Response to HGC Literature Review
by John Harrison

"Low Frequency Noise and Infrasound Associated with Wind Turbine Generator Systems – A Literature Review**" by HGC Ltd.**

Introduction

The low frequency report, prepared by Howe Gastmeier Chapnik Ltd. was commissioned by the Ministry of the Environment (MOE), released in draft form in August 2010, released in final form to MOE in December 2010 and to the public in August 2011. Why MOE is issuing it now as a press release is a mystery. This response will address the report itself and the news release from the Ministry of the Environment.

A glaring omission from the report and the news release is the motivation for the commission to HGC. The motivation of course is that a large number of residents living in proximity to wind turbines are suffering from annoyance, sleep deprivation and resulting adverse health effects. The root cause of the annoyance is the noise generated by wind turbines. The commission focused on low frequency audible sound and infrasound because at a distance of several hundred metres from a turbine much of the high frequency sound has been absorbed by the atmosphere.

The annoyance associated with turbine noise is considerably larger than noise of a similar sound pressure level generated by traffic or industrial noise. For instance field studies by Pedersen, van den Berg, Bakker and Bouma (referenced in the report) show 15% and 27% of a population are annoyed [1] by sound pressure levels in the ranges 35 to 40 dBA and 40 to 45 dBA respectively. These numbers are to be compared to 3% of a population annoyed by traffic noise in the same sound pressure level range. The present Ontario noise limit is 40 dBA; the noise limit before the Green Energy Act was 51 dBA in a sufficiently high wind. As noted below the Ontario noise limit is based upon prediction with significant noise contributions to the prediction not considered.

Possible reasons for the difference in response to turbine noise and road or industrial noise is the predominance of low frequencies in the turbine noise and the characteristic amplitude modulation of turbine noise at the blade passage frequency; this amplitude modulation draws continual attention to the turbine noise in the way that a dripping tap does. The wind industry and its lobbyists make much of the contribution of attitude to wind turbines to the annoyance. However, it is difficult to think that the attitude to industrial plants or road noise would be any less benign. In addition, while Pedersen et al. show a linear dependence of annoyance on the turbine sound pressure level there is no similar study showing a linear dependence of annoyance on attitude!

Not only does the report and news release avoid mention of the motivation for the commission, neither MOE, the Ontario Chief Medical Officer of Health nor HGC made any attempt to interview those suffering from adverse health effects

Not for nothing do the following health and other experts propose setbacks well beyond those allowed by the Ontario Ministry of the Environment:

Reference	Limit
Harry (UK)	2.4 km
Frey & Hadden (UK)	2.0 km
UK Noise Association	1.6 km
French Acad. of Medicine	1.5 km
Nina Pierpont (USA)	2 km
Daniel Shepherd (Australia)	2 km
World Health Org.	30 dBA (inside bedroom)
Int. Standards Org.	25 dBA (inside bedroom)
Sierra Club	Near Background

The HGC report gives considerable prominence to the Colby et al. health study and to the Chief Medical Officer of Health, Dr. Arlene King, health study. The one was commissioned by the Canadian/American Wind Energy Authorities and the other by the Ontario Government which is far from unbiased with respect to wind energy. Both are seriously flawed, notably in having no interest in the numerous people suffering from adverse health effect and in emphasizing the absence of direct health effects. Generally the adverse health effects are indirect: sleeplessness and annoyance leading to stress-related illnesses. This is recognized by the World Health Authority which considers annoyance and stress as adverse health effects. A recent paper by Dr. Carl Phillips, a noted epidemiologist, offers a detailed critique. The King report is marred by an erroneous quotation from the 2009 Pederson et al. paper of the number of people annoyed by turbine noise. Dr. King has yet to acknowledge this error/deception.

Technical Review

As must be, much of the HGC report concerns technical aspects of noise generation and sound propagation. Here there is a fairly complete literature review. However, this section fails to emphasize that the turbine manufacturers are aware that the future of widespread acceptance of wind energy will depend upon reducing noise and low-frequency noise. To quote:

"The acoustic noise radiating from wind turbines continues to be the dominant design driver that must be incorporated into the design process. The tip speed of many turbine designs is limited by the amount of noise created by the blades passing through the atmosphere." Moriarty (NREL, USA) et al., AIAA Conference Proceedings (2005).

" …noise emission….has become one of the most important environmental impacts of wind energy." (Romero-Sanz and Matesanz (GAMESA Spain), Wind Engineering, 32, 27-44 (2008))

As stated in the report a major cause of turbine noise is aerodynamic trailing-edge vortex creation. There has been theoretical and wind-tunnel research to investigate the effect of different blade cross-sections on TE noise.

Perhaps of far more importance for low frequency and infrasound noise is the work on inflow turbulence. HGC, the Ministry of the Environment and CanWEA continue to bury their heads in the sand concerning this issue. This important noise source has been brought to the attention of MOE and the Canadian acoustics community by bringing to light the early work at the National Renewable Energy Laboratory (NREL) in the USA. This work demonstrated through theoretical work based upon the mathematical modeling by Amiet and through experimental work with the NREL CART up-wind test turbine that turbulent inflow considerably enhances the low frequency noise emitted by turbines. More recently, Dr. Moriarty has brought to my attention their continuing work, in collaboration with Dr. Guidati, well-known as a co-author of the Wagner et al. treatise on wind turbine noise.

On July 8th, 2011, The National Laboratory for Sustainable Energy, Risø, Denmark placed the following description in an advertisement for a scholarship: "*Noise is an interesting concern for wind turbine manufacturers and communities living near wind turbines. These concerns are exacerbated by the constant increase of wind turbine sizes and the cost advantages of placing turbines close to the consumers. The design of low-noise turbines requires the use of validated and accurate engineering models. The main sources of noise generated by a wind turbine have been identified as turbulent inflow noise and trailing edge noise"*

If still not convinced then Figure 32 of a recent report by K.D. Madsen and T.H. Pedersen should be enough ("Low Frequency Noise from Large Wind Turbines" DELTA report AV-1272/10 (2010)).

Other work not referenced concerns measurement of turbulence intensity. This work is being done because turbulence increases dramatically low frequency noise, because it puts stress on the turbine blades and because, with associated wake loss, it decreases the capacity factor of downwind turbines. A list of references that needed to be addressed is as follows:

Lange et al., "Modelling of Offshore Wind Turbine Wakes", Wind Energy, 6, 87 (2003).

Barthelmie et al., "Modelling and measured Power Losses and Turbulence Intensity …", Wind Energy, 10, 517 (2007).

Wagner et al., "Influence of Wind Speed Profile on Wind Turbine Performance Measurements", Wind Energy, 12, 348, (2009).

Barthelmie et al., "Off-Shore Wind Turbine Wakes Measured by Sodar", J. Atmos. Oceanic Tech., 20, 466 (2003).

Bertaglio, "NACA0015 Measurements in LM Wind Tunnel and Turbulence Generated Noise", Risø National Laboratory for Sustainable Energy (2008) (report # Risø-R-1657(EN))

In Europe, the European Commission is supporting turbine research through the SIROCCA Project: (http://www.ecn.nl/nl/units/wind/projecten/sirocco/).

Propagation of Low Frequency Noise (Section 3.2)

The report makes important points concerning the propagation of turbine noise: The cylindrical decrease in sound energy, the acoustically hard character of ground for low frequency sound, the low absorption by the atmosphere for low frequency sound and the ready penetration through residence walls. These points needed to be emphasized in the executive summary, the conclusions and the recommendations. At present they are not acknowledged by the Ministry of the Environment. This is especially important as guidelines are drawn up for off-shore wind energy.

Noise Annoyance (Sections 3.5, 3.6 and 3.8)

Laboratory studies have their place. Nevertheless, for reasons that Dr. Leventhall gives, as referenced in section 3.6, far more weight needs to be given to field studies in comparison to laboratory studies. Missing from Section 3.6 is consideration of the amplitude modulation. This is typically 5 dBA but higher values have been reported. Dr. Leventhall himself has written: *"A time-varying sound is more annoying than a steady sound of the same average level and this is accounted for by reducing the permitted level of wind turbine noise"*. As we are well aware, the Ministry of the Environment refuses to do this.

Section 3.8 quotes the work of Pawlaczyk and Luszczynska. It was only fair to have quoted also the work of Persson Waye et al. ("Low Frequency Noise "Pollution" Interferes with Performance", Noise Health, 4, 33, (2001)). This paper comes to the opposite conclusion for low frequency noise at the 40 dBA level.

Health Effects (Section 3.11)

The Colby et al. and King reports were dealt with above. Turning to the discussion of Dr. Pierpont's work, the report is bizarre. There is no mention of the bulk of the work on the medical study of a large number of people suffering adverse health effects resulting from wind turbine noise. This work analyses the range of symptoms and finds reason to treat them collectively as a syndrome. Separately, there are hypotheses for the cause of the syndrome. Hypotheses are not proofs; scientifically, the presentation of a hypothesis is reason to study the problem and to demonstrate proof or otherwise. Whether the hypotheses are correct or not is irrelevant to the fact that there are adverse health effects. The energy devoted by Colby et al., King, CanWEA to denigrate the medical and diagnostic work of Dr. Pierpont is reminiscent of the methods we saw some decades ago used by the tobacco industry! Again, I recommend a reading of the Phillip's report on the power of crossover analysis in understanding the reality of adverse health effects from wind turbine noise. There is a reference to Leventhall (2010) missing from the bibliography; nevertheless, I know that Drs. Leventhall, Colby and King are not epidemiologists!

Conclusions (section 5.0)

1) Although turbine noise is broadband, at a distance of 500 metres, much of the high frequency sound has been absorbed. Distance enhances the low frequency component as does turbulent inflow.

3) Reference needs to be made to the Salt study demonstrating other pathways for the perception of very low frequency sound.

4) This conclusion is wrong and is a red herring. Turbine noise in the range 35 to 45 dBA causes annoyance and sleep disturbance. These are adverse health effects and in turn lead on to other adverse health effects. 100 people reporting adverse health effects and more than a dozen families abandoning their homes in Ontario alone gives the lie to this conclusion.

5) Non-trivial (a derogatory and unworthy expression) has no place in a professional report. It should be replaced by about 20% being annoyed.

Recommendations (Section 6)

Given that the review of current technical literature in the HGC report has missed completely research dating back to Amiet and forward to detailed comparisons between theory and experiment on turbulent inflow noise, the first recommendation needs to be revised. MOE does need to revisit its guidelines to include turbulent inflow noise, to treat the ground parameter as hard for low frequency sound, to reconsider spherical spreading, particularly for off-shore sound propagation, to address the uncertainty in the prediction of sound at a residence and, given the accepted enhancement of annoyance due to amplitude modulated noise, to apply a penalty for amplitude modulation.

Response to Backgrounder: Low Frequency Sound and Infrasound Report

What kind of noise do wind turbines produce? Turbines do indeed produce a wide range of frequencies. However, the noise 550 metres or more from the turbine is skewed towards low frequency noise because of selective absorption of the high frequencies by the atmosphere.

Is wind turbine sound harmful? The Minister of the Environment writes that there is no direct health risk. However, **f**ield studies have demonstrated that 15 to 27% of people exposed to turbine noise at the Ontario regulated limit will suffer annoyance. This is an adverse health effect and in time leads on to other adverse health effects such as stress, tinnitus, headaches and sleep disturbance.

Are Ontario's rules to control wind turbine sound stringent enough?

The minister writes that at the Ontario regulated setback much of the sound that turbines produce lays outside the range that people can hear. This is untrue. Field studies show that at the regulated setback, 80% of people can hear the turbine noise. Also, the minister fails to note that Germany, with its more extensive experience with wind energy, has a lower night-time noise limit than Ontario.

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[1] Pedersen et al. consider five reactions to turbine noise: do not notice; notice but not annoyed; slightly annoyed; rather annoyed; and very annoyed. They group rather and very annoyed together under the heading "annoyed".

Compliance Protocol for Wind Turbine Noise – Guideline for Acoustic Assessment and Measurement – *produced for the Ontario Ministry of Ontario by HGC Engineering, an active member of CanWEA*