Technical Considerations in Siting Wind Developments:

NWCC Research Meeting

Dec. 1-2, 2005

Washington, D.C.

March 2006

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Foreword

Over the past 30 years, the U.S. Federal Wind Energy Program has studied and addressed a variety of environmental issues associated with wind energy development, including:

- Possible effects on flora and fauna
- Audible and low frequency impulsive noise measurement and mitigation methods
- TV and other electromagnetic interference from wind turbines
- Public reaction to different turbine configurations and aesthetics
- Ways to avoid or reduce bird and bat collisions with rotor blades.

The National Wind Coordinating Committee (NWCC) establishes dialogue among key stakeholders and catalyzes appropriate activities related to these types of wind power issues. The intent of NWCC's December 2005 meeting *Technical Considerations in Siting Wind Developments* was to provide a forum for presentation and discussion of leading activities addressing non-wildlife siting issues.[1] These proceedings provide a summary of presentations offered at the meeting and the ensuing dialogue among participants. Information and issues discussed herein need to be viewed in the context of the entire range of environmental benefits and impacts arising from wind power development. Key points to remember include the following.

- Environmental impacts are important considerations in siting wind energy facilities, just as they are for any other power plant or transmission line.
- As with any energy facility, environmental impacts of wind projects may not affect all people equally.
- While these impacts need to be carefully addressed, the significant environmental benefits of wind energy also need to be taken into account when designing and implementing the siting process:
    - Wind energy is a domestic, inexhaustible renewable resource.
    - Wind energy reduces dependence on imported fuels that are subject to large price fluctuations.
    - Wind energy facilities displace fossil-fuel combustion in conventional power plants, eliminating substantial amounts of harmful atmospheric emissions and reducing water use, consumption and pollution.

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[1] Wildlife-related siting issues have been and continue to be extensively addressed by the NWCC Wildlife Workgroup.

The Planning Committee thanks all those who participated in the December 2005 research meeting, and especially those whose presentations will help to inform the consideration, reduction, and mitigation of impacts in ongoing and future siting of wind energy projects.

Planning Committee

Technical Considerations in Siting Wind Developments
Dec. 2005 Research Meeting

March 2006

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http://www.nationalwind.org/events/siting/presentations.htm

GLOSSARY OF ACRONYMS

CFS	cubic feet per second
DOE	See "US DOE"
EMEC	European Marine Energy Centre
EPRI	Electric Power Research Institute
FERC	Federal Energy Regulatory Commission
FONSI	Finding of No Significant Impact
INL	Idaho National Laoratory
kW	Kilowatt
LIPA	Long Island Power Authority
MMS	Minerals Management Service
MTC	Massachusetts Technology Collaborative
MW	Megawatt
NHA	National Hydropower Association
NIMBY	"Not In My Backyard"
NEPA	National Environmental Protection Act
NOAA	National Oceanic and Atmospheric Administration
NRDC	National Resources Defense Council
NWCC	National Wind Coordinating Committee
NYSERDA	New York State Energy Research and Development Authority
OEP	Ocean Energy Program (DOE Program authorized by the 2005 Energy Bill)
ORNL	Oak Ridge National Laboratory
PNNL	Pacific Northwest National Laboratory
RPS	Renewables Portfolio Standard
SEPA	State Environmental Protection Act
USDOE	United States Department of Energy
USFWS	United States Fish and Wildlife Service

INTRODUCTION

The National Wind Coordinating Committee (NWCC) is a national collaborative of wind industry, government, utility, and environmental organizations formed in 1994 to provide a forum for identifying issues that impact the use of wind power, to serve as a catalyst for dialogue and debate, and build consensus among varied stakeholder groups. The NWCC's Siting Workgroup has published two editions of a siting handbook, fact sheets on siting policy in nine different states, and case studies.

Meeting Purpose and Agenda

The purpose of this meeting was to examine what tools and techniques are available to developers, communities, and consultants to look at non-wildlife siting questions. In particular, the Siting Workgroup identified the following questions:

- What are examples of technical requirements or standards that must be met?
- What are the main technical issues to be addressed in siting?
- What issues are particular to wind?
- What modeling / research techniques / analytic methods exist?
- Is mitigation possible? What alternatives are there?

The agenda (see Appendix C) was divided into five sessions, with presenters addressing the following specific areas of potential siting impact:

- Visual impacts
- Lighting, FAA regulations, and air hazards
- Sound impacts
- Electromagnetic interference
- Safety impacts

The *NWCC Siting Technical Meeting* was funded by the U.S. Department of Energy (DOE). DOE contracted RESOLVE Inc. to assist with convening and facilitation of the meeting.

The meeting was held in Washington, DC in December 2005. These proceedings provide summaries of the presentations made at the meeting, and of the question/answer sessions and discussions that followed. A bibliography of resources referenced by presenters is included as Appendix A. Contact information for all meeting participants is included as Appendix B. The meeting agenda can be found in Appendix C. A list of the slide presentations (available with this Proceedings narrative as individual *pdf* files) is provided in Appendix D.

SESSION I: VISUAL IMPACTS

Moderator: Martin J. (Mike) Pasqualetti

The purpose of this session is to explore visual impact analysis, tools for reviewing visual impacts, and factors that influence public and community opinion on visual impacts. Participants should come away from the session with an understanding of the considerations that influence public opinion about wind power projects, how these opinions are influenced by location, how they can be measured, and how they can be mitigated.

Visual Impacts Overview

M Pasqualetti-Visual Impacts.pdf

Mike Pasqualetti, Arizona State University

Mike Pasqualetti is Professor of Geography and member of the graduate faculty in the program Global Technology and Development at Arizona State University. He specializes in the environmental costs of energy, particularly renewable energy, and serves on the editorial board of the International Journal of Sustainable Energy Technologies and Land Use Policy. A member of the National Wind Coordinating Committee, his publications on wind power have appeared in numerous journals and books.

Our first speakers will be giving perspectives on how wind power is visually perceived and on the factors that influence those perceptions – in both the Western and Eastern US, and in the UK. We will open the floor to discussion following each presentation, and I invite participants to ask tough questions so that we can have a good discussion.

Some people perceive wind power positively, others not. While we can do all kinds of things to make wind power more acceptable and regulate their siting, we cannot make them invisible. What factors influence people's reactions to wind power? Resource factors include the site-specific and intermittent nature of the wind resource. Location-related factors include both landscape and land use conditions, as well as jurisdictional situation. Perceptual factors include the potential for financial return to those who must contend with the visual impacts, the environmental sensitivity, and other personal values. Factors that can enhance our perception of wind power include regulatory control, technical improvements, and education.

Western US Perspective on Wind Power

[M Pasqualetti-Western US Perspective on Wind Pwr.pdf]

Mike Pasqualetti, Arizona State University

In general, natural and cultural conditions almost always trump technical issues when it comes to people's perceptions. Natural conditions relevant to the perception of Wind Power in the Western U.S. include:

- ***Greater visibility*** – up to 140 miles – is a function of both landscape (open spaces, higher ridgelines), vegetation, and climate.
- ***Dry climate*** increases visibility distances, and also makes it harder to restore the landscape once it is disturbed.
- ***Active and rising coastline*** – means that the continental shelf is narrow, not wide like on the East coast. (Hence, offshore wind is not as much of an option.)
- ***Sparsely populated*** landscape tends to increase the visual impact of distant and moving objects, but also means fewer back yards (fewer "NIMBY" situations).
- ***Indian lands*** are highly concentrated in the west, presenting both opportunities and the potential for conflict.
- ***National parks***, which are off-limits to wind power, are more concentrated in the west.
- ***Transmission lines*** are longer and more visible in the west.

Cultural conditions, including past and present land uses, also play an important role. Much of the West, particularly the Great Plains, once was defined by wind power; small windmills brought electricity to farms and ranches, and are now considered icons. Today, modern wind turbines are providing additional income, allowing small family farms to continue. Ironically, in some places where wind turbines are replacing oil derricks the two kinds of structures are perceived similarly.

Public perception of visual impact rests heavily upon existing site conditions and use. This is illustrated by four California examples. All four of these wind energy development locations are in passes that are good not only for wind but also for highways and for bird migration. Yet each has evoked different responses, and in some cases these responses have evolved over time.

1) ***Solano Hills*** – located in Northern California between San Francisco and Sacramento, this location, away from principal highways and occupied largely by wheat farms, has not generated objections to wind development.

2) ***Tehachapi Pass*** – Tehachapi, although not on an Interstate highway, does get a lot of traffic. Yet a different mentality (open to wind energy development) prevails here, perhaps because the area is sparsely populated, perhaps because an Air Force base is one of the existing uses.

3) ***Altamont Pass*** – Since wind turbine development began here, this wind resource area continues to be largely used for grazing cattle, but is intensively used for multiple other purposes

as well: an essential Interstate route to and from San Francisco and the growing bedroom communities of its workers; a transmission line corridor; and the Pacific Flyway. It is a very concentrated area, and wind energy development has generated substantial opposition as a result of bird mortality.

4) ***San Gorgonio Pass*** (Palm Springs) – Everything goes through this pass: the wind, Interstate 10, the San Andreas Fault, smog. In the early mornings, when the sun is low, the wind turbines become highly visible glinting in the sun.

The initial perception of the wind developers was that people in the area of the pass would not oppose wind energy development. However, as it turns out, people who lived in North Palm Springs tended to be there because they wanted a more isolated spot – away from people and development. Residents of this community formed a "substantial minority" of people most likely to object. In the community of Snow Creek, northwest of Palm Springs, there was a population of 100 people who objected strongly and succeeded in keeping wind development plans from coming to fruition.

Over time, however, wind power has come to be not only accepted by most Palm Springs residents, but to be positively perceived. People gave tours of the wind facilities. Wind turbines appear in local advertising and community logos. Housing developers use them to sell real estate. The city annexed territory to get the tax revenues from the wind development.

One way to address potential conflicts between wind development and land use is to rank landscapes and uses for compatibility with wind energy development.

Rank #1 – properties where wind energy development is not only suitable but overtly requested: e.g., Iowa and Kansas farming communities where the land is seen as an economic resource, and the people who own the land are looking for alternative "crops," including energy.

Rank #2 – areas where wind is likely to be acceptable: e.g., sparsely populated grazing/agricultural land (southeastern Washington).

Rank #3 – acceptable in certain circumstances: e.g., the Palm Springs area, where perceptions shifted from opposition to advocacy

Rank #4 – properties that would be considered completely off-limits: e.g., Mt. Rushmore.

Questions and Observations: Western US Perspective on Wind Power

Several questions focused on the fact that the Western US is characterized by more "wide open spaces" with concentrated areas of population, as opposed to the more evenly distributed population of the Midwest and East. How wide a geographic area should the population be surveyed to get a sense of the community's perspective on wind? Are houses selling in developments within view of turbines, and how do their sales compare with similar sites in non-wind developed areas? Key points made in response to these questions were:

- When surveying people to get a sense of the visual impact of wind turbines, it is important to consider not just residents but also people who visit the area or travel through it. Palm Springs, for example, is a resort/vacation destination with a lot of non-resident traffic. The turbines are not visible from the city, but are seen by people when entering or leaving.
- This can be generalized to other wind development areas in the West; as contrasted with the East, people in the West are more likely to see wind sites when they are on the road, rather than from their own backyard, so to speak.
- There is no data on housing sales as a function of proximity to wind sites in Palm Springs area. However, a 2003 study conducted by the Renewable Energy Policy Project (REPP) found that houses adjacent to wind sites sold as quickly for the same (or even higher) prices than comparable houses not adjacent to wind sites. [http://www.repp.org/articles/static/1/binaries/wind_online_final.pdf]

Another point that was made was that older wind development areas, such as Palm Springs and Altamont, may influence a lot of people's perceptions of what wind developments look like. Key points to keep in mind include:

- In older wind development areas, the machines are different sizes, not well laid out, etc.
- Problems encountered at early wind developments have resulted in a number of technical solutions that are being applied in newer developments.

In response to a question about "scale" impact as machines have become bigger, fewer, more slow-moving, with strobe lights, the lighting aspect is the major factor.

- Strobe lights are a real issue in the desert, where a dark night sky is the norm. With the larger turbines that require lighting, night-time visibility can be a bigger problem than daytime visibility.

Visual Impact Assessment, the Eastern Experience

R Benas-Visual Impact Assessment.pdf
R Benas-NY Mitigation List.pdf

Richard C. Benas, Saratoga Associates

Rick Benas is an Associate Principal with Saratoga Associates, of Saratoga Springs, New York. He has more than 30 years experience in private and public service including work as a professional forester, as a landscape architect, and as an environmental analyst. As expert land use and visual assessment witness for the State of New York's Department of Environmental Conservation (NYSDEC), Mr. Benas established all of the visual criteria by which projects are currently evaluated by NYSDEC.

The National Environmental Policy Act of 1969 (NEPA) and subsequent NEPA-derived state environmental laws require that all environmental impacts, including visual and aesthetic, be revealed, avoided, and mitigated.

Many northeastern states have promulgated regulations that put visual assessment and mitigation into broad social perspective. For example, in New York, the State Environmental Quality Review Act (SEQRA) requires that impacts be "minimized to the maximum extent practicable consistent with social, economic, and other essential considerations" [see Part 617.11(d)(5) of 6NYCRR)], while in Massachusetts damage to the environment must be minimized and mitigated to the "maximum extent practicable" [see 11.01 of 301CMR]. Other northeastern jurisdictions mimic this language and legislative intent.

New York State is representative of the highly crowded and environmentally sensitive northeast. The visual impact assessment discipline evolved through many contentious administrative trials through the 1970s, 1980s, and 1990s. A variety of visual analysis tools were tested by the penetrating scrutiny of cross-examination. In July of 2000, the New York State Department of Environmental Conservation (NYSDEC) institutionalized those tools that survived this trial experience.

In that year, a Visual Assessment Policy was drafted, peer reviewed by the highest level of State practitioners as well as academic leaders from both Cornell University and the college of Environmental Science & Forestry at Syracuse University. The Policy is now sanctioned and used by NYSDEC Permit Administrators and many other jurisdictional authorities to administer SEQRA and to assure that visual and aesthetic impacts are fully revealed, avoided, and mitigated to the maximum extent practicable. Other northeastern jurisdictions have adopted the Policy (e.g., Maine incorporated much of the unaltered language into their environmental regulations), and it was recently used to permit a wind energy facility in Pennsylvania.

This year, the Policy was used as the basis for the aesthetics section of the New York State Energy Research and Development Authority's Wind Energy Tool Kit.[2]

Visual Impact Assessment Procedure

1. *National, state, and local aesthetic resources inventory and aesthetic attribute description.* All aesthetic resources must be designated by law and be open for public enjoyment and appreciation. This list distinguishes legitimate concerns of the public-at-large from individual expressions of concern called "nimbyism." That these places deserve special attention is not a matter of opinion or the product of any rating system. It is a matter of law and public record, and therefore, trumps all other social science techniques that attempt to rate landscape quality.

2. *Visual impact determination.* Visual simulations, line-of-sight profiles and digital viewshed tools are all sanctioned under the Policy.

3. *Aesthetic impact determination.* Does the wind energy facility compromise any identified aesthetic attributes of the aesthetic resources? Does it compromise the character of the host community?

4. *Mitigation assurance.* All strategies from the universal list should be employed to the maximum extent practicable.

Mitigation Strategies – New York's Universal List

To demonstrate that all visual and aesthetic impacts have been "revealed and minimized to the maximum extent practicable," applicants are required to take the following steps.

1. Inventory the "full menu" of all known visual and aesthetic resources and address all mitigation strategies

• Siting	• Alternate technologies
• Professional design	• Non-specular materials
• Screening	• Lighting
• Downsizing	• Maintenance
• Relocation	• Decommissioning
• Camouflage/disguise	• Offsets
• Low profile	

2. Employ those mitigation strategies that are applicable and practicable while providing justification for those that are not.

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[2] A copy of a memo issued by NYS DEC's Division of Environmental Permits was distributed to meeting participants. See R Benas-NY Mitigation List.pdf which is included with Mr. Benas' slide presentation.

The first item on NYSDEC's universal list – the "full menu" – of all known visual and aesthetic impact mitigation strategies is *siting.* Developers should "avoid siting within visual proximity to Aesthetic Resources of National, Statewide, and Local significance." Such "rated" landscapes are a matter of law and public record. If a local planning board designates a location as scenic, and a proposed development "compromises the aesthetic value" protected by the law; that's what matters to a judge. (See slides for list of rated sites.)

Professional design in the case of wind turbines generally is optimized for performance, noise reduction, and other non-visual impacts. Because turbine installations will continue to use "off-the-shelf" hardware, other forms of visual impact mitigation are more likely to be used.

Screening applies mainly to the substation, but may serve as a useful offsite mitigation strategy provided the wind resource value is not diminished.

Relocation may be an option if a project site offers some alternatives to the project developer for locating specific turbines.

For overhead electric transmission facilities, project sponsors should commit to using cables made of *non-specular materials* (cables that do not shine).

FAA requirements for safety *lighting* should be met in such a way as to minimize off-site lighting, glare, and light pollution.

The physical plant, ancillary facilities, and the land under the control of the wind farm owner should be kept in a *clean and well-maintained* condition.

Decommissioning means removing all or part of the project after its useful life. Project sponsors should commit to a detailed decommissioning plan, including a budget.

If negative impacts cannot be minimized acceptably, then these impacts can be *offset* by (for example) removing a chronic eyesore within the project viewshed.

Visual Impacts - UK and European Perspective

C Stanton-Visual Impacts UK and European Perspectives.pdf

Caroline Stanton, horner + maclennan

Caroline Stanton is a Chartered Landscape Architect who has researched the landscape and visual impacts of windfarms in the UK, the Netherlands, Germany, and Denmark. She has worked as a landscape advisor to Scottish National Heritage (SNH), the government agency charged with protecting Scotland's natural environment. Currently with the private landscape architecture firm of horner+maclennan, she has, in combination with a firm of computer experts, completed a good practice guidance document on visualization techniques.

Modern wind energy development did not really arrive in the United Kingdom until the early 1990s, while extensive development had previously occurred across Denmark and the Netherlands. (See slide presentation for wind atlas of Europe.) Although these countries seemed small players at that time compared to the US, seventy-five percent of worldwide installed wind capacity is now located in Europe, with targets of 5000 MW installed in Denmark, 6000 MW installed in the UK, and 28000 MW installed in Germany by the year 2010.

Changes call attention to wind development

Rapid development of the wind resource has raised concern regarding landscape and visual impacts in many parts of Europe, including the UK, with people analyzing the results of wind energy development and questioning whether it is going in the right direction. Several of the recent changes that have made people take notice are as follows.

- *Increasing size and output of wind turbines.* From an aesthetic standpoint, larger turbines may relate to a large-scale open landscape; however smaller turbines are usually preferable within more intimate scale landscapes
- *Increasing numbers of turbines* within single developments.
- *Increasing numbers of wind farms*, making it necessary to analyze not only the potential landscape and visual impacts of a proposed project, but also the cumulative impacts with all the existing or proposed projects within an area.
- *Increasing development of the offshore wind resource*, having both its own impact and cumulative impacts with onshore developments.

Social and political issues have played a major part in promoting wind energy development, with some areas in favor of wind development, others not. The UK and many European countries see wind as a way to help meet their Kyoto commitments to reduce CO_2 emissions. More recently, wind is also seen as a way to help secure National energy supply. Most public opinion studies seem to suggest that 80-90% of the population is supportive of the principle of developing wind energy. Nevertheless, local opposition to project proposals still occurs, with local sensitivities depending in part on whether the wind farm is being proposed by a community or by a private developer.

Methodologies and techniques for assessing visual impact

Different countries have responded differently to the need for assessing landscape and visual impacts. However, within the European Union, most windfarms are required to carry out a defined process of Environmental Impact Assessment (EIA), controlled through Statutory Regulations. In the past, the Environmental Statement (ES) that reports the EIA was considered more as a technical document for decision-makers, rather than for the public for whom a 'Non Technical Summary' was targeted. Now, however, the public seems to increasingly expect to understand what is being proposed and how the impacts have been assessed within an EIA, particularly in relation to the landscape and visual resource. Consequently, although assessment methodology and illustrative techniques have always had to be transparent and robust, it is now increasingly expected that they should be easy to understand. Some of the techniques commonly used to inform the landscape and visual impact assessment part of an EIA are:

- "Zone of theoretical visibility"(ZTV) maps
- Photographs to record the baseline visual resource (subject to the limitations of photographs to represent conditions)
- Wireline diagrams to give a technical indication of the scale, shape and positioning of the proposed development
- Photomontages to show how the proposed development might appear in a photograph

As the saying goes, "pictures speak louder than words." Images are very powerful. This means that people often jump to the images within an ES report, without reading all the explanations and caveats. This provides a real challenge to the reporting of visual impacts. In addition, we have to keep in mind that different people interpret images in different ways and will often not appreciate the complexity of interpretation that is required for visualizations to be used as tools to understand potential visual impacts. This means we must try to provide visualizations that are not misleading, and we must be transparent regarding how these have been produced and how the information was used by the assessor carrying out the EIA.

Questions and Observations: UK and European Perspectives

In response to a question about whether the European Union uses a standardized Environmental Impact Assessment process, the key point made was that EU regulations require an EIA to assess the significance of landscape and visual impacts.

- The sensitivity of the resource and the magnitude of predicted impacts, results in a measure of significance.
- Every wind farm will result in some significant impacts. EU regulations require the developer to methodically identify and assess all of these impacts, but it is for the decision-maker to decide, finally, whether the significant effects are acceptable or not.

- The more objective we can be in the assessment of the impacts illustrated – or at least, the more systematic we can be about presenting the elements that influence perception, the better.

Discussion also focused on the topic of studies or analyses of peoples' preferences with respect to the visual impact of wind energy projects. The work of landscape architect Robert Thayer [Professor Emeritus of Landscape Architecture in the Department of Environmental Design at the University of California at Davis][3] in this regard. The question of whether the significance of a project's visual impact can be quantified was also raised and debated. Key points made during this discussion included the following.

- The basic principles of design are well-established – for example, using the artistic principles of focal points, repetition, scale, balance, single element v. co-dominance – and apply to wind farms as to any other project.

- Among other findings, Thayer has shown that giving people the same picture with different labels (e.g., "lake" v. "reservoir") makes a difference in their perceptions. Likewise, the image of a cooling tower has come to represent nuclear power, whether or not the structure actually is part of a nuclear power plant.

- Thayer's work also includes some effort to quantify people's response to changes in a landscape. This is difficult to do, but policy makers certainly appreciate quantitative measures of impact.

- The US Army Corps of Engineers has developed a methodology for quantifying whether response to change in landscape crosses some threshold. However, New York State does not accept numerical systems; only the legislature can establish such standards.

- Numbers can mask the many assumptions that are made in making these kinds of judgments. It's important to be systematic in laying out what assumptions are made in doing these analyses, and to do so in such a way that the lay reader can understand.

- There is a whole area of inquiry that attempts to tease out the many variables that influence people's perceptions of aesthetic impact, using interviews with groups of people rating slides of different landscapes. This multi-variant approach could provide a more nuanced quantitative assessment, rather than a single number.

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[3] *Gray World, Green Heart: Technology, Nature and the Sustainable Landscape*. Robert L. Thayer, Jr. John Wiley & Sons, 1993.

Visual Characteristics of Wind Turbines

J Hecklau-Visual Characteristics of Wind Turbines.pdf

John Hecklau, Environmental Design and Research

John Hecklau is a Principal with Environmental Design and Research, P.C. (EDR), an environmental consulting and design firm based in Syracuse, New York. Since 1995, Mr. Hecklau has overseen the majority of EDR's visual impacts analysis projects, including visual impacts analyses of over 20 commercial wind power projects.

For those not familiar with the visual characteristics of wind turbines, the basic components are:

- Tower – a tubular steel structure typically 70-90 m tall and 4 m wide at the base.
- Rotor – 3 blades spinning at approximately 10-20 rpm. The diameter of the circle described by the rotating blades (the rotor-swept area) typically is 70-100 m wide.
- Nacelle – Generally a rectangular shaped box or capsule, approximately 10 m long, 3 m wide, and 3 m tall, located at the hub of the rotor, and containing the equipment that converts the wind power captured by the rotor blades to electric power.

The total height of these structure, from ground level to the highest point of the blade tips, has gone from 100 ft. to between 100-140 m (330-460 feet) – much taller and larger than anything else you see in the rural environment.

Turbines in the landscape

Several factors result in a high level of visibility for wind turbines in most locations. In addition to being very tall structures, they typically are sited on high points in the landscape to take advantage of higher wind speeds and lower turbulence. Visibility is further enhanced by the motion of the rotor, as well as by the fact that there typically are multiple wind turbines within a project.

However, high visibility does not always equate to adverse visual impact. Based on public reaction to existing projects, wind turbines are not viewed in the same way as other highly visible infrastructure projects. Many people react positively to wind turbines because they see wind energy as clean, green. Wind is most likely to be perceived as compatible with working agricultural landscapes. (As wind developments become more common – as they become larger and more numerous – they are more likely to be perceived as being more industrial or utility-oriented facilities than as being in character with agricultural landscapes.)

The same structures are more likely to be perceived as out-of-character with other types of landscapes, such as wooded ridgetops or offshore. Such perceptions depend on viewers' personal attachment to a landscape and its value.

Turbine color. White or off-white is typical. Some of the offshore projects have red blade tips, and one project in Vermont used black blades because of concern about icing. There is a conflict between wanting to diminish visibility for aesthetic reasons and wanting them to be visible for FAA or wildlife purposes.

Turbine design. There is not a great deal of variability in the design of modern turbines; some are sleeker and more graceful than others. (See slide for examples of differently-shaped nacelles with variety of manufacturer logos.) As turbines get bigger, their rotors begin to appear disproportionately large. However, while balancing of rotor and tower proportions is important from an aesthetic view, economics trumps this consideration.

Facility design. Older projects tended to be smaller and well-defined (e.g., 7-20 turbines), and seemed to fit well in the landscape. However, multiple small projects using different turbine types and sizes, might be less graceful than a single larger project (25-75 turbines) if the larger project is well-designed.

Turbines may be arranged in a cluster, a line, or laid out in a grid. Where older facilities tended to be smaller and more remote, newer projects generally are larger (some in excess of 100 turbines) and located "in the community." Proximity to the viewer is certainly a factor. Offshore projects, while large and potentially "out-of-character" with their setting, generally are far away from most viewers. Turbines are always visible, and to an increasing extent they are no longer a discrete component of landscape, but a feature dominating the landscape.

Night-time visual impact

At night any positive connotation with wind power is lost – lights at night are more visible than the turbines are during the day. From the viewer's perspective, they could be cell towers, transmission towers, or anything. In a dark rural setting, this impact is significant.

When considering what the visual impact will be of FAA lighting, real world examples are the best, but simulations can be used. It is trickier to simulate nighttime visual impact than daytime impact. Ambient light in nighttime photos is hard to control, and the best way to depict turbine lighting is open to question. The usual choice is to present the clear (pinpoint) red light you would see on a clear night, but bear in mind that viewers will get something different when there is fog or low clouds. Also, the impact at night is more on residents, not on people traveling through (as it is in daytime).

The FAA's new wind turbine lighting guidelines represent an improvement, but while they provide flexibility, they do not eliminate the need for lighting. Mitigation options that need to be further explored include flash rate, intensity, and shielding.

Lessons learned

- Wind power projects usually fit well in a working agricultural landscape
- White color generally works well
- Visibility is highly variable with weather and sky conditions
- Do not underestimate visibility from distant locations

- Do not ignore the impacts of support features (roads, substations – especially when lighted – and interconnects).
- Aviation warning lights can have significant visual impact which should be addressed on a site by site basis, using the new FAA guidelines.
- People react more positively to moving turbines; the motion of the rotors actually reduces the visual impact.
- Clustering turbines in discrete groups is preferable, but the proliferation of clusters in an area can create the appearance of random siting
- Public perception has been overwhelmingly positive for built projects (in New York State) to date; but public perception/acceptance may change as projects proliferate and get larger.

Questions and Observations: Visual Characteristics of Wind Turbines

Questions about visual characteristics touched on lighting, paint schemes, and how wind turbines fare in comparison to other tall towers with respect to visual impact review.

With respect to lighting:

- Marine navigation lights (on off-shore facilities) have not posed a problem to date.
- Lighting has not been a problem in UK/Europe; we've always had screening from below.
- The Federal Aviation Administration (FAA) has ruled out screening lights from below because of a need to protect low-flying planes and helicopters, including search and rescue pilots who may need to fly low.
- Back-lighting may be worse than front-lighting from a visual impact perspective.

With respect to how cell towers have fared in comparison to wind towers with regard to public acceptance:

- In the UK, each cell company has its own mast [towers are not shared, as they are in the US] and this creates a big problem in terms of public acceptance. But wind farms don't seem to face the same opposition.
- A single cell tower in a single community doesn't get the kind of review that multiple towers in a wind project do. Size and movement are what call attention to wind projects. Also, widespread cell phone use has generated acceptance – even demand for – those towers.

With respect to paint colors to minimize visual impact:

- The FAA does not accept gray paint precisely because it reduces turbine visibility. In one instance, the developer could not use a dark marine gray because daytime lighting had been eliminated, and this would have presented an air traffic safety problem.
- The FAA does not distinguish among shades of gray; however, the FAA has been working with manufacturers on the color definitions.

Tools for Evaluating Wind Turbine Visibility

[*M Allen-Tools for Eval Wind Turbine Vis.pdf*]

Matthew W. Allen, Saratoga Associates

Matthew Allen, RLA, is an Associate Principal with Saratoga Associates, Landscape Architects, Engineers, and Planners, P.C., based in Saratoga, New York. Highly skilled in the application of advanced computer-generated visual simulation and viewshed development technology, he has served as a peer reviewer for the July 2000 NYS Dept. of Environmental Conservation Program Policy concerning visual impact assessment and mitigation, and serves as a third-party advisor to the NYS DEC helping state regulators understand and minimize aesthetic impacts associated with large development projects, with a focus on power generation and transmission infrastructure.

This presentation will cover four tools:

– Line-of-sight profiles
– Viewshed mapping
– Photographic simulations
– Shadow flicker

Line-of-sight profile is the oldest, simplest tool used to identify the degree of project (in this case turbine) visibility along a single line-of-sight. Traditionally done by hand drafting on a map, it can also be generated using digital systems such as computer-aided design and geographic information systems (GIS). The advantages of this tool are that it is simple, cheap, and easy way to quantify the degree of turbine visibility from a given location. However, because it only shows what can be seen of a single turbine along a single line of sight, it is not sufficient for complex projects.

Viewshed mapping is used to identify the geographic area within which there is a high probability some portion of the proposed project would be visible. This used to be done by hand plotting, but can now do be done digitally (using GIS-based systems). Viewshed mapping allows a quantitative measure of the geographical extent of project visibility, and allows one to see how project modifications will alter this extent. The area included within the "viewshed" limits the extent of visual impact analysis. This tool makes it easier to evaluate complex circumstances and "what if" scenarios.

The value of viewshed mapping is limited by the accuracy of source data. It tends to work better in more rural areas where there are fewer structures and plantings. Also, this tool does not quantify how much of each turbine is visible from various points within the viewshed. (See slide presentation for examples.) A viewshed map doesn't tell you what you will perceive from 20 miles away, it only tells you that you will have a line of sight to the project.

Example #1: viewshed map shows places within a 5-mile radius where you would be able to see at least one turbine of a 36-turbine proposed project.

Example #2: Given only topography (not vegetation), map shows how many turbines would be visible from various locations

Example #3: Same as example #2, but with vegetation added; note that in a largely forested area, vegetation is assumed to provide a 100% visual screen.

Note that this kind of viewshed mapping is just one step in the process.

Photographic simulations illustrate the degree and character of project visibility from a specified receptor. The traditional methods for creating a simulation were artist renderings (sketch, or airbrush on a photograph). There now exist many digital systems for creating photographic simulations. This is the easiest of all tools for the public to understand; the main limitation is that it provides only a momentary snapshot, and thus cannot take into account different weather and light conditions (time of day, season, etc.). Another limitation is that the public tends to focus on the photo, ignoring the bulk of the visual impact analysis. (See slide presentation for examples of photographic simulations.)

How accurate are photo simulations? How can you produce one that will accurately inform the visual impact analysis process? To testify as to the accuracy of a photo simulation, you have to know how it was produced.

The first requirement is a good baseline photo. The photo should be taken in good weather conditions, at an appropriate time of day, with the sun at photographer's back, from an unobstructed "worst case" vantage point. Other conditions for producing a good baseline photo include knowing where the project would be, using appropriate camera settings (45-55 mm focal length, which is comparable to human eyesight). It is important to record the field camera position so that it can be matched with GPS coordinates, and to record the time and date.

The next step is to create a digital elevation model, using the correct geographic position and scale, and sufficient detail to communicate the visual character of the landscape and to align the model with the photo. The overlay process requires matching the field and model camera positions (using GPS coordinates), aligning target context elements, and matching lens focal length, digital resolution, and light setting. Post-production editing involves eliminating context data and other adjustments (e.g., removing parts of towers that are blocked by other features).

Digital models can be used for still-frame or animated simulation, or even for real-time animated simulation. (However, these are expensive to produce.)

Shadow flicker is the visual impact of a rotating turbine's rotor shadow profile on the landscape. Flicker occurs when certain conditions coincide:

- Date and time – longer shadows cast when sun is low in sky
- Weather conditions – shadows more pronounced on bright, sunny days

- Wind direction – rotor orientation (yaw)
- Distance from rotor – light reduction diminishes with distance
- Topography
- Human presence in the shadow zone

Although there is little regulatory guidance or requirements on shadow flicker, 20-30 hours/year of flicker typically is considered the threshold for concern. Project developers are increasingly being asked to assess shadow flicker. This can be done using mathematical calculations (astronomy and trigonometry). A simple online calculator is available;[4] *Wind Pro*®, a modeling tool for siting, has Shadow Module software for evaluating shadow flicker exposure.

Modeling shadow flicker costs anywhere from $2,000-$10,000 to generate an animated photo simulation (fly-by). Building the model is the main component of up-front cost; once this has been done it is possible to do additional simulations at not too much additional cost.

Questions and Observations: Tools for Evaluating Wind Turbine Visibility

Questions touched on the phenomenon of "shadow flicker," the accuracy of photo simulations, and the use of other tools for evaluating turbine visibility.

With respect to the "shadow flicker" phenomenon:

- Delft University has conducted research on flicker effect. The same study also looked at mitigation measures – for example, planting a row of long skinny trees along a road.

- There is no rule-of-thumb regarding the distance from a turbine where shadow flicker may be an issue. However, if the shadow hits you at its longest point, you will not be in that shadow for long.

With regard to photo simulations:

- Haze could be added to a photo simulation, but the depiction may not be perceived as realistic.

- As to whether there have been comparisons made between photo simulations and post-construction photos, assuming the project layout doesn't change too much, and if simulation is done correctly, it is very accurate. However, rarely is anything built exactly as it was modeled.

- Walking people through the process of generating a photo simulation is one way to dispel the idea that it is "just hokus pokus that a sixteen year-old could do with a computer."

[4] http://www.windpower.org/en/tour/env/shadow/shadowc.htm

Sacred and Historic Places

[abstract only]

Konnie Wescott, Argonne National Laboratory

Many factors need to be considered when evaluating the visual impacts of siting and operating a wind energy facility. One such factor is sacred and historic places. Stakeholders who will view the wind development, or who have or manage resources in view of the wind development, will be critical participants in a successful project and will likely have information to share regarding sacred and historic places in the vicinity of the project. Early planning and coordination involving these local stakeholders is critical for (1) identifying and understanding their issues of concern regarding the addition of a wind facility to the landscape, and (2) formulating a productive approach for evaluating whether a wind project is feasible and could be successful in a particular area.

The principal stakeholders of interest when evaluating visual impacts to sacred and historic places are Tribal governments (Native American, Native Alaskan, or Native Hawaiian, depending on the location of the project), the appropriate State Historic Preservation Office(s) (SHPO), and local historical societies and organizations (e.g., various historic trails associations). Other members of the public may also contribute to the discussion, as the definition of sacred and historic places can be applied more broadly than intended here to describe important areas at a very personal level. However, this discussion is aimed at visual impacts to significant cultural resources, as defined in the federal regulations.

The National Historic Preservation Act (NHPA) of 1966, as amended, is applied when projects take place on federal land, use federal dollars, or require federal permits. This act requires consultation with the appropriate SHPO(s) and Tribes by the lead Federal agency regarding the proposed project. An evaluation of the potential impacts (including visual impacts) of the project to archaeological sites, historic structures or features, and traditional cultural properties that are considered significant (i.e., meet eligibility criteria for listing on the National Register of Historic Places) is required under Section 106 of the NHPA. Section 106 also describes the process for mitigating adverse effects to significant properties.

The earlier the SHPO and Tribal (government-to-government) consultation can be initiated (such as during the earliest planning stage prior to site monitoring and testing), the better for all parties involved. Potential impacts to sacred places are not likely to be known or anticipated in advance of meeting with the stakeholders; this information is not publicly available. Early consultation can save considerable time and expense if significant cultural resources are identified in an area being considered for wind development. A proactive stance by the developers, with a willingness to listen to stakeholder concerns and an appreciation for the need to identify areas of concern early on, can also facilitate the building of good will and cooperation.

Important tools for communicating the specifics of wind development projects to stakeholders are visual simulation software and a geographic information system (GIS). These tools allow for a spatially based, interactive dialogue among all of the parties and preserve certain confidentiality concerns regarding locations of sacred places and other significant archaeological sites that are protected from public dissemination under the Archaeological Resources Protection Act. GIS-based visualization software and tools not only allow stakeholders to view what a wind development might look like in a particular area, they also can enable viewing of the area from multiple vantage points, including from specific properties (like the center line of a historic trail or the window of a historically significant building), and they allow for manipulation of different design features to show possible mitigation solutions to some types of impacts. Visualization provides a clearer concept of the potential magnitude of impact from a variety of perspectives and allows both the developers and the stakeholders to explain their constraints and arrive at possible solutions for mitigating impacts.

Visual Analysis of Windfarms: Good Practice Guidance

C Stanton-Visual Analysis Good Practice Guidance.pdf

Caroline Stanton, horner + maclennan

One of the problems we run into when presenting visualizations of wind farms is that, however accurate they are in terms of being generated using the correct mathematical and technical formulae, people sometimes say: “we don’t believe you!” Project opponents produce their own photomontages that may show different things (depending on the methodology used), exacerbating the sense of mistrust. And, if people start questioning the visualizations, they will usually start questioning other impact data within an Environmental Impact Assessment (EIA).

To reassure people regarding the standards and processes for visual representations, Scottish Natural Heritage, the Government Agency charged with protecting Scotland’s landscape, asked horner + maclennan and Envision, a firm of computer simulation specialists, to produce a good practice guidance document for visibility maps and visualizations. The aim of this guidance is to ensure that the methods used are technically sound, and that their different strengths and weaknesses are understood. One difficulty with trying to do this is that the available technology is always changing. Within this presentation, I will talk about three tools considered by the good practice guidance:

- Zone of theoretical visibility (ZTV) mapping
- Viewpoints
- Visualizations

"Zone of Theoretical Visibility"

As was mentioned in an earlier presentation, the Zone of Theoretical Visibility (ZTV) map, also referred to as the "Zone of Visual Influence" (ZVI), the "Visual Envelope Map" (VEM), or simply, the Viewshed, is only as accurate as the data on which it is based. Moreover, it is only a first step in assessing potential visual impact, in that it only identifies potential visibility. It does not provide any information on the nature or magnitude of visual impacts that may result from being able to see a wind farm. For example, if you see multiple turbines from a distance, it doesn't necessarily mean that the impact is greater than if you saw a single turbine close-up. So the first thing to keep in mind is not to equate ZTV with potential visual impacts.

How far to extend the ZTV? This is a frequently asked question. Our advice is that it should extend far enough to include all areas from where there *might* be significant visual impacts. This is an iterative process, with the ZTV informing the landscape and visual impact assessment, and the assessment in turn informing judgment about the extent of the area where there is potential for significant impacts to occur. The good practice guidelines use turbine height as a starting point for how far to extend a ZTV, ranging from a 25 km radius for turbines up to 85 m tall, to a 35 km radius for turbines over 100 m tall. However, ultimately this decision should be subject to consultation and depend upon the specific circumstances of the landscape, the visual resource, and the type of development proposed.

How to present the ZTV? As with any tool, it is important that the information presented by the ZTV aids understanding. Considerations include the scale of the underlying map, the colors used to indicate different degrees of project visibility, and the number of bands used to indicate the various ranges of visibility (e.g. 1-9 turbines; 10-19, 20-29 etc.). Again, it is important to be clear when presenting the ZTV map and to indicate what the information can and cannot show. Be transparent about your methods, and about their strengths and limitations.

Viewpoints

Viewpoints are chosen within the landscape and visual impact assessment process to represent areas from where significant visual impacts of a wind farm may occur. Viewpoints are by definition static and site-specific, although viewers will usually see a sequence of views when moving through a landscape. The choice of viewpoints is very important. These should represent the most likely view types and viewer types (known as 'receptors'), taking into account (for example) different directions to the wind farm, distance to the wind farm, types of landscape character, and visual amenity.

Depending on the viewshed and the size and extent of the project, it may be necessary to explore viewpoints within a Study Area extending as far as 35 km, especially when cumulative impacts need to be considered. The process of viewpoint selection usually begins with the identification of high numbers of viewpoints within the Study Area, 35-40 not being unusual. This selection is gradually refined, often with the aid of computer-generated wireline diagrams, to focus on a smaller number of viewpoints where the visual impact is most likely to be significant.

Visualizations: three key issues

In developing our good practice guidance, three key questions have been repeatedly raised with respect to using visualizations, as discussed below.

1) How do you make a visualization "true to life"?

The reality is that you can't! We all know the case – when we look at our holiday snapshots, they never seem like the real thing. This is not just because of the limitations of our photographic skills, it is because photographs, although very powerful in conveying information, have significant shortcomings in being able to represent a scene. These limitations must be acknowledged.

- Recognize that you can only do so much with a 2-dimensional image.
- Photographs cannot represent what the human eye perceives. There are two issues to be considered in reproducing the visual experience: 1) adequate resolution of the image to ensure that sufficient detail is captured; and, 2) adequate contrast in the images as presented, to ensure that the detail is visible. Unfortunately, reproducing the full contrast range visible in a scene is, in general, impossible. On a bright day, the naked eye has a brightness ratio of 1000:1 between the brightest highlights and the shadows, while a good computer monitor's brightness ratio will only be about 100:1, and the printed page will be about 10:1.

These limitations are not a problem for the landscape architect whose analysis and judgments are based on site assessment. However, for many people – often including the decision-makers – there is not an opportunity to get out on site to compare printed images directly with real-life views and thus to carry out some calibration. For these people, it is very important to highlight the limitations of the images and how they should be interpreted.

2) What are visualizations for?

Visualizations are useful in different ways: as background information, as a tool for the assessor, and for others to understand the assessor's analysis and judgments. However, different people tend to use visualizations in different ways, depending on why they are using them and their ability and/or experience to interpret visualizations (generally based on having compared them in the past to built developments).

Wirelines are very useful for giving a technical indication of the scale and positioning of a proposed development. Because they are based on digital terrain data, wireline diagrams provide objective information. Typically, they are all that an experienced landscape architect will require to be able to predict the likely visual impact of a proposed development on site. However, photos of the baseline visual resource may help those unable to visit a site understand how the assessor has come to his or her judgments. In addition, for people unfamiliar with wind farms or with a particular landscape, a photomontage may be useful in combining the information provided by a photo and a wireline, rendering these to resemble what would appear in a photo of the proposed development. However, it is important to highlight that a photomontage will have the same limitations as a photograph – it cannot represent exactly what would be seen in reality and, for this reason, cannot compensate for the information that would be gained by a site visit

3) *How should visualizations be presented?*

In most cases where visualizations have been analyzed in comparison with a built development, they have found to be technically accurate. However, to appear accurate to the viewer, visualizations must be produced to a size exactly related to the geometry of the image, and held (by the viewer) at an exact viewing distance from the eye. Failures to meet these two criteria have been responsible for much misinterpretation of images. This frequently occurs because the viewer holds the visualization at a comfortable distance and then, when the image does not look right, assumes that the visualization is incorrect. Basically, for an individual photograph, the larger the image, the further it should be held from the eye to represent the real landscape beyond. Visualizations fail in two cases.

1) They are produced too small, requiring the viewer to hold the paper too close to the eye to achieve the correct viewing distance. This makes it impossible for the viewer to comfortably focus or compare the image with the landscape beyond.

2) They are produced too big, requiring the paper to be held at further than arm's length to achieve the correct viewing distance. The good practice guidance recommends that visualizations should be based on a viewing distance of 40-50 cm for material aimed at being hand-held.

In addition, misinterpretation of visualizations often occurs because the size of image is too small to be clear or does not contain enough information, or because the vertical or horizontal field of view presented was insufficient to convey the key characteristics of the visual resource. This often occurs when people crop images to fit standard paper sizes, rather than determining their paper size based on the nature and extent of information required to be presented. Cropping out the sky and foreground or failing to portray the full width of view can eliminate important context from the visualization. The good practice guidance recommends that images should be over 20 cm high for the sake of clarity, while the horizontal field of view should be determined by the landscape architect, based on the nature of the visual resource. When deciding which format and size of image to produce, it is always necessary, however, to strike a balance between facilitating the comparison of images, and the ease of practical use.

Summary

- A photograph or photomontage cannot reproduce the experience of an on-site view.
- Different people use visualizations in different ways for different purposes – the danger is that, while a sketched rendering is understood to be subjective, people expect photographic visualizations to portray an accurate 'real life' view and, if they find them unrealistic, they question the findings of the entire EIA.
- The presentation of visualization images should be determined on a case-by-case basis, based on the nature and use of information required.

Questions and Observations: Visual Analysis of Wind farms – Good Practice Guidance

When multiple projects proposed for an existing landscape, there is a great deal of complexity of information that needs to be incorporated into the analysis and presentation. Essentially, in this situation one has to show the range of scenarios associated with cumulative impacts. Some proposed projects might never be built; others may start small and expand.

It was also pointed out that a correction for the curvature of the Earth must be applied to the generation of ZTVs and visualizations.

Visual Impact Assessment: Practical Issues and Links to Research

T Priestley-Visual Impact Assessment.pdf

Thomas Priestly, CH2M Hill

Thomas Priestly is a Senior Environmental Planner with CH2M Hill, overseeing aesthetic analysis work for projects being developed in the firm's Western Region. He has over 25 years experience as a professional urban and environmental planner, researcher, and academic, with a focus on evaluation of the aesthetic, land use, and community acceptance issues associated with electric power facilities, including transmission lines. During the past several years, he has applied his knowledge and experience to the analysis of aesthetic issues associated with planned wind energy facilities in California and the Pacific Northwest.

This presentation reflects my background as someone who does visual assessment for a whole range of projects, not just wind. It also reflects a lot of the perception research that has been done. Understanding how perception informs visual impact analyses can help us to conduct analyses that will stand up to close scrutiny. I will touch on:

- practical problems in assessing the aesthetic effects of wind power;
- how perception research findings can address these issues;
- the available research and its limitations; and
- directions for a research agenda that can help fill in the gaps and meet the needs of practice.

We have the tools

As a starting point, we have reasonably well-developed tools for assessing aesthetic impacts. In the U.S., the paradigm for aesthetic impact assessment is the National Environmental Policy Act (NEPA), and the approaches to visual resource management developed by various federal agencies in response to NEPA requirements. The standard procedure for impact assessment entails the following steps.

1) Determine the viewshed.

2) Identify key viewpoints.
3) Assess existing conditions, including landscape character and quality, and view sensitivity.
4) Document the changes the proposed project will have.
5) Analyze those changes in terms of both the degree and the significance of the changes.
6) When required, identify mitigation measures.

As other presenters have mentioned, our assessment tool kit includes "zone of visual impact" (ZVI) analysis – or better yet, to use Caroline Stanton's term, "zone of theoretical visibility" (ZTV). We can do cross-sectional analyses, and we can create visual simulations – which, as Matthew Allen has demonstrated in his presentation, is *not* "something a 16-year old could do at home with a computer."

Practical issues remain

Despite our well-stocked tool kit, there remain many practical issues that are not entirely resolved. Applying these tools takes skill and judgement, both of which can influence your results and how well they can be communicated to public and to decision-makers. For example, in the case of ZVI (or ZTV) analyses, several such issues arise. (See slide showing ZVI analysis of projects on the high plateau along the Columbia River.)

- *How far out do you go with your zone of visibility analysis?* Oregon State's Facility Siting council stipulates a 30-mile radius – rather too far. Yet there is not a lot of consistency.
- *How do you present the information?* How do you indicate the number of turbines visible, and how do you take into account the different impact of turbines viewed from various distances?

Perception research can help to address these issues

There exists a body of perception research that can be useful in addressing these practical issues. In England, the "Thomas" matrix is used to identify the extent of the zone of visibility. But this matrix was developed at a time when the turbines in use were much smaller. It needs to be updated, and for different settings. Also, such a tool needs to be tied in with surveys of public responses to the presence of turbines in a landscape at various distances.

How do you indicate the number of turbines visible from various distances? You can't show 150 colors on a map; if you have 150 turbines, you have to group numbers of turbines in a way that makes sense. What is the difference to the viewing public between seeing 3 turbines and seeing 5? Or 12? It would be useful to get some idea.

Likewise, ZVI or ZTV maps are color-coded by number of turbines visible, but without taking into account the effect of distance. Seeing 20 turbines from a distance of two miles is very different than seeing 20 turbines from a distance of 15 miles. Is it worse to see one turbine at 100 feet, or the tips of 100 turbines at 30 miles? Again, it would be helpful to survey the public to find out what distance thresholds determine visual impact. Absent these surveys, you need to think carefully about how you present a ZVI analysis to public and decision-makers. Even the color selection can make a big difference in how the impact is perceived – red, for example, sends a negative signal.

For public lands, the US Forest Service and the Bureau of Land Management (BLM) have come up with ratings of landscapes' visual qualities and how much change allowed. Some states (Oregon, New York) have designated scenic areas. In other places, we have to come up with our own assessments. The Federal Highway Administration's designation system is useful in more "humanized" landscapes.

There is a whole body of research relevant to the selection of scenic viewpoints and assessment of existing conditions (e.g., Buhyoff, et al. – see bibliography). Local postcards are a good indication of what scenes are considered iconic to the community. It also is important to consider what's representative of larger landscape. Most of the people who will perceive the project will do so when looking out their windows or going about their daily business; these are not what would necessarily be considered the "sensitive" views, but you have to take them into consideration.

The next step is the assessment of visual change and identification of appropriate mitigation measures. To what extent do residents and travelers notice turbines, and how do they perceive them? We can look to the basic principles of design and siting that Caroline Stanton described. We can make use of Federal agencies' visual assessment paradigm: to what extent do turbines change character of the landscape, dominate the landscape, etc. It is helpful to go back to the literature, but again, there is not much specifically on turbines.

"Environmental Design Research" (EDR) offers a useful paradigm in response to the needs of project designers and planners. EDR employs environmental psychology principles that systematically assess people's perceptions (see slides about perception studies), using such methods as: observational studies, interviews and surveys, focus groups, responses to photo images, post-occupancy evaluations, and perception studies. Perception studies document and analyze the affected population's perceptions and evaluations of completed projects. They consist of:

- Surveys of the affected population, including perceptions, demographics, and other data related to the individual

- Field work and map analysis to document each viewer's physical relationship to and views of the project

- Statistical analysis, including both simple descriptive statistics and advanced analysis to establish causal relationships

Questions that studies of perceptions of wind projects can help to answer include:

- What are the context variables that influence how noticeable a project is and the perceived level of impact?

- What is the effect of distance from turbines and the number of turbines on noticeability and the perceived level of impact – are there thresholds? Do the thresholds vary with context?
- How do project design variables (turbine dimensions, spacing, color, lighting, grading) affect perceptions?
- How effective are mitigation measures?
- When and how are cumulative impacts perceived?
- Do perceptions of impact change over time? (This is of particular interest.)

There are a number of examples of wind power perception research. (See slide presentation for list, bibliography for complete citations.) However, it is a small body of research, not always easy to access. Many of the studies were based on earlier projects that are not representative of wind projects being proposed and built now. These studies tend to rely on simple, descriptive statistics, and differences in study design and question formulation limit the potential for cross-study comparisons.

Steps toward research that links to practice

Research that links to current practice would enable us to better understand how and why people respond to wind projects and how siting and design can make these projects more acceptable. The International Electric Transmission Perception Project is a precedent for such an integrated research approach related to the needs of practitioners. Specific recommendations:

- Create an informal international network of practitioners and researchers interested in wind project perception issues.
- Interest national research institutes and regulatory agencies in supporting a coordinated program of perception research.
- Compile the existing research in a systematic way, and make it more accessible.
- Develop standard conceptual frameworks and uniform study designs to guide and facilitate further research.
- Identify what the most important questions are, and develop standard questionnaire items to facilitate comparison of findings.
- Coordinate research efforts, replicate studies, apply findings to practice, and continue to apply feedback from practice to research design.

Questions and Observations: Practical Issues and Links to Research

People with different attitudes towards wind power may have different physiological responses to noise from those projects. Likewise, overall attitudes towards renewable energy in general and wind power in particular affect how people evaluate projects' aesthetic impact. Environmental psychologists have studied how disposition affects the way people attend to sensory input. Perceived impact of a project is in part a function of how people see the land: whether as an economic base or as a "retreat" from economic activity. This is something that can be learned by doing social surveys.

Facilitator Abby Arnold commented that mapping exercises are sometimes used in mediations to bring out people's concerns. In the case of assessing the visual impact of a wind project, rather than bringing people a set of completed maps, it might be useful to bring people together with a blank map and get their input as to what should go into that map. In other words, integrate the mapping exercise with the stakeholder interview process. Involving the community early on in developing the map may result in an assessment that stakeholders (both pro and con) feel is more representative of their reality than a map produced by a landscape architect and delivered to the community. Several participants commented on the topic of when, how, and which stakeholders might be brought in to discuss wind turbine siting.

- Group mapping is a great idea – however, with wind projects the main changes you can make have to do with layout and land acquisition. It is important to do as much evaluation as possible of secondary sources before bringing people to the table.

- When dealing with a local site-specific issue, it is important to consult with people early on to ask them "what does it look like to you?"

- It is important to look at social sensitivity, but whom do you consult and how? Sometimes locals are fine with a development, but people living in a city many miles away perceive that area as part of their national heritage.

- There's always someone who comes out of the woodwork at the last minute and says "we weren't consulted!" You have to be transparent about the process.

- It is important to break it down to what people's issues and concerns are – to get away from just "for" and "against." People can and do change their ideas, if they are given robust information on which to base that change. Often people against a project are few but more vocal than people who are either in favor of the project or neutral.

SESSION II:

LIGHTING, FAA REGULATIONS, AND AIR HAZARDS ISSUES

The purpose of this session is to explore the potential effects of wind turbine construction on aviation, and establish an understanding of how wind turbines might impact aviation safety. Participants should come away from the session with a thorough understanding of how turbines can impact aviation safety, what can be done to minimize any safety risks, and ways to promote a favorable relationship between developers, the FAA, and the military. [Questions and discussion are summarized following the two presentation summaries.]

Obstruction Lighting for Wind Turbine Farms

J Patterson - Obstruction Lighting for Wind Turbine Farms.pdf

Jim Patterson, Federal Aviation Administration (FAA)

Jim Patterson is an Airport Safety Specialist with the Airport Technology Research and Development Branch at the FAA William J. Hughes Technical Center in Atlantic City, NJ. In cooperation with the Department of Energy, the American Wind Energy Association, and the FAA's Office of Air Traffic, Jim has been managing a research effort specifically focused on developing FAA Obstruction Lighting Standards for wind turbine farms.

The Federal Aviation Administration (FAA) is represented at this meeting because we want to get the word out, to educate the wind industry so that obstruction lighting can be less visually obstructive.

Why does the FAA have to get involved?

Any structure 200 feet or more above ground level is considered to be within navigable airspace. The Federal Aviation Administration (FAA) is concerned with ensuring that pilots can see and avoid any such obstructions, particularly after the sun goes down. Hence, the FAA requires obstruction lighting on tall structures such as wind turbines.

There is increased interest in renewable energy and increased development of wind energy facilities in many parts of the county. In many cases, large arrays of wind turbines (over 200 towers) are being proposed. A single wind farm may consist of turbines extending over 20 miles along a mountain ridge. Previous standards called for some kind of lighting on each turbine. But is that always necessary? Are there situations in which the entire wind farm might be treated as a single obstruction, rather than each turbine being treated as an individual obstruction?

Because the FAA is organized regionally, the wind industry has received different obstruction lighting requests from different regional FAA individuals. In some cases, more than one light has been required for individual turbines. Some turbines have been fitted with steady on lighting, some with flashing lights, some red, some white.

FAA-DOE Interagency Agreement

Recognizing the need to resolve these inconsistencies, the FAA and the Department of Energy (DOE) signed an interagency agreement to come up with the most effective and efficient technique for obstruction lighting. Aviation safety remains our primary concern. However, we also recognize that lighting requirements in excess of what is necessary for aviation safety can pose problems for wildlife, the surrounding community, and for the wind industry. Lighting requirements have to address the various sizes and configurations of wind energy developments. At the same time, we want to be consistent across FAA regions.

FAA Advisory Circular AC 70/7460-1K, which explains how to do obstruction lighting, was published in 2000, and needed to be updated. We decided to conduct airborne evaluations at four DOE-selected sites: Somerset, PA, Clear Lake, IA, Big Spring, TX, and Tehachapi, CA. The sites are representative of differently configured wind farms in different parts of the country. The Tehachapi site, for example, consists of long strings of turbines on ridgelines. The Texas site consists of clusters on top of mesas. The Iowa site is on more level terrain, but likewise presents a layout that is not well-defined. An additional seven sites were evaluated because of their proximity to the original four sites.

The preliminary report consisted of analyses of flight evaluation results at each of the 11 sites. We then used simulation and modeling techniques, as well as the creation of an actual test site, to evaluate the effectiveness of the updated obstruction lighting guidelines on typical wind farm configurations. Our final report provides recommendations for guidelines to be published in new Advisory Circulars.

Preliminary conclusions

Several preliminary conclusions can be drawn from our analyses.

Lighting needs to be seen not from above, but from the sides. In many cases we found FAA lighting mounted on the back of the nacelle, which is useless. Light fixtures mounted to the turbine housing should be positioned above the rotor hub.

Position lighting on the outer turbines. It is not necessary to light interior turbines within a cluster.

Maximum separation gaps for "unlit" turbines should be ½ statute mile (804 meters). European standards, which are based on FAA standards, use 900 meters – roughly in the same ballpark.

Simultaneous flashing lights or strobes are highly desirable. A wind farm with multiple lit turbines all blinking on and off at different rates creates a red glow that communities don't like, and pilots find distracting. More than one light coming on together tells a pilot this should be treated as a single structure. (Red or white lights may be used, but not a combination of the two.)

Red flashing lights of 2000 candela are preferred. Red is easier for pilots to work with. However, if white strobes are used, it is best to use them alone without red, as this combination is very distracting.

Mount lights on meteorological towers. Met towers make cost-effective, unobstructed platforms on which FAA safety lights can be mounted.

Daytime lighting can be omitted on white-painted turbines. Unlike a cell tower, which is more skeletal, a wind turbine can be seen easily in daytime, but only if both tower and turbine blades are painted white. The FAA won't require turbines to be painted white, but if they are not painted white, then daytime strobe lighting will be required. (White turbines provide dramatic contrast to virtually all types of terrain – even snow.)

There is no need to use two light fixtures on a single turbine. Provided that a site is well-maintained (i.e., lights are replaced if they fail), temporary blocking out by rotor blades is not a problem.

Lawton, Oklahoma was selected as a test site for the newly developed FAA standards. The test site became operational in June 2004. It is a long ridge site with three smaller clusters to one side of the ridge. (See slide for illustration: 43 turbines with only 14 lights.) Evaluations were conducted of the new lighting configuration in August 2004. So far, we feel that the test site supports the revised standards. Washington now has the data (from Final Technical Note, published 11/05) from this project, and interim guidance material is being distributed to the FAA regional offices. A revised Adivsory Circular is expected to be issued in the first quarter of 2006.

In conclusion…

Synergistic approach to lighting. Some points to keep in mind when designing your site:

- Maximum ½ statute mile between lit turbines
- Standards have to be designed with low-flying aircraft in mind.
- LED or "rapid-discharge" lights that can go on and off again immediately are preferable to incandescent lights.
- Other countries (through the International Civil Aviation Organization, or ICAO) are adopting many of the FAA's guidelines.
- Lighting should only be utilized for a reason.

General aviation v. military. Both general aviation and the military are concerned with low-altitude flight, including search and rescue work involving rotor-propelled aircraft. The military flies heavier, more maneuverable equipment at faster speeds. General aviation requires basic flight training, whereas military pilots have advanced training, using more sophisticated equipment. Wind turbines located in remote areas are more likely to encounter issues with use of military airspace.

Wind Energy Development and Air Force Flying Operations

W Crowe-Wind Energy Dev and Air Force Operations.pdf

Major William Crowe, US Air Force

Major Bill Crowe is the Chief of Airspace Policy, Headquarters United States Air Force, Washington, DC. His responsibilities include establishing Air Force procedures and guidance on reviewing wind energy proposals and the coordination required with other Air Force agencies to assess the potential impact to Air Force flying operations. He also serves as the Air Force representative to the Airspace Subgroup of the Department of Defense's Policy Board on Federal Aviation.

The Department of Defense (DOD) is very supportive of renewable energy. However, the Air Force is a very traditional organization, conservative, slow to change. We are not familiar with wind energy, and are in the process of trying to get up to speed. People at military bases have not known what to do with wind energy proposals. Air Force Headquarters is not in a position to evaluate whether a proposed wind energy project is problematic for a given base. But we are now trying to provide some guidance to help coordinate between developers and local bases.

Air Force review procedures

The military has a number of functions that involve special use of airspace. Restricted air space includes areas where weapons are tested and where air to air combat maneuvers are practiced. We have military training routes where people practice navigation skills.

When a developer submits a proposal to a local air force base, that unit is responsible not only for assessing the impact to its own flying mission, but also for coordinating with other units that could potentially be impacted. For example, a wind energy facility proposed for a site in California may actually interfere with the operations of a unit in Texas that has a training route through the proposed California site.

When a unit gets a proposal, the contact person should ask the project proponent how long they have to respond; the unit has to work with others in the Air Force to evaluate the proposal.

Factors to consider

Flight safety is the first consideration. Other factors to consider include:

- *Electromagnetic interference* with on-board navigation and missile guidance systems, ground based radars, and other electronic equipment (radios, data link equipment, etc.)
- *National security*. In some of our remote ranges we are considering putting up wind farms to provide energy resource locally. There are areas on our ranges no one can overfly or view from close distances for security reasons.
- *Associated structures*. Factor in associated equipment and power lines when you come to a unit for evaluation. We need to know not just where the turbines are going to be, but also where other structures will be.

Community outreach

One area where we have been weak is community outreach. We are trying to get and stay more engaged with local and state planning commissions, encouraging permitting officials to let us know if they get wind proposals. We are also using public forums and the media to educate the public about our unit mission and flying areas, some of which are changing as bases are closed.

Airspace Stoplight Chart. Edwards Air Force Base has done this, and found it to be a very helpful tool in Kern County, California. We're asking other bases to do same. (See slide for illustration: green = no problem; yellow = come and talk to us; red = no.)

Public meetings scheduled. Stakeholders are invited to come to our public meetings, put faces to names, and establish relationships so that we can communicate. We need to know what you're doing. Contact Major Bill Crowe (William.crowe@pentagon.af.mil). Scheduled meetings:

- West - January 18-19, 2006 (Phoenix)
- Southeast - February 22-23, 2006 (Savannah)
- Northwest - March 22-23, 2006 (Salt Lake City)
- Eastern-New England – April 19-20, 2006 (Pease, NH)
- Central-Great Lakes – May 17-18, 2006 (Volk Field, WI)

Questions and Observations:

Session II - Lighting, FAA Regulations and Air Hazards Issues

Asked whether there had been any reported incidents of aircraft colliding with wind turbines, Jim Patterson responded that the FAA has only one record of a collision – not with a wind turbine but with a met tower. (There were in this case extenuating circumstances.) The question was raised as to whether lighting could be shielded from below to minimize visual impact from the ground.

- The logic [used in the UK] was that if the light is situated at the nacelle, there shouldn't be a need to see it from ground level up to 10 m above ground level.

- The Federal Aviation Administration (FAA) has ruled out screening lights from below because of a need to protect low-flying planes and helicopters, including search and rescue pilots who may need to fly low.

- While the [FAA] cannot promise no light anywhere below the nacelle, lights below the nacelle should require less than half the intensity (~ 700 candela v. 2000 candela). The fixtures are designed to shove most of the light upward; so, by design, you shouldn't be seeing bright light from below. Possibly you could baffle the light fixture so that nearby structures don't see any light from below.

The question was raised whether there was a way for developers to communicate with all branches of the military (not just the Air Force). One participant commented that developers can submit maps, including coordinates for each of the turbines (and other structures) in a proposed facility, to the National Telecommunications and Information Administration (NTIA). NTIA in turn will submit the information to all branches of the military, each of which is given an opportunity to review maps, coordinates, turbines, and schedule. NTIA then comes back to the developer – typically within 30 days – with a response.

Major Crowe offered the following comments:

- As long as the information is getting to the units, then I don't need to be involved. My job is to make sure the process works. Keep in mind that, just because one person in the Air Force knows something doesn't mean that the people at the local units know it.

- Right now we're focused on establishing the wind energy policy for the Air Force. Eventually, we would like to see a Department of Defense policy – but it's hard to get everyone together.

- Some training protocols require low-flights. We already have "bubbles" where we have to fly higher to satisfy the noise requirements of small towns. We can't have too many bubbles. It's not so easy to re-do routes, because we have to do a new Environmental Impact Statement.

- There is nothing that says you (a developer, a consultant) can't contact a base and find out about special use airspace.

Developers commented that they have to look on a broad scale for possible sites – e.g., up and down a coast. How should developers proceed? Are there Web sites they can use to identify special use airspace they need to avoid? Are there any special issues with regard to the Canadian border? Who in the US government should developers be talking to? Major Crowe responded:

- There are four of us at the Pentagon who are dealing with airspace issues. I can tell you who to talk to, and you can access the following Web page: http://sua.faa.gov. However, keep in mind that just because there is special use air space doesn't mean you can't develop wind energy, only that you need to check with the unit (or with me) to find out about how that air space is used, and what restrictions there are.

- The Department of Homeland Security (DHS) is involved with airspace also. The Canadian border probably doesn't present an issue, because DHS mostly is operating at a very high altitude (though if they have to come down to the ground to apprehend someone, it may become an issue). Although DHS has no plans to establish special use airspace, they may be involved in utilizing military special use airspace. As DHS has no airspace management personnel, in the interim, Major Crowe is the best person to contact for any issues regarding DHS operations.

SESSION III: SOUND

As wind turbines move closer to people and their communities, there are questions and concerns about the sounds wind turbines emit. This session will present the issues, tools, facets, regulation, and perspectives of wind turbine sound and siting.

Arlinda Huskey (NREL), Moderator

This panel will talk first about sound measurement, then about infrasound and psychoacoustics, then about modeling and the European perspective, and finally about United States regulations and experience from the West coast. References are provided in the bibliography. [Participants were asked to hold questions until the end of the session.]

Wind Turbine Noise

J van Dam- Wind Turbine Noise.pdf

Jeroen van Dam, Windward Engineering

Jeroen van Dam has about ten years experience in the testing and certification of wind turbines. Prior to being employed by Windward Engineering, he worked for Underwriters' Laboratories (UL), the National Renewable Energy Laboratory (NREL), and the Energy Research Center of the Netherlands (ECN). He has been actively involved in the International Energy Certification (IEC) and Cenelec committees writing noise testing standards.

Terminology

There are several terms useful for discussing wind turbine noise. The two most important terms are *sound power* and *sound pressure*.

- *Sound power* level (L_{WA}) is a measure of the *source* strength.
- *Sound pressure* level (L_{aeq}) is a measure of the sound level at a receptor (e.g., a neighbor's house, a microphone). Both are given an A-weighted equivalent to compensate for the human ear's sensitivity over a range of frequencies.

People often confuse sound *power* with sound *level*, obtaining a sound power (source strength) level from a turbine manufacturer, and comparing it to tables showing sound pressure levels for various noises. (See slides for table.) Typical sound *power* values for wind turbines are in the range of 90-105 dB(A), L_{WA}. However, at a distance of 350 m, the sound *pressure* level for a wind farm is typically less than 45 dB(A), L_{aeq}. This is within the range of a rural night-time background sound pressure level. (The sound pressure level in a quiet bedroom measures about 35 dB(A).)

The dB scale is logarithmic. So, for example, doubling the distance between a turbine and the sound receptor reduces the sound pressure level 6 dB Doubling the number of turbines at the same distance does not double the sound pressure level measured at a receptor point. For example, two turbines each producing a 40 dB(A) sound pressure level will together produce 43 dB(A); a turbine producing 40 dB(A) together with a turbine producing 45 dB(A) will have the combined effect of producing 46 dB(A). Other terms used to measure the impact of sound pressure levels are L_{90}, which refers to a noise level exceeded 90% of the time, and L_{dn} (or "DNL"), which refers to a 24-hour average of energy averages over each hour, adding 10 dB to night-time noise, because people are more susceptible to noise at night.

Turbines have several parts that generate noise. These include the gearbox, cooling fans, the generator, the power converter, hydraulic pumps, the yaw motor, bearings, and blades. (See slide for diagram.) Modern turbines are designed with noise-reduction in mind, with improvements in noise ratings of turbines, insulation of nacelles, proper mounting of gearboxes, and other developments.

Measurement standards

The International Energy Agency (IEA) has recommended practices for wind turbine testing, including Part 10, "Measurement of noise emission from wind turbines at noise receptor locations." Measuring the source and calculating emission typically is preferred. Background noise increases with wind speed, tending to mask turbine noise. Typical background noise sound pressure levels range from 30-45 dB(A). From a measurement perspective, it is difficult to distinguish turbine and background noise.

IEC 61400-11, 2nd edition is the international standard for turbine noise measurement. It defines measurement techniques that are widely accepted, producing high quality, reproducible results used for certification. These standards take three years to revise. *Measnet* is an unofficial standard based on IEC; because it is unofficial, it can be more quickly revised. AWEA also has an IEC-based standard. IEC also has a standard for the "Declaration of sound power level and tonality" (*IEC 61400-14*).

Results and conclusions

The IEC 61400-11 method calls for a microphone placed at ground level, downwind of the turbine at a distance equal to the total height of the turbine from base of tower to tip of blade (tower height plus half the rotor diameter). For wind speeds ranging from 6-10 m/s at a height of 10 m above ground level, the IEC method measures:

– Apparent sound power level
– 1/3rd octave spectra (used for propagation models)
– Directivity (optional)
– Tonality

Low frequency noise and impulsiveness are not quantified. A correction is calculated for background noise and the apparent sound power level is calculated based on the background-corrected sound pressure level. (See slides for correction and apparent sound power level calculations, and for graphs illustrating results.) Peaks in the sound spectrum represent tones. (Surrounding frequencies, which may mask the tone – are referred to as the "critical band.") Tones may result in penalties that need to be added to the sound power level.

The main conclusions to take away from this are:

- *Turbines make noise.*
- *Standards are available for determining the source and receptor levels.*
- *Noise level is not the only important measure* – sound quality and psychological attributes affect perception.

Infrasound and Psychoacoustics

A Rogers Infrasound and Physchoacoustics Corrected.pdf

Anthony L. Rogers, Ph.D., University of Massachusetts

Dr. Rogers is the Director of Research and Technology at the Renewable Energy Research Laboratory (RERL) at the University of Massachusetts at Amherst. He has been with RERL since 1996, focusing on wind turbine dynamics and testing, hybrid power system design issues, wind resource measurements, and teaching. He is co-author of a graduate level textbook, Wind Energy Explained: Theory, Design and Application.

Sound and Infrasound

Sound is defined as vibrations in the air down to the frequency of 20 Hz. Vibrations at frequencies below 20 Hz are defined as *infrasound*.

There are many sources of infrasound, both natural and anthropogenic. Natural sources of infrasound (between .001 Hz and 2 Hz) include ambient air turbulence, waves on the seashore, meteorites, distant explosions, among many others. Man-made sources of infrasound include: road vehicles, aircraft, machinery, artillery, air movement machinery, wind turbines, compressors, ventilation units, and many other human activity-based vibrations.

Sound measurement uses frequency weighting to approximate the response of the human ear to different types of sound. A-weighting approximates the response of the human ear to sounds of medium intensity, and is used to assess environmental and occupational noise (see Jeroen van Dam's presentation, above). C-weighting approximates the response of the human ear to loud sounds. G-weighting is designed for the measurement of infrasound.

Human Perception of and Response to Infrasound

Human perception of sound vibrations is a function of frequency. We perceive sounds ranging in frequency from 2-100 Hz. The primary human sensory channel for infrasound is auditory, but our perception is a mixture of auditory and tactile sensations. Between 16-18 Hz, we lose the perception of tonality. Because of long wavelengths, we may hear something but not perceive where it is coming from.

Perception threshold increases as sound frequency decreases. At frequencies as low as 20 Hz, most people will not hear anything below 80 dB. However, the standard deviation of human response to perception thresholds is about 6 dB. Some people will start perceiving 100 dB at 10 Hz, but some people require higher dB to perceive anything at all at 10 Hz.

At the same time, human sensitivity to increases in dB level is greater at lower frequencies. So, for example, whereas a 10 dB increase at 1000 Hz (high-frequency) causes us to perceive a doubling in the sound level, it takes only a 5 dB increase for us to perceive a 20 Hz sound to have become twice as loud. Given the variability in human hearing, at low frequencies, small differences can have a highly variable impact on different people in terms of how annoying the sound is.

The primary effect of loud infrasound is annoyance, with resulting secondary effects. Annoyance, in turn, is a function of the sound's intensity and temporal variation (impulses, loudest sound, periodicity, etc.). Human sensitivity to such annoyance is affected by the type of activity creating the sound, the number of events, and the time of day.

When sound vibrations occur at too low a frequency to be "heard" as a tone, we perceive the sound as a feeling of static pressure. Other "annoyance mechanisms" from loud infrasound include periodic masking effects (at medium and higher frequencies), and the rattling of doors, windows, and other objects.

Contrary to rumors (including "information" which may be found on the Internet), infrasound is not dangerous unless it is very loud. Some humans may experience fatigue, apathy, abdominal symptoms, or hypertension when exposed to infrasound levels at about 115 dB(G). At 10 Hz, the threshold of pain is about 120 dB(G). Exposure to infrasound at 120-130 dB for a period of 24 hours causes physiological damage. It is important to reiterate, however, that *there is no evidence of adverse effects below 90 dB(G)*.

Infrasound Emissions from Wind Turbines

Sound pressure levels decrease as sound propagates. This is a function of:

- absorption by ground cover (varying with the terrain and frequency content of the ground cover)
- molecular absorption (which decreases at low frequencies), and
- spherical radiation, which causes sound pressure level to decrease 6 dB with doubling of the distance between sound source and receptor.

Infrasound does propagate more efficiently – that is, it can travel further with less diminution – than audible sound.

There is a big difference between sound emissions traveling upwind from the rotor v. those traveling downwind from the rotor. When wind passes the turbine tower before passing the blade, there is a sudden change in aerodynamics, creating a pulse that can rattle windows and cause vibrations. Downwind rotor design is no longer used by commercial turbine manufacturers. All modern utility-scale wind turbines have upwind rotors, emitting broad band noise emissions that include low-frequency sound and infrasound.

Note that the "swish-swish" noise created by rotating blades – caused by the change in amplitude as blade gets closer and further away – is *not* infrasound. This sound diminishes with distance and blurs with multiple turbines.

Examples of sound profiles measured at specified distances (80-118 m) from various turbines show the range of sound pressure levels at various frequencies, including the infrasound range (see slides 16-19). For turbines ranging from 450 kW to 2 MW, maximum sound pressure levels are well below the perceptibility threshold of 90 dB. At 10 m/s wind speed, the infrasound level measured at a distance of 80 m from a 850 kW Vestas peaked at 70 dB, well below perceptible levels. Measurements taken at 100 m from a single turbine can be used to calculate low frequency sound pressure levels at a distance of 400 m from a wind farm. (See slides #20-21 for calculations and results.)

To conclude, the ear is the most sensitive receptor of infrasound; if it cannot be perceived, it has no effects. Modern turbines do emit infrasound, but at levels below the minimum threshold of perception for most of the population, and well below the threshold for any adverse effects.

Psychoacoustics

Psychoacoustics is the psychological study of hearing, including the study of the subjective and behavioral responses of human listeners to sound. Characteristics of sound that affect human perception include:

- *Amplitude* – changes with time;
- *Frequency content* – broadband, distinct tones, overall spectral character, harmonic content, changes with time; and
- Other *temporal characteristics* – duration, periodicity, impulses

Sound perception thresholds vary with frequency and vary from one person to another. Nearby tones may not be distinguishable. Sounds may be masked by louder sounds.

Lessons from Research on Community Noise Sensitivity. A meta-analysis of 136 community noise studies found that noise annoyance is only weakly related to noise levels, with the relationship being strongest at low noise levels. Annoyance is related to:

- Noise sensitivity
- Fear of danger from the noise source

- Attitudes toward noise prevention
- Attitudes about the importance of the noise source
- Annoyance with non-noise aspects of the noise source

Even at low noise levels, a small percentage of people in these studies were highly annoyed.

A 1993 study by Wolsink et al. looked at 564 people exposed to a sound pressure level (SPL) of 35 dB(A) +/- 5 dB. Only 6% of those surveyed were annoyed, with only a weak relationship between annoyance and A-weighted SPL. Variables related to annoyance included stress related to turbine noise, daily hassles, visual intrusion of wind turbines in the landscape, and the age of the turbine site. (Annoyance decreased the longer the facility was in operation.)

A more recent noise sensitivity study (Pederson and Waye, 2005) looked at 518 people in a rural setting. Respondents were divided into six SPL categories. Annoyance was found to increase with noise level, but factors other than noise levels also were found to strongly affect annoyance.

The perception of annoyance with noise rises more quickly with wind turbines than with other stationary industrial noise sources. People with negative attitudes toward wind turbines and their impact on the landscape are more likely to be annoyed by turbine noise than are people with positive or neutral attitudes towards turbines. Negative attitudes towards wind turbines (and corresponding annoyance in response to turbine noise) was greater when respondents:

- saw the countryside as a place for peace and quiet rather than a place for economic activity;
- felt a lack of control (lack of awareness turbines were going to be built, inability to stop the noise when it annoyed them) or a lack of influence;
- sensed that they were being subjected to an injustice or that others did not understand the implications of living close to a wind turbine.

Careful work at the planning stages of a project may help to address some of these factors, thus mitigating noise concerns.

[See slides for overview of sound and infrasound and sound characterization terms and measurements, and for references.]

Propagation of Noise from Wind Turbines on-shore and offshore

B Sondergaard-Propogation of Noise from Wind Turbines.pdf

B Sondergaard - European Perpectives.pdf

Bo Søndergaard, Danish Electronics, Light and Acoustics (DELTA)

Bo Søndergaard is a Project Manager in the Wind & Energy Department of Danish Electronics, Light & Acoustics (DELTA). Mr. Søndergaard has 18 years of experience at DELTA in the field of measuring and calculating noise, with special interest in measuring noise from wind turbines using Danish and international standards in Denmark and other countries.

There are multiple noise propagation models (see slide). Most of these were developed for noise from industry, for wind speeds below 5 m/s, and for standard meteorological conditions. All of these models must be expected to give poor results at larger distances. Most of these models calculate only downwind noise propagation. Upwind propagation should (ideally) be calculated differently, taking into account the shadow zone (see slide).

Models designed more specifically for wind turbine noise propagation include a Danish and a Swedish model (see slide), as well as the Nord2000, a new model which can handle complex terrain with varying surface conditions and varying terrain and meteorological conditions.

Factors determining noise propagation

In noise propagation models, the starting point is the source strength (L_W) describing the total amount of acoustic energy emitted by the source, in this case the wind turbine. The source strength is modified by correction factors for:

- *Distance* (spherical spreading)
- *Air absorption* (varies with weather conditions)
- *Reflection*
- *Screening* (terrain affects noise just as it affects sightlines)
- *Vegetation*
- *Ground* (see slides)

The *ground effect* takes into account how sound waves reflected from ground surface interfere with sound waves reaching the receptor directly from the source. It is a key factor to consider in differentiating upwind from downwind propagation. The relative hardness or softness of the ground determines how much is reflected. The worst case (most reflective) is hard ground – which applies to offshore propagation. In the Danish model, agricultural land is treated more like hard ground than like soft ground overestimating the noise level by 1 – 1.5 dB. The Nord2000 model allows for detailed description of the ground reflection characteristics.

Different models yield different results

Examples of model behavior (see slides) show the combined effects of screening and ground effect for downwind and upwind propagation in mountainous v. flat terrain. Also shown is the “shadow zone” effect for upwind propagation, which becomes more pronounced over water.

The various models incorporate the ground effect differently, with different results (see slides). The ISO 9613-2 model is quite good for the downwind situation, but not for upwind. The Nord2000 model is better for modeling upwind noise propagation. This differentiation among models can be problematic. It is not just a question of buying software, putting in some data and getting results. Expertise is required to use and interpret the results of these models.

Tonality can be measured near the source, but as you get farther away you lose a well-defined particular tone. In general it is not possible to calculate the tonality at the receptor from measurements close to the wind turbine.

Other perspectives and considerations

No uniform European perspective. Noise standards vary from one country to another. Denmark has a perspective, but Germany has a different one, Spain yet another, and so on. For example, in Denmark, noise limits are based on outdoor noise levels, whereas further south in e.g. Greece where windows can be open all year they are based on indoor noise levels. In the UK and several other countries the noise limits are related to the local background noise level while the Scandinavian countries and Germany have fixed noise levels (though not the same). Distance requirements likewise vary from one place to another. In Denmark, the required setback is four times the total turbine height from the nearest residence. In general it is all based on tradition and there is a long way to a standardized way of looking at wind turbine noise.

It is recommended that countries and states without a formalized treatment of wind turbine noise look to the experiences and knowledge from established methods instead of contributing to the variety of methods.

Low frequency noise. People tend to complain about low frequency noises. One of the things we are trying to figure out is why there is more “annoyance” from wind turbine noise than from comparable levels of industry noise, perhaps related to special characteristics such as modulation? Psychoacoustics, including listening tests, is becoming a way to gain more insight.

Collaborative planning. The 42nd IEA Topical Expert meeting, “Acceptability in implementation of wind turbines in social landscapes” was held in 2003 in Stockholm. This is a good example of the importance of collaborative planning.

Conclusions

A more reliable and nuanced description of the environmental noise around wind turbines – one that can differentiate between downwind and upwind propagation and can take into account complexity of terrain and meteorological conditions – will enable wind farm planners to work with a higher degree of confidence in their predictions. This in turn could facilitate optimum control strategies for operating wind farms. See slides for detailed list of references and relevant links.

Regulation of Noise in the United States

M Bastasch-Regulation of Noise in US.pdf

Mark Bastasch, P.E., CH2M HILL

Mark Bastasch is a registered acoustical, environmental and civil engineer with more than nine years experience in conducting acoustical studies, environmental audits, and multimedia environmental permitting. He has provided acoustical consulting and regulatory negotiations services to the wind turbine development community, assisting the Renewable Northwest Project to modify the Oregon Noise Rule to more readily accommodate wind energy facilities, and supporting the American Wind Energy Association in preparing comments on the Bureau of Land Management's Draft Wind Energy Programmatic EIS.

In the United States, noise is regulated at the federal, state, and local levels.

Federal noise regulation

The National Environmental Policy Act (NEPA) provides the regulatory framework for federal regulation of environmental impacts, including noise. However, the federal agencies (e.g., Federal Energy Regulatory Commission (FERC), the Federal Highway Administration, the Federal Aviation Administration, etc.) utilizing this framework have leeway to establish their own standards for what constitutes acceptable noise levels, depending on the purpose. (See slide for standards used by various agencies.)

Federal Rail & Transit Administration. This is the only federal agency with a standard that operates on a sliding scale, taking into account existing noise levels (L_{EQ} for "Category 1" land uses and L_{DN} for "Category 2" land uses, including residential), and coming up with an "Allowable Increase" – based on a "no impact" "impact," and "severe impact" scale.

Bureau of Land Management. BLM, which administers large portions of the Western United States, is the only federal agency with guidelines related to noise increases from wind projects (See slide for specific guidelines from BLM's programmatic wind EIS.)

Noise regulation at the state and local level

According to a 1997 survey, only 13 states had state-level noise regulations. Five of those states had regulations "on the books," but did not enforce them, although state permitting processes may require compliance. Some states, such as New York and California, do not have noise regulations, but do have guidance or model ordinances. For the most part, noise is regulated at the local level. At both the state and local levels, however, noise regulations are written by planners and lawyers, not by acoustic professionals, and so tend to be poorly worded and ambiguous.

Relative v. absolute criteria. If a regulation is defined in terms of "increase over existing," "existing" noise levels need to be defined and measured. It is important that the baseline metric (Leq, L50, L90, Ldn) and time period (24 hour average, nighttime average, lowest hourly level) be defined, otherwise, the "increase over existing" is ambiguous and begs the question, increase over what? And what if the regulation stipulates a 10 dB increase as the maximum acceptable increase, but results in a level that is less than 40 dBA, does that constitute a significant impact? Is there an absolute noise level below which the magnitude of the increase should be irrelevant? On the other hand, what if an absolute maximum noise level is given, but existing noise levels already exceed this? And, most importantly, how will compliance ultimately be determined?

In the U.S., regulators have not adopted a particular wind turbine noise model (as several other countries have done), and may require compliance monitoring instead. This can be problematic if the background noise exceeds the standard, and it is difficult to separate out turbine noise from the background noise.

The following is a sampling of regulations and guidance

Colorado. Colorado's noise regulations stipulate that noise shall "not be objectionable due to intermittence, beat frequency, or shrillness," and impose a 5 dBA penalty for "periodic, impulsive, or shrill noises." However, none of these terms are defined by the regulations, and there are over 340 local jurisdictions which may impose additional standards.

Washington State. Criteria are not clear for determining noise impacts under Washington's State Environmental Policy Act (SEPA). Again, terms are not rigorously defined – neither by SEPA nor by the Energy Facility Siting regulations. State regulations refer to an absolute limit rather than setting limits on noise level increases, however, even the "absolute" limit is subject to different interpretations.

California. Wind turbines are not regulated by the California Energy Commission (CEC), but the California Environmental Quality Act (CEQA) requires assessment of project-related noise increases. The metric and time period for defining increase over what is not defined by CEQA. Local ordinances vary, with some specifically addressing wind turbines, others not. (See slide for county-specific wind turbine noise standards.)

New York State has a policy guidance issued by the Department of Environmental Conservation, but again, it does not define the baseline metric or time period (increase over what). They reference a modified *composite noise rating* (CNR) is used in many power/utility cases. A mCNR makes adjustments for various characteristics, including background noise and tonal content, as well as community attitudes. But it is not clear when a detailed mCNR analysis would be required.

Oregon's Wind Turbine Noise Standard

The State of Oregon has a new wind turbine noise (WTN) standard that references IEC 61400-11 to ensure reliable sound power level (PWL) data. The Oregon WTN regulation, which has received input and support from the Governor, developers, and some environmental groups:

- establishes minimum existing ambient noise levels (26 dBA) – resulting in a 36 dBA maximum project level (if landowners choose not to waive it), which is consistent with maximum project levels set by British and Australian guidance documents;
- requires maximum sound power level to be used in predictions ("worst case" analysis);
- allows wind developers to negotiate with landowners; and
- includes compliance demonstration requirements.

Conclusions

Perception is subjective. While we can predict noise levels, there is no perfect way to predict "annoyance." Annoyance should not be equated with significant impact, and compliance with regulations or standards does not guarantee that no one will be annoyed. Project "participants" (those who stand to realize financial gain) are unlikely to be annoyed by perceived increases in noise levels. Site visits and full disclosure are encouraged as part of project planning.

Questions and Observations: Session III - Sound

With regard to whether noise standards address frequency and tonal qualities in addition to decebel levels, presenter Mark Bastasch responded that there are sometimes penalties for a tonal component, which may be defined as a "whine." Oregon defines limits within an octave or one-third octave band, but not many jurisdictions do this. The penalty might typically be on the order of 5 dBA.

Another area of inquiry pertained to noise propagation. Noise propagates differently upwind of the turbine than downwind. Downwind propagation represents the "worst case" scenario. (This is the scenario measured by the *WindPro* model.) The difference has to do with the "ground effect." Sound curves back down toward the earth – a pinwheel image – resulting in an interference pattern between direct and reflected sound waves.

SESSION IV: ELECTROMAGNETIC INTERFERENCE

Siting wind turbines near airports, radar sites, military installations, and communication facilities raises unique technical considerations. This session will provide a discussion of challenges, considerations, and solutions to address potential concerns with electromagnetic and other interference issues. [Questions and discussion are summarized following the presentation summaries.]

Wind Radar Interference: Fact or Fiction?

G Seifert -Wind Radar Interference Fact or Fiction.pdf

Gary Seifert, Idaho National Laboratory

Gary D. Seifert, P.E., E.E., is senior program manager at the Idaho National Laboratory (INL). He has worked at the INL since 1979, where his responsibilities include multiple technical tasks for the US Air Force, US Department of Energy, US Navy, and NASA. He was involved with the Ascension Island Wind Project, and has provided support to the Wind Powering America program. Gary currently is involved in studies for multiple additional Department of Defense government wind projects and supporting wind prospecting activities in Idaho.

Major Bill Crowe in his presentation mentioned that the Department of Defense (DOD) is very interested in renewable energy. DOD's renewable energy assessment report, completed in March 2005, identifies a need for renewable energy on military bases to enhance national security and reduce energy costs. DOD assessed all renewable energy systems, identifying 30-40 bases with wind or geothermal resources or both. This is quite significant, as the military spends billions of dollars on energy costs.

Despite this interest in wind and other renewable forms of energy, the military has some valid concerns about the impacts of wind on mission and radar systems. Wind interferes with highly sensitive radar systems. Multiple radar interference impacts have been identified in the United Kingdom. The Federal Aviation Administration (FAA) also has raised concerns about the impact of wind energy facilities on their radar systems.

Types of interference

There are two main types of interference from wind turbines: direct and doppler. *Direct interference* is a function of radar energy reflecting off the wind tower, nacelle, and rotor blades – much as they would be by transmission lines. *Doppler interference* poses a more serious problem. Rotating turbine blades cause reflected radar frequencies to increase in one direction while decreasing in the other direction (relative to the turbine), creating a doppler effect that impacts both airborne and fixed radar. The challenge is exacerbated as the turbine itself is re-orienting in the direction of the wind.

Interference reduces the sensitivity of radar, creating false images ("ghosting"), dead zones beyond the wind farm, and shadow areas. (See slides for illustrations.)

Myth or reality?

At 95% of the military bases, wind has no discernable impact on mission, but Nevada is the anomaly. The Nevada Test Site (NTS) is surrounded by some of the most critical military training area in the world. Very precise systems are being tested in this area, and a wind project proposed for NTS had to be cancelled. How does a county commissioner in Nevada, 100 miles away from the sensitive training area, know that your wind project is going to pose a problem for that base? Major Crowe's office has been quite helpful in this regard, but there is not (as yet) a single process by which you can permit wind through DOD/Air Force.

Not all concerns are founded on fact, however. When INL proposed a small wind site for Ascension Island, which is used by the BBC to broadcast to the Southern Hemisphere and by Cape Canaveral as a radio telemetry site, objections were raised. The wind turbines were installed in 1994, and no impact has been documented, either on broadcasting or on radio telemetry activities. The point to take away from this is that "interference" is a relative term. It is often difficult to quantify the impact of wind installations on radar or broadcast transmissions. The real question is not whether there is any impact, but whether impact affects the mission.

Addressing the issues

Impacts come primarily from two communities: the military, and air traffic control. In addition to specialized radar and telemetry areas, the military does a lot of training with night operations and low-altitude routes (under 500 ft.). The FAA is concerned with radar operations in airport approach and exit zones. In most cases, the issues can be resolved, but it is important to communicate with people about their concerns and how to address them. In the case of the military, the difficulty is that this information may be highly secret – not available to someone without proper clearance.

The wind resource doesn't move, and often the best resources are located up on ridge lines, potentially interfering with radar/telemetry systems' lines of sight. It may not always be possible to mitigate, but sometimes a win-win situation is possible. One wind project recently was saved because information about the location of a training route and existing "bubble" (area excluded from military operations) enabled the developer to relocate the proposed site a quarter mile to a mutually acceptable location.

There is no such thing as a project with no impact on electromagnetic resonance. The question is, does that impact affect ability of people to do a critically important job? By taking the time to look closely at what the job is and what the impact would be, and communicating openly about the issues and what can be done to address them, more win-win situations might be possible.

Recommended next steps

- Perform testing and validation impacts and develop better guidelines based on verifiable and defensible information.
- Train military personnel on real impacts.
- Develop universal guidelines so that agencies are processing requests consistently.

- Make sure that all military organizations are consulted, keeping in mind that impacted groups may be "temporary tenants" conducting flight or test operations at a base.
- Be good neighbors.

Prediction of Radar Impact

[*No slides available*]

Steve Appleton, QinetiQ

Steve Appleton is an applied physicist by training and has worked on stealth materials for more than 15 years. He leads a team of scientists and engineers working on the design, prototyping, and manufacture of radar absorbers, and on adapting such military technologies to address civil problems, including interactions between wind farms and radar. He is the technical leader for QinetiQ's stealthy wind turbines programs.

Introduction

In the United Kingdom, we are attempting to install wind power in a relatively small area (compared to the US) with a lot of radar coverage, so interference is more of a problem to us. QinetiQ's expertise in predictive codes was developed initially for military targets, using physical optics, diffraction, or method-of-moments approaches. Formed from UK Ministry of Defense research agencies, QinetiQ first became involved in the windfarm-radar topic through work funded by the UK Department of Trade & Industry to develop predictive software. The tools developed in that project allow assessments of the impact of wind turbines on systems such as:

- Civilian and military aviation radar and marine radar;
- Aviation and marine navigational aids;
- Geo-positioning systems (GPS);
- Television broadcast;
- VHF communications; and
- Microwave links.

The radar cross-section (RCS) modeling tool is created from a detailed computer-aided design (CAD) of the turbine, developed from drawings or photos. Elements of the mesh can be given material properties (e.g., fiberglass) with appropriate levels of reflectivity. The model allows us to rotate the blades to collect RCS data for all blade positions, and multiple bounce mechanisms help to identify areas of the blade that are "hot spot" contributors to the RCS. This also allows us to study the impact of candidate materials solutions to reduce radar reflection from turbines.

RCS modeling confirms that Doppler shifting is the biggest problem to air traffic control (ATC) radars, particularly when rotor blades are in the vertical configuration i.e. 90° yaw angle (i.e., blades moving towards and away from the radar) gives the highest Doppler RCS component.

Propagation and radar effects

Models use digitized topography data and radar antenna information to account for impact of terrain propagation and radar effects. For example, primary ATC radar uses a moving target indicator (MTI) to discriminate between aircraft and stationary clutter, and this functionality can be allowed for. If data exists for other effects, such as prevailing wind directions, it is possible to calculate a weighted distribution of RCS probability, which can possibly be used to identify more favorable turbine locations and to eliminate higher RCS levels. Slides show how ATC and marine radar display simulations can predict false plots on radar displays caused by high wind turbine reflectivity.

See slides also showing how secondary surveillance [aircraft guidance] radar installed on an aircraft flying at 1,200 m altitude can be affected by reflectivity from a 2 MW turbine. (Worst case geometry is used to generate plots from the wind turbine, with colors used to indicate the likelihood of false plots due to wind turbine reflections.)

Solving the problem through stealth materials

Many people believe that composite materials are transparent to radar signals, but that’s not true. Glass fiber reinforced plastic (GRP) is partially (~40%) reflective, depending on the frequency. Solid laminates can also be highly reflective. A blade cross section diagram shows some of the different types of blade components, some of which are more reflective than others.

Radar absorbent materials (RAM) can be used to reduce reflectivity. However, it is not desirable to add a parasitic, thick coating to the rotor blades. The question becomes how to take the various materials that go into the blade and render them radar-absorbent, while minimizing the manufacturing and maintenance costs. (See slides for diagrams showing what can be achieved in various layer dimensions using simple *resistive* layers). It is often not possible to achieve high absorption at ATC frequencies using such resistive layers, because there is not enough material thickness available.

The QinetiQ approach to this problem has been to introduce *controlled impedance properties* into the current glass cloths to electrically tune even thin (relative to wave length) composites. This allows us to achieve a reduction of radar reflectivity with very little change in mechanical properties and very little addition to weight or thickness.

(See slide diagram showing how Doppler spikes in the RCS are reduced (red trace) by using “stealth” blades. Most of the RCS contribution is now coming from the tower. We may still be concerned about the residual RCS levels, because 5 dBm^2 is a typical small aircraft RCS. If the whole turbine is treated with RAM, rather than just the blades, then predictions show that the bulk of the RCS spectrum falls below 0 dBm^2, and the turbine would be less detectable than a small aircraft.

Simulations/models indicate that this treatment is effective, and we have just recently begun to prove the predictions through a demonstration on a 2 MW turbine, with 80 m tower and 40 m blades. The 15-month demonstration project at a site near Glasgow (Scotland) will be completed in early 2007. We will look at how RCS varies with various radar absorbing material (RAM) treatment schemes, so that we can arrive at an economical solution to this problem.

Identifying and Avoiding Radio Frequency Interference (RFI) to Microwave Systms, TV Reception, Telephone Operations from Wind Turbines

L Polisky-Identifying Radio Frequency Interference from Wind Turbines.pdf

Lester E. Polisky, Comsearch

Les Polisky is the Senior Principal Engineer with Comsearch, responsible for analyzing and solving complex electromagnetic interference problems. He has been with Comsearch for 30 years, and has been heavily involved with wind power facility telecommunication compatibility issues over the past five years. He is a member of the National Spectrum Managers Association, currently serving as Chairman of the Interference Mitigation Working Group.

Comsearch became involved with the wind industry in Iowa in 2000 when there were problems with television signal reception related to wind turbines. Since that time, Comsearch has assisted the wind industry in all types of telecommunication issues with respect to wind facility developments. In 2005, we found out there could also be issues with government telecommunication systems, and they could be serious enough to stop a wind project. With AWEA, we set up a mechanism for notifying the government of wind installations so that any issues could be identified and dealt with early in the development of a wind facility.

How can wind developers and regulators deal with radio frequency interference issues in an objective way?

Microwave Propagation Issues

Comsearch has all of the communications systems – microwave, television, telecommunications, telephone systems – in our database. We use Geoplanner^{TM} a software tool to map an overlay of different microwave systems with respect to the wind turbine locations. Many systems operate within each of the many licensed microwave bands.

When we analyze a wind development, we plot microwave links on a map, overlay the worst-case Fresnel Zone, and then identify which turbines represent a potential obstruction. In the first tier analysis, we look at the worst-case Fresnel Zone (see slide for calculation of formula). In the second tier, we look at the actual Fresnel Zone. In the example given (see slides), the worst case eliminated 5 turbines, while the second tier analysis restored one of the five. The developer can either eliminate or move these turbines still found to cause an obstruction.

With government telecommunications, the National Telecommunication Information Agency (NTIA) is the equivalent of the Federal Communications Commission (FCC) for government frequencies. The government Master File is classified, requiring special clearance to see it. Comsearch came up with a notification letter listing the proposed new wind facility, turbine dimensions and coordinates, so that the NTIA can run it by the Interdepartmental Radio Advisory Committee (IRAC). IRAC meets twice a month, and includes representatives from DOD, DOE, FAA, and other government agencies. We have sent about 25 notification letters to date; NTIA's IRAC turns them around in 30 days with a letter summarizing the results of the IRAC review. In 25 NTIA responses to date a letter has come back indicating the wind facility could proceed, and no problems have arisen to date. In the majority of cases, there will not be a problem. Most of this is about being proactive.

Television Signal Reception

Comsearch also has all the television stations in our database. Using a standard (calibrated) Radio Shack television antenna, we measure the field strength of the television signal for all available channels in a given area where a wind facility is proposed, and get a baseline condition assessment. Video quality evaluation is subjective. We use a rating scale of 1-5, with 1 being "perfect" (cable quality), and 5 being no television signal received. Signal level can be measured quantitatively. Audio is FM modulated, video is AM modulated – audio normally is unaffected by wind turbines, but video intensity may be affected, resulting in effect known as "shimmer. It is important to make measurements *in advance of installation* so that the baseline condition is known.

By February 19, 2009, all television transmission signal modulations will be digital. Whereas 2-8 dB attenuation from a wind turbine can severely block analog TV reception, a digital signal is much more robust and may not be degraded.

Telephone Systems

With wired (land line) service, interference is not a problem. There have been no reported cases of problems with cell phone use in and around wind turbines, because cellular telecommunications operate at higher frequencies (800-900 MHz). In a given area where there may be two or three wireless carriers operating, the layout of cells to achieve coverage is proprietary, not public knowledge. However, if a problem occurs, it is easy to mitigate by putting additional cell antennas on the wind turbine, cell, or utility towers within the wind facility.

In general, the audio medium is much less affected (than video) by wind turbines. This applies to wireless telephone, land mobile radio (LMR) and AM and FM radio. Only 35% of reception is presently from off-air TV broadcasters. Sixty-five percent is from cable or satellite. However, there probably is a higher percentage of off-air TV reception in remote areas where wind systems are normally installed.

Major issues for wind developers are:

- Microwave link-path avoidance
- TV reception in 5-mile vicinity of development
- Notification of US government.

Going through the NTIA is the most efficient way to get information about a proposed development to the various agencies that need to know.

Radio operation

There is presumed to be no problem when an omnidirectional AM radio broadcast antenna is located beyond 1 km of a wind turbine. Likewise, there is presumed to be no problem when a directional AM radio broadcast antenna is located beyond 3 km of a wind turbine. From a safety standpoint, if someone had to climb a wind tower within close proximity to an AM broadcast facility, there could be the possibility of radio frequency (RF) burns from the RF currents that are induced on the metallic structures. These currents will not cause death, but they can cause harm – either by burning an individual or causing that person to lose his balance or drop a tool that might harm the individual or someone else.

Questions & Observations: Session IV - Electromagnetic Interference

Questions following this session touched on the impact of wind turbine facilities on radar systems, including both those used for air traffic control (ATC) and for defense purposes, and on the effect of wind facilities on broadcast and communications signals. Ohio University is doing a US analysis to determine prospective impacts to air traffic control (ATC) radar systems from wind turbines. Specific questions (and responses) were as follows.

- There is one instance in which a phased array radar system was confused by a wind facility – there was an anomaly in the software that was incongruent with what they expected. Because many countries use this software for coastal defense, Comsearch is looking for fix; however, if someone is using this system, that dead zone is created.
- Where does the rule-of-thumb that there is no impact in excess of 5 miles from ATC? At a certain distance out, air traffic control goes from direct radar to secondary transponder system. People in ATC found that five miles out there was no trouble discerning air traffic from reflected radar signals from wind turbines.
- It is feasible to mount cellular communications devices on a turbine tower, anywhere from 50 to100 feet above ground level. Provided the devices are clear of the turbine blades, they should not be affected. However, you would have to put up more to avoid tower shadow – usually you would just put the equipment on a met tower.
- Attenuation associated with microwave link Fresnel Zone has been measured. Any systematic interruption of the signal, even if it reduces the signal level just a small amount, is a problem for the carriers because of their contractual obligations to deliver a certain level of signal to their customers.

SESSION V: SAFETY IMPACTS

Wind turbines are designed before installed site conditions are known. This session will describe how modern utility-scale wind turbines are designed for safety in different site conditions and the related international standards and certification requirements. In addition, wind turbine designs for cold weather climates will be discussed, including recent operational and safety experiences. [Questions and observations are summarized at the end of the session.]

Turbine Design Requirements for Safety

B Smith-Design and Standards for Safety.pdf

Brian Smith, National Renewable Energy Laboratory

Brian Smith is Technology Manager of Wind & Hydropower Technologies at the US Department of Energy (DOE)'s National Renewable Energy Laboratory (NREL). He has been involved with the DOE Turbine Research & Development and DOE-EPRI Turbine Verification Program activities since their inception in the early 1990s, and is well versed in many aspects of wind turbine research, design, product development, manufacturing, installation, testing, certification, operation and maintenance.

How do site issues relate to turbine design?

Turbines are designed for different classes of winds (high to low), for turbulence and wind shear, and also for special environments (icing, oceans, etc). The International Electrotechnical Commission (IEC) defines the standards for the different design classes (IEC Turbine Standard 61400-1 = utilty-scale turbines; IEC 61400-2 = small turbines). Site conditions will be different than the design conditions, however. Site assessment reconciles the differences between site and design conditions. For example, today's offshore wind turbines are designed to withstand hurricane conditions.

The IEC standards set the framework for third-party type certification and project certification used by insurers and the investment community. (The U.S. relies more on due diligence process than on certification.)

How are standards integrated into design?

We have been hearing about how wind technology is getting big. The earliest wind turbine designs were as large as today's, but we didn't have the design standards or the materials to make such large turbines work then, and now we do. At various points along the way, the wind industry has said "this is the optimum size." However, as designs improve, the turbines keep getting bigger, creating greater economies of scale.

Standards are intimately linked to all product development phases, with design standards and documentation integrated at every step, from conceptual design through testing of components, performance testing of prototype, design refinements and reliability testing. (Slides diagram process and list the elements of wind turbine design evaluation that contribute to wind turbine type certification.)

Verification tests are performed at all levels of the design process. Modern testing equipment allows us to get the results a lot faster than we could formerly. For example, blade testing is required by IEC standards; it is now possible to get a 20-year life cycle's worth of fatigue testing data in a few months. The next version of the IEC gearbox standard will require drive train testing. (The National Wind Testing Center at NREL has a 1.8 MW Dynamometer test stand making it possible to perform testing on multi-megawatt drive trains.)

What are Type Certification and Project Certification?

Type Certification is the first step in the design certification process. Once a turbine has received IEC type certification, there remains the question of ensuring that site-specific design and operations and maintenance (O&M) surveillance conforms to Project Certification requirements. Project Certification is not widely-practiced in US, where the "due diligence" model predominates. However, it has become more common for offshore wind projects in Europe.

What are turbine design conditions?

Wind turbines are classified according to wind speed (Class I = high, Class II medium, and Class III = low), as well as a special class for which values are specified by the designer. In addition to wind speed distributions (which are the inverse of the wind classification system), the basic parameters for wind speed turbine classifications include turbulence intensity (l_{ref}) and 50-year extreme gusts (V_{ref} = highest 10 min mean).

How are turbine design and site compatibility assured?

It must be demonstrated either that site conditions are less than design conditions OR that they will not result in loads in excess of maximum design loads. IEC standards include definitions of various site assessment characteristics. "External conditions" are defined by wind and turbulence models, electrical network conditions, temperature, and humidity at the site.

How is "site assessment" defined in IEC?

The IEC standards require quantified measurement of the following site conditions:

- Topographical complexity
- Estimate of 50-year 10-minute extreme wind
- Estimate of probability density function
- Turbulence intensity
- Flow inclination
- Wind shear
- Air density
- Wind plant wakes
- Icing, humidity, lightning, solar radiation, salinity
- Earthquakes
- Electrical network
- Soil conditions

Examples: See slides showing turbulence intensity as measured for Lamar, Colorado site assessment. Turbulence is a measure of variation around average wind speed. The first graph shows how turbulence changes at different heights above the ground, the second set of graphs shows how the seasonal variation in turbulence at the site over the course of a year. The data indicate that wind shear is a problem in Lamar for at least one month of the year.

Low level nocturnal jet. Using a 120-m. met tower with SODAR (sonar) and LIDAR (laser) wind profiles, our measurements indicate that there are waves of turbulence associated with high wind speeds between 10 pm and 4 am. Another slide shows the average wind shear by time of day over a year-long period for a large (40 MW) wind farm in Big Springs, Texas. During early morning hours, wind shear was above IEC design wind shear. This correlated with the time of day when turbines faulted out. This is the kind of complex site assessment information that can be used to modify design to ensure good reliability and performance.

See last slide for references.

Ice and Snow – and the Winds do Blow

I Baring-Gould-Turbine Operation in Icing Climates.pdf

E. Ian Baring-Gould, NREL

Ian Baring-Gould has worked with NREL since 1995, focusing on innovative applications engineering for renewable energy technologies and international assistance in use of these technologies. Currently acting as a technical expert for the DOE Wind and Hydropower Technologies Program in Washington, DC, Ian also sits on IEA and IEC technical boards, and is an editor for Wind Engineering who has authored or co-authored over 60 publications.

Ice and snow are a problem for many wind energy projects. Projects located throughout the north are in areas where ice, snow, and cold temperatures can impact the assessment and operation of wind plants. (See slide showing map: any project north of the red line should be assessed for ice and snow impacts). Impacts include higher maintenance, increased downtime, higher loading on components, and increased safety risks for staff and the public. In all cases, these impacts should be assessed at the start of the project, accounted for in project development, and supported through long-term assessment and consideration.

Current experience in this field

Most of the studies of ice and snow/ cold temperature impacts on wind energy facilities have been done in Northern Europe. There have been two general sources of information on wind turbines in cold climates, the international BOREAS conference series on wind in northern climates, and the International Energy Agency (IEA) wind technologies program, which has an Annex called Wind Energy in Cold Climates (see http://IEAwind.org). The purpose of the IEA Annex is to gather and provide information about wind turbine icing and low temperature operation. IEA Annex XIX has produced a report that summarizes existing experiences in wind energy production in cold climates.

To date, little data has been collected in the United States on the impacts of cold and ice on wind systems. The Canadian Wind Energy Association (CanWEA) has held one conference on wind turbine operation in northern climates, although this is expected to become a standard conference series.

Assessment of site characteristics

Key considerations for determining whether icing will be an issue at a given site are: the number of low temperature (below freezing) days, number of days with cloud cover or heavy fog, and the number of days of precipitation (snow). Additional factors include altitude and the height of the towers. Local airports are one good source of this data. See also two National Oceanic and Atmospheric Administration (NOAA) web sites: www.nws.noaa.gov, and www.ncdc.noaa.gov.

Sites with severe weather require re-thinking of the current paradigm for measuring site conditions. This is an inexact science. (The IEC ranks all "severe weather" sites as being places where its standards do not apply.) Anemometers can ice over, preventing accurate wind measurement. Heated anemometers are needed to accurately assess wind speed and direction. Towers must be built stronger, energy requirements are higher, and more analysis is required to ensure data accuracy. All of these requirements entail higher costs.

Moreover, it is not enough to know that icing occurs; data must be gathered on icing events, including their frequency, severity, and duration. This is critical, because these events impact: turbine structural loads, forced downtime, energy capture, maintenance needs and level of difficulty, project risks, site accessibility, and the cost of ice mitigation strategies.

Mitigation strategies

Strategies for mitigating icing impacts can be categorized as "ice prevention" and "ice removal" strategies. Turbine modifications to prevent ice accumulation can include the heating of the inside of the blades, but this must be conducted during the entire icing event. Ice removal strategies involve methods such as heating the leading edge of the blades following an icing incident. Different strategies are suitable for different conditions and have different costs. As much as 10% of a turbine's energy production can go into ice mitigation, so this is something the developer needs to know when calculating project economics. Likewise, ice build-up affects turbine performance, hence project economics.

Depending on the severity of icing, reliability requirements may necessitate modification of sensors and control algorithms, and improved remote assessment technology to compensate for the lack of site accessibility.

Safety considerations

In Europe, safety considerations are paramount in the siting of wind turbines in icing climates. Typical safety-related requirements for locations in Germany and Austria are:

- Manual start-up following and icing shutdown
- Special monitoring requirements
- Special use permits
- Controlled site access
- Ice through and risk analysis
- Rejection of siting permits where safety issues cannot be resolved

Risk assessment considers area use and ice fall probability, given local conditions both during operation (ice throw) and when turbines are at a standstill (falling ice). Primary conclusions are that service personnel and local infrastructure (buildings) are at greatest risk. There has been very little scientific study so far, but more will be conducted, particularly in Europe. In the US, icing is considered more of an insurance risk than a safety risk. There are not so many requirements, and safety considerations are handled on an *ad hoc* basis. Very few incidents have occurred of icing resulting in injury.

Ice throw. Ice does get thrown off blades, and it can go as far as 125 m depending on the height of the tower, the size of the ice, wind speed, and turbine characteristics. A simple (but crude) formula for ice throw during operation is

$$d = (D+H) * 1.5$$

where d = maximum throw distance, D = rotor diameter (m), and H = hub height (m)

A more complex formula takes into account wind speed and direction in relation to obstacles, and specifies where you are likely to get ice throw. (This type of analysis can be used to shut down a turbine if wind is coming from a direction during icing conditions that is likely to result in ice throw on a road or any other place where safety is a concern.)

Ice fall. The simple formula for calculating where ice will fall when rotor is at a stand still is

$$d = v\frac{(D+H)*1.5}{15}$$

where d = maximum falling distance, v = hub wind speed (m/s), D = rotor diameter (m), and H = hub height (m)

A more advanced analysis uses ice size, wind speed, and rotor position to assess safety areas. This is no different than ice falling off a tower or any other structure.

Risk analysis and mitigation strategies

The results of the above calculations need to be put in context with the likelihood of icing events, site access, weather conditions, and turbine operation. In a study by Henry Seifert (see bibliography), it was calculated that if 15,000 people walked by the study turbine each year, there would be one accident every 300 years. Such an assessment has to be evaluated in perspective with other community risk factors and local regulations.

Risk mitigation strategies include site access limitations (including moving trails and redirecting traffic), public awareness and signage, and signal warnings when starting up turbine after an icing event.

Questions and Observations: Session V – Safety Impacts

Questions following the safety impacts session touched on design requirements for offshore site evaluations, design research on nocturnal high shear or turbulence conditions, and impacts related to icing.

With respect to offshore design requirements:

- The IEC has a unique set of design standards for offshore. Most of what we know is based on research from Denmark, and other European countries.

Regarding failures correlated with the late night/early morning high shear or turbulence:

- In the West, towers with long blades designed for lower wind speed capture are experiencing abnormally high transmission failures during these periods – this is worthwhile research.

With respect to icing conditions:

- In Europe, ice fall is a bigger concern than ice throw because they choose not to run the turbines after icing events. Icing on anemometers can result in inappropriate shut-down of wind turbine facility.
- A sheet of ice as large the size of the blade face could be thrown, though this is not likely. Ice chunks up to a few kg have been reported.
- Painting blades black is an effective strategy only in very light icing climates, more like frost.
- In terms of turbine design, icing is not generally considered an actual structural concern in the United States, but it is in Northern Europe. The structural impact of icing on turbines or towers should be considered any place that can get heavy icing.
- Most of the early research on different anti-icing methods shows them not to be overly effective, though this research has not been exhaustive. One has to be clear what's anti-icing, and what's de-icing; mostly these systems are effective only in very light icing conditions.

SESSION VI:

DISCUSSION OF PRIORITIES, NEEDS ASSESSMENT, INFORMATION GAPS, MITIGATION DIRECTIONS/STRATEGIES

Due to time constraints, there was no attempt to facilitate a discussion of priorities, needs, information gaps, and mitigation strategies. Rather, the final session was an opportunity for moderators and meeting participants to make concluding observations and respond to questions.

Wrap-up Questions and Observations

<u>Have there been studies about how the sound affects wildlife?</u>

- Bats, no. Other animals tend to habituate. Transient events seem to have a bigger impact.
- Copenhagen conference on the impact of sound from offshore turbines on sea mammals seems to confirm that sea mammals habituate.
- To the extent there is an impact, it’s not the kind of threat presented by thermal outflow (or the cessation of outflow) from power plants.
- Pile driving during construction has a bigger impact than the operational sound.
- There have been some low frequency sonar studies.

<u>Are there maps of restricted airspace and training routes?</u>

- Red, green, yellow diagrams are just a tool for county commissioners to use; actual maps are available, but they are much more detailed.
- The mission of wind energy developers and the Department of Defense (DoD) are congruent.
- DoD management is very supportive, for these very reasons. But individual units have their own missions to think about, the people at the base have a very narrow mission with a classified training route – and they may not even learn about a plan until much later when they are asked to review EIS much later. It is important to have a clearinghouse early-on.
- There are three pieces to the radar issue: FAA air traffic control; marine radar; and the military.
- We didn’t really talk about the marine side, but this is something we should start talking about.
- As for the military – it was great to have Major Crowe from the Air Force here to talk to us, but we need to get all branches of the military in on this, and talking about offshore as well as onshore.

Facilitator: Offshore has been (and will be again) looked at by the National Wind Coordinating Committee. The Massachusetts Technology Collaborative – and other local collaboratives are also looking at this.

Conclusions

Planning Committee members thanked panelists and all participants. This has been a good opportunity to share a great deal of information, expertise and difference perspectives on a number of key wind energy development siting topics.

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conference by November 1, 2005. The paper presentations will be followed by an expert topical roundtable to identify key research issues in social science R&D on social acceptance of energy innovation.

For more information:

http://www.iwoe.unisg.ch/org/iwo/web.nsf/18d08957e7711e48c12569f50045e851/9aa66bc9873d4cc1c125704d00484585?OpenDocument

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APPENDIX C: MEETING AGENDA

NATIONAL WIND COORDINATING COMMITTEE

TECHNICAL CONSIDERATIONS IN SITING WIND DEVELOPMENTS: RESEARCH MEETING

December 1-2, 2005

Purpose:
Review and discussion of existing research, methods, and tools available to address non-wildlife related technical issues associated with siting and operation of wind energy systems. Proceedings may be used as an unbiased source of technical information for those engaged in siting and permitting wind facilities.

DRAFT AGENDA

DAY ONE: THURSDAY, DECEMBER 1

12:00 – 12:30 **Registration**

12:30 – 1:00 **Introductions**
Abby Arnold, RESOLVE

- Welcome and introductions
- Review purpose of meeting & agenda
- Overview of primary meeting questions
  - *What are examples of technical requirements or standards that must be met?*
  - *What are the main technical issues to be addressed in Siting?*
  - *What issues are particular to wind?*
  - *What modeling / research techniques / analytic methods exist?*
  - *Is mitigation possible? What alternatives are there?*

1:00 – 5:00 (includes break) **Session I: Visual Impacts**
Moderator: Mike Pasqualetti, Arizona State University

The purpose of this session is to explore visual impact analysis, tools for reviewing visual impacts, and factors that influence public and community opinion of visual impacts. Participants should come away with an understanding of the considerations that influence public opinion about wind power projects, how these opinions are influenced by location, how they can be measured, and how they can be mitigated.

Overview of Visual Impact Analysis
Mike Pasqualetti, Arizona State University

- Introduction
- Western U.S. Perspective

Rick Benas, Saratoga Associates

- Eastern U.S. Perspective

Caroline Stanton, horner + maclennan

- U.K. and European Perspectives

Physical Turbine Characteristics, Placement, & Modeling
John Hecklau, Environmental Design and Research

- Colors
- Tower & turbine design
- Turbine array
- Shadow flicker

Matt Allen, Saratoga Associates

- Computer imaging
- Day vs. night approach
- Digital viewshed development

Alternate Policy Approaches to Technical Considerations

Caroline Stanton, horner + maclennan

- Visual impact assessment guidance

Rick Benas, Saratoga Associates

- NY State universal mitigation list

Tom Priestly, CH2M Hill

- The paradigm for visual impact assessment
- Practical issues in conducting wind power visual impact assessment
- Linking research to practice
- Directions for research and development of information resources

Questions and Observations *Facilitated Discussion*

5:00 – 6:00 **Session II: Lighting, FAA Regulations, and Air Hazard Issues**

Moderator: Jim Patterson, FAA

The purpose of this session is to explore the potential effects of wind turbine construction on aviation and establish an understanding of how wind turbines might impact aviation safety. Participants should come away with a thorough understanding of how turbines can impact aviation safety, what can be done to minimize safety risks, and ways to promote a favorable relationship between developers, the FAA, and the military.

Turbine Visibility

Jim Patterson, FAA

- FAA required lighting: technologies, regulations & issues
- Strobe lights & lighting technical issues
- Other lighting, warning, and safety issues
- Color / lighting tradeoffs
- Synergistic approaches to lighting, warning, safety

Airspace & Military Operations

Major William Crowe, U.S. Air Force

- Airfield approach & military operations

Questions and Observations *Facilitated Discussion*

6:00 ***Adjourn Day 1***

DAY TWO: FRIDAY, DECEMBER 2

8:00 – 8:30 **Reconvene**
Review of Day One Activity, Introductions, Invited and Day 2 Agenda

8:30 – 10:15 **Session III: Sound**
Moderator: Arlinda Huskey, NREL

As wind turbines move closer to people and their communities, there are questions and concerns about the sounds wind turbines emit. This session will present the issues, tools, facets, regulations, and perspectives of wind turbine sound and siting.

Sound Properties, Perspectives, and Challenges
Jeroen van Dam , Windward Engineering
- Overview of noise characteristics
- Measuring techniques, terminology, standards

Anthony Rogers, University of Massachusetts
- Infrasound
- Psychoacoustics

Bo Søndergaard, DELTA
- Propagation / models
- Offshore noise
- European perspective

Mark Bastasch, CH2M Hill
- Regulation of turbine noise in the U.S.

Questions and Observations *Facilitated Discussion*

10:15 - 10:30 ***Break***

10:30 – 12:00 **Session IV: Electromagnetic Interference (Communications and Other Interference Issues)**
Moderator: Gary Seifert, INL

Siting wind turbines near airports, radar sites, military installations, and communication facilities raises unique technical considerations. This session will provide a discussion of challenges, considerations, and solutions to address potential concerns with electromagnetic and other interference issues.

Radar Interference
Gary Seifert, INL
- Energy reflection & radar return
- Doppler interference
- Ghosting
- Shadowing
- Military operations, U.S. perspective

Assessing Radar Impacts & Mitigation Strategies
Steve Appleton, QuinetiQ
- Modeling techniques
- Radar absorbing materials
- Military operations, U.K. perspective

Signal Propagation Interference
Les Polisky, Comsearch
- Television interference
- Microwave interference
- Telephone interference

Questions and Observations — *Facilitated Discussion*

12:00 – 12:45 **Lunch (Served On Site)**

12:45 – 2:00 **Session V: Safety Impacts**
Moderator: Brian Smith, NREL

Wind turbines are designed before installed site conditions are known. This session will describe how modern utility-scale wind turbines are designed for safety in different site conditions and the related international standards and certification requirements. In addition, wind turbine designs for cold weather climates will be discussed, including recent operational and safety experiences.

Turbine Design Requirements for Safety
Brian Smith, NREL
- Design/safety standards
- Turbine certification
- Turbine integrity

Weather-related Safety Concerns
Ian Baring-Gould, NREL

Questions and Observations — *Facilitated Discussion*

2:00 – 2:45 **Session VI: Discussion of Priorities, Needs Assessment, Information Gaps, for Mitigation Directions / Strategies**
Facilitator: Abby Arnold, RESOLVE

Facilitated Discussion among Moderators and Meeting Participants
- What has been presented here that we can apply immediately?
- Where is more knowledge needed?
- How can it be obtained?
- What are proposed next steps for the NWCC Workgroup to Consider?

2:45 – 3:00 **Summary and Wrap-Up**

3:00 ***Adjourn***

APPENDIX D: LIST OF PRESENTATION SLIDE FILES

Slide presentations are available as *pdf* files, and may be downloaded from:
http://www.nationalwind.org/events/siting/presentations.htm

Session I: Visual Impacts Presentations

Mike Pasqualetti, *Arizona State University*

M Pasqualetti-Visual Impacts.pdf

M Pasqualetti-Western US Perspective on Wind Pwr.pdf

Rick Benas, *Saratoga Associates*

R Benas-Visual Impact Assessment.pdf

Caroline Stanton, *Horner + MacIennan*

C Stanton-Visual Impacts UK and European Perspectives.pdf

John Hecklau, *Environmental Design and Research*

J Hecklau-Visual Characteristics of Wind Turbines.pdf

Matt Allen, *Saratoga Associates*

M Allen-Tools for Eval Wind Turbine Vis.pdf

Caroline Stanton, *Horner + MacIennan*

C Stanton-Visual Analysis Good Practice Guidance.pdf

Rick Benas, *Saratoga Associates*

R Benas-NY Mitigation List.pdf

Tom Priestly, *CH2M Hill*

T Priestley-Visual Impact Assessment.pdf

Session II: Lighting, FAA Regulations, and Air Hazards Issues Presentations

Jim Patterson, *FAA*

J Patterson - Obstruction Lighting for Wind Turbine Farms.pdf

Major William Crowe, *U.S. Air Force*

W Crowe-Wind Energy Dev and Air Force Operations.pdf

Session III: Sound Presentations

Jeroen van Dam, *Windward Engineering*

J van Dam- Wind Turbine Noise.pdf

Anthony Rogers, *University of Massachusetts*

A Rogers Infrasound and Physchoacoustics Corrected.pdf

Bo Søndergaard, *DELTA*

B Sondergaard-Propogation of Noise from Wind Turbines.pdf

B Sondergaard - European Perpectives.pdf

Mark Bastasch, *CH2M Hill*

M Bastasch-Regulation of Noise in US.pdf

Session IV: Electromagnetic Interference Presentations

Gary Seifert, *INL*

G Seifert -Wind Radar Interference Fact or Fiction.pdf

Steve Appleton, *QinetiQ*

Slides not available

Les Polisky, *Comsearch*

L Polisky-Identifying Radio Frequency Interference from Wind Turbines.pdf

Session V: Safety Impacts Presentations

Brian Smith, *NREL*

B Smith-Design and Standards for Safety.pdf

Ian Baring-Gould, *NREL*

I Baring-Gould-Turbine Operation in Icing Climates.pdf