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IMPORTANT NOTE: While most of the information in this report remains useful, AEI's more recent wind farm noise reports and conference presentations add valuable new information and context for understanding the subtlety and complexity of this issue.

A section here that may be particularly valuable, and is not reprised in detail elsewhere, is the material about more cautionary acousticians.

Likewise, the Appendix on AEI's NEWEEP presentation remains a good introduction to community response research (as does the full presentation, available at the link below).

See http://www.acousticecology.org/wind for the most current information.

Wind Farm Noise 2011

Science and policy overview

Compiled by Jim Cummings

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Preface: About this Report

It's been over two years now since wind farm noise issues showed up on my radar here at the Acoustic Ecology Institute. In early 2010, I published AEI's first annual report on the issue, in which I tried to make sense of the wildly incongruous perspectives that seem to dominate our discourse: on the one hand, wind boosters minimize the extent and effect of noise near wind farms, insisting there's nothing to bother ourselves over, while on the other hand, increasing numbers of apparently clear-headed citizens say their quality of life is destroyed by the incessant noise of nearby turbines. A few cranks harping on their latest pet peeve, or brave souls speaking truth to power? Is wind energy a benign key to our energy future, or a scourge in our communities that we'll live to regret?

In typical AEI fashion, the Wind Farm Noise 2009 report came down somewhere in the middle on these questions. It's clear that wind turbines are often audible in the surrounding landscape – often audible to a half mile, sometimes to a mile or more. They may not be loud, but they can be heard; several aspects of the nature of wind turbine noise seems to makes their sound more noticeable and more disturbing than other noise sources. In some communities, a significant minority (a quarter to half) of those hearing the turbines are upset about the new noise in their local soundscape; we're definitely hearing from far more than a few local naysayers. At the same time, most wind farms are built in areas distant from concentrations of homes, and so create few if any noise problems. In the wide-open spaces of the US west and in receptive farm and ranch communities in states like Iowa and Texas where the income is welcome and/or homes are few and far between, noise has been only an occasional problem.

The issue of wind farm noise has exploded in importance over the past few years as wind developers set their sights on rural communities in the upper Midwest and northeast, where individual parcels are smaller and a significant proportion of the population holds strong to a passion for the peace and quiet of rural living. In July 2010, I was asked to take part in a DOE-funded webinar to provide some perspective on community responses to wind farms; the resulting research review opened up fascinating new perspectives on the dichotomy of responses we hear in wind farm communities, which will be summarized in this report as well. Sneak preview: working farmers and ranchers are far less bothered by low and moderate noise levels from wind turbines than are those who live in the country for peace and refuge from the urban and suburban life. This isn't surprising, but it's central to the challenges at the heart of community siting decisions. One of the recurring themes you'll find here is the idea that what's right for one community or region may not be right for another; what I am trying to offer is a set of resources that will help community, county, or state planners to understand likely noise impacts, and to make choices about setbacks that they feel are appropriate for their citizens.

This report attempts to share the most useful new information that I've garnered over the past year or so. For some, it will seem long; I encourage them to scan the text using the underlined and colored sections as skimming aids, and dive in where they wish. For others,

it may seem that I gloss over important points; I will make more detailed source material available on the AEI website.

If you don't have time to digest the full report, another approach would be to focus on the first several pages, where I introduce the main themes of the report and offer a sense of my emerging perspective on the issue. Reading or scanning the rest will obviously help you understand why I have come to the perspectives I hold, and will introduce you to some of the key aspects of emerging research.

The bulk of the report focuses on what I see as the most important – and also the least controversial – of the emerging new information on wind farm noise, the idea that existing community noise standards may not protect all types of towns from unacceptable levels of negative community reaction to wind turbine noise. Over the past couple years a growing cadre of extremely experienced acousticians has begun to examine the question of why we are seeing unexpectedly high levels of complaints in some wind farm communities. Most of these acousticians have long worked as industry and military consultants (not wild-eyed radicals by any means), and each offers interesting and important insights that can help us to address the question. These acoustics and community noise experts are responding to their professional obligation to investigate noise issues, and deserve to be heard. Their work reinforces my long-held belief that the clearly audible noise around wind farms is the central issue, and that addressing this issue is the clearest, most easily understood and justifiable, approach to dealing with community acceptance of wind energy.

I will also address, far more briefly, the two other noise-related policy questions being pressed in many communities: low-frequency noise and infrasound as it relates to health effects, and property values. Both of these topics are far harder to assess than the audible noise impacts being primarily addressed by most of the acousticians featured in the report's first section. While there is clearly more to learn about both topics, they also can become quite a quagmire for folks like me trying to understand what's known, and for community groups relying on these as foundations for their efforts for more protective setbacks. Perhaps another year will find AEI fleshing these themes out in more detail, but for now, I'll do my best to give you a sense of what I've learned so far about these hot-button topics.

Of course, no summary can be all-inclusive, and because of this, any report bears some editorial selection in its author(s) choices of themes to stress. In an appendix, I offer a sense of my history as an editor on similar topics, and my choices of what to include here, so you can judge for yourself to what degree you can place your faith in me as an honest broker of the information presented here about this complex and controversial topic. I hope that what I've gathered here is useful to most of you.

Introduction: AEI's Perspective

Since the beginning of 2011, as I continue to watch and listen to the content and tenor of the public policy debate around wind farm noise, I'm increasingly struck by two key thoughts:

> Most wind advocates, including both industry players and regional renewable energy organizations, appear to continue to be in a state of disbelief that the noise of turbines could possibly be a significant issue for nearby neighbors. While they do increasingly acknowledge that turbines will be audible much of the time, they consistently paint complaints about noise as being unworthy of serious consideration, either because turbines are not all that loud, or because they believe all noise complaints are bogus surrogates for a broader opposition to wind energy that is "really" based on visual impacts or economic arguments (driven in some cases by climate change denial). While there is some overlap between people who are disturbed by seeing turbines and by hearing them, this connection is often overstated as wind advocates seek to discount noise issues. Perhaps most crucially, wind advocates rarely acknowledge that turbine noise is often 10dB louder than background sound levels (sometimes even 20dB or more); acousticians have long known that any increase over 6dB begins to trigger complaints, with 10dB the threshold for widespread problems.
>
> Most community groups are over-reaching in their approach to raising the issue of noise, by focusing too much of their argument on possible health impacts of wind turbine noise exposure. While there are numerous reliable anecdotal examples of people having physical reactions to nearby turbines, the mechanisms behind these reactions remain obscure, as to other possible factors that may contribute; evidence for direct health impacts caused by the noise itself is not yet solid enough to win legal arguments, and making the case for indirect impacts (due to sleep disruption or annoyance) is difficult at best. In addition, even the accumulating number of reports of health reactions to new turbines represents a small minority of people within a mile or so of turbines. Much more convincing are community response rates that affirm that – in some types of rural communities – large proportions of people hearing turbines feel that their quality of life is severely impacted. While it may seem harder to push for larger setbacks without relying on the dire possibilities of health impacts, I believe that in many rural towns, counties, and states, the rural quality of life argument would be a far more defensible foundation from which to obtain more protective and flexible setback requirements that could minimize or eliminate nearly all noise issues (including whatever health effects may be occurring) – right now, without arguing about research techniques that few understand.

This new annual report aims to frame the current state of research and policy in a way that can help those trying to find a constructive middle ground that protects rural residents from an intrusive new 24/7 noise source while also encouraging wind development as part

of our renewable energy future. Most of the emphasis here will be on giving communities the information they need in order to make their own choices about what degree of new noise makes sense in their particular situation.

There are still plenty of locations in the US and Canada where wind farms can be built without causing undue impacts on the sense of place that rural residents so treasure. In ten years, as an ever wider array of renewable energy sources become part of our electricity mix, we'll look back and wonder what we were thinking when we erected giant wind turbines in and amongst homes, with such little regard for the fact that these machines irrevocably change the nature of rural life. We can avoid the surprisingly invasive effect of moderate or even faint wind farm noise in otherwise pastoral landscapes without causing wind development to grind to a halt; such scare talk is unwarranted, based on what we can easily see is possible in the many, many locations where wind farms have been built with little or no noise issues in their local communities. All it takes is not building *quite* so close to unwilling neighbors – just being a bit more neighborly as we plan new wind farms.

Noise issues in context:
Anti-wind smokescreen? Undue fear? Unacknowledged plague? Shocking surprise?

It may be worth a moment's pause from the focus of this report—the effects of audible noise on the quality of life of wind farm neighbors—in order to note the several larger contexts within which the realities of the noise issue is sometimes lost or confused.

Too often, noise complaints are discounted altogether as merely an easy excuse for those who are simply anti-wind, or who don't like wind turbines in their view. There's no doubt that some people who are more broadly resisting wind development latch onto the noise issue as one part of their argument, but it's clearly false to imply that all those with noise concerns are anti-wind. Over and over again, the most compelling testimonies from wind farm neighbors who are struggling with noise issues come from those who were actually in favor of their local wind farm and excited about renewable energy in their communities. For most of these folks, the impact of 40-45db turbine noise comes as a total surprise, and it is this shock, as well as the ways the noise intrudes on their sense of place and rural quiet, that they most want to share, so that others can make decisions with this awareness about the perceptual intrusion of moderate noise that they lacked.

There is some research that shows correlations between noise annoyance and dislike of the wind farm itself. However, most such research took place after wind farms were in place, so it's hard to know whether the negative attitude toward the wind farm is *because of* the noise issues, or *contributes to* the noise complaints. It's entirely plausible that the experience of struggling with noise would lead to a negative attitude toward the wind farm. In addition, none of these studies show anything close to a one-to-one correlation; there are always neighbors for whom the noise is the primary problem, or the aspect of the wind farm that they find hardest to get used to.

In small rural communities, many people report that tensions run high between those hosting or supporting wind development and others who are having problems with the noise or their health. It can be hard to know exactly how many people are struggling with noise issues, since some people shy away from making waves. It's commonly reported by those in communities with noise issues that there are others either struggling with noise or trying to adjust to it who are not speaking out. These folks tend to question AEI's generalization, based on the few formal surveys that have been published, that annoyance rises only to around half of those hearing turbines; they often suggest that most people hearing the noise are bothered, unless they've got some hearing loss. This may well be, though I am content with the idea that a strongly negative impact on a quarter to half of those exposed to turbine noise is enough to justify considering changes in current setback standards.

Both the discounting of noise issues, and the belief that they must be nearly universal, are natural consequences of differences in noise sensitivity (see Appendix A). Those who are sensitive to noise have a hard time imaging how anyone could tolerate the intrusion, while those who are tolerant of noise can't see why it would bother anyone.

Finally, the objection is often voiced that community groups raising noise concerns are creating excessive fear about proposed wind developments, and that this fear itself may amplify or even create the negative reactions that are reported. This is a hard one to grapple with, because it does seem that some of the risks raised by community groups are presented as more definite or widespread than they actually are around active wind farms, while other concerns are clearly based on solid evidence. My observation is that the pre-construction level of fear *is* likely being amplified somewhat out of proportion, but that once wind farms are operating, those who report struggling with audible noise impacts are *not* delusional, and are reporting actual experiences. Suffice to say that just because some people highlight relatively rare cases of serious health impacts or people driven from their homes by lack of sleep, that doesn't mean either that these examples are irrelevant, *or* that they will occur everywhere. And most centrally, even if these most dire experiences are rare and unlikely to happen to most wind farm neighbors, that doesn't change the fact that high proportions of nearby neighbors in many communities say that the turbine noise has been an unpleasant and disruptive intrusion into their lives. It is this simpler yet perhaps more fundamental and universal value that I think is the most important thing to keep in mind.

But then, I'm someone who by vocational and personal experience is especially interested in, and connected to, the quality of the natural and human soundscape and the ways that new sounds change our experience of place. The arrival of spring migrant songbirds, the gradual fading away of night insects in the fall, the subtle play of breezes on trees nearby and hills in the distance, and the seasonal coming and going of the hum of the highway a mile away—these sounds all inform my sense of place. While I may be more focused on this than many people thanks to my line of work, such experiences are very common among a large segment of the rural population. This is the reason that AEI feels it's

important and worthwhile to keep emphasizing the extent of audible wind farm noise, and to encourage communities to make decisions based on some clear appreciation for how this may play out for their friends and neighbors.

Problems grow when turbines are close enough to be easily heard by neighbors

While wind farms in the wide-open spaces of the west operate with few if any complaints, many towns and counties around the US and Canada are finding that the noise levels commonly allowed around wind farms (40-50dB) are triggering strong negative responses in a high proportion of neighbors close enough to hear these levels—often 25-50% of those living within a quarter of mile to three-quarters of a mile or so. These proportions closely match those found in the rare peer-reviewed studies of community responses. Not every close neighbor is disturbed, which leads some to think the problem is not with the noise, but with the people complaining. However, we'll see that it's entirely normal to see a range of noise sensitivity in a population, with around half being unlikely to be bothered by any but the loudest noises.

Likewise, when surveying the entire town (including those far from turbines), noise issues seem to affect only a small proportion of people. It's when we look at those living close enough to experience clearly audible noise levels on a regular basis that the problem comes more clearly into focus. The problem is not building wind farms; the problem is placing turbines close enough to homes that they are clearly audible much of the time. So the real nut of the question for towns preparing to host wind farms is to consider the impact on those closest, within a half-mile to mile or so. If all turbines were a mile or two from homes (as is the case in many wind farms), we'd have virtually no noise issues. However, since current setback limits are often a quarter mile or less, shifting to mile or more setbacks can seem to be going to far; in recent months, some places (including the county next door to mine) have adopted half-mile setbacks in an attempt to find a new middle ground. This will clearly reduce noise issues by keeping peak sound levels closer to 40dB at the nearest neighbors, though they will still sometimes creep higher, and in many rural areas it's likely that a quarter or more of those between a half mile and three-quarters of a mile to a mile will continue to be negatively impacted.

This becomes the concrete community decision point: should we put the turbines close enough to rob a significant proportion of these neighbors of the peace and quiet around their home that all of us living here enjoy? What is an acceptable level of disruption? While it may be considered acceptable to set a noise limit that will bother a small proportion of those hearing it, I think that few would feel that they've found the right noise limit if it triggers complaints in a quarter to half of those who hear the allowable noise. According to the research we have to work with, as well as reports from several recent towns where noise has become an issue, there are real questions about whether wind farm noise limits of 40-50dB actually provide the kind of protection that we expect from our noise ordinances.

Again, these "real questions" do not have universal answers—what works in one community may not work in another. Some communities may want to provide near absolute protection from non-household noise (including wind turbines), while others may easily accept routinely audible noise from turbines, motorized equipment, or industry; many will likely fall somewhere in between. It may be appropriate to look at programs that either compensate or buy out neighbors whose quality of life is being "sacrificed" in the name of the greater public good; some wind developers have done so[1], though this option is more often seen as introducing unacceptable levels of uncertainty into project budgets. This report won't attempt to assess such options, but they are certainly being discussed by many citizens and other observers.

Where wind farms make sense

Over the past year, I've been fortunate to find myself driving across several different regions in the U.S., and have often come upon wind farms. Every single time I encountered a wind farm in the wide open spaces of the west and midwest (in NM, TX, Iowa, Nebraska, Kansas, and Wyoming), they seemed to be totally *right* for their place; ranging in size from a dozen turbines to sixty or so, to many hundreds or thousands spread over tens of miles, these wind farms were rarely within a mile, or even several miles, of homes. Sometimes there would be one or two homes on the edges of the wind farm, likely owned by the lessees. Even these homes, several hundred feet to a half-mile from the nearest turbines, somehow made sense in the larger context of the place and the landowner's commitment to wind.

Conversely, when visiting wind farms in Wisconsin it was downright unsettling to enter a wind farm filled with small homes and farms, all surrounded by turbines; these folks are living *in* a wind farm, rather than near one. Similarly, neighbors in places like Vinalhaven, Maine, and Falmouth, Massachusetts who were excited about renewable energy in their communities have found that living within half to three-quarters of a mile of even one or a few turbines can be shockingly disruptive to their enjoyment of backyards and to their sleep. My experience in wind farms has been very consistent: I have always been able to clearly hear any turbines that were within a half mile of me (faintly, but clearly there); at a quarter to third of a mile, the sound stood out, and as I approached three-quarters of a mile, the sound faded into the background sounds of distant roads or ground breeze.

Occasionally in my travels, the turbines would be close to the road or highway I was driving on. Once, in Kansas, I pulled off the road to take a look and listen. The nearest turbines towered above me; I guessed they must be within a quarter mile. Once I moved away from the two-lane federal highway and crossed the nearby railroad tracks, several turbines were clearly audible between passing cars from my upwind location, despite ongoing faint background road noise. Then I drove out the dirt road that ran perpendicular to the turbine arrays, and was surprised to find that the closest turbine was in fact four-tenths of a mile from the tracks.

This is a recurring experience when exploring in wind farms: they always seem much closer than they really are. Driving toward my first wind farm, I was *sure* I must be within a couple miles when I was still between three and four miles away, and likewise, was certain they were within a mile when I was still nearly two miles away. Similar distortions of perception occur at close range, even now that I should know better: turbines a half mile away seem *incredibly* close, and ones a mile away seem to be just far enough away to minimize that sense of looming closeness.

Stated simply: building close to neighbors is just plain rude

While this may come off as ridiculously fuzzy-wuzzy, it seems to me that the best argument for larger setbacks in populated rural areas is that it's simply *impolite* to put a 400-foot turbine closer than around a mile to someone's home without their agreement. Or to put a sharper edge on it, it's just plain rude.

It's easy to make a less subjective/emotional version of this point: noise control and community noise specialists have long known that a new noise source will become noticeable when it is 5dB louder than existing sounds, and will cause widespread complaints at 10db louder. Wind turbines making 40-50dB of noise will often be 10dB louder than background ambient, and sometimes as much as 20dB or more. Some states (notably New York) attempt to avoid noise intrusions by limiting turbines to 6dB louder than existing ambient; this leads, predictably, to arguments about how low existing ambient really is when turbines are operating. But the emerging consensus is that in some fairly common situations, ambient can be as low as 20-25db. So, unless you keep the turbine noise to 30-35db, they are likely to be rudely loud.

At the same time, a setback of a half-mile (with the accompanying noise levels of around 40dB) could well be enough for some non-participating neighbors, especially if they don't spend a lot of time outside their homes, or are old enough to have some hearing loss. Indeed, many people would probably not mind a turbine a quarter mile away or closer, especially if it offers some supplemental income, as is clearly evident in some farm and ranch areas where noise has not become much of a community issue.

A possible route forward: larger setbacks, with simple easements for closer siting[1]

My experiences around wind farms – walking, driving, looking and listening – as well as taking in both the reports of neighbors affected by unexpectedly intrusive levels of noise from turbines a half mile away and of industry experience that suggests noise levels of 45-50dB are often tolerable, lead me to my current perspective that the most constructive and

[1] **A note on the word "siting":** some readers of previous AEI reports have said this word confused them. I think they saw it as a variation on sit or sitting, and weren't sure how it applied. It is a variation on the word "site," with an "-ing" suffix: i.e., choosing where to place turbines.

widely beneficial path forward would be a shift toward larger setback requirements (in effect, lowering the maximum noise levels at homes nearly to quiet night time ambient noise levels), combined with easily crafted easement provisions that allow turbines to be built closer to landowners who agree to allow it. This would protect communities and individuals who have invested their life savings in a quiet rural lifestyle, while acknowledging that there are many in rural areas who are ready and willing to support wind energy development, even near their homes.

Fortunately for the rest of you, I'm not the boss of the world, so what I think doesn't really matter. However, in towns, counties, states, and provinces across the continent, groups of diligent citizens are trying to make sense of confusing information and starkly opposite yet adamantly stated opinions. I hope that this report can help to clarify some of the reasons that such differing views exist, and give some support to efforts to find a workable path forward for both the wind industry and rural lifestyles.

Three key themes

This year's report will focus on three key themes that have become the central pillars of local resistance to current wind farm siting standards. None of these three need to be obstacles to wind development, *if* the industry and local and state regulators can move beyond simplistic denial, and forge a way forward that acknowledges the validity of community concerns about the changes that industrial wind farms inevitably bring with them. Indeed, the continued growth of the wind industry in the US and Canada may depend upon a fundamental shift of attitude, centered on providing communities with assurances that the negative impacts they fear will be incorporated into project planning—and more importantly, addressed if they occur.

1. Community Noise Standards: Are standards used for other noise sources sufficient, or is wind farm noise unique enough to need lower noise standards? Are "one size fits all" noise standards essential to foster wind development, or is it acceptable for different communities to choose different standards, based on local land use patterns and lifestyles?

2. Infrasound and health effects: Always inconsequential, or worthy of serious study?

3. Property values: How should we make sense of studies that counter-intuitively conclude that the presence of wind turbines has no effect on property values? Is there any practical need, or community-relations role, for property value guarantees and/or buyout provisions?

The need for respectful engagement with differing opinions

Cutting through all three of these themes is an underlying dynamic that is truly poisoning the waters of general public discourse as well as attempts by countless county commissions and statewide task forces to make sense of the controversies: there is a growing tendency for professionals (acoustical engineers, physicians, assessors) to vilify their peers who have a different view of the extent of problems with current wind farm regulation and siting. The "truth" about physical acoustics (sound levels around wind farms, frequencies of concern), health impacts (how prevalent or how severe), and property values are not as cut-and-dried as advocates for either side suggest. Most importantly, it's clear to me as an outside observer that well-educated, experienced experts in each of these fields are coming to diverse interpretations of the data we have to work with. I see professional disagreement after diligent assessment, not wayward acousticians or doctors or assessors who are biased anti-wind crusaders or shills for industry. This is a very important point, and is in some ways the central theme of this report.

If we frankly engage these three issues, and cultivate an underlying tone of respect and openness to each other – building a bridge over the current chasm that separates those who interpret the research differently – it seems likely that we can craft siting guidelines

that protect local citizens from drastic quality of life impacts while providing clear and flexible avenues for future expansion of the wind industry as part of our future energy mix. That is the underlying goal of AEI's efforts to help both sides understand the other, and to help regulatory authorities to find their way to a balanced perspective on the contentious issues they are trying to address.

A huge business upside awaits for flexible wind developers

It's becoming increasingly clear is that communities *do* differ in their tolerance for noise, and in their willingness to accept the obvious (as well as the uncertain) trade-offs that come with wind farm development in their midst. There is no reason that we need a one-size-fits-all approach to wind farm siting. Some communities may decide (as the Roscoe TX area has) that wind farms are a positive addition to their communities. Others may seek to keep noise levels relatively low, as is the case in rural Oregon, which has an effective 36dB upper limit. Some may want to ensure that residents rarely if ever even hear turbine noise, adopting setbacks of a mile or more. A wind industry that is committed to being a good social citizen will accept these differences, and focus their development efforts accordingly, rather than trying to convince regulators that noise standards that work for the most noise-tolerant communities are the standards that should be adopted in all communities. There will often be some higher costs imposed by stricter siting standards (most commonly, the need to build extra miles of transmission lines to link to the grid), but such costs are often modest in the context of a large wind farm project.

Yes, some locations – in fact many locations in rural areas with relatively small lot sizes – may be hard or impossible to build in, but these are exactly the locations where the social tradeoffs, and the resulting balancing of costs and benefits, are least clearly favorable to wind development anyway. If the industry can accept that it doesn't have the *right* to build anywhere the noise can be kept to 50dB (which is becoming the preferred target standard for industry advocates), and that its future development will be taking place within the fabric of a diverse society, then there is a clear business opportunity emerging for those companies that take the lead by crafting truly responsive community relations programs. These companies will commit to working with the standards set by local tolerance for industrial wind development, rather than pushing local or state authorities to make it easy for them by adopting minimal siting standards. These leading edge wind companies may also put their money where their mouth is on property values by establishing programs that compensate landowners for moderate changes in property value, and helping create programs that buy and sell homes, so residents who wish to sell their homes can do so quickly at fair market value. These companies will develop reputations as companies that are ready to be good local citizens, and will find that the increases in some costs and a willingness to forsake some locations altogether leads to dramatic benefits in terms of long-term stability and acceptance in the communities where they work, and especially, in communities where they propose new projects.

Community Noise Standards

At the heart of the debate that's raging in communities around the world is the question of how far wind turbines need to be from homes. Beyond the basic safety buffers of 1.5 to 3 times turbine height that protect people from the rare occasions when a turbine falls down or breaks apart, the question of the proper setback from neighboring homes boils down to noise impacts. Some regulations set a maximum noise limit, while others define a minimum distance between turbines and homes. In practice, though, the distance-based standards are also generally based on an assessment of the likely maximum noise levels at the regulated distance.

The way it's "always" been

In recent years, it's been common for US and Canadian regulations to require setbacks of 1200-1700 feet, which roughly correspond to noise limits of 40-50dB. In most of the communities that have become "poster children" for wind farm noise issues, the residents living just beyond these distances (from 1200 to 3000 feet) are finding that noise levels in the range of 45dB, or even 40dB, are perceived as quite loud in quiet rural landscapes. This has led many in those communities to seek operational changes in the turbines to reduce noise; however, in most cases, the turbines are operating within the legal noise limits. In a few cases, recordings made by residents or hired acoustics consultants have found noise levels in violation of limits, but only by a few decibels (almost always just 1-3dB). Such small differences are effectively inaudible (it takes 3-5dB to be perceptible as a difference in loudness), which suggests that legal noise limits of 40-45dB may not be low enough to minimize impacts. In apparent response to some cases of turbines in existing wind farms slightly exceeding limits of 45dB, the industry has more recently been advocating noise limits of 50dB.

At the same time, the wind industry can point to many wind farms where residents are living 800-1500 feet from turbines, with very few if any noise complaints arising from received levels of 45dB or even 50dB. Indeed, I've searched in vain for reports of noise problems at wind farms in Iowa, which generates more wind energy than any state other than Texas (I don't doubt there are some homeowners who dislike the local turbines, but they appear to be few and far between, compared to other areas that spawn pages of Google results in simple searches). And in Texas, with a quarter of the nation's wind power output, nearly three times more than Iowa[2], there have been a couple of high-profile cases, but no widespread uprising over noise such as we see in Wisconsin, New York, and Maine. These past experiences are what lie behind the industry's insistence that current standards are sufficient.

Likewise, decades of experience have led to the adoption of community noise standards of 45-55dB for many kinds of industrial noise. Based on research into annoyance responses, effect on sleep and health, and general community acceptance of noise, when a new factory, or office building with its ventilation systems, or even a new road, is proposed it must meet

community noise standards that virtually always allow noise at nearby residents to be 45dB, and often 50dB or more. These noise standards are not designed to reduce complaints or even displacement of the more sensitive residents to absolutely zero; but experience suggests that negative impacts should affect no more than a very small minority of nearby residents. Based on this long history of community tolerance for such noise levels, the wind industry strongly encourages local wind regulations to conform with these "generally accepted" community noise standards.

So how are these noise standards working?
(see Appendix A)

This leads naturally to the simple question: how are the generally accepted community noise standards working near wind farms? Do people hearing 40-50dB turbine noise find it is an acceptable presence in their lives, in the same way that these levels of road noise are easily tolerated? This was the topic of my presentation to the New England Wind Energy Education Project (NEWEEP) webinar in the summer of 2010. Funded by the DOE as part of its wind advocacy Wind Powering America program, this NEWEEP webinar was one of the first pro-wind events to take a direct look at community responses to wind farm noise. The presentation takes a close look at the Scandinavian research into annoyance rates at varying sound levels, as well as two lines of research that seek to explain why some people (and communities) react more strongly than others to wind farm noise. I had initially included a several-page overview of this research in the body of this report, as it offers a concrete picture of why many acousticians are questioning whether current community noise standards are sufficient for wind farm noise. However, it seemed to interrupt the flow of this section, so I moved it to Appendix A. If you have not seen the NEWEEP presentation, I do encourage you to flip to Appendix A now or later. The key points that inform what follows are:

- In rural areas, turbine noise levels of 40dB or more trigger a rapidly increasing level of annoyance in 25-50% of those who live close enough to hear these levels. Initial increases in annoyance rates occur as soon as turbines are audible, at 30-35dB.
- Individual differences in reactions to wind farm noise may be largely explained by referring to forty years of research into noise sensitivity.
- Community-wide differences in acceptable noise levels may reflect differing "place identities": those who work the land are far more tolerant of wind farm noise than those living in a rural area for peace and restoration.

Does wind turbine noise require tighter noise standards?

The crux of the current controversy is the suggestion that – at least in deeply quiet rural areas – wind turbine noise can cause problems at lower sound levels than other industrial noise sources, so that lower noise limits may be justified or necessary. This suggestion is based on the experience of communities where noise is an issue, and on some new (and old) ways of assessing noise annoyance potential.

A growing number of acoustical engineers have come to the conclusion that "generally accepted" community noise standards are clearly not protecting communities from wind turbine noise to the degree that 40-50dB limits would protect them from other noise sources. These acousticians have begun to suggest that noise limits of 35dB, or even 30dB, at nearby homes are more apt to lower annoyance levels to those that we have come to expect from other sources of community noise; aiming for lower noise exposure leads to setback recommendations that seem to be coalescing around distances of between a mile and a mile and a half (2km, or 1.25 miles, is a common recommendation).

Unfortunately, as these more cautionary acousticians have come to more prominence, submitting testimony to local and state wind ordinance task forces and generating detailed reports and recommendations that are cited by community groups, they've often been vilified by industry advocates. I heard the reputations of some of these acousticians directly attacked in a county commission meeting I attended, suggesting that their assessments are based on fundamentally faulty understanding of basic acoustics literature. (Equally unfortunately, acousticians that write environmental assessments for wind projects implying that the status quo is acceptable are often characterized by community activists, and sometimes even by their more cautious acoustician peers, as scientifically suspect yes-men for wind development.)

The fact is that nearly all of the acousticians who question the effectiveness of current community noise standards for wind farms are just as experienced in their field as the acousticians that are cited by the industry to support the status quo. Most of those recommending larger – sometimes much larger – setbacks and/or much lower noise limits have worked for decades as fully credentialed acoustical engineers, and have turned their attention to wind farm noise over the past few years after hearing of the experiences of some neighbors, or being asked for their professional opinion by people who don't fully understand the noise reports being generated by the industry.

When these more cautionary acousticians present their findings and recommendations before local commissions or in legal challenges, they are often accused of being biased, with the suggestion that their opinions should be disregarded. This charge appears to be based on the idea that anyone who recommends lower sound levels or larger setback is fundamentally opposed to wind power development. In my reading of the various reports and testimony submitted by these acousticians, I don't see evidence of bias. There are, in many cases, clear opinions presented as to the effectiveness of various proposed noise limits as community noise standards, and clear recommendations about what noise levels or setback distances the particular acoustician feels is likely to provide the level of acceptance of turbine noise that communities generally seek in their noise standards for other sound sources.

By contrast, noise studies and noise models included in industry-generated environmental assessments and project planning documents present the projected noise levels around the turbines, and do not directly assess whether these noise levels are likely to be acceptable to

residents. Rather, the projects are designed to meet the local noise standards at homes, which are presumed to be sufficient. So, these acousticians may be perceived as simply providing information, rather than opinions. However, when it comes time for a community, or a state Public Regulatory Commission, to set noise standards or setbacks, the industry tends to make a case for standards in line with those for other noise sources. They plead for "fair" standards, which generally mean standards that will not preclude construction, and that are no stricter than those used in other places. Hence, the status quo of 45-50dB becomes self-replicating, based on being the most common standard used elsewhere.

This is the habit that the more cautionary acousticians appear to be encouraging regulators to break out of, because of the high incidence of problems in some communities where the status quo standards were applied. It's not clear to me why an acoustician who feels that, say, 35dB is a more reasonable noise limit for rural residential areas, so that turbine noise will be faint or inaudible to neighbors, is biased against wind power, while an acoustician who supports a 50dB day/45dB night standard, effectively saying it's OK for neighbors to live with more noticeable turbine noise, is considered to be unbiased. Most likely, neither is fundamentally biased; each has an opinion as to what is likely to work for communities, based on what they've seen elsewhere. (While some consultants may write what their client wants to hear, in my experience, most scientists and engineers are more interested in facts than spin, so I don't presume that being paid for your opinion or expertise sullies the veracity of the final product.)

As noted above, we are beginning to see that not every community has the same tolerance for noise. At the same time, we're learning that wind farms generate higher rates of annoyance and disruption at lower sound levels than other noise sources. Thus, our generally accepted community noise standards may need to be revisited and revised to be applicable for wind farm noise. This is the essence of what the cautionary acousticians are trying to say.

What do the more cautionary acousticians recommend, and why?

I want to stress once more that the increasing numbers of professional acoustical engineers calling for revised community noise standards for wind farms are not yahoos who just enjoy challenging the status quo: they have decades of experience in acoustics, community noise, and noise control, mostly for corporate and governmental clients (most with very little if any prior work for community or environmental groups). And, to this relatively disinterested observer who supports the growth of the wind industry and has no stake in whether any particular wind farm is or is not built, they don't appear to be operating from a biased perspective. To the contrary, their analyses, field measurements, and recommendations appear to be less connected to a preferred outcome than many of the local and industry voices, which are often quite explicit in saying that a key element of a "workable" regulation is that it will allow large wind farms to be built in most locations, or in a particular location. Part of my purpose in highlighting their work here is the hope that

other acousticians reading this will see the integrity of what they are doing, and so turn more professional attention to these important questions. I even have enough faith (or naïveté) to believe that some of their peers who have been content with earlier convictions that wind turbine noise is no different than other noise sources may have their interest piqued as well.

It's important to remember that these recommendations are not meant to bar wind development, and do not spell the death knell of the industry. Any regulations that adopt larger setbacks or lower sound limits can be, and usually are, combined with provisions that allow building closer to landowners who are willing to live with the occasional, or even regular, noise. The point of adopting more cautionary setback guidelines is to protect residents from unwanted noise, not to prevent wind developers from working with willing neighbors.

And while two of the following (Kamperman and James) have gotten the most attention and drawn the most vehement attacks, I can't help but notice that experienced voices are appearing in many regions and countries, all coming to generally similar conclusions. In keeping with my (floundering) intention to stay concise, I will refrain from quoting at length from their various reports and testimonies, but will focus on the particular contributions that each is making toward better understanding of the varied and at times vehement responses we're getting from different communities. I encourage you to read some or all of the footnoted sources, to draw your own conclusions about the relevance of these observations to your community's wind farm setback decisions.

George Kamperman, Illinois
Practicing noise control specialist since 1952, now semi-retired. Independent consultant since 1972, doing environmental assessments of all sorts of noise: industrial facilities in residential areas, mines and quarries, airports, a roller coaster(!), firing range, and many others. Designed noise control systems for industry: production facilities, heavy equipment, drawbridges, outboard motors and lawnmowers. Led development of the Chicago and State of Illinois noise ordinances, and served on committees that created several SAE and ANSI noise standards.

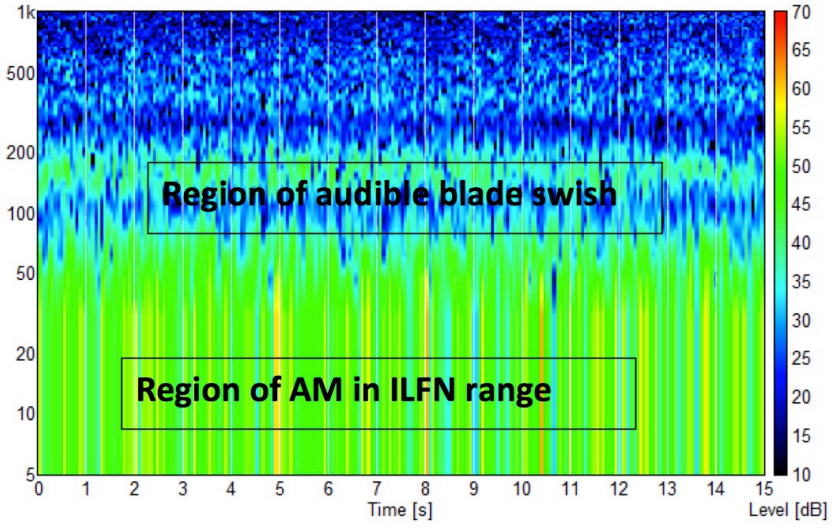
Rick James, Wisconsin
Has worked in noise control and measurement since 1971. Began with GM/Chevrolet, trained specifically to address emerging EPA noise regulations for the auto industry. Since 1976, as an independent consultant, he has provided noise control engineering services to GM, John Deere, and many other large companies; his company peaked with a staff of 45 working across North America. Early practitioner of computer modeling of sound, beginning in the 1970s. Years of testifying for corporate clients, affirming their use of the best available noise control technology.

> George Kamperman and I spent over six months reviewing wind turbine EIS statements and noise studies done in response to complaints before we felt we understood enough about wind turbines to support the position that they are unique and require a different type of criteria than more traditional noise sources found in communities. There is also the unique nature of the communities involved. When I first started reporting the low background sound levels I was measuring at night in many of these communities, people

like George and even Paul Schomer (who has done considerable work in wilderness settings for the Park Service) were shocked to see that rural residential properties were so quiet.
Rick James, email communication

Kamperman and James threw down a gauntlet in the summer of 2008 with the publication of "The 'How to' Guide to Criteria for Siting Wind Turbines to Prevent Health Risks from Sound." The tone of this guide is indeed aggressive, pushing back hard against perceived industry obfuscation about the noise levels around wind farms; no doubt one source of the reaction against Kamperman and James is the combative tone here. Yet, when faced with industry spokespeople presenting their opinions as unassailable fact, some of this feistiness can be accepted as necessary. Kamperman and James are also among the few more cautionary experts (in acoustics or health professions) who have explicitly incorporated Nina Pierpont's preliminary case series results (published as *Wind Turbine Syndrome*) into their thinking and arguments. Since 2008, James has made clear that he generally defers to medical experts on health issues, but the health basis of this early Guide is another reason that the Kamperman-James work has faced a strong backlash.

Digging into James' more recent field work and writings clarifies that his recommendations are grounded in measurements of audible noise, and in community responses to the sound levels, low-frequency amplitude modulation, and mid-frequency blade swish/thump that is characteristic of the newer, larger turbines. He appears to be most struck by the relatively extreme Amplitude Modulation he's recorded in several locations, both infrasonic and audible. In infrasonic ranges, the "dynamic modulation" is often 30-40dB between low and high sound levels, shifting in well under a second, sometimes peaking as high as 90dB, which even in these extremely low frequencies are likely to be perceptible by the 10% of the population whose hearing is more sensitive than most at these frequencies.



Meanwhile, audible "blade swish," the pulsing louder/softer pattern, which is most often in the 3-5 dB range (just perceptible difference in loudness), has been recorded as high as 13dB:

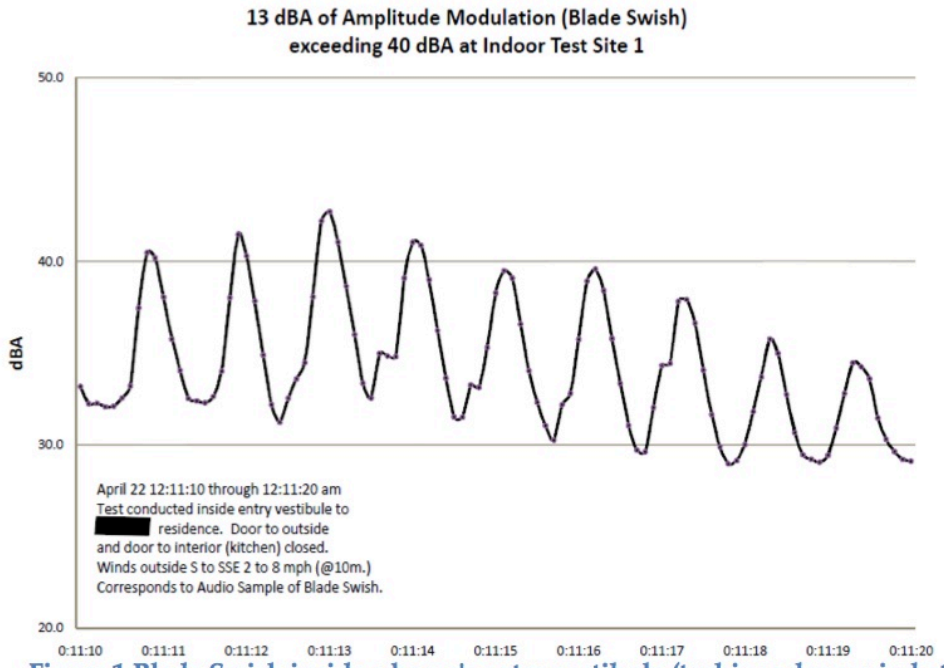


Figure 1 Blade Swish inside a home's entry vestibule (turbines downwind at 1500 feet)

James has often taken exception to fairly widespread assertions that "there is no significant infrasound from current designs of wind turbines." Such statements really mean that infrasound is well below normal perceptual thresholds, while in fact wind turbine sounds are heavily weighted toward low and infrasonic frequencies, with over half their total acoustic energy below 200Hz. When addressing infrasonic issues, though, James is generally careful to stress that his recordings suggest only that they could be audible to those with the most sensitive low-frequency hearing, and does not imply these sound levels are perceptible to most.

The Kamperman-James siting guidelines suggest keeping modern industrial wind turbines at least 1.25 miles (about two km) from homes, with the goal to keep turbine noise to 35dB, or 5dB above the ambient noise levels, whichever is lower. At the time they were published in 2008, James notes that they were aiming to find a precautionary distance that should provide some comfortable room for error; after doing several more years of field recording, he now considers the 1.25mi/2km buffer to be a minimum, if the goal is to avoid widespread impacts on the nearest neighbors.

While Kamperman and James are the lightning rods for both attacks by the industry and cheers from community groups, they are far from the only experienced acousticians who've come to believe that neighbors need larger setback from wind farms because of the noise impacts. Two other "acousticians emeritus," in addition to George Kamperman, have voiced their concerns: Malcomb Swinbanks and Paul Schomer. And several others with thirty years experience have added important perspectives to these questions.

Malcom Swinbanks, UK and Wisconsin

After getting his Ph.D. in applied mathematics in the early 1970's, Swinbanks became an expert in fluid and wave mechanics (which includes sound waves), and became a noise control specialist. Like many other acousticians, he became a consulting engineer, and worked with both the UK and US Navies on noise dampening of Naval vessels, focusing on exhaust and propeller noise. He is especially well-versed in low-frequency and infrasonic sound.

> I have stood beside two people on a site where low-frequency noise was present. One person said 'I can't really hear anything.' The other said 'I feel ill. I should like to leave.' Both were reporting accurately; there can often be more than 12dB difference (a factor of 4) in the sensitivity of individuals to low-frequency noise. Given that for very low frequencies, 12dB represents the difference between just audible, and uncomfortably loud, it is clear that very real problems are experienced by some individuals, while others remain largely unaffected.
>
> It is important to emphasize that there does not yet appear to be a full understanding of how to assess low-frequency wind-turbine noise. So it is difficult to understand how it can be argued emphatically that there is no problem, when it is clearly reported that significant ambiguity still remains in assessing these effects.
>
> The misunderstanding may lie in a failure to take into account correctly the impulsive nature of the turbine noise…Although it is now widely recognized that this can give rise to low-frequency modulation of higher frequency aerodynamic noise, resulting in a "swishing sound" (aerodynamic modulation), it remains the case that the low-frequency effects of the impulse are often incorrectly analyzed. This latter effect has been described as a distinct repetitive "thumping sound" audible at distances of 500 to 1000 meters (~ 1600 to 3300 ft.)
>
> The feature of impulsive noise is that there is a large signal present for a short period of time. Consequently, the mean, or root-mean-square (rms) level of the signal may be very low, apparently well below the threshold of hearing, but the peak level is much higher and can be perceived. [3]

This would help explain why so many neighbors report low-frequency sounds as troublesome, even at distances out to a mile or more at times, because hearing

curves are determined using "sinusoidal" waves at various frequencies, which rise and fall gently. By contrast, the impulsive turbine sounds are likely to be more easily heard, because they have a sharper nature, called higher "crest-factors". As Swinbanks notes:

> C.S. Pedersen has reported that band-limited 2Hz-20Hz (infrasonic), and 2Hz-40Hz (infrasonic and low frequency) white noise is audible 7-10dB below the threshold defined for sinusoidal signals. This observation is consistent with the increased crest-factor of such noise. But low-frequency, repetitive impulsive sounds possessing a multiplicity of harmonic components have an even more recognizable characteristic, and are likely to be audible at even lower levels.
>
> Preliminary calculations indicate that periodic 1Hz impulses may be audible even when the individual components of spectral lines lie 25dB below the threshold of hearing. So simply examining low-frequency spectra and observing that individual spectral lines lie well below the threshold of hearing does not begin to summarize this situation accurately.[4]

Swinbanks has also addressed a little-discussed factor: the possible influence of the large wake of turbulent air that flows downwind from each rotating turbine. It may be that some of the physical sensations reported by wind farm neighbors are responses to the air pressure differences in these wakes, rather than sound waves. In addition, Swinbanks suggests that the wakes may contribute to the low-frequency sounds that are reported in some situations:

> For wind-turbines, a likely cause of infrasound is the downstream wake, which can reduce much more slowly than acoustic waves. There are regulations defining the separation time and distance which must be observed between large aircraft taking-off from a runway, because of the slow rate of decay of the wake turbulence and the danger of one aircraft flying into the wake left behind by a preceding aircraft.
>
> There is a downstream helical wake from a wind-turbine, and Denmark (e.g. Vesta) recommend a downwind separation of 7 wind-turbine blade diameters to avoid one wind turbine operating in the wake of another. But recent research at Johns Hopkins University has suggested that this figure should be increased to 15 blade diameters. For 100m diameter turbines, this would then require 1500m separation or just under 1 mile. The intensity of low-frequency wake fluctuations at this distance is probably significantly greater than the acoustic effects associated with the wind turbine.[5]

This seems a good spot to stress that the illustrative quotes I'm sharing here are meant to affirm the depth of careful and creative thinking that these acousticians are applying to the

problem of high complaint rates in some wind farms. These brief observations all appear in more detailed contexts, and should not be cited from this report as evidence or proof of any particular effect in submissions to local or state wind farm siting proceedings. Interested parties are advised to read the full citations, and to initiate in-depth conversations with trained acousticians in order to understand and interpret the significance of any particular statement included here.

Paul Schomer, IL

Schomer is perhaps the acoustician with the most impressive standing to have challenged the validity of current wind farm siting standards. He is the Chair of the American Acoustical Society's Standards Committee, and widely seen as having an impeccable reputation in his field.

Paul Schomer is one of many to critique the techniques often used in wind farm environmental assessments of existing background ambient noise levels. Such estimates are then the basis of estimating how much louder turbines are apt to be.

The prevalence of faulty pre-construction noise assessment is one reason that community groups have often called on more cautionary acousticians to "assess the assessments." Schomer did his own recordings, designed to avoid insect noise, which had dominated the pre-construction assessment recordings done by consultants for a wind developer. The results were starkly different:

> In Cape Vincent, daytime, evening, and nighttime A-weighted L90s average at 35.5, 30.7 and 24.6 dB, respectively. Thus, the overall day-evening-night simple arithmetic average is about 30 dB compared with (the developer's consultant's) reported average of 45 to 50 dB—a range of levels that exceed the true ambient by 15 to 20 dB—a huge error.[6]

Schomer stresses the relevance of the New York standard of keeping noise to less than 6dB over existing ambient:

> What is the bottom line? During warm-weather months, almost every other night, the ambient…will be about 25 dB(A). At the same time the wind turbine can be producing on the order of 50 dB. Rather than the permitted 6 dB increase, the true increase will be about 25 dB, and this huge increase may occur almost every other night. People will be very unhappy—and rightfully so.[7]

In some later work for the town of Hammond, New York, Schomer drafted a noise ordinance that offers a good sense of his still-evolving[8] recommendations. In this ordinance[9], he recommends varying noise limits for different times of day: 45db in the daytime, 40dB in the evening (7-10pm), and 35dB overnight (10pm-7am). When ambient background levels are lower than these limits, even if 10dB or more lower, he feels these sound limits are sufficient; when ambient levels are close to

(within 5dB) or greater than the limits, then turbine sounds of ambient+5dB are allowed[10].

Schomer's work for Hammond also specified some particular approaches to establishing existing background ambient levels, including the use of hourly L90 levels (the use of hourly, rather than longer-period, averaging helps to identify the quietest periods of the night), and an emphasis on avoiding recording during times when insects can increase the ambient measurements (while insects may be loud for some months or hours of the day, these should not be used to establish year-round or full-night ambient conditions). As he explains[11]:

> In relatively quiet areas insect noise, especially during summer months, can easily dominate the A-weighted ambient sound level. This domination occurs partly because the primary frequencies or tones of many, if not most, insect noises are in the range of frequencies where the A-weighting is a maximum, whereas, most mechanical and WECS (wind turbine) noises primarily occur at the lower frequencies where the A-weighting significantly attenuates the sound. Also, insect noise and bird song do not mask WECS noise at all because of the large differences in frequencies or tones between them.

Schomer has developed a weighting/correction method to be used when insects are unavoidable during the ambient assessments, which he terms Ai weighting[12].

Rob Rand and Steve Ambrose, ME
Thirty years experience in general acoustics including ten years in the Noise and Vibration Control Group at the international Stone & Webster Engineering Corporation. INCE member.

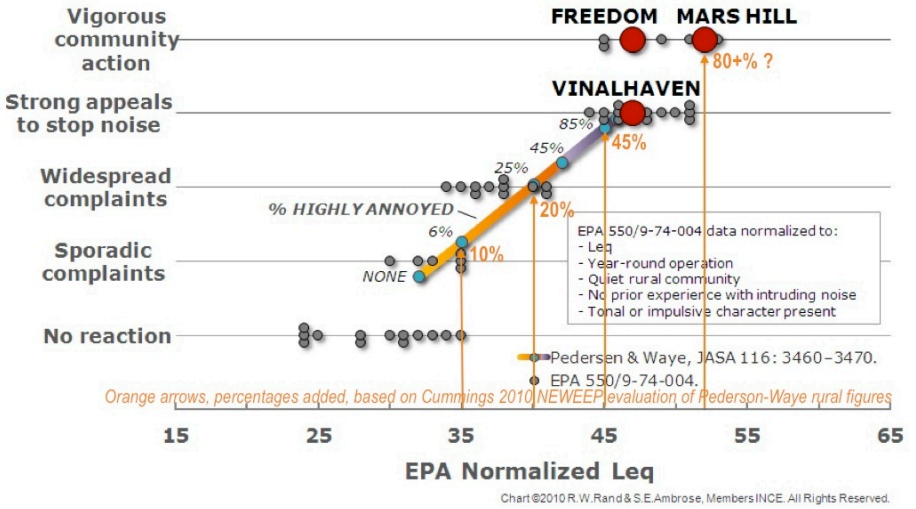
Rand and his equally experienced colleague Steve Ambrose have contributed some very clear reminders about what has long been known: that similar sounds are experienced very differently in different situations. In particular, they have stressed that when the EPA was developing recommendations for community noise standards in the 1970's, it looked very closely at the rates of community disruption caused by increasing noise levels; they correlated noise levels with community responses ranging from "No reaction although noise is generally noticeable" to "sporadic complaints," "widespread complaints," "strong appeals to local officials to stop noise," and "vigorous community action."

While for much of the country, a recommended upper noise limit of 55dB (and 45dB at night) would assure that complaints were sporadic or non-existent, the EPA noted that in quiet rural areas, correction factors should be applied in setting local limits. Rand suggests that for many communities where wind farms are being proposed, three EPA-recommended correction factors make sense: 10dB for quiet or rural areas, 5dB for a noise source the community has no prior experience with, and 5dB for the impulsive character of the blade swish.

If all these correction factors were applied, it would result in noise limits of 35dB; if just the rural correction were applied, it would result in limits of 45dB in the day and 35dB at night. Rand notes that as he and other acousticians have repeatedly found, existing ambient noise conditions in quiet rural areas tend to range from 25-35dB, so these lower noise limits would keep turbines close to existing background noise levels. Again, the early EPA work stresses what has long been accepted: sporadic complaints begin as new noise sources reach 5dB over current background, become widespread when the new noise is 10dB louder than background, and are vigorous and sustained at 20dB above background.[13]

Note: This long-known relationship has been stretched in many places in recent years: it's become quite typical for noise ordinances to allow up to a 10dB increase over the background ambient. I don't know how this gradual shift has been justified, since the record suggests that a 10dB increase will trigger widespread complaints. The New York standard that sets the limit at 6dB over ambient is a much better application of this standard acoustics relationship.

Rand has gone further, demonstrating that these predicted community responses match up very closely with both the peer-reviewed Pederson-Waye survey data from near Scandinavian wind farms, and to the measured levels of sound at recent problem sites in New England. Below is a chart he produced that includes the early EPA measurements of community responses to noise (black dots—original chart was for urban area; here the dB levels are reduced by 20dB as described above to represent rural wind farms as the noise source), along with Rand's overlay of Pederson-Waye annoyance rates from one of their studies (orange bar, extrapolated by Rand to the purple section of the bar), and actual community response levels at three locations in Maine (red dots).[14] *I have added, in orange, my slightly different interpretation of Pederson-Waye, based on response rates in their two rural studies, along with the unusually high complaint rates at Mars Hill, which far exceeds that found at other locations).*



Rand has said:

> As a member of INCE, I am pledged to the INCE Canon of Ethics, including the first fundamental canon, "*Hold paramount the safety, health and welfare of the public.*" If I have a professional disagreement with other INCE members, it's not really about the evolving understanding of infrasound. It's the ethics. It's easy to do an environmental impact prediction (of likely community responses) of wind turbines in rural areas. Yet I have not seen one wind turbine application in which even this most basic assessment was done. We never designed projects to produce "Widespread Complaints" at Stone & Webster, let alone "Vigorous Community Action"![15]

Robert Thorne, New Zealand

Over thirty years experience in measurement and assessment of noise and the effects of noise on people. Degrees in Health Engineering as well as Acoustics, and a Ph.D. focusing on "Assessing Intrusive Noise and Low Amplitude Sound," which addresses both the measurement of low background sound levels and the assessment of moderate noise sources on people. He represents the Australian Acoustical Society on the International Institute of Noise Control Engineering (INCE) Technical Study Group 7, which is working on a global approach to noise control policies.

Thorne has added some interesting new ways of looking at the ways that the experience of new noise sources is different in rural areas than in suburban or urban areas. His recent Ph.D. thesis built on some earlier work (by Zwicker) to propose assessment of how "intrusive" a noise source is, which may provide some subtler ways of assessing likely annoyance. He also stresses the impact of "rural amenity" factors, which provide a way to recognize that a truly quiet ambient environment is important in rural areas. And, he incorporates a recognition that 20-30% of the population is more noise sensitive, and favors taking this into account in predicting local responses to new noise sources.

He has investigated community responses near several New Zealand wind farms where negative reactions occurred at greater distances than reported in other situations. At the Makara wind farm, 906 complaints have been received from residents living 1200-2200meters (three quarters of a mile to a mile and a half) from turbines. The Te Rere Hau wind farm has spurred complaints from "most, if not all, of the non-stakeholder residents within 3 to 4 kilometers (two and a half miles) of the wind farm."[16]

He has observed that 30dB L_{eq} can be clearly audible inside homes on quiet nights, and that "severe annoyance due to noise can be expected" at sound levels as low as 40dB.[17] He suggests that 2km (1.25 miles) is the "minimum buffer" from homes, representing the threshold between moderate and severe annoyance responses, and that a 3.5km buffer "may be required," noting that this distance "does not reduce perceived noise to zero; rather, it provides a working zone between distances of known moderate annoyance to infrequent annoyance."[18]

Richard Horonjeff, MA
Over forty years experience; INCE member with a focus on perception and effects of noise, prediction and modeling techniques, and community noise. Has done research and publication for agencies ranging from the National Park Service (visitor perception of park soundscapes) to NASA (very low frequency noise) and major airports.

Horonjeff has also stressed the need to use the old EPA recommendations to adjust community noise standards downward in rural areas where wind farms are being built; he suggests using two of the three adjustments Rand speaks about, noting that the same total 15dB adjustment is included in the current American National Standard 7, so that "if it is not considered for the rural/new source case (of wind turbines), there should be some justification for why it has not."[19]

Horonjeff also makes the important observation that new noise sources often spur a decade-long evolution of noise standards, as previous standards that are initially assumed to be sufficient are gradually seen to not fully apply to the new situation. He cites the introduction of jet engines as one prior example that may be especially relevant to today's larger wind turbines; as with the change from propeller planes and jets, which generated similar noise levels but spurred more complaints due to the nature of the noise, wind turbines with much larger rotor diameters, generating more low frequencies and encountering more wind shear from bottom to top, are spurring a new kind of community response as compared to older, smaller turbines with similar noise levels.

> This evolutionary process generally begins with anecdotal evidence being presented. This evidence takes the form of some new source's health and welfare effects not being accounted for by existing regulations. Scientific inquiry then begins and research is conducted until a consensus is reached regarding the cause/effect relationship. Next, appropriate national and international standards committees develop new standards to be applied, or existing ones are modified for source specificity. These new standards eventually find their way into guidelines and regulations.
>
> From the time a new source is brought to the attention of the acoustics community it is not unusual for a period of five to ten years to elapse between the onset of literature review and research and the promulgation of an agreed upon noise standard for the source. This has been true for highways, for aircraft, for railroads, industry, and many other sources.[20]
>
> A number of reports have been prepared in recent years purporting that symptoms reported by wind farm neighbors should not be attributed to wind turbine noise since such symptoms are not supported by existing literature. This is particularly the case regarding the controversy regarding the issue of low-frequency wind turbine noise. However, it is safe to say that the existing peer-reviewed literature does not address the specific attributes of wind turbine temporal patterns and long-term exposure to them. Hence, an

important body of information by which standards might be set has simply not yet been developed. It is important to remain mindful that the absence of research and reported findings does not prove the absence of an effect.[21]

Why might wind turbines trigger more annoyance at moderate sound levels than other community noise sources?

In addition to the various points made by the acousticians above, ongoing research is seeking the answer to this key question. The two most significant factors are likely to be the variable nature of the sound and the lack of predictable reduction in noise at night. This has been addressed in many other places, so there's little need to belabor it here.

In brief, a common (though not constant) feature of wind turbine noise is that the noise pulses about once per second. It used to be thought that this was caused by blades moving past the tower; more recently, research has been coalescing around the effect of higher wind speeds at the top of the turbine rotors causing louder air flow (perhaps also aggravated by the fact that blade angles can't be instantaneously optimized for the differential wind speeds). Some additional thumping noise may also be caused by smaller patches of turbulence passing through the rotor plane. In addition, there are indications that the noise can be somewhat directional as it moves off the trailing edges of the turbine blades. As modern turbines continue to increase in size, it's likely that they will encounter even larger wind-speed differentials between the bottom and top of their rotation, as well as more micro-turbulence, perhaps increasing the presence or intensity of these amplitude modulations.

Most community noise sources occur at predictable hours, generally during the workday, and almost always decreasing or ceasing at night. Also, most other noise sources have one characteristic sound. Wind farms noise can come and go at any hour of the day or night, based on changing wind directions and speed and shifting atmospheric conditions. Neighbors report that turbines can create a surprisingly variety of sounds, from whooshing or roaring to thumping, clattering and whining[22]. Many of these changing sounds are caused by wind turbulence at the blades, and some by transient mechanical issues or tiny holes in the blades that can be addressed in routine maintenance. The nighttime sound of nearby turbines is often the primary issue for neighbors who find themselves struggling with turbine noise; sleep loss is often mentioned as the hardest to accommodate issue.

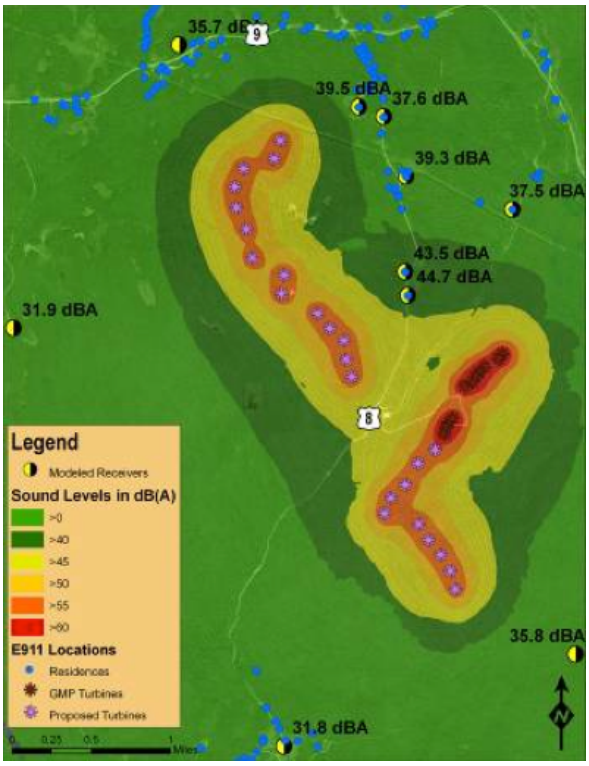
What about acousticians who feel that current community noise guidelines are sufficient?

There are certainly plenty of acousticians who continue to support noise limits of 40-50dB, and the resultant smaller setbacks that have been in use up until now. For a sense of their thinking, readers can seek out nearly any sound modeling or sound monitoring study commissioned by wind farms or government entities. As part of routine permitting, a

sound modeling study is completed for virtually all new wind farms; and, if complaints arise, a sound monitoring study will usually be commissioned.

As noted above, most of these formal reports are oriented toward predicting and confirming sound levels around wind farms, rather than assessing what the likely impact of the noise will be on those hearing it; their purpose is to help wind developers to design a site layout that will conform to whatever the local noise or setback ordinances require. When called to testify on their work before county or state regulatory bodies developing wind ordinances, these acousticians present the acoustic data or models in a straightforward way, generally without assessing likely impacts. When pressed to provide some context for the sound levels they are talking about, they often compare the turbine sound levels at homes to familiar sounds, such as a conversation or a refrigerator running. This is accurate, as far as it goes. What is rarely considered is how these moderate noise level may be experienced by people in their daily (and nightly) lives—for example, how will someone react to a sound as loud as a conversation in their backyard while gardening, or one as loud as a refrigerator in their bedroom at 2am? I don't see this as any sort of intentional misleading on the part of these acousticians; rather, it's simply a standard way of viewing and thinking about moderate noise levels. In my experience, the acousticians I've met who are regularly contracted to write these reports are quite open to the perspectives that I'm adding to the conversation, stressing that they work with data, not with subjective interpretation.

Such reports often include a "sound contour" map that shows decreasing sound levels around the turbines, based on local topography and ground cover. Here's a typical example, from Ken Kalisky's NEWEEP presentation[23]:



In this proposed turbine layout, no homes are in the 45dB and above zone (yellow). Based on the distance scale in the lower left corner, received sound drops below 45dB in less than a quarter-mile in some areas, and in about a half-mile in others.

Two homes are located in the 40-45db zone (dark green); one is a half-mile from the closest turbine, and the other a bit more.

Sound levels remain above 40dB (dark green) out to around a half-mile in nearly every direction, and to about three-quarters of a mile in the three highest-sound directions.

Some examples of sound studies:
(see AEI Wind Farm Noise Resources page to download copies)

- Allegheny Ridge Wind Farm Sound Monitoring Study, Prepared for Juniata Township by Resource Systems Group, Inc., 2009
- Noise Analysis PPM Clayton Wind Farm, CH2M HILL, 2007

Some more general reports by acoustic consultants and/or wind developers, industry trade groups, or other wind advocates have provided a summary of what is known about the effects of noise, especially low-frequency noise and infrasound; by and large, these summaries tend to cover similar ground, generally supporting the status quo noise limits. They point out that infrasound is well below perceptible levels (using standard perception curves, without considering Swinbanks' observations as noted above, p. 20-21), and that the noise of turbines is no louder than many other noises that people seem to easily live with. It often seems that the purpose of these reports is to reassure people that they should not expect problems with noise, while they rarely if ever address or investigate the experiences of those who are struggling with noise. These overview reports do usually note that turbines will be audible, and may annoy some nearby residents, and then go on to affirm that annoyance is not a health impact, usually leaving it at that. By contrast, the acousticians noted above treat widespread annoyance as a problem worth investigating, and more actively seek to understand what acoustic properties of the turbine noise may be triggering the unexpectedly high levels of annoyance.

Some examples of noise overviews (also available at the AEI Wind Farm Noise Resources page)

- AWEA Siting Handbook, 2008

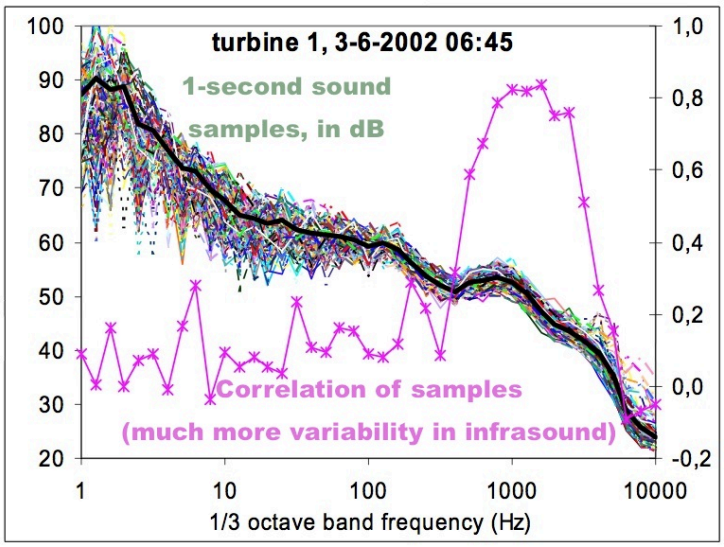
- State of Maine: Tracking Progress Toward Meeting Maine's Wind Energy Goals, Including an Examination of Current Wind Energy Noise Guidelines and the Opportunity for Public Hearing, 2011
- Mark Bastasch et al. Wind Turbine Noise – An Overview. Canadian Acoustics Vol. 34(2). pp. 7-15. 2006.

Note: The methods used by acousticians to assess existing ambient background noise levels, as well as to model likely sound levels once operational, are subject to differing techniques, assumptions, and interpretations. Many of the assessments done on behalf of developers have been criticized by other acousticians, and likewise, the work of acousticians suggesting that ambient levels are very low or that turbines may generate troublesome low-frequency noise increases at homes have been criticized by others. I am including links to both types of reports in order to allow readers to see both approaches.

Low-frequency sound, infrasound, and health

As stated at the outset, this report will not attempt to fully assess the controversies or state of research into low-frequency and infrasound levels around wind farms, or the widely discussed question of possible health effects triggered by such sound. Perhaps next year.

I do want to make a few observations, though. First and foremost, any shorthand claim that wind turbines do not produce much low-frequency or infrasound should be taken with a grain of salt. The vast majority of the acoustic energy of large wind turbines is indeed in the lower end of the frequency spectrum, and the lower the frequency, the higher the sound level. Nonetheless, it is also true that below around 40Hz, near the bottom of normal human hearing range, wind turbines tend to be quieter than what humans can hear (on the fringes of our hearing range, sounds must be very loud for us to hear them), and this is why some observers suggest that this (large) part of the wind turbine noise spectrum is insignificant.



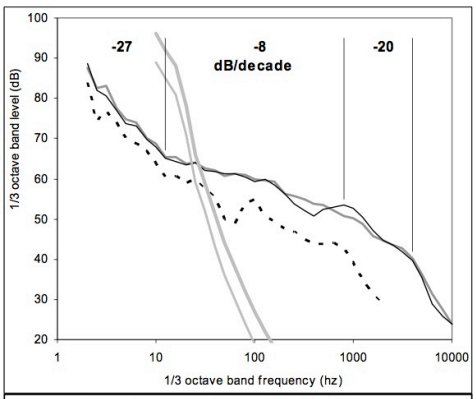


Figure 3: regions in 1/3 octave band spectra near turbines (grey and thin black line) and dwelling (dotted line) with average spectrum slope in dB/decade, and 10 and 50 percentile hearing threshold level for young adults

These two graphs from Fritz van den Berg[24] show the frequency spectrum of wind turbine sound. On the left graph, note the increasing (unweighted) dB levels in lower frequencies, and the extreme variability of infrasound (below 20Hz) as compared to relatively much more consistent sound levels at higher audible frequencies. On the right graph, the steep light grey lines show typical hearing thresholds, while the darker lines and doted lines show mean sound levels of turbines; when the turbine sound level is below the hearing curve (as it is below around 40Hz), the sound should be inaudible to most people.

Two key things need to be kept in mind, however. First, ongoing research continues to assess the actual noise around wind farms (rather than modeled levels), and as noted earlier and illustrated above, there are some indications that at very low frequencies the sound can be very dynamic, much different than the pure-tone lab sounds used to determine human perceptual thresholds. We are still learning much about the complex frequency and temporal patterns of wind turbine noise, and it's clearly premature to close the book on possible perceptual effects.

Second, whether or not LFN (low-frequency noise) and infrasound from turbines triggers direct health effects, it's entirely plausible that this relatively extreme aspect of the wind turbine noise could contribute to the higher levels of annoyance triggered by wind farms, or to the sense of wind farm noise being especially hard to ignore, even at moderate sound levels. This could be simply due to the lower audible frequencies, which make turbines noticeable even when rustling leaves are making similar levels of noise, or it could be due to barely-perceptible inaudible low frequencies or infrasound, as suggested by Malcomb Swinbanks above. In addition, there will always be some people who perceive even the lowest frequencies at lower sound levels than most; these will be few, but the impact on them will be real. Speculation that people with compromised or hyper-sensitive vestibular systems may be more apt to be affected by these extreme low frequencies also deserves continued investigation; it's not uncommon to hear from war veterans or others with injuries that cause balance or inner ear problems who find themselves more sensitive to wind farm noise than their neighbors or spouses.

There are several different ways to "weight" noise measurements, each of which highlights different parts of the sound spectrum. A-weighting, which reflects the way the human ear hears sounds, discounts low-frequency sounds and disregards infrasound altogether. C-weighting focuses more on the lower frequencies, and G-weighting highlights the lowest frequencies. Wind farm noise assessments nearly always use just A-weighted sound levels, which makes sense in terms of what we will hear, but doesn't reflect the increased sound energy that accompanies operating turbines heavy in lower frequencies, and which may contribute to an increased annoyance response.

In a paper presented at the spring 2011 Acoustical Society of America meeting[25], Bill Palmer reported that LFN and infrasound increased notably as soon as turbines begin operation, even before the turbines were perceptible in audible sound frequencies. His well-designed study measured the full sound spectrum from about a third of a mile away during turbine operation, and in a location close enough to have similar weather and topographical conditions, but far enough away (3 miles) that turbines noise was not measurable. He reports an increase of 20dB at all frequencies below 1000Hz even at very low-power operational speeds, with very little further increase as the turbines spun faster in higher winds. His study also noted a cyclical shift in frequency around 125Hz, which could be audible as a subtle siren-like sliding of the tone up and down, and may contribute to attracting perceptual attention to even a barely audible noise.

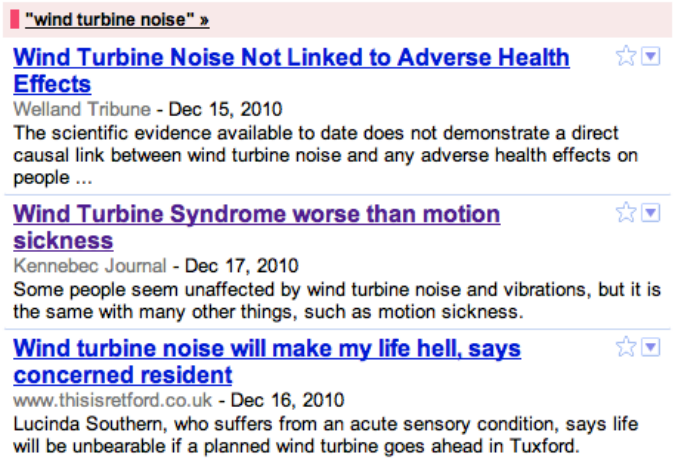
It is important to note, of course, that such on-site recordings often vary from site to site and even more so, over time. It is common that acousticians are called in to investigate locations that have especially bothersome low-frequency sound issues, and we should be careful not to assume that what is found in one time and place represents what is happening everywhere. This goes for both the worst-case examples and the reassuring no-problem examples offered by various acousticians. At the same time, though, such examples can help us to understand that the noise conditions around wind farms do vary, and that sound models or predictions of impacts can't represent the whole story. We do

need to have such models and predictions as starting points as we assess impacts, but we also need to acknowledge the real-world variability that is central to the actual experience of those living near wind farms.

I should also mention new research published this year by Alec Salt[26], which suggests that our outer ear hair cells (tiny hairs that stimulate auditory nerve responses) may respond physiologically to very low frequency sounds at levels up to 40dB lower than what is necessary to actually hear the sounds; this is important because wind turbine infrasound is often 20-40dB below hearing thresholds. His work doesn't address whether this response in the outer ear hair cells is or can be related to any reported symptoms or full-body sensations, or even suggest any mechanism (process) by which they might do anything more than their known role in amplifying or dampening the responses of the inner ear hair cells. But the research has intrigued many observers, including the National Institutes of Health, which noted[27] that this may be related to the physical sensations and odd perceptual experiences some people report when exposed to inaudible levels of low-frequency sound. See the footnote above for much more detail on this work.

Health Effects

Regarding health effects, it's again beyond the scope of this report to provide a full assessment. With several studies underway in particular locations (notably Wolfe Island, Ontario, which includes an all-too-rare "before the wind farm" phase of study[28]), as well as some governmental agencies putting together overview reports (including among others Japan, Oregon, Massachusetts), the next couple of years will provide us with more data to use in assessing how prevalent reported health problems really are around wind farms. Meanwhile, a typical daily set of headlines in my Google News customized "wind turbine noise" section sums up the current situation pretty well:



For now, I'll just mention a couple things to keep in mind as you try to make sense of the starkly opposing views about health impacts of wind farm noise. First is the fact that there

are clearly some people who are experiencing physical reactions to turbine operation; many have left their homes to find relief, and find that they get worse again when they come back. While some of these cases may be "just" caused by their negative feelings toward the wind farm, or fear of problems, when you hear the people's stories, it's hard to chalk it all up to such hysteria. Something is going on for some people. At the same time, it also seems clear that only a small proportion of those bothered by wind turbine noise report definite physical health symptoms; the few surveys we have suggest that most of those annoyed by turbines don't even report sleep disruption. It appears that health problems, while all too real for some individuals, are not nearly as widespread as the quality-of-life impacts that are at the heart of most negative reactions to audible turbine noise. One location where health impacts have been reported by a much higher proportion of residents is Mars Hill, Maine[29]; this exception may be helping to highlight the possible impacts, in that the residents are being exposed to higher sound levels than most other locations due to an exemption this wind farm received, allowing it to create noise of up to 50dB at neighboring properties. As is the case elsewhere, though, it's very difficult to make the case that health effects are being caused directly, by the noise itself, or to prove an indirect connection, via quality-of-life impacts including annoyance and sleep disruption.

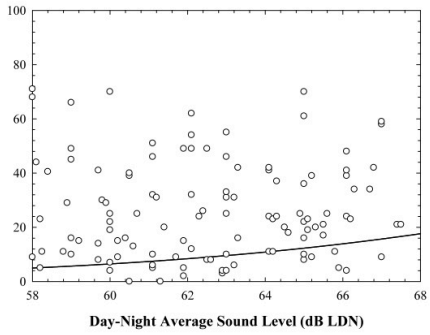
AEI has covered the various health reports as they have come out; for more detail on the strengths as well as the missing pieces in these reports, see the following links:
CanWEA/AWEA report: http://aeinews.org/archives/584
Ontario report: http://aeinews.org/archives/915 and http://aeinews.org/archives/937
Two earlier studies provide more comprehensive assessments of possible health effects near wind farms:
State of Minnesota Department of Health: http://aeinews.org/archives/456
World Health Organization night time noise: http://aeinews.org/archives/429
In October, 2010, the Society for Wind Vigilance put together a symposium on health effects that featured many of the leading voices of concern about this issue; it could be considered the polar opposite of the CanWEA/AWEA report in that the range of views is similarly constrained, but from the opposite perspective: rather than focusing solely on previous peer-reviewed studies (many of non-wind farm noise, and none investigating actual reports of health reactions to wind turbines), the proceedings of the SWV symposium present a range of research and on-the-ground reports that take the effects being reported near turbines at face value, and make attempts to develop possible explanations.
http://www.windvigilance.com/international-symposium/proceedings-first-international-symposium

One recent overview of health effects[30], put together by Jevon McFadden of the Wisconsin Department of Health Services, offers a relatively fair overview of the research that has been done to date, and concludes with this perspective on the key impact of turbine noise, annoyance:

> Annoyance is not a disease, and does not require a public health intervention. It is a quality of life issue, and can be a legitimate factor to consider in wind turbine siting.

Another recent overview that I found especially useful came from Daniel Shepherd, a New Zealand psycho-acoustician. His submission[31] for consideration by authorities considering a wind farm in the Ohariu Valley provides a comprehensive look at the fascinating interactions between sound levels, annoyance, and health effects (direct and indirect) in different types of communities. Shepherd's Masters and Ph.D. theses focused on human perception of low level sounds, and among his key points are:

- The study of health effects of wind farm noise is in the early stages of a well-recognized progression in public health *(note: similar to Horonjeff's perspective on community noise standards)*; one feature of the earliest stage of response is that symptoms are seen as either caused by some other factor, or as psychosomatic.
- Noise sensitivity plays a key role in annoyance levels, and there is solid evidence that rural populations attract higher proportions of noise-sensitive people. (I don't think there have been studies of noise sensitivity rates in people who work with farm machinery routinely, but it would seem likely this attracts less noise-sensitive people, and/or leads to moderate hearing impairment over time, helping explain why some rural communities do better with nearby wind farms than others do.)
- He shares a dramatic pair of graphs to illustrate the fact that annoyance responses are very poorly correlated with noise levels, and are clearly affected by many other factors; but also notes that noise regulations are often based on large-scale average responses rather than the likely more-relevant local factors.



Shepherd's interpretation of this graph[32]: Note the incompatibility of the theoretical dose-response curve (solid curve) and the empirically derived data (data taken from Fidell, 2003). Scrutiny reveals that annoyance reactions to noise vary substantially and do not appear to be correlated with noise level.
(I would add that it's extremely revealing to see the incredibly wide annoyance levels found at any one dB level; for example, at 58dB (which we might equate with 43dB wind farm noise, using corrections/normalizations recommended earlier), annoyance in some studies is 10% or less, while others find annoyance of 70%. These are differences between studies, not individuals! Clearly there is wide variation based on location, expectation, and other factors. Also: this graph addresses annoyance from aircraft; the dB levels in the dose-responses to wind farm noise would be 15-20dB lower.)

There's much more in Shepherd's two reports[33], and I highly recommend them to anyone seeking to understand the subtleties that are necessary to address either the quality of life or health impacts in rural communities.

Quality of life protections will likely address future understanding of health effects

I am surely moved and disturbed by the stories of people who have had physical reactions to wind farm noise, especially those who have taken the undeniably non-imaginary step of abandoning their homes. There's no doubt that some people are physiologically affected by the nearby presence of wind turbines. Yet I can also clearly see that the experiences of these few have triggered outsized fears in the many; while a town with a dozen nearby neighbors upset about noise may have a handful who've felt health impacts, those in other towns fear that they all will find themselves with degraded health. While it's natural to want to protect oneself from the worst possible outcome, there is as yet not enough clear evidence to provide a legal underpinning for authorities to impose restrictions based on public health concerns. By all means, we need to continue researching this issue, before and after construction, in a variety of locations. Concrete measures, including blood pressure and stress hormone levels, would provide much-needed clarification as we continue to assess the possible indirect health effects of living near wind farms.

But I suspect that as we learn more about these health questions in the coming years, it will become clear that both (relatively rare) acute physiological reactions and (much more widespread) subtler indirect effects fade to insignificance at about the same distances that the more easily understood quality-of-life impacts also become tolerable. With the notable exception of several New Zealand communities living in valleys below wind farms (which may capture or otherwise enhance the sound fields), it's extremely rare to hear of health problems from residents more than 1.5-2km from wind turbines (three quarters of a mile to a mile and a quarter). This coincides closely with the recommended community noise levels of 30-35dB that has become the most common recommendation of acousticians looking at the nature of the audible turbine noise in rural areas. And yes, rural areas that are predominantly home to working farmers and ranchers appear to be more tolerant of turbine noise, so it's important to take the nature of the community into account as we make siting decisions. Again, using larger standard setbacks, with easily adopted provisions for closer siting to willing neighbors, is likely to address both quality of life and health concerns in a way that is effective for communities while providing the wind industry with plenty of opportunities for future expansion in areas where few neighbors will find their lives irrevocably changed.

Property Values

I suspect that you are as exhausted by now in the reading of this report as I am in the compiling! So, this final section will be mercifully brief, while also serving as a conclusion.

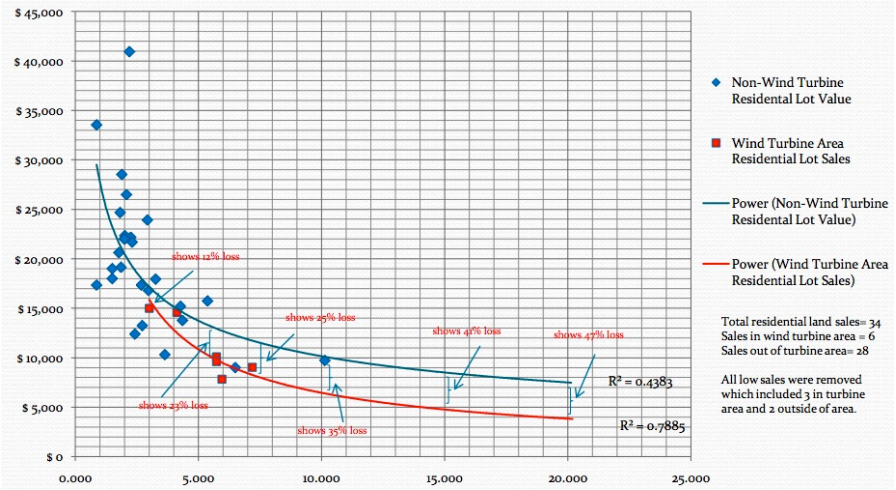
This is possible because the short version of what we know about property values echoes what we know about the overall effects of wind farm noise: while there is no appreciable effect at distances of several miles, once we move into the range of a mile or so, there is far less certainty and some moderate impacts likely, and within a half-mile, there's apt to be a notable impact on some but not all properties and people.

There have been two key academic studies that sought correlations between property values and proximity to wind farms. Both were more focused on possible impacts of seeing turbines than hearing them (neither assessed noise levels, just distance), so both looked at properties out to several miles from the edge of the wind farm. In neither study did enough properties sell within a mile to provide "statistical significance," which means that the variability in sales trends that close was too great to be sure of whatever hints of an effect of proximity might appear among the few sales. The authors of both reports, though, stressed that their results (which overall saw no clear relationship between sales price and distance to turbines) were more confidently applicable to the many homes at greater distances, and that there's a pressing need for more data and study to determine whether sales prices closer to turbines are impacted.

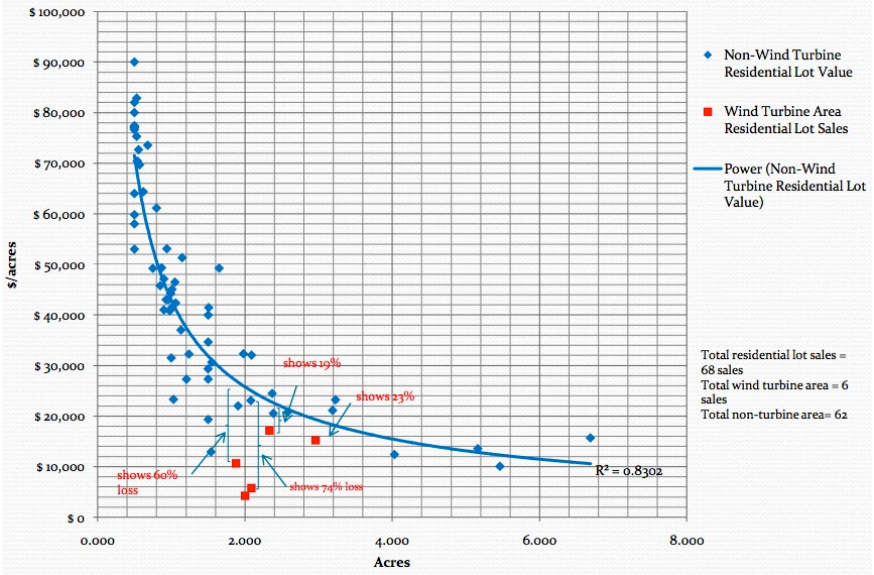
In both cases, there were slight decreases in average sales price for homes close enough to wind farms for the sound to be regularly audible, in the range of 5% decreases on average, though the data suggests that it's likely this average was driven by a few homes with more dramatic decreases. Also in both cases, the biggest impact on sales prices occurred after the wind farm was announced, and before it was operational, with prices bouncing back after the wind farm was operating. For more on these studies, see AEI's summaries and commentary at the time of their release (both posts include download links for the full reports):
Jennifer Hinman, property values around two Illinois wind farms:
http://aeinews.org/archives/1114
Ben Hoen and Ryan Wiser, DOE/Lawrence Berkeley Lab nationwide report:
http://aeinews.org/archives/529

Anyone who's been involved in the wind farm issue over the past couple of years will also know that there have been several other reports released which say property values are significantly reduced near wind farms, with declines of 20-40% being suggested. Michael McCann has put together the most comprehensive argument for decreases[34], some of which is based on his interpretation of the Hoen/Wiser study (which seems to ignore some of the study's key findings[35]), and

some on analysis of sales around an Illinois wind farm, which is more convincing. Kurt Klielisch, a Wisconsin appraiser, has done similar work, surveying realtors who had worked in wind farm areas, and charting the actual sales prices of homes near two wind farms[36]. The sales data largely confirmed the realtors' reported likely price differentials, but also offers a good illustration of the ambiguity that exists in most of the real-estate data to date:



The top graph shows sales of 1-20 acre residential lots in and around the Forward Wind Farm, with low sales removed. As you can see, the red curve tracing and extrapolating the average price-per-acre paid for homes within the wind farm area (distance not specified) is clearly lower than the blue curve of homes outside the wind farm. At the same time, though, it seems that the sales within the wind farm area (red squares) fall largely within the lower-range scatter of non-wind farm home sales (blue diamonds); that is, the normal variability in price is large enough to account for the red sales.



This similar graph is from the Blue Sky Green Field Wind Farm. Here, all sales are included (probably in order to have more than 2 or 3 in the wind farm area), and once again, we see that all the red sales fall below local average price-per-acre. However, two sales are generally within the normal range of variability, one marginally lower than the lowest similar distant lot, and two sales well below all others (this type of outlier was presumably removed from the study shown in the upper graph, presuming impacts of some other, non-wind farm factor, such as poor condition of the house).

There have been other surveys of assessors or real estate agents[37], asking their opinion about likely impacts, which did not include actual price data. These generally find that, on average, decreases are expected; but there is always divergence of opinion, with a substantial minority saying there will be no decrease, while a somewhat higher proportion expect some decrease, and many remain unsure. Such surveys do seem useful, as a bellwether of expert opinion, but hard to base policy decisions on.

I want to mention one other report. Chris Luxemburger, a Canadian real estate broker and director of his local Real Estate Board, looked at property sales in and around a big wind farm in Ontario[38]; while he found that prices were lower for those within 3 miles of the wind farm, more interesting was a dramatic increase in the "days on market" for the closer properties (twice as long to sell) and an 11% rate of homes not selling at all, compared 3% for those further away. His report is not very detailed, and likely also suffers from the typical problem of relatively few sales close to the wind farm, but offers some useful new perspective on the real estate questions.

Not surprisingly, real estate professionals and researchers disagree on the best ways to assess potential property value impacts; those finding little impact are not impressed by the studies finding decreases, and vice versa. For now, AEI's stance on the property value question is decidedly uncertain. As with health effects, it seems clear that there are some homes that are dramatically impacted (some have been unable to find a real estate broker to even list them), but that overall it's hard to say what the degree of impact is, or how widespread it is. And, as with the other aspects of the wind farm noise issue, those within a half-mile are more likely to see impacts than those over a mile or so.

Buy-out provisions, Property value guarantees

Some community groups and other observers[39] say that if wind developers are so sure that they won't be decreasing property values, then they should be willing to stand behind their words (and shoulder the risk that they are wrong) by providing Property Value Guarantees or buying out unwilling neighbors at current market value, then reselling the homes themselves.

Property value guarantees have been used in support of other types of municipal projects, including landfills, transmission lines, and public parks[40]. Three Illinois counties have extended the concept to wind farm permitting; one of them has abandoned the practice after no claims were made during the 5-year time period enforced on the first wind farm permit that required a property value guarantee.

While claims under Property Value Guarantees are rare (partly due to lower-than-feared decreases in property values, and partly due to the complexities of proving a change), they serve to shift the risk from local homeowners to the developers of the project in question. One of Michael McCann's analyses of property value decreases (which you may remember predicts more dramatic property value decreases than most other studies) finds that a theoretical 3-square mile wind farm with 100 turbines could decrease local property values by about 3% of the cost of the project[41]. His point is that even in this worst-case scenario, the company should be able to shoulder this indirect cost of their operations.

In a few cases[42], developers have bought homes in or near wind farms from people who found that they could not live with the turbines. This practice makes developers nervous, as do property value guarantees; they cite the unacceptable budgetary uncertainties that such programs would impose. However, such buyout programs (which can lead to the company reselling properties to willing buyers) would go a long way to calming local fears, which may often run higher than their eventual experience will warrant. Certainly, the fact that some developers do buy multiple homes suggests that such a policy does not threaten the viability of most wind farm projects.

Banging the drum one more time for AEI's preferred path forward

Of course, the need for property value guarantees or buyouts would evaporate if wind developers agreed to maintain even moderately larger setbacks from existing homes. Once more, it appears to AEI that the combination of larger setbacks and the availability of waivers for closer siting to willing neighbors offers the best way forward. Failing that, then these financial guarantees would provide a fair way out for those close neighbors who find that their quality of life or health is being severely impacted enough to uproot them.

You will have probably have noticed that this report has resisted the temptation to name a single setback or noise limit that should be applied across the board. As must be readily apparent, this is because it's clear that different types of communities will need different standards. Ideally, each region, county, or town could set standards appropriate to their location; if this is deemed too complicated or unpredictable a path forward for successful wind development, then the combination of strongly precautionary limits and easy-to-negotiate easements may be the best universal solution. If pressed to suggest such a "precautionary limit" I would lean toward setbacks of at least three-quarters of a mile, or sound limits of 35dB or less, while once again stressing that there are clearly places where closer siting is locally acceptable and waivers will be easy to obtain. It's encouraging that setbacks of 2000 feet to a half mile have become an acceptable "middle ground" option in recent months; these setbacks should significantly reduce the extent of noise issues and I look forward to hearing how these distances work out, but there

are a fairly consistent reports of disruptive noise out to 3000 feet or so, which leads me to favor a slightly larger minimum setback.

Many areas will indeed be "off the table" for wind development if this sort of approach were to take hold; but these are exactly the locations where wind farms would be squeezed into minimally-sufficient spaces among people who especially value their rural peace and quiet, and we are not yet that desperate for suitable locations to have to go there.

And I bid you goodnight…

As stated up front, I certainly hope that this report has provided some useful perspective and information to those seeking to untangle the knot of conflicting information about wind farm noise. The Appendices include more useful information, especially on the factors that seem to influence disparate community responses to moderate wind farm noise, if you have the endurance to keep going!

Please feel free to be in touch with any questions or comments. I can be reached at cummings@acousticecology.org or at 505-466-1879.

Many of the sources cited in the footnotes, along with a collection of publications by AEI on the issue, are available for download on the AEI Wind Farm Noise Resources page:
http://AcousticEcology.org/wind

For ongoing coverage of sound-related environmental issues, follow the AEI News blog/feed at http://AEInews.org
Or, zero in on the wind farm noise posts by using this url:
http://aeinews.org/archives/category/wind-turbines

Appendix A

NEWEEP presentation on Community Responses to Wind Farm Noise

What about in the real world?
How do people actually respond to increasing wind farm noise levels?

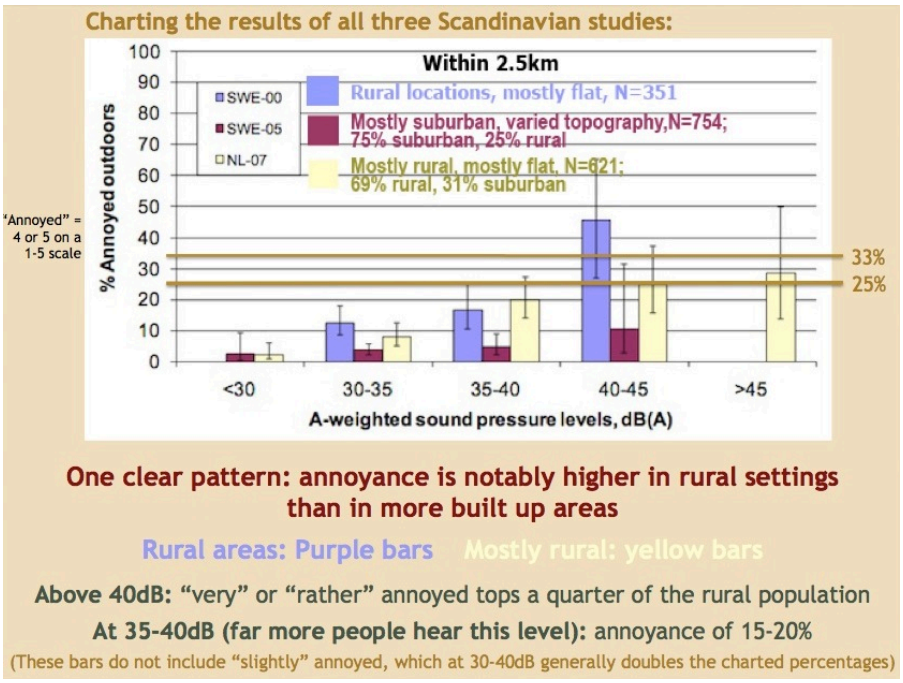
As is probably clear from what you've already read, "people" do not all respond in any one way to wind farm noise—this is why we so often seem to talking at cross-purposes to each other, with each side acting as if their preferred examples of noise disruption, or lack of any problems, represent the entire story. Some communities are more tolerant as a whole to new noise, and some individuals in any community are likewise more tolerant, or more sensitive, than others.

This is the theme of the research I did for last summer's New England Wind Energy Education Project webinar on wind farm noise. Rather than repeat all that is there, I'll point you toward a pdf version of the Powerpoint, and summarize a few of the key points of the presentation. As with the above research excerpts, I do encourage you to read the full presentation for a more nuanced and complete understanding of these central themes.

The full presentation is available at http://aeinews.org/archives/972
Links are included there to the other two other presentations made that day.

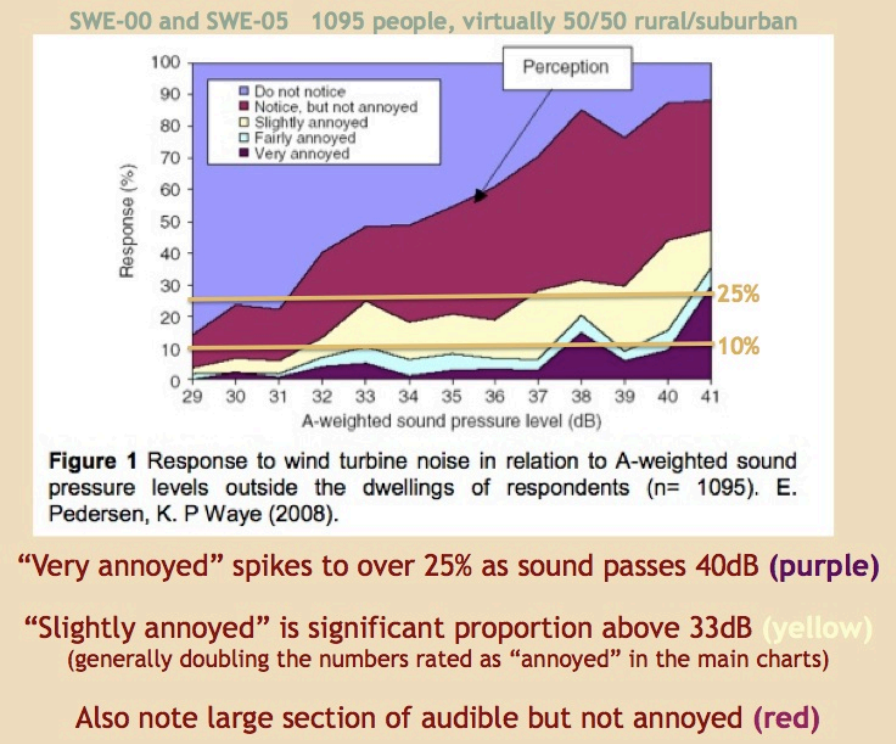
How about asking people around wind farms about how it affects their lives?

There have been surprisingly few surveys of community responses to existing wind farms. There's just one widely recognized, peer-reviewed series of studies that are the primary source for secondary interpretation, and they're used by nearly everyone, including industry reports, some of the acousticians mentioned above, and AEI. These three main studies sampled from thousands of people living near wind farms in Scandinavia; the annoyance rates they report varied widely from study to study, though when considering the proportion of rural to suburban respondents in each study, the variation begins to make more sense, and suggests that rural respondents report far higher annoyance rates than suburban people:



Over the course of about a decade, the research team published many papers, most of which focused on one or two of the three large surveys. Most advocacy groups that cite these studies tend to draw on one or two of the papers, and imply this is the entire body of research; in particular, there are some papers in which the authors combined the results of their two studies in Sweden (in purple and red above). As you can see, these Swedish results combine the surveys with the highest and the lowest annoyance rates; the difference in annoyance can likely be explained by the fact that one location is entirely rural (purple) and the other mostly suburban (red), where existing noise levels are higher. However, when the studies are combined, the much larger suburban-focused study dominates the average response rate. What results is a sample that is about half rural and half suburban, which is informative, but should not be considered a reliable prediction of annoyance rates in rural areas; the purple study and yellow studies are more predictive of rural response rates.

An especially useful perspective on the range of annoyance responses is provided when we chart all five levels of response to the wind farm noise, from "very annoyed" down to "notice, but not annoyed." This comes from one of the papers that combines the most rural and most suburban studies (purple and red above), to create a sample that is just about evenly split between rural and suburban locations:



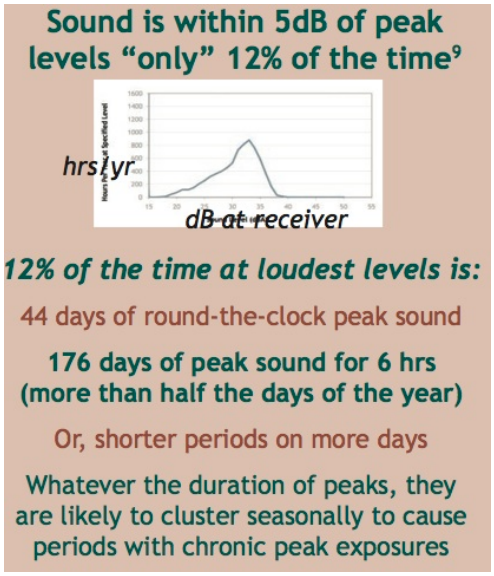
The NEWEEP presentation considers several things we should keep in mind as assessing these results; a few bear mentioning here. These studies included residents out to 1.5km (almost a mile) and 2.5km (1.5 miles) from relatively small turbines (600kw); the vast majority of these residents were far enough away to only hear turbines very faintly, if at all (35-40% were totally out of earshot, and 87-97% did not experience noise levels above 40dB). Yet even so, among rural respondents who could hear turbines at any level, 22% reported moderate to extreme annoyance, and when sound was over 40dB, annoyance was 28% in all studies combined, 30% in the rural-dominated studies, and 44% in the most rural study. It's not surprising that standard US regulatory limits (which usually allow sound levels of 45dB) will lead to widespread noise issues. Wind farms that are built in and amongst existing homes are often designed to keep noise at the homes just under the regulatory limits; in these situations, as compared to the Scandinavian studies, a much higher proportion of the nearby population is likely to be within a half mile or so of turbines, and to experience noise levels of 40dB or above.

It's often noted that this Scandinavian research found that annoyance levels are more strongly correlated to seeing turbines than to noise levels, and that there is a strong association between annoyance and a generally negative attitude toward turbines.

However, we have to be careful not to overstate these correlations, or to jump to conclusions that the sound is an insignificant factor in the problem. It's a natural consequence that turbines within line of sight will be more audible than those hidden by a hill; in addition, there is a perceptual synergistic effect in that the sight of spinning turbines can draw our attention to their sounds. This does not mean that what is really annoying everyone is the sight of the turbines; the sound often becomes the more omnipresent factor as neighbors go about their day-to-day life in and around their homes, when they are rarely seeing the turbines, but often hearing them. Likewise, the studies assessed current attitudes toward the wind farm in general, along with current annoyance; there was no pre-construction assessment of whether people started out with a negative attitude toward the wind farms. So, the causality is murky; it's equally plausible that once the turbines arrived, that those who were being bothered by the sound would develop a negative attitude toward the project. And most importantly, this is just a partial correlation: it cannot be used to explain away the fact that many people are primarily bothered by the noise.

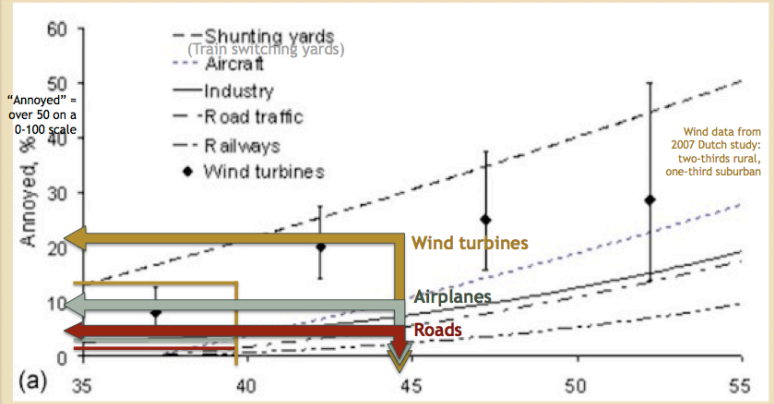
An interesting point was raised by one of the other NEWEEP presenters, Ken Kalisky, who did a fascinating study[43] that analyzed weather conditions over the course of a year, and showed that turbine noise levels are within 5dB of their predicted maximum sound output only 12% of the hours in a year. On the face of it, this seems quite reassuring: even for the close neighbors who may hear 40-45dB, the experience will be rare and fleeting. Is it really too much to ask folks to hear turbines a tenth of the time?

However, a little number-crunching paints a picture that may be helpful in explaining why people living in such places feel that their lives are being disrupted on a chronic basis, and don't experience it to be a once-in-a-while problem[44]:



The Scandinavian research also affirms that annoyance is triggered by wind farms at lower sound levels than any other common community noise source other than train switching

yards. It is likely that the variability and around-the-clock nature of the noise is a big part of the problem. This chart uses data from just one study, the yellow one in the first graph, that took place in an area that was mostly rural with some suburban areas as well, which averaged to create slightly less annoyance than the purely rural study.



Moderate wind farm noise seems to trigger more than twice the annoyance caused by other typical noise sources

Even when it meets statutory noise limits for wind farms:
State/local US limits: 50dB 45dB 40dB 36dB

Why are some people so annoyed by 40dB noise, while others aren't particularly bothered?

The last important points from the NEWEEP presentation involve Noise Sensitivity and Place Identity. One more, the presentation offers a more complete picture, but the nut of it focuses in on two research findings that offer a good sense of why individual and community reactions to moderate noise varies so much:

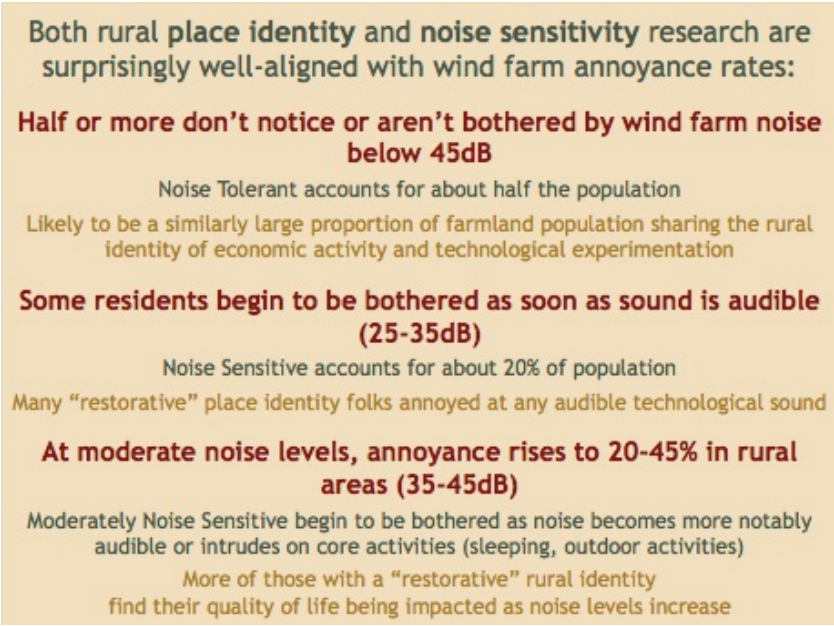
Noise Sensitivity: A 40-year body of research has studied the natural range of individual sensitivity to noise. About half the population is broadly noise-tolerant, and will rarely react to a noise unless it is very loud and/or intrusive. On the other end of the spectrum, about a quarter of the population is quite noise-sensitive, noticing and often bothered by noise as soon as it becomes audible; meanwhile, about 30% of the population is moderately noise-sensitive, with negative reactions increasing as the noise increases in volume or intrudes on daily activities. These percentages seem to line up remarkably well with the Scandinavian research as well as with the proportions of neighbors reacting with varying degrees of vehemence to wind farms in their areas.

Interestingly, the differences in responses of Noise Sensitive and Noise Tolerant people are most striking at soft and moderate noise levels, exactly the situation around wind farms.

Place Identity: The Scandinavian team did detailed interviews with a subset of their research subject who had reacted very differently to noise levels of 37-40dB (some had

heard but not been bothered, others had been very annoyed). They found that those who are most bothered saw the countryside as a place for peace and restoration, while those not bothered were far more apt to see the countryside as a place for economic activity and technical developments/experimentation. Those who are not bothered by turbine noise tend to like new machines and technologies, and see turbine noise from neighboring land as outside their territory, while those bothered by neighboring turbines are more apt to feel that the noise intrudes into their space and privacy.

This place identity perspective goes a long way toward helping us understand why wind farms in and among agricultural spreads in Iowa are easily accepted, while similar layouts in New York or Wisconsin trigger widespread community push-back. It also bears a close resemblance to the Australian and New Zealand approach that includes local "amenity values" or "rural amenity" as a factor that should be considered as authorities assess the likely impacts of wind farms.



While it may seem extreme to set our standards so as to protect the most noise-sensitive from any disturbance (by setting noise limits of 25dB), it is equally extreme to suggest that noise is too loud only when the most noise tolerant part of the population begins to be bothered (45dB or above). It seems eminently reasonable to set our noise limits to assure that those who are moderately noise sensitive are not impacted; this would lead us to a limit of around 35dB, still likely to bother that 20% of the most sensitive. In rural areas with many folks looking for peace and quiet, any limit above 35dB will lead to negative impacts on a rapidly increasing proportion of the population; while in rural areas where most people are working the land, it's likely that more of the moderately noise sensitive will find the noise tolerable, so noise limits of 40-45dB may work well.

Once again, you see the full NEWEEP presentation at http://aeinews.org/archives/972

Appendix B

About AEI

And some background on how and why this report was written

This section takes a few minutes to read and isn't directly related to the topic. It's included in order to provide some important context for understanding who I am and how I decided what to include in this report, so you as a reader may be more likely to trust me as an interpreter, and understand how what you read here fits into the larger world of wind farm effects research.

First off, AEI is not an advocacy organization; it's a non-profit information and resource center, funded by donations from people who value clear information about current science findings and policy options. I am not an engineer or acoustician or scientist. I am an editor and writer who has become comfortable over the past 25 years with reading science journals, in-depth environmental impact statements, and "white" and "grey" literature reports from government agencies, trade organizations, and researchers. My expertise as an editor is in translating and synthesizing complex science and policy for a lay audience.

Since 2004, my work as the sole full-time employee of the Acoustic Ecology Institute has been focused on sound-related environmental issues, especially ocean noise and wind farm noise. Top agency staff, professional organizations, and academic researchers in the US and Canada consider me an honest broker of what is known about these often contentious issues: the Canadian Department of Fisheries and Oceans, US Navy, and US Department of Energy have all asked for my participation in expert committees and specialized symposia. I was guest-editor of a special double issue of the *Journal of International Wildlife Law and Policy* on ocean noise, and was twice invited to be a plenary speaker at the biannual Alberta oil and gas industry noise control conference.

AEI's first annual wind farm noise report, Wind Farm Noise 2009 (published in February 2010) has been widely read and disseminated. I receive several calls a month from county commissioners, wind ordinance task force members, and engaged citizens working to help their own communities grapple with questions about wind farm noise. My relatively unbiased stance has been the primary reason that people seek me out as they try to make sense of the strident or overly assured tones of much of what is available online and in industry presentations. Since the publication of that first report, I've been asked to contribute my perspectives on wind farm noise to two well-established and very mainstream sources of wind energy information, both of which fundamentally support the expansion of the industry: the trade magazine and website *Renewable Energy World*, and the New England Wind Energy Education Project, a regional effort of the DOE-funded Wind Powering America project. Likewise, my work has become an important contributor to many community groups working to help neighbors, local governments, and wind developers better understand the real effects of wind farm noise on those living nearby, even though my conclusions are not generally as absolute as some of them may wish. The fact that both wind advocates and opponents find value in what I have put together

suggests that I'm on the right track toward the ultimate goal of finding a workable middle ground on these issues.

Since the turn of the new year, I've been stymied in my efforts to get this next annual report written. Three challenging factors have slowed me down.

First is the steady stream of new research, local and regional siting guideline decisions, and reports from communities that deserve to be incorporated into my understanding of the issues. Now, as we move from spring to summer, I've decided to just go ahead and write what I can, knowing that my self-education continues on a weekly basis. I hope that by framing the report around these three key themes, along with the call for respect and openness, I can contribute something to the situation, knowing that I don't yet know all I need to.

The fact is, we are all in this same situation, even – and perhaps most crucially – the "experts" who those on all sides of the issue rely upon to help us understand how to balance large societal questions about energy priorities with the local and very personal quality of life considerations that are raised as wind farm development expands. We *don't* know all we need to, and we *all* are learning more every month.

Second is the question of how much detail to include here. This question is always at the heart of AEI's reports: finding balance between being comprehensive and concise. Given the complexity and subtlety of the topics covered, there is a temptation to include many excerpts from relevant research reports, testimony, and environmental assessments of various kinds, so that readers can draw their own conclusions. Yet this amount of detail would overwhelm readers, I'm sure. Most will want to be able to get the key information they need in a few minutes. I've decided my job here is *not* to try to give readers all the information they need to make a decision, but rather to help them get a better perspective on where we are in our current understanding.

So, for the purposes of this overview it seems I can best serve by including just some of the key ideas and themes of the research that I've pored over. In making this choice, I'm asking you to trust that I am indeed being a fair broker of all this information, that I am presenting the information fairly and in a proper context. The fact that I'm asking for this trust is the main reason I've included this Appendix, in an attempt to help you feel comfortable with who I am and where I'm coming from. I plan to follow up this overview report with more detailed collections of source links and excerpts on the three key issues, which will be available online for those who want to read more and dig deeper for themselves.

The third and final challenge has been the question of how to best frame the information in this report. It was not my intention to stress anti-wind opinions or cautionary voices more prominently than those of acousticians, physicians, and property value researchers who are more comfortable with the current wind farm siting standards.

However, my sense is that these "business as usual" voices are well represented in most existing wind farm planning documents (put together by wind energy developers, trade organizations, and consultants hired to write environmental assessments of wind farm proposals). Certainly, this point of view is strongly voiced by wind energy companies in their presentations to local and county planning boards and state public utility commissions, as such authorities consider new wind farm siting regulations. I will be mentioning and linking to some of the reports and research that is used to buttress the argument that current consensus siting standards are sufficient, and that community noise standards designed for other noise sources are easily applicable to wind farms as well.

Nonetheless, the bulk of the material presented here is more cautionary or contrarian, largely because it's my perspective that these voices have been unduly marginalized by the voices of the status quo. After reading and listening to the full spectrum of research, interpretation, and opinion, I believe that the key questions about wind farm noise impacts are not as settled as those on either end of the spectrum suggest. The goal of this report is to help create a balanced perspective on the current state of our understanding and research; I hope that this is helpful to citizens, elected leaders and decision-makers – and to the wind industry itself – as the robust debate about siting guidelines continues over the coming year or two.

In writing this report, I've worked hard to not harp on negative reports or exaggerate the problems that come with wind farm development. At the same time, it's important to not disregard negative reports or accept broad-brush reassurances about minimal noise intrusions without looking closely at the actual experiences of wind farm neighbors. I hope that readers will note the tempered tone that I try to maintain, as well as the underlying desire to help chart a way forward that enhances the industry's ability to plan and develop new projects with a minimum of delays and unexpected legal or community relationship costs. The past two years have seen some important shifts within the industry, in the ways it deals with communities: specifically, it's become very rare to hear project planners claim that turbines will always be masked by wind noise, and there is an increasing commitment to community engagement. So far, though, these positive shifts have been focused largely on making the case for development-as-usual, with relatively little understanding that not all communities will have the same tolerance for wind farm noise as those that the industry has been working with over the past decade or so.

I hope that this summary will help everyone involved to understand both the current sources of disagreement among experts, and the likelihood that some communities will require a different approach to wind farm siting than has been the norm.

Personal experiences with noise: highway at home, wind farm in Texas

On a personal note, this year I've had a startling realization: the interstate highway that sits a bit over a mile from my house is clearly audible most of the time that wind is not blowing very much! My home is in a quiet rural valley of five- to twenty-acre lots, shielded from the

highway by nearby hills; yet the sound easily travels the mile and a quarter or so to where I am, and many times the highway noise actually bounces off hills on the other side of the valley, surrounding me with its gentle rumble. I've lived here for 16 years, and while I sometimes noticed the highway, I'd filed it away as an occasional thing. Indeed, in spring when the winds are high, the multi-layered symphony of breezes in the tree-covered slopes around me is a highlight of living in this place; in these times, the highway noise is swept off to the east rather than spreading in all directions, including south to me. And the nighttime insects and morning birdsong are still a delight, whether the still air also holds some traffic noise or a slight breeze keeps it at bay.

I've learned two things from this emerging awareness of the road noise. First, that thinking about noise intrusions can make subtle noise more noticeable. And, now that I notice it the noise *is* annoying to me. With each passing week, I'm more surprised by how present the noise is. Obviously, it's always been here, and I have and will continue to live with it.

Interestingly, the highway noise became obvious to me after a visit to an active large-scale wind farm area this past November, in the Roscoe TX area. There, I noticed the similarities, as well as the differences, between the sounds of turbines and distant roadways. I had some very interesting listening experiences there, but I knew I was only getting a snapshot, a few hours on two days. While the turbines were not objectively *loud*, they were clearly the loudest thing in the landscape except when a car passed closer to me than the turbines. I can imagine how some people might "tune them out" over time, and others would have a hard time ignoring their intrusion on the natural sounds of their homes.

I visited several wind farms over the course of an afternoon and the following morning, one on a small mesa and the rest on broad open plains, much planted in cotton, and the rest grassy scrubland. Throughout, the wind was moderate, but usually enough to get the turbines rotating at their maximum speed of about 20rpm (one blade per second passed the high point of the turbine). I did lots of listening, while measuring distances using my car's odometer. I could nearly always hear any turbine within a half mile, and generally they faded into distant background traffic (a mile or so away) when I was about seven tenths of a mile or so from the closest turbine. There were times when I was near rustling bushes, and could still easily hear turbines about a third of a mile away; the turbine hum was clearly at a lower frequency than the leaf rustling. At one point the wind was strong enough that the roaring in my ears drowned out turbines a third to half mile away; but when I oriented my car to block the wind noise I could again easily hear the turbines through the open window (i.e., moderate wind noise in the grasses did not mask the turbines; it seems likely that the open car window mimics what it would be like in a house with an open window on a windy night). The only time I really felt that a turbine seemed objectively loud was when I drove very close and stood perhaps 600 feet away; my thought was, "I don't understand how anyone could stand under a spinning turbine and hear nothing!" (Such reports are relatively common; perhaps they are turning very slowly, not at full operating speed.)

In one location, I could hear three or four turbines in various directions; each one had the characteristic amplitude modulation, with louder pulses of sound about once per second as the top blade passed through higher wind speed. The pulses were not in synch, of course, and the random, chaotic nature of the beats was very noticeable. I was only there for a few minutes, but I got a sense of how this experience could be disorienting or distressing to someone if it was going on for hours at a time.

This leads back to the second thing I've learned from the presence of highway noise in my own personal soundscape: very moderate noise can indeed become a dominant sound in my experience of my home place. I estimate that the highway noise varies from around 30dB to 40dB, from just audible in my quiet environs, to very noticeable. It may even hit 45dB sometimes, perhaps when the light breeze is headed my direction. I'm tempted to go buy a sound meter, to find out for sure. What I can say is that it is generally quieter than my refrigerator, to use a common descriptor of 40-45dB sound in wind farm circles.

By hearing this sound outside my home every day, I've come to have a more concrete sense of what wind farm neighbors are talking about when they describe the noise of turbines as being obvious, or dominant, or disruptive, even when the noise is not all that loud by objective measures. For many of us in rural areas, where gentle wind in the trees, distant birdsong, and a fundamental absence of chronic human noise is central to our sense of place, even quiet technological sounds can be jarring.

At the same time, this is a good example of the way that paying attention to a noise can change how someone experiences it. In particular, I found that paying attention to the sound made it seem – or, more to the point, actually made it *be* – worse than it was before I noticed it so closely. The road noise shifted *in my mind* from being an occasional presence, to being something that was always here except in certain situations; with that shift, I began listening for it when I went outside, and found, yes, there it is! Again. Previously, it was here, but I didn't listen for it; so, most of the time I was unconscious of it. I can easily imagine how this happens for many people living within earshot of wind farms.

Once in a while the highway noise is notably louder than normal; it's some sort of atmospheric condition(s) in which the sound carries far better. Perhaps these are the times I used to notice. Even when the sound was present but not bothersome, there were times when it intruded enough to be noticed. Then, I might have said, oh, there's the highway. I probably wouldn't say, "that damned highway!" Yet for some people, the nearly constant presence of the noise could indeed be distracting, disturbing, and distressing.

So, I find that this personal experience helps me to understand the responses both of neighbors who are bothered by nearby wind farms, and of others who feel the noise is generally inconsequential even when it is noticeable. I've lived with both of these responses over the years with this highway.

Footnotes

(links in the notes are live in the pdf version, though not formatted to show it)

[1] See, for example: http://aeinews.org/archives/1344 and http://aeinews.org/archives/350

[2] Source: AWEA website data as of 9/30/10. National Total Power Capacities: 36,698 MW. Texas: 9,727 MW; Iowa 3,670 MW
web page accessed 2/10/11: http://www.awea.org/la_usprojects.cfm

[3] From Swinbanks letter submitted to the Michigan PSC, December 9, 2009

[4] Ibid.

[5] Email correspondence, 2/19/01

[6] Ibid. Hessler later did a winter noise monitoring study, which Schomer found further fault with; see next footnote to read more on this.

[7] Paul Schomer letter to Cape Vincent NY Supervisor, 4/23/10

[8] In an email on June 23, 2011, Schomer noted about his Hammond ordinance proposal: "in the few months since I wrote it, I have learned enough that I would make some minor changes--this is a rapidly evolving field…The changes I would make involve the parameters for the use of ISO-9613-2 for predicting turbine levels in the community, and I would treat the limits I suggest as energy averages and not as 'not to exceed' limits."

[9] Noise Standards and Enforcement for Wind Energy Conversion Systems, Hammond, NY, revised wind law, November 19, 2010.

[10] For example, if daytime ambient is 44dB, then turbine noise limit would be raised from 45dB to 49dB.

[11] Noise Standards and Enforcement for Wind Energy Conversion Systems, Hammond, NY, revised wind law, November 19, 2010, page 2 footnote.

[12] Schomer, Paul D. *et al.,* "Proposed 'Ai'-Weighting; a weighting to remove insect noise from A-weighted field measurements," InterNoise 2010, Lisbon Portugal, 13-16 June 2010.

[13] Rand, Community reactions to noise. Report/letter submitted to Riga, Michigan Township Planning Commission, 2/5/11

[14] Rand, Wind Turbine Sound, An Independent Investigation: Siting to Prevent Adverse Noise Impacts. Powerpoint presentation to Informed Citizens Coalition, 2/5/11

[15] Email correspondence, 1/21/11

[16] Thorne, Statement of Evidence, Planning Panel Hearing on Moorabool Wind Farm, May 19, 2010, p28.

[17] Thorne, Statement of Evidence, Planning Panel Hearing on Moorabool Wind Farm, May 19, 2010, p25

[18] Ibid, p31

[19] Horonjeff, Siting of wind turbines with respect to noise emissions and their health and welfare effects on humans. July 6, 2010.

[20] Ibid, p4

[21] Ibid, p6

[22] One example of this is documented in a report by an acoustic consultant hired by a town to do sound monitoring in an area where complaints had arisen. The consultant found that sound levels were within statutory limits, but the field representative noted two "atypical noises" and described them: "1. A fluttery, high frequency sound was heard from the

direction of turbine A32 on the nights of February 13 and 14; and 2. A highly annoying and perceived high level low frequency swoosh was heard from the direction of turbine A31 on the night of February 16." From the Allegheny Ridge Wind Farm Sound Monitoring Study, Prepared for Juniata Township by Resource Systems Group, Inc., 2009.

[23] Kenneth Kalisky. Wind Turbine Noise Regulation: Perspectives in New England. NEWEEP Webinar #2, July 2010.

[24] G.P. van den Berg. Do wind turbines produce significant low frequency sound levels? 11th International Meeting on Low Frequency Noise and Vibration and its Control, 2004.

[25] William K.G. Palmer. Collecting Data on Wind Turbine Sound to Identify Causes of Identified Concerns. Paper 3aNSa2, Acoustical Society of America 161st Meeting, May 2011.

[26] Alec N. Salt and Timothy E. Hullar. Responses of the ear to low frequency sounds, infrasound and wind turbines. Hearing Research, Vol. 268, Issues 1-2, September 2010, pp12-21.
Also: Alec N. Salt. Responses of the Inner Ear to Infrasound. Presentation at Wind Turbine Noise 2011, Rome, Italy.
And: Alec N. Salt. Infrasound, the Ear and Wind Turbines. Presentation to the Arkansas Academy of Audiology, 2011. (more slides and detail than the WTN presentation)
See also Salt's lab page: http://oto2.wustl.edu/cochlea/

[27] Press release: http://www.nidcd.nih.gov/news/releases/10/07_28_10.htm

[28] Neil Michelutti of Queens University is conducting this study. For an early news report about it, see http://www.theglobeandmail.com/life/health/study-to-determine-health-effects-of-turbines/article1210357/

[29] Physician Michael Nissenbaum, who initially interviewed residents near the wind farm, has expanded his study to include a sampling of local residents over 3 miles from the turbines, as a control "cohort" to examine differences in reported health. For links to his work, see http://aeinews.org/archives/380

[30] Jevon D. McFadden. Wind Turbines: A Brief Health Overview. Centers for Disease Control and Prevention, Epidemic Intelligence Service, Wisconsin Department of Health Services.

[31] Daniel Shepherd, Mill Creek Wind Farm submission, 2010. See also his independent white paper, Wind Farm Noise and Health in the New Zealand Context, 2010.

[32] Shepherd, Mill Creek Wind Farm submission, 2010, p. 6 and 7

[33] See footnotes 25 and 26 above.

[34] Michael McCann, Property Value Impact and Zoning evaluation, Cape & Vineyard Electrical Cooperative, Brewster, MA. January 2011.

[35] In particular, McCann notes the study's observed price benefit of a good view as compared to a poor view, and presumes that seeing turbines will produce the poor view condition, whereas the study found that seeing turbines did not reduce prices; that is, seeing turbines did not equate with the study's findings about places with poor views. McCann likely basis this different assessment of the data on his fundamental critique of the statistical technique used in the Hoen/Wiser and Hinman; I can't assess this critique due to my lack of training in statistics, but the point seems to be that the hedonistic regression analysis of diverse location sales data that's used in these two studies can obscure real effects, which are more apparent when studying particular locations over time.

[36] Kielisch, Wind Turbines and Property Value presentation/pdf submitted to the Wisconsin PSC, June 2010.
[37] Royal Institute of Chartered Surveyors, Impact of wind turbines on the value of residential property and agricultural land: An RISC survey, 2004. This survey found that 60% of surveyors who had sold land near wind farms saw a negative effect, while 40% reported no negative effect. The negative impact on homes was expected to be more noticeable, with effect on agricultural land seen to be negligible.
[38] Chris Luxemburger, Living with the impact of windmills, November 2008.
[39] Even including one co-author of the DOE/Lawrence Berkeley property values study, Ben Hoen, who has been quoted by Clif Schneider as saying: "'You know we are very cautious about what happens close to the turbines. We really don't know what's going on there (e.g., 1,250 ft from turbines). I just spoke in Illinois about this. You might know about a Property Value Guarantee. It's a dicey situation and complicated, but I think homes that are very close, there is just too much unknown right now; that seems reasonable. I think one of the things that often happens is that (wind) developers put our report forward and say look property values aren't affected, and that's not what we would say specifically. On the other hand, they have little ground to stand on if they say we won't guarantee that. I think for homes that are close we have a lot more ambiguity and real issues. If we are talking about views that's one thing, but if we are hearing it or shadow flicker that might be really regular, the kind of things that happen at night. ... I'm not a lawyer and I'm not the developer, these (PVGs) are just options in the tool kit."
[40] See Pete Poletti, Property Value Guarantees and Decommissioning Costs, presentation to the Siting, Zoning, and Taxing of Wind Farms in Illinois Conference, February 2011.
[41] See McCann, response to Hoen study, December 2009, page 9.
[42] Notably two in Canada: near the Ripley Wind Power project–see http://aeinews.org/archives/1344 and the Melancthon EcoPower Centre–see http://aeinews.org/archives/350
[43] Kenneth Kalisky and Eddie Duncan. Calculating annualized sound levels within a wind farm. Acoustical Society of America 159th Meeting. Proceedings of Meetings on Acoustics, Vol. 9, 2010.
[44] Graphic from Cummings, The management implications of individual variability in sensitivity to noise within wildlife populations. Poster presented at the National Wind Coordinating Committee's 8th Annual Wind and Wildlife workshop, Denver, CO, 2010. Embedded in this graphic is the annualized sound level data from the Kalisky and Duncan paper cited in the previous footnote; the horizontal axis shows the dB level, and the vertical axis shows the number of hours per year at that sound level; the vast majority of hours per year are at moderate noise levels of 30-35dB, with most of the rest lower than this, and just 12% of the hours within 5dB of the loudest measured sound levels at this location, which were about 40dB, where the curve goes horizontal against the bottom axis.