Adequacy of Environmental Permitting and Review of Terrestrial Wind Energy Projects

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1.0 INTRODUCTION

The potential environmental impacts of terrestrial wind energy projects are well understood and have been extensively studied. Utility-scale wind energy projects were first developed in the United States in earnest in the 1990s. By 2024, there were approximately 1,500 utility-scale terrestrial wind energy projects that include more than 76,000 installed wind turbines located in at least 45 states, totaling 155 gigawatts in electrical generation capacity (ACP, 2025; Hoen et al., 2025). The siting and permitting processes for these projects have resulted in a robust body of research.

Federal, state, and local regulations and policies that address siting and permitting wind energy projects have grown in complexity, scope, and scale concurrent with the evolution of the industry over the last three decades. Topics of concern that have been raised by regulators, environmental advocates, host communities, and wind energy opponents have often focused on potential impacts on wildlife, economic costs, visual resources/community character, and property values. These concerns have driven the need for public engagement, comprehensive environmental assessments, and robust permitting processes. As a result, the potential environmental impacts of constructing and operating terrestrial wind energy projects are extensively documented, and appropriate measures to minimize and mitigate these impacts have been thoroughly vetted and demonstrated to be effective.

This report summarizes the more significant environmental impacts and concerns associated with terrestrial wind energy projects, including the current state of knowledge, established conclusions, and best practices to minimize and mitigate those effects. This report also summarizes existing permitting processes on both federal and private lands, reviews the impacts and issues that are typically addressed through environmental review processes, and considers the benefits of wind energy. The purpose of this report is to demonstrate the thoroughness and adequacy of established assessments and environmental review procedures, the clear understanding of the potential impacts of land-based wind energy, and the effectiveness of standard practices to minimize and mitigate those potential effects.

2.0 PERMITTING PROCESS

- The rigorous permitting processes to obtain required authorizations for wind energy facilities on both federal and private lands have resulted in an extensive public record.
- This exhaustive collection of pre-construction studies and post-construction monitoring reports demonstrates that the environmental impacts of constructing and operating wind energy facilities are thoroughly understood, and that appropriate measures to mitigate such impacts are established, time-tested, and successful.

Although it varies by location for most land-based wind projects, reviews and approvals must comply with local (town/county), state, and/or federal regulations. To obtain the necessary permits/approvals, proposed wind energy projects typically undergo a thorough review process assessing the potential impacts of project construction and operation. This process typically takes 3 to 7 years for projects on federal lands (e.g., USFS, 2012; BLM, 2024a, 2025a) and 1 to 4 years for projects on private lands (e.g., OPSB, 2025; NYSDPS, 2025; SD PUC, 2025). On both public and private lands, permitting processes include numerous site-specific studies and opportunities for public involvement. Then, once local/state permits have been issued, additional time is often required to obtain federal approvals, such as wetland permits from the U.S. Army Corps of Engineers (USACE) and/or wildlife permits from the U.S. Fish and Wildlife Service (USFWS), and to prepare compliance filings or additional studies required by permit conditions. These processes result in an extensive public record of documents that evaluate the potential impacts of land-based wind energy facilities. This section presents an overview of the permitting processes associated with land-based wind energy projects on both public and private land.

2.1 Federal Land

There are currently operating wind energy facilities on both Bureau of Land Management (BLM) and National Forest System (NFS) lands. Both agencies have prepared programmatic siting and permitting policies that require thorough site-specific analyses and formalize procedures to avoid, minimize, and compensate for potential impacts.

2.1.1 Bureau of Land Management Lands

Section 211 of the Energy Policy Act of 2005 (Public Law No. 109-58) established a goal that the Department of the Interior approve 10,000 megawatts (MW) of non-hydropower renewable energy projects on public lands by 2015. In anticipation of that legislation, the BLM initiated the preparation of a programmatic environmental impact statement for wind energy development under the National Environmental Policy Act of 1969, as amended (NEPA). On June 24, 2005, the

BLM released the *Final Programmatic Environmental Impact Statement on Wind Energy Development on BLM Administered Lands in the Western United States* (PEIS) (BLM, 2005a). A Record of Decision (ROD) was signed on December 15, 2005, to implement the best management practices (BMPs) and land use plan amendments identified in the PEIS (BLM, 2005b). The BLM subsequently issued its *Wind Energy Development Policy* (IM 2006-16) on August 24, 2006, establishing the basic framework for assessing proposed wind energy facilities on BLM lands. That framework was carried forward and supplemented by BLM's revised *Wind Energy Development Policy* (IM 2009-043), issued on December 22, 2008. More recent BLM regulations include the 2020 Energy Policy Act (43 United States Code Chapter 48), which further incentivized development on BLM lands by directing the Secretary of the Interior to permit at least 25 gigawatts of renewable energy on public lands no later than 2025; and the Rights-of-Way, Leasing, and Operations for Renewable Energy Rule (43 Code of Federal Regulations [CFR] 2800), which was most recently revised May 1, 2024, to update procedures governing renewable energy and right-of-way (ROW) programs. Collectively, this record of documents, which spans over two decades, establishes the regulatory review process for wind energy facilities on BLM lands and includes measures to mitigate the potential impact of wind energy on wildlife, wildlife habitat, and other resources.

To build and operate a wind energy facility on BLM lands, project proponents must obtain an ROW authorization (BLM, 2025b). The BLM provides a pre-application checklist describing the information applicants should provide during a pre-application meeting with BLM staff (BLM, 2025c). The information reviewed in this meeting helps BLM staff determine the appropriate level of analysis required under NEPA. Depending on the complexity of a proposed project and site/habitat conditions, the project-specific analysis typically requires an Environmental Assessment (EA) or Environmental Impact Statement (EIS). The BLM will also inform the applicant of additional special studies that may be required, depending on the site, and the standards for such studies. To initiate the agency review of the authorization request, applicants must submit a completed SF-299 Application form (BLM, 2025d), along with a project map(s), a plan of development, and other project details. The BLM then has 60 days to determine whether the application is complete; additional information may be requested if submitted materials are deemed insufficient. Once the application has been deemed complete, the BLM issues an acceptance letter that requests funds from the applicant to cover agency costs and estimates processing time. The BLM assembles an interdisciplinary team, consults with other federal agencies to ensure compliance with the Endangered Species Act and National Historic Preservation Act, and prepares the NEPA analysis. Upon completion of the NEPA documentation, an ROD is issued, and the application is either granted or denied (BLM, 2025e).

2.1.2 National Forest System Lands

The U.S. Forest Service (USFS), an agency of the United States Department of Agriculture, follows regulations to implement the NEPA according to 40 CFR 1500-1508. USFS NEPA procedures are codified in 36 CFR 220. Guidance to interpret the regulations may also be found in the Forest Service Handbook, FSH 1909.15. USFS objectives, policy, and responsibilities to meet the intent of the NEPA are contained in Forest Service Manual (FSM) 1950. In addition to the NEPA framework, the USFS published final directives for Wind Energy Special Use Authorizations (76 FR 47354) in August 2011. These directives add a new Chapter 70, "Wind Energy Uses," to the Special Uses Handbook, FSH 2709.11, and a new Chapter 80, "Monitoring at Wind Energy Sites," to the Wildlife Monitoring Handbook, FSH 2609.13. These new chapters supplement existing special-use and wildlife directives. The new Chapter 70 provides direction on siting, processing applications, and issuing permits for wind energy use. Specifically, Section 72 provides guidance regarding proposals for wind energy permits, including topics to be addressed during pre-proposal meetings; Section 73 addresses applications for wind energy permits, including application requirements for all wind energy permits, and Section 74 provides guidance on processing applications for wind energy permits, including environmental analysis and NEPA compliance requirements (USFS, 2011). The new Chapter 80 provides specific guidance on wildlife monitoring at wind energy sites before, during, and after construction. In addition, the directives make corresponding revisions to FSM 2726, "Energy Generation and Transmission," and FSH 2709.11, Chapter 40, "Special Uses Administration."

Applicants for a special use permit for the construction and operation of a wind energy facility on NFS lands must submit a study plan, a plan of development, and a site plan. The study plan must provide a brief description of the studies required for processing the application, including the methodologies to be used. The study plan must include the following:

- A review of existing information regarding identified species of management concern, including habitat use, location, or presence in the study area, and identification of ecologically sensitive areas in or near the study area, including landscape and topographical features known to attract or concentrate birds or bats.
- Identification of information and methods to gather information for the development of biological assessments and evaluations of project-specific species of management concern and their habitats.
- An inventory of historic properties and cultural resources.
- An inventory of invasive species.
- An inventory of existing land uses, including existing recreational use and facilities, special uses, grazing, and mining.

- An inventory of existing infrastructure and resource investments such as power lines, other utilities, and access roads under the jurisdiction of the USFS or a public road authority; reforestation; landscape restoration; wildlife habitat improvements; and fencing.
- An inventory and assessment of the landscape using the SMS (FSM 2380) or an alternate visualization technique suitable for assessing potential impacts on scenery.
- A review of land ownership records, noting any valid outstanding rights, including mining claims and land use authorizations (USFS, 2011).

The plan of development (POD) is used to determine if a wind energy project is consistent with the applicable land management plan and facilitates the safe and orderly use of land for wind energy production. The applicant must ensure the POD provides all the wide-ranging information listed in FSH 2709.11, Section 73.32, which is then used to inform the NEPA analysis. The site plan must display the location of all proposed facilities, including wind turbines, buildings, service areas, roads, office and maintenance structures, and the project area, including any specific areas the USFS excludes from development. If the USFS authorizes the permit approval at the end of the environmental review process, the applicant must revise both the POD and site plan to address changed conditions and specific requirements contained in the agency decision document (USFS, 2011).

2.2 Private Land

For wind energy projects on private land, permitting regimes vary by location. Some states have state-level siting boards or councils that review and permit utility-scale energy projects, including New York (NYSDPS, 2025), Minnesota (MN PUC, 2025), Ohio (OPSB, 2025), and South Dakota (SD PUC, 2025). In other states, permitting occurs at the county or local level (e.g., Utah, California, Montana). However, environmental impacts are considered for projects on private land, often in the form of an EA, EIS, or siting permit application, no matter who the permitting authority is. Impacts addressed through state and local permitting/review processes typically include impacts on natural resources (including land, wetlands/water, vegetation, wildlife), cultural resources (including archaeological and historic sites), visual/aesthetic resources, agricultural resources, and nearby residents/receptor (including impacts associated with noise, shadow flicker, traffic/transportation, land use, and community character). Because utility-scale wind energy facilities have been built and operated on private lands across the United States for decades, these impacts are well studied and understood. The Tethys database is a knowledge repository regarding impacts associated with wind energy facilities. The database is sponsored by the U.S. Department of Energy (USDOE) and is part of the Wind Energy-Environmental Research & Engagement Network (Tethys, 2025). The USEPA's NEPA EIS database is part of a series of guidance and support documents intended to assist practitioners in the environmental review process (USEPA, 2025). Using the Tethys and USEPA NEPA EIS database, hundreds of federally and privately conducted EISs and other EA reports are publicly available. The environmental review processes used by state and local siting boards are almost always based on carefully prescribed criteria adopted through public rulemaking processes and typically require the project developer to demonstrate that impacts have been avoided or minimized to the extent practicable.

In addition, wind energy projects on private land often require additional permits to authorize specific impacts to state or federally protected resources such as wildlife, wetlands/waters, etc. For instance, if there remains a risk of taking listed threatened or endangered species after implementing all feasible mitigation measures, project developers can apply for an Incidental Take Permit (ITP) from the USFWS. Under the Endangered Species Act of 1973, "take" (i.e., killing or otherwise harming) of a listed species is prohibited (USFWS, 2016). However, a provision added in 1982 allowed for "incidental take" or take that occurred during an otherwise lawful activity. To apply for an ITP, project developers must first develop a Habitat Conservation Plan (HCP) that is approved by the USWFS. In essence, HCPs describe project-related impacts; harm-reduction measures that would be employed to monitor and mitigate take; and documentation of the funding available to support implementation of these measures. This process is intended to be interdisciplinary and generate productive partnerships that create long-term, ecosystem-level benefits for listed species. The process of compiling an acceptable HCP is lengthy and involves providing extensive information about the project, site (including habitats and species), and impact avoidance measures. In addition to project-related information and biological context, preparation of an HCP requires a detailed understanding of the regulatory framework and overall permitting process. To provide guidance on agency expectations, the USFWS developed the "Habitat Conservation Planning and Incidental Take Permit Processing Handbook" (USFWS, 2016). This HCP Handbook provides information on navigating the planning process, the various types of HCPs and ITPs that may be relevant to a given project, and how best to approach communication and coordination between the various stakeholders involved. The Handbook also describes what activities an ITP covers, what information is required to generate an HCP, and details on how conservation measures and monitoring plans should be implemented to ensure that conservation goals and all aspects of the HCP are fulfilled (USFWS, 2016). Consequently, receipt of an ITP requires extensive documentation of potential impacts and commitment to undertake measures that would avoid, minimize, or compensate for take of the listed species in question.

3.0 ISSUES

This section of the assessment focuses on the potential environmental impacts associated with land-based wind energy that have been raised by regulators, environmental advocates, host communities, and wind energy opponents.

3.1 Wildlife

- Programmatic analyses of permitting impacts, agency guidelines for impact mitigation (including impact avoidance, minimization, and compensation), site-specific pre-construction studies, and post-construction monitoring ensure a thorough and well-established process for comprehensive assessment of wind energy impacts on wildlife.
- This already-robust body of knowledge is continually expanding as more studies are completed, and the data continue to show that mitigation strategies are effectively preventing adverse impacts to protected species.

As part of the permitting process for proposed onshore wind energy facilities, multiple site-specific studies are typically completed to evaluate a project's risk to wildlife. Wind energy developments are subject to existing state and federal laws that regulate wildlife, including the Bald and Golden Eagle Protection Act, the Migratory Bird Treaty Act, and the Endangered Species Act. Consequently, careful consideration is given to the siting of wind energy facilities and individual turbines to minimize impacts on wildlife. In 2012, the USFWS released the *Land-Based Wind Energy Guidelines*, which provide a structured, scientific process for addressing wildlife conservation concerns at all stages of wind energy development, including pre-construction studies to document site wildlife and habitat, as well as post-construction monitoring during project operations to quantify impacts. The *Land-Based Wind Energy Guidelines* use an iterative tiered approach for assessing potential adverse effects to species of concern and their habitats. During prescribed pre-construction stages of a project (Tiers 1, 2, and 3), developers work to identify, avoid, and minimize risks to species of concern. Tiers 1 and 2 consist of preliminary site evaluation, screening, and characterization, where project developers conduct desktop assessments, consult with state and federal agencies, and review available datasets to determine whether protected species or habitats may occur in a project area, as well as what field studies and environmental regulations may be relevant. Tier 3 consists of site-specific field studies to better predict project impacts (USFWS, 2012).

Required pre-construction studies generally consist of field surveys that document the animals and habitats on site, and depending on the location, may include breeding bird surveys, acoustic bat surveys, mist-netting, winter raptor surveys, and/or other specific targeted surveys for various threatened and endangered species. These requirements are common, regardless of a project's geographic location, and applicable to wind energy development on both private and public lands. For example, the BMPs for wind energy development on BLM lands were formulated through development of the PEIS (BLM, 2005a). The ROD for the PEIS includes the stipulation that "BMPs will be applicable to all wind energy development projects on BLM-administered public lands" (BLM, 2005b). The BMPs contain many provisions specific to wildlife, including the following (among others):

- Applicants must review existing information on species and habitats in the vicinity of the project area to identify potential concerns.
- Applicants must conduct surveys for federal and/or state-protected species and other species of concern (including special status plant and animal species) within the project area and design the project to avoid, minimize, or mitigate impacts to these resources.
- Applicants must identify important, sensitive, or unique habitats in the vicinity of the project and design the project to avoid (if possible), minimize, or mitigate impacts to these habitats.
- Applicants must evaluate avian and bat use of the project area and design the project to minimize or mitigate the potential for bird and bat strikes (e.g., development shall not occur in riparian habitats and wetlands). Scientifically rigorous avian and bat use surveys shall be conducted; the amount and extent of ecological baseline data required shall be determined on a project basis.
- Turbines must be configured to avoid landscape features known to attract raptors, if site studies show that placing turbines there would pose a significant risk to raptors.
- Applicants must determine the presence of bat colonies and avoid placing turbines near known bat hibernation, breeding, and maternity/nursery colonies; in known migration corridors; or in known flight paths between colonies and feeding areas.
- Applicants must determine the presence of active raptor nests. Measures to reduce raptor use at a project site (e.g., minimize road cuts, maintain either no vegetation or non-attractive plant species around the turbines) shall be considered (BLM, 2005b).

The *Land-Based Wind Energy Guidelines* also address post-construction project stages (Tiers 4 and 5). Tier 4 consists of additional studies that developers conduct during project operations to quantify impacts, including both fatality monitoring and evaluation of habitat impacts. The data collected in these studies are necessary to assess whether actions taken to avoid and minimize impacts on wildlife have been successful. Tier 5 consists of additional steps to implement adaptive management and/or compensate for unanticipated impacts, when necessary (USFWS, 2012).

Potential impacts on wildlife from wind energy must be considered because populations of many animal species and the natural ecosystems on which they depend are declining due to a myriad of threats, including climate change and habitat loss. Climate change is one of the biggest threats to wildlife, affecting the breeding, distribution, abundance, behavior, morphology, phenology, and survival rates of a broad range of plant and animal species (Weiskopf et al., 2020; Bates et al., 2022). A study investigating the center of abundance for North American bird species found a strong northward shift over the past 40 years: of 305 species evaluated, 208 (68%) had shifted north (Niven et al., 2009). However, different species adapt at different rates, and such shifts can lead to mismatches in demand and availability of food sources (Visser at al., 2006; Robertson et al., 2024; Both et al., 2009). Two-thirds of North American birds are at increasing risk of extinction from global temperature rise (National Audubon Society, 2025a), and climate change is estimated to be the most significant threat to bat species in the United States over the next 15 years (Adams et al., 2024). Bats are especially vulnerable to climate change impacts because their high surface-to-volume ratios make them prone to dehydration and because their slow reproductive rate makes them more susceptible to extinction under rapid environmental changes (Festa et al., 2023). Data suggest that the risk of extinction due to climate change will continue to accelerate, with one in six wildlife species facing extinction from future global temperatures (Urban, 2015).

Renewable energy is vital to reducing the primary cause of climate change; pollution produced by burning fossil fuels. On average, a wind turbine repays its carbon footprint in 5 to 7 months (Haapala and Prempreeda, 2014; Guezuraga et al., 2016) and provides carbon-free electricity for the remainder of its operating lifespan (typically 20 to 25 years). As a result, many conservation groups advocate for the development of wind energy to protect wildlife from the threats posed by climate change. For example, the National Wildlife Federation (2025) works to expand renewable energy, like solar and wind, to confront the threat of climate change while ensuring this expansion is done responsibly to protect wildlife and habitat. According to the National Audubon Society (2025b), "The climate threat facing birds is urgent. To achieve a future where both people and wildlife thrive, we need to rapidly build out photovoltaic (PV) solar and onshore and offshore wind infrastructure – as well as transmission lines to bring that power to the people who need it."

Although wind energy facilities can have adverse impacts on wildlife, such impacts are mostly limited to species that use the airspace in which turbine blades rotate (i.e., birds and bats) and, for most of these species, are not considered significant relative to other sources of impact. Land-based wind turbines present minimal risk of direct impacts to terrestrial or aquatic organisms, and impacts to habitat are modest for most species, given the relatively small area of land disturbed during the construction and operation of wind energy facilities. In a life cycle assessment of the documented effects of electricity generation on vertebrate wildlife in the New York/New England region, an objective comparison was made among six types of electricity generation: coal, oil, natural gas, hydro, nuclear, and wind. The analysis evaluated all stages of the electrical generation life cycle, including facility construction, resource extraction, fuel transportation, power generation, transmission of electricity, and facility decommissioning. The study found that risks to wildlife vary substantially by the energy generation source and the life cycle stage. However, non-renewable electricity generation sources, such as coal and oil, pose higher risks to wildlife than renewable electricity generation sources, such as hydro and wind, and the study concluded that wind energy had the lowest overall risks to wildlife (NYSERDA, 2009).

The risks to birds and bats from operating wind turbines have been studied extensively and robustly, using powerful statistical tools (USGS, 2019). Post-construction monitoring of avian mortality at operating wind energy facilities has been ongoing since the early 1980s (Erickson et al., 2001) and bat mortality monitoring has been conducted since the mid-1990s (Osborn et al., 1998). Several long-term databases have been compiled that summarize the direct impacts of wind energy on wildlife. As of November 2020, the Renewable Energy Wildlife Institute's databases contained the results of 336 post-construction monitoring studies that document bird and bat fatalities associated with wind energy facilities from 2002 to 2018 (AWWI, 2020a, 2020b). As of April 2023, the similar Renew Database, compiled and maintained by Western EcoSystems Technology, Inc., contained the results of 617 post-construction monitoring studies that document bird and bat fatalities associated with wind energy facilities from 1998 to 2022 (WEST, 2023). These enormous datasets allow for analysis of species composition, regional distribution, and seasonal timing of bird and bat mortalities. This type of data is extremely valuable because it supports the development of impact mitigation measures that target the times of year when birds and bats are most vulnerable to collision mortality, as well as the individual species that are most impacted.

This section describes the risks posed by wind turbines to these organisms, based on decades of academic and government research, along with monitoring data collected at operating wind energy facilities. Also discussed are the studies typically conducted as part of the permitting process and the mitigation measures used to avoid, minimize, and/or compensate for impacts on birds and bats.

3.1.1 Birds

- Impacts on birds due to collisions with land-based wind turbines have been thoroughly studied and are well understood. The USFWS estimates that approximately 234,000 birds are killed per year due to wind turbine collisions.
- The USFWS estimates that numerous other sources of mortality are far more impactful (e.g., over 845 million birds per year are killed from collisions with buildings, vehicles, electric lines, and communication towers).

- Despite the growth in wind energy, threats to eagles are being successfully managed – bald eagle populations are thriving, and overall golden eagle populations are stable.

During the initial operational phase of a wind energy project, impacts to birds are typically tracked through post-construction mortality monitoring (PCMM). Detailed plans for these monitoring efforts are submitted to regulatory agencies for approval; such plans are frequently included in the impact assessment documents outlined above or are referenced in authorizations/approvals as a permit requirement or compliance filing. PCMM plans establish when the turbines would be monitored (depending on location, this may be a portion of or the entire year), as well as the frequency of monitoring. The plan specifies which turbines will be monitored and the interval at which searches will be conducted. Monitoring takes place in the form of regular systematic surveys under turbines, with biologists or wildlife technicians walking transects and searching for bird carcasses. Because small birds can be difficult to locate and may be removed by scavengers feeding on carcasses, searcher efficiency tests and scavenger removal tests are almost always included as part of these surveys (WEST, 2023).

Hundreds of PCMM surveys at operating wind projects have found that small passerines (i.e., perching birds) constituted the largest percentage of avian fatality incidents (58%) among 19 aggregated bird groups, followed by diurnal raptors, doves/pigeons, and upland game birds. Studies revealed seasonal patterns in fatalities for small passerines, with peaks in spring, fall, or both (AWWI, 2020a). In a document that summarizes peer-reviewed scientific studies and other publicly available information about the impacts of land-based wind power on wildlife in North America, the American Wind Wildlife Institute concluded, "Fatality rates at currently estimated values do not appear likely to lead to population declines in most bird species" (AWWI, 2021).

In the 2019 Final Environmental Assessment for the Prevailing Wind Park, the Western Area Power Administration concluded, "Bird deaths at wind farms have been minor compared to other human-caused sources of avian mortality" (WAPA, 2019). The USFWS has compiled data on human-caused sources of bird mortality and concluded that bird deaths from onshore wind turbine operations are relatively insignificant compared to other causes of avian mortality. Based on data through 2017, the USFWS estimates the following (USFWS, 2025a):

- 234,012 birds per year killed due to collisions with onshore wind turbines
- 2.4 billion birds per year killed by cats
- 599 million birds per year killed due to collisions with buildings
- 214.5 million birds per year killed due to collisions with vehicles

- 72 million birds per year killed due to poison
- 25.5 million birds per year killed due to collisions with electrical lines
- 6.6 million birds per year killed due to collisions with communication towers
- 750,000 birds per year killed by oil pits

In the Final Environmental Assessment for the Habitat Conservation Plan and Incidental Take Permit for the Bitter Ridge Wind Farm, the USFWS (2021a) determined that, "In the U.S. and Canada, wind turbines are responsible for approximately 214,000 to 368,000 bird collisions each year, accounting for a small proportion of the human causes of mortality (0.01%)."

Effective strategies for mitigating wind energy impacts on avian populations have been developed and are commonly employed. For example, in 2024, the USFWS authorized a new general permit for eligible wind energy projects that have low risk to eagles and conform to well-established avoidance, minimization, and compensatory mitigation measures that are formalized as permit conditions (USFWS, 2025b). Implementation of the following impact avoidance and minimization measures are required conditions of the new general permit:

- Remove existing anthropogenic eagle attractants (e.g., garbage, animal remains).
- Avoid creating features that attract small mammals (e.g., rock piles).
- Design and modify infrastructure to minimize perching.
- Implement a maximum 25-mile per hour speed limit on project roads.
- Design above-ground power lines to be avian safe (i.e., in compliance with 50 CFR 22.260).
- Implement practicable measures to reduce collisions with wind turbines.
- Restrict non-emergency activities within 1 mile of bald or golden eagle nests.
- Train on-site staff at least once every three years on the relevant requirements of the permit, including how to report and dispose of discovered bird remains or animal remains and informing landowners on the process to report any dead eagles (USFWS, 2025c).

For compensatory mitigation, the general permit requires the applicant to purchase eagle credits from a USFWS-approved conservation bank or in-lieu fee program, in an amount to be determined using the USFWS General Permit Eagle Mitigation Calculator (USFWS, 2025d). All eagle permits must continue to meet the preservation standard, which requires any take to be consistent with the goals of maintaining stable or increasing breeding populations in all eagle management units and the persistence of local populations throughout the geographic range of each species (50 CFR 22.6).

Field data show that USFWS policies have been very effective in protecting bald eagles. Surveys conducted in 2019 in the Atlantic Flyway, Mississippi Flyway, Central Flyway, and Pacific Flyway North eagle management units found 4.4 times more eagles than in 2009 surveys (USFWS, 2021b). These USFWS surveys demonstrate that bald eagle populations are growing alongside wind energy development, which was also growing during the same period: the amount of electricity generated from wind energy facilities in 2020 was 3.6 times higher than in 2010 (USEIA, 2025). Despite the growth in wind energy, threats posed by operating wind turbines are being successfully managed, and bald eagles are thriving. Although there is some regional variability, overall golden eagle populations are, and have for some time been, stable in both the western and eastern United States. Therefore, current levels of mortality appear to be compatible with the maintenance of stable golden eagle populations. As with other bird species, wind energy is not a primary cause of eagle mortality. For example, wind energy facilities were responsible for only 1.6% of fatalities in a recent peer-reviewed study; of 126 golden eagle deaths for which the cause of death could be determined, only two were attributable to collisions with wind turbines (Millsap et al., 2022).

3.1.2 Bats

- Impacts on bats due to collisions with land-based wind turbines have been thoroughly studied and are well understood. Multiple federal agencies (BLM, USDOE, USFWS) have prepared programmatic environmental impact statements that evaluate the impacts of wind projects on bats.
- Bat species listed as threatened or endangered are not frequently killed by wind turbines, and the reasons for their population declines are not related to wind energy development.
- Using curtailment to reduce bat fatalities has been subject to extensive research for nearly two decades, and because bats are more active at lower wind speeds, has proven to be very effective.

Impacts from land-based wind turbine operations on bat species are well understood. The first published record of a turbine-related bat fatality in the United States was nearly 30 years ago (Osborne et al., 1998), and since then, this issue has been studied extensively (Keeley et al., 2001; Johnson et al., 2003; Dürr and Bach, 2004; Kerns and Kerlinger, 2004; Nicholson et al., 2005). As a result, multiple federal agencies (e.g., the BLM, USDOE, and USFWS) have prepared programmatic EISs to evaluate the impacts of wind projects on bats (BLM, 2005a; USDOE, 2015; USFWS 2019a). These impacts can be broken down into two generic categories: construction-related impacts and operation-related impacts. Construction-related impacts involve both direct and indirect impacts. Indirect impacts occur through loss of habitat (clearing of trees), and direct impacts consist of mortality through injury/death to bats roosting in trees that are cut down (USFWS, 2024a). Operation-related impacts involve turbine-related fatality by direct collision or, more rarely, barotrauma (Hayes, 2013; Baerwald et al., 2008). This discussion focuses primarily on operational impacts.

As described for birds, during the operational phase of a wind energy project, impacts to bats are often tracked through PCMM. Monitoring takes place in the form of regular systematic surveys under turbines, with biologists or wildlife technicians walking transects and searching for bat carcasses. This method of monitoring bat fatalities has been designed and refined for more than two decades (WEST, 2023). As such, turbine-related bat mortality has been extensively documented and is well understood. Studies evaluating annual mortality have suggested that turbine-related bat fatalities may number in the hundreds of thousands annually in the United States (Kunz et al., 2007; Hayes, 2013). Although approximately 60% of bat species in the United States (28 out of 47 species) have been documented in PCMM studies at onshore turbine facilities, this mortality is strongly skewed toward three foliage-roosting migratory species of bat: eastern red bat (*Lasiurus borealis*), hoary bat (*Lasiurus cinereus*), and silver-haired bat (*Lasionycteris noctivagans*) (WEST, 2023). These three species account for 72% of bat fatalities attributed to wind turbines (AWWI, 2020b). Although the lack of empirical demographic and population data for migratory bats limits the ability of scientists to quantitatively assess the potential impact of wind energy on these species (Diffendorfer et al., 2019), none are listed as threatened or endangered by the USFWS.

Bat species listed as threatened or endangered are not frequently killed by wind turbines, and the reasons for their population declines are not related to wind energy development. Northern long-eared bats (*Myotis septentrionalis* or NLEB) and tricolored bats (*Perimyotis subflavus*) are listed, or are candidates for listing, as endangered due primarily to population declines caused by white nosed syndrome (WNS). WNS was first documented in Schoharie County, New York, in the winter of 2006–2007, when hundreds of thousands of dead bats were found during routine bat hibernacula surveys (Cohn, 2008; Blehert et al., 2009; White-Nose Syndrome Response Team, 2025). Four years after the discovery of WNS, Turner et al. (2011) estimated that NLEB experienced a 98% decline in winter counts across 42 sites in Vermont, New York, and Pennsylvania. More recently, Cheng et al. (2021) used data from 27 states and two provinces to conclude WNS caused estimated population declines of 97–100% across 79% of NLEB's range. The effect of WNS on tricolored bats has also been extreme. Most summer and winter colonies experienced severe declines following the arrival of WNS, with documented declines of 90–99% (Ingersoll et al., 2016). Other listed bat species, such as the Indiana bat (*Myotis sodalis*) and the gray bat (*Myotis grisescens*), have been listed due largely to habitat loss, concentration of the populations in a relatively small number of hibernacula where they were vulnerable to human disturbance, changes in hibernacula conditions, and other impacts unrelated to wind energy development (USFWS, 2025e, 2025f).

According to the USFWS (2022), mortality associated with wind energy facilities is “not currently acting as a driver” of NLEB population decline. USFWS (2024g) mortality data show a cumulative total of 35 NLEB deaths attributed to wind energy, most of which occurred at facilities that were not yet implementing curtailment regimes (see discussion below) and/or occurred before WNS became endemic. The most recent known death of an NLEB at any wind energy facility was in 2016 (USFWS, 2024g), despite the growth in wind energy facility development and increased monitoring and search efforts. Tricolored bats comprise less than 1% of bat fatalities in the United States, mostly from Pennsylvania and West Virginia (WEST, 2023).

Potential construction and operation-related impacts to bats are extensively studied and quantified during a wind project's planning and permitting phases. State and federal endangered species regulations and environmental review guidelines are followed to evaluate and address potential impacts to bat species. To evaluate potential bat impacts, project developers typically conduct a number of environmental surveys, which may include:

- Consultation with federal and state regulatory agencies to assess the potential for the presence of listed species.
- Detailed habitat assessments that analyze tree class, cover, and species composition.
- An estimation of project-related forest loss to quantify potential impacts.
- Pre- and post-construction bat surveys (acoustic and/or mist-netting) to characterize the bat communities and determine presence or probable absence.
- An estimation of take from turbine-related deaths.

Based on the results of these pre-construction studies, projects may outline mitigation measures proposed to prevent, reduce, or otherwise address impacts to bats. Avoidance measures are typically developed during project planning phases and may include efforts to site turbines away from bat habitats, such as documented roost trees and hibernacula, and/or scheduling construction activities outside of the bats’ active season. Minimization measures include efforts to reduce impacts to forests, wetlands, or other sensitive habitat features and the development of operational curtailment plans to reduce bat fatalities from collisions with spinning turbine blades. Curtailment refers to increasing a turbine’s cut-in speed, or the speed at which a turbine starts operation. This can be accomplished by feathering the turbine blades or rotating the blades to alter aerodynamics and adjust how fast the rotors are spinning. Using curtailment to reduce bat fatalities has been the subject of extensive research for nearly two decades (Arnett et al., 2009;

Baerwald et al., 2009; Arnett et al., 2011; Arnett et al., 2013; Martin et al., 2017; Hayes et al., 2019), and because bats are more active at lower wind speeds, it has proven to be extremely effective.

Curtailment was first tested in Canada, where a study found a 50–70% reduction in fatalities by raising cut-in speeds to 5.5 m/s (Baerwald et al., 2009). A corresponding first study in the United States found a 44–92% reduction in bat fatalities (Arnett et al., 2009). Although the effectiveness of feathering turbine blades below various cut-in speeds differs among sites and years, recent review studies that compiled publicly available data from multiple wind energy facilities in North America have consistently found mortality reductions greater than 50% (Adams et al., 2021; Whitby et al., 2024). Curtailment can be applied throughout the active season for bats, during the biologically sensitive migration periods in spring and fall, or using more nuanced approaches, often called smart curtailment, which may include algorithm-based and activity- or acoustic-based curtailment. Because of its effectiveness, curtailment has been widely adopted as a BMP (ACP, 2015). Where "take" of a listed bat species is anticipated, compensatory mitigation measures are often proposed. Such efforts have included protection of known hibernacula through land conservation, protection of forested buffers around hibernacula, gating of cave entrances, protection of known roost trees or otherwise suitable habitat for bat species, purchase of credits from an approved bat mitigation bank whose geographical range service area includes the project, improving bat habitat through ecological restoration efforts (e.g., creation of snags via girdling, invasive species control, native plantings, creation of travel corridors etc.), and/or research that could benefit the species (e.g., investigating treatments of WNS and deployment of those treatments). Although proposed mitigation measures vary between projects, each must demonstrate that the efforts will more than compensate for project-related mortality.

As mentioned previously, if, after all feasible impact mitigation measures have been proposed, there remains risk of taking listed bat species, project developers can apply for an ITP from the USFWS. To apply for an ITP, project proponents must first develop an HCP that is approved by USWFS. In essence, HCPs describe project-related impacts; harm-reduction measures that would be employed to monitor, minimize, and mitigate take; and documentation of the funding available to support implementation of these measures.

In summary, the issue of turbine-related bat mortality has been intensively studied for decades. WEST's 2023 report shows that hundreds of examples of federally or privately sponsored mortality monitoring projects go back over two decades. Dozens of EAs, EISs, and HCPs can be reviewed through federal agency repositories, many of them drafted by federal agencies (i.e., BLM, 2005a, 2008, 2012, 2013a, 2020, 2024b; USDOE, 2012, 2014, 2015; USFWS, 2013, 2019a). Impact mitigation measures are widely employed and have been found to be effective at avoiding, minimizing, and/or compensating for turbine-related bat mortality. In addition, numerous guidance documents have been drafted by agencies such as USFWS to assist developers in reducing bat mortality and complying with federal regulations (USFWS 2019b, 2021c, 2022, 2024a, 2024b, 2024c, 2024d, 2024e, 2024f). Data gaps, refinements in analyses, and technological limitations are routinely assessed and proactively addressed through ongoing research (e.g., Voigt, 2016; Hein and Straw, 2021; Whitby et al., 2021; Maclaurin et al., 2022; Whitby et al., 2024) to ensure that impacts to bats are being mitigated to the maximum extent practicable.

3.2 Transportation Safety

- Route evaluation studies and road use agreements are used to safely manage construction traffic and ensure public roadways remain in good condition.

Existing agency review and approval mechanisms have been very successful in minimizing potential public safety risks from wind energy with respect to transportation systems. As part of the permitting process for proposed onshore wind energy facilities, multiple studies are typically completed to strategically minimize impacts to land-based transportation. State transportation permits must be obtained to allow for the regulated use of overweight/oversized delivery vehicles. Route evaluation studies determine the best delivery options for turbine components and other construction materials, considering constraints like bridge weight limits, overhead clearance, and turn radii. Road use and restoration agreements are executed with host municipalities so that developers are responsible for repairing local roads, should they be damaged by construction or maintenance activities, and often include a bond or other financial security. Traffic control plans are developed for any necessary temporary signage, lane closures, placement of temporary barriers, or traffic diversions.

These requirements apply to wind energy development on both private and public lands. For example, BMPs that are applicable to all wind energy projects on BLM lands include provisions specific to roads and ground transportation, including requirements for an access road siting and management plan, a construction transportation plan, a construction traffic management plan, and ongoing ground transportation planning during project operations (BLM, 2005b). Similarly, wind energy facilities on NFS lands require the preparation of plans to address:

- Transportation and traffic management, including the size, weight, origin, destination, unique handling requirements, and alternative transportation that may be necessary for turbine components, main assembly cranes, and other large equipment.
- Identification of any permits required for movement of these loads.
- Measures for minimizing hazards from increased truck traffic.
- Temporary traffic control measures (USFS, 2011).

3.3 Property Values

- Numerous peer-reviewed and government studies of property values near wind energy facilities have found little statistical evidence of real estate prices being affected by views of, or proximity to, turbines. Where effects have been detected in more populous counties, drops in home prices have been short-term and disappear a few years after the wind farm begins operations.

Numerous long-term studies of property value impacts from nearby wind energy facilities are available from the U.S. Department of Energy and others, with most finding little or no statistical evidence of prices being affected by either views of or proximity to wind facilities (Hoen et al., 2013; Vyn and McCullough, 2014; Hoen et al., 2015; Hoen and Atkinson-Palombo, 2016). A 2023 peer-reviewed study of nearly half a million transactions within 5 miles of wind projects in the United States found a short-term reduction in some home sale prices within 1 mile of wind turbines. However, this effect was only detected in more populous counties, where home prices were reduced after the announcement of wind energy development but returned to prior levels 3–5 years after wind farm operations began. No impact was found in less populous counties (Brunner et al., 2024). Another more recent peer-reviewed study examined data from more than 300 million home sales and 60,000 wind turbines in the United States from 1997 to 2020, and found similar results: a small, short-term drop in home value for residences with visibility of a wind turbine within 5 miles. The effect is most considerable for those residences closest to the wind turbines (i.e., less than 1 mile), is indistinguishable from zero for larger distances (i.e., greater than 5 miles), and disappear entirely within 7 years (Guo, et al., 2024).

3.4 Decommissioning

- Existing permitting regulations require that wind energy facility applicants provide decommissioning plans for agency review before permits are issued. In most cases, posting bonds or other financial securities to cover the cost of decommissioning is required prior to construction.

A decommissioning plan is typically required as part of the permitting process for modern onshore wind energy facilities. These plans must describe the process, notifications, disposal procedures, cost estimates, and decommissioning and site restoration timelines. Developers must provide financial securities prior to construction to ensure appropriate resources are available to local municipalities in the event that decommissioning is necessary. Such requirements are widespread for wind energy development on both private and public lands. For wind energy projects on private lands, these requirements are imposed as part of state or local permit conditions. In contrast, on federal lands, decommissioning terms are part of the permit granted by the host agency. For example, for wind energy projects on BLM lands, an agency-approved performance and reclamation bond must be provided before the BLM can authorize the commencement of ground-disturbing activities (BLM, 2025f).

3.5 Cultural Resources

- Existing permitting regulations require that wind energy facilities be constructed and operated in a manner that prioritizes consultation with stakeholders, minimizes potential impacts to archaeological sites, and mitigates for potential visual effects that could alter the integrity of historic properties.

Historic properties may include individual buildings, sites, monuments, objects, historic districts, landscapes, and traditional cultural places listed on the National Register of Historic Places, determined eligible for listing, or otherwise determined to be historically or culturally significant. As part of the permitting process for proposed onshore wind energy facilities, multiple site-specific studies are typically completed to evaluate a project's risk to cultural resources (i.e., archaeological sites and above-ground historic properties). Wind energy developments are subject to existing state and federal laws that regulate potential impacts to cultural resources, including Section 106 and 110(f) of the National Historic Preservation Act of 1966 and similar applicable state-level laws and standards. Consequently, careful consideration is given to the siting of wind energy facilities and individual turbines to minimize impacts on cultural resources.

Section 106 and 110(f) of the National Historic Preservation Act of 1966 prioritize consultation with relevant stakeholders who have a vested interest in cultural resources and/or historic properties in the vicinity of a given project. The lead federal agency is required to identify and engage with appropriate consulting parties, who may include State Historic Preservation Offices (SHPOs), Indian Nations, Tribal Historic Preservation Offices, regional or local historic preservation organizations, property owners, and interested members of the public. Consulting parties are engaged throughout a project's review, including identifying historic properties, determining effects, and developing appropriate mitigation efforts.

Cultural resources studies completed in support of wind energy projects typically identify an Area of Potential Effect (APE), which defines an appropriate study area to evaluate potential impacts to archaeological and above-ground historic resources. For wind energy facilities, the APE includes an Archaeological APE, defined as those areas where soil disturbance or direct physical impacts are proposed to occur during construction (potentially impacting below-ground archaeological resources), and an APE for Visual Effects, which includes those areas where a wind facility may be visible and affect the visual setting of above-ground historic properties and/or buildings. These potential effects, and the studies undertaken to evaluate them, are typically described in detailed cultural resources survey reports. These studies are prepared following applicable SHPO guidance, appended to the permitting application for a project, and reviewed by the lead permitting agency, applicable SHPO(s), and other identified consulting parties, which may include Indian Nations and other regional stakeholders.

3.5.1 Archaeological Resources

Permitting studies for onshore wind facilities often include archaeological surveys, which are conducted in accordance with applicable state guidelines or SHPO standards. Potential effects on a given archaeological site typically result from ground disturbance (via site clearing, grading, trenching, or excavation), which has the potential to adversely affect an archaeological resource's integrity, or the "ability of a property to convey its significance" (NPS, 1990). The goal of archaeological surveys is to identify archaeological sites within a proposed project's APE that may be impacted by facility construction or operation.

Archaeological surveys typically include stakeholder consultation, desktop research, historical context development, archaeological sensitivity modeling, pedestrian site walkover survey, shovel testing (or other subsurface sampling), remote sensing and geophysical technologies, and other appropriate methodologies. When sites are identified, further consultation with applicable parties (and potentially further archaeological investigation) ensues to evaluate the significance of identified sites, determine potential impacts or effects, and develop appropriate measures to avoid, minimize, or compensate for such impacts. Because wind energy projects typically have a very limited footprint (in terms of ground disturbance) and allow for flexibility in the siting of most project components, onshore wind energy projects typically avoid impacts (or have minimal effects) on archaeological resources.

3.5.2 Above-ground Historic Properties

Wind turbines are tall structures that are widely visible in most landscapes. A wind project's potential effect on a given above-ground historic property would be a change (resulting from the introduction of wind turbines or other project components) in the resource's visual setting. As it pertains to historic resources, setting is defined as "the physical environment of a historic property". It is one of seven aspects of a resource's integrity, which refers to the "ability of a property to convey its significance" (NPS, 1990). The potential effect resulting from the introduction of wind turbines into the visual setting for any historic or architecturally significant resource is dependent on several factors, including the existing character of the property's setting, the importance of the setting to the significance of the property, distance, visual dominance, orientation of views, and viewer context and activity.

The APE for Visual Effects for wind energy facilities is typically defined by the viewshed for the project, or the areas from which a project is theoretically visible. For a given project, the review of potential effects on historic resources typically includes stakeholder consultation, historical research, historical context development, reconnaissance, and intensive historic survey fieldwork, photography, extensive documentation, development of photorealistic visual simulations, and/or other visibility assessments.

In some instances, review of wind energy facilities has resulted in determinations by a lead federal agency, SHPO, or other consulting party that a project will have an adverse visual effect on above-ground historic properties. Wind projects have limited ability to avoid or minimize impacts, given the nature of the facilities and their siting criteria (i.e., very tall structures generally located at the highest locally available elevations). Therefore, an agreement to implement compensatory mitigation projects is often developed to offset the potential visual impacts to historic resources resulting from the introduction of renewable energy infrastructure into their visual setting. Compensatory mitigation projects may provide benefits to municipalities, communities, and agencies with ownership or interest in historic properties. Examples of compensatory mitigation projects include monetary contributions to historic property restoration causes, development of heritage tourism promotional materials, development of educational materials and lesson plans, the development of organizational capacity for historic organizations, sites, and museums, regional historic resources surveys, and nominations of individual properties or districts to the State/National Registers of Historic Places.

3.6 Visual Impacts

- Wind turbines are tall structures that are visible in many landscapes. However, visibility does not necessarily equate to an adverse visual impact.
- Existing permitting regulations require that visual impacts associated with wind energy facilities are evaluated and appropriately mitigated, as necessary.
- The FAA requires that wind turbines be painted white to ensure daytime visibility and that nighttime obstruction lighting be installed to ensure nighttime visibility and maintain aviation safety.

As with any energy project or other large structures, wind energy facilities are very visible and can change the visual character of their host communities. Visual impact analyses can accurately portray how a proposed wind energy facility would appear during construction and operation and are used to assess the potential effects on the landscape and viewers. Such analyses help local residents and staff at reviewing agencies better understand what a project might look like when completed (USDOE, 2025c) and how it may affect landscape character, scenic quality, and visually sensitive resources and receptors. The procedures widely accepted as standard visual impact methodology for proposed wind energy facilities are based on methodologies developed by various agencies, including the BLM (1980; 1984), the USFS (1995), the Federal Highway Administration (1981), and the U.S. Army Corps of Engineers (Smardon et al., 1988).

Requirements for evaluating visual impacts are widespread for wind energy development on both private and public lands. The ROD for the wind energy PEIS established the policy that the BLM must consider the visual resource values of the public lands proposed for wind energy development, consistent with established BLM Visual Resource Management (VRM) policies and guidance. This policy requires the BLM to work with the ROW applicant to incorporate visual design considerations into the planning and design of the project to minimize potential visual impacts and to meet the VRM objectives of the area (BLM, 2005b). The ROD also established BMPs that apply to all wind energy projects on BLM lands, with a number of requirements addressing visual resources, including the following:

- The public shall be involved and informed about the proposed wind energy facilities' visual site design elements. Possible approaches include conducting public forums for disseminating information, offering organized tours of operating wind projects, and using computer simulation and visualization techniques in public presentations.
- Turbine arrays and turbine design shall be integrated with the surrounding landscape. Design elements to be addressed include visual uniformity, use of tubular towers, proportion and color of turbines, non-reflective paints, and prohibition of commercial messages on turbines.
- Other site design elements shall be integrated with the surrounding landscape. Elements to address include minimizing the profile of the ancillary structures, burial of cables, prohibition of commercial symbols, and lighting. Regarding lighting, efforts shall be made to minimize the need for and amount of lighting on ancillary structures.
- Operators shall reduce visual impacts during construction by minimizing areas of surface disturbance, controlling erosion, using dust suppression techniques, and restoring exposed soils as closely as possible to their original contour and vegetation (BLM, 2005b).

Further guidance was issued in the 2013 *Best Management Practices for Reducing Visual Impacts of Renewable Energy Facilities on BLM-Administered Lands*. This publication includes BMPs for avoiding and reducing visual impacts associated with the energy generation components of a facility, such as wind turbines or solar energy collectors. Also, it includes many BMPs for reducing visual impacts associated with associated components, such as electric transmission lines, access roads, and ancillary structures. Unlike the BMPs in the ROD listed above, the measures discussed in this publication are not prescriptive, as not every BMP described is appropriate for every project or landscape. Some BMPs do not apply in all landscapes, and some site conditions might preclude the application of certain BMPs or render the BMPs ineffective. Suggested BMPs include:

- Using fewer, larger turbines to achieve desired power output rather than using a greater number of smaller turbines.
- Using non-reflective coatings on wind turbines and other facility components.
- Incorporating stakeholder input into the siting, design, and mitigation planning processes.
- Ensuring that qualified individuals conduct and review visual impact analyses and mitigation plans.
- Maintaining turbines and turbine sites to ensure they are clean, attractive, and operating efficiently.

The document concludes that "there are many highly effective visual BMPs that are not particularly expensive or difficult to implement, particularly if incorporated early in the development process; these include successful revegetation, recontouring to match existing terrain characteristics, or painting facility components to blend with the landscape background" (BLM, 2013b).

For wind energy projects on private lands, visual impact assessments are typically required as part of the state or local permit application. For example, in Oregon, wind energy facilities are permitted through the state Energy Facility Siting Council. Before the Council can issue a site certificate approving a proposed facility, it must find that the design, construction, and operation of the facility, taking into account mitigation, are not likely to result in significant adverse visual impacts to significant or important scenic resources. As per Oregon Administrative Rules 345-022-0080, the application for a site certificate must contain:

- An analysis of potential visual impacts of the proposed facility on significant or important scenic resources within the analysis area, and must include an inventory of scenic resources identified as significant or important in a land use management plan adopted by one or more local, tribal, state, regional, or federal government or agency applicable to lands within the analysis area for scenic resources, as well as a list of the land management plans reviewed.
- A map or maps showing the location of the identified scenic resources in relation to the site of the proposed facility.
- A description of the methodology the applicant used to identify and assess potential visual impacts to the scenic resources.

- Identification of potential visual impacts to the scenic resources identified, including but not limited to loss of vegetation or alteration of the landscape as a result of construction or operation, and visual impacts of facility structures, such as changes in landscape character or quality.
- An assessment of the significance of the visual impacts described under subsection.
- A description of the measures the applicant proposes to avoid, reduce, or otherwise mitigate any significant potential adverse visual impacts.
- The applicant's proposed monitoring program, if any, for impacts to scenic resources.

Similar requirements exist in other states, such as New York and Ohio.

Visibility of wind turbines is a critical component of aviation safety. Because of their height, the Federal Aviation Administration (FAA) requires wind turbines to be visible to ensure aviation safety. Required measures include painting all turbines white to ensure daytime visibility. In addition, the FAA requires the lighting of turbines with FAA L-864 aviation red flashing strobe lights, which provide pilots with the highest visibility. Some projects have sought to use Aviation detection lighting systems (ADLS) to minimize the visual effect of aviation lighting. ADLS are radar-based systems that activate turbine lights when an aircraft is approaching or descending near a wind project. FAA reviews and evaluates requests to use ADLS on a case-by-case basis for each wind turbine based on factors such as proximity to airports, low-altitude flight routes, military training areas, or other areas of significant aviation activity (ACP, 2022; FAA, 2024). Therefore, each project's efficacy in minimizing night lighting effects is evaluated relative to safety and defense considerations.

3.7 Shadow Flicker

- Existing permitting regulations require that wind energy facilities be operated in a manner that minimizes shadow flicker impacts to nearby residences and other sensitive receptors.
- Minimizing the potential occurrence of shadow flicker at residential receptors is an important siting consideration for wind energy projects.

Shadow flicker refers to the moving shadows that an operating wind turbine casts during the day when the turbine rotor is between the sun and an observer's position. Shadow flicker is most pronounced in northern latitudes during winter months because of the lower angle of the sun in the winter sky. However, it is possible to encounter shadow flicker anywhere for brief periods after sunrise and before sunset (BLM, 2005a). During intervals of sunshine, wind turbine generators will cast a shadow on surrounding areas as the rotor blades pass in front of the sun, and if these moving shadows pass over a window, they can cause a flickering effect. Shadow flicker can be perceived as annoyance or distraction by project neighbors; however, there is no scientific evidence to suggest that shadow flicker can cause adverse health effects (ACP, 2020; Hübner, et al., 2019; Ellenbogen, et al., 2012; McCunney, et al., 2014). Shadow flicker does not occur when fog or clouds obscure the sun, or when turbines are not operating. The distance between a wind turbine and a structure affects the intensity of the shadows cast by the blades, and therefore the intensity of flickering. Shadows cast close to a turbine will be more intense, distinct, and focused. This is because a greater proportion of the sun's disc is intermittently blocked by the turbine (BERR, 2009). Obstacles such as terrain, vegetation, and/or buildings occurring between structures and wind turbines may significantly reduce or eliminate shadow flicker effects. Shadow flicker effects are generally considered negligible at distances beyond roughly 10 rotor diameters (BERR, 2009; DECC, 2011; MADOER, 2011).

Many state and local jurisdictions, as well as the wind industry's model ordinance, mandate a threshold of 30 hours of shadow flicker exposure per year at neighboring residences, or approximately 0.3% of available daylight hours (ACP, 2024). For example, in New Yok State, as per the Regulations Implementing Article VIII of the Public Service Law, Chapter XI, Title 16 of NYCRR Part 1100, Section 1100-2.9, "Shadow Flicker shall be limited to thirty (30) hours per year at any non-participating residence, subject to verification using shadow prediction and operational controls at appropriate wind turbines." Siting applications for wind energy facilities reviewed by the New York Department of Public Service must include a "Visual Impacts Minimization and Mitigation Plan" that provides:

- A full year of hourly potential and realistic receptor-specific predicted flicker based on sunshine probabilities, operational projections, and facility design.

- A protocol for monitoring operational conditions and potential flicker exposure at the wind turbine locations.
- Details of the shadow detection and prevention technology that will be adopted for real-time meteorological monitoring and operational control of turbines.
- A schedule and protocol for temporary turbine shutdowns during periods that produce excessive flicker to meet required shadow flicker limits.
- Shielding or blocking measures (such as landscape plantings and window treatments) to be implemented to reduce shadow flicker at receptor locations that exceed the 30-hour annual limit, with approval by the resident (NYSDPS, 2024).

Shadow flicker impacts can be minimized with proper planning, which is accomplished using computer modeling programs, such as Wind PRO, that calculate the location and duration of shadow flicker based on site-specific data inputs and conservative assumptions. Site-specific data inputs include sunshine frequency and prevailing wind data for the site, digital elevation data, proposed turbine dimensions, and the location of the proposed turbines and nearby receptors. These models conservatively assume that wind conditions allow continuous turbine operation, and do not take into consideration daily or seasonal variation in sunlight intensity and duration or obstacles that block shadows (such as terrain, vegetation, and buildings). Shadow flicker models are commonly used as part of an iterative siting process early in project development. If high shadow flicker is predicted, the turbine layout can be modified to minimize or eliminate shadow flicker at residences or other sensitive receptors.

Other mitigation measures can be implemented if layout changes are insufficient to adequately reduce shadow flicker at a sensitive receptor. For example, landscape plantings can be installed between the wind turbine and windows to screen shadow flicker, or window treatments can be provided. Limited, targeted curtailment of specific turbines has also proven effective at reducing shadow flicker if other mitigation options are not available.

3.8 Noise

- Existing permitting regulations require that wind energy facilities be constructed and operated in a manner that minimizes noise impacts to nearby residences and other sensitive receptors.
- At the closest distance, turbines are typically sited from residences; the sound levels produced by operating turbines are generally less than those produced by a refrigerator, and one can have a conversation at normal volume directly underneath a turbine and elsewhere on a wind farm.

Operating wind turbines can create several types of sounds, including a mechanical hum produced by the generator and a "whooshing" noise produced by the blades moving through the air. The presence of wind turbine sounds can depend on atmospheric conditions, as well as a person's ability to perceive the sound, which varies based on site-specific topography and the presence of other nearby sources of sound. According to the USDOE, land-based wind turbines produce sounds that fall in the range of 35–45 decibels (dB) when heard from 984 feet (300 meters) away, which is the closest distance a wind turbine is typically placed to a home or other occupied building. This is less than the sound levels produced by other common noise sources, such as a typical refrigerator, which produces noise of approximately 50 dB, and average city car traffic, which is approximately 70 dB (USDOE, 2025d). The industry model ordinance recommends setbacks for siting turbines 2.1 × maximum blade-tip height from non-participating residences and 1.1 × maximum blade-tip height from participating residences (ACP, 2024). Such setbacks help to minimize potential noise levels at neighboring residences.

As part of the permitting process for proposed land-based wind energy facilities, site-specific studies are conducted to record and evaluate ambient pre-construction sound conditions, thereby establishing a baseline against which impacts can be determined. Computer modeling is then used to predict operational noise levels, based on inputs including meteorological data, terrain, the turbine layout, and the manufacturer's noise specifications for the proposed turbine. The noise model generates noise contours (i.e., predicted noise levels based on location) that can be mapped along with the location of sensitive receptors (such as residences, schools, and churches) to evaluate sound impacts. The predicted sound levels can then be compared to the baseline ambient levels. In some cases, existing ambient sound effectively masks the sounds generated by operating wind turbines. In other locations, where ambient noise levels are low, turbine noise may be more noticeable. The increase in sound above ambient levels is considered the measure of impact.

Requirements for evaluating noise impacts are widespread for wind energy development on both private and public lands. For example, BMPs that apply to all wind energy projects on BLM lands contain provisions specific to noise, including the following requirements:

- Proponents of a wind energy development project shall take measurements to assess the existing background noise levels at a given site and compare them with the anticipated noise levels associated with the proposed project.
- Noisy construction activities (including blasting) shall be limited to the least noise-sensitive times (i.e., daytime only between 7 a.m. and 10 p.m.) and on weekdays.

- All equipment should have sound-control devices that are no less effective than those provided with the original equipment. All construction equipment used shall be adequately muffled and maintained.
- All stationary construction equipment (i.e., compressors and generators) shall be located as far as practicable from nearby residences.
- If blasting or other noisy activities are required during the construction period, nearby residents shall be notified in advance (BLM, 2005b).

Many state and local jurisdictions require the same types of studies. For example, the Ohio Power Siting Board reviews permit applications for electric generation facilities, electric power transmission lines, and gas pipelines. Applications for all such facilities must include the following information, as specified under §4906-04-08(A)(3) of the Ohio Administrative Code (OAC):

- A description of anticipated noise from the construction, operation, and maintenance of the facility, including sound from blasting activities, operation of earth-moving equipment, pile driving, rock breaking, horizontal directional drilling, erecting structures, and truck traffic.
- A description of the cumulative operational noise levels at the property boundary for each adjacent non-participating parcel area under both day and nighttime operations.
- The operational noise level at each habitable residence, school, church, and other noise-sensitive receptor within one mile of the facility, under both day and nighttime operations.
- A description of equipment and procedures to mitigate the effects of noise emissions from the proposed facility during construction and operation, including limits on the time of day at which construction activities may occur.
- A pre-construction background noise study of the project area includes measurements taken under both day and nighttime conditions.

In addition, OAC §4906-04-09(E) outlines further noise-related requirements only applicable to renewable energy facilities, including that "The facility shall be operated so that its daytime and nighttime noise contributions do not result in noise levels at any non-participating sensitive receptor within one mile of the project boundary that exceed the greater of 40 dBA or the project area ambient daytime and nighttime average sound level (L_{50}) by five A-weighted decibels (dBA)."

3.9 Health Effects

- There is no evidence in peer-reviewed medical and public health literature of adverse health effects from wind turbines.
- Hundreds of thousands of people around the world live and work in the vicinity of wind turbines with no ill health effects.

Some residents living near wind energy facilities have reported adverse health effects, with symptoms such as tinnitus, headache, sleep disturbance, anxiety, and depression (Pierpont, 2009). These alleged health effects were attributed to vibration, low-frequency noise, or shadow flicker from nearby turbines. Such reports were largely anecdotal, with only small numbers of people reporting ill effects, while most people living near the same turbines experienced no symptoms. Also, the reported adverse effects are all common in the general population, and no evidence was presented showing that such symptoms occur more frequently in persons living near wind turbines than persons living far from wind turbines (Colby et al., 2009). Nevertheless, concerns about these reports resulted in the initialization of numerous more rigorous studies. The peer-reviewed scientific studies do show that some people are annoyed or stressed by wind turbines (Pederson and Waye, 2007; Bakker et al., 2012; Michaud et al., 2016a). Aside from annoyance, the resulting scientific consensus is clear: there is no evidence in the peer-reviewed medical and public health literature of adverse health effects from wind turbines (Kurpas et al., 2013; Michaud et al., 2016b).

Health Canada and Statistics Canada conducted a robust study of wind turbines and health, which is considered a "gold standard" study because it included both objective and subjective measures of health and included a large sample size. Study participants consisted of people living near operating wind turbines in Ontario and Prince Edward Island, which included homes located from 820 feet to 7 miles from one or more operating turbines. All homes within 1,968 feet (600 meters) of a wind turbine were included in the study, as were additional randomly selected residences up to 7 miles (11.2 kilometers) away. One adult from each residence was randomly selected to participate. The response rate was 78.9%, yielding a total sample size of 1,238 people. Outdoor sound levels from the wind turbines reached 46 dBA at the study homes during the study period. The subjective data were obtained through a questionnaire, which consisted of basic socio-demographics, modules on community noise and annoyance, health effects, lifestyle behaviors, and prevalent chronic illnesses. Validated psychometric scales were also incorporated to assess perceived stress, quality of life, and sleep disturbance. Objective measures for sleep latency, sleep efficiency, total sleep time, rate of awakening bouts, and wake duration after sleep onset were recorded using the wrist-worn Actiwatch2® from a subsample of 654 participants for a total of

3,772 sleep nights. In addition, blood pressure and heart rate data were obtained from 1,077 participants, and hair samples were obtained from 917 participants.

The results of this study were conclusive. Self-reported and objectively measured sleep outcomes consistently revealed no apparent pattern or statistically significant relationship to wind turbine sound levels (Michaud et al., 2016c). No correlation was found between exposure to wind turbine noise and cortisol concentrations in hair, blood pressure, resting heart rate, or perceived stress (Michaud et al., 2016d). Other self-reported health effects (e.g., migraines, tinnitus, dizziness, etc.) and quality of life were not related to wind turbine sound levels. Beyond annoyance, no association was found between living near wind turbines and adverse health impacts (Michaud et al., 2016b).

Studies have shown that annoyance related to wind turbines is generally related to personal factors, such as noise sensitivity and negative attitudes toward wind turbines, rather than any specific physical characteristics of wind turbine projects (Knopper et al., 2014; McCunney et al., 2014). One lengthy, detailed review of published studies on health effects attributed to wind energy facilities concluded that "… wind turbines in some places annoy a minority of those who live in their vicinity [and] annoyance can sometimes generate health problems consistent with those associated with stress and anxiety, but that there is no strong evidence of direct health effects from turbine exposure. Moreover, [the studies] conclude that pre-existing negative attitudes toward windfarms are generally stronger predictors of annoyance than distance from the turbines or recorded levels of noise" (Chapman and Crichton, 2017).

Many studies have shown that expectations can influence perceived health. When individuals expect a feature of their environment or medical treatment to produce illness or symptoms, then the individual tends to look for symptoms or signs of illness to confirm these negative expectations (Crichton et al, 2014a). In one experiment, participants were randomly divided into either positive or negative expectation groups and subsequently exposed to audible wind farm sound and infrasound. Prior to exposure, participants in the negative expectation group were shown video footage about adverse health effects said to be caused by infrasound produced by wind turbines. In contrast, participants in the positive expectation group were shown video footage that outlined the possible therapeutic effects of infrasound exposure. Reported symptoms and mood were strongly influenced by expectations. Participants in the negative expectation group experienced a significant increase in symptoms and a significant deterioration in mood, while participants in the positive expectation group reported a significant decrease in symptoms and a significant improvement in mood (Crichton et al., 2014b).

Epidemiological work has confirmed that health complaints have primarily been reported from areas that have received the most negative publicity about the harmful effects of turbines

(Crichton et al., 2014a). For example, a study reviewed all complaints made about 51 wind energy facilities operating in Australia from 1993 to 2012. Prior to 2009, health and noise complaints were rare, despite wind energy facilities having operated in Australia for many years. The study found that 90% of complainants made their first complaint after 2009, when anti-wind groups began to add health concerns to their wider opposition, and that 73% of complaints were associated with the six wind energy facilities most heavily targeted by opposition groups (Chapman et al., 2013).

More recent studies and reviews confirm the lack of adverse health effects from wind turbines. For example, based on existing research, the Ohio Department of Health (ODH) conducted a review to assess whether living near utility-scale wind energy facilities has the potential to cause harm to human health. This document was prepared at the request of the Ohio Power Siting Board, which reviews applications for wind energy facilities in the state of Ohio, and concluded, "There is no significant body of peer-reviewed, scientific evidence that clearly demonstrates a direct link between adverse physical health effects and exposures to noise (audible, LFN [low-frequency noise], or infrasound), visual phenomena (shadow flicker), or EMF [electromagnetic fields] associated with wind turbine projects" (ODH, 2022). Additional peer-reviewed studies have continued to show no compelling evidence supporting an association between wind turbine sound exposure and sleep disturbance (Hübner et al., 2019; Michaud et al., 2021; Liebich et al., 2022).

4.0 SOME CONSIDERATIONS REGARDING THE BENEFITS OF WIND ENERGY

- Wind energy provides many economic benefits, including lower electricity rates, direct and indirect employment, land lease payments, and local tax revenue.
- Wind energy generates electricity without harmful air emissions. By displacing electricity generated through the combustion of fossil fuels, wind energy provides health and climate benefits.

According to the U.S. Department of Energy (USDOE), "Wind energy offers many advantages, which explains why it's one of the fastest-growing energy sources in the world." These advantages include economic benefits and health and climate benefits associated with the displacement of air pollutants and greenhouse gases (USDOE, 2025a). The environmental and economic benefits of terrestrial wind energy have been described and documented in numerous policy documents, briefly summarized here to frame the potential environmental impacts of wind energy projects in context.

Electricity generated from wind energy has the benefit of not contributing to pollution or climate concerns. Further, electricity generated by wind energy facilities reduces carbon dioxide, nitrogen oxides, and sulfur dioxide emissions, providing public health and climate benefits. According to the USDOE, "The health and climate benefits of wind are larger than its grid-system value, and the combination of all three far exceeds the levelized cost of wind" (USDOE, 2024b). For example, a peer-reviewed study conducted by scientists at the Lawrence Berkeley National Laboratory concluded that between 2007 and 2015, electricity generation from wind power led to the avoidance of 2,900–12,200 premature human deaths (Millstein et al., 2017). These health and climate benefits also have economic value. Emissions avoided due to wind generation between 2007 and 2015 produced $28.4–107.9 billion (median value of $54 billion) in air-quality and public health benefits and $4.9–98.5 billion (median value of $29 billion) in climate benefits (Millstein et al., 2017).

Land-based, utility-scale wind turbines provide one of the lowest-priced energy sources available. Compared to the cost of energy associated with new electricity generation plants, wind energy projects are more economically competitive than gas, geothermal, coal, or nuclear facilities (USDOE, 2025a).

Wind power also creates jobs. According to the United States Energy and Employment Report 2024, there were approximately 130,000–150,000 people directly employed by the U.S. wind industry in 2023 (USDOE, 2024a, 2025a). According to the Occupational Outlook Handbook published by the U.S. Bureau of Labor Statistics, wind turbine service technician is the occupation expected to experience the fastest growth from 2023 to 2033 (USBLS, 2025). In addition to direct employment, wind energy also creates indirect job opportunities. For example, an influx of workers to an area can result in more spending at local hotels and restaurants, creating an increased demand for service industry workers (USDOE, 2025b).

Wind energy projects can be a source of significant revenue for the communities that host them, particularly rural communities. Utility-scale wind energy projects make payments to state and local governments through taxes or payments-in-lieu of taxes. In 2022, the U.S. wind energy industry paid approximately $1 billion in state and local taxes (USDOE, 2025b). These payments to municipalities can benefit all residents of the community. In addition, wind energy companies typically lease the land on which turbines are sited, creating an additional revenue stream for those landowners. Because wind turbines and associated infrastructure such as access roads have a small physical footprint, landowners commonly continue planting crops and grazing livestock under turbines. In 2022, wind energy projects on private land provided rural landowners approximately $935 million in land lease payments (USDOE, 2025b).

5.0 CONCLUSIONS

This report was prepared to summarize the siting and permitting processes for utility-scale wind energy projects, which have evolved over the past three decades and resulted in a robust body of documentation and research. As described herein, the permitting process for wind energy projects includes thorough NEPA reviews for all projects on federal lands. Additionally, many projects on private lands are also subject to NEPA, in addition to robust state and/or local review processes. As a result, the environmental impacts of constructing and operating land-based wind energy facilities are well documented. New studies of each facility's risks and impacts continue to add to this already extensive body of knowledge. Appropriate and demonstrably effective measures to avoid, minimize, and compensate for impacts have been thoroughly vetted and are implemented in all phases of wind energy facility development and operation. Wind energy provides many benefits that outweigh its limited impacts. In conclusion, this report has established the thoroughness and adequacy of existing environmental reviews, the clear understanding of the potential impacts of land-based wind energy, and the demonstrated ability to minimize and mitigate those potential effects.

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