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New York Wind Energy Guide for Local Decision Makers:

Community Considerations: Planning for Construction and Operations Impacts



NEW YORK
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NYSERDA



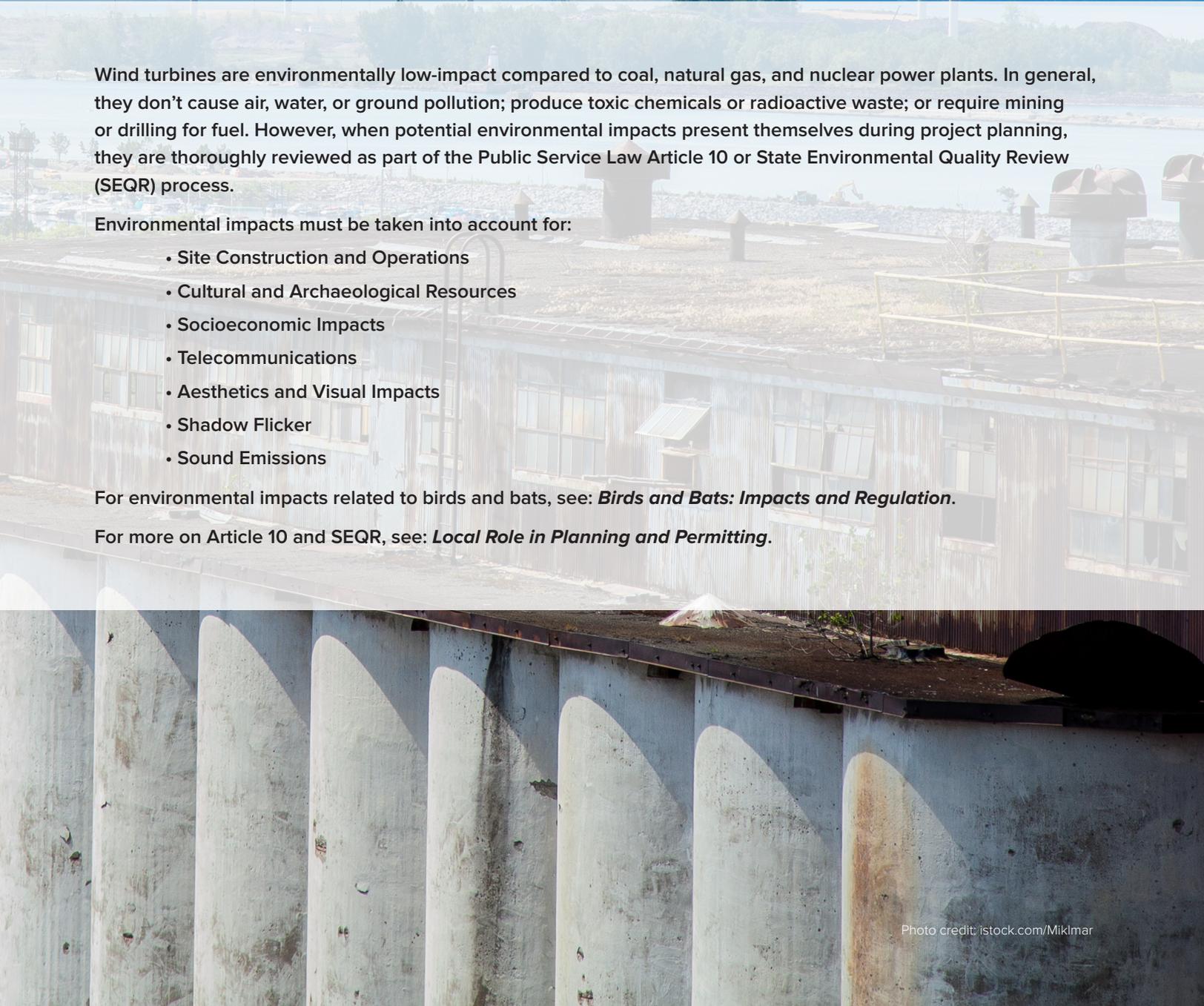
Wind turbines are environmentally low-impact compared to coal, natural gas, and nuclear power plants. In general, they don't cause air, water, or ground pollution; produce toxic chemicals or radioactive waste; or require mining or drilling for fuel. However, when potential environmental impacts present themselves during project planning, they are thoroughly reviewed as part of the Public Service Law Article 10 or State Environmental Quality Review (SEQR) process.

Environmental impacts must be taken into account for:

- Site Construction and Operations
- Cultural and Archaeological Resources
- Socioeconomic Impacts
- Telecommunications
- Aesthetics and Visual Impacts
- Shadow Flicker
- Sound Emissions

For environmental impacts related to birds and bats, see: *Birds and Bats: Impacts and Regulation*.

For more on Article 10 and SEQR, see: *Local Role in Planning and Permitting*.



Site Construction and Operations

Like any other major construction project, wind energy projects introduce the possibility of a variety of potentially harmful environmental impacts, many of which can be prevented or remediated. Once operating, wind project sites may also have environmental impacts. Wind projects are more complex than just the turbines themselves, and large wind farms will typically include a number of temporary and permanent components:

- Construction trailer, lay-down yard, and equipment staging
- Access roads to the turbines (temporary access may be wider than the permanent road that remains after construction)
- Public road improvements (allowing local roads to accommodate heavy construction equipment)
- Wind turbines (foundations, towers, turbines, and a temporary construction staging area)
- Interconnection between turbines (temporary clearing prior to the installation of, typically buried, electrical collection-system lines)
- Disposal areas for cleared vegetation, rock, and excess subsoil
- Substation design and placement
- Transmission line and associated access
- Permanent operations and maintenance facilities

To ensure responsible site construction, project developers should follow quality assurance standards that meet federal, State, and local environmental permit requirements.

Common Construction-Related Concerns

Some of the most common construction-related concerns are listed below. A construction quality-assurance plan should address all of these concerns.

- Are all construction activities properly approved by the appropriate agencies prior to the start of construction?
- Are construction activities and access occurring only in approved areas and along approved routes?
- Has the work area been properly defined, staked, and fenced prior to construction?
- Is regular notice of road closures or other traffic inconveniences being adequately communicated to police and emergency services, local residents, and others?
- Have all underground utilities been identified prior to ground disturbing activities?
- Are agricultural protection measures being appropriately implemented?
- Have wetland resources been properly delineated and staked prior to construction?
Do construction crews know to avoid access through or disposal of debris in wetlands?
- Have sediment and erosion control measures been installed? Are they properly maintained, especially after storm events?
- If there is to be blasting on site, have all appropriate landowner notifications been made?
- Is dust being properly controlled?

An environmental construction compliance program has several components, which enable projects to be built in compliance with environmental and land-use permits. Such permits typically cover landowner restrictions; sensitive resources (biological, geological, agricultural, and cultural); limits of clearing; proposed stream crossings; location of drainage features; layout of sediment and erosion control features, and post-construction restoration requirements.

The project developer ensures all environmental permit conditions are met, trains construction crew on permit requirements for environmental compliance, and employs an environmental inspector to help develop and implement procedures for compliance prior to and during the construction process, particularly in environmentally sensitive areas.

When the construction phase is completed, the developer will be responsible for restoring the project site according to the conditions of the environmental permits. Permits and bond-release provisions often require project proponents to conduct a multiyear post-construction monitoring program of restoration efforts.

Local and State regulatory agencies may wish to participate in Public Service Commission siting proceedings under Article 10 of the Public Service Law, where applicable, and should be familiar with the requirements of the project's various permits. Sometimes regulatory agencies retain their own environmental monitors to track the project's compliance status. As part of their permit conditions, project developers may be required to submit reports based on the environmental inspectors' daily logs. These reports may be developed weekly, monthly, or quarterly, and submitted to the federal, State, and local agencies with permit oversight. Some regulatory agencies conduct a regular weekly, monthly, or quarterly compliance assessment at project sites. In addition, compliance tours can be periodically arranged for local, State, and federal officials.

Impacts on Agriculture

Generally, wind energy projects are compatible with agricultural land uses and may help farmers who lease land to wind developers preserve their farms by providing them a supplemental income. Because wind turbines physically occupy only a small fraction of the land, most of the leased land remains available for crops and grazing. However, impacts to the agricultural resources can occur during wind project construction.



Photo credit: istock.com/Guliyev

Two types of agricultural impact can result from the construction of wind energy projects on agricultural land:

- Permanent loss of productive land as a result of the installation of access roads, turbine towers, and interconnection facilities
- Damage to soil resources and a loss of crops in areas disturbed during construction

Both of these impacts can be minimized with proper planning and communication.

Properly siting access roads and towers can significantly reduce the amount of land permanently lost from agricultural production. Generally, building roads and tower sites along the edge of fields results in the least amount of productive land being permanently lost.

Loss of productive farmland can occur at the point of connection between the wind energy project and the electric transmission line. Good communication is needed between the New York State Department of Agriculture and Markets (DAM), the project developer, the landowner, and the utility company concerning the transmission line interconnection. All parties need to fully understand the type and location of all facilities required for the interconnection.

Another concern is the potential for permanent damage to the soil. Since the depth of the topsoil layer is generally quite shallow in New York, it is critical to protect it. Topsoil should be stripped from any areas disturbed by construction—access roads, tower sites, and any other areas where excavation is necessary—and stockpiled. Following construction, the topsoil must be graded to the original depth. Project developers should negotiate adequate work space with landowners to allow for proper topsoil protection. When properly coordinated, farmers can successfully plant crops in close proximity to access roads and towers once the project is complete.

Wind farm construction may cause compaction to the topsoil and subsoil layers, which, if not properly mitigated, can reduce crop production for a number of years. Deep soil tillage in agricultural areas is recommended during restoration. On average, approximately 3.5 acres per megawatt (MW) are temporarily disturbed during construction. Of that amount, about 1 acre/MW is used permanently by the project during operation (Union of Concerned Scientists, 2013). The remainder is used for staging, temporary placement of the rotor and tower sections, and the assembly work area. These areas should be subject to soil protections as appropriate to soil characteristics.

Many of the soils in the areas where wind energy projects have been constructed or are proposed are shallow to bedrock or have a high concentration of rock in the subsoil. Extensive excavation in these types of soils can result in a higher-than-normal concentration of rock in the upper subsoil and topsoil layer. If not properly removed or used as appropriate for other project needs (e.g., foundation backfill, access road cover), this rock concentration can create difficulties for the farm operator.

Traffic and Road Conditions

Wind project construction results in a short-term increase in the number and size of tractor trailers present on rural roadways. Like any large construction project, there are many deliveries of supplies, tools, and construction materials, including cement for foundations and gravel for access roads. Transportation of tower sections, nacelles, blades, and large-capacity cranes requires multiple deliveries using specialized transport vehicles.

The increased truck traffic combined with the increased loading on the roads is a concern for transportation departments responsible for road maintenance and repair. Wind energy project developers recognize that the increased traffic may cause damage to roadways and usually include provisions for the turbine supplier and contractors to be responsible for any necessary road repairs.

Town governments, in conjunction with the project developer, should document local road conditions in the vicinity of the project prior to construction. Project developers should be required to restore any road damage to the documented preconstruction conditions (or better).

Sometimes roads must be reinforced or widened to accommodate oversized trailers and trucks. These changes are permanent. While some residents welcome the upgrades, others may object, fearing an increase in traffic or traffic speeds after construction is completed.

Erosion and Sediment Control

Stormwater runoff during construction can be a significant issue, and both state and local governments have codes for addressing it. During construction, as soils are disturbed, stormwater runoff may carry away sediment and other pollutants to surface waters.

Approaches to prevent or minimize soil erosion for wind energy projects are similar to requirements for other forms of construction projects. Road, building, and foundation construction are the principal wind project construction activities of concern. The potential for soil erosion at a wind project is examined during the permitting process. Any project that results in the disturbance of one or more acres of land (or 5,000 square feet in the New York City East of Hudson watershed) must seek authorization under the State Pollutant Discharge Elimination System (SPDES) General Permit for Stormwater Discharges from Construction Activity prior to beginning construction. In addition, the local municipality may also have review authority of the erosion and sediment controls under the SPDES General Permit for Stormwater Discharges from Municipal Separate Storm Sewer Systems (MS4s). Design professionals should refer to the New York State Standards and Specifications for Erosion and Sediment Control for the selection and design of erosion and sediment controls to be used for the project. The erosion and sediment controls must be identified in the Stormwater Pollution Prevention Plan (SWPPP) required by the Construction General Permit.

Drainage and Post-Construction Stormwater Runoff

Natural surface and subsurface drainage patterns can change as a result of final site grading and construction of permanent impervious cover, such as permanent gravel access roads and support buildings. Stormwater runoff impacts need to be considered during the planning/design phases of the project and properly addressed by post-construction stormwater management controls designed in accordance with the SPDES General Permit for Stormwater Discharges from Construction Activity and the New York State Stormwater Management Design Manual. The post-construction controls to be used for the project must be identified in the SWPPP required by the Construction General Permit.

An SWPPP must be filed as part of Article 10 or SEQR review; however, authorization for implementation of the SWPPP is granted under the SPDES Stormwater General Permit (described above) separately from the Article 10 certification process.

Wetlands and Stream Crossings

If a part of the project (e.g., access road, transmission line, or turbine) is located in or adjacent to a wetland or will disturb the bed or banks of a stream, river or other waterbody, requirements for compliance with applicable regulations will be incorporated into the Article 10 review and certification process. These regulations may include: Clean Water Act Section 401 Water Quality Certification (WQC); ECL Article 15, Protection of Waters; and ECL Article 24, Freshwater Wetlands and associated State regulations (NYCRR Parts 608 and 663). If the project will have a generating capacity of less than 25 MW, the developer must apply for approval of the referenced permits from the New York State Department of Environmental Conservation (DEC). Impacts to federally delineated wetlands require approval from the U.S. Army Corp of Engineers.

The DEC maintains information about the [Protection of Waters](#) and [Freshwater Wetlands Permit](#) Program. The following agencies are also involved in protecting freshwater wetland and stream resources and may be involved in issuing permits associated with impacts to those resources:

- US Army Corps of Engineers
- NYS Office of General Services
- Local governments
- NYS Department of State
- Adirondack Park Agency

These permit programs define the allowed work in a particular location, as well as any required mitigation measures. Wetlands are typically identified by field delineation early in the project development process and developers make significant efforts to avoid disturbing these areas. Impacts to wetlands are assessed prior to project construction. Both temporary and permanent impacts to wetlands and waters of the U.S. are assessed and appropriate permitting is obtained depending on the extent of calculated impacts, including mitigation for those that are unavoidable.

Solid and Hazardous Waste

As a part of permitting review, any solid or hazardous waste from construction or operation of the wind energy project must be addressed. Waste from wind energy projects primarily consists of general solid waste associated with the shop office, packaging material from equipment and supply shipments, spent lubricants, and small components that have failed. It also includes hazardous wastes, such as solvents used for cleaning turbine parts. Project operations and maintenance buildings have conditions typically found within automobile or boat repair facilities. Leaks of hydraulic fluids or lubrication oils from components within the nacelles or shop handling of lubricants represent the most common places for accidental releases of hazardous material into the environment. All projects are required to handle and store lubricants in accordance with local, State, and federal requirements.

Minor equipment leaks can occur with turbines, pad mount transformers and the main power transformer, which all contain oil lubricants. Pad mount transformers and main power transformers will have spill control countermeasures in place as well as a hazardous material handling plan to address spills as they occur, as required by the DEC. Occasionally, small amounts of lubricant can leak from a turbine nacelle. The amount of material that can potentially be released, however, is less than the amount regulated by environmental agencies and rarely poses an environmental concern because the materials don't usually extend beyond the turbine components.

The use of hazardous materials is typically minimal during the operation of a wind energy facility, which makes complying with solid and hazardous waste permit requirements relatively straightforward. Solid waste is typically managed through a solid waste removal service contract. Lubricant suppliers have established programs for collecting waste lubricants and oils generated during routine maintenance activities, such as gearbox or hydraulic station oil changes, and large components that are replaced can be returned to the manufacturer for refurbishment. These programs allow developers to comply with requirements and maintain the health of the environment.

Additional Resources for Site Construction and Operations

- [DEC: Stormwater Management Design Manual](#)
- [DEC: Stormwater Permit for Construction Activity](#)
- [DEC: New York State Standards and Specifications for Erosion and Sediment Control \(Blue Book\)](#)
- [DEC: Stormwater Management Guidance Manual for Local Officials](#)
- [NREL: Report on Land Use Requirements of Wind Power Plants](#)
- [DEC: Guidelines for Agricultural Mitigation for Wind Power Projects](#)

Cultural and Archeological Resources

Historic, cultural, and archeological surveys are typically conducted as part of the environmental assessment for a proposed project. Because wind projects include vegetation clearance, disturbance of ground surface, excavation below the ground surface, and aesthetic impacts, they have the potential to affect archaeological and historic resources that may be present in the area. Negatively impacting a historic site does not necessarily automatically halt a project; instead, mitigation or offset measures may be considered before determining whether a project goes forward.

Federal and New York State preservation legislation includes the following:

- **National Historic Preservation Act 1966, Section 106.** If a project uses federal funds or requires federal approval or permitting, the involved federal agencies consult with the State Historic Preservation Office (SHPO), which is housed within the State Office of Parks, Recreation and Historic Preservation, regarding efforts to identify and manage historic and cultural resources within the area of potential impact. Sometimes the recipient of federal funds will be required to consult with the SHPO on behalf of the federal agency, although this does not remove the federal agency from ultimate Section 106 compliance responsibility.
- **New York State Historic Preservation Act of 1980, Section 14.09.** State agencies are required to consult with the State Office of Parks, Recreation and Historic Preservation for undertakings that could impact historical and archeological resources that are listed or eligible for listing on the State Register of Historic Places. Undertakings by a State agency include funding, approval, and/or physical activity conducted by the State agency.
- **SEQR, Article 8.** This establishes a set of uniform procedures by which all state, county, and local governmental agencies incorporate consideration of environmental impacts into their planning, review, and decision-making processes. Historic and archeological resources are components of the environment and must be assessed during the SEQR process, or during Article 10 review.
- **New York State Public Service Law Section 1001.20.** This section of the regulations implementing Article 10 of the Public Service Law also identifies a process for identifying and addressing potential impacts on cultural resources.

Cultural and Archeological Surveys

Archeological surveys, which contain cultural surveys, are often needed when a project involves ground disturbance in areas known to contain archeological sites or have conditions favorable to finding such sites. Many wind energy project developers conduct cultural, historic, and archeological resource surveys as part of their environmental assessment. Surveys in New York State are conducted in accordance with the federal and State legislation listed above. If historic or archeological resources are found in the survey area, mitigation plans will be developed to preserve those areas.

The New York Archeological Council's [Cultural Resource Standards Handbook](#) assists nonarcheologists in understanding the professional standards for cultural resource investigations.



The SHPO does not maintain a list of archeological consultants, but has developed [guidelines](#) to help select a consultant to conduct a survey.

More information can be found through the following agencies and organizations:

- DEC
- Society for American Archeology
- National Trust for Historic Preservation
- Advisory Council on Historic Preservation
- New York Archeological Council
- New York State Museum
- US Army Corp of Engineers
- New York State Office of Parks, Recreation and Historic Preservation

Additional Cultural and Archeological Resources

- [SHPO: How to Choose a Cultural Resource Consultant](#)
- [SHPO: Geographic Information System \(GIS\) for Archeological and National Register](#)
- [AWWI: Landscape Assessment Tool \(LAT\)](#)
- [NYS: Orthos Online](#)

Socioeconomic Impacts

Development of a wind power project can have socioeconomic impacts on a community or region. The local workforce; infrastructure (e.g., water, sewage, waste removal, traffic/roads, housing); emergency personnel and systems, and schools may be affected. The extent of potential impacts depends on the scope of the industry and the project.

Examples of socioeconomic impacts include:

- Temporary or permanent job creation increasing demand for short-term housing
- Increased demand for municipal and emergency services (police, fire, medical care)
- Increased enrollment in local school system

Telecommunications

Construction of wind turbines and other structures may impact microwave communications, point to point, off-air television reception, RADAR, land mobile radio (LMR), cellular and PCS telephones, AM radio coverage, and amateur radio operations. The potential impacts on telecommunications can be studied during development of a project and mitigated, when necessary.

The operation of wind turbines can interfere with all of the above listed modes of communication. Remedies vary based on the severity of the impact, the modes impacted, and when the impact is discovered (preconstruction versus post-construction). Developers are aware and often provide community solutions, such as turbine relocation; placement of repeater antennas for LMR and base station antennas for cellular and PCS service; and offering alternatives to over-the-air television, like cable.

Aesthetics and Visual Impacts

Aesthetics and visual impacts are among the greatest concerns raised about proposed wind farms. Because wind resources in the Northeast tend to be best at high elevations and near large bodies of water, turbines can sometimes be visible for long distances and may alter scenic vistas. Therefore, it's important to consider ways to minimize and mitigate unavoidable adverse aesthetic and visual impacts during the preconstruction planning and permitting process.

Developers typically perform a visual impact analysis to quantify the potential visual impact of a proposed project. The analysis contains the following steps:

- Determine turbine locations and heights
- Determine the viewshed
- Identify key viewpoints
- Assess existing conditions
- Document project changes
- Analyze changes
- Develop mitigation where needed

Community concerns about visual impacts can be addressed by a project development process that includes:

- Open, early, and frequent communication
- Proactive outreach to educate and involve the community
- Continued support of public involvement throughout the process
- A final project design that addresses visual impacts through turbine location, spacing, and setbacks
- A financially beneficial arrangement for the community

These steps will generally be taken as part of the initial site-selection process. The zone of visual influence, or viewshed, is determined based on the existing environment and land uses. Key points within this viewshed are then determined by field inspection and discussions with local officials or stakeholders. These key viewshed points may include historic monuments or markers, scenic views, local landmarks, high-traffic routes, dwellings adjacent to the project, schools, sports fields, recreation areas, or business districts.

The process of assessing and mitigating visual impacts for wind turbines is the same as for any other highly visible structure, such as cell phone, radio, and television transmission towers. The following is a brief summary of the responsibilities of the applicant and permitting parties as defined by DEC, as well as the tools available when considering visual impacts. For complete information, refer to DEC Program Policy [Assessing and Mitigating Visual Impacts](#). Project developers generally provide all the information necessary for the host communities to understand what is being proposed; where it's being proposed; and what is being done to avoid, minimize, and mitigate visual impacts of the project.

The community should review the information provided by the developer and ensure that project impacts have been minimized to the maximum extent possible consistent with social, economic, and other essential considerations.

Influences on Visual Impact

Visual impacts vary from different viewpoints surrounding a project site. In areas with hilly terrain, the surrounding topography can hide turbine views from many locations. Turbines may also be more visible during different lighting conditions and during winter when surrounding trees are bare.

Turbine spacing can also have an impact on the aesthetics of a wind project. Spacing between turbines is primarily determined to optimize the energy output, but topography can also dictate turbine spacing. Sufficient space between turbines is necessary to optimize winds and reduce turbine-to-turbine turbulence (which could affect long-term turbine life). The use of larger turbines can reduce visual impact because fewer turbines are used and the space between them is greater.

The color of the turbines can also influence the magnitude of visual impacts. Local ordinances may require that nonreflective, unobtrusive colors be used to paint the tower and blades. Most wind turbines are painted either a light gray or off-white to minimize contrast against the sky when viewed from the ground, yet remain visible to pilots when viewed from the air.

Wind turbine visual impacts may include lighting. Federal Aviation Administration (FAA) requirements may include strobe, red flashing, or steady red lights. Depending on the lighting requirements, a project's nighttime visual impact may be greater than the daytime impact.

Uniformity of color, structure types, and surface finishes can mitigate the visual impact. Local ordinances sometimes specify uniformity requirements.

Visualization Modeling

Modern software can digitally simulate the view of a wind energy project from a variety of locations and in different light conditions. Such software is used prior to construction, during the design and permitting phase of development. This tool helps communities understand the visual impact and helps project developers identify areas that may need a mitigation plan. In areas with differing seasonal vegetation and lighting, such as New York State, it could be valuable to see summer and winter photo simulations of the proposed area. In addition, topographic maps can be incorporated into the software to develop a map overlay that estimates the number of turbines visible from any location within a region. Communities can request submittal of visualization maps and simulated project views to help assess the impacts.

Visualization modeling tools help communities understand how turbines would look to the unaided eye in a landscape. Photos are taken from populated spots, such as a shop, residence, or school, and from locations that have been identified by concerned citizens. To model the maximum impact, pictures are taken on a clear day. The time is recorded so the shading of the turbines and surrounding landscapes can be modeled accurately.

Visualization programs contain digital pictures of most major manufacturers' turbines, so an accurate picture can be developed of the turbines planned for the particular site. Figure 1 shows a simulation as compared to the same view once the turbines were constructed.

Several other methods of evaluating the visual impact of a project can be used. For example, a developer may float a large balloon to help assess visibility at the proposed tower height and location.



Figure 1
Wind farm simulation (upper) and photograph (lower).

(Source: EDR)

Mitigation Strategies

Once visual impacts have been quantified, mitigation techniques can be employed. The potential changes to the viewshed at key points are documented through visualization modeling and then analyzed. The analysis should provide answers to the following questions:

- To what extent is the project or specific turbines visible?
- When is the project or turbine visible (season or time of day)?
- Who sees the project or turbines and under what circumstances (season, light conditions, or during what activities)?
- To what extent does the visibility of the project alter the character and quality of the viewshed?
- What is the relationship of visual impacts to the policies and values in that location?

Questions like these attempt to quantify what often is a qualitative problem. For example, the project may be visible along a stretch of road, but the impact of that visibility depends on the surrounding environment and land uses (e.g., if the road is a scenic byway or the view is already dotted with homes, business, or other structures). It also depends on the length of time the project is visible (e.g., as the viewer travels in a car), and at what time the project is visible (e.g., only visible on sunny to partly cloudy days but not at night, or the turbines are visible all day and the required FAA lights are seen at night). Understanding impacts at this level helps quantify the potential impact on the community and helps developers create a project layout that is sensitive to these issues yet optimizes energy production.

The following is a list of mitigation strategies for wind energy facilities:

Downsizing. Downsizing or eliminating certain turbines may significantly reduce visual impacts. A project developer may be encouraged by the community to eliminate turbines with the greatest visual impact. However, tower sites with greater visual impact may be more economically productive. Thus, downsizing mitigation strategies are most successful when benefits exceed costs (in reduced income) to project developers.

Relocation. Project components with the greatest visual impact may be moved to other locations of less impact, where the screening effects of topography and vegetation may be taken advantage of. As with downsizing, proposed relocation may encounter a similar tradeoff of productivity vs. visual impact.

Lighting. Minimize off-site lighting, glare, and light pollution. However, FAA lighting criteria must be met. Some projects employ a radar-based detection system that turns lighting on only at the approach of airplanes.

Nonspecular materials. For overhead electric transmission facilities, cables that do not shine should be employed.

Screening. Visual barriers, like trees, earthen grassy berms (with or without trees or shrubs), or fences, may be employed in suitable locations.

Camouflage. Utility substations are usually screened using landscape architectural treatments, such as coniferous shrubs and trees. The substations can also be designed to blend in with the background.

Offsets. If negative impacts cannot be acceptably minimized, offsets can be employed (e.g., removing an existing chronic eyesore within the project viewshed).

Additional Resources for Aesthetics and Visual Impacts

- [DEC: Assessing and Mitigating Visual Impacts](#)
- [Clean Energy States Alliance: Visual Impact Assessment Process for Wind Energy Projects](#)
- [Macalaster College: Visual Impact Assessment](#)

Shadow Flicker

Shadow flicker can occur when the blades of the wind turbine cast a moving shadow on a residence or other structure within 1,400 m of a turbine (DPH, 2012). The pulsating light effect caused by the frequent movement of the shadows across a window may be unpleasant for the occupants. Shadow flicker is most likely to occur at sunrise or sunset, when shadows are cast over the longest distance. Factors that determine how often a wind turbine will cast a shadow on a residence or other structure are unique to a given project site, and include: height of turbine, length of turbine blades, site topography and distance between turbine and structure, season and time of day, wind direction and speed, and cloud cover.

Some residents living in close proximity to turbines have experienced occasions when shadow flicker occurs and have reported experiencing headaches and dizziness (CLF Ventures, 2011). Some residents also raise complaints because the moving shadows are bothersome to them. Concerns have been raised that flickering shadows could trigger epileptic seizures. However, studies have shown flicker-induced seizures are highly improbable, because the frequency of blade rotation on utility-scale turbines is significantly lower than the flashing frequency that could trigger seizures (Epilepsy Society, 2012). No case of a seizure caused by shadow flicker from a wind turbine has been documented to date.

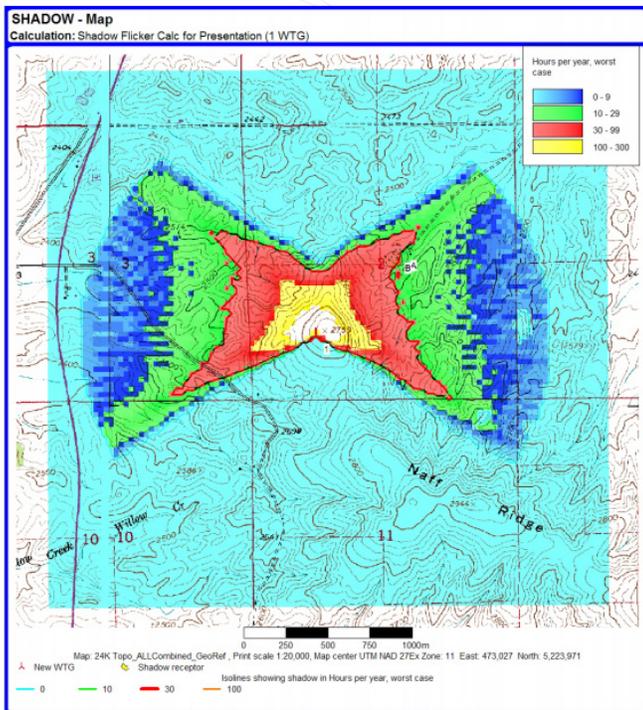


Figure 2

Modeled Shadow Flicker Map

(Source: ©2017 CH2M. Used with Permission.)

There is no conclusive scientific evidence that indicates shadow flicker from industrial wind turbines causes negative health effects, although it can be annoying to nearby residents (DPH, 2012). For this reason, it's important to study and mitigate shadow flicker when siting and designing turbines.

The occurrence of shadow flicker is easily calculated, and computer models can be used to determine the appropriate setbacks necessary to minimize impacts. When proper planning and mitigation strategies are implemented during the project design process, the occurrence of shadow flicker can be greatly minimized or avoided entirely.

Visualization models can calculate the shadow zones or flicker zones around wind turbines during different times of the day and during different seasons to calculate the affected areas. Figure 2 is an example shadow flicker map. The colored areas indicate how many hours per year each location may experience the shadow flicker effect. The maps will vary for each specific site and are mainly influenced by topography of the land and dimensions of the turbine. This map shows the “worst case” scenario, or the maximum amount of shadow flicker that could possibly occur in each area. The actual amount of shadow flicker that a location would experience is also determined by operational hours, wind direction, and cloud cover, all of which lower the expected total hours of flicker effects (Priestley, 2011).

There are no specific federal or New York State regulations regarding shadow flicker from wind turbines. State and local rules in other parts of the country vary, but tend to be ambiguous and lacking quantitative requirements. Some require that developers make “reasonable efforts” to minimize flicker on neighboring properties, while others require that shadow flicker projections or estimates accompany applications (F.Oteri, 2008). Without binding regulations, some states have published guidance or model ordinances that address shadow flicker. Some local governments specify a setback requirement to reduce shadow flicker or specifically limit the number of hours per year shadow flicker is permitted to occur at nearby residences. When specific numbers are mentioned, the standard limit for shadow flicker on occupied buildings is set at 30 hours per year (Lampeter, 2011). Other local governments require studies on shadow flicker, but lack strict guidelines for mitigation techniques. For example, the [Town of Chautauqua code](#) requires a study to “identify areas where shadow flicker may interfere with residences and describe measures that shall be taken to eliminate or mitigate the problems.”

Additional Resources for Shadow Flicker

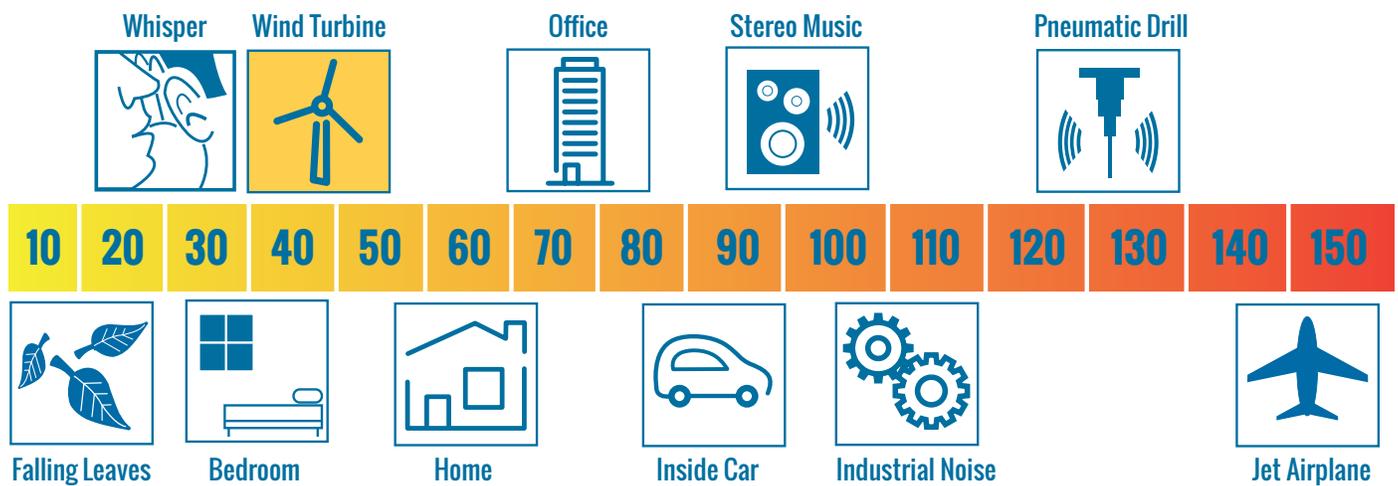
- [MA Wind Working Group: Evaluating Shadow Flicker in the Current Regulatory Environment](#)
- [MA Wind Working Group: The European View and Practical Mitigation Methods](#)



Sound Emissions

Wind turbines produce sound when they operate. Communities, regulators, and the developers of production facilities of all types have been dealing with the impacts of man-made sound on humans for decades. As wind projects increase in number, the sound emissions from wind turbines are an often-cited concern during the siting and permitting process. Because of the unique characteristics of wind turbine sound, communities, local decision makers, and residents have questions about the sound a wind project makes, sound limits wind projects have, ways to reduce exposure to the sound, and whether sound emissions from wind turbines can cause adverse health impacts.

The illustration below shows the relative decibel (dB) levels of common sources of sound. Typically, an operating wind energy project at a distance of 400 meters (1,312 feet) emits sounds at 40 dB(A)—a level comparable to a kitchen refrigerator or a moderately quiet room.



Brief Background on Acoustics

The field of acoustics provides the parameters by which wind sound is measured. There are several qualities to sound that, in combination, determine whether sound is audible, tolerable, annoying, or harmful. These components of sound are described briefly below. For more background on acoustics, please see the resources listed at the end of this section.

Sound Pressure. The loudness of sound is most typically quantified according to the relative atmospheric pressure using the decibel (dB) scale. This scale is logarithmic and quantifies sound from the entire range of audible frequencies. A-weighting, noted as dB(A) is the most common method of expressing sound pressure, as it takes human sensitivities to certain frequencies into account. Importantly, sound pressure varies by the distance between the source of sound and the receptor.

Frequency. The pitch of sound comes from a “repeating cycle of compressed and expanded air. The frequency of the sound is the number of times per second, Hertz (Hz), that the cycle of sound transmission repeats. Sound at a single frequency is called a tone while sound that is a combination of many frequencies is called broadband.” (DPH, 2012). “Higher frequencies tend to be reduced more indoors and with increasing distance. Lower frequencies are more likely to be transmitted indoors” (Council of Canadian Academies, 2015).

Amplitude. The height of the sound wave is described in terms of its amplitude. Sounds with greater amplitude will produce greater dB changes (changes in atmospheric pressure from high to low) (Hass, 2003).

Amplitude Modulation. When the height of a sound wave varies, the sound pressure it produces also varies from quieter to louder back to quieter.

Low-Frequency Sound. Low-frequency sounds have fluctuating cycles that occur within a range of 10 to 200 Hz. The range of audible sound goes up to 20,000 Hz. “The sound pressure level of low-frequency sounds declines less with distance than the level of high frequencies” (Council of Canadian Academies, 2015).

Infra-Sound. The term infra-sound describes sounds with a frequency below 20 Hz. Examples of man-made sources of infra-sound include sonic booms, explosions, machinery, diesel trucks, and subwoofer speakers. There are also many natural sources of infra-sound, such as surf and wind. Infra-sound can be heard and felt at relatively high amplitudes over 100 dB to 110 dB (DPH, 2012). Infra-sound and low-frequency sound are distinct terms.

Sound, Noise, and Subjectivity of Perception

Unwanted sound is considered noise. Since the response to noise varies by individual perception and is a subjective matter, it’s difficult to define objectionable noise. One person may regard a wind turbine as noisy and disruptive while another person may not, even under the same conditions. So, while sound pressure levels can be measured and compared to regulatory limits, the individual perception of that sound pressure level cannot. Because determination of sounds as noise is a subjective matter, control and mitigation of concerns is difficult.

Components of Wind Turbine Sound Emissions

Wind turbines produce two types of sounds: mechanical and aerodynamic. Mechanical sounds come from the operation of turbine components, including the gearbox, the generator, drives, and fans. Mechanical noise is typically not a major factor due to additions of soundproofing, insulation, and use of direct-drive technology. Generally, aerodynamic sound is the subject of regulation and concern. The majority of aerodynamic sound is caused by the flow of air over the surface of the wind turbine blades, especially at the blade tip. Aerodynamic sound transmits (or propagates) differently for every wind farm.

Depending on the size and configuration, turbines may emit up to five types of sounds during operation.

- **Tonal** sounds emanate at discrete frequencies (e.g., meshing gears).
- **Broadband** (multitonal) sounds characterized by a continuous distribution of sound pressure with frequencies over 100 Hz.
- **Low-frequency** sounds range from 20 to 160 Hz.
- **Amplitude-modulated** sounds are short acoustic impulses (e.g., swishing or thumping sound).
- **Infra-sound**

Environmental conditions can significantly affect the type of sounds emitted from a turbine as well as the distance sounds travel from the turbine. A number of factors determine whether a wind project emits any of these five types of sounds—turbine design, hub height, distance between turbine and receptor (building), wind speed and direction, surrounding terrain and vegetation cover, atmospheric conditions, and background noise.

Because several of these factors change over the course of a given day or season, the amount and type of sound from wind turbines experienced by receptors can vary. For example, sounds from turbines are typically more perceptible in low-to-moderate wind conditions since the natural background sound of the wind masks turbine sounds in high wind-speed conditions. Likewise, background noise is lower at night, making wind turbine sound more noticeable.

Wind Turbine Sound and Health Effects

Turbine sound is a persistent and highly controversial public health concern. Some residents living in close proximity to operating wind farms have reported a number of health issues attributed to the sound emissions. The health concerns raised by these residents include headaches, migraines, nausea, dizziness, insomnia, fatigue, ringing in ears, cardiovascular diseases, and diabetes.

While advances in wind turbine technology, sound testing, and sound regulation continue to evolve to address concerns, studies have not yet provided conclusive empirical evidence linking sound from wind farms and negative effects on human health.

Several broadly accepted comprehensive studies (such as those conducted by the Massachusetts Departments of Public Health and Environmental Protection and the Council of Canadian Academies) have recently examined all scientific peer-reviewed data and have reached similar conclusions that there is:

- Inadequate evidence to link sound from properly sited wind turbines to negative impacts on human health
- Sufficient evidence to link exposure to wind turbine noise and annoyance
- Limited evidence to link exposure to wind turbine noise and disturbed sleep

Health problems have been anecdotally attributed to infra-sound generated by wind turbines. While wind turbines do produce infra-sound, it's below the audible threshold and, to date, expert panels reviewing research on this topic have found inadequate evidence linking infrasound and adverse effects on a person's health (Council of Canadian Academies, 2015).



These studies also concluded that the amplitude-modulated noise (rhythmic whooshing or thumping) is perceived to be more audible at night, which is a contributing factor to annoyance. In turn, this “annoyance may be associated with some self-reported health effects (e.g., sleep disturbance) especially at sound pressure levels >40dB(A)” (Knopper, et al., 2014).

Because the advent of wind turbines and exposure to their unique sounds are relatively recent phenomena, most experts agree that there are gaps in the current knowledge. Additional studies using long-term epidemiological methods, particularly on sensitive populations, may provide better data on whether infra-sound and wind turbine noise either directly or indirectly (due to annoyance, for example) increases stress or interferes with sleep.

Regulation of Sound from Wind Projects

Because environmental noise above certain levels is a recognized factor in a number of health issues, as well as a factor in overall well-being and freedom from annoyance, siting restrictions have been implemented in many jurisdictions to limit noise exposure.

All proposed electric generation projects of 25 MW or greater, including wind projects, are subject to Article 10, and therefore must conform to local noise requirements. In addition, when applying for certification under Article 10, project developers must submit a sound study meeting the requirements in Section 1001.19, which specify what the sound study must contain. The study requirements include identifying any sensitive sound receptors, preconstruction measurement of ambient baseline noise, estimates of future noise levels during operations, design of the approach to comply with local noise standards, possible noise abatement measures, post-construction noise studies, and mitigation measures to address post-construction complaints.

As part of a SEQR that applies to wind projects less than 25 MW, all potential environmental impacts must be assessed, including the potential sound emission impacts. Projects subject to SEQR review may refer to DEC's [Assessing and Mitigating Noise Impacts](#) policy and guidance issued in 2000. The document “presents noise impact assessment methods, examines the circumstances under which sound creates significant noise impacts, and identifies avoidance and mitigative measures to reduce or eliminate noise impacts.” The developer may perform a site characterization analysis that includes an evaluation of sound characteristics, receptor locations, and thresholds for significant sound pressure level increases.

During the siting and permitting process, the developer should conduct sound emission studies to determine how the sound will propagate to surrounding residences, outdoor public facilities and areas, hospitals, and schools, thereby providing a sound emission constraint in the project design process.

Sound emission modeling software programs may be utilized to simulate the built wind farm and potential sound emissions. These models may take the turbine type, layout, and site characteristics into account to help estimate the project's potential impact. These models may also be useful in determining the impact a project will have on multiple towns and communities in the vicinity of the project.

Most turbine manufacturers provide turbine sound data, determined in accordance with IEC international standards. These standards are referenced to an 8 meters per second (m/s) wind speed at 10 meters above the ground. The measurements are usually taken at ground level, using a microphone, and then normalized to IEC standards. The levels given by wind turbine manufacturers allow a direct comparison between turbines and facilitate sound studies.

States, counties, and municipalities have used a combination of noise limits and setback requirements to limit exposure to wind turbine sound. Noise requirements can come either in the form of an absolute limit on sound levels (background plus turbine sound) or a limit on the exceedance over measured background levels as a threshold. Typically, the absolute limits are in the range of 40 dB to 55 dB. The limit on exceedance over background level can vary from 5 dB to 10 dB (Consensus Building Institute, 2013).

In 2009, the World Health Organization recommended a limit on general nighttime absolute sound pressure in residential areas of 40 dB(A). The 2012 Massachusetts DEP/DPH Wind Turbine Health Impact Study looked at promising practices from around the world related to nighttime sound pressure levels for residential and sparsely populated areas. Nighttime limits for these areas ranged from 37 dB(A) to 45 dB(A), depending on the wind speed and development density.

Setback requirements are typically established to reduce sound exposures because the propagation of some types of sound diminishes over distance. Common setback requirements and guidelines can set an absolute distance between the turbines and property boundary or occupied building, or set a distance determined by the hub height of the turbines. Because distance is the most effective measure for addressing sound from wind turbines, setbacks that specify a certain sound level at a certain distance from the turbine is an effective approach to addressing the annoyance associated with wind turbine noise.

Mitigation of Wind Turbine Sound

Even with the siting requirements and applicable permit conditions described here, the presence of operating wind projects may occasionally give rise to complaints about noise from community members or, less often, documented exceedances of permitted sound limits (Cummings, 2012). In cases where there is a need to mitigate the sound from wind turbines to address complaints or exceedances, permitting agencies, local decision makers, community members, project developers and other stakeholders have a range of options available.

- **Curtailment** by reducing rotation speed or shutting down under certain conditions (wind speed or direction), or times (night)
- **Turbine relocation**
- **Retrofitting turbines** with modifications that reduce sound
- **Retrofitting homes** with soundproofing, double-glazed windows, or air conditioning systems
- **Purchasing the homes** of residents impacted by noise (rarely done)

The Future of Sound from Wind Turbines

Manufacturers of wind turbines and blades are focused on producing components with greater energy generating potential and less sound. Technological advances in mechanical components, direct drives, and sound insulation have all effectively reduced mechanical sound and manufacturers are researching the benefits of a range of sound reducing designs, including (Cummings, 2012):

- **Pitch control optimization.** Changing the angle that wind hits the leading edge of the blade
- **Load control.** Sensors along the blade that can instantaneously relieve transient pressures by triggering small flaps along the trailing edge of the blade
- **Blade designs (such as trailing edge modifications).** Adding serrations or brushes to reduce sound production
- **Turbine array positioning.** Minimizing turbulence and turbulence wakes that contribute to sound production

Another area with room for future advancement is the measurement of sound. There are multiple challenges around measurement of sound from wind turbines. For example, current measurement protocols and equipment may not fully measure low-frequency or infra-sound. This is because most measurement protocols are based on long averaging times, while amplitude modulated sound occurs in shorter intervals. Acoustic scientists are examining ways to improve both sound measurement equipment and measurement protocols to better predict sound emissions from wind projects and fully capture sound emissions once projects are operating.

Other Recommended Community Efforts

Both the Massachusetts DPE/DHP study and the Canadian Bodies study found that residents of communities where wind projects are being proposed, who perceive the process as unfair, are more likely to be annoyed. The authors of the Wind Turbines and Human Health, 2014 study found that subjective variables, such as attitudes and expectations, are also linked to annoyance.

The authors of these studies concluded that communities and developers can moderate annoyance levels by investing considerable effort in conducting a transparent process of assessing a wind project's noise impacts and enabling a high level of early community engagement and empowerment throughout the development and operation of a wind project.

Additional Resources for Sound Emissions

- [CBI: An Introduction to Sound and Wind Turbines](#)
- [NYS Public Service Law: 1001.19 Exhibit 19: Noise and Vibration](#)

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