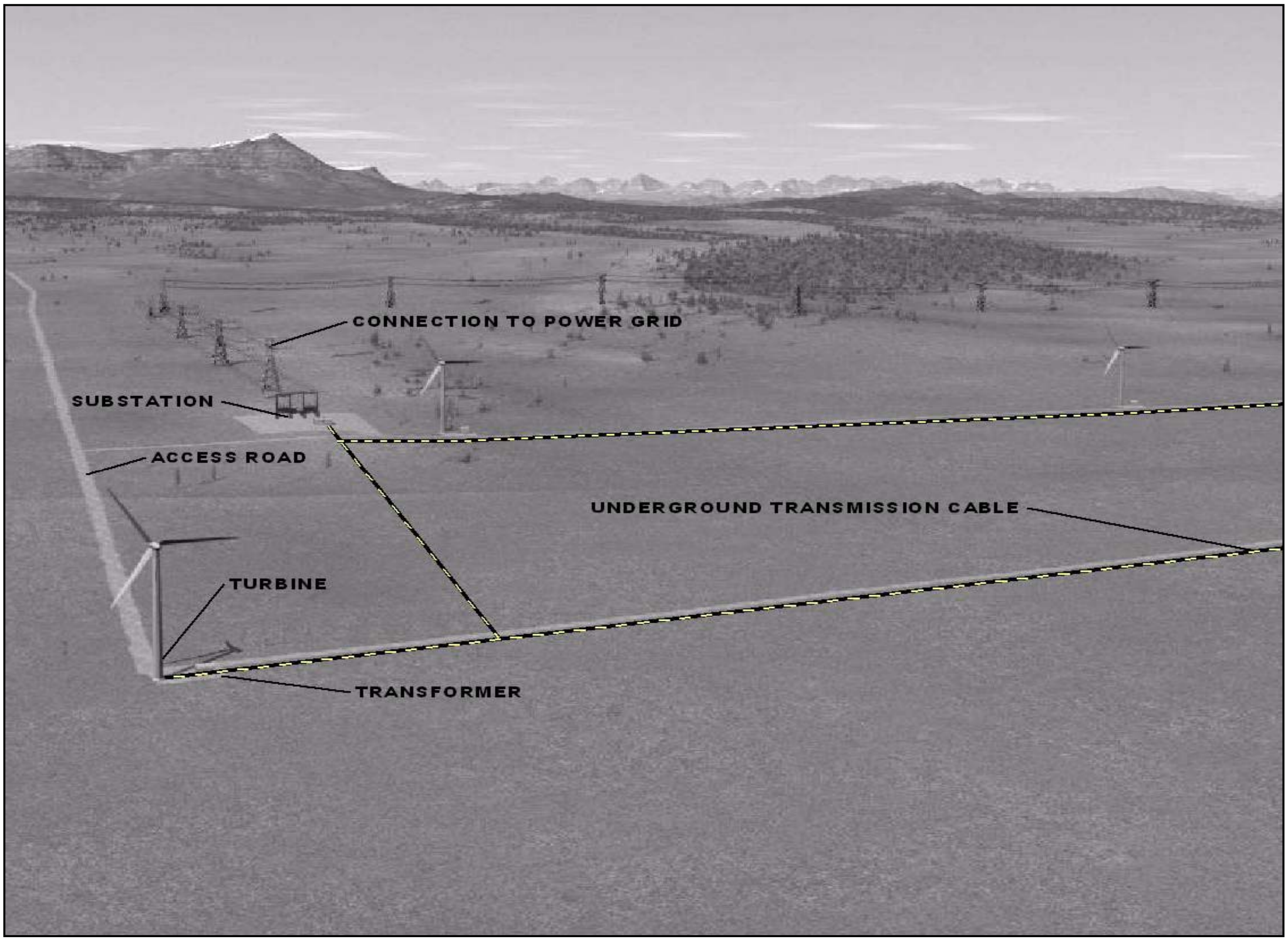


Figure A-2: Typical Components of an Onshore Wind Energy Facility



100. As the wind speed increases, the rotor blades begin to rotate. This rotation turns the generator inside the nacelle, thereby converting some of the wind's energy to electricity. Most wind turbines start generating electricity at approximate wind speeds of 3 to 4 meters/second (m/s) (10.8 to 14.4 kilometers/hour (km/h)), generate maximum power at wind speeds of around 12 m/sec (43 km/h), and shut down to prevent damage at around 25 m/s (90 km/h).[84] The maximum blade tip speed can be approximately 90 m/s or 320 km/h. At high wind speeds, rotor power can be limited in one of three ways: stall control, variable pitch control, and active stall control. In stall control, the aerodynamic design of the rotor blade regulates the power of the rotor. At high wind speeds, a stall-controlled blade will begin to go into stall above a pre-determined power limit, according to the aerodynamic design of the rotor blade. In pitch control, the pitch of the rotor blades can be altered up to 90^o to maximize wind capture. Once the power limit is reached, the pitch is changed to begin spilling energy from the rotor. Active stall control is a

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[84] BWEA 2005b.

combination of stall and pitch control whereby the blades are similarly designed to stall control blades but can still be turned to adjust the pitch. Until the 1990s, passive stall regulation was the preferred strategy, however pitch regulation is now the favored means of limiting rotor power for large turbines.

101. The amount of energy in the wind is proportional to the cube of the wind speed. In other words, doubling the wind speed results in eight times the energy contained in the wind. A turbine will typically generate electricity 70 to 85 percent of the time.[85] The turbine's energy production does not change in the same proportion, however, but roughly with the square of the wind speed. The electricity generated by a wind turbine is generally at 700 volts, which is not suitable for power transmission.[86] Therefore, each turbine will use a transformer to “step up” the voltage to a level sufficient for the wind farm’s collector system (e.g., 11 kilovolts (kV)). The collector system is connected to a transformer that increases the voltage to a level suitable for connection to a utility substation. The connection between a turbine transformer and the substation, on one hand, and the substation and the electrical grid on the other can be made using underground or aboveground transmission cables. Depending on the project layout, the turbine transformers can be connected independently to the substation, or the turbines can be connected to one another and then connected to a substation.

102. The design lifetime of a wind turbine is approximately 20 years, but in practice turbines may last longer with proper maintenance.

103. Routine maintenance will be conducted throughout the lifetime of the wind turbine. Maintenance activities may include turbine and rotor maintenance, lubrication of parts, full generator overhaul, and maintenance of electrical components, as necessary.

104. The operation and maintenance of wind energy facilities does not typically involve air emissions or effluent discharges. Fluids and other waste materials associated with typical maintenance activities are not normally stored onsite and are disposed of according to appropriate regional or national regulations and/or best management practices.

A.2 Facilities Unique to Offshore Wind Energy Facilities

105. The structural elements and operation of an offshore wind energy facility are similar to those of an onshore wind energy facility. The main differences between offshore and onshore turbines are the size of the turbines, the height of the turbine towers, and the diameter of the rotor blades. Another difference is that offshore wind energy facilities typically use subsurface (marine and terrestrial) cables to transmit electricity from the turbines to the transformer and from the transformer to a substation located on land (Figure A-3).

106. The structural component materials (e.g., towers) will be similar to their onshore counterparts, however some different methods are used to adapt the structure to the marine environment, including coating the metal parts to protect them from corrosion; using sealed nacelles; designing different foundations/towers to cope with wind, wave, current, tide, and seabed interactions (see Figure A-2); and providing special access platforms for maintenance.

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[85] BWEA 2005d.
[86] BWEA 2005b.

107. Typical activities for the construction of offshore wind turbines include establishment of the turbine foundation, marine transport of the turbine components, tower assembly, lifting of the nacelle and rotors onto the wind tower, and rotor/nacelle assembly.

108. The types of foundations and associated applications that can be used for offshore wind turbines include:

- Monopile: Most conditions, preferably in shallow water and not in deep, soft material.
- Tripod: Most conditions, preferably not in deep, soft material; suits water depths greater than 30 meters (m).
- Concrete gravity base: Virtually all sediment conditions.
- Steel gravity base: Virtually all sediment conditions, and deeper water than concrete.
- Monosuction caisson: Sands, soft clay conditions.
- Multiple suction caisson: Sands, soft clay conditions; deeper water than monosuction.
- Floating: Deep waters to 100 meters.

Figure A-3: Typical Components of an Offshore Wind Energy Facility