Visual Looming Effect in the Landscape: Research, Analysis, and Case Study

Desert Claim Wind Power Project
Ellensburg, Washington

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Introduction

We understand that some individuals have expressed concern about the visual effect of wind turbines. In particular, we understand that some individuals have expressed concern that if turbines are located too near residences, occupants of those residents may feel that the turbines are looming over them. Accordingly, we have been asked to consider the so-called "looming effect" of wind turbines.

The purpose of this Analysis of Visual Looming Effect in the Landscape is to: (1) summarize the existing body of analytical work addressing the physiology of human vision; (2) summarize the psychological effect of an object's height in relationship to distance in the visual landscape; and (3) apply this research to existing and proposed wind power projects in the landscape to assess the effect of visual looming.

The concept of "looming" is not a concept that is generally considered in standard visual impact analysis. The methodology for this study, therefore, involved examining existing research regarding the physiology of the human eye, and considering concepts of looming found in scientific research and in architectural and urban design practice. This research was then applied to a case study of an existing wind power project in the landscape and the proposed Desert Claim Wind Power Project.

Human Vision

In this study, the physiology of human vision must first be considered, providing the necessary context to evaluate how the looming effect is physically perceived in humans. This study focused on a stationary field of vision, or what the eyes can see within the vertical and horizontal fields of view without moving one's head or eyes. The horizon line for this study was set from a standing position of five feet (5'-0") from the ground plane (Smardon et al. 1986).

Physiology of the Eye

The vertical field of view is generally measured both above and below the horizon line. The normal sight line depicts the field of view without movement of one's eyes or head from a fixed position or object, and has been measured at a range from 10 degrees to 15 degrees from the horizon sight line. With easy eye movement (but no head movement), the maximum field of view without a loss of focus on an object equates to a 60 degree cone of vision, or 30 degrees above or below the horizon sight line (Dines and Harris 1998, Nelson and English 2008).

On a horizontal plane, the field of view is measured in monocular and binocular visual fields. Monocular vision depicts the field of view in the horizontal plane that focuses on both retinas (eyes) without distortion and with the correct depth perception necessary to elicit physiological reactions in the human mind. For humans, the monocular field of view is typically measured at 166 degrees in front of the eyes. Binocular vision, commonly referred to as peripheral vision, depicts the entire field of vision in the horizontal plane as 208 degrees in front of the human eyes and extends beyond the monocular field of view (Smardon et al. 1986). The field of monocular vision is then narrowed to a 40 to 60 degree cone of vision that depicts the central angle of view, which affects the perception of a scene and is the more detailed cone of vision for the human eye. This angle corresponds to the angle over which a viewer could recall objects from a scene if he had kept his eyes in the same position (Forum 2008).

Photography is used to capture a stationary field of view in the horizontal and vertical plane and is typically employed for visual simulations using a standard 35 millimeter (mm) camera with various lens focal lengths.

A 35 mm camera equipped with a 50 mm lens takes a 45 degree field of view in the horizontal plane and a 31 degree field of view in the vertical plane (Nikon 2008, Smardon et al. 1986). It has the closest relationship to the central angle and normal sight lines in the stationary human field of vision, without distortion of an object's scale in the captured scene.

Looming

The concept of "looming" is not generally considered in standard visual impact analysis. Therefore, we considered the common definition of the term as well as researching the use of the term and concept in the fields of science and architecture and urban design.

The common definition of looming is, "to come into view as a massive, indistinct, or distorted image, appear in the mind in an exaggerated or hostile form, and seem imminent" (Webster's 1998). Current scientific research considers visual looming as "the expansion of the projection size of an object on the retina, is usually the indication of an approaching object....normally perceived as a threat for a possible collision and is known to elicit reactive behavior in animals" (Caviness 1962). As discussed below, in the field of architecture and urban design, although the term looming is not used, the concept of the appropriate ratio between open space and building heights is considered.

Looming in Science

The scientific community has studied visual looming, its effect on the retina, and psychological reactions in object movement, obstacle avoidance, and accident prevention (Raviv 1992). Mathematical algorithms, scientific studies, and measurement of looming have involved testing with animals, humans, and robotics.

Scientific research on looming in animals has used rhesus monkeys to study the avoidance of obstacles at various distances within the field of view. These studies concluded that animals have the ability to avoid potentially harmful situations involving objects moving toward them (looming) by recognizing distance perception. "From this series of studies, it seems that an abstract optical representation of a rapidly approaching object elicits marked avoidance responses in rhesus monkeys. This visual stimulus ordinarily means a danger in the environment" (Caviness 1962). Similar conclusions were found in studies of accident prevention in vehicles that examined human reactions in combination with distractions and objects in a driver's field of view (Charlton and Perrone 2008).

Research on the "looming phenomenon" has computed a moving object's size and distance as a direct indicator of danger and avoidance in mobility. Movement has been tested in the vision sensor devices of mobile robots as a way to extract range information for navigation. This study used a looming algorithm to test distances at which an object signals a sense of danger and triggers the mobile robot to change course (i.e., elicits an avoidance reaction) (Sahin and Gaudiano 1998).

The scientific literature focuses on objects moving toward the viewer. As a result, it does not provide insight on the appropriate relationship between the height and distance of objects that are stationary, not moving toward the viewer, such as wind turbine towers.

Looming in Architecture and Urban Design

Architectural and urban design studies have examined looming in the context of the enclosure or exterior building forms in the urban realm. These studies demonstrate how humans behave and function within various enclosures that create most urban spaces (for example, plazas). The scale, form, and ratio of large objects in a space influence pedestrian behavior and the type of social communication that occurs within that space (Dines and Harris 1998). Historically, and in recent architectural and urban design studies, the relationship of the height of a building to the adjacent open space (typically expressed as a ratio) has been shown to illicit a sense of enclosure reaction in humans.

In the 1400s, the famous Italian architect Leon Battista Alberti noted, "a proper height for a building around a square is one-third of the breadth of the open area," to avoid the sense that a building is too high or out of scale with its surroundings (Alberti [Translation] 1965). In 1570, Italian Renaissance architect Andrea Palladio similarly concluded "...none of the buildings built around the square may be taller than a third of the breadth of the square nor less than a sixth; one should go up to the porticoes by steps which should be made as high as a fifth of the column height" (Palladio [Translation] 1997). More recently, eminent professors of landscape architecture, Nicholas Dines and Charles Harris concluded that "an external enclosure is most comfortable when its vertical planes are one-half to one-third as high as the width of the space enclosed. If the ratio falls below one-fourth, the space begins to lack a sense of enclosure" (Dines and Harris 1998).

Beyond the 3:1 enclosure ratio studies, urban planner and educator Harris Blumenfeld (1953) (as citied in Yang and Putra 2005), citing H. Maertens' similar work on the subject, related the mathematics for the measurement of optics and human field of view with architectural scale and building design. Blumenfeld explained Maertens' work as follows:

> *the maximum angle at which an object can be perceived clearly and easily, is about 27 degrees, corresponding to a ratio of 1:2 between the size of the object and its*

distance from the beholder....At an angle of 27 degrees...the object appears... 'as a little world in itself' with the surroundings only dimly perceived as a background; at an angle of 18 degrees (1:3) it still dominates the picture, but now its relation to its surroundings becomes equally important. At angles of 12 degrees (1:4) or less, the object becomes part of its surroundings and speaks mainly through its silhouette.

More recently, Speregen (1965), urban planner Kevin Lynch (1962), and celebrated architect Yoshinobu Ashihara (1983) (as summarized in Yang and Putra 2005) have all reached similar conclusions, using the same height to open space ratios in the correlation of optics and perceptual scale. At a 4:1 setback ratio, these researchers found that the sense of enclosure "loses its enclosure" and "enclosure ceases." These studies on the sense of enclosure in architecture and urban design can be applied to the open landscape, with the conclusion that a single object of vertical scale will not create a sense of enclosure or elicit a negative psychological response at a 4:1 distance to height ratio.

Based on research in the fields of visual physiology and architecture and urban design, the so-called looming effect can be defined as the psychological reaction of a viewer based on the ratio between the height of an object in view and the distance from a viewer's eyes to that object, within the normal field of view.

Case Study: Goodnoe Hills Wind Power Project, Washington

<u>Purpose</u>

The purpose of this case study was to analyze the visual looming effect and appropriate setback distance of an installed wind turbine in the field that was of the same type as proposed at the Desert Claim Wind Power site near Ellensburg, Washington. The Goodnoe Hills Wind Power Project in southwest Washington was selected as the case study site. The same wind turbine model is installed there that is proposed for the Desert Claim project, a 2.0 megawatt REpower Turbine Model MM-92 with a 410-foot-high rotor tip.

This case study documented the findings of the field work, including selection of an appropriate setback distance to mitigate for the visual looming effect of the wind turbine for later application at the proposed Desert Claim site. A series of four setback distances from the wind turbine were tested to assess the visual looming effect of the turbines. This test included setback distance ratios (distance to height) of 1:1, 2:1, 3:1, and 4:1, ranging from 410 feet to 1,640 feet.

Field Work Logistics

The EDAW team traveled to the Goodnoe Hills Wind Power Project site on November 24, 2008, to conduct the case study. The weather was dry, cool (42 degrees F), and overcast with sun breaks. The topography of the site was a ridge line/plateau edge with moderate topography sloping downward. Digital photography was used to document existing conditions and was conducted between 1:00 pm and 3:00 pm.

EDAW met with Goodnoe Hills staff to discuss the general layout and topography of the Goodnoe Hills Wind Power Project. An existing operating wind turbine was selected (#30) that allowed straight-line visibility and photography without significant elevation change or drop-off, out to a setback distance of 1,640 feet.

At wind turbine #30, the EDAW team set up digital photography equipment to document conditions at the site at the four selected ratio setback distances: 410, 820, 1,230, and 1,640 feet. A Nikon D70 DSLR camera with 50 mm lens was used to digitally photograph the wind turbine. A 50 mm lens most closely approximates the image seen by the human eye. A 3-point tripod was used to maintain a consistent photo height and was set at a height of 5 feet, 0 inches. This height best approximates the eye height of an average person. The photo points and the wind turbine were documented using a Magellan global positioning system (GPS) unit.

Wind Turbine Specifications and Components

The REpower MM-92 wind turbine consists of the following:

- 2.0 megawatt generator housed in a nacelle atop a tower, lightning protection, painted non-glossy gray-white.
- Tubular steel tower with internal stairs and equipment/cabling, 258 feet high, painted non-glossy gray-white.
- Fiberglass and metal rotor atop a tower with three rotor blades, electrical pitch and cut-off control, 304-foot three-blade rotor diameter, 152-foot rotor blade length, tip of blade is 106 feet above the ground, painted non-glossy gray-white.
- Reinforced concrete foundation, buried underground.
- Underground electrical lines along road routes.
- Dirt/gravel roads and turbine pads.

Analysis

Digital photographs were taken at the four setback distances at the Goodnoe Hills Wind Power Project site. Various dimensions, distances, and angles are defined for each of the four setback ratios that were examined in this analysis. Overall visibility of the wind turbine and its components is summarized below.

At a setback of 410 feet (1:1 ratio), the resulting view of the wind turbine, without moving one's head or eye focal point, was the bottom portion of the tubular steel tower.

The base of the wind turbine tower, the pad, and the access road were also very visible. None of the three rotor blades were visible at this distance. To view the entire wind turbine, one would need to tilt back one's head and look up approximately 45 degrees. It took approximately two and three-quarter vertical camera frames using a 50 mm lens to view the entire wind turbine.

At a setback of 820 feet (2:1 ratio), the tubular steel tower was still highly visible, but a portion of the three rotor blades was now in view as well. The center rotor hub and nacelle with generator were not visible at this distance. The base of the wind turbine tower and the access road were less visible at this distance. To view the entire wind turbine, one would need to tilt back one's head and look up approximately 27 degrees. It took approximately one and three-quarter vertical camera frames using a 50 mm lens to view the entire wind turbine.

At a setback of 1,230 feet (3:1 ratio), the entire wind turbine was much more visible; however, one still could not see the upper tip of the rotor blades without moving one's head or eye focal point. The base of the turbine tower and access road was less discernable at this distance. To view the entire wind turbine, one would need to move one's eye focal point upward and/or tilt back one's head and look up approximately 18 degrees. It took approximately one and one-quarter vertical camera frames using a 50 mm lens to view the entire wind turbine.

At a setback of 1,640 feet (4:1 ratio), the entire wind turbine, including the tubular steel tower and three-blade rotor, was now completely visible. There was observable airspace beyond the tip of the rotor blade and the upper limit of the image that one would see. Variation in topography and details of the surrounding site became readily apparent at this greater distance. To view the entire wind turbine, one would not need to adjust one's eyes or tilt one's head up. It took less than one camera frame using a 50 mm lens to view the entire wind turbine, thus providing some buffer within the view.

Findings

The finding of the case study conducted at the Goodnoe Hills Wind Power Project site was that the visual looming effect of the 410-foot high wind turbine was largely dissipated at a setback ration of 3:1, and was non-existent at a setback ratio of 4:1, or 1,640 feet for the REpower MM-92. The visual looming effect was most evident in the setback ratios of 1:1 and 2:1. A 4:1 setback ratio provided some buffer distance to further dissipate the visual looming effect and to account for changes in site topography and viewing angle.

Site Analysis: Desert Claim Wind Power Project Site

Purpose

A site analysis was conducted of the proposed layout of the Desert Claim Wind Power Project site as presented in the Revised Application for Site Certification (Desert Claim Feb. 2009) and the Draft Supplemental Environmental Impact Statement (SEIS) (Kittitas County 2009). This site analysis followed field work conducted at the Goodnoe Hills site, where a constructed wind turbine of the same model and height as the proposed Desert Claim site was assessed using four setback ratios (1:1 to 4:1). The previous case study concluded that a planning and design setback ratio (4:1) and setback distance (1,640 feet) mitigate for the so-called looming effect of a wind turbine. The purpose of the site analysis was to apply the recommended setback ratio and setback distance to the proposed Desert Claim Wind Power Project site and to assess whether the proposed turbine layout adequately mitigated for the looming effect of the proposed project.

Logistics

The EDAW team reviewed the proposed layout of the Desert Claim Wind Power Project. The evolution of the proposed project and how the project layout had changed over time were discussed with Desert Claim Project staff. Desert Claim provided EDAW with GIS-based maps (1:48,000 or approx. 1 inch = 0.75 mile) showing the proposed locations of all wind turbines and nearby residences. Seven of the existing non-participating residences were within 2,500 feet or less of a proposed wind turbine. Views of existing site conditions and visual simulations with proposed wind turbines were reviewed using 50 mm photography and digital photosimulations provided by Desert Claim.

The EDAW team traveled to the Ellensburg, Washington, area on November 25, 2008, to observe the proposed Desert Claim Wind Power Project area in the field. Weather conditions were similar to those during the site visit to the Goodnoe Hills Wind Power Project area (i.e., dry, cool, and overcast).

Analysis

Information on viewpoints analyzed in the Draft SEIS was examined with the purpose of selecting views near residences, particularly seven non-participating residences within 2,500 feet of a proposed wind turbine. Based on this review, four viewpoints were selected for further site analysis: View 1D, View S1I, View S1J, and View S1K. This study built upon the computer-generated visual simulations of future views on the landscape with construction of the proposed project under the current layout design (EFSEC 2009).

View 1D looked southwest across the Northwest Valley Visual Assessment Unit, from immediately northeast of the project area along Pleasant Lane. A number of wind turbines would be in view in this area, with the closest turbine in View 1D being 1,530 feet away. This distance was less than proposed in the Draft SEIS. Three non-participating residences were located along this roadway near the viewpoint. The closest proposed turbine locations were 2,241 feet, 1,687 feet, and 1,694 feet away from these three non-participating residences. The topography in this area was relatively flat and sloping to the southwest. Fenced grassland and the proposed wind turbines were in the foreground.

View S1I looked northeast across the Northwest Valley Visual Assessment Unit, from immediately south of the project area along Reecer Creek Road. Three wind turbines would be in view in this area, with the closest turbine from View S1I being 2,129 feet away. One residence was located nearby, but was located greater than 2,500 feet away from a turbine. The topography in this area was relatively flat and sloping to the south. Fenced grassland and the proposed wind turbines were in the foreground.

View S1J looked northwest across the Northwest Valley Visual Assessment Unit, from immediately south of the project area. A number of wind turbines would be in view in this area, with the closest proposed turbine from View S1J being 2,944 feet away. Three non-participating residences were located along Lower Green Canyon Road and Smithson Road. The closest proposed turbine locations were 1,914 feet, 1,798 feet, and 1,855 feet away from these three non-participating residences. The topography in this area was relatively flat and sloping to the south. Fenced grassland and the proposed wind turbines were in the foreground.

View S1K looked south across the Northwest Valley Visual Assessment Unit, from immediately north of the project area. A number of wind turbines would be in view in this area, with the closest proposed turbine from View S1K being 2,679 feet away. One non-participating residence was located off Reecer Creek Road in this area. The closest proposed turbine to this residence was 1,778 feet away. The topography in this area was relatively flat and sloping to the south. Fenced grassland and the proposed wind turbines were in the foreground.

Findings

This site analysis assessed the potential visual looming effect of the proposed Desert Claim Wind Power Project on nearby non-participating residences. Seven non-participating residences were within 2,500 feet of a proposed turbine; other residences were located farther away. The minimum setback distance between a proposed turbine and a nearby non-participating residence was 1,687 feet. Within 2,500 feet of a proposed turbine, setback distances to non-participating residences ranged from 1,687 feet to 2,394 feet. The general topography and vegetative conditions of the four viewpoints assessed were all similar, with gently sloping land and open, low grassland vegetation. Therefore, the foreground visual landscape condition of the Goodnoe Hills case study site and the proposed Desert Claim Wind Power site were similar.

All of the non-participating residences near the project are located greater than a 4:1 setback ratio (distance to height), or more than 1,640 feet from a proposed turbine. Nothing we found in reviewing GIS maps of the proposed location of wind turbines and distances to residences, visual simulations of proposed wind turbines, or field reconnaissance observations near Ellensburg countered the results of the Goodnoe Hills case study. I, therefore, concluded that a minimum setback distance of 4:1 would mitigate any visual looming effect, with some additional buffer distance included to account for changes in topography and sight angles. Because the turbines at the proposed Desert Claim Wind Power Project were sited beyond the recommended setback distance of 1,640 feet (4:1 ratio), I determined that no visual looming effect would exist at any of the seven non-participating residences.

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