



Australian Government
National Health and Medical Research Council

N|H|M|R|C

Expert Review: Comments in full

NHMRC Draft Information Paper:
Evidence on Wind Farms and Human Health

February 2015

Publication Details

Publication title:	Expert Review: Comments in full. NHMRC Draft Information Paper: Evidence on Wind Farms and Human Health
Published:	February 2015
Publisher:	National Health and Medical Research Council
NHMRC Publication reference:	EH57F
Online version:	www.nhmrc.gov.au/guidelines/publications/eh57
ISBN Online:	978-1-925129-27-4
Suggested citation:	National Health and Medical Research Council. <i>2015 Expert Review: Comments in full. NHMRC Draft Information Paper: Evidence on Wind Farms and Human Health</i> . Canberra: National Health and Medical Research Council; 2015

Copyright

© Commonwealth of Australia 2015



All material presented in this publication is provided under a Creative Commons Attribution 3.0 Australia licence (www.creativecommons.org.au), with the exception of the Commonwealth Coat of Arms, NHMRC logo and content identified as being owned by third parties. The details of the relevant licence conditions are available on the Creative Commons website (www.creativecommons.org.au), as is the full legal code for the CC BY 3.0 AU licence.

Attribution

Creative Commons Attribution 3.0 Australia Licence is a standard form licence agreement that allows you to copy, distribute, transmit and adapt this publication provided that you attribute the work. The NHMRC's preference is that you attribute this publication (and any material sourced from it) using the following wording: Source: National Health and Medical Research Council.

Use of images

Unless otherwise stated, all images (including background images, icons and illustrations) are copyrighted by their original owners.

Contact us

To obtain information regarding NHMRC publications or submit a copyright request, contact:

E: nhmrc.publications@nhmrc.gov.au

P: 13 000 NHMRC (13 000 64672) or call (02) 6217 9000

Table of contents

Introduction	2
Professor Takayuki Kagayama (Ōita, Japan)	3
Professor Lin Fritschi (Perth, Australia)	6
Dr Frits van den Berg (Amsterdam, The Netherlands)	8
Emeritus Professor Colin Hansen (Adelaide, Australia)	11
Associate Professor Cornelius Doolan (Adelaide, Australia)	23
Dr Mathias Basner (Pennsylvania, United States of America)	28

Introduction

Expert Reviewers

The *NHMRC Draft Information Paper: Evidence on Wind Farms and Human Health* was critically appraised by six Australian and international reviewers whose expertise covered:

- acoustics;
- aerospace engineering (including aero acoustics);
- mental health and sleep;
- epidemiology; and
- environmental health.

The expert reviewers were asked to consider whether the rationale applied in examining the evidence was clearly explained and whether the evidence was accurately translated into the draft Information Paper. They were also asked to evaluate the appropriateness of the conclusions based on their understanding of the latest evidence in their specific area of expertise.

The reviewers raised a number of issues, most of which related to wind farm noise. The Wind Farms and Human Health Reference Group gave due regard to expert review comments and, over several meetings, carefully considered issues that were raised. A summary of the Reference Group's responses to the key issues raised by the expert reviewers can be found in the *Expert review: Summary of key issues* on the NHMRC website at: www.nhmrc.gov.au/guidelines-publications/eh57.

NHMRC acknowledges the time and expertise provided by the expert reviewers Dr Mathias Basner (Pennsylvania, United States of America), Associate Professor Cornelius Doolan (Adelaide, Australia), Emeritus Professor Colin Hansen (Adelaide, Australia), Professor Lin Fritschi (Perth, Australia), Professor Takayuki Kagayama (Ōita, Japan) and Dr Frits van den Berg (Amsterdam, The Netherlands).

This document contains the full comments provided by each expert reviewer, published with their consent.

Comment to consultation draft (Feb 2014)

Dr. Kageyama, Takayuki
Professor, Department of Psychiatric & Mental Health Nursing,
Oita University of Nursing & Health Sciences

This draft is produced through a great effort for selecting appropriate literatures and critically summarizing their contents, so that I almost agree with this draft from the viewpoints of study selection, discussion, and conclusion. However, I would like to present some comments to the appraisal, which is mainly written in 3.4, because this draft will be cited by many persons concerned for many purposes, if once published.

Study design

In general cross-sectional studies have disadvantages to determine causal relationship. However, if an individual has lived near wind turbine generator for a long time (and power level of wind turbine has been stable for a long time), recently measured exposure to wind turbine noise (WTN) level may equal to long-term exposure level. Furthermore, noise does not accumulate in human body. Effects of too much noise on sleep occurs shortly after exposure to the noise. Taking account of the above facts, the weak points of cross-sectional studies on noise and sleep seem to be lessened.

Outcome of sleep

Sleep is assessed in terms of physical/objective and psychological/subjective phenomena. However, we often observe large variance in physiological features of sleep at one night, and the features also depend on measurement condition. This means long-term measurement is required for a study. On the other hand, we can report our long-term state of sleep, suggesting that single question for sleep can be long-term assessment. Therefore the weak points of previous studies, which focused on self-reported measures of sleep quality, are not meaningless.

However, the previous studies have other kinds of weak point. Most of the studies focused on *WTN-induced* sleep disturbance. However, sleep disturbance is multicausal in general, and it is sometimes difficult for an individual to specify the reason for sleeplessness (Pressman 1996). Questions about WTN-induced annoyance may affect the responses to the following questions about WTN-induced sleeplessness (van den Berg 2012). Furthermore the definition of sleeplessness in the above studies often lacks specifying frequency, or often includes infrequent sleeplessness, e.g. once a month. To define insomnia, researchers should specify frequency and aftereffects of sleeplessness (American Psychiatric Association 1987; American Academy of Sleep Medicine, 2005). In future studies,

Please note: the expert reviewers were asked to consider whether the rationale applied in examining the evidence was clearly explained, whether the evidence was accurately translated into the draft Information Paper, and whether the conclusions were appropriate based on their understanding of the latest evidence in their specific area of expertise.

therefore, sleep disturbance should be assessed apart from WTN, taking account of its frequency and aftereffects. This is more important than using established tools such as PSQI for sleep assessment.

Confounding factors

Confounding factors are associated with both the exposure and the outcome, being differentiated from modifiers or correlates to the outcome. The systematic review identified a number of modifiers or correlates that might associate with health or health-related outcomes. In these studies, however, the correlations between WTN and these factors were not always reported; namely they were possible confounding factors. If economic benefit from wind farms is not a confounder but a modifier, this factor does not explain the associations between wind farms and health or health-related outcomes. More correct terminology is required.

It also should be noted that a part of the above possible confounding factors are concerning wind turbines. If we want to collect these informations, it is difficult to mask intent of studies.

Terminology

I would like to point out a trivial question. Although problems of multiple comparison are discussed in p166, *multiple test* is more correct than *multiple comparison*. For example, repeated test for correlation coefficients will raise similar problems to multiple comparison in ANOVA.

Ongoing research

This draft includes introduction to ongoing research (p166-168). I would like to inform additional research in Japan. We have conducted a research project on evaluation of WTN impact on human health over three years from fiscal year 2010, taking the above into consideration, and being funded by the Ministry of the Environment, Japan. This study is partly reported in the following paper;

Tachibana H, Yano H, Sakamoto S, et al. (2013). Nationwide field measurements of wind turbine noise in Japan, Inter-Noise2013.

Kuwano S, Yano T, Kageyama T, et al. (2013). Social survey on community response to wind turbine noise in Japan, Inter-Noise2013.

Yano T, Kuwano S, Kageyama T, et al. (2013) Dose-response relationships for wind turbine noise in Japan, Inter-Noise2013.S.

Results of further analysis will be reported by Kageyama at ICBEN 2014. In this study, sound measurement was performed in field studies, and administered-questionnaires were developed on the basis of previous literatures and international criteria for annoyance, sleep, and self-reported symptoms concerning physical/mental health. Some important confounders, modifiers, or correlates to the above outcomes are taken into account. According to our tentative results, annoyance due to WTN and insomnia regardless of reason for sleeplessness seem to associate with WTN, even after

Please note: the expert reviewers were asked to consider whether the rationale applied in examining the evidence was clearly explained, whether the evidence was accurately translated into the draft Information Paper, and whether the conclusions were appropriate based on their understanding of the latest evidence in their specific area of expertise.

adjustment for main correlates. If you want to get more information on this study, please contact with Dr. Tachibana, chief in research project.



Professor Lin Fritschi

School of Public Health
Curtin University
GPO Box U1987
Perth Western Australia 6845

31 March 2014

Professor John McCallum
Head, Research Translation Group
NHMRC
Canberra

Dear Professor Mc Callum,

Re: Expert review of Information Paper on the potential health effects of wind turbines.

Thank you for inviting me to provide expert comments on this Information Paper. I thought overall the paper was well-written and summarized the information in the systematic review quite well. I have a few comments regarding the structure and the clarity of the explanations.

1. The introduction carefully explains the differences between wind turbines and wind farms. There is then a footnote which states that the terms are used interchangeably. As this document comes from a scientific body, it would look much more professional if this footnote was dropped and care was taken to ensure that the terms were used correctly.
2. Section 3 is titled "...methods and results". This is confusing as it does not contain actual results. It would be more correct to entitle this section "Systematic review methods and assessment of quality of evidence".
3. Similarly, to avoid the reader expecting results in Section 3.4, it could be entitled "Critical appraisal of the quality of evidence" or "Assessment of the quality of evidence"
4. I don't know that Section 4.3 is necessary. It is a background review, not a systematic review so you wouldn't expect to do a formal appraisal. It just seems to detracts from the value placed on this review.
5. In Section 4 there are no results. It would be useful to summarize the findings from the background review here. Some of this information is in Section 6.
6. Section 5 seems to be redundant. It contains some new information about how to make a decision on a scientific question. This information would fit better in the introduction and should include formal mention that the quality of evidence is important. However Section 5 also contains conclusions of the review and when I read the paper I thought I was reading the final results. I was surprised at such a brief conclusion after all the evidence. When I got to Section 7 I realized that this was the final conclusion, so in light of that, the preview of the conclusions placed in Section 5 seems unnecessary.
7. Section 6 seems out of place at the moment as it seems to appear after the results (see my comments on Section 5). Some of this information could be summarized in Section 4 and others put in an appendix and referred to in the introduction. However, if Section 5 is omitted, this section may be retitled something like "Results of background review". (Although it still may fit better as part of Section 4).
8. The summary in Section 7.1 could be placed after the full text as it contains information which, up until there, has not been mentioned. I suggest it is placed as a separate section to conclude the report.
9. In Section 7.2.1 the section on physical health p 14, the results of one study are quoted, but there are several studies which do not find a link. It would be good to make this difference in numbers of studies on one side or the other clear, and comment on the quality of this evidence.
10. Section 7.2.2 reports that laboratory studies showed hearing loss may be associated with high levels of low frequency noise. It's important to add the level of noise in those studies as these studies used exposure to over 90 dB which is well
Please note: the expert reviewers were asked to consider whether the rationale applied in examining the evidence was clearly explained, whether the evidence was accurately translated into the draft Information Paper, and whether the conclusions were appropriate based on their understanding of the latest evidence in their specific area of expertise.

above the level produced by wind turbines.

11. Section 7.2.2 should also mention the results of the study by Evans et al 2013. It is mentioned in the summary (section 7.2.3) but not in the text.
12. Section 7.3.3 could replace the word “very” with “extremely”.
13. Section 7.4.2 should also mention the results of the study by Windrush Energy 2004. It is mentioned in the summary (section 7.4.3) but not in the text.

I hope these suggestions are useful.

Yours sincerely

Lin Fritschi

Comments on the NHMRC Draft Information Paper: Evidence on Wind Farms and Human Health

dr G.P. (Frits) van den Berg, March 2014

General comments on the Draft information paper ('the paper').

1. There is no clear definition or description of health effects. This may create confusion. In the WHO Guidelines for Community Noise and the Night Noise Guidelines annoyance is mentioned as one of the health effects without restrictions. Apparently in the paper 'direct' health effects do not include noise annoyance or sleep disturbance (e.g. section 7.1: "There is *no* (...) evidence that wind farms directly cause adverse health effects", but "There *is* (...) evidence that proximity to wind farms is associated with annoyance and (...) sleep disturbance and poorer quality of life."). Thus the paper implies annoyance and sleep disturbance are 'indirect' health effects. Later (p.14) they are 'health-related outcomes' as opposed (?) to 'health outcomes'. I suggest to be clear about this and describe what health effects are considered and why/how they are classified as direct (somatic?) or other, or as health or health-related effects.
2. I agree largely with the critical appraisal in section 3.4 and the prudence in interpreting research results. However, the text is too academic and suggests a partiality with respect to overinterpretation by lay (?) readers. It is academic and my objection is that the critical observations apply to most if not all environmental health effect studies, not just to wind turbine studies. Low participation rates are not uncommon in surveys, and there is no generally accepted minimum participation rate. If selection bias occurs, this would affect many other environmental health effect studies. One of the ways to try to take this into account is a non-response analysis, as was done in some studies. Of course masking may not be effective, but again this problem may affect other environmental health effect studies as well: if people close to an airport find a question on airport noise in their questionnaire, they may think that the presence of the airport is a reason for the survey. The same may be true for information bias: residents near an airport perhaps recall more health details than those further away. Confounding is a very important issue to consider, but confounding factors may have been identified and can in principle be anything the imagination produces. Secondly, the text suggests partiality in that most examples caution for positive results. But it could also be otherwise: why would recall be better at short distances from a source?; confounding factors could also reduce an association (e.g. over time those being most annoyed having moved away);
3. Visual impact is not addressed here, except for shadow flicker. A literature review should reveal that it is a major issue in wind farm planning (e.g. M. Wolsink, Planning of renewables schemes: Deliberative and fair decision-making on landscape issues instead of reproachful accusations of non-cooperation Energy Policy 35 (2007), 2692–2704; P. Devine-Wright, Beyond NIMBYism: towards an Integrated Framework for Understanding Public Perceptions of Wind Energy, Wind Energy 8 (2005), 125–139). The visual impact of wind turbines on landscape may be associated to visual annoyance as noise is to noise annoyance. Visual impact has been investigated in several studies (such as references 8

and 10 in the paper), but not with regards to its effect as a separate stressor. Although it is plausible that such visual annoyance could lead to chronic stress, I know of no evidence supporting this. However, as this issue is important in the public debate on wind farms, it seems logical to include it as a health (related) topic, even though there may be no publication supporting a 'direct' link with health. Results may not show up in the systematic scientific review of studies, but it could be identified as a gap in the knowledge of the impact of wind farms. In a later stage NHMRC could recommend to be careful in planning wind farms. A guide to this could be the "What is good planning; position statement" from the Planning Institute of Australia.

4. I strongly support the use of 'parallel evidence' or additional knowledge from exposure to other sources to study the effects of wind turbines. It is highly relevant when it has been shown that a specific acoustical or other characteristic increases or reduces the effect on residents. The use of parallel evidence acknowledges that we can build on available knowledge and it implies that we need not address all issues again specifically for wind turbines.

Specific comments:

5. End of page 10: "NHMRC could not conclude that exposure to wind farm noise *causes* annoyance, sleep disturbance or poorer quality of life". The same is true for the effects of noise from road traffic or aircraft. Although strictly and academically true, in normal life we accept that annoyance from passing cars or aircraft is the result of those passages. Even though we acknowledge that the effect is not the same for all people: some or not bothered, others may be very sensitive, some are deaf. That is also the case for somatic effects, e.g. from allergens or viruses.
6. The term 'louder' in the text "a low-frequency sound (lower than 100 Hertz) needs to be at a higher level ("louder") to be heard than a mid-range frequency (e.g. 1000 Hertz)" (p. 11, 2nd par.) is incorrect. Louder refers to hearing, not to level. Suggestion: a low-frequency sound (lower than 100 Hertz) needs to be at a higher level (more physical sound, more 'volume') to be heard as loud as a mid-range frequency sound (e.g. 1000 Hertz).
7. I suggest to drop "if sleep is disturbed" from the last sentence but one on p. 11. This may apply to subjective (self-reported) sleep disturbance, but not (always) to objective sleep disturbance.
8. There is original German research on the effects of shadow flicker (Pohl J, Faul F, Mausfeld R. *Belästigung durch periodischen Schattenwurf von Windenergieanlagen*. Kiel, Germany: Institut für Psychologie der Christian-Albrechts-Universität; 1999. If language is the problem, it is mentioned in Parsons Brinckerhoff's Update of UK Shadow Flicker Evidence Base (Newcastle upon Tyne, UK: Parsons Brinckerhoff; 2011) that also mentions some case studies.
9. Reference 22 at the end of p. 12 is about German, not 'Australian suburban homes'.

10. I agree with “effects on sleep are likely to be modest” (section 7.2.2) from a statistical point of view. However, it may not apply to individuals: a vulnerable group are those that sleep with an open window and live close to and with a bedroom facing a wind farm.
11. In ‘Physical health’ (p. 14) reference is made to the WINDFARMperception report (ref. 10), where the better (peer-reviewed) reference is E Pedersen, F van den Berg, R Bakker, J Bouma: Response to noise from modern wind farms in The Netherlands; Journal of the Acoustical Society of America, volume 126 nr 2 (2009), p. 634-643. There is no mention here of the Polish and Japanese wind turbine noise studies, that largely confirm the studies that are reported. Although as yet only reported in conference papers, should these not have come up in the literature search?
12. In ‘Mental health’ (p. 14) reference is again made to the WINDFARMperception report (ref. 10), where the better (peer-reviewed) reference is ref. 14 with respect to psychological distress. I think it is relevant that in this study distress in noisy areas (with main road) was significantly related to annoyance, not to sound level. In quiet areas there were no significant relations.
13. In the last sentence of the paragraph on ‘Annoyance’ on p. 14 the word ‘contributed’ suggests these factors all increase annoyance, but they can also reduce the prevalence of annoyance (as was the case for the ‘healthy farmers’). I suggest to use ‘influence the prevalence of annoyance’.
14. In the paragraph on ‘Sleep’ (p. 14/15) there is no mention of ref. 14 where it was found that self-reported sleep disturbance was significantly related to noise annoyance but not to noise level.
15. It is hard to believe that there is no background evidence on shadow flicker or other visual effects. Apart from the visual intrusion (see point 4 above) there must be psychological evidence that moving (rotating) objects attract more attention than static objects and severe light modulation (flicker) has more impact than a constant light level. As parallel evidence this would imply a possibly higher risk on annoyance.
16. I agree with the recommendations for further research (p.20). However, as many concerns do not arise from scientific considerations but from public concerns, I recommend to involve representatives from the public in the definition and interpretation of new studies. This is to ensure that factors thought to be important from a public point of view are included in the studies.

Expert Review of the NHMRC Draft Information Paper, “Evidence on Wind farms and Human Health”

Emeritus Professor Colin H Hansen
University of Adelaide

April 10, 2014

Summary

The NHMRC Draft Information Paper: “Evidence on Wind Farms and Human Health”, is a document that seems to be predisposed to the notion that noise from wind farms has no direct or indirect effects on the health of people living in their vicinity. This conclusion is reached on the basis that no evidence in the numerous studies published on the subject is of sufficient scientific merit to be considered reliable and thus taken into account. Based on the evidence or supposed lack thereof, it would be equally valid to conclude that there is **no evidence that wind farms do not have** a substantial impact on the health of some people who live in their vicinity. However, this notion is never mentioned in the paper, which could lead to the unfortunate conclusion that the paper is biased towards the interests of the wind farm industry.

Another unfortunate conclusion that one may reach on reading the Draft Information paper is that suggestions of associations between environmental noise and adverse health effects “*are based on limited evidence.*” This is in direct contravention of what is stated in the 2009 WHO report titled, “Night Noise Guidelines for Europe”, which states, “*While noise-induced sleep disturbance is viewed as a health problem in itself (environmental insomnia), it also leads to further consequences for health and wellbeing*” and “*For the primary prevention of subclinical adverse health effects related to night noise in the population, it is recommended that the population should not be exposed to night noise levels greater than 40 dB of $L_{night, outside}$ during the part of the night when most people are in bed*”.

The Draft Information Paper contains a few errors of fact and also seems to not appreciate the current state of the art in noise surveys. This results in incorrect conclusions being made and these are outlined in some detail in the following discussion. The Draft Information Paper is based on the document, “Final Report: *Systematic review of the human health effects of wind farms*”, which has excluded, on questionable grounds, many important studies that show a link between wind farms and health effects.

The discussion of the need for further research to properly evaluate the effect of wind farm noise on the health and well-being of people in surrounding communities is relegated to Appendix C. This is perhaps the most important outcome of the review and should occupy a more prominent place in the Draft Information Paper.

Introduction

In undertaking this review I note that the systematic review of the literature, Final Report: *Systematic review of the human health effects of wind farms*, which has been finalised, also underpins the Draft Information Paper. Therefore I begin my review with some brief comments on the systematic review document in so far as they are relevant to my “*evaluation of the appropriateness of the conclusions made in the Information Paper regarding the potential health effects of wind turbines*”.

There seems to be a misunderstanding in the systematic review document regarding the current state of the art in noise surveys. The state of the art for community surveys of noise from sources other than wind farms has been well established by extensive peer review (see Schomer and Parmidighantam, 2013) and such studies do not necessarily meet the general criteria specified for inclusion in the systematic review. For example it is not generally possible to hide the purpose of a noise study; aircraft noise studies are invariably done in the vicinity of airports, traffic noise studies are invariably done where there is a significant amount of traffic and military noise studies are done near military bases, with little chance of hiding the purpose of the survey. In addition almost all noise studies are necessarily cross sectional studies as it is generally not possible to predict sufficiently far in advance when and where a particular noise source may arrive. Nevertheless, this is the state of the art of noise surveys and as such should be applied to selecting appropriate studies for the systematic review of wind farm noise.

It is also unfortunate that studies by medical researchers such as Pierpont (2009) were excluded on the basis that they were case reports and case series studies. It is difficult to justify such exclusions, especially in the case of Pierpont whose work involved comparison studies (before and after turbines were operating as well as before and after relocation of residents).

An important study by Moller and Pedersen (2011) clearly establishes that as wind turbine power generating capacity increases so too do the LFN emissions and therefore it is predicted that so too will their effects be increased on residents in their near vicinity. This study was not mentioned in the systematic review. However, it has great importance to the conclusions drawn in the Draft Information Paper, as many current wind farms contain turbines of much greater generating capacity than turbines that were the basis of many previous studies, and it is generally expected that future wind farms will include turbines of even higher generating capacity than is the current case, leading to even more serious health effects on surrounding communities.

The 7 studies that met the criteria listed in the systematic review were all rated by the document as “D, *The body of evidence is weak and findings cannot be trusted.*” This effectively implies that no studies that have ever been done on the health effects of wind farm noise provide any useful information. This is an extraordinary result considering the extensive peer review undergone by numerous articles not included in the above mentioned seven, which were rejected on the basis of not satisfying some very strict criteria, but which have been published in reputable international journals. Rejection of all of these peer reviewed papers is the main limitation of the systematic review and this has led to the Draft Information Paper reaching incorrect conclusions.

The following paragraphs document specific comments in response to the review request from NHMRC in which I was asked whether:

- the rationale applied in examining the evidence on the potential health effects of wind turbine noise is understandable and clearly explained;
- the evidence has been accurately translated into the messages in the draft Information Paper; and
- the conclusions in the documents align with my understanding of the latest evidence in my area of expertise (i.e. acoustics).

Rationale applied in examining the evidence on the potential health effects of wind turbine noise is understandable and clearly explained

Although the rationale applied to examine the evidence is understandable and has been explained reasonably clearly, this does not mean that the rationale is logical or acceptable. As explained above, the rejection of peer reviewed papers in reputable international journals, which clearly show a link between wind turbine noise and adverse health effects has not been sufficiently well justified. Also the rejection of case series studies has not been sufficiently well justified. In addition, the argument that any health effect claimed to be due to noise has to have a direct physiological link with noise in order to be considered, is also flawed, as there is no logical reason to exclude indirect effects such as adverse health effects due to stress and disturbed sleep, which in turn have been shown in many studies to be directly linked to excessive wind turbine noise.

The evidence has been accurately translated into the messages in the draft Information Paper

In **Sections 3.2 and 3.3**, of Draft Information Paper the selection of evidence and included studies are discussed. As mentioned above, the main limitation of the systematic review procedure is that it rejected peer reviewed papers in reputable international journals, which clearly demonstrated a link between wind turbine noise and health effects (e.g. Phillips, 2011) and this has led to the Draft Information Paper reaching some incorrect conclusions.

In **section 3.4**, under the heading, **study design**, the Draft Information Paper states, *“All seven studies that met the inclusion criteria for the systematic component of the independent review used a cross-sectional design. Cross-sectional studies examine the relationship between an exposure (in this case wind turbines) and specific health outcomes in a defined population at a single point in time. Because the health outcomes were assessed at a single point in time, none of the included studies were able to provide any indication of the order of events — that is, whether a health outcome first occurred before or after the exposure began. This might mean that a person’s self-reported health outcomes were present prior to the person’s exposure to wind turbines.”*

The above statement shows a lack of appreciation of the current state of the art in noise surveys. As discussed in Schomer and Parmidighantam (2013), where the lead author is an expert in such surveys, almost all noise surveys are cross-sectional studies, as it has not been possible to predict in advance where and when an annoying noise source would be located. Schomer and Parmidighantam (2013) write, “cross-sectional is the state-of-the-art in acoustics. There are hundreds of refereed papers on cross-sectional surveys in acoustics.” They go on to point out that of the 43 international surveys undertaken for aircraft noise, 42 were cross-sectional studies, of the 37 international surveys for road traffic noise, 37 were cross-sectional studies and of the 11 international surveys of railroad noise, 11 were cross-sectional studies. If we use the same logic as the Draft Information Paper is applying to wind farm noise, then we would conclude that there is no valid scientific evidence that aircraft noise, traffic noise and railroad noise adversely affect the health of communities and that for all we know, any reported adverse health effects may have been there before the noise was. We could further conclude that all the militant communities around airports are making it up and further, that the curfew for many airports around the world should be lifted, as airport noise studies are not “scientifically sound”. Of course these conclusions would be in direct contravention with the conclusions reached by international experts responsible for the 2009 WHO document, which states categorically that transportation noise is responsible for a range of serious adverse health effects.

Under the heading, **selection bias**, in **Section 3.4**, the Draft Information Paper states, *“There is a high risk of selection bias in a study with a low participation rate, as those who chose to participate in the study may have different exposure and health outcomes to those who did not participate.”* One would have thought that the whole purpose of the review was to determine if wind farms caused adverse health effects so one would expect that those most exposed or affected would be those most likely to participate in studies. The logic for excluding such studies is flawed, as they provide excellent evidence that there are adverse health effects from wind farm noise.

Under the heading, **selection bias**, the Draft Information Paper states, *“In many of the studies, the purpose of the research was not masked (i.e. hidden) from participants. Where the studies did attempt to hide the intent of the study from participants, this may not have been effective. A lack of successful masking of a study’s purpose can contribute to selection bias by making it more likely that a person who is concerned about wind farms will take part than a person who is not concerned about wind farms.”* As pointed out by Schomer and Parmidighantam (2013), this is an argument that ignores the state-of-the-art in noise surveys for which it is virtually impossible to mask the intent of a survey. One may ask how well an aircraft noise survey is hidden in a survey near an airport for which the answer is invariably “not very well”.

Under the heading, **information bias**, in **section 3.4**, there is a very unbalanced discussion attempting to explain why surveys may show that people living near wind farms suffer worse adverse health effects than those living further away, when in fact their health outcomes may be the same. The same argument could be used for any noise survey, including all the transportation noise surveys that have been used to shape government policy. Again this statement is in direct contravention to what is argued by other international experts and the World Health Organisation.

The same argument as above can be applied to the statements made under the heading, **confounding factors** in **Section 3.4**. It would be virtually impossible in practice to take account of every possible confounding factor and again this argument would null the results of almost every noise survey taken to date.

Under the heading, **consistency** in **Section 3.4**, the Draft Information Paper states, *“Among the seven studies reviewed, there was no consistency in finding an association between wind turbine exposure and self-reported physical or mental health outcomes. However there was some consistency in showing associations between wind farm exposure and annoyance, disturbed sleep and poorer quality of life.”* Perhaps it would be helpful if the link between disturbed sleep / annoyance and adverse health effects were made at this point in the document, rather than waiting until Section 7. This would also be a good place to reference the 2009 WHO report on night noise levels.

Under the heading, **overall quality rating** in **Section 3.4**, the Draft Information Paper states, *“the body of evidence is weak and cannot be trusted), following NHMRC criteria for assessing the quality of evidence. This grading is largely due to the methodological weakness of the cross-sectional design used by all studies.”* For reasons discussed above, cross-sectional studies are the state of the art in noise surveys. Almost all peer reviewed and published papers are cross-sectional as it is generally not possible to predict sufficiently far in advance the location and installation date of a future noise source.

The summary dismissal of all published evidence of sleep deprivation and health effects could indicate bias in favour of finding that wind farms do not adversely affect the health of neighbouring communities.

In **Section 4**, the Draft Information Paper states, *“In addition, it examined whether any health or health-related effects have been observed from these emissions when produced by sources other than wind farms (parallel evidence).”* It is not sufficient to just examine the level of a noise when comparing two different exposures. Also important are the frequency content, variability and impulsive nature, as well as the duration and time of day or night that it is experienced. It is unlikely that any studies of noise other than wind farm noise would be suitable for comparison with a wind noise study. Note also that the 2009 WHO document has already reported on the health effects of relatively low-level night-time environmental transportation noise.

In **Section 5**, the Draft Information Paper states, *“Deciding whether an association between wind farm exposure and a particular health outcome is causal — that is, wind farm exposure causes the health outcome — requires more evidence. First, it must be clear that the exposure (to wind turbines) preceded the outcome (the health or health-related effect).”* Although this is a desirable requirement, it may not be a very practical one. In cases where the adverse health effect is due to a wind farm, there will obviously be no evidence of such an effect prior to the wind farm being constructed. However, obtaining this evidence through medical records of participants may be problematic and so the proposed requirement in itself may not be achievable.

In **Section 5**, the Draft Information Paper states, *“Second, it must be possible to rule out alternative explanations for the association, including both: bias resulting from the design of the study or the way the study was conducted; and causation by one or more confounding factors associated with wind farm exposure.”* When one looks at all the possible confounding factors listed in the systematic review, one could easily conclude that it would not be possible to eliminate all of them simultaneously. It would be more helpful to examine the accepted state of the art for the numerous published surveys of other noise sources such as transportation noise and use those requirements and methods of analysis.

In **Section 5**, the Draft Information Paper states, *“Third, it should be shown: that the association is consistent with other evidence on the effects of the exposure (e.g. noise from some other source); and ideally, that there is a biological mechanism by which the exposure could cause the health outcome with which it is associated.”* It would be clearer if it was pointed out that “exposure” refers to the character of the noise (impulsiveness, frequency content etc.), and its duration in addition to its level. It is unlikely that one would find groups exposed to such noise, except in the vicinity of wind farms, so this requirement may be impractical to satisfy. Likely biological mechanisms have been suggested in the scientific literature (e.g. see Salt and Lichtenhan, 2014), even though the Draft Information Paper implies that no such mechanisms exist. More importantly, if a noise source leads to sleep disturbance on a prolonged basis, it is well known that adverse health effects are likely to result. This effect is discussed in some detail in the 2009 WHO report.

In **Section 5**, the Draft Information Paper states, *“NHMRC found no consistent direct evidence that exposure to wind farms was associated with any health outcome. The few associations reported by individual studies could have been due to chance. Therefore NHMRC concluded there is no reliable or consistent evidence that wind farms directly cause adverse health effects in humans.”* This is written in a way that could indicate bias. A more balanced version would be “NHMRC found no consistent direct evidence that exposure to wind farms was **or was not** associated with any health outcome. The few associations reported by individual studies **may or may not** have been due to chance. Therefore NHMRC concluded there is no reliable or consistent evidence that wind farms directly **cause or do not cause** adverse health effects in humans.”

In **Section 5**, the Draft Information Paper states, *“Therefore even though there was support for some of these associations in studies of effects of noise from other sources, NHMRC could not conclude that exposure to wind farm noise causes annoyance, sleep disturbance or poorer quality of life.”* This statement is written in a way that could indicate bias. To make it more balanced, the following statement should be added. *“On the other hand, NHMRC could not conclude that exposure to wind farm noise **does not cause** annoyance, sleep disturbance or poorer quality of life.”* Of course a result such as this only occurred because all of the evidence pointing to health effects was rejected during the systematic review.

The conclusions in the documents align with my understanding of the latest evidence in my area of expertise (i.e. acoustics)

Regarding Section 7.1, in the Draft Information Paper, it seems that the statements are written with a clear bias towards the belief that wind farm noise does not cause adverse health effects. The first dot point states that *“there is no reliable or consistent evidence that proximity to wind farms or wind farm noise directly causes health effects.”* This statement could also be written as *“there is no reliable or consistent evidence that proximity to wind farms or wind farm noise **does not cause** health effects.”* The two statements effectively state the same thing but with a different bias. To eliminate any unintended bias, the word **“cause”** in the original statement should be replaced with **“causes or does not cause”**.

To remove bias in the second dot point which states, *“Finding an association between wind farms and these health-related effects does not mean that wind farms cause these effects”* the following words should be added at the end, *“nor does it mean that wind farms do not cause these effects”*. The statement *“These associations could be due to selection or information bias or to confounding factors.”* Should be replaced with *“These associations **may or may not** be due to selection or information bias or to confounding factors.”*

The fourth dot point which states, *“It is unlikely that substantial wind farm noise would be heard at distances of more than 500–1500 m from wind farms”* is incorrect. I have many measurements showing that wind farm noise can be heard at distances up to 8 km from a wind farm. There are many factors that contribute to how far away a wind farm can be heard, including wind farm layout and size (number of turbines), individual turbine size, terrain and atmospheric conditions. Regarding wind farm layout, it is well documented that some wind farms produce a low-frequency thumping noise that can disturb people several kilometres away and this is likely to be worse if turbines are located too close together so that some turbines are in the wake of upstream turbines in some wind directions.

The fifth dot point states, *“Noise from wind turbines, including its content of low-frequency noise and infrasound, is similar to noise from many other natural and human-made sources. There is no evidence that health or health-related effects from wind turbine noise would be any different to those from other noise sources at similar levels.”* The first part of the statement may be true of some mining noise sources but is certainly not true of surface transportation noise which has been the subject of most of the health impact studies. The second sentence in the above statement ignores the completely different character of wind farm noise when compared with surface transportation noise and should be removed from the document. This is discussed in more detail earlier in this review.

The sixth dot point which states, *“People exposed to infrasound and low-frequency noise in a laboratory (at much higher levels than those to which people living near wind farms are exposed)*

experience few, if any, effects on body functioning” is misleading. First, there is no quantitative definition of how much higher the words “much higher” mean. Second there is no distinction between acute and chronic exposure. As shown by Swinbanks (2012), the **length** of exposure to infrasound is important, with effects becoming more pronounced as the exposure duration increases. Typical laboratory exposures are of very short duration (less than 1 hour), whereas wind farm exposures prior to adverse effects can often (but not always) be measured in terms of weeks or months. Also, the above statement does not take into account the differences in character of wind farm infrasound and the character of the sound typically used in laboratory tests. As explained by Salt and Lichtenhan (2014), there are a number of physiological mechanisms whereby infrasound and low-frequency noise from wind farms can adversely affect human health. The fact that all people are not affected does not diminish the importance of recognising these mechanisms in people who are affected and who are physiologically more disposed to being affected.

Under the **Annoyance** heading in Section 7.2.1, the Draft Information Paper states, *“The five studies all reported an association between annoyance and higher estimated levels of wind farm noise or living closer to a wind farm.”* And then goes on to state, *“Factors other than the noise produced by wind farms, such as the participants’ demographic, psychological and biological factors, their attitudes and perceived degree of control, and situational factors (including day and time, activity disturbance, type of area and features of the dwelling) may have contributed to the annoyance reported by participants.”* I find it puzzling that consistent results from five different studies can be so easily discarded. All those other factors mentioned should even out when looking at the effect of distance from a wind farm and clearly the **most likely** effect on annoyance is the wind farm, when it is shown that annoyance decreases with distance.

Under the **Sleep** heading in Section 7.2.1, the Draft Information Paper states, *“Six studies reported poorer sleep (mostly disturbed sleep and poor sleep quality) among people exposed to higher estimated levels of wind farm noise or living closer to wind farms.”* And then goes on to state *“The reported associations of wind turbine noise with sleep quality were generally weak.”* Again, it is difficult to justify this statement given that six different studies all reported that people living closer to wind farms had poorer sleep. Under the same heading is the statement, *“The studies did not assess whether poorer sleep associated with wind farm noise might have had any effect on health.”* One would have thought that the effect of poor sleep on health was well understood and did not need to be further considered in these studies, as this consideration would make the studies more complicated and expensive to undertake. So it would be better if this statement were removed or qualified. Another statement, *“participants who did not economically benefit from wind turbines reported more sleep interruption than others”* is made without any mention of the other differences between the groups which could represent equal or more important confounding factors (see page 61 of the referenced paper).

Under the **Quality of life** heading in Section 7.2.1, the Draft Information Paper points out that all 3 studies that assessed quality of life, found that it decreased following the construction of a nearby wind farm. The last sentence in this section attempts to explain away this association and is not at all helpful. It could be construed as significant bias in favour of the wind farm industry and should be deleted.

Under the **Noise in other environments** heading in Section 7.2.2, the Draft Information Paper states *“The World Health Organization reported a number of effects on sleep when night noise is in the range of 30–40 dBA (measured outside)”*. This statement is correct. However, later statements, *“There is no evidence that health or health-related effects from wind turbine noise would be any different to those from other noise sources at similar levels. Based on the studies referred to above,*

wind turbines would be unlikely to cause any direct health effects at distances of more than 500 m. At 500-1500 m from a wind farm, wind turbine noise levels are generally in the range 30–45 dBA. At these distances, effects on sleep are likely to be modest, if any,” are incorrect on a number of levels (see below) and again indicate the possibility of bias by the writers of the document.

- If noise levels supposedly vary from 30 to 45 dBA at distances of 500–1500 m from a wind farm, then why is it stated that wind farms “*are unlikely to cause any direct health effects at distances of more than 500 m*” and that the effects on sleep will be modest, if any? One would assume that in the above statement, 30 to 45 dBA corresponds to the distance range of 500 to 1500 m, so one would expect 30 dBA at 1500 m and 45 dBA at 500 m so the statement should read, “*are unlikely to cause any direct health effects at distances of more than 1500 m*”.
- I do not agree that wind farm noise will be below 30 dBA at 1500 m. Of course it depends on the size and layout of the wind farm, individual turbine size, terrain and atmospheric conditions as well as distance to the nearest turbine. I have data taken in high wind shear conditions, when background noise levels are low, that show noise levels above 40 dBA at distances over 2000 m. I also have seen noise predictions made by acoustical companies working for wind farm developers that show estimated noise levels of 37 dBA at 1670 m. So the estimated noise levels given in the Draft Information Paper are way too low.
- Wind turbine noise does not have the same character as transportation noise. By the time it reaches residents located more than 1 or 1.5 km away, it has a much higher dominance of low frequency noise and infrasound. The A-weighted noise level underestimates the importance of low-frequency noise and infrasound (Salt and Lichtenhan, 2014) and it is incorrect to state that “*there is no evidence that health or health-related effects from wind turbine noise would be any different to those from other noise sources at similar levels*”. This is because the level referred to here is the dBA or A-weighted level and this is not a good measure of the effects of environmental noise on health as it does not adequately take into account the effect of infrasound and low-frequency noise, nor does it account for variability or amplitude modulation associated with the noise.

Under the **Noise in other environments** heading in Section 7.2.2, the Draft Information Paper states, “*the noise in the studies discussed above would have included infrasound, which is considered by some to be an important component of the noise from wind farms. The infrasound from these other noise sources would be at similar levels to that from wind turbines. Therefore the evidence summarised above applies as much to infrasound as it does other sound frequencies from wind farms.*” The effect of wind farm infrasound and low-frequency noise on people is a far more complex phenomenon than implied by the Draft Information Paper (see Salt and Lichtenhan, 2014).

The **laboratory studies** referred to in Section 7.2.2 of the Draft Information Paper are not relevant to wind farm noise. The studies involved higher level and much shorter exposure durations and neither the wind farm noise spectrum nor crest factors (ratio of peak to rms levels) were duplicated.

Comments on Section 6 of the Draft Information Paper

I have the following comments regarding section 6 on noise in the Draft Information Paper, which is directly in my area of expertise.

In **Section 6.1**, it is implied that the A-weighting scale adequately takes into account the lower sensitivity of the ear at low frequencies. However, the A-weighting scale is a very inaccurate estimate of the loudness of a noise at low levels and low frequencies. It is an even more inaccurate

estimate of the annoyance of low-frequency sound. It is well known that low-frequency noise is more annoying than noise characterised by a balanced frequency spectrum with the same overall A-weighted level. Although the generation of wind farm noise may be characterised by a relatively well-balanced spectrum, by the time it propagates the 2 kilometres or so to a residence and then passes through walls and windows to reach the inside, it becomes dominated by low frequencies below 200 Hz, which are much less attenuated by ground, atmospheric and building transmission effects. Thus, wind farm noise is more annoying than one may expect from the A-weighted level, especially in quiet rural environments where noise from other sources is very low, and especially late at night and in the early hours of the morning when people are trying to sleep.

In **Section 6.1**, the Draft Information Paper states, “*Wind turbines produce mechanical sound at a frequency of 20–30 Hertz (for a 1500 kilowatt turbine) and a “whooshing” aerodynamic sound in the range of 200–1000 Hertz. Noise from wind farms is mostly aerodynamic.*” This is an oversimplification and not quite right. Noise from modern wind turbines (which are now all 3 MW in size or greater for recent and proposed wind farms in Australia) is mainly aerodynamic in nature and covers the frequency range from below 1 Hz to 500 Hz. Although aerodynamic sound is also produced at higher frequencies, these higher frequencies do not propagate sufficiently well for this higher frequency sound to be detectable at residences located 2 or more kilometres away. Low frequency aerodynamic sound is mostly a result of in-flow turbulence and possibly stall (see Laratro et al. 2014). It has been suggested that stall noise becomes more significant when there are high levels of wind shear, such as in the early hours of the morning. It has been further suggested that this type of noise is what appears as a “thumping” noise (Oerlemans, 2013), which can be very annoying when one is trying to sleep. However, more research is needed to properly demonstrate the link between blade stall and thumping noise. Aerodynamic noise generated by in-flow turbulence is worse when turbines are located in hilly terrain and also when they are placed in the wake of other turbines. This latter situation occurs more often in wind farms where turbines are placed closer together than recommended by the manufacturer. In addition, it is not definitively known how much the aerodynamically generated vibration of the tower and blades contribute to the noise levels experienced at residential locations.

In **Section 6.1**, the Draft Information Paper states, “*It is difficult to estimate the level of noise from wind farms in the presence of background noise.*” This is true but it is not impossible if the wind farm operator cooperates by shutting the wind farm down at various times so background noise levels can be established.

In **Section 6.1**, the Draft Information Paper states, “*As the sound level decreases with distance, it is unlikely that substantial noise would be heard at distances of more than 500–1500 m from wind farms.*” This is not correct. See the first two dot points on the previous page.

In **Section 6.1** the Draft Information Paper states, “*Infrasound is considered by some to be an important component of the noise from wind farms. Evidence suggests that levels of infrasound are no higher in environments near wind turbines than in a range of other environments. For example, a South Australian study observed similar levels of infrasound at rural locations close to wind turbines, rural locations away from wind turbines, and at a number of urban locations.*” Wind turbine infrasound has very specific characteristics. Its frequency content is the blade pass frequency and its harmonics (usually around 0.8 to 1 Hz and multiples thereof, respectively). In addition it varies in intensity over a turbine blade revolution and also over longer time frames. The periodic nature of the noise means that it could possibly have a different effect on people than noise that is random in nature, such as other environmental infrasound. There are experts in this area (e.g. Salt and Lichtenhan, 2014) who have demonstrated that one does not need to be able to “hear” infrasound

or low-frequency sound for it to have a physiological effect on some people, causing them to have similar symptoms to motion sickness. There is still much to be understood about the effects of low-level infrasound and low-level, low-frequency noise on people, as well as the effects of the infrasound frequency content and peak to average levels. There is a well-founded suggestion that increasing the exposure duration can also affect the response of a subject (Salt and Lichtenhan, 2014), as can the presence or absence of noise in the audio frequency range (Swinbanks, 2012). It is also possible that low-frequency sound can have similar effects to those attributed to infrasound (Salt and Lichtenhan, 2014). Much more work needs to be done on the effects of infrasound and low-frequency sound on people before any definitive statement can be made.

Considerations that Appendix B suggests I should have been asked to provide

In Appendix B, the Draft Information Paper states, *“Expert reviewers have been asked to consider a number of factors, including: the comprehensiveness of the literature reviewed; the validity of conclusions drawn from the evidence and any alternative conclusions that could be drawn”*. This does not seem to agree with the review request that I received. To be consistent with what I was asked to comment on, the word “validity” in the above statement should be changed to “appropriateness”. The request that I received did not ask if I could draw any alternative conclusions as mentioned in the above statement. I was also not asked to comment on the comprehensiveness of the literature reviewed. Assuming that I should have been asked to consider the factors outlined in Appendix B, I have the following comments.

- I do not consider that the literature reviewed was sufficiently comprehensive as it stopped before the end of 2012 and did not include references to many surveys of transportation noise which would have informed the current state of the art for noise surveys. In addition, a number of relevant papers have been published since November 2012 and these should be included in the review prior to it being finalised. The references listed in the papers under the heading “References” below should be reviewed. Also, no reason has been given for omitting series case studies from the review. There are a number of this sort of study that show a definite link between wind farm noise and health effects and if included in the review, may have resulted in the NHMRC arriving at a more balanced conclusion such as, “There is some evidence that wind farms can cause adverse health effects in nearby residents. However, more research is needed to properly quantify these effects.”
- I believe that the conclusions drawn are written in a very unbalanced way that could suggest bias in favour of the wind farm industry. The conclusions are written in a way that implies that the NHMRC is already predisposed to believing that wind farms pose no threat of adverse health effects, even though the statements in Appendix C call for more research to be done in order to be able to provide a definitive answer. I have made many suggestions in the preceding paragraphs regarding how the conclusions could be written in a more balanced way.

Other General Comments

I could find no evidence of any effort in the systematic review to determine whether there was any source of bias by the authors of any of the seven studies that were deemed to have met the criteria. In cases where such studies are funded by the wind industry, it would not be surprising to find outcomes that suggest no adverse health effects, in a similar way that many early medical studies on the effects of smoking that were funded by the tobacco industry found no adverse health effects for

smokers. Thus any studies funded by the wind farm industry should have been excluded due to the potential for bias.

In appendix C, there is the statement, *“Given the lack of objective health measurements in these studies, information bias cannot be excluded as an explanation for any apparent association.”* This sort of statement in itself is unhelpful and insulting to all of the researchers who have undertaken these studies and found a link (either direct or indirect) between wind farms and health. The statement should be removed or at the very least changed to *“Given the lack of objective health measurements in these studies, information bias, **however unlikely it may be**, cannot be excluded as an explanation for any apparent association.”*

Much is made of the need for longitudinal studies. Given the difficulty in undertaking such studies, it is surprising that nothing is mentioned about giving people with reported health problems 2 weeks holiday far away from any wind farm and checking their symptoms then. There are many reported cases where this sort of break has resulted in the cessation of symptoms and one would think this would be an acceptable alternative to a longitudinal study and in many cases it would clearly demonstrate the influence of the wind farm on a person’s health.

In addition to the research areas discussed in Appendix C, research is needed to develop more accurate noise propagation models so that the expected range of noise levels over the entire frequency range can be accurately predicted at each residence likely to be affected. The single number A-weighted time averaged values provided by current models do not adequately relate to the disturbance of the noise. There are factors other than the noise level, such as crest factor (ratio of peak to average (or rms) noise level), frequency content, variability over the short and medium terms, difference between the intrusive noise level and ordinary background noise levels, especially at night, which determine how disturbing a noise will be. More research is also needed to establish suitable metrics that take into account the low-frequency nature and variability of the noise from wind farms that is experienced at residences (Salt and Lichtenhan, 2014).

In the Glossary, the definition for decibel is given as, *“A unit of measure used to express the loudness of sound, calculated as the logarithmic ratio of sound pressure level against a reference pressure”*. This is incorrect. The decibel rating of a sound pressure is not a measure of loudness – the Phon measures loudness. So the words *“A unit of measure used to express the loudness of sound”* should be replaced with *“A unit of measure used to express the sound pressure amplitude associated with a sound in the form of a more manageable logarithmic scale, in place of using the linear scale of Pascals. It is calculated.....”*

In the glossary, the definition of “A-weighting” is missing. It is a weighting applied to a measured sound pressure level that reduces the importance of low-frequencies and high-frequencies when calculating an overall sound pressure level. It is supposed to approximate the response of a normal ear but it does a very poor job of this.

There is no mention anywhere in the document of the effect of wind farm size (ie number of turbines), wind farm layout, terrain in the wind farm vicinity, atmospheric conditions (including wind shear) and the size of the individual turbines within a wind farm. All of these factors influence noise levels that will be experienced by communities in the vicinity of wind farms. Differences in these factors between some recent wind farms in Australia and wind farms studied in Europe mean that conclusions of earlier studies may not necessarily apply to more recently installed and planned wind farms in Australia.

It is unfortunate that the argument for further research and the suggested areas of further research are relegated to Appendix C, where it is unlikely that any policy makers will find it. Surely the conclusion that further evidence is needed “*to explore the relationships between noise at varying distances from wind farms and other health-related effects such as annoyance, sleep and quality of life*” should occupy a prominent place in the Information Paper. This should be included in an executive summary which unfortunately seems to be missing at the moment.

As stated by Nancy Timmerman and repeated by Salt and Lichtenhan (2014), “the time has come to acknowledge the problem and work to eliminate it”.

References

Laratro, A., Arjomandi, M., Kelso, R. and Cazzolato, B. (2014). “A discussion of wind turbine interaction and stall contributions to wind farm noise.” *Journal of Wind Engineering and Industrial Aerodynamics*, **127**, 1–10.

Moller, H and Pedersen, C. (2011). “Low-frequency noise from large wind turbines.” *Journal of the Acoustical Society of America*, **129**, 3727–3744.

Phillips, C. (2011). “Properly interpreting the epidemiologic evidence about the health effects of industrial wind turbines on nearby residents.” *Bulletin of Science, Technology and Society*, **31**, 303–315.

Pierpont, N. (2009). “Wind turbine syndrome: a report on a natural experiment.” K-Selected Books, Santa Fe, New Mexico.

Oerlemans, S. (2013). “An explanation for enhanced amplitude modulation of wind turbine noise.” In *Wind Turbine Amplitude Modulation: Research to Improve Understanding as to its Cause and Effect*, Work Package A1. Renewable Energy, U.K. www.RenewableUK.com

Salt, A. and Lichtenhan, J. (2014). “How does wind turbine noise affect people?” *Acoustics Today*, **10**, 20–27. Available from www.acousticstoday.org

Schomer, P. and Parmidighantam, P. (2013). “A critical analysis of: Wind turbine health impact study: Report of independent expert panel.” *Proceedings of the 166th meeting of the Acoustical Society of America*, San Francisco, California, 2-6 December. Session 3aNS: Noise. Full paper published in *Proceedings of Meetings on Acoustics*, **20**, 040008. (2014).

See <http://scitation.aip.org/content/asa/journal/poma/20/1/10.1121/1.4870639>

Swinbanks, M. (2012). “Numerical simulation of infrasound perception with reference to prior reported laboratory effects.” In *Proceedings of Internoise 2012*, New York.

World Health Organisation. (2009). Night noise guidelines for Europe. WHO. Available from www.euro.who.int/__data/assets/pdf_file/0017/43316/E92845.pdf

Review of NHMRC Draft Information Paper: Evidence on Wind Farms and Human Health

Associate Professor Con Doolan
School of Mechanical Engineering
The University of Adelaide, SA, 5005

April 4, 2014

Introduction

This document is a review of the NHMRC Draft Information Paper: Evidence on Wind Farms and Human Health. It is written from the perspective of the field of expertise of the reviewer (aeroacoustics) and specifically considers the points posed by the NHMRC. These points are addressed in three separate sections below with a fourth dedicated to some additional comments by the reviewer.

The rationale applied in examining the evidence on the potential health effects of wind turbine (sic) is understandable and clearly explained

I believe the rationale is clearly explained and is broadly acceptable. One area that I believe can be approved is the critical appraisal (§3.4). It is uncertain whether the criticisms are based on professional opinion, some analysis, or both. If the criticisms of some studies are the opinions of the authors (reached in the absence of further analysis), then that should be clearly stated. If the criticisms have some analytical or other basis, then similarly these need to be stated in the paper.

The evidence has been accurately translated into the messages in the Draft Information Paper

In §7.4, this statement is made: “It is unlikely that substantial wind farm noise would be heard at distances of more than 500–1500 m from wind farms. Noise levels vary with terrain, type of turbines and weather conditions.” The statement

is vague in one way, yet a little too prescriptive in another, which may lead to confusion. It is true that wind turbine noise sound pressure level decreases with distance from the turbine tower, but how do you define “substantial”? The actual level will depend on the size and power output of the turbine, wind farm design as well as the meteorological conditions the turbines are operating in. It also depends on the noise sensitivity of the individual. What I think this points to is a lack of reference to the reasons for the existing environmental noise regulations for wind turbines in this report. These regulations (such as the South Australian EPA guidelines) describe noise limits for wind farms. I suggest that these limits, as regulated, can be used to better define what is meant by “substantial noise” in this report. It should be noted that most regulations need improving to include the effects of low-frequency noise, amplitude modulation and tonality, but nevertheless, they are the regulations at the moment.

This brings me to another point. It is not very clearly stated in the report that wind turbines are noise generators with significant sound power. One may get the impression that they don't produce significant noise at all. However, it is already recognised that noise generated by them is significant enough to be regulated by governments to protect the amenity of communities and prevent unwanted noise pollution. In fact, noise from turbines significantly affects the number of turbines that can be placed in a farm, limiting their profitability. I think the report needs to recognise more clearly that the sound power of wind turbines is significant enough to be regulated by governments to ensure the protection of communities from environmental noise pollution.

The following statement is not accurate and must be changed (§7.2.2, referring to the effect of environmental noise on health, in general): “Associations between noise exposure and some other health conditions (including high blood pressure, heart attack and depression) have also been suggested, but these associations are based on limited evidence¹⁹.”

First, Reference 19 is not an appropriate reference to support this statement. Second, the World Health Organisation (as reported in Reference 21 in the NHMRC report) concludes:

There is sufficient evidence from large-scale epidemiological studies linking the population's exposure to environmental noise with adverse health effects. Therefore, environmental noise should be considered not only as a cause of nuisance but also a concern for public health and environmental health.

I am sure the authors of the NHMRC report do not mean to contradict the World Health Organisation (WHO) and many decades of study linking environmental noise pollution with health. Please change the statement or delete it.

Further, please carefully consider the statement in the same section, referring to

the effect of environmental noise (from all sources) on sleep disturbance: “However even in the worst cases, the effects are modest”. The WHO (cited as Ref 21 in the NHMRC report) calculate that in Europe alone, the burden of disease sustained by noise-induced sleep disturbance is enormous. There are many other studies that show and warn of the very serious health effects of noise-induced sleep disturbance, as well as other health impacts (as mentioned above). As this document is aimed at informing the public and policy makers, the last thing I would want to see is an incorrect opinion formed in the public mind regarding environmental noise pollution and its effect on health. The statement on health effects of sleep disturbance goes beyond the original scope of the report in that it extends the discussion to all forms of noise, when it should be limited to noise from wind turbines. Hence the statement must be corrected.

The conclusions in the documents align with your understanding of the latest evidence in your area of expertise

I broadly agree with the conclusions made in §7.2.3; however, there are some points that need discussion and/or improvement. The statements made earlier in the report (and discussed above in this review) give the impression that the effects of environmental noise pollution from *all* sources (aircraft, rail, road, etc) are unimportant or have an inconclusive effect on health, which is not true. This impression or style seems to have percolated into the concise conclusions of §7.2.3. The emphasis appears to be on negating claims already made concerning wind turbine noise, when it could equally be concluded that the the existing evidence is poor and more work is needed to obtain better quality data. Indeed, the NHMRC report does suggest this in an appendix, but I feel that the inconclusive nature of the existing body of literature needs to be stated in a more balanced manner in §7.2.3 (as it may be the only section a busy policy maker will read) with a direct reference to a requirement for new research.

Other comments

1. An executive summary or abstract should be at the beginning of the report.
2. In §1.2, please rewrite: “Wind turbines are towers with rotating blades that harness wind to produce electricity.”, to read: “Wind turbines use rotating blades attached to towers in order to convert wind energy into electricity.”
3. I have a few problems with this statement that appears on page 12:
“Wind turbines produce mechanical sound at a frequency of 20–30 Hertz (for a 1500 kilowatt turbine)² and a “whooshing” aerodynamic sound in the range

of 200–1000 Hertz^{33,34}. Noise from wind farms is mostly aerodynamic^{8,9,35}

In my opinion, these statements are too definitive and the references used are not suitable to support these statements. While it is true that wind turbines may produce mechanical noise at low-frequency, whooshing noise can be produced below 200 Hz and above 1000 Hz. Two well known aerodynamic noise mechanisms are responsible. In-flow turbulence (from the atmospheric boundary layer or other sources) can create lower frequency sound, certainly below 200 Hz and quite probably up to 1000 Hz and above. Further, turbulent trailing edge interaction noise can be produced from low frequencies (the lower limit has not been determined, but would likely be below 200 Hz) to well above 1000 Hz. I recommend that the references listed below be used to provide a more accurate statement. Another (infrasonic) source mechanism - thickness noise - is not mentioned at all. Any rotating blade will create thickness noise at the rotational frequency. While the infrasonic source strength may be very low (as supported by the evidence), I would think it is only fair to inform the reader that infrasonic sources do exist on a turbine.

Grosveld, Ferdinand W. "Prediction of broadband noise from horizontal axis wind turbines." *Journal of propulsion and power*, 1(4) (1985): 292-299.

Wagner, S. *Wind Turbine Noise*. Springer Berlin Heidelberg, 1996.

Oerlemans, Stefan, P. Sijtsma, and B. Mndez Lpez. "Location and quantification of noise sources on a wind turbine." *Journal of sound and vibration* 299(4) (2007): 869-883.

Glegg, S. A. L., S. M. Baxter, and A. G. Glendinning. "The prediction of broadband noise from wind turbines." *Journal of sound and vibration* 118(2) (1987): 217-239.

4. Please change the definition "Aerodynamic sound: For wind turbines, the sound generated by the interaction of the blade trailing edge, tip or surface with air turbulence." to:

"Aerodynamic sound: For wind turbines, the sound generated by the interaction of the blade trailing edge, tip or surface with turbulent air flow."

In my opinion this is more precise. "Air turbulence" may be interpreted to apply to atmospheric turbulence only, where wind turbine noise is generated by more forms of turbulence than that.

5. The definition of decibel: "Decibel: A unit of measure used to express the loudness of sound, calculated as the logarithmic ratio of sound pressure level against a reference pressure." needs improving. *Loundness* is measured in a

another unit (Phon), Decibels is a standard way to express any measurement in a logarithmic scale, while *Sound Pressure Level in Decibels* is a unit of measure to express sound pressure level only, calculated as the logarithmic ratio of sound pressure level against a reference pressure, multiplied by 20.

Mathias Basner

As I am an expert on the effects of noise on sleep, I mainly concentrated on this aspect.

Overall, the report is well written, and the methodology behind the review seems to be rigorous and sound. I noticed that only papers published until October 2012 were considered in the review. Although understandable from a logistic point of view (at some point a cutoff has to be made), a number of relevant studies have been published in the meantime, and the review would have profited from those.

I have one major concern with the review. In multiple locations one can read statements like:

- The few associations reported by individual studies could have been due to chance. Therefore NHMRC concluded there is no reliable or consistent evidence that wind farms directly cause adverse health effects in humans. (p10)
- Therefore even though there was support for some of these associations in studies of effects of noise from other sources, NHMRC could not conclude that exposure to wind farm noise causes annoyance, sleep disturbance or poorer quality of life. (p10)
- There is no reliable or consistent evidence that wind farms directly cause adverse health effects in humans. (p13)

I agree that, at this time, the scientific literature on health effects of wind farms is only emerging and that the evidence does not allow to draw valid conclusions. However, I believe that this needs to be formulated more neutrally throughout the report, as this limited evidence does neither support that there are health effects nor that there are not. In other words, if the evidence for health effects is limited, this does not mean that there are no health effects (but only that more evidence needs to be gathered to support or reject the hypothesis).

The report states on page 15: "Associations between noise exposure and some other health conditions (including high blood pressure, heart attack and depression) have also been suggested, but these associations are based on limited evidence." I believe it is generally accepted in the field of noise effects research that long-term noise exposure is one contributing factor to cardiovascular disease. The discussion is not so much about "whether" but "at what level" noise starts to promote these negative health consequences.

The report also states on page 15: "There is no evidence that health or health-related effects from wind turbine noise would be any different to those from other noise sources at similar levels." The acoustic characteristics of wind farm noise can differ greatly from other types of environmental noise exposure. I therefore doubt that this statement is true.