Wind Turbine Noise 2011
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Brief Post Conference Oversight

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This was the third Wind Turbine Noise Conference personally attended (of 4 which have occurred). This was the largest conference to date. 22 countries were represented this year. The conference has grown each year, in number of participants (199 on the list this year) and papers presented (70 this year). In 2005 – 29 papers were presented, in 2007 - 33 papers, and in 2009 – 47 papers. The increase in size posed some challenges. The conference organizers added a half-day to the conference paper presentation schedule at the beginning of the conference after we had booked our flights, so we missed the 8 papers presented on the first day, which was unfortunate. The organizers also shortened the time for presentation for each paper to 15 minutes, which made it tight for some presenters (myself included) to be able to present a thorough review of their material, however, that happens, when a topic is popular. These comments are from a review of my notes taken during the presentations I did hear, and from overall impressions of the conference, but not from a thorough review of each paper, (yet to be done) so will be somewhat limited in scope.

Jane and Julian Davis, who had spoken in 2007 of noise concerns caused by wind turbines near their farm in the UK, took on the role of being the catalyst to make sure that many of the "like minded" speakers who were identifying concerns got to meet each other. Jane and Julian introduced a sub-group consisting of Chris Hanning, Alex Salt, Daniel Sheppard, Malcolm Swinbanks, Jean and I. However, we were not the only speakers identifying concerns. (More below.)

The proceedings followed these general topic areas, moderated by 10 session chairs:

- Propagation and Prediction (the session I missed)
- Standards
- Long Term Measurement
- Assessment
- Low Frequency (2 sessions)
- Amplitude Modulation
- Perception and Effects (2 sessions)
- Regulations, Policies and Planning
- Noise Generation
- Vibration

Each speaker was tightly limited to 15 minutes, and each sequence of 4 to 6 presentations was followed by a question and answer period of typically 30 minutes for the grouped speakers of that session. As is often the case, it seemed that a few questioners asked many of the questions, while many participants were silent.

Some of the oft-repeated questions and the usual answers included:

- When assessing low frequency noise, why are measurements not taken at distances greater than 1 km? (Ans – generally difficult to find sites at greater distances that are not subject to other noise sources.)
- Are you assessing the effect on receptors when doing sound level measurements? (Ans – generally no, only studying sound levels.)
- Alternately, are you collecting data from receptors on what conditions exist when they are most annoyed? (Ans – Generally no.)
- How can you relate a short laboratory based listening test of less than 1 hour to the sensitization impact perceived by a human subject to noise 24/7, particularly when trying to rest? (Ans – consider short listening tests to be not necessarily complete, but do provide useful input.)

Three subjects generated the most heated debate, and most clearly identified the split between "camps":

- The use of the difference between dBC and dBA to identify low frequency contributors.
- The Use of the WHO definition of health (as a state of well being) – versus a concern that by using that definition would result in no person in the world meeting the criteria of being healthy.
- The use of "road traffic" derived limits of 40 dBA to be applied to wind turbines since road traffic is short and sharp, while wind turbine sound is less "sharp."

As at the last conferences, many of the papers identified that national governments had identified a goal of increasing the contribution of wind power to their generation mix. Unfortunately, this often meant that the participants were identifying how much noise contributions at homes would be increasing, rather than identifying a limiting value based on effects to people or the natural environment. We seem to be still largely reactionary to the placement of wind turbines, monitoring the noise produced and the human perception of the noise, rather than having thought through the level of acceptable conditions. I felt the few papers that attempted to quantify the effect, so that a "line in the sand" could be drawn that identifies the maximum acceptable conditions were the important ones.

The challenge is that the limit is not easily defined as a clear "cliff edge" since like the effect of other environmental, chemical, or psychological stressors (stress here does not refer only to a state of the mind, but simply any state that produces a reaction) there seems to be a sensitization effect. Not only are different people impacted differently in sensitivity threshold (individuals have vastly different sensitivities to some chemical stressors, such as poison ivy, or peanut butter), but also there are significantly different dose relationship thresholds to stressors. The first exposure to poison ivy might have no effect, the second might result in a minor ash, and yet subsequent minor exposures might result in full blown outbreaks, even some time after the previous exposure. Difference in sensitivity and dose relationship is known to be factual for many different agents. Similarly, it has been demonstrated that different adverse impacts result for people living near wind turbines. An initial "dose" might have little impact (those people who state emphatically, I stood under the wind turbine, and it didn't bother me), while ongoing

smaller doses seem to create a sensitivity that results in adverse impacts for other people. As a society we are continuing to create situations that will produce the same or even more intense impacts, as we build more and more wind turbines without fully respecting the impact on people.

A brief summary of the key points from my notes made listening to the papers follows. Points of particular note are highlighted in italics.

From the "Standards" session, chaired by Mark Bastasch:

- Measuring method of wind turbine noise at residential area – consideration by using various noise indices – Hiroyuki Imaizumi (and others) Japan. *This paper outlined measurements being taken in Japan in response to "complaints against wind turbine noise." The research identified that 10 second measurements of Leq was effective to exclude contamination of the data by wind noise, birds, and passing vehicles. (This was of particular interest to me since the measurements I have been taking use a 30 second window for the same reason, by listening to the sound samples to ensure that the analysed window is free from "contaminants".) The data was limited though as measurements were only taken to a distance of 400 metres from the wind turbines.*
- Towards a National Standard to Support the Assessment of the Noise Impact of Wind Farms – Roberto Ziliani (and others) Italy. An introduction to work in developing Italian standards.
- Application of IEC 61400-11 in Italian Land – Fabio Serpilli (and others), Italy. Some introduction in the growth of wind farms in Italy, from 1908 MW in 2006 to 4898 MW in 2009. Notes issues of monitoring turbines that are at a higher elevation than the points of measurement. Notes Italy has lots of regional rules.
- Testing New Version of IEC 61400-11 – Bo Sondergaard, Denmark. New standard is still under test, but will be ready for implementation soon. Some errors in the current standard have been corrected. One significant change is to use the hub height wind speed instead of the 10-metre wind speed as reference.
- Acoustic Analysis of a wind Turbine with Vertical Axis – Jacek Szulczyk (and others) Poland. Acoustic tests on a small 400-watt vertical axis turbine.

From the "Long Term Measurement" session chaired by Bo Sondergaard:

- A Long Term Noise Measurement System for Wind Farms – Paul McDonald (and others) Ireland. What stood out most was how the presentation represented the challenge faced by those suffering from the effects of wind turbines. Mr. McDonald clearly believes wind energy is a great thing for Ireland. He spoke proudly of plans for 15,000 MW of wind generation in Ireland as a "clean and stable alternative to fossil fuels." For comparison, Ireland is a country with 7% of the area of Ontario and 34% of the Ontario population, and the peak wind contribution would be about 60% of the Ontario grid demand, hence, I would estimate could more than supply all of the electrical needs of Ireland – sometimes, yet that contribution could drop like a rock at other times. I could only think of a "heaven help you" under my breath as I considered the power surges, the turbine density, and the impact on people. His material spoke of the soft concerns of

residents for natural beauty, visual impact, and oh yes, a "perceived impact" of noise "annoyance." He noted the economic benefits of wind turbines were not contested, and that "engaging the public will mitigate public concerns," as the public will "feel better when involved and educated." He noted that the barrier to technical information is that it is not understood, so as they collected information on noise from long-term monitors, the proponents and regulators would get "all the data" while the public would get "only enough data to say the wind farms are in compliance." During the question period, he commented that "you get the cranks" when asked about supplementing pure noise measurements with softer personal feedback data as to why people get annoyed. What bothered me most was that as he spoke in a lovely Irish accent of his pride in the wind turbines, I could hear in my mind another Irish voice, telling me of the misery those turbines had caused. Both voices were equally sincere, yet mutually exclusive. At the end of the session, I took the opportunity to speak privately to Mr. McDonald for 10 minutes or so. I tried to gently note to him that when he used the words, "you get the cranks" who complain, he would not engage the public. I gently suggested to him that those with complaints did deserve to be listened to and respected, as they were certainly not all "cranks." They are for the most part honestly hurting. Had he ever sat down to chat about their complaints? "Well, no." Hopefully after our polite chat, perhaps he understood the value if he did speak to the complainers.

- Long term measurements: a way to minimize uncertainties on acoustic impact control of wind farms – Giovanni Faratto (and others) France. *The significant aspect of this paper was the reinforcement of the French standard. Wind turbines in rural areas where ambient sound is > 30 dBA, are limited to a maximum sound level of the ambient + 3 dBA. Thus, a 30 dBA ambient is limited to 33 dBA at night.* I could only contrast to the readings I knew I was going to present from Ontario, where the sound levels at homes at approved distances from turbines were 20 dB higher than the sound level at a home in the same environment on the same night, but distant from the wind turbines. The paper went on to describe how perhaps 20 days of monitoring and having 70 to 80 samples would provide a sufficient statistical analysis. Again, this matched nicely with the data I was to present showing the results on about 30 days over a year, with some 250 discrete samples.
- Continuous noise monitoring of wind turbines – Mike Dijkstra (and Tom Kerkers), the Netherlands. *Mr. Dijkstra discussed the change in monitoring criteria in the Netherlands from a ramped value of sound levels depending on wind speed to a Lden criteria, where 10 dB are added to measured noise levels for 8 hours at night, 5 dB to the measured noise levels for 4 hours in the evening, while the noise levels in the 12 daytime hours are used as read, with all combined to give a daily Lden criteria of 47 dBA.* If one considers that noise levels at night are often above noise levels in the daytime due to the increased wind shear producing greater turbine output at night, it can be seen that using the example of a case with 38 dB in the daytime, 40 dB in the evening and 42 dB at night, adding 10 dB to a value of 42 dB at night, plus 5 dB to 40 dB in the evening, plus 0 dB to 38 dB in the day, produces a summed impact of about 48 dBA Lden, while without adjusting for the differences in impact in the evening and night, would be

about 40 dBA, which are comparable. However, these again have to be contrasted to the Ontario regulations, which permit a greater value than 40 dBA for any wind speeds over 6 m/sec.

- Lessons learned from Long-Term Noise Monitoring at Project West Wind – Paul Botha, New Zealand. Mr. Botha described the results of monitoring around the West Wind project some 15 km west of Wellington consisting of *62 Siemens 2.3 MW wind turbines, the largest wind project in New Zealand. By his estimate there are 150 homes within 1 to 2 km from the turbines, which are mostly aligned in a linear array.* I had to mentally contrast this to the Enbridge Array in Ontario with 115 Vestas V-82 turbines (slightly smaller turbines, although rated at a higher noise level), which have 313 homes within 2 km of the turbines, that are arranged in a matrix arrangement, so homes are impacted by turbines from more than one side. *For the West Wind project, the conditions imposed on the wind farm by the New Zealand court, required the sound level at homes to be fixed to 35 dBA, as the background without turbines was generally less than 25 dBA, while in Ontario, the noise assessment submitted as part of the regulatory approval shows sound levels up to 50 dBA under some conditions.* The contrast is striking. Mr. Botha noted that the lessons learned are that although the turbines showed more tonality than initially expected, the subjective response showed that the amplitude modulation (i.e. blade swoosh) was of more concern than the tonality.

From the "Assessment" session, also chaired by Bo Sondergaard:

- Prediction, Validation, Assessment & Compliance of Wind Farm Noise in Australia, Peter Teague (and Andrew Leonard) Australia. Mr. Teague noted the proposed increase in wind power in Australia, from 30 wind farms now, rated at about 2500 MW, to be able to supply 20% of their electricity from renewables (wind primarily) by 2020. He noted that wind is now already >15% of Southern Australia's power with a state target of 33% by 2020 (he was not clear if nameplate or energy produced). *Typically there will be only 10 to 20 homes within 1 to 2 km of wind turbines at a wind power development in Australia (contrasted to Ontario, again, with 313 homes within 2 km of the Enbridge array turbines). He noted that Southern Australia guidelines call for maximum noise levels of 35 dBA or background LA90 + 5 dB). He suspects in the larger arrays there will be few if any homes within 1 km of turbines.* Again, the contrast with Ontario is remarkable.
- Accounting for Background Noise When Measuring Operational Sound Levels from Wind Turbine Projects, David Hessler, United States. *Mr. Hessler suggested the use of "proxy" monitoring stations to create a history of on-site background sound levels. He noted that for many wind arrays, the background sound level is very similar at monitoring sites within up to 22 km from the proposed turbine site.* He noted the need to measure background at the same time as wind turbine sound conditions are recorded to be able to properly account for the background at the wind farm site. He noted that in some cases the project itself was "very obtrusive" compared to the background measured at the same time. *This paper was particularly relevant to me as my paper shows the use of measurements at a "control site" some 10 km from other measurement sites to represent the*

background impact, and provides some confidence that this practice is acceptable.

- Analysis of Noise Immission Levels Measured from Wind Turbines – Payam Ashtiani (and Steven Titus), Canada. Mr. Ashtiani reported on work being done to develop an Ontario standard for wind turbine sound level monitoring. However, to be able to achieve monitoring at all ground level wind speeds, he showed how some measurements would be taken on a particularly windy night, binning data for the different wind speeds monitored that night. A problem that I perceive with this method is that it may result in taking data on a night when wind shear is low as opposed to high (typically a windy night indicates a low wind shear, and high turbulence) thus might predict a higher ambient sound level at the ground than on nights of higher wind shear, when the ground level wind speeds may be low, and hence the background sound level low, even while the turbine output may be high. I expressed concern that this manner of developing a standard may not necessarily represent all conditions. I will need to study the report more.

From the Low Frequency session chaired by Eja Pedersen:

- Noise From Large Wind Turbines – an update on low frequency noise – Kaj Dam Madsen (and Torben Pedersen) Denmark. The paper compares low frequency noise from new larger wind turbines compared to earlier smaller turbines. In particular it noted the need to measure the low frequency noise inside homes. *The work does show that the relative amount of low frequency noise is increasing as turbines get bigger, but there is greater variation between turbines (of different type) within the same power output range than between turbines of varying power level. When large and small turbines were compared at the minimum separation distance (4 x the tip height, or say 600 m for the GE 2.5 MW turbines being proposed in Ontario with 100 m towers and 50 metre blades), then the small turbines have more high frequency noise (expected as closer) and the larger turbines have reduced high frequency noise, but increased low frequency noise (due to greater attenuation of the high frequency at greater distance, but the limited attenuation of the greater low frequency noise levels.) The example of a typical new Danish array was shown of 6 x 3 MW turbines. For this array, only 2 homes in total are within 550 metres of the 6 turbines, and 10 within 1 km. In comparison, at the Kent Breezes 10 turbine array in Ontario, there are 37 homes within 1 km and 213 within 3 km.* Repeatedly, examples show that turbine to home proximity appears to be considerably greater in Ontario than Denmark, and other countries. As an aside*, in discussion with Jesper Morgensen, of the Danish Environmental Protection Agency, Mr. Morgensen reaffirmed that in Denmark, any turbine within 6 times the total turbine height to the property (in later communication, Mr. Morgensen states this is interpreted as a residence, and not the property line) of a neighbour (900 metres for the Kent Breeze array) would qualify for an automatic assessment of reduction of property value. If any reduction in value of greater than 1% is identified, this is paid to the neighbour at the time of construction by the wind developer. For setback distances of greater than 6 times the tip height (i.e. 900 m for the Kent Breeze turbines) then the landowner might request an assessment to be carried out for a fee of about $750.*

If the assessment determines that a property value reduction (or greater than 1%) has occurred, then the assessment fee is reimbursed as well as the property value deduction payment.

- Correlating Very Low Frequency Sound Pulse to Audible Wind Turbine Sound – Werner Richarz (and others) Canada. *Mr. Richarz notes that the human perception of sound is governed by temporal (that is time based) stimuli. Thus, a cyclical "swoosh" is more easily perceived than a steady sound. Their work was able to identify low frequency pulses that contribute to the characteristic lundmark"swoosh."*
- The Assessment of Low Frequency Noise and Amplitude Modulation of Wind Turbines – Denis Siponen (Finland). Mr. Siponen is a researcher with VTT, the Technical Research Centre in Finland. *His paper identifies concerns due to the increasing component of low frequency sound and the cyclical swoosh from large wind turbines, and suggests that the use of A-Weighting for noise control should be re-evaluated.* This resulted in fairly intense debate.
- Monitoring and Mitigation of Low Frequency Noise from Wind Turbines to Protect Test Ban Seismic Monitoring Stations – Peter Styles (United Kingdom). While not related to human response, *this paper describes an interesting fact of the detection of low frequency pulses 10's of kilometers from wind turbines, that impact Seismic Monitoring Stations that monitor for nuclear weapon testing, resulting in a 50 km exclusion are for large wind turbines around the test site.*

From the continuing "Low Frequency" session chaired by Dick Bowdler:

- Measurement of Infrasound from Wind Farms and Other Sources – Chris Turnbull (and JP Taylor), Australia. *The paper describes an interesting method of measurement of sound without influence of wind speed by using a hole in the ground 0.5-metre square, and 0.5 metres deep. The microphone is mounted in the hold and the cavity is covered by a secondary windscreen level with the ground. This raises the question if it might be possible to fabricate a "portable hole" consisting of a cavity that is above ground, but surrounded by a gradual slope to deflect wind. The testing reported showed that the G-weighted "infrasound" is generally below the 85 dBG limit of audibility, and comparable to the sound levels near a beach, a gas fired generating station, or in the city. Note the further information in later papers by Gunnar Lundmark about comparing to the sound from a beach due to the lower cyclical frequency of the beach waves, and by Alec Salt about the fact that lack of audibility is not necessarily a measure of lack of human effect.*
- The Case for Spectral Measurements of Ambient Noise Levels in the Assessment of Wind Farms – Matthew Terlich, Australia. *This paper suggested the use of spectral analysis of measured background sound to identify contributions of insects or birds. This was relevant to me since my paper was specifically focusing on spectral analysis of the sound, as opposed to simple A-Weighted sound levels.*

From the "Amplitude Modulation" session chaired by Dick Bowdler:

- Fundamental Research in Amplitude Modulation – A Project by Renewable UK / Research to Improve Understanding as to it's cause and effects, Matthew Cand (and others) United Kingdom. This will be a project to start in 2011. Renewable UK was formerly the British Wind Energy Association. *Mr. Cand requested a copy of my database of sound files. They note the effect of wind shear on changes in the angle of attack (as was identified in my 2009 paper).*
- Detection and Quantification of Amplitude Modulation in Wind Turbine Noise – Nick McCabe (Canada). *Recognizes that wind turbines may cause more annoyance than other sounds at the same sound level. Notes that the characteristic "swish, the amplitude modulation of the broadband sound is frequently suggested as one quantitative factor which may increase the annoyance." Notes that New Zealand applies a penalty when Amplitude Modulation is present. (Ontario does not.) Noted a clear diurnal pattern (day/night change) and that more modulation is present at night. Noted good correlation of modulation factor with gradual changes in wind direction and wind speed variation. Notes modulation is stronger in crosswind direction. Notable to me that Ontario consultants are willing to admit internationally to the issues we have been raising, but deny there is concern during testimony in Ontario.*
- Measurement of Amplitude Modulation Frequency Spectrum – Dave McLaughlin, United Kingdom. *Notes that modulation may result from a greater wind shear across the turbine disc than in predicted by the power law.*
- Long Distance Amplitude Modulation – Carlo di Napoli, Finland. *Noted significant shift in frequency of sound some 700m downwind from wind turbines when modulation occurs. Also noted strong pulse variation in crosswind direction that can be noted 2 km away from the turbines. Noted that it is impossible to conclude that amplitude modulation decreases with distance.*
- Measurement of Swish Noise, A New Method. Gunnar Lundmark, Sweden. Mr. Lundmark identified his work as the product of a "garage company." I had met a kindred spirit! *Mr. Lundmark noted that although an accredited company measured sound at a home near wind turbines and took correct measurements, they missed the point. They said that a waterfall and a wind park is the same … but not so. Standard measurement methods, of time averaged dBA measurements hides the swish noise. He then described a simple method that made the difference of the amplitude modulation of wind turbines very clear compared to the stochastic (random) pattern of a waterfall. Similarly, he identified that beach waves have a strong amplitude modulation, but at a low frequency, which is more calming than wind turbines. Beach wave frequency is 0.1 to 0.4 Hz. while wind turbines produce amplitude modulation at a higher and more troubling frequency.*

From the "Perception and Effects" session chaired by David Colby:

- Dr. Colby opened the session with a brief statement about bird flight developing an amplitude modulation effect, but noted that owls can fly silently, and asked how they do it? Then he added the note that "If you cannot measure it, you cannot manage it, so try to approach the subject scientifically."

- Responses of the Inner Ear to Infrasound – Alec Salt (and J. Lichtenhan), United States. Salt noted he had been studying the ear physiology for 37 years. *He noted his "take home message" was "the ear is sensitive and responds to low frequency sound amplitude modulation."* He described experiments on guinea pigs as surrogates for humans, and went on to describe the *response of the inner ear hair cells, responsible for hearing, and the outer hair cells, which respond to displacement but not velocity. He noted that although we hear through the inner hair cells, the outer hair cells respond at up to 40 dB below what we hear.* However there is a maximum response to infrasound when the ambient is low, as higher frequency sound suppresses the infrasound response. *A-weighted sound under represents the influence of low frequencies. In conclusion, it is not possible to say that infrasound effects on the ear are insignificant, and it is premature to say that long-term exposure to wind turbine noise can have no physiological effect.* During the question period, M. Bastasch made the point that enhanced audibility did not necessarily mean enhanced adverse effect. Salt replied that learned stimulation pathways results in the brain locking on to it, and hence means that people become susceptible to recognition of the effect. The question of the guinea pig to represent human ears was raised, which was defended.
- The Audibility of Low Frequency Wind Turbine Noise – Malcolm Swinbanks, United Kingdom. Initially, *he noted that the issue of low frequency and infrasound impact from wind turbines is being recognized worldwide. He noted that it is not possible to merely look at the tones from wind turbines and show they are inaudible, as it is possible to detect impulses which increase audibility to levels significantly below previously acknowledged from an examination of cumulative mean square energy level of the signal.*
- Ear Training on Wind Turbine Noise Emissions – Pierre Dutilleux, Germany. This struck me a fairly self evident presentation that used a number of examples to show that *measurements of wind turbine noise will never replace an actual listening test to identify objectionable sounds. It is not simply sound, but the quality of the sound that makes it noticeable and objectionable.*
- The influence of vision on noise annoyance evaluation of wind farms – M. Masullo (and others) Italy. In this test short duration (~ 40 minute) listening test, subjects were presented with visual pictures of different configurations of turbines on a computer monitor (number of turbines, colour of blades, rotor speed, and height) as they listened to the sound of wind turbines to determine if there was any link. Again, I expressed the concern that short duration tests in a laboratory at a computer terminal are not necessarily representative of the impact felt by persons living near turbines day after day. *David Colby seemed to be impressed that the research indicated that noise might be perceived differently depending on visual form – that is, that it is not only sound that influences acceptability.*
- Selection of outcome measures in assessing sleep disturbance from wind turbine noise – Chris Hanning (and M. Nissenbaum), United Kingdom (and United States). *Hanning presented mostly on the effects of sleep deprivation and noted that rather than trying to record awakenings (which may not be recalled), or on arousals (which may be detected by movement) a reasonable manner of measuring the effect is via a "sleepiness score" which asks a number of*

questions. The results of performing such a questionnaire on residents both near (within 375 to1400 metres) and far (3000 to 5000 metres) from wind turbines were presented. During the question and answer period, Geoff Leventhall noted concern in using traffic noise survey results (a 40 dBA limit) to wind turbines, as traffic noise is short and sharp. *Hanning noted that the worst situation for sleep disruption is a lot of events just below the threshold that results in awakening, since the smaller events result in arousals and thus greater sleep disturbance. He noted that wind turbines could well be worse than traffic events that wake people up.* Julian Davis noted that individual traffic noise is not like wind turbines, which display a short rise time in the "thump" as noted by C. di Napoli in his tests.

- An overview of residential health effects in relation to wind turbine noise – Frits van den Berg, The Netherlands. *Van den Berg noted that the issue for wind turbines has shifted from purely measuring the physical sound to determining the health effect.* He noted that he was working on a section on "the effects of wind turbine noise on people" for a book on Wind Turbine Noise to be issued in 2011, edited by Geoff Leventhall and Dick Bowdler. Issues include annoyance and sleep disturbance, mental health and stress, effects on performance, and interference with speech communication.
    - *Van den Berg noted that perhaps the greatest effect on annoyance was the easily perceived cyclical "amplitude modulation" of swishing/beating.*
    - He noted, "I'm not aware of any effect on performance. We do not see hearing or cardiovascular effects from noise at these levels, but they may result from annoyance and sleep disruption."
    - He noted that his comments flowed from three peer-reviewed surveys by Pedersen and Persson Waye in 204, by Pedersen and Persson Waye in 2007, and by Pedersen in 2009.
    - *Wind turbines are relatively annoying, in fact pose higher annoyance than all other sources of sound except railway shunting yards. If 5 dB is added to sound from wind turbines to account for amplitude modulation, then they would become the same as the highest other effect.*
    - He expressed his opinion that the low frequency factor is not clearly relevant. It is not dominant in tonal sound, but is increasing with wind turbine size. Infrasound is usually inaudible, causing no effect, except perhaps for specific medical conditions. *He stated, "I am not convinced that low amplitude modulation frequency is important on a larger scale."* The public locks onto low frequency, it gets spooky, but it is not understood by people.
    - *At 45 dBA and up, sound may lead to annoyance and disturbed sleep. It is particularly an issue in quiet rural areas where people hear the wind turbine sound, but not in busy areas near roads and built up areas. Bad sleep may make you vulnerable, and annoyance may lead to bad sleep.*
    - *There is evidence that non-acoustical factors may pose an influence, such as visibility. If there is economic benefit there is almost no serious annoyance. A factor is predictability and lack of control. Attitude about the fairness of the issue is a factor, and may lead to noise sensitivity.*

- *It is probable that non-acoustical factors, social factors, trust and recognition by authorities of impacts, the ability to speak and to be listened to by authorities, and awareness of economic benefits may influence effects.*
- He noted that a paper by Eja Pedersen on the health effects associated with wind turbines has been accepted by the Noise Control Engineering Journal for publication.
- Van den Berg briefly noted that a book on Wind Turbine Syndrome by Pierpont brought forward a term "visceral Vibration Vestibular Disease – VVVD" but these seemed to be stress related disorders. He felt that VVVD was probably not a new combination of stress symptoms.
- *Van den Berg concluded that wind turbines are relatively more annoying than other sources, with the most relevant acoustical factor being the swish. They might result in sleep disturbance, and this might lead to distress. Mitigation might result from decreasing the sound level or decreasing the modulation level. People expressing concern should get respect, and why would a developer not help people adapt by installing double-glazing for example.*

- Why Turbine Noise Annoys – Dick Bowdler, UK. The bulk of this presentation was a week by week over a 33 week period of the story of a wind farm neighbour who expressed concerns to local officials yet had no satisfaction in spite of repetitive contacts. *Bowdler concluded that the person was ill because the noise was too loud, the special characteristic makes it worse, the local government is of no help, and the wind developer is unapproachable and arrogant.* It was a familiar story! *He noted that at the UK government limits of 40 dBA (daytime) the sound was perhaps 10 dB above the average, and at night the UK 43 dBA limit is perhaps 15 dB above background. The special characteristic of the sound (cyclical character) makes it perceptible,* and the government and consultants are well aware that listener attitude is important. Non-acoustical factors are identified as important. *People do not feel valued, or fairly treated, and the government is perceived to be on the side of the developers. He notes that Britain stands to loose a considerable amount of development money if the complaints are listened to.* As a result, Bowdler suggested that there is a rise in mysterious explanations, and complaints are now being made at distances of 2 km. "What should have been the opportunity of the century has split the community."
- *David Colby expressed his conclusions to the session on "perception and effects" as follows:*
  - *"What you see is what you get" (in reference to the study by Masullo that suggested visibility factors influenced annoyance from audibility.)*
  - *"The older you get, the more arousals you experience" – quipping "contrary to my experience" (as his summary of Hanning's work)*
  - *"There is a mind body continuum" (in reference to Van den Berg's summary of other factors influencing annoyance)*
  - *"Government is devious and incompetent" (in reference to Bowdler's paper.*

- *Colby concluded, "What we say leads to toxic pathology – that is why people are getting sick. It produces anger. Yes, it's not all in your head, but there are a lot of psychological factors."*

The "Perception and Effects" session continued, chaired by Frits van den Berg.

- Evidence Based Study of Noise Impacting Annoyance – William Palmer, Canada. I'll confess that I was not happy with my presentation. Three factors seemed to be at play. I was internally seething following the previous session, and what I perceived as the trivialization of issues of concern. Secondly, to try to ensure I was able to present all of the material in my presentation I had set my slides to auto-advance for fear of being cut off before I reached the conclusions, and found myself "chasing" the slides through the presentation rather than being at ease. Finally, I had embedded 4 sound files in my presentation that were important to summarize effects, and although I had checked they worked in the "practice – set up room" none of the sound files would play during the presentation, which really left the presentation unfinished, and me upset at having to try to get them to work during the presentation – causing a distraction to attendees. *In summary what the presentation tried to convey was lessons learned from a series of over 250 sound samples taken at "approved locations" (meeting regulatory approval) and at "control locations" at distances twice and ten times the approved distances. The measurements showed that there was a difference of some 20 dB at all low frequency octaves at the "approved locations" compared to the "control location" any time turbines were operating, and that the sound level at the "approved locations" was roughly the same during conditions with very low ground level ambient wind speed as it was at the "control location" when the wind speed there was in the order of 8 metres per second (a fresh breeze).* There were no questions related to the presentation in the post session discussion, which indicates that it had little effect, although there were 4 conference participants who did subsequently ask for copies of my sound files to review. A copy of my paper (about 1 MB) and presentation file (about 10 MB with the sound files) is available to anyone interested.
- Perception of Noise from Large Wind Turbines – Sabine Hünerbein (and others), United Kingdom (and Denmark.) This paper summarized the results of another laboratory listening test of 20 participants, who either lived, or said they wanted to live in the county. In this case, a series of different tones from 30 to 400 Hz. were superimposed on a general broadband spectrum, to determine if there were differences in annoyance. The effect of amplitude modulation was not included in the test. A second test compared annoyance from a large and small wind turbine sound recording to road traffic in indoor and outdoor situations (where garden sounds were superimposed on the outdoor simulations.) In conclusion, the listening tests did not identify a significant difference in annoyance between the wound of large and small wind turbines. Lower frequency tones (simulating the lower frequency noted from large turbines) were not found to be more annoying than higher frequency tones. They also found that the more the tone is above a threshold "masking sound" the more annoying it is perceived to be. This would

seem to indicate a higher level of annoyance in quiet rural backgrounds more than just comparing sound levels.

- A Note of the Debate about Health Effects from Low Frequency Noise (LFN) from Modern Large Wind Turbines – George Hessler, United States. Mr. Hessler presented his arguments that although a lot has been heard about sleep effects and low frequency noise, much of it is based on very old NASA work 20 to 30 years ago. He suggested to start with the source sound level of the proposed turbine, use an appropriate propagation model and evaluate the results. He noted that from his experience so long as the project designs for 40 dBA and uses 45 dBA as a regulatory limit, there will be no adverse response. He noted that he had personally never experienced the "thumping noise" spoken of from wind turbines, although he admitted his son David had done so. From his point of view, so long as the dBC reading is 60 or less, there will be no complaints. *His conclusion was, "there is no significant low frequency noise problem with wind turbines."* He commented that he is not a health expert, but he added, neither are most of the opponents of wind turbines expressing opinions. In questions after the session, Hessler was asked for what evidence of complaints he faced from the 60 projects he said he had been involved with. Hessler noted that he only knew of 6 homes that had expressed concern in the 8 projects that he had followed from beginning to end. In all 8 projects about 4% of homes in the project area had expressed any concern. Annoyance is not related to noise dose, and it is less severe than anticipated.
- Wind Turbine Noise in Sheltered Dwelling Areas – Paul Appelqvist (and M. Almgren), Sweden. The paper described the specific case of complaints from persons living in relatively sheltered locations, often in valleys compared to the location of wind turbines on hilltops. In the sheltered valley location there is very low background noise, and the wind turbine noise is particularly bothersome.
- Wind Turbine noise and Health-Related Quality of Life of Nearby Residents: A Cross-Sectional Study in New Zealand – Daniel Shepard (and others) New Zealand. *Shepherd reported on a survey conducted among residents living in 56 homes within 2 km of a wind turbine in the West Wind project area, about 10 km out of Wellington, and among a control group of residents living in 250 homes located 8 km or more from wind turbines. Both groups were considered to be matched socio-economically. The survey was carefully designed to mask the primary intent of looking for input related to wind turbines by calling it a "2010 Wellbeing and Neighbourhood Survey" asking first about general "Health-Related Quality of Life" (HRQOL) and questions about factors such as street lighting and garbage collection before touching on concerns of noise and vibration. In summary, he reported that the survey groups responded in a similar proportion (of 32 to 34% of those in the control and turbine groups surveyed) and that the results were statistically significant to show a decreased physical and environmental HRQOL. The study results identified that utility scale wind turbine developments do pose adverse impacts on the health of those living nearly, and suggests a setback distance of greater than 2 km be established.*
- In discussion after the session, David Colby noted "for non medical types" that using the WHO definition of health (as had been done by Daniel Shepherd) posed

a problem, as there is not a single person in the world who meets the criteria as healthy. It is not helpful to use that criterion he noted. No one should think it is a realistic expectation to achieve. Most data is atrocious from an epidemiological point of view. The data is uncontrolled and unverified. Shepherd responded that use of the WHO definition was indeed of use, and is used routinely when considering cancer treatments, as the decision is whether the quality of life is enhanced by the treatment regime. He suggested that it was necessary to start somewhere. Eja Pedersen suggested that the surveys should take account the perception of people, and not just sound levels. Chris Hanning suggested it would be appropriate for David Colby to initiate an epidemiological study of wind turbine effects in Canada, to which Colby replied that he only was involved with a very small part of Canada.

- In concluding the session, Fritz van den Berg noted that he would not summarize the points raised, but would pick up on the discussion on the WHO definition of Health. He noted that he did not think the WHO meant all should have that state, but noted that wind farms affect people in many ways, and the WHO definition is useful to show how they affect health. He noted his support for the call for more surveys looking at effects, and applauded the work about to begin in the UK to look at amplitude modulation.

From the Regulations, Policies and Planning Requirements Session, chaired by Patricia Davies:

- Italian Regulations on Wind Farm Noise – Michelangelo Mariani (and A Bartolassi), Italy. Mr. Mariani began by noting that Italy plans to more than double wind output from 2010 (5728 MW) to 2020 (12,000 MW planned). He noted the progression of the Italian noise regulations, noting that they are not specific to wind farms, which are considered as industrial areas. *There is a 3 dB maximum differential between the noise allowed at night and the background at night. Protected areas are limited to a maximum of 40 dBA at any time.*
- Assessment of Wind Turbine Noise Using NZ Standard NZS6808:2010 – Malcolm Hunt (and S. Chiles), New Zealand. Hunt noted that the *2010 New Zealand Standard tried to recognize the "special audible character" of wind turbines.* He noted that a number of other changes occurred in the revisions, including *a change in reference point for wind speeds from a 10 metre level to the hub height, noting a high amenity noise limit (for areas with quiet background) and a penalty for the special audible characteristic (tonal, or amplitude modulation, or impulsive sound) from wind turbines. Developers have to identify the 35 dB contour resulting from a wind farm, and measure background in the area before the project commences to identify special amenity areas.* The goal was to protect against health effects particularly sleep deprivation, based on the WHO requirements with open windows. *The limit is 40 dBA or background + 5 dB. In low ambient sites, the background might be 15 to 20 dBA at night, resulting in a special amenity limit of 35 dBA at night.*
- Wind Energy in Catalonia Trends – Alexander Deltell (and others), Spain. Noted that the Catalonia region of Spain was he area of the first Spanish wind farm. Spain now has 20 MW (peak) of installed wind generators. However, the areas

with the best wind speed are generally incompatible with wind development until an environmental impact assessment is carried out. *He notes there is increasing social pressure against wind energy in Spain.* Like Italy, Spain has no specific regulations for wind turbine noise, and treat it like other industrial sources. He notes that in Catalonia, the social perception of wind energy is poor.

- Review of Noise Conditions from Planning Permits in Victoria Australia – Christian Delaire (and D. Griffin), Australia. This was a review of monitoring from a number of projects under development in Australia.
- Application of Policy by Local Authorities to Wind Turbine Noise Applications in England – Richard Perkins (and GA Perry), United Kingdom. Noted the key is the DEFRA report, "Statutory Nuisance and Wind Farms" but *local councils can pose tighter standards than the DEFRA* (but may not have enough information to do so.) In contrast, on Ontario, local councils can add no additional information to the Renewable Energy Approval Regulations.
- Health Based Guidelines for Wind Turbines – Martin van den Berg, The Netherlands. Reviewed the development of new regulations in the Netherlands. *Trying to meet new national ambitions for wind generation.* (Government wants 6 GW on land in the Netherlands.) Noted from the Good Practice Guide on Health Effects:
    - ECG Awakening Lmax 32 dB
    - Highly Disturbed Sleep Lnight 42 dB
    - High Blood Pressure Lden 50 dB
    - Cognitive Effects Lden 50 dB
    - Cardiac Infarcts Lden 60 dB

  To achieve government objective, based on land layout, had to increase the final regulatory limit to 47 Lden, or 41 Lnight. It is believed that at that level, 9% of people will be bothered, which is considered to be acceptable.
- Wind Turbine Noise – French Regulations – Advantages and Inconveniences – Renee Gamba (and Sambastien Garrigues), France. The paper provides a useful review of the different regulations in Germany, Denmark, Sweden, the United Kingdom, and Italy. The *French regulations were described as being the most stringent in Europe. If the ambient sound level is < 30 dBA, the regulations limit the daytime noise from wind turbines as 5 dBA higher, and the night-time noise as 3 dBA higher than the ambient. There are also regulations for inside the home with windows open or closed. French regulations are anticipated to be revised to give limits of 4 dB above ambient limits up to 35 dBA at night.*

From the Noise Generation Session Chaired by Werner Richarz:

- Implementation and Verification of an Aeroacoustic Wind Turbine Blade Analysis Tool – Mohammed Kamruzzaman (and others), Germany. A very mathematical paper describing the development of a 3D aeroacoustic simulation tool.
- Trailing Edge Noise Reduction of Wind Turbine Airfoils by Active Flow Control – Mohammed Kamrussaman (for A. Wolf and others), Germany (and Israel). Again a mathematical approach to show that constant suction leads to a reduction of trailing edge noise. No immediate application.

- Computational Aerocoustics for Rotating Systems – Stefan Becker (and others) Germany. Again highly mathematical models developed. Suggest term "sound design" vs. "noise" to improve the optics!
- CFD Analysis of the Influence of Central Shaft on Vertical-Axis Wind Turbine Noise Emission – Maarco Castelli (and others) Italy. Model and simulations of noise nearby a small vertical axis turbine.
- Integrated Airfoil/Blade Aerocoustics Modeling and Validation – Sidney Xue (and others) United States. Describes research at Vestas to reduce wind turbine noise. Shows development of modeling tool. Of note from the presentation, is *confirmation that airfoil noise is primarily trailing edge noise. Can get impulsive modulation at far field microphone from downdraft and tower interaction. Changing angle of attack on the blade can change dominant frequency from low frequency to higher frequency or vice versa. Need to consider the elastic blade effect. Wake changes blade loading, so changes acoustic response.*
- Enhanced Wind Turbine Noise Prediction Tool SILANT – Kurt Boorsma (and JG Schepers), The Netherlands. *Notes that wind turbine noise is often quantified in terms of time averaged overall sound power levels (A-Weighted) while the annoyance due to noise level fluctuations in mid-to-high frequency range frequencies ("swish") are not taken into account. States that research has shown the major cause of swishing noise is due to directivity of noise sources and convective amplification effects on the moving turbine blades.* The "SILANT" noise prediction tool has been revised and compared to experimental results with good agreement. Wind turbine blade is divided into 10 to 20 elements, and model trailing edge noise, inflow noise, and tip noise. Tailing edge noise changes as angle of attack changes due to wind shear and changes in wind direction. Amplitude modulation changes downwind, possibly due to the influence of turbulence following the turbine. *As shear changes, the low frequency changes – but notes that A-Weighting gets rid of it – as measurement, but not in actuality!* In discussion after presentation notes that the size of the rotor is a major factor for changes in angle of attack. Incoming velocity is the most important term.
- Analysis and Optimization of Wind Turbine Performance and Noise Under Uncertainty – G. Petrone (and others), United States. Mathematical modeling of noise resulting from insect contamination, variability of wind conditions, and manufacturing tolerances. Can give rise to considerable change in noise levels. Showed change in noise of up to 9 dB. Change in noise also can impact performance. (Noise is lost energy.)
- Wind Turbine Blade Noise Mitigation Technologies – Benoit Petitjohn (and others), Germany and United States. Describes work by GE Wind Energy to reduce noise from wind turbines. Although trailing edge noise is dominant, tip noise can be an issue. Describes tests on modified tip design that lowered noise considerably (a change of 5 to 6 dB in total). Also shows a reduction due to a serrated blade edge of 2 to 4 dB. States both of these changes have been incorporated into newer GE designs. Would be costly to implement on existing designs.
- Appropriate Resolution Models for MINI Wind Turbine Noise – Michela Bonsignori (and Michael Carley), Italy and United Kingdom. Describes design

work on small wind turbine (13 metre rotor). Design can reduce noise. Notes noise limits and the major issue for acceptability.

From the Vibration Session, chaired by Geoff Leventhall:

- Test Bed for Acoustic Assessment of Small Wind Turbine Drive-Beds – Ganesh Raman (and others) United States. Describes laboratory test-bed to measure vibration of small wind turbines. Also have acquired large turbine for phased array sound testing, but not started yet. Notes, *the noise produced by a wind turbine is a sign of its inefficiency, thus there are advantages in having a quiet turbine.* Want to use phased array to measure noise. However, at lower frequencies, the beam forming measurement may not be effective at determining the noise source.
- Microseismic Noise From Wind Turbines in the Vicinity of the Virgo Gravitational Wave Detector – Irene Fiori (and others) Italy. *Describes how the 1.7 Hz vibration produced by wind turbines is still above background noise at a distance of 11 km. These are small amplitude vibrations, but can be important for scientific measurements needing high precision.*
- Long Term Hydro Sound Measurements at the Alpha Ventrus Offshore Wind Farm Focusing on Pile Driving Noise – Joachim Gabriel (and others), Germany. Describes how pile-driving noise is transmitted through the sea.
- Monitoring and Modeling of Vibrational Effects of Small (<50 kW0 Wind Turbines on the Eskdalemuir IMS Station – Rachael Westwood (and others), United Kingdom. *Describes the 10 km exclusion zone, and the 50 km consultation zone required before building wind turbines in the vicinity of the nuclear weapon test-monitoring site. Vibration from wind turbines large and small can impact the measurements. Described monitoring of vibration from small (<50 kW) turbines, to permit them to be installed at distances of > 10 km from the site.*
- Ambient Underwater Noise in High and Low Energy Flow Conditions – Merin Broudic (and others) United Kingdom. Describes measurements of underwater noise to determine background conditions before offshore turbines are installed.

As usual, a lot of the benefit of the conference was the opportunity to speak with on a face to face basis many of the people involved in wind turbine noise including (in no particular order):

- Carlo di Napioli (Finland) – acoustical consultant monitoring wind turbines and attempting to explain the findings – we first met at 2007 WTN
- Denis Siponen (Finland) – researcher with VTT – the Technical Research Centre of Finland
- Alec Salt (United States) – researcher in physiology of the inner ear
- Chris Hanning (United Kingdom) – retired sleep specialist, and medical doctor
- Daniel Shepherd (New Zealand) – psychological researcher, conducted and evaluated study in New Zealand at West Wind development
- Malcolm Swinbanks (United Kingdom & United States) – mathematician and scientific researcher
- Nigel Lloyd (New Zealand) – acoustical consultant – we first met at 2007 WTN

- Eja Pedersen (Sweden) – researcher in environmental psychological – doing work in what influences peoples attitudes and reactions to wind farms – first met in 2007
- Frits van den Berg (The Netherlands) – Amsterdam public health service – writing chapter on health effects of wind turbines for book edited by Geoff Leventhall and Dick Bowdler – first met in 2007
- Dick Bowdler (United Kingdom) – acoustical consultant, now working on UK Renewables amplitude modulation study
- Martin van den Berg (The Netherlands) – worked on new Netherlands sound regulations for wind turbines
- Conny Larsson (Sweden) – meteorology (specifically effect of changing wind speeds and temperature on sound propagation – discussed propagation into river valley below turbines)
- Hiroyuki Imaizumi (Japan) – researcher into sound near wind turbines in Japan
- Paul McDonald (Ireland) – acoustical consultant, setting up long term unattended monitoring systems near wind turbines
- Sidney Xue (United States) – principal engineer and acoustical researcher, Vestas
- Matthew Cand (United Kingdom) – acoustic engineer leading the UK Renewables amplitude modulation study
- Matthew Terlich (Australia) – acoustical consultant
- Michael Stigwood (United Kingdom) – acoustical consultant working with community groups in noise monitoring
- Malcolm Hunt (New Zealand) – acoustical consultant with major input into NZ Standard
- Bo Sondergaard (Denmark) – acoustical consultant formerly with Delta, now independent – first conversed at 2009 WTN
- Nick McCabe (Canada) – engineer with HGC Consulting
- Brian Howe (Canada) – principal with HGC Consulting
- Werner Richarz (Canada) – principal with Aercoustics Consulting – provided useful feedback on my paper and a spreadsheet useful for calculating 1/3 octave bands. Notes wind turbines now proposed near his mother's home.
- Chris Turnbull (Australia) – conducted infrasound measurements near wind farm and other locations
- Paul Appelqvist (Sweden) – acoustical consultant
- Bob Davis (United Kingdom) – acoustical consultant – working on UK Renewables amplitude modulation study
- Karl Boorsma (The Netherlands) – researcher – energy research centre
- Jane & Julian Davis (United Kingdom) – "victims" of British wind development – first met at 2007 WTN
- Jesper Morgensen (Denmark) – Danish Environmental Protection Agency – first met at 2009 WTN
- Geoff Leventhall (United Kingdom) – organizer – first met at 2007 WTN