NSW PLANNING GUIDELINES: WIND FARMS: A resource for the community, applicants and consent authorities
(DRAFT)

Submission to the NSW Department of Planning & Infrastructure

By

Parkesbourne/Mummel Landscape Guardians Inc.

March, 2012

Preface

13 March 2011

To: The Hon. Brad Hazzard MP
Minister for Planning and Infrastructure

Minister

I am chair of Parkesbourne/Mummel Landscape Guardians Inc. As you know, I and the members of my association are concerned at the prospect of the Gullen Range Wind Farm, already approved, being built in our local area. We believe that the assessment of this wind farm has not been adequate, and represents a threat to the health, well-being and amenity of those who will be its neighbours. The Australian noise expert Bob Thorne has testified that in his professional opinion, on the basis of his research, annoyance, sleep disturbance, and other adverse health effects can be experienced by neighbours of wind farms out to 3.5 kilometres from turbines. As the Gullen Range Wind Farm will have 32 non-involved residences within 1.5 kilometres of turbines, about 60 non-involved residences within 2 kilometres, and 118 non-involved residences within 3 kilometres, we think we have serious grounds for concern. The neighbours of the existing wind farms Crookwell One, Cullerin and Capital are already suffering adverse noise and health impacts, including chronic sleep disturbance. We find it quite unacceptable that you refuse to order a review of the Gullen Range Wind Farm's approval, and conditions of consent.

The Gullen Range Wind Farm, and other wind farm projects in NSW have been approved under the *South Australian Noise Guidelines* (2003). These noise guidelines are demonstrably inadequate to protect the health of neighbours. Before the *South Australian Noise Guidelines* (2003) are displaced by your new guidelines, over 2000 turbines will have been approved under the inadequate *South Australian Noise Guidelines*. This will lead to a planning disaster and a public health hazard on a grand scale. Hundreds of households will suffer the unacceptable impacts which the neighbours of Crookwell One, Cullerin and Capital already have to endure.

You have ordered an independent noise audit of the Capital, Cullerin and Woodlawn Wind Farms. Will this noise audit be genuinely independent? And what will be the result, if the audit finds that these wind farms do not comply with their conditions of consent? Will you order turbines to be shut down, to protect the health of neighbours?

An even more poignant question is: what will you do, if the audit finds that these wind farms are having adverse noise and health impacts on their neighbours, *even though they are found to comply with their conditions of consent*? Will you then order a review of all wind farm approvals made under the *South Australian Noise Guidelines* (2003)? That is what you ought to do. That is what needs to be done, if the health and well-being of NSW citizens are to be protected.

You and your government have been dilatory in facing up to the challenge of cleaning up the mess of wind farm development in NSW, bequeathed to you by the previous Labor government. We looked to you to carry out this task. It is still unclear whether you will do so.

The proposed draft Guidelines will not meet the need. They are too close in spirit, and in detail to the *South Australian Noise Guidelines*. Moreover, the new guidelines will only apply legally to future proposals. The 2000+ turbines to be approved under the *South Australian Noise Guidelines* will be unaffected by the new guidelines. This is totally unacceptable, and a formula for disaster.

We urge you to realize the dangers to rural residents implicit in badly regulated wind farm development in NSW, already obvious from the impacts of the existing wind farms in NSW, and even more from the impacts of the wind farms of Victoria, South Australia, and New Zealand. People have already abandoned their homes. On what sort of scale does that have to occur before you take effective action?

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Acknowledgments

This submission depends on the research of many researchers, especially the research of Professor Alec Salt, Professor Frits van den Berg, Professor Philip Dickinson, Dr Bob Thorne, Dr Huub Bakker, Mr Bruce Rapley, Professor Colin Hansen, Professor Mariana Alves-Pereira, Professor Nuno Castelo Branco, Mr George Kamperman, Mr Richard James, Dr Daniel Shepherd, Professor John Harrison, Mr Stephen Ambrose, Mr Robert Rand, Mr Steven Cooper, Mr M. A. Swinbanks, Professor Henrik Moller, Dr Eja Pedersen, Dr Paul Appelqvist, Dr Martin Almgren, Dr Christopher Hanning, and Dr Nina Pierpont. It goes without saying that none of them is responsible for any errors I may have committed.

I have benefited from personal communications from Professor Salt, Professor van den Berg, Professor Dickinson, Dr Thorne, Mr James, Mr Cooper, Dr Hanning, Mr Calvin Martin, and Dr Sarah Laurie, and to others who may wish to remain anonymous.

I am especially grateful to Mr Paul Miskelly of Taralga Landscape Guardians, who first introduced me to the intricacies of the "van den Berg Effect", and to other aspects of wind turbine operation.

I owe my thanks to all. None of them is responsible for my errors, if I have committed any.

Everyone concerned about inappropriately located wind farms in NSW owes a great debt of thanks to Alby Schultz MP, Federal Member for Hume, for his constant and vigorous defence of the needs and interests of those residents impacted, or likely to be impacted by such wind farms.

I must also thank the Hon. Katrina Hodgkinson and the Hon. Pru Goward, State Members for Burrinjuck, and for Goulburn, for their unfailing sympathy and support.

It should not be assumed that the above named politicians necessarily agree with what is written in this submission.

My wife has put up with my absences, mental and physical, to write this submission. I cannot thank her enough.

Contents

Critical Comments on the Draft Guidelines

Note: recommendations will be found in bold in the following text.

The Gateway Process

The Gateway Process is discussed in 1.3 (a).

The Gateway Process does not have much meaning, since the developer can apply for an exemption in the form of a Site Compatibility Certificate (SCC). As each turbine represents a capital investment of about $2.5 million, and as the revenue to be earned from each turbine will be vastly larger than the cost of carrying out the assessments necessary to get the SCC, it is certain that the developer will choose to apply for the SCC. The award of the SCC then depends on the criteria and standards relating to noise, visual impact, and landscape values. So, it all comes back to the criteria and standards adopted for the Guidelines. All that the Gateway Process means is that the developer has to do the noise and visual assessments for particular properties before he has to do them for the project as a whole. In reality, the resident who has objected has no influence over the decision, which will be made effectively by the Department of Planning in the usual way. This is only business as usual in a different form.

The application for an SCC is to be publicly exhibited for 21 days, and forwarded to the local council and relevant landowners, with an invitation for comment. In the circumstances 21 days is far too short. If the application is to be forwarded to the local council and landowners through the post, this process will consume several of the 21 days, if one may judge by the usual dilatoriness of posted communications from government departments. But, even the maximum period of 21 days is far too short for effective comment. Merely to read the consultants’ reports on noise and visual impacts is likely to take much longer than 21 days, especially if the resident works, or has a family to look after. If the landowner wishes to read up on the impacts of wind turbines, in order to understand what the outcome of situating the wind turbines close to his residence is likely to be, that in itself would take much longer than 21 days. If the council wished to hire a consultant to get professional advice on the proposal in relation to the properties in question, that would also take much longer than 21 days. **In general, if a period of public exhibition is intended as a period in which submissions from members of the public are sought, then the period ought to be no less than 90 days.** If the period of public exhibition is not long enough for submissions to be researched, and composed, then the process is a sham, and is biased to favour the commercial interests of the developer.

The department next assesses the application, and makes a recommendation to the Joint Regional Planning Panel (JRPP). The department will almost certainly recommend the award of the SCC to the developer, since the inadequate noise assessment criteria (see below) will guarantee that the department will be unable to object on the ground of noise. And the visual assessment in the draft guidelines is still lacking in definite criteria that would enable the departmental officials to determine that a proposal has not passed the test. When it impossible to say on what grounds a proposal fails its test, then clearly no proposal will ever fail. This account of the inadequacy of visual assessment of wind farms by the NSW Department of Planning is amply corroborated by the Department's assessment of the visual assessment carried out for the Gullen Range Wind Farm. There is nothing in the draft guidelines to suggest that the Department's assessment of visual impact will be any different from what it has been in the past. Departmental officials will retain the power of discretion to approve all wind farm proposals in relation to visual impact, since there are no criteria to determine that any proposal must fail. The assessment of visual impact by the NSW Department of Planning is not an intellectually serious process.

The Department's recommendation is passed to the Joint Regional Planning Panel. Why this body? What are its peculiar qualifications to decide the question of an SCC? According to my information, a JRPP has three state nominated members and two locally nominated members. Clearly, this means that local opinion can always be overridden.

The JRPP "may" hold a public meeting. **This should be "must".** On what grounds will the JRPP decide whether to hold to public meeting, or not? There is nothing in the Guidelines to explain this. It would appear that the JRPP, an unelected body, has the discretion to decide this question according to its wish. This lack of definite and transparent criteria is an invitation to bias, injustice, and abuse of power. **The only way to avoid this is to make a public meeting mandatory.**

What kind of public meeting? A forum with selected speakers making a presentation, and questions from the floor? Or an "open day" with the developer showing maps and tables, and a transient audience drifting through? Or a full-dress hearing, with expert witnesses, solicitors and barristers? There is nothing in the Guidelines to show exactly what is intended.

"If a Site Compatibility Certificate is not issued, then the development cannot proceed as proposed with the turbines within 2 km of a neighbour's house, unless the land owner issues their written consent." In what circumstances would the JRPP not grant the SCC? Is it envisaged that the JRPP might reject the recommendation of the Department to grant the SCC? On what grounds? Or, would the JRPP only refuse to grant the SCC, if the Department recommended that the SCC not be granted? Will the JRPP be a "rubber stamp" for the Department? Or will the JRPP ever decide in contradiction to the Department's recommendation? If so, on what grounds? So long as all this remains unknown, how can residents have any confidence in this process? It looks like an elaborate formality with a foregone conclusion.

This process is supposed to have been designed to increase consultation with relevant landowners, and to ensure some local community representation in the decisions concerning the location of turbines within 2 km of residences. However, the lack of transparency in the nature of the determinations, and the overriding of local opinion by state nominated members make the whole process appear to be only an elaborate method to ensure that the local residents have no real influence over the decision to locate turbines close to their homes, and that local councils have no real influence either. Neither the "consultation" nor the "local community representation" has any reality, because they have no effective power to influence the outcome.

The Gateway Process looks like an instance of pseudo-democracy. There is a facade of democratic process, but the real power is retained by departmental officials and state appointees, who are thus in a position to favour the developer. There are no real checks and balances to prevent this from happening.

Finally, it must be asked whether there is any real distinction between the award of a Site Compatibility Certificate, and approval of the proposal, at least for that part of the proposal that is in question? Formally, the award of an SCC, and final approval of the proposal are two distinct determinations. But, in reality it is hard to see any difference. This is because the criteria and evidence used to determine the award of the SCC are precisely the same criteria and evidence as will be used to determine the approval of the proposal, at least that part of the proposal that is in question. It is true that at the time of final approval many other issues will be taken into account for the proposal as a whole. But, so far as the interests of the resident in the amenity of his property are concerned, and whether or not the resident is granted acquisition rights, the issues of noise and visual impact are decisive. Consequently, once the Department and the JRPP have determined that the SCC may be awarded to the developer, the resident must know that the issues of noise and visual impact in relation to his property have already been decided, and that he cannot expect any reversal of this by the Department or the Planning Assessment Commission (PAC). Once the SCC relating to the turbines impacting his property has been granted, it is all over for the resident. It is inconceivable that the same criteria and evidence would lead to both (i) the location of the turbines close to the residence being considered “compatible” (with what?) for the sake of the SCC, and (ii) a final judgment that the location of the turbines close to the residence would have sufficiently adverse impacts as to justify the award of acquisition rights to the resident. How can the same criteria and evidence lead to contradictory conclusions? And if at the stage of the application for an SCC the Department judges that the location of the turbines would lead to unacceptably adverse impacts, justifying acquisition rights, how could the Department then justify recommending the award of the SCC? This process is therefore fundamentally flawed. Being so, it can only lead to lack of rigour and transparency in the determinations of the Department, the JRPP, and the PAC, and so be productive of sophistry and evasion, injustice, and abuse of power.

As the Gateway Process is fundamentally flawed in these ways, and will be impossible to administer with transparency, rigour, impartiality and justice, it should be abandoned. The only measure in this area that is clear, definite, and practical is a setback distance. As I shall argue later, this should probably be 5 kilometres, or more. **But the declaration of a setback distance should wait upon the completion of the necessary medical and acoustic research. Until then a moratorium on all wind farm development in NSW should be declared.**

Community Consultation

Community consultation is discussed in 1.3 (b), also in 2., and in Appendix C.

Site compatibility certificate

I have already discussed the application for a Site Compatibility Certificate (see previous section).

Engagement with neighbours early in the process

This topic is discussed at 2.1 (b).

It would appear that the developer is required to consult with neighbours within 2 km of the proposed turbines, but only encouraged to consult with neighbours further out (p. 9). **Since there are grounds for thinking that adverse impacts of annoyance and sleep disturbance may be experienced by neighbours out to 3.5 km from turbines (see later), consultation should be mandatory with all neighbours within 3.5 km.**

This process should commence with the proponent writing to each neighbour, offering to visit the neighbour with evidence of predicted impacts. But, the neighbour must have the right to decide whether to allow the proponent's representatives to visit the neighbour's home, whether to have a solicitor or other representative present, or whether to keep all communication with the proponent in the form of posted letters or e-mail. This restriction is necessary because of the unacceptable behaviour of proponents in the past. All possibility of intimidation and deception during the consultation process must be eliminated.

Proponents are to consult with neighbours within 2 km of turbines concerning "landscape and visual amenity issues, noise, health, property values, blade glint and shadow flicker." (p. 9) This sounds well, but it is hard to see what good it will do, when these are issues that are likely to lead to irreconcilable disagreements. If a neighbour regards the proposed wind farm as a something that will ruin the beauty of the landscape, and destroy the neighbour's own visual amenity, how can this be accommodated? Planting trees around the neighbour's house (ignoring for the moment that they may take 30 years to grow) will not alter the appearance of the landscape, or protect the neighbour's visual amenity when walking in his paddocks. If the neighbour does not trust the proponent's noise predictions, because the neighbour is aware of the divergence of opinion within the acoustic community, and has read up on spherical or cylindrical propagation, Heightened Noise Zones, synchronicity, increased night-time noise from a stable atmosphere, caused by temperature inversions, amplitude modulation and crest factor, low frequency noise and infrasound, and the possibility of different judgments by different acousticians as to whether a particular wind farm complies with its conditions of consent – if the neighbour has all these grounds of distrust (knowing that the proponent's consultants will present the proposal in the best possible light), how is the resulting disagreement to be accommodated? The proponent will give assurances that the neighbour will not believe. The neighbour may support his side of the dispute with reference to existing wind farms in NSW, Victoria, South Australia and New Zealand, where severely adverse impacts have been experienced, even though the wind farms were approved by their planning authorities. Similar disagreements may occur over health, property values, blade glint and shadow flicker, with the proponent citing industry-sponsored research, and the neighbour citing independent research. Such disputes will not be resolved, and the consultation will be a waste of time.

The draft Guidelines seem to be completely oblivious to the global disputes over the location and impacts of wind farms, which have been growing over the last ten to fifteen years. The Guidelines also seem to be equally oblivious of the medical and acoustic research by independent researchers, which has been accumulating since around 2002.

These issues are intractable, because there is an irreconcilable conflict of interest between the proponents who wish to locate their wind farms close to existing power lines, in order to reduce costs, and neighbours who, not unreasonably, wish to protect their health and well-being, their amenity and quality of life, and the value of their property.

The only way to transcend such disagreements is to impose a definite setback, which is sufficiently large (probably 5 km or more) to protect neighbours. But this setback should not be declared, until the necessary medical and acoustic research has been completed. Until then, a moratorium on all wind farm development in NSW should be declared.

Community consultation committees

Community consultation committees are discussed at 2.1 (c), and in Appendix C.

It is said that guidelines for establishing community consultation committees are provided in Appendix D (p. 10), but in fact these guidelines are provided in Appendix C.

In general, it may be better to have consultation committees than not to have them, since communication is usually better than no communication. However, one must be sceptical of whether they can actually be of use. And the procedure for their formation given in the Guidelines is unacceptable.

The reasons for scepticism as to their usefulness are contained in the previous section. In other words, there are intractable conflicts of interest between wind farm operators and neighbours. Merely providing a channel of communication is not going to solve these problems. The Guidelines seem to assume naively that all disputes will be unreal, the result of failures of communication, and will be able to be talked through. The Guidelines indicate this when (p. 42) they state that irreconcilable disputes are to be managed by getting rid of current members of the committee, and appointing new members! Presumably, what is meant is that the old members cannot manage the art of communication, whereas the new members will be able to. However, it is much more likely that there will be really intractable issues due to real conflicts of interest. Neighbours may want turbines turned off, and operators will probably refuse so as not to jeopardize their profits. In such a situation, all that the Guidelines allow for is for the membership of the committee to be changed! So, if there is a real issue that is intractable, it is to be “resolved” by finding committee members who will pretend not to recognize the issue. This is not serious.

Intractable conflicts of interest can only be avoided, or dealt with if:

1. There are adequate noise limits, and setbacks that really protect neighbours’ health, well-being, amenity and property value (see later).
2. There is a rigorous system of compliance monitoring, performed by an independent compliance authority (see later).

With regard to the procedure for forming the committee:

1. **The chairperson cannot be appointed by the Director-General, but must be elected by the committee itself.**
2. **The number of local representatives, and the number of the proponent’s [i.e. operator’s] representatives must be equal. To give the “proponent” more representatives is preposterous.**
3. **The community representatives cannot be appointed by the Director-General. There must be a meeting of all owners of residences within 3.5 kilometres of turbines, who will vote on their own representatives. Anything else is quite unacceptable.**
4. **If the number of the “proponent’s” representatives, and the number of the community representatives are equal, it will be natural, and not unlikely that they elect the local council representative as chairperson. (However, it is likely that the local council will want more than one representative.)**
5. **If the final number of members of the committee is an even number, threatening a tied vote, then whoever is entrusted by the committee to act as chairperson can have a casting vote.**
6. **The committee cannot go begging to the “proponent” for funds. The “proponent” must be obliged to pay a fixed sum annually into an account administered by the Department, to which the committee can apply for funds. This *is* something that can be delegated to the Director-General.**
7. **It will almost certainly be more important to inspect the residences of neighbours who complain of adverse impacts, than to inspect the wind farm itself. The neighbours must of course give their permission for the inspection.**

The Guidelines’ proposals as to the formation of the committee are undemocratic, and unacceptable. Members of the committee must not be representatives of the Director-General. If the “proponent”, and the local council can nominate their own representatives, then the directly affected community must be able to do the same. The wider local community can be represented by the representatives of the local council. That is proper. What the Guidelines propose looks like an attempt to deny any genuine representation to the neighbours of the wind farm, and to retain control of the committee in the hands of the Director-General. This is quite unacceptable.

Public exhibition of development applications

This topic is discussed at 1.3 (b), under the heading *Community consultation*.

On p. 4, under *Community consultation*, it is said that development applications are to be exhibited for 60 days. This is still insufficient, for reasons already given. Reading, research, and composition cannot be done in less than 3 months, given that many neighbours will work, and/or have a family to care for. **A minimum of 90 days is necessary.**

It should be remembered that the development application for a wind farm may be 1000 pages long, and contain many sections of a specialised and technical nature. Some neighbours or the local council may wish to hire a consultant. The local community or the local council may wish to convene public meetings to discuss the proposal.

The period of exhibition should not be restricted, merely to suit the convenience and interests of the developer. It should be remembered that the developer and future operator of the wind farm will have a state-guaranteed market (in the form an emissions-trading scheme/carbon tax, and the system of Renewable Energy Certificates), and so state-guaranteed profits. This is a sufficient advantage. Balance requires that the interests of the local community be considered.

Landscape and Visual Amenity

These topics are discussed at 1.3 (c) and in Appendix A. I will also include the issues of blade glint, shadow flicker, and night lighting under this heading (all discussed in Appendix A.).

Landscape and landscape values

The essential question for local communities, and especially impacted neighbours, is: how seriously will the Department of Planning take this issue? Past experience with the Department's assessment of wind farm proposals suggests some grounds for scepticism.

Landscape character and landscape values are to be assessed by the proponent; key features of the landscape are to be described; and the proponent's methodology is to be described and justified (p. 4). The significance of the landscape values and character in a local and regional context are to be described. Community and stakeholder values of the local and regional visual amenity are to be described (p. 5). The sensitivity of the landscape features to change is to be considered (p. 18). It is even said that turbines are to be located "where possible" [!] "away from areas with high scenic values" (p. 19). But what will all this mean in practice?

First, the phrase "high scenic values" seems to imply that the Department is concerned about something that would usually be called "beauty", and that the comparative beauty of an area is not something totally subjective. However, Departmental officials have in the past tended to dismiss this kind of issue with the notion that beauty is in the eye of the beholder. That then serves as a reason not to consider the matter any further. In the *Major Project Assessment* for the Gullen Range Wind Farm the Departmental author writes:

> The acceptability of changes to the visual outlook will always be a matter of conjecture because of the subjectivity of individual likes and dislikes. (p. 25)

That statement explicitly argues that the issue is subjective. However, in the same report the same author also writes:

> In assessing any wind farm proposal, the Department deems it necessary that the landscape value be seen from a regional, if not State-wide perspective..... The Department's assessment is consistent with the general approach taken for previous wind farm proposals in that a wind farm would have to impact a landscape of regional, if not State or national importance, for it to be refused on the basis of scenic quality alone. (p. 20)

That statement presupposes that the estimate of landscape value is *not* entirely subjective. If it were, how could any landscape be declared to be of regional, State, or national importance? In reality, everyone believes that some landscapes are more beautiful than others, and that therefore beauty is not entirely subjective. If it were not so, then no landscapes would ever be preserved from development.

It seems clear, then, that the Department of Planning is acting inconsistently. It only invokes the subjectivity of aesthetic judgments when convenient. It is convenient to dismiss landscape concerns in a local context, in order to promote development. The reason for this becomes painfully clear in the Gullen Range report cited above. The author states:

> In assessing any wind farm proposal, the Department deems it necessary that the landscape value be seen from a regional, if not State-wide perspective. *For example, if a wind farm proposal such as this project is refused solely upon a local perspective of scenic quality, it would probably eliminate opportunities to construct wind farms possibly anywhere in the region, and possibly in the State*. (p.20) (italics added)

This lets the cat out of the bag. Local scenic quality is to be sacrificed, in order to facilitate wind farm development. It is clear from this declaration that local scenic beauty does not count. But, if it does not count, then the whole assessment of landscape character, and landscape values is a sham.

So, the question is: does the Department of Planning intend to behave any differently from how it behaved in its assessment of the Gullen Range Wind Farm? Do the above sentiments still represent the Department's view of landscape assessment? If they do, then we are all still involved in an elaborate game, that is merely a waste of time.

The proponent is to describe and justify his methodology. And the sensitivity of the landscape to change is to be assessed (pp. 4, 18). In the past these requirements have been little more than a joke.

In the case of the Gullen Range Wind Farm the proponent classified the landscape of the site of the proposed wind farm as either "gently undulating farmland", or "hilly farmland". Both types of landscape were declared by the proponent to be insensitive to the kind of change represented by the wind farm. The reason for this was, apparently, that the area was agricultural and pastoral, and so already affected by human modification. On account of this it was held by the proponent that the area could "absorb" the change introduced by the wind farm (GRWFEA, pp. 103-104, 118).

This absurd claim took no account of the fact that the wind farm would be grossly out of proportion with everything else in the landscape, that it would dominate everything else in the landscape, that trees – hitherto the tallest items in the landscape – would lose their dominant character, and that the landscape would be radically transformed, to an extreme degree. This obvious common-sense judgment was ignored both by the proponent, and by the author of the *Major Project Assessment*.

The proponent made no attempt to assess the beauty or value of the landscape, beyond stating that he recognized that some people liked the look of it, and were fond of it (GRWFEA, attachments, vol. 2, 3.1, p. 36).

It must be concluded that the Department of Planning simply does not take seriously the issue of landscape value, and that compelling the proponent to make an assessment of impact on the landscape is no more than an elaborate game.

But, if so, what is the point of the Department now saying, in the draft Guidelines (p. 19) that turbines are to be located "where possible" ... "away from areas with high scenic values"? Does this stipulation have any reality? Are wind farms to be refused in areas like that of the Gullen Range Wind Farm? Or, are all potential wind farm sites along the Great Dividing Range to be declared areas of low scenic value, so that the turbines can go in? Are we all supposed to accept the aesthetic judgment of Departmental officials on this issue? Do they have any qualifications in this area?

Time will tell.

Visual amenity

Once again the question is: how seriously will the Department of Planning take this issue?

The assessment of the impact on visual amenity is to take into account the visibility of the proposed development, and the locations and distances from which the development can be viewed (p. 4). There is to be a particular focus on any neighbours' houses within 2 km of a proposed wind turbine that do not host the wind farm facility (p. 4). There is to be a discrete justification of the methodology for assessing impacts at neighbours' houses within 2 km of a proposed wind turbine. And photomontages of the project and associated transmission lines, taken from, *inter alia*, potentially affected residences (including approved but not yet developed dwellings or subdivisions with residential rights) within 2 km of a proposed wind turbine or other associated infrastructure must be provided (p. 4). Moreover, photomontages depicting how the turbine(s) will appear from each neighbouring house within 2 km of a turbine must be provided during the Gateway and in the assessment (p. 5). In chapter 2 on *Consulting with the community and stakeholders* it is said that proponents should consult with affected neighbours (where a turbine is proposed within 2 km of a neighbour's house) on specific issues, including landscape and visual amenity (p. 9). Finally, it is also recommended as a possible measure of mitigation that turbines be located "where possible" [!] "away from areas with high visibility from local residents" (p. 19).

It is certainly a good thing that the proponent is obliged to consult with all neighbours within 2 km of turbines about landscape and visual amenity. In the past proponents have failed to do this, or claimed that newsletters and one or two "open days" were enough to satisfy the obligation for consultation. In the case of the Gullen Range Wind Farm, the Department of Planning mildly criticised this in its *Major Project Assessment* (MPA) , but by then it was too late to do anything about it, since in the MPA the proposal was recommended for approval by the Minister. According to the Director-General's Requirements for the Gullen Range Wind Farm, the proponent was obliged to assess visual impact, with photomontages, on all dwellings within 10 kilometres. Not a single visual assessment on any residence was carried out by the proponent, until Parkesbourne/Mummel Landscape Guardians (PMLG), at their own considerable expense, entered a merit appeal against the Minister's approval in the NSW Land & Environment Court. And even then the Court only obliged the proponent to do about half a dozen photomontages. There were in fact about 60 non-involved residences within 2 km of the proposed Gullen Range turbines, 118 within 3 km, and about 240 within 5 km. Nobody knows how many non-involved residences there were within 10 km, since the proponent did not bother to count. None of this was objected to by the Department of Planning.

When turbines are placed upon a ridge, and the residences are mostly in the valley below, the wind farm will be "visually dominant in the landscape from most viewing locations" within 1.5 km, and will be "highly visible, and will usually dominate the landscape" between 1.5 and 3.0 km. These descriptions and figures come from the assessment of visual impact for the Gullen Range Wind Farm (GRWFEA, p. 102). But since most of the wind farms planned for NSW will be located on hilly terrain in the Great Dividing Range, with residences in the valley below, it is reasonable to take the descriptions and figures as valid generally. **Turbines set on a ridge cannot be missed. Therefore, the proposal for consulting neighbours within 2 km on visual impact should be amended so that all non-involved neighbours within 3 km are consulted.**

There is to be a "discrete justification" of the methodology for assessing impacts at neighbours' houses within 2 km of a proposed wind turbine (p. 4). If we may judge from the past conduct of proponents and of the Department of Planning, rather more than the proponent's justification of his methodology will be necessary. In the case of the Gullen Range Wind Farm, the methodology used must be judged, by any rational criteria, deficient, and the Department of Planning made no objection to it. The proponent insisted that the estimation of visual impact had to be determined by the application of three criteria. Only one of these was visibility as a result of distance from turbines. The other two were "landscape sensitivity", and "viewer numbers". The way that these criteria were applied was such that what was in reality a high visual impact was converted in the proponent's estimation to a low visual impact. According to the first criterion, distance from turbines, the estimate of visual impact might be "high". This was consistent with the finding already mentioned that within 1.5 km the turbines would be visually dominant, and that between 1.5 and 3.0 km the turbines would be highly visible and would usually dominate the landscape. However, when applying the second criterion, "landscape sensitivity", the proponent arbitrarily declared the landscape to be insensitive to the kind of change represented by the wind farm, and concluded that according to this criterion, the visual impact was "low". Finally, according to the third criterion, "viewer numbers", the visual impact was declared to be "low", presumably because local roads in the country do not have the volume of traffic of George Street, Sydney. As a result of this dubious kind of reasoning, the proponent was left with three estimates of visual impact, namely, one "high", and two "lows". When these were combined, the net result was declared to be "low". (GRWFEA, Attachments, vol. 2, 3.1, pp. 50, 52)

In this way, the real visual impact, which will undoubtedly be colossal when the wind farm is built, is reduced to "low". This procedure cannot be taken seriously. The Department of Planning made no objection to this procedure, when it was assessing the Gullen Range proposal in 2009. Why would it object to it now? Even if future proponents offer a "justification" for using such a methodology, what guarantee is there that the Department of Planning would object to it? Would the Department in fact object to it? Who knows?

It is still the case that proponents are invited by the draft Guidelines to take into account "the sensitivity of the landscape to change", as well as "visibility" and "distances from which the development can be viewed" (p. 18). There is, however, no reference in the Guidelines to "viewer numbers". That will probably not stop proponents from invoking the notion, since it will still be in their interest to make the estimate of visual impact as low as possible. Can local residents depend on the Department of Planning to defend the standards of intellectual integrity? Or will the whole process still be a formality with a foregone conclusion, which functions to promote wind farm development in NSW?

Time will tell.

The draft Guidelines recommend as a possible measure of mitigation that turbines be located "where possible" [!] "away from areas with high visibility from local residents" (p. 19). How is it possible to believe that this recommendation has any reality or force? Wind farm developers want to locate their wind farms on ridges, because that is where the high winds are. To suggest to them that they might put their turbines somewhere else, if residents can see them would only be met with a laugh. The Gullen Range Wind Farm is to have 73 turbines located on a series of ridges stretching for about 25 kilometres. There will be 118 residences within 3 km of the turbines, within which distance the turbines will be "visually dominant', or "highly visible", usually "dominating the landscape". Are we to infer that under the new Guidelines the turbines of the Gullen Range Wind Farm would not have been approved, because they would be "highly visible" to several hundred residents? This is impossible to believe. The Department of Planning can only be playing games.

If the Department responds by claiming that the view of the turbines can be obscured by landscaping, this is not an effective answer. Setting aside the fact that trees may take 20 to 30 years to reach their full height, it is likely that the fact that the turbines will be on a ridge, while the houses are in a valley, will make it impossible for any screening to be successful, unless the house is imprisoned in a solid wall of trees, and deprived of any view at all.

It is thus extremely difficult, if not impossible, for local residents to have any confidence that these draft Guidelines will protect their visual amenity.

Blade glint, and shadow flicker

Blade glint and shadow flicker have been much investigated, and there is general agreement that neighbours need to be protected from them. However, the draft Guidelines only require these to be assessed in relation to residences within 2 kilometres (p. 20) This distance may not be enough. Dr David McBride and Mr Bruce Rapley have written on these topics in an essay 'Blade Flicker, Shadow Flicker, Glint: Potential Hazards of Wind Turbines', published in a peer-reviewed volume of essays. They conclude:

> Of more significance [than Photosensitive Epilepsy] is the general annoyance and visual nuisance that can be caused by the sun either being occluded by the blades (blade flicker)

> or the resultant shadow falling across a building (shadow flicker) or close to people. This can be very irritating even if it does not cause an immediate health problem such as triggering photosensitive epilepsy. Wind turbine farms should not be placed so close to human habitation as to cause significant shadows falling on any structures or outside areas where people normally would congregate. This problem would largely be eliminated by siting turbine farms more than 2.5 km from human habitation, although glint may require a greater setback distance. (McBride and Rapley, 2010, p. 91)

In view of McBride and Rapley's recommendation, the Guidelines should stipulate that an assessment should be made for blade glint, blade flicker, and shadow flicker on all residences within 3 kilometres. This will fit in with the need to do a visual assessment on all residences within 3 kilometres, because – as we have seen – a wind farm is likely to dominate its landscape out to 3 kilometres from turbines.

Night lighting

At present, night lighting as a warning system for aircraft is not obligatory. But it is fairly certain that it will become obligatory in the near future. Therefore, we must consider this possibility as the future reality.

The draft Guidelines require photomontages, and a design of the system to minimise impacts (p. 21). Unfortunately, the reality is that even with the kind of restrictions imposed on existing wind farms, night lighting will dominate the nightscape, especially in areas like Upper Lachlan Shire, where multiple wind farms are planned. This was grossly apparent when parties to PMLG's merit appeal case in the Land & Environment Court visited the Cullerin Wind Farm at night. The lights could not be hidden or obscured, and totally transformed the scene.

Night lighting will dominate the nightscape, and totally transform it. In this way, the local area will be industrialised by night, as well as by day. This is a real loss of visual amenity for local residents.

The only way to avoid this is to have a sufficient setback distance, based on completed research, to prevent wind farms from being built in rural residential areas.

Further remarks

It must be noted that nowhere in the draft Guidelines is there any suggestion that a wind farm proposal might fail its test for approval with regard to visual assessment. There is no marker or criterion for failure to qualify for approval. This suggests that the Department is already determined to approve all proposals, and place the burden of this on residents. If the Department finds that some turbines will have an adverse visual impact on a residence, the Department will order "landscaping", i.e. the planting of trees around the residence, as a "mitigating" measure. If the adverse impact is very severe, and incapable of mitigation, then the Department will grant acquisition rights to the owner of the residence. The one thing that the Department will not do is to order that turbines be removed from the proposal. The Department has never done this yet, at least not for the sake of residents. The Department will order turbines to be turned off at certain times to protect the Powerful Owl. The Department will even remove some turbines to protect an airstrip, or other piece of important infrastructure. But the Department will not eliminate turbines to protect residents, even though the adverse impact of those turbines proves that the wind farm has been badly designed. All rural residents are on notice that wind farm developers who own no property in the neighbourhood now have more rights to the use of the land than the neighbours who own the existing property.

Unless this attitude of the Department of Planning changes, local residents can have no confidence in the assurances of the Minister of Planning, and his officials. When the Department of Planning eliminates a turbine from a proposal because of the potential adverse impact on a resident, then – and only then – will residents be able to believe that anything has changed with the change of government. At present, all the signs are that we are looking at business as usual.

Noise

Noise is discussed at 1.3 (d), and in Appendix A, and Appendix B. As the proposed noise guidelines are given fully in Appendix B, I will discuss the contents of Appendix B.

Introduction

In the Introduction it is said : “It is recognised by developed countries and all Australian states that wind farms need specific guidelines because wind turbines have unique noise generating characteristics including noise output that varies with wind speed and their location, which is often a quiet rural setting.” (p. 27)

It is commendable that the Department of Planning recognizes the uniqueness of wind turbine sound, and the quietness of wind farms’ rural setting. But it is worth remarking immediately that the specific and problematical features of wind turbine sound go well beyond a variation of noise output with wind speed and location. These specific features include:

- The impulsive character of the sound (amplitude modulation)
- The dominance of low frequency sound and infrasound in the sound mix by the time that the sound reaches a residence
- The tendency of the presence of multiple turbines, either in rows or in lines, to create Heightened Noise Zones, such that the sound level can be higher at one point, and lower at another point only metres away
- Increased noise levels due to the synchronicity of multiple turbines
- An uncertainty as to whether the sound propagation from the turbine is spherical, hemispherical, or cylindrical
- A continuity of fluctuating noise that tends to render both L_{eq} and L_{90} inaccurate representations of the peak sound levels actually present
- Modulation on a micro-time scale (e.g. once every 60 milliseconds), as well as amplitude modulation on a macro-time scale at the blade pass frequency (about once per second)
- A liability to an increase at night due to a stable atmosphere, caused by temperature inversions, an especially important problem as wind turbine sound may continue all night, so long as the wind is blowing, and continue for several nights in a row
- A liability to an increase because the wind speed at the turbine on the ridge is greater than the wind speed at a sheltered residence down in the valley

It is unfortunate that these features are not all treated adequately, or even at all, in the draft noise guidelines.

In the introduction the authors also state that they have given consideration to the noise guidelines of overseas jurisdictions, and to those of Australia and New Zealand. They state that these draft Guidelines closely follow the methodologies and practices in the 2009 version of the *South Australian Noise Guidelines*, and those in AS4959:2010. It is especially regrettable that the *South Australian Noise Guidelines*, whether in their 2003 or their 2009 version, should have had any influence over the composition of the current draft Guidelines, as the *South Australian*

Noise Guidelines are demonstrably inadequate to protect neighbours from adverse impacts. The fact that the *South Australian Noise Guidelines* (2003) have been used hitherto by the NSW Department of Planning to assess the noise impacts of wind farm proposals is probably a large part of the explanation of the fact that the existing wind farms in NSW, Cullerin and Capital, approved under those guidelines, have generated, and are continuing to generate complaints about excessive and intrusive noise from neighbours. These wind farms, along with the Woodlawn Wind Farm, are now the object of an independent noise audit to be commissioned by the Minister of Planning (Hazzard, 2012). As the 2009 version of the *South Australian Noise Guidelines* is not very different from the 2003 version, it is unfortunate that any consideration has been given to the *South Australian Noise Guidelines*. If, or rather when it is shown that the Cullerin, and Capital Wind Farms have been operating at levels higher than predicted, and in breach of their conditions of consent, this will prove the inadequacy of the *South Australian Noise Guidelines*.

The composition of these draft Guidelines was an opportunity to retreat from the inadequacy of the *South Australian Noise Guidelines*. It seems that this opportunity has not been taken.

The introduction makes no mention of any research that may have influenced the composition of the draft Guidelines. Appendix F, entitled *Additional information and resources*, lists under noise only three articles from refereed journals: one by Broner, one by Hellweg, O'Neal and Lampeter, and one by Moller and Pedersen. Three articles is a minute number in proportion to the volume of research that is being published year by year, both in journals and in the proceedings of international conferences. One has to ask, why these articles in particular, from amongst all those published? Are these really the only studies that have influenced the authors' thinking? If so, that is very regrettable. If it is not so, would it not be better to publish a full bibliography, so that interested parties could get a clearer view of the Department's thinking?

A reading of the draft Guidelines suggests that much research by independent researchers has been ignored, whereas research favourable to the interests of the wind energy industry has had considerable influence. The grounds for this view will become apparent below.

Modelling and prediction

The source of wind turbine sound

It is commonly assumed that the source of wind turbine sound should be treated as a point, that point being the hub of the turbine. It is, however, known that this assumption is false. Because there are several noise sources from a wind turbine, including leading edge noise, trailing edge noise, noise from the blade passing the tower, and vortex-shedding from the tip of the blade, the total noise source is in fact the whole area described by the blades as they rotate. If a blade is 45 metres long, then the area described by the blades (pi x r^2) equals 6364 square metres. This is certainly not a point. If it is also considered that the vortex-shedding from the tip of the blade may travel for 15 to 20 metres before turning away from the turbine, then the total area of the sound source is increased up to 13,278 square metres.

This topic has been discussed by Philip Dickinson, Professor of Acoustics at Massey University, New Zealand. Dickinson writes that the sound sources of a wind turbine "may cover an area bigger than 3 football fields." (Dickinson, 2010, p. 185) He also states:

> The result of these three sets of noise sources is a pulsating wall of sound, not of any high intensity, but sufficient to carry many kilometres downwind and still have the power to excite room resonances and to disturb sleep. (Dickinson, 2010, p. 185)

Con Doolan of the School of Mechanical Engineering in the University of Adelaide has given a fairly full account of the multiple sources of wind turbine sound, in a recent conference paper (Doolan, 2011).

This topic, whether the sound source of a wind turbine is a point, or not, is not explicitly raised in the draft Guidelines. It ought to be. To consider the sound source as only a point could lead to an underestimation of the turbine's noise impacts. It is not enough for the draft Guidelines to require the proponent to select "a suitable model" (p. 35). The Department has the responsibility of stating what the suitable model ought to be, on the basis of the best research. **If the Department thinks that at present there is not enough research for it to be possible to set a model, then that is another reason for instituting a moratorium on wind farm development, until sufficient research has been completed.**

However, if there is already sufficient research on this topic, then the model should be specified in the draft Guidelines, and it should be insisted that the true size of the sound source of each turbine, given the dimensions of the turbine, should be taken into account when the potential noise impacts of the proposed wind farm are being modelled.

Operation

The draft Guidelines state that wind turbines "typically start generating electricity at around 4 m/s (14 km/h) and reach maximum or 'rated' capacity at wind speeds of around 11 m/s (40 km/h) at the turbine's hub height." (p. 27)

Until now it has been commonly assumed that the cut-in speed of a typical wind turbine is 3 to 4 m/s, and that rated power is reached at 9 m/s. These are the assumptions made by the noise consultant hired by the proponent of the Gullen Range Wind Farm (GRWFEA, Attachments, vol. 2, 3.2, p. 12). This assumption is also made by the Australian acoustician Mr Steven Cooper in a personal communication (Boorowa District Landscape Guardians, 14.2.2012).

Blade stall

Another source of wind turbine noise, partly aerodynamic and partly mechanical is blade stall, or what has been called "woomping". This phenomenon is clearly described by Dickinson:

> As the blades cover such a large area, it is possible for one blade to have insufficient wind to move it, while the other blades still have lift. This causes one blade to stall and produces an imbalance in the system and eccentric bending moments on the rotor shaft. When a blade partly stalls and starts up again, the imbalance is exacerbated and results in a thumping noise in the turbine itself. The sound has been described as a 'woomping', by local residents in New Zealand at distances of between 1 and $1^1/_2$ kilometres from the turbine. The directionality of this sound depends on the rotor housing and may propagate equally in an upwind as well as a downwind direction. The sound downwind however is encircled by the spinning helix of sound from the vortex shedding by the blades and carried along by the airflow. (Dickinson, 2010, p. 185)

This topic, blade stall, is not discussed anywhere in the draft Guidelines. It ought to be. It needs to be taken into account in the modelling and prediction of a proposed wind farm's noise impacts, and it needs to be considered during the compliance monitoring after the wind farm has commenced operation.

Mechanical noise

It s generally agreed that the operation of the mechanical components in the nacelle – at least when new – is relatively quiet. The problems begin as those components age, and suffer wear and tear. This can lead to significant increases in noise. Dickinson writes:

> A new turbine is fairly quiet, but as it gets older the components wear, particularly the rotor shaft, bearings and gearbox, and the noise emission increases. *An increase of 10 dB through wear and tear, or even more, should not be unexpected.* The same also applies to the blades. As time goes on and they wear or become corroded or dirty, the boundary layer airflow becomes less smooth and produces more drag. The blade is then less efficient and produces less power in the turbine. Arguably there may be more turbulence and hence more noise generated. (Dickinson, 2010, p. 185) (italics added)

An increase of 10 dB at the turbine is likely to lead to an audible increase in sound level at a neighbour's residence, and may bring the turbine into non-compliance with its conditions of consent.

This topic is not discussed anywhere in the draft Guidelines. Although the draft Guidelines have section on the *Management of specific noise characteristics* (pp. 33-34), this topic is not raised there.

Furthermore, increased noise due to wear and tear require that compliance monitoring be ongoing and regular during the lifetime of the wind farm, and not limited to a single act of

compliance monitoring in the year or so after the wind farm commences operation. (see below under *Compliance monitoring*.)

Propagation

There appears to be a debate amongst acousticians as to whether the propagation of wind turbine sound should be regarded as spherical (or hemispherical), or cylindrical, or a combination of the two. The issue is of crucial importance to the modelling and prediction of wind turbine sound, as spherical spreading is supposed to see the sound attenuate at a rate of *6 dB per doubling of distance*, whereas cylindrical spreading is supposed to see the sound attenuate at a rate of *3 dB per doubling of distance* (Dickinson, 2010, pp. 186, 192).

Dickinson cites NASA studies from the 1980s and 1990s which suggest that the concept of cylindrical spreading cannot be ignored:

> NASA studies [Hubbard and Shepherd, 1991] show that at distances greater than about 750 metres from a wind turbine the sound propagation more closely follows that of cylindrical spreading, i.e. a line source. (Dickinson, 2010, p. 190)

Dickinson discusses the case of a wind farm in the Manawatu of New Zealand, where conventional noise modelling, using the concept of spherical spreading, predicted a noise level of 30 or 33 dB at a point 2.5 kilometres from the nearest turbine (depending on whether NZS 6808:1998, or ISO 9613-2 were used). In fact, the actual noise level at that point (L_{eq}) was 50 dB. Thus, the discrepancy between the noise predicted and the actual noise received was 17 to 20 dB. However, modelling the noise level as a line source gave a much more accurate prediction:

> For this same situation, using a line source as suggested in the NASA studies [ibid] gives a predicted sound level of 49 dB ... which is not far from being within the tolerances of the Class 1 instrumentation used. (Dickinson, 2010, p. 190)

In another study Dickinson presents a photograph of a smoke trace marking the path of the airflow carrying the sound of vortex shedding from the blade tips of a wind turbine. The path is clearly heliacal, and cylindrical (Dickinson [2011], p. 5). In the same study Dickinson presents another photograph (taken from Shephard, I., 2010), which shows the plumes of condensed airflow carrying the vortex shedding sound from the Horns Rev Wind Farm in the North Sea. Once again, the spreading is clearly cylindrical (Dickinson [2011], pp. 5-6). Dickinson comments:

> These are the same vortices that generate and carry the sound on the wind. The sound does not propagate equally in all directions, as most standards assume, but is highly directional. (Dickinson [2011], p. 5)

If conventional modelling of wind turbine sound assumes spherical propagation, while the reality is cylindrical propagation, then the predicted levels of sound received at neighbours' residences are likely to be very inaccurate. This is likely to be another large component of the explanation of the fact that existing wind farms generate ongoing noise complaints from neighbours, even though these wind farms have been approved under current noise guidelines.

This issue is regrettably not discussed anywhere in the draft Guidelines. The proponent is required to select a "suitable" model of sound propagation, but the Guidelines do not state what such a suitable model would be (p. 35).

The draft Guidelines note that "[t]here is no standard procedure directly applicable to sound propagation from wind farms, although ISO9613-2: 196 *Acoustics – Attenuation of sound during propagation outdoors – Part 2: General method of calculation* or the CONCAWE noise propagation model is commonly used." (p. 35)

If there is no standard procedure for modelling the propagation of wind turbine sound, and further research is needed to establish one, then there should be an immediate moratorium on wind farm development in NSW, until that research is completed. The issue is of fundamental importance to the protection of neighbours' health, well-being, and amenity, given the degree of discrepancy between predicted and actual noise levels noted by Dickinson above.

Failing that, cylindrical spreading rather than spherical spreading should be assumed, and the method used by NASA (see above) should be required to be used.

Influence of the wind on sound propagation

Another reason for calling in question the validity of a simple model of spherical propagation is the influence of the wind itself. Wind speed and direction determine the refraction of a turbine's sound waves, and consequently whether the resulting sound level at a neighbour's residence is increased or decreased. Dickinson explains:

> The wind velocity generally increases with height and so downwind the combined velocity [sc. of the sound and of the wind] increases with height and the sound waves are refracted towards the ground, giving an increase in the expected level of sound at some distant point ... Upwind the combined velocity decreases with height and the sound waves are refracted away from the earth, producing areas where no sound is heard. These areas are called shadow zones. In fact, sound can enter a shadow zone as a result of diffraction, scattering off objects, wind turbulence, and by the propagation along the surface of the ground itself. (Dickinson, 2010, p. 186)

Refraction by the wind thus explains the commonly observed phenomenon that turbine noise heard downwind is greater than turbine noise heard upwind. If the host of a wind farm has his house upwind of the turbines, he may affirm that he is not troubled by the noise, while his neighbours downwind are complaining vociferously about the noise.

This aspect of wind turbine sound propagation must be considered especially important when it is considered that the majority of neighbouring dwellings are likely to be situated downwind of any rising ground on which a wind farm will stand. The dwellings will have been located downwind of the rising ground in order to benefit from the shelter it gives from the wind. Ironically, it is this very sheltered position that will expose those dwellings to increased noise. What was shelter from wind now turns into extreme exposure to noise. (As we shall see below, a downwind location is especially important in relation to increased night-time noise.)

Refraction by the wind, therefore, needs to be taken into account in the modelling done for a proposed wind farm.

This topic is not mentioned anywhere in the draft Guidelines. It ought to be. It must be factored into the calculations of the noise levels that the wind farm will probably produce.

Heightened noise zones, and Wake and turbulence effects

An array of multiple turbines can give rise to increased noise at a neighbouring residence, whether the turbines be in a row across the line of sight from the residence, or whether the turbines are all in a line with the residence. These situations have been studied by Dr Huub Bakker of Massey University, New Zealand, and Mr Bruce Rapley of the environmental consultancy Atkinson & Rapley Consulting Ltd. Bakker and Rapley modelled the variations in noise received, and corroborated their predictions by field studies (Bakker and Rapley, 2010).

In the first case, where the array of turbines is in a row across the line of sight from the residence Bakker and Rapley refer to *Heightened noise zones*. The Heightened noise zone is created by the way in which sound waves and vibrations from the multiple turbines converge and interfere with one another. They write:

> The Heightened Noise Zone (HNZ) is the combined effect of directional sound and vibrations (wave trains) from the towers, the phase between turbines' blades and lensing in the air or ground. The interference between the noise (audible), or vibration, from different turbines creates very localised patches of heightened or lowered noise/vibration in much the same way as ripples on a pond can combine to form large ripples (*antinode*) or relatively still water (*node*).
>
> The sounds/vibrations travel outwards from the individual turbines to any affected home. Here the interference creates the larger peaks and troughs of a Heightened Noise Zone...
>
> The HNZs can be small in extent – even for low frequencies – leading to turbine sounds 'disappearing' and 'appearing' in areas spaced only a few paces apart...
>
> These attributes of Heightened Noise Zones – small size and the dependence on time-related factors like wind direction – explain much of the problem of wind farm noise and its variability as heard by residents. (Bakker and Rapley, 2010, pp. 233-236)

If a residence happens to be in the *antinode*, given the current wind direction, then the noise at the residence will be increased. As the wind direction changes, so will change the location of the *antinode*, and the residence will no longer receive increased noise. But, meanwhile, because of the changed wind direction some other residence may now find itself in an *antinode*, and so experience increased noise levels.

Bakker and Rapley report that Heightened Noise Zones can mean a difference in sound level of *10 to 20 dB* within only a few metres (Bakker and Rapley, 2010, p. 258). It is conventionally assumed that a difference of 10 dB means that the higher sound level is twice as loud as the lower, and that a difference of 20 dB means that the higher sound level is 4 times as loud as the lower. It follows that if the noise level predicted at a residence is just on the official noise limit, and the actual noise produced by the turbines is 20 dB higher because of a Heightened Noise Zone, then the actual noise at the residence will be four times as loud as what the official noise limit allows. *Thus, Heightened Noise Zones can totally subvert the function of the official noise limit.*

And, as Bakker and Rapley suggest, Heightened Noise Zones can explain a large part of the variability of wind turbine noise, as heard by residents.

The other situation, where multiple turbines are all in a line with a residence, and the wind is blowing along the line of turbines, can give rise to *Wake and turbulence effects*.

A wake and turbulence effect is produced when the blades of a downwind turbine pass through the turbulent outer wake of an upstream turbine, and enter into the smooth *inner* wake of the upstream turbine. This can happen if the turbines are located within 10 rotor diameters of each other, as is commonly the case. When this happens, there will be increased noise. (Bakker and Rapley, 2010, pp. 243-244)

Even if the turbines are further apart, when the wind speed increases, as with a gust, the length of a turbine's smooth inner wake can be extended. As Bakker and Rapley state: "Should the smooth wake extend to the downwind turbine, it will interact with the turbine blades to cause increased sound until the wind gust dies and the smooth wake retracts (Bakker and Rapley, 2010, p. 245).

Bakker and Rapley describe the change in what is heard:

> The audible effect will change from a smooth characteristic ('plane landing' sound) to a dissonant characteristic (the 'rumble/thump', for example, where the normal 'swish' becomes much louder). (Bakker and Rapley, 2010, p. 245)

Finally, there is the quasi-musical effect of variations in the vortex shedding of multiple turbines. Bakker and Rapley write:

> A vortex travels downwind as a helix, rotating about its axis. As each new vortex is created it replaces the previous one at approximately 1 second intervals – sometimes more, sometimes less depending on the speed of rotation and number of blades. When two or more turbines are rotating at a similar speed they will shed these vortices at nearly

> the same rate. As the rates of shedding change with respect to each other the sounds can create a 'beating' similar to two, slightly different notes of music. (Bakker and Rapley, 2010, p. 246)

Heightened Noise Zones, and these wake and turbulence effects are obviously very important as sources of increased noise, and in the variations of noise experienced by different receivers, and in different circumstances. And, as suggested above, these effects can totally subvert the function of official noise limits.

It should be emphasised that the effects described above are *specific to wind turbine noise*. It is therefore essential that they be taken into account in the modelling of wind turbine noise impacts. Not to take them into account is to ignore one of the most typical sets of characteristics of wind turbine noise, and to undermine the whole purpose of the modelling.

It is therefore very unfortunate, to say the least, that neither Heightened Noise Zones nor these wake and turbulence effects are discussed in the draft Guidelines. They ought to be. A failure to consider them during the noise modelling is likely to lead to a gross underestimation of the peak levels of noise experienced at neighbours' residences. If there is any difficulty in modelling them, then that is another reason for a moratorium and further research. At the very least, a generous penalty is required to take account of them, for the sake of the precautionary principle.

The impulsive nature of wind turbine sound

It is well known that wind turbine sound is characteristically *impulsive*. This phenomenon is sometimes referred to as aerodynamic modulation, and sometimes as amplitude modulation. The amplitude, or sound pressure level of the sound energy rises and falls periodically.

If the sound is at a level to be audible, then the hearer hears the sound getting louder and softer, louder and softer ... But, amplitude modulation can still be present even if the sound is inaudible. The infrasound generated by wind turbines (see below) is amplitude modulated, even though it is inaudible.

Amplitude modulation is usually said to occur at a rate of about once every second (the *blade pass frequency*). However, recent acoustic research has shown that there can also be modulation on a micro-time scale, in milliseconds rather than seconds. Both of these kinds need to be considered.

Once again, it must be emphasised that we are dealing here with phenomena that are specific to wind turbine sound, and which therefore must be adequately taken into account by any new noise guidelines.

Amplitude modulation on a macro-time scale:

As said above, amplitude modulation is usually discussed as occurring at a rate of about once every second. This is due to the facts that a wind turbine rotor usually has three blades, and characteristically rotates at a rate of about 20 revolutions per minute. This means that a blade passes the tower about every second. Dickinson gives the following general account:

> A further sound source is a slicing of the airflow as the blades pass the pylon on which the wind turbine is supported. As the blade passes the pylon, the airflow (from the wind) is sliced from hub to tip, and this happens once per second for a three bladed rotor working at 20 rpm. At the hub the airflow is impeded, as it is by the pylon, but further down the blade the air is chopped at the speed the blade passes that position on the pylon. Near the hub the frequency generated is about 2000 Hz but near the tip of a 45 metre blade, which will be passing the pylon at a speed of around 475 km/h, the frequency generated will be more than 10 kHz. (Dickinson, 2010, p. 185)

It has been claimed that noise problems have been reduced with modern turbines that have their rotor upstream of the tower. But, Doolan points out that even such modern turbines involve the blades passing through a disturbed airflow, resulting in the production of noise. He writes:

> The interaction of the rotor blade with the tower can also be an important source of noise. In the early development of wind power, downwind turbines were common and produced high levels of noise associated with the interaction of the tower wake with the rotor blades. This form of noise is generated in a similar way the leading edge interacts with turbulent eddies, instead in this case the eddies are created by the tower itself. Modern horizontal axis wind turbines place the rotor upstream of the tower, thus eliminating the wake-rotor interaction. *However, the blades still pass through a region of perturbed flow upstream of the tower (Wagner et al., 1996), creating unsteady lift and hence noise.* (Doolan, 2011, p. 1) (italics added)

Doolan writes, under the heading *Blade-Tower Interaction*:

> Impulsive noise may be generated by the interaction of the blades with the perturbed flow upstream of the tower. Figure 3 illustrates the phenomenon. The flow over the tower creates a region of non-uniform flow upstream of the tower, represented by the curved streamlines in Fig. 3. As the rotor blade passes through this perturbed flow region, the angle of attack changes on the blade, causing a fluctuation in lift force. This fluctuation in lift force creates radiated sound with a time scale associated with the size of the perturbed flow region upstream of the tower....
>
> .... As shown in Fig. 4, three pulses are generated during each revolution. The creation of each pulse occurs when a blade passes the tower and interacts with the perturbed flow region. (Doolan, 2011, pp. 3-4)

Doolan notes that such "a repetitive impulsive noise source will contain a variety of frequency components." While most of the sound energy in his example is contained at 4 Hz (infrasound), with multiple components at 24 Hz (just audible low frequency sound), there is also sound energy present at about 500 Hz, which is responsible for the audible ‘swish’ (Doolan, 2011, p. 4). He writes:

> Broadband noise at a relatively high frequency is the dominant component of blade swish. Although modulated at the blade passing frequency (approx. 1 Hz), blade swish cannot be considered a low frequency noise source. Rather, it is an amplitude modulated broadband source with dominant energy at about 500 Hz (for the example turbine in this paper). Swish has been recorded from wind turbines for many years (Hubbard et al., 1983, Oerlemans and Schepers, 2009) and can be attributed to noise generated at the trailing edge of the outer part of the turbine and its forward looking directivity pattern coupled with blade rotation. (Doolan, 2011, p. 4)

But, developing his statement that most of the sound energy present in his example is at 4 Hz (i.e. infrasound), he generalises about the presence of such low frequency sound:

> The analysis above also shows that a low frequency noise source is also present due to BTI [blade-tower interaction] and turbulence leading-edge interaction mechanisms. However, the analysis is only sufficient to predict the dominant frequencies. Determination of the strength of these noise sources will depend on many factors that include the aerodynamic coupling of the blade and tower, viscous effects on the blade, the dimensions of the turbine and tower as well as the aeroelastic properties of the rotor and atmospheric turbulence levels. (Doolan, 2011, p. 4)

The preceding two quotations show that the relatively high frequency *swish* is associated with *trailing edge sound*, whereas the *low frequency (infrasonic) modulation* is associated with *turbulence leading edge interaction*.

The question arises whether the presence of amplitude modulated infrasound is important or not. I will consider this later.

There can be little doubt, however, that audible amplitude modulation is a major source of disturbance to neighbours. Doolan describes observations made by van den Berg:

> Recent measurements and observations taken at a European wind farm (van den Berg 2004) show a marked difference between day and night. During a summer’s day, the level of noise from the wind farm was low or not perceivable, even in strong winds (on the ground). On “quiet nights”, residents up to between 500-1000 m observed “pile-driving” noise at a rate coinciding with the blade passing frequency. An observer at 1900 m described the noise as an “endless train”. (Doolan, 2011, p. 4)

These descriptions, “pile-driving” and “endless train”, suggest a much more severe noise, going well beyond “swish”. This difference between two kinds of audible amplitude modulation is discussed by Bakker and Rapley. They report on noise measurements for the Makara Wind Farm in New Zealand. Referring to a sonogram depicting noise from the wind farm, they write:

> The vertical lines indicate pulsing or beating in the sound at slightly over 1 second intervals. This is the 'swish' that is often described by residents. The differences in colour indicate that *this pulsing has a magnitude of as much as 10-14 dB....* (italics added)
>
> The triplet of vertical lines is somewhat different in that it spans many more frequencies and the peaks are louder – more than 20 dB louder at some frequencies.... Because of the larger peaks and the many more frequencies involved, this triple peak is more easily picked up by the human ear from the background, i.e. is more salient.
>
> This is the 'rumble/thump' that has been described by residents. (Bakker and Rapley, 2010, p. 251)

It is commonly said that amplitude modulation is typically only 3 to 4 dB (e.g. Dickinson, 2010, p. 184). It must be noted here that even the 'swish' observed at the Makara Wind Farm was 10 to 14 dB. Recall that a difference of 10 dB is supposed to mean that the higher sound is twice as loud as the lower. A difference of 14 dB would mean that the higher sound is almost three times as loud as the lower.

On Bakker and Rapley's graph (Bakker and Rapley, 2010, p. 251, Fig. 23) one of the modulations of the 'rumble/thump' is clearly about 16 dB from peak to trough.

Regular modulations of audible sound level of this magnitude cannot be ignored. The human hearing mechanism is designed to register them, as a warning device to ensure the survival of the species. Bakker and Rapley sum this up, and draw out the corollaries:

> Sound that has modulation at the frequencies of about 0.3 Hz to 10 Hz [i.e. at intervals of several seconds to about one-tenth of a second] is distinctive; the ear and brain of our primitive predecessors (mammals and reptiles) evolved to pick these types of sounds out from the background. In this respect this modulation displays 'salience', the property of standing out from their surroundings. Again, because of the evolution of the brain, distinctive, or salient, sounds trigger the 'alert mechanism' in the primitive hind-brain because they do stand out from the background. Repetitive, or sustained, triggering of the human alert mechanism causes increases in anxiety levels and, over days and weeks, the attendant symptoms associated with anxiety; sleep disturbance, tiredness, nausea and depression. (Bakker and Rapley, 2010, pp. 246-247)

Amplitude modulation is, therefore, directly connected to the issue of adverse health effects from turbines. Even if audible amplitude modulation is only partly responsible for sleep deprivation of neighbours of wind farms, this is sufficient reason for it to be subjected to the most rigorous regulation.

Amplitude modulation on a micro-time scale:

The recent work of US acousticians Wade Bray and Richard James has established that there is amplitude modulation of wind turbine sound at low and very low (infrasonic) frequencies, at and below 50 Hz. This amplitude modulation has a very high *crest factor* (i.e. very sharp peaks and troughs), occurring about once every 60 milliseconds, or about 16.7 times per second. This kind of amplitude modulation has hitherto been undetected, because it is not registered by the usual kind of macro-time scale measurements (e.g. L_{eq}), becoming apparent only when micro-time measurements are made (Bray and James, 2011).

Bray and James emphasise:

> Human hearing and other senses (vision, touch...) are sensitive to and provide information from our environment on a micro-time scale.... Many acoustical measurements (L_{eq}, etc.) are on a macro-time scale, yet we are immersed over macro-time in a life comprised of micro-time detail. It is incorrect to present only macro-time measurement results as representative of sensation ....we must always try to assemble context-valid measurement data sets best representing “the *human* function.” (italics in original) (Bray and James, 2011, section 1. Introduction)

Micro-time measurement is especially important for auditory phenomena involving a high crest factor, such as the amplitude-modulated low frequency noise emitted by wind turbines:

> A common measurement with wind turbines employs very high frequency-domain resolution enabling display of the harmonic series due to the blade-pass rate as an apparent near-steady pure tone family (macro-time scale), yet in the micro-time sensation range of human hearing and the function of its transducer, that result is completely unconnected to the high crest factor short-term events at low and very low frequencies resolvable at shorter time-scales and by wider acquisition bandwidths. The central measurement guiding other supporting analyses in any class of sound quality/human perception issues must be an auditorily-relevant one, involving the time-scale of the human receiver. (Bray and James, 2011,section 1. Introduction)

In other words, if the true dimensions of the amplitude modulation of wind turbine low frequency sound are to be measured, then the usual methods and descriptors of wind turbine sound measurement will not do, and the new method on a micro-time scale, proposed by Bray and James, must be used. They explain in simpler language in a note introducing their paper, on the website of *Windaction*:

> The reason the wind industry experts could claim that wind turbines produced insignificant levels of infra and low frequency sound is not because there isn’t any, but instead, because the instruments/methods they used could not detect it. They went hunting for a needle in the haystack using a magnet when the needle was made out of plastic.
>
> When analysed using a tool that can detect it, we find that it is there and at SPL’s much higher than previously considered likely. The infrasound from wind turbines rises and falls in sound pressure level (amplitude modulation) at a very rapid rate (approximately 60 msec peak to peak or so) and with a high dynamic range, phenomena too fast to be

> ‘noticed’ when standard acoustical filters are used to isolate this region of acoustic energy (a 1 Hz ANSI S1.11 1/3-octave filter has an impulse response of about 5 seconds).
>
> The understatement of the true peaks that occurs during analysis using standard acoustical instruments/methods flattened and stretched out the dynamic modulation (crest factor) leading to a misconception that the levels were insignificant. (Bray and James/Windaction, 2011)

We shall have to return to Bray and James’ research below, when we consider the issue of the presence of infrasound in wind turbine sound. For now, what we are concerned with is the simple fact that there is a kind of amplitude modulation of wind turbine sound, at very low frequencies, *which has hitherto gone undetected*.

Bray and James measured very low frequency sound and infrasound, at and below 50 Hz, at the Michigan Wind I Wind Farm at Ubly, Michigan. The receiver location was about 1500 feet (about 455 metres) from one of the 46 x 1.5 MW turbines (Bray and James, 2011, section 2. Description of test site).

Using High-resolution Spectral Analysis, Bray and James determined that the dominant energy of the wind turbine signals was in the 1.5-10 Hz range, strongest between 2 and 8 Hz (Bray and James, 2011, section 8. Short-term high-resolution time-frequency information). This is of course infrasound.

Introducing the concept of crest factor, Bray and James state:

> A particularly important characteristic often separating perception from measurement is the crest factor of the time signal (ratio of peak to rms value [root mean square] over an interval. Usually assessed in linear units, not in dB although it may be so expressed, it provides near-zero time weighting limited only by the available signal bandwidth. A perfect sine wave has a crest factor of 1.414, Gaussian noise between 3 and 5, and thermal noise (a Gaussian noise) approximately 4. *Higher values suggest impulsiveness and identify a clearly time-varying signal*. (Bray and James, 2011, section 3.2 Crest factor) (italics added)

So, a crest factor higher than 4 suggests impulsiveness, i.e. amplitude modulation. Bray and James’ graph of the crest factor of the wind turbine signals recorded at Ubly shows a crest factor varying mostly between about 10 and 18, with a high point at about 21 (Bray and James, 2011, section 6. Wind turbine results). This is noise with a very high degree of impulsiveness.

Another graph shows the peak sound pressure levels corresponding to these crest factors. The graph shows the peak values varying between about 77 dB SPL and almost 100 dB SPL (Bray and James, 2011, section 6. Wind turbine results).

The high crest factor values are associated with the rapidity of the occurrence of this kind of amplitude modulation. As stated above, the rate is about once every 60 milliseconds, or about 16.7 times per second. As Bray and James emphasise, this micro-modulation is detectable by the human hearing mechanism. They hypothesize that the high crest factor could influence the probability of such modulation either being heard, or still being unconsciously detected at levels different from those calculated on the basis of macro-time measurements:

> We have shown that wind turbine signals are strongly and varyingly time-structured, perhaps unusually so at frequencies below 100 Hz which may affect the likelihood of audibility or other physiological response from low-frequency and even infrasonic wind turbine noise proving to be different from thresholds calculated from L_{eq} and from tone-sensitivity such as by ISO 226 because of the crest factor, rapid rate of change on the order of ~60 milliseconds, and the pattern sensitivity of the human receiver (Bray and James, 2011, Discussion).

Concluding their discussion, Bray and James recommend that the current macro-time scale methods of measuring wind turbine sound (L_{eq}, etc) be supplemented by micro-time scale methods, since this is the only way that this kind of amplitude modulation can be measured, and assessed:

> To help bridge the gap between conventional macro-time measurements in level and frequency and the heretofore-missing consideration of the micro-time-sensitive human receiver, the authors suggest adding to the conventional measures some others which track these sensitivities. A plot of low-frequency peak value, rms value and crest factor, calculated at ear-appropriate time resolution for example ... in 1-minute bins and plotted versus time would assist, as would statistic tabulations from them such as the peak, rms and crest factor values exceeded 50%, 5%, and 1% of the time. (Bray and James, 2011, Discussion)

Inevitably, they call for further research. (As we shall see below under *Low frequency noise*, further research has been carried out and presented by the British acoustician M. A. Swinbanks.)

Finally, to bring out the significance of their research for the issue of potential adverse health effects from this kind of micro-amplitude modulation of low frequency wind turbine noise, Bray and James, in their *Windaction* statement refer to the work of the US medical researcher Professor Alec Salt. We shall refer to Salt's work below, under *Infrasound*, and under *Health*. Bray and James include a statement by Salt in their Appendix 3. In this statement Salt summarises his own research, which has established that inaudible infrasound stimulates the Outer Hair Cells in the cochlea at 60 dBG, and that inaudible infrasound levels of about 70 dBG are commonly generated by modern upwind turbines. Salt points out that the effect of such stimulation on the nervous system remains at present uninvestigated, but that the signals could be transmitted to the brain by type II afferent fibers. He asserts that it is too soon to conclude that the ear cannot be affected by wind turbine noise. He points out that the annoyance experienced by the neighbours of wind farms could be due to the modulation of audible wind turbine sound, but that it could also be due to a biological modulation of infrasonic turbine signals inside the cochlea, caused by a variation of Outer Hair Cell gain, as operating point is biased by the infrasound. (Bray and James, 2011, Appendix 3)

It is in this context that Bray and James state:

> This study shows that when analysed according to the time response of the human transducer, the peaks of the energy waves can be above 90 dB SPL. Combined with the findings of Dr Salt's research this analysis shows that the dynamically modulated infrasound can be perceived by the auditory system at levels that are below the conventionally-determined threshold of audibility.
>
> It is the short duration and extent of the change in sound pressure that is stimulating the vestibular system, not the overall energy level. This is not about the average energy but instead about the short duration, peak values and extent of change in energy assuming that some lower threshold like Dr Salt's 60 dBG for OHC activity has been reached. (Bray and James/Windaction, 2011)

The NSW draft guidelines:

The NSW draft Guidelines seem to be unaware of the latest research, both on amplitude modulation at the blade pass frequency, and on the amplitude modulation of low frequency and infrasonic turbine noise on the micro-time scale.

The Guidelines refer to "reasonable levels" of amplitude modulation, and seem to imply that a reasonable level is 4 dB or less (p. 34). Since a difference of 3 dB is audible to human hearers, even 4 dB could keep people awake if it is persistently audible in a bedroom at night.

However, what is even more important is that the Guidelines seem to be oblivious to the fact that the real magnitude of the audible modulation may be as much as 10 or 14 dB. If this can be predicted in advance, what justification can there be for only a 5 dB(A) penalty (p. 34)? If the modulation cannot be predicted in advance, then neighbours are being put at risk by reckless planning, and capital is likely to be wasted, if turbines have to be turned off after the wind farm has begun to operate.

It is said that the penalty applies only if the modulation is audible at the relevant receiver (P. 34). It then undermines this notion by stipulating that absence of excessive modulation measured at an intermediate location is sufficient proof that the modulation is not a feature of the wind farm (p. 34). This is one occasion where the Guidelines offer to allow the operator not to take measurements at the neighbour's residence, but to take a measurement somewhere else instead. What is the point of this? Why should not the operator be compelled to take a measurement at the place where the complaint is made? That is the only rational procedure. It is certainly the only procedure in which neighbours can have any confidence. **This ruling that the operator can take the measurement at an intermediate location must be withdrawn.** The Department of Planning should have more respect for the communities who will be forced to live beside wind farms.

Amplitude modulation *for all frequencies*, including low frequency noise and infrasound needs to be accurately modelled. If this cannot be done, then there should be a moratorium on wind farm development until the necessary research is completed.

The methods used by Wade Bray and Richard James to measure amplitude modulation on a micro-time scale need to be incorporated into the modelling, and compliance monitoring of wind turbine sound in NSW. *This is essential.* The same methods can be used for higher frequency turbine sound as well as for low frequency sound and infrasound. This should therefore be done. If this is done, the misrepresentations resulting from using macro-time scale measurements like L_{eq} can be avoided.

The NSW government must commission research into the connection between amplitude modulation (at all frequencies) and the potential adverse health effects of annoyance, sleep disturbance, and the cluster of symptoms, including headache, nausea, dizziness, vertigo, ear pressure, ear fullness, tinnitus, tachycardia, etc, etc. The NSW Department of Health has been most remiss in ignoring this issue. The evidence of acousticians such as Bakker and Rapley, and Bray and James, taken in conjunction with the work of Salt and his colleagues is sufficient to give grounds for serious concern. (See under *Health* below.)

Low frequency noise (audible)

I will discuss audible low frequency noise in this section. I will discuss inaudible infrasound separately in the next section.

Although there is some variation in professional opinion as to where the threshold is between infrasound and (audible) low frequency sound, I shall follow Thorne (2010). Thorne writes:

> The sound [sc. from wind turbines] can be characterised as being impulsive and broadband, audible and inaudible (infrasonic):
>
> - Infrasound below 20 Hz
> - Low frequencies 20 Hz to 250 Hz
> - Mid Frequency 250 to 2000 Hz (broadly, although the higher level could be 4000 Hz)
> - High frequency 2000 Hz to 20,000 Hz (Thorne, 2010f, p. 217)

(Dickinson quotes some sources that put the threshold between infrasound and low frequency sound at 15 or 16 Hz. (Dickinson, 2010, p. 198))

The draft Guidelines state: "Analysis of wind turbine spectra shows that low frequency noise is typically not a significant feature of modern wind turbine noise and is generally less than that of other industrial and environmental sources." (p. 34)

Whether wind turbine low frequency noise is less than that of other industrial and environmental sources is beside the point. What is in question is whether wind turbine noise is sufficient to disturb neighbours unless adequately regulated. As we shall see below, even the Australian wind industry now admits that this is so.

It is astonishing that the NSW Department of Planning persists in the view that low frequency noise is typically not a significant feature of wind turbine noise. This is totally untrue, and indeed the very opposite of the truth. *Wind turbine noise is predominantly low frequency noise and infrasound*, as recent independent research has abundantly shown.

As we have seen above, the Australian acoustician Bob Thorne has described wind turbine sound as "impulsive and broadband, audible and inaudible (infrasonic)."

Dickinson writes:

> Almost all standards, including NZS 6808, assume wind turbines do not generate low frequency sounds of any significance. So, in that case, the effects do not need to be considered, and a simple A-frequency weighted sound level control is all that will be required.

> **Yet as the local residents report it is the coming and going, low frequency rumbling that is the main noise problem.** (Dickinson, 2010, p. 197) (bold in original)

Dickinson analyses a graph of wind turbine sound, taken from the work of US acoustician Richard James, finds that the sound energy present is predominantly low frequency and infrasound, and explains that the A-weighted measurements on which the wind industry relies will simply not register the true magnitude of the low frequency noise and infrasound present:

> In terms of energy, more than 98% of the sound energy in the figure [Fig. 5, p. 193] is below 125 Hz, yet wind farm proponents say "there is simply no dominance of low frequency sound." This is not strictly true, of course, as the statement is based on A-frequency weighting each 1/3 octave band and refers to each band individually. (Dickinson, 2010, p. 199)

John P. Harrison of Queen's University, Kingston, Ontario writes:

> The noise emitted by a turbine is broadband; however, at a distance of 500 meters and more, the higher frequencies have been absorbed by the atmosphere so that *it is predominantly low-frequency noise that reaches a receptor*. This low-frequency noise enhances annoyance and is more readily able to penetrate walls and resonate inside rooms. Many people report a thumping, rumbling, or impulsive character to the turbine noise (e.g. Frey & Hadden, 2007; Harry, 2007); the reason is not clear. (Harrison, 2011, p. 258) (italics added) [N.B. Doolan, Dickinson, and Bakker and Rapley have offered analyses relevant to the explanation of "rumble/thump": see above.]

Even the wind energy industry in Australia now admits that there is an issue with low frequency noise, because of the different rates of decay of high and low frequency noise. This is apparent from the Sonus report for the Clean Energy Council. Sonus states:

> Noise reduces over distance due to a range of factors including atmospheric absorption. The mid and high frequencies are subject to a greater rate of atmospheric absorption compared to the low frequencies and therefore over large distances, whilst the absolute level of noise in all frequencies reduces, the relative level of low frequency noise compared to the mid and high frequency content increases.

Sonus goes so far as to admit:

> This effect is exacerbated in an environment that includes masking noise in the mid and high frequencies, such as that produced by wind in nearby trees.

Sonus now admits that at a neighbour's residence the turbine sound received is likely to be predominantly low frequency, and that this will be an increasingly important problem as wind turbines get bigger:

> A typical separation distance between wind farms and dwellings is of the order of 1000 m. At similar distances, in an ambient environment where wind in the trees is present, it

> is possible that only low frequencies remain audible and detectable from a noise source that produces content across the full frequency range [i.e. a wind farm!]. This effect will be more prevalent for larger wind farms because the separation distances need to be greater in order to achieve the relevant noise standards. A greater separation distance changes the dominant frequency range from the mid frequencies at locations close to the wind farm to the low frequencies further away, due to the effects described above. (Sonus, 2010a, p. 9)

Low frequency sound is not only less attenuated by distance, but is less likely to be kept out by the walls of a house. One only has to think of the experience of listening to the music coming from an all-night party, as one tries in vain to fall asleep: one cannot hear the melody of the music, but one can certainly hear the bass. An article in the *Journal of Low Frequency Noise, Vibration and Active Control* states:

> Unlike higher frequency noise issues, LFN [low frequency noise] is very difficult to suppress. Closing doors and windows in an attempt to diminish the effects sometimes makes it worse because of the propagation characteristics and low-pass filtering effect of structures. Individuals often become irrational and anxious as attempts to control LFN fail, serving only to increase the individual's awareness of the noise, accelerating the above symptoms. (DeGagne et al., 2008, p. 116)

As Harrison notes above, low frequency noise can resonate inside rooms. It can even resonate the organs inside a human body, as is affirmed in a study by the chief author of the World Health Organization's *Guidelines for Community Noise*, Birgitta Berglund:

> Low frequency noise (infrasound included) is the superpower of the frequency range: it is attenuated less by walls and other structures; it can rattle walls and objects; it masks higher frequencies more than it is masked by them; it crosses great distances with little energy loss due to atmospheric and ground attenuation; ear protection devices are much less effective against it; *it is able to produce resonance in the human body*; and it causes greater subjective reaction (in the laboratory and in the community studies) and to some extent physiological reactions in humans than mid- and high frequencies. (Berglund et al., 1996, p. 2993) [italics added]

The draft Guidelines claim that *analysis of wind turbine spectra* shows that low frequency noise is typically not a significant feature of modern wind turbine noise (p. 34). It is precisely the analysis of wind turbine spectra that shows that low frequency noise *is* not just "a significant feature", but an inseparable and indeed the dominant feature of wind turbine noise. Any number of studies by independent researchers have appeared in the last few years, providing a full spectral analysis of the sound from the wind farms studied. They all show the same thing: at residences the sound immitted has most of its energy in the low frequency and infrasonic ranges, with much less energy in the high and mid frequency ranges. I have already discussed Dickinson's analysis of James' data (see above). I could also cite studies by Bray and James (2011), Thorne (2011b), Bakker and Rapley (2010), Ambrose and Rand (2011), and Cooper (2011). There is no doubt whatever that low frequency noise and infrasound predominate in the sound mix that arrives at the residences of the neighbours of wind farms. This no longer has to be proved.

In view of Sonus's admissions, on behalf of the Clean Energy Council, it is absurd for the NSW Department of Planning to maintain that low frequency noise is not a "significant" [weasel word] feature of noise from modern wind turbines. The sentence expressing this falsehood should be removed from the Guidelines.

Low frequency noise and crest factor:

We saw above that Bray and James have shown that amplitude modulation of low frequency and infrasonic wind turbine sound occurs on a micro-time scale, at a rate of about once every 60 milliseconds, with high levels of sound pressure, commonly above 90 dB SPL. This rapid modulation is associated with a very high crest factor, between about 10 and 20. Bray and James raise the issue of how such a high crest factor could affect the audibility of, or the physiological response to the low frequency turbine noise (Bray and James, 2011). In a recent paper the British acoustician Dr M. A. Swinbanks takes up this issue.

Swinbanks offers to show that low frequency sound and infrasound from wind turbines can be audible at lower sound levels than is commonly recognized. He points out that the hearing threshold is defined by using single, isolated pure-tone signals, whereas wind turbine noise spectra (narrow band or 1/3 octave band) represent a measure of broadband rms energy which inevitably varies in amplitude according to the precise measurement bandwidth. The two measures – that of the hearing threshold, and that of the wind turbine noise spectra – are derived according to two entirely different measurement conventions The method used for the hearing threshold, involving pure sinusoids, is unsuitable for wind turbine noise signals, which have a much higher crest factor. Wind turbine signals require a dynamic time-domain simulation. Summing up, Swinbanks states:

> As a direct consequence, this approach reveals that typical wind-turbine infrasonic and low frequency noise can be readily audible at very much lower levels than has hitherto been acknowledged. (Swinbanks, 2011, p. 1)

Swinbanks draws on his own experience in 1979 of dealing with problems of intrusive low frequency noise emitted by the compressor of an industrial gas-turbine. The compressor gave out a low frequency 'rumble', which neighbours found objectionable late at night. Swinbanks was able to reduce the noise by 11 to 12 dB in the lowest audible octave. A few years later Swinbanks was asked to deal with a similar installation, but one with taller stacks. This time the noise emissions were at lower frequencies (Swinbanks, 2011, p. 6) . Comparing the two situations, Swinbanks concluded:

> The resultant acoustic resonances were at lower frequencies because of the increased stack height. (Swinbanks, 2011, p. 6)

The correlation between tower height and lowness of frequency, affirmed by Swinbanks here, agrees with recent work by Moller and Pedersen, who compared the low frequency emissions of smaller (≤ 2 MW) and larger (2.3-3.6 MW) wind turbines. Moller and Pedersen found that the relative amount of low frequency noise was higher for the larger turbines, involving a downward shift of the sound spectrum of about one-third of an octave (Moller and Pedersen, 2011, p. 3727).

Swinbanks notes that the low frequency noise levels complained of by the neighbours of the gas turbines were very similar to documented wind turbine low frequency noise levels (Swinbanks, 2011, p. 7). He comments that these noise levels would have been conventionally understood to fall below the hearing threshold. Nonetheless, they were audible, to the point of being objectionable to neighbours:

> Moreover, if a simplistic criterion is adopted of comparing these levels to the tonal threshold of hearing, it is clear that the resonant peak levels would be considered to fall below this threshold.
>
> Yet it was clear that these levels were of sufficient amplitude to give rise to complaints, while the subsequent active sound attenuation was considered to resolve these complaints. (Swinbanks, 2011, p. 7)

On the basis of this earlier work on the low frequency noise emissions of industrial gas turbines Swinbanks concludes:

> It is therefore appropriate to revisit the assessment of low-frequency noise and infranoise, to establish more rigorous criteria for evaluating its effects relative to the threshold of hearing, and to attempt to reconcile these different effects, namely the audibility of individual pure tones, the apparently enhanced audibility of periodic or impulsive noise, and the audibility of low-frequency random noise. (Swinbanks, 2011, p. 7)

Swinbanks carries out simulations of clean, impulsive low frequency noise, and of random low frequency noise, and concludes that the real hearing threshold for these kinds of noise can fall:

> Thus, taken overall, these simulations have indicated that for clean, impulsive noise, the threshold of perception can be -8 dB to -11 dB lower for purely impulsive signals, but as the signal becomes mixed with noise and progressively starts to assume a more random character, this threshold of perception rises to -5 dB. For the low frequency, but locally resonant random noise of the industrial gas turbines, the corresponding figure appears to be -5 dB. (Swinbanks, p. 17)

Swinbanks now applies his findings to the data presented in one of van den Berg's research papers on low frequency wind turbine noise (van den Berg, 2004a). He points out that for 10% of young adults the hearing threshold is on average -8 dB lower than the conventional threshold of hearing. So, he subtracts 8 dB from the threshold. He then subtracts a further 6 dB, because van den Berg's turbine noise was impulsive. The total reduction is thus -14 dB. Applying this reduction to van den Berg's data, he finds that it applies to the frequency range of 17 Hz to 21 Hz, i.e. the upper limits of the infrasonic range (Swinbanks, 2011, p 17)

Swinbanks also points out that 2.5% of adults are expected to have more sensitive hearing, corresponding to a threshold of -12 dB relative to the median value. In relation to van den Berg's data, he finds that this condition corresponds to even lower infrasonic levels (Swinbanks, 2011, pp. 18-19)

He sums up:

> This immediately leads to the conclusion that under the circumstances reported by van den Berg, a small proportion of adults, namely 2.5%, may indeed have been able to perceive a broader bandwidth of infrasound level. (Swinbanks, 2011, p 19)

Swinbanks concludes:

> Based on these results, it is considered that a clean impulsive low-frequency signal can be audible at levels 8-11 dB below the threshold defined according to mean square energy. As in-band broadband noise is increasingly mixed with this clean spectrum, this margin progressively reduces to a value approximately 5 dB below the conventional threshold....
>
> A consequence of these results is that low-frequency and infrasonic noise due to wind turbines may be audible at significantly lower sound levels than has hitherto been acknowledged. (Swinbanks, 2011, p. 19)

The NSW Draft Guidelines:

The draft Guidelines propose a two-stage method for dealing with the issue of low frequency noise. First, it is to be examined whether C-weighted low frequency noise (measured from 20 Hz upwards) is repeatedly greater than 65 dBC during the day, or 60 dBC at night. If this is so, then a more detailed low frequency noise assessment is to be carried out. This more detailed assessment is to examine whether "excessive" levels of low frequency noise "above the human threshold of hearing" are occurring internally at non-involved residences ("as described in the UK Department for Environment, Food and Rural Affairs document *Proposed criteria for the assessment of low frequency noise disturbance*"). If so, then a 5 dBA penalty should be applied to the predicted or measured noise level from the wind farm, for the periods and meteorological conditions under which the low frequency noise has been identified.

The proponent is allowed to substitute measurements at an intermediate location, and make an extrapolation, using "relevant geometric spreading techniques". If this measurement indicates that the C-weighted noise levels are less than the trigger levels, then it is to be judged that there is an absence of excessive low frequency noise impacts (p. 34).

This method is unsatisfactory in every respect.

First, the limits of 65 dBC (day) and 60 dBC (night) are far too high. 60 dBC equates to about 50 dBA. So I am informed by the Australian acoustician Bob Thorne in a personal communication.

The usual basic principle to protect people from excessive and intrusive noise is a limit of background noise + 5 dB. In the country, background noise at night, outdoors, can fall to 20 dBA, or even lower. To allow an outdoor low frequency noise level equivalent to 50 dBA would mean that the difference between actual noise and background noise would be 50 – 20 = 30 dB. This is 25 dB greater than background noise + 5 dB. This is far too high. A difference of 25 dB means that the higher sound is 6 times as loud as the lower sound. A difference of 30 dB means that the higher sound is 8 times as loud as the lower sound. Such noise levels at night are totally unacceptable, and will guarantee regular sleep disturbance. Most of this sound would penetrate the fabric of the residence merely because it is low frequency noise. Inside the residence, the background noise may be close to zero. So, the received low frequency noise level in someone's bedroom would be unbearable.

The Guidelines refer to "excessive" noise. What is "excessive"? Is it 65 dBC by day, and 60 dBC by night? If so, then these limits are totally unacceptable for the reasons given above.

The Guidelines then require a more detailed assessment of low frequency noise "occurring internally at non-associated residences. But this requirement is immediately undermined by the allowance made to the proponent not to take any measurements inside the non-associated residence, but instead to take measurements at an intermediate location, and to make an extrapolation using "relevant geometric spreading techniques". But, what is a "relevant" geometric spreading technique? Is the propagation spherical, hemispherical, or cylindrical? Will the turbines be treated as point sources, or as line sources? There is ample scope here for a serious underestimation of the magnitude of sound present inside the residence. **The only way to estimate this accurately, at least at the stage of compliance monitoring is to take the measurements inside the house (with the owner's permission). The turbines must be turned off to estimate background noise for both windy and non-windy conditions (with attended monitoring). Then, the actual levels of low frequency noise inside the house, both when there is wind at the house, and when there is no wind at the house, must be measured. This is the only way to get at the truth.**

Allowing the proponent to take measurements at an intermediate location, and do a sum, looks like another instance of bias towards the developers and operators. It means less trouble for the developers and operators, but at the expense of the protection of neighbours. Are neighbours really to be forced to pay thousands of dollars to hire a noise consultant, and then thousands of dollars more to take the operator, and the Minister for Planning to court?

Finally, the draft Guidelines propose a penalty of 5 dBA, if excessive levels of low frequency noise above the human threshold of hearing are occurring inside neighbours' houses. It seems to be implied that this notion is derived from the British DEFRA document *Proposed criteria for the assessment of low frequency noise disturbance* (Moorhouse et al, 2005, pp. 61-64). (But see below.)

It must be considered that this DEFRA document was published in 2005, and that the research it contains has been superseded by the work of Bray and James, and the work of Swinbanks, discussed above. Swinbanks only considers low frequency noise that is amplitude-modulated at the blade-pass frequency, but even Swinbanks suggests that the hearing threshold for such noise can be lowered by between 5 and 11 dB, depending on the sound mix (and this ignores the special situation of the noise-sensitive). This suggests that a fixed penalty of 5 dB may not be enough to take account of the real situation. And in any case, one needs to distinguish between a penalty for the annoying characteristic of the amplitude modulation, and a penalty for the lowering of the threshold of hearing. N.B. Just to compare LFN noise levels with the standard threshold of hearing is no longer acceptable.

But the work of Bray and James represents a much more radical transformation of our knowledge regarding amplitude-modulated low frequency noise. The DEFRA document is still only concerned with measurements on the macro-time scale, using the descriptors of L_{eq} and L_{90} (Moorhouse et al, 2005, p. 64). The whole thrust of Bray and James' work is that such macro-time scale measurements are inadequate to represent the true magnitude of the crest factor, and the peak sound levels of wind turbine low frequency noise. Moreover, Bray and James' findings need to be considered in relation to Alec Salt's work on the effect of inaudible low frequency noise on the inner ear and the nervous system.

It can only be concluded that the proposed guidelines on low frequency noise cannot be allowed to stand, as they do not reflect the latest and best research. This is yet another reason for a moratorium on wind farm development, until the necessary research has been completed.

Note:

There seems to be some confusion about the exact relation between the draft Guidelines and the DEFRA document. The draft Guidelines propose a 5 dB penalty for exceedances, but this is not the approach of the DEFRA document. The latter proposes a reference curve that correlates low frequency ranges (10 Hz to 160 Hz) with dB L_{eq} values, and regards the 5 dB penalty as already incorporated in the reference curve. What the DEFRA document is concerned with is the relaxation of the penalty for steady sounds (Moorhouse et al., 2005, pp. 61-63). With regard to exceedances of the values in the reference curve, all that the document suggests is that the exceedances "may indicate a source of LFN [low frequency noise] that could cause disturbance." (Moorhouse et al., 2005, p. 64) There is therefore no correspondence between the approach of the draft Guidelines and that of the DEFRA document. This confusion needs to be clarified.

Moreover, it is perhaps worth noting that the authors of the DEFRA document propose that low frequency noise as low as 10 Hz in frequency should be measured (Moorhouse et al., 2005, pp. 61-64). But in the NSW draft Guidelines the proponent is only obliged to consider low frequency noise down to 20 Hz (p. 34). This is clearly a bias in favour of the developers and operators, since it frees them of the responsibility of considering infrasound. I shall have more to say about this below.

Note on Broner:

In the draft Guidelines Appendix F: *Additional information and resources*, lists an article by N. Broner, *A simple criterion for low frequency noise emission abatement* [sic. 'abatement is an error for ‘assessment’] (p. 54). This article was published in the *Journal of low frequency noise, vibration and active control*, vol. 29, no. 1, 2010.

A reading of this article suggests that it is the source of the draft Guidelines’ proposed method of dealing with low frequency noise, and not the DEFRA document. This is unfortunate from the point of view of wind farm neighbours, as what Broner proposes as a method for dealing with low frequency noise from all sources does not take into account the specific characteristics of wind turbine noise, nor the specific situation of rural locations where background noise may be very low. I will make some comments on the article.

1. Although it briefly mentions wind farms as a source of LFN (p. 2), the article is about LFN generally, and proposes a criterion that is supposed to apply to all emissions of LFN, whatever the source.

2. Broner offers a simple overall criterion, so that planners and proponents will not be put to the trouble of making a detailed spectral analysis of the sound (p. 1). This is clearly in the interest of proponents, but not in the interest of neighbours.

3. Broner recognizes that ideally the limit for LFN should be an indoor limit, but proposes instead an outdoor limit, because “in planning terms, it is much easier to set criteria for the outside of residences” (p. 1) Again, this is in the interest of proponents, but not in the interest of neighbours.

4. Broner assumes “geometrical spreading” (p. 2). If this means spherical spreading, then it must be noted, as I have already discussed above, that this assumption of spherical propagation has been called in question for wind farms.

5. Broner wrongly asserts that LFN has been eliminated from wind turbine noise by the shift from downwind to upwind rotors (p. 3). See my earlier discussion of the work of Dickinson, Doolan, Bakker and Rapley, Thorne et al.

6. Broner acknowledges that there are now units in dBZ for unweighted measurements. (p. 4) But if so, why is he persisting with dBA and dBC?

7. Broner assumes that inaudible infrasound is not a problem (p. 5). Salt has refuted this false assumption (see below).

8. The 65/60 dBC limits come apparently from Hessler (2005). The NSW Department of Planning does not seem to have noticed – as Broner tells us (p. 9) – *that Hessler cautions that these levels contain no factor of safety or margin of error, and should be considered the maximum allowable.*

9. Broner recommends 60 dBC as the desirable night limit, and 65 dBC as the desirable day limit, for “residential” locations (p. 11). I have already criticised these above as far too high, given the extent to which background noise in a country location can

fall: 20 dBA, or lower. Broner does not make any distinctions for residences in an urban, suburban, or rural setting. This is unacceptable.

10. Generally, Broner takes no account of the specific characteristics, and specific problems of wind turbine noise, as recently discussed by Bray and James, Swinbanks, Bakker and Rapley, Thorne et al. In particular, Broner's method involves macro-time scale measurements, and takes no account of the micro-time scale measurements desiderated by Bray and James. It does not make much sense for the NSW Department of Planning to take notice of an article that does not deal with the specific characteristics of wind turbine sound, and the rural setting of wind farms, when taking no notice of the research work performed by acousticians who have dealt with these thoroughly and in great detail. This is not rational.

11. It may be noticed that Broner, like DEFRA, recommends that all low frequency sound energy down to 10 Hz be considered (p. 11). The draft Guidelines only consider sound energy down to 20 Hz, thus eliminating infrasound.

12. Finally, Broner points out that mitigation of LFN noise problems can be very expensive, and difficult, because of the wave-length of the sound energy (p.10). In the case of wind farms, it must be very difficult indeed, as mechanical noise dampers cannot be applied to a wind turbine. The sound is inseparable from the movement of the blades through the air. Sound-proofing at the residence is also unlikely to be very successful, given the super-penetrative capacity of the LFN. **All this being so, it only makes sense to locate wind farms in places where they are unlikely to disturb neighbours. But, this means having an adequate setback distance, based on adequate research. If that research is not yet complete, then there needs to be a moratorium. The noise limits in the draft Guidelines will not protect neighbours. LFN problems are bound to occur. Turbines will have to be turned off. Capital will be wasted.**

Attenuation, outdoors to indoors:

Since the issue of attenuation from outdoors to indoors has been raised by the consideration of low frequency noise, it will be convenient to discuss it here.

As we have seen, low frequency noise (and infrasound) has a super-capacity to penetrate the fabric of buildings, because of the relatively great wave-length of the sound energy. This means that an accurate knowledge of the attenuation that can be expected from outdoors to indoors is essential.

Unfortunately, that accurate knowledge seems to be lacking, or will be when the noise impacts inside particular residences are to be predicted. The rate of attenuation varies with the nature of the materials used in the building. Many old houses in the country are wooden, or fibro. Many new houses are also wooden. Their rate of attenuation may be close to zero. (Kamperman and

James, 2008b, p. 4) The rate of attenuation also varies with the size of a window opening. **But we are here in the region of conjecture. This is yet another reason for a moratorium and further research.**

The US noise engineers George Kamperman and Richard James suggest that while the rate of attenuation for relatively high frequency noise, measured in dBA, may be 15 dBA, the rate of attenuation for low frequency noise may only be about 6 or 7 dBC (Kamperman and James, 2008a, 2008b, p. 5).

Philip Dickinson gives a table which shows the attenuation for a weatherboard house, for various frequencies of sound, according to the proportion of the window opening to the total wall space. His table shows that if the percentage of opening is 30%, then for LFN at 125 Hz the attenuation is 5 dB; for LFN at 31.5 Hz it is also 5 dB. For the attenuation to be as much as 12 dB, the percentage of opening has to be reduced to 3% (Dickinson, 2010, pp. 196-197). **Clearly, predictions could only be made on a case-by-case basis, and would require the proponent's consultant to visit each residence, and note the building materials, the design of the windows, etc. If this is impractical, then it is another reason for an adequate setback distance, based on adequate research.**

An element of confusion has been introduced into the discussion of this issue by the WHO document *Night Noise Guidelines for Europe* (2009). In this document the assumption is made that the rate of attenuation outside to inside is as high as 21 dB (WHO, 2009, pp. 9-10). It is hard to know what to make of this. However, as this document suggests an *outdoor* limit of 40 dBA, that implies an *indoor* (night) limit of only 19 dBA (WHO, 2009, p. 109).

(It should also be noted that the noise limits in the *Night Noise Guidelines for Europe* are for noise generally. They take no account of the specific characteristics of wind turbine noise. They do not even take account of low frequency noise.)

Noise limits for low frequency noise:

Kamperman and James (Kamperman and James, 2008a) recommend as an *outdoor* limit the *lower* of either:

- A maximum not-to-exceed sound level of 50 dBC (L_{90c})
- L_{eqC} – L_{90A} no greater than 20 dB

Dickinson (2010, p. 205) recommends for an *outside* limit:

- 20 dBA ($L_{eq, 10\ mins}$) in the frequency bands 31.5 to 125 Hz

Steven Cooper (in a personal communication) recommends as an *indoor* limit:

- 45 dBC

It is obvious that there is a serious disagreement between the NSW Department of Planning and its noise consultants, on the one side, and independent noise consultants on the other side. This disagreement by itself should encourage caution. **It is clear that the issue of low frequency noise needs to be given much more consideration than the Department of Planning has given it hitherto. A simple adoption of Broner's recommendations, with a somewhat confused reference to the DEFRA study will not do. While this issue is being adequately investigated, there should be a moratorium.**

Note:

The Danish Environmental Protection Agency has recently introduced an *indoor* limit for LFN of 20 dBA (for frequencies between 10 and 160 Hz). In a letter, now in the public domain, to Mark Duchamp, Executive Director of the European Platform against Windfarms (EPAW), the eminent Danish acoustican Professor Henrik Møller warns that even LFN of 20 dBA will be audible within a house, and that even small exceedances of the limit will have severe consequences, as loudness increases more steeply for LFN than for higher frequency sound. Professor Møller writes:

> Without an acoustical background, it may be difficult to understand how much 20 dB(A) 10 – 160 Hz noise is, but the limit is the same as for industrial noise in Denmark, and it is in the same order of magnitude as the limits in most other countries that have low-frequency limits (the limit may be defined in completely different ways). Most people will easily hear noise at that level, and some will find it annoying, in particular *if it goes on round the clock.* (italics added)
>
> At low frequencies, the perceived intensity, the loudness, increases more steeply above threshold than at higher frequencies. This means that when the level is a few decibels above the 20 dB limit, the consequences are more severe, than if a limit for higher frequencies is exceeded by the same amount. Few people would accept 25 dB(A) in their home at night and hardly anyone would accept 30 dB(A). Therefore, measurements must be accurate. (Møller, 2012)

Professor Møller states that 25 dBA indoors at night would not be acceptable to many. It should be remembered that the draft Guidelines propose an outdoor limit of 60 dBC at night. If this is attenuated by only about 7 dBC (according to Kamperman and James), then the sound inside the house will be about 53 dBC. If 60 dBC equates to about 50 dBA (Thorne), then 53 dBC will be very much more than 25 dBA, which Møller tells us would be found generally unacceptable. The sound level would be even more unacceptable, if it is amplitude-modulated with a high crest factor, and especially *if it goes on round the clock.* But wind turbine noise *is* amplitude-modulated with a high crest factor, and if the wind stays up, it *can* go on round the clock, possibly for several days. The noise in these circumstances would be unbearable. This is another indication that the Department's proposed dBC limits are far too high.

Infrasound

Wind turbines do generate infrasound:

In Appendix B of the draft Guidelines it is stated that the proposed NSW noise guidelines closely follow the methodologies and practices of the *South Australian Noise Guidelines* (2009) (p. 27). The *South Australian Noise Guidelines* (2009) state:

> Infrasound was a characteristic of some wind turbine models that has been attributed to early designs in which turbine blades were downwind of the main tower. The effect was generated as the blades cut through the turbulence generated around the downwind side of the tower.
>
> Modern designs generally have the blades upwind of the tower. Wind conditions around the blades and improved blade design minimise the generation of the effect. The EPA has consulted the working group and completed an extensive literature search but is not aware of infrasound being present at any modern wind farm site. (SANG, 2009, p. 15)

The same view was expressed in slightly different words in the 2003 version of the *South Australian Noise Guidelines*, under which many wind farm proposals have already been approved in NSW.

The assumption that modern wind turbines, with upwind rotors, do not generate infrasound, or generate very little is totally false. We have already seen the evidence for this in our discussion of low frequency noise.

The sound energy immitted at the residences of neighbours of wind farms is predominantly low frequency sound and infrasound. This has been demonstrated by full spectral analyses of wind turbine sound received at neighbouring residences around existing wind farms, in Europe (van den Berg, 2006), North America (Bray and James, 2011; Ambrose and Rand, 2011), Australia (Thorne et al, 2010; Cooper, 2011), and New Zealand (Bakker and Rapley, 2010).

The origin of the infrasound generation in the motion of the rotor blades has been explained by Doolan (2011). Doolan refutes the idea that modern upwind turbines do not produce infrasound (Doolan, 2011, pp. 3-4). It is indisputable that modern upwind turbines do generate infrasound.

The Departmental workshop and the draft Guidelines:

On 18 July 2011 the Department of Planning held a workshop for the wind energy industry. At this workshop a departmental official gave a presentation *Planning for wind farms in NSW* (Department of Planning, 2011c). In this presentation criteria were proposed for noise limits, including 85 dBG, on the basis that NSW Director-General’s Requirements require a consideration of infrasound, but set no criteria (Department of Planning, 2011c, [p. 6]).

In a letter to a senior policy officer in the Department of Planning Jonathan Upson, Senior Development Manager of Infigen, made comments on the workshop's proposals. Amongst other things, he argued that an 85 dBG criterion would be superfluous, as Larry Clark, the manager of the Noise Assessment Unit in DECCW [sic] had stated at the meeting that "it would essentially be impossible for any wind farm to exceed the proposed 85 dB(G) noise limit while still satisfying the DB(A) criteria." (Upson, 2011) [Both the departmental presentation, and Upson's letter were provided by the Department to Friends of Collector, as the result of a Freedom of Information application.]

Presumably, as a result of this objection the dBG criterion has been removed from the proposed criteria in the draft Guidelines. Moreover, there is no section on infrasound, and no mention of infrasound in the draft noise guidelines. In addition, low frequency noise only has to be measured down to 20 Hz. As 20 Hz is commonly taken as the threshold between infrasound and low frequency noise, this implies that the Department of Planning no longer thinks that the magnitude of infrasound emissions needs to be estimated (draft Guidelines, p. 34).

This puts the Department of Planning in clear contradiction with itself, since recently issued DGRs for wind farm applications in NSW clearly require that the proponent "identify any risks with respect to tonal, low frequency or infra-noise" (DGRs for Rugby Wind Farm, 26.11.10, [p. 3]; cf. DGRs for Collector Wind Farm, 15.10.10, [p. 3]). What are we to suppose? **If the proponent is obliged to identify the risk of adverse infrasound impacts, but not required to estimate the magnitude of infrasound emissions, will the proponent assert briefly and dogmatically that infrasound is not a problem, and will the Department accept that without criticism? Or will DGRs in future delete the requirement for the proponent to identify any risk from infrasound? This muddle needs clarification. Residents have the right to know whether the Department of Planning has abandoned any interest in infrasound, and if so why.**

What this exchange of communications, and its effect on the draft Guidelines shows is (i) that the Noise Assessment Unit in the Office of Environment and Heritage does not take seriously the latest research on infrasonic emissions from wind turbines, and has abandoned the precautionary principle in respect of this issue, and (ii) that the Department of Planning is too willing to accommodate the wishes of the wind energy industry, and to sacrifice needed protection for the neighbours of wind farms. All this is reprehensible. Local residents clearly cannot depend on the NSW government to protect their needs and interests.

To justify these assertions, we need to look at the latest research on infrasound, on infrasound and adverse health effects, and on infrasound and wind turbines.

Infrasound and its effects:

We saw above that the Department of Planning proposed in 2011 that a criterion of 85 dBG be established to take account of infrasound. The choice of 85 dBG can only be the result of a misunderstanding of the nature of infrasound impacts. 85 dBG is commonly taken to be the threshold of audibility for infrasound. In other words, infrasound (below 20 Hz) has to have a sound pressure level of at least 85 dBG before almost everybody can hear it (e.g. Sonus, 2010a,

p. 10). The threshold is sometimes said to be 95 dBG (e.g. Salt, in Appendix 3 of Bray and James, 2011).

The assumption implicit in the choice of 85 dBG is that infrasound that is inaudible is not a problem.

If this assumption is correct, and infrasound is only a problem if it is at a high enough level to be audible, then wind turbine infrasound does not represent a problem, since the levels of wind turbine infrasound are likely to be below 85 dBG. If this is so, then there is no point in measuring wind turbine infrasound levels, and the wind energy industry is justified in objecting to having to do so.

Unfortunately, the latest research suggests that the assumption is not correct, or at least that it is premature to hold that it is correct. This research comes from Professor Alec Salt of the Cochlear Fluids Research Laboratory in the School of Medicine, at Washington University, St Louis, Missouri. Also, regard needs to be paid to the research of Professors Mariana Alves-Pereira and Nuno A. A. Castelo Branco, of ERISA-Universidade Lusofona, Lisbon, and the Center for Human Performance, Alverca, Portugal.

Salt and his colleagues:

Salt considers the assumption that inaudible infrasound is not a problem, and rejects it:

> Renewable UK (2011), the website of the British Wind Energy Association, quotes Dr, Leventhall as stating, "I can state quite categorically that there is no significant infrasound from current designs of wind turbines." Thus, the fact that hearing is insensitive to infrasound is used to exclude the possibility that the infrasound can have any influence on humans. This has been known for many years in the form of the statement, "What you can't hear can't affect you." The problem with this concept is that the sensitivity of "hearing" is assumed to equate with sensitivity of "the ear." So if you cannot hear a sound then it is assumed that the sound is insufficient to stimulate the ear. Our present knowledge of the physiology of the ear suggests that this logic is incorrect. (Salt and Kaltenbach, 2011, p. 297)

On his website Salt explains that the assumption probably originated in journalism, and certainly not in medical research:

> So, one wonders what was the scientific basis of the assumption that sounds that could not be heard could have no influence on the body. According to Alves-Pereira and Castelo Branco (Prog Biophys Mol Biol 2007; 93:256) the statement that "What you can't hear, won't hurt you" is attributable to a 2001 newspaper article by a sound engineer (Campanella) related to the "Kokomo Hum". *The point is that this concept was not established by a medical doctor or researcher with specific knowledge of the ear but was introduced by someone with limited knowledge of inner ear physiology. As such, this concept represents an unfounded speculation.* Nevertheless it has been repeated often

> enough to become accepted in some circles as a proven fact. (Salt, website, "What you cannot hear CAN affect you.") (italics added)

Salt's international standing in the world of medical research makes his authority on this point unimpeachable. If he says that the assumption that inaudible sound cannot hurt people is false, that it is unfounded speculation, and did not originate in medical research, his assertion must be accepted. Is the NSW Department of Planning really going to refuse to accept Salt's statement? Is the NSW Department of Planning really going to continue to act on the basis of an assumption, which a medical researcher of Salt's stature says is false? Does the NSW Department of Planning wish to appear ridiculous?

Salt points out that the A-weighting commonly used to measure wind turbine sound is inadequate to measure low frequency sound and infrasound (Salt and Kaltenbach, 2011, p. 299). Salt also points out that if G-weighting is used, then inaudible infrasound is found to stimulate the Outer Hair Cells in the cochlea of the inner ear at 60 dBG. This is a level of infrasound that modern wind turbines do commonly generate:

> By applying the function [sc. of G-weighting] to the normal human hearing sensitivity curve, it can be shown that sounds of approximately 95 dBG will be heard by humans, which agrees with observations by Van den Berg (2006). Similarly, by G-weighting the OHC [the Outer Hair Cells] sensitivity function in Figure 3, it can be estimated that sound levels of 60 dBG will stimulate the OHC of the human ear. In a survey of infrasound levels produced by wind turbines measured in dBG (Jakobsen, 2005), upwind turbines typically generated infrasound of 60 to 70 dBG, although levels above and below this range were observed in this and other studies. From Jakobsen's G-weighted measurements, we conclude that the level of infrasound produced by wind turbines is of too low a level to be heard, but in most cases is sufficient to cause stimulation of the OHC of the human ear. (Salt and Kaltenbach, 2011, p. 300)

Salt points out that the Outer Hair Cells are connected by Type II nerve fibres to the brainstem (Salt and Kaltenbach, 2011, p. 299). By this pathway stimulation of the Outer Hair Cells could lead to the kinds of symptoms experienced by some neighbours of wind farms:

> If Type II fibers excite granule cells, their ultimate effect would be to diminish responses of fusiform cells to sound. Evidence is mounting that loss of or even just overstimulation of OHCs may lead to major disturbances in the balance of excitatory and inhibitory influences in the dorsal cochlea nucleus. One product of this disturbance is the emergence of hyperactivity, which is widely believed to contribute to the perception of phantom sounds or tinnitus (Kaltenbach et al., 2002; Kaltenbach & Godfey, 2008). The granule cell system also connects to numerous auditory and nonauditory centers of the brain (Shore, 2005). Some of these centers are directly involved in audition, but others serve functions as diverse as attentional control, arousal, startle, the sense of balance, and the monitoring of head and ear position (Godfey et al., 1997). (Salt and Kaltenbach, 2011, p. 299)

Salt sums up:

> Our present understanding of inner ear physiology and of the nature of wind turbine sounds demonstrates that low-level infrasound produced by wind turbines is transduced by the OHC of the ear and this information is transmitted to the cochlear nucleus of the brain via Type II afferent fibers. *We therefore conclude that dismissive statements such as "there is no significant infrasound from current designs of wind turbines" are undoubtedly false. The fact that infrasound-dependent information, at levels that are not consciously heard, is present at the level of the brainstem provides a scientific basis for the possibility that such sounds can have influence on people. The possibility that low-frequency components of the sound could contribute both to high annoyance levels and possibly to other problems that people report as a result of exposure to wind turbine noise cannot therefore be dismissed out of hand.* (Salt and Kaltenbach, 2011, p. 300) (italics added)

Salt considers the question whether such levels of inaudible infrasound from wind turbines could be said to "cause harm". He notes that the levels are too low to damage physically the internal structure of the inner ear, so that "infrasound from wind turbines is unlikely to be harmful in the same way as high-level audible sounds." (Salt and Kaltenbach, 2011, p. 300) But he also notes that the duration of exposure is a major complicating factor:

> Individuals living near wind turbines may be exposed to the turbine's sounds for prolonged periods, 24 hours a day, 7 days a week for weeks, possibly extending to years, although the sound level will vary over time with varying wind conditions. (Salt and Kaltenbach, 2011, pp. 300-301)

This kind of exposure has not yet been researched:

> In a search of the literature, no studies were found that have come close to replicating the long-term exposures to low-level infrasound experienced by those living near wind turbines. *So, to date, there are no published studies showing that such prolonged exposures do not harm humans*. (Salt and Kaltenbach, 2011, p. 301) (italics added)

Unlike the wind energy industry, Salt is prepared to consider the reports of wind turbine neighbours, on the basis of our current knowledge of the physiology of the inner ear:

> On the other hand, there are now numerous reports (e.g. Pierpont, 2009; Punch, James, & Pabst, 2010), discussed extensively in this journal, that are highly suggestive that individuals living near wind turbines are made ill, with a plethora of symptoms that commonly include chronic sleep disturbance. *The fact that such reports are being dismissed on the grounds that the level of infrasound produced by wind turbines is at too low a level to be heard appears to totally ignore the known physiology of the ear. Pathways from the OHC to the brain exist by which infrasound that cannot be heard could influence function.* (Salt and Kaltenbach, 2011, p. 301) (italics added)

Salt thinks that there is already enough evidence for serious concern, and further research:

> So, in contrast, from our perspective, there is ample evidence to support the view that infrasound could affect people, and which justifies the need for more detailed scientific studies of the problem. Thus, it is possible that people's health could suffer when turbines are placed too close to their homes and this becomes more probable if sleep is disturbed by the infrasound. (Salt and Kaltenbach, 2011, p. 301)

The conclusion is:

> We can conclude that based on well-documented knowledge of the physiology of the ear and its connections to the brain, it is scientifically possible that infrasound from wind turbines could affect people living nearby. (Salt and Kaltenbach, 2011, p. 301)

In another paper Salt develops his research. He points out that the stimulation of the Outer Hair Cells by amplitude-modulated infrasound could cause the higher frequency sounds also received to become amplitude-modulated within the inner ear. This is a biological kind of amplitude modulation quite distinct from the acoustic amplitude modulation occurring at the wind turbine:

> This raises the possibility that there are multiple mechanisms by which infrasound or low-frequency sounds, at levels too low to be heard, could influence the representation of sounds in the brain. They can suppress and amplitude modulate responses to higher frequency sounds. By slowly displacing the organ of Corti, they can modulate harmonic distortions to higher frequency stimuli or two-tone emissions (Brown et al., 2009). Such modulation of distortion has been observed both in animals and in humans through acoustic emission measurements from the external ear canal (e.g. Marquardt et al. 2007). The outer hair cells could also stimulate their own afferent innervation directly....
>
> These findings are relevant to the perception of the "amplitude modulation" of sounds, and represent a biological form of modulation by low-frequency sounds that cannot be measured with a sound level meter. (Salt and Lichtenhan, 2011, p. 9)

Salt also notes that when higher frequency sounds are present, they can suppress some of the response to infrasound. He recognizes that typically the situation of a rural residence in the vicinity of a wind farm is the opposite, with a predominance of low frequency sound and infrasound. The implication is that in such a situation the infrasound may have more of an impact:

> The presence of high-frequency sounds suppresses some aspects of the ear's response to infrasound. This means that under conditions where infrasound levels are high, while ambient sounds are low, the ear may be maximally affected by the infrasound. This may be relevant to the exposure of people to wind turbine sounds in a quiet listening environment (such as a bedroom), where response to the infrasound may be augmented relative to listening conditions where higher levels of other ambient sounds are present. (Salt and Lichtenhan, 2011, pp. 9-10)

The conclusion is:

> We conclude that the ear exhibits a number of complex physiological responses to infrasound stimulation at moderate levels that may exist in the vicinity of wind turbines under some operating conditions. *Because the ear is undoubtedly responding to these sounds, it cannot be concluded that infrasound effects on the ear are insignificant because the sounds are not heard. It is therefore premature to assert that long term exposure to wind turbine noise can have no physiological effect on humans*. (Salt and Lichtenhan, 2011, p. 10) (italics added)

In another study Salt calls for further research into the effects of the kind of long-term exposure to the levels of infrasound experienced by the neighbours of wind farms:

> Based on our understanding of how low frequency sound is processed in the ear, and on reports indicating that wind turbine noise causes greater annoyance than other sounds of similar level and affects the quality of life in sensitive individuals, *there is an urgent need for more research directly addressing the physiologic consequences of long-term, low level infrasound exposures on humans*. (Salt and Hullar, 2010, Conclusions) (italics added)

In the light of Alec Salt's research, how can the NSW Department of Planning justify ignoring the infrasonic components of wind turbine noise? Does the NSW Department of Planning really prefer the opinion of the wind energy industry on a matter of medical research to that of an internationally distinguished medical researcher, expert in the relevant speciality?

It is clear, on the basis of Salt's research, that the NSW noise guidelines must stipulate the measurement of expected, and actual infrasound levels in dBG. Not to do so would be the height of irresponsibility.

Salt's research also suggests that the indoor limit for infrasound should be 60 dBG.

But, more important than anything, is that there should be a moratorium until the research desiderated by Salt and his colleagues has been completed. This is the only way that the precautionary principle can be observed. Anything else is simply reckless.

Alves-Pereira and Castelo Branco:

Professors Mariana Alves-Pereira and Nuno A. A. Castelo Branco are Portugese medical researchers who have been studying the effects of infrasound and low frequency noise (ILFN) since 1980. In 2007 they delivered two refereed conference papers, at international conferences, presenting evidence that ILFN levels at a residence near a wind farm were high enough to cause vibro-acoustic disease (VAD) (Alves-Pereira and Castelo Branco, 2007a and b).

They compared ILFN levels in two cases. In one case, there were documented instances of vibro-acoustic disease, ascribed to the generation of ILFN at a port grain terminal. In the other case, there were even higher levels of ILFN found at the residence in the vicinity of the wind farm.

They remark: “ILFN levels contaminating the home of Case 2 [the residence near the wind farm] are sufficient to cause VAD.” They conclude: “ILFN generated by WT [wind turbine] blades can lead to severe health problems, specifically, VAD.” (Alves-Pereira and Castelo Branco, 2007a, Abstract)

The measurement of sound levels in the two cases was taken down to 6.3 Hz. In relation to our concern with noise guidelines, it should be noted that in the case of the home near the port grain terminal, where there were documented cases of VAD, the infrasound level at 6.3 Hz was only about 50 dB(lin). [dB(lin) is the older unweighted scale for measuring sound levels. It has been displaced by the more recent dB(Z).] At 10 Hz the infrasound level was in the mid 50s dB(lin).

In the case of the home near the wind turbines, the infrasound levels were in the low 50s dB(lin) at 6.3 Hz, and in the high 50s dB(lin) at 10 Hz (Alves-Pereira and Castelo Branco, 2007b, sections 4.2, 4.3).

It is obvious that on the basis of the work of both Salt and his colleagues, and of Alves-Pereira and Castelo Branco there should be urgent medical research into the potential contribution of infrasound to adverse health effects. And, as I have already suggested, there should be a moratorium on wind farm development until that research is completed. However, while the work of Salt and his colleagues justifies a stipulation that wind turbine noise be measured in dBG, the work of Alves-Pereira and Castelo Branco justifies a further stipulation that wind turbine noise also be measured on the unweighted scale. This means in units of dBZ.

The units of dBZ are necessary to measure the infrasound below 10 Hz. This is because the units of dBG are only appropriate for measurements down to 10 Hz. Measurement of infrasound in the range between 0 and 10 Hz requires dBZ.

The Bruce McPherson study:

The need to measure infrasonic levels of wind turbine sound has received further support by the recent *Bruce McPherson study*, conducted by two US noise engineers Stephen Ambrose and Robert Rand. This study of noise impacts from wind turbines at Falmouth, Massachusetts was commissioned by a US philanthropist Bruce McPherson, after complaints from Falmouth residents living near three new industrial wind turbines (Ambrose and Rand, 2011).

Ambrose and Rand measured amplitude-modulated sound emissions occurring at the blade pass frequency, including amplitude-modulated infrasound below 10 Hz. These infrasonic modulations were, significantly, stronger indoors than outdoors:

> Dynamic amplitude modulations occurred at 1.4 second intervals that were consistent with the blades rotating past the wind turbine tower (the blade pass rate). *Dynamic amplitude modulations below 10 Hz were stronger indoors than outdoors*. Modulations measured indoors were 0.2 Pascal peak to peak consisting mostly of energy below 20 Hz [i.e. infrasound]. (Ambrose and Rand, 2011, p. 2) (italics added)

The wind turbine noise also exhibited tonality in the low frequency range:

> Two tones were detected from both the NOTUS and the WIND 1 turbines, at 22.9 Hz and 129 Hz, and are considered signatures of the wind turbines' acoustic profile. (Ambrose and Rand, 2011, p. 2)

One especially interesting finding, in relation to the modelling of wind turbine noise, is that the higher frequency sound measured in dBA diminished at the expected rate of 6 dB per doubling of distance, but the infrasound was propagated by cylindrical spreading, and diminished by only 3 dB per doubling of distance. This, and the modulation and strength of the infrasonic sound, were not registered by A-weighted measurements:

> Outdoors, the A-weighted sound level decreased at a predictable rate of 6 dB per doubling of distance from the nearest turbine. The linear unweighted sound level decreased according to cylindrical spreading at 3 dB per doubling of distance *and was controlled by acoustic energy below 20 Hz* [i.e. infrasound]. A-weighting does not reveal this low-frequency information. Sound-level averaging with L_{eq} for any time length hides the low-frequency dynamic amplitude modulations. (Ambrose and Rand, 2011, p. 2) (italics added)

The importance of the infrasonic measurements was underlined by the fact that the investigators experienced the same adverse health symptoms as those complained of by neighbours:

> The investigators were surprised to experience the same adverse health symptoms described by neighbours living at this house and near other large industrial wind turbine sites. The onset of adverse health effects was swift, within twenty minutes, and persisted for some time after leaving the study area. *The dBA and dBC levels and modulations did not correlate to the health effects experienced. However, the strength and modulation of the un-weighted and dBG-weighted levels increased indoors consistent with worsened health effects experienced indoors*. (Ambrose and Rand, 2011, pp. 2-3) (italics added)

This shows that it is inadequate to measure wind turbine sound only in dBA and dBC, as the NSW draft Guidelines propose. Measurements in dBG, and on the unweighted scale (either dB(lin) or dBZ) are essential, if the issue of potential adverse health effects is to be seriously assessed.

Both the infrasonic sound and the low frequency tonality were *inaudible*, but were measured at levels in excess of Salt's threshold of 60 dBG:

> The dBG-weighted level appeared to be controlled by in-flow turbulence and exceeded physiological thresholds for response to low-frequency and infrasonic acoustic energy as theorized by Salt [i.e. 60 dBG]. The wind turbine tone at 22.9 Hz was not audible yet the modulated amplitudes regularly exceeded vestibular detection thresholds. (Ambrose and Rand, 2011, p. 3)

They note:

> The 22.9 Hz tone lies in the brain's "high Beta" wave range (associated with alert state, anxiety, and "fight or flight" stress reactions). The brain's frequency following response (FFR) could be involved in maintaining an alert state during sleeping hours, which could lead to health effects. Sleep was disturbed during this study when the wind turbine operated with hub height wind speeds above 10 m/s. (Ambrose and Rand, 2011, p. 3)

They tell us:

> It took about a week to recover from the adverse health effects experienced during the study, with lingering recurring nausea and vertigo for almost seven weeks for one of the investigators. (Ambrose and Rand, 2011, p. 3)

Inevitably, they call for further research, both epidemiological and laboratory-based, to be conducted by both medical researchers and acousticians (Ambrose and Rand, 2011, p. 3).

They emphasise that adequate setbacks should include *"a margin of safety sufficient to prevent inaudible low-frequency wind turbine noise from being detected by the human vestibular system."* (Ambrose and Rand, 2011, p. 3)

It must be apparent that at present there is an enormous gulf between the views of professional researchers such as Salt, Ambrose and Rand, and the thinking of the NSW Department of Planning (supported by the Office of Environment, and the Department of Health). The Department of Planning needs to recognize that its view of wind turbine noise impacts is seriously inadequate in the light of recent medical and acoustic research. The draft Guidelines should be withdrawn, and there should be a moratorium until adequate research, both medical and acoustic, has been completed. This is the only way that the neighbours of wind farms will get any protection.

Bray and James, and Swinbanks:

Any adequate study of wind turbine infrasound must take account of the recent work of Wade Bray and Richard James, already discussed above under *Amplitude modulation on a micro-time scale*. It must also take account of the work of Swinbanks, already discussed above under *Low frequency noise and crest factor*.

Bray and James measured the levels and modulation of infrasound and low frequency sound below 50 Hz at a wind farm at Ubly, Michigan. They found that the dominant energy of the wind turbine signals was in the 1.5-10 Hz range, strongest between 2 and 8 Hz, i.e. infrasound. Peak sound levels varied between about 77 dB SPL and almost 100 dB SPL. There was amplitude modulation on a micro-time scale of about once every 60 milliseconds (almost 17 times per second), with a very high crest factor. They hypothesize that a high crest factor could influence the probability of such modulation either being heard, or still being unconsciously detected at levels different from those calculated on the basis of macro-time measurements (Bray and James, 2011).

It must be emphasised that this kind of amplitude modulation has hitherto gone undetected, merely because methods appropriate for detecting it have not been used. What the potential adverse health effects of such modulation of infrasound and low frequency sound might be is completely unknown, because it has never been investigated. But, it clearly needs to be investigated, in the light of the findings of Ambrose and Rand's *Bruce McPherson study*.

Swinbanks' conclusions about the lowering of the threshold of audibility for modulated sound, because of a high crest factor, apply to infrasound as to low frequency sound (Swinbanks, 2011).

The work of Bray and James, and of Swinbanks demonstrates that low frequency sound, and infrasound can become more of a problem, if amplitude-modulated, especially with a high crest factor. **Since wind turbine infrasound is amplitude-modulated with a high crest factor, it follows that it must be considered in any adequate assessment of wind turbine sound. Therefore, the NSW Department of Planning is completely wrong to remove the consideration of infrasound from its draft Guidelines. This cannot be allowed to stand. It would constitute a gross failure of care.**

Studies cited by the draft Guidelines:

In Appendix F the draft Guidelines cite only two studies bearing on the issue of infrasound. These are:

- Hellweg, O'Neal and Lampeter (2011), Low frequency noise and infrasound from wind turbines, *Noise Control Engineering Journal*, vol. 59 (2), March-April 2011

- Sonus (2010b), Infrasound measurements from wind farms and other sources, study commissioned by Pacific Hydro Pty Ltd.

Both of these studies were in fact commissioned by the wind energy industry. The Hellweg et al study was commissioned by the wind energy developer NextEra Energy Resources LLC (O'Neal et al, 2011, p. 135). As stated above, the Sonus study was commissioned by Pacific Hydro Pty Ltd.

As the senior author of the Hellweg study was in fact O'Neal, I will cite this as O'Neal et al., 2011.

O'Neal et al.:

What the O'Neal study offers to prove is that the infrasound and LFN emissions of the wind turbines studied comply with the limits contained in various existing standards, including

ANSI/ASA S12.2, ANSI/ASA S12.9, the UK DEFRA guidelines for disturbance from LFN, and similar guidelines from the Japanese Ministry of Environment.

While O'Neal and his colleagues may have been successful in their demonstration, what they have proved misses to point. The most recent research on wind turbine noise impacts by Salt, Bray and James, Ambrose and Rand, and Cooper, to say nothing of Thorne, Bakker and Rapley and Dickinson, offers persuasive argument and evidence that call in question existing standards which currently regulate wind turbine noise emissions. Therefore, merely to prove that wind turbine noise emissions comply with existing standards does not address the issues which have now been raised.

Throughout their study O'Neal et al assume that inaudible infrasound does not matter. To support this assumption, they cite a WHO author, Berglund, but in a study from as far back as 1995. They also cite Leventhall (2006); Hayes McKenzie (2006); Howe (2006); and some French studies from 2006 and 2008 (O'Neal et al, 2011, pp. 140-143). What these citations ignore is that all these studies, expressing the view, that inaudible infrasound can be disregarded, have been superseded by the work of Salt (see above). The work of Salt is not mentioned anywhere in this study, even though Salt's first publication was in 2010. Since Salt has shown that inaudible infrasound from wind turbines cannot be dismissed, but should be investigated, the findings of O'Neal and his colleagues are not worth much.

Since the standards that they invoke also assume that inaudible infrasound does not matter, those standards are also called in question by Salt's work.

In relation to Alves-Pereira and Castelo Branco's work on wind turbine infrasound and VAD, O'Neal and his colleagues cite a paper by Alves-Pereira and Castelo Branco from 2004, but ignore their papers from 2007, even though the 2007 papers present the case of a residence near a wind farm where the infrasound levels were higher than those of another residence near a port grain terminal, where there were documented cases of VAD. Once again, O'Neal and his colleagues are not facing up to the issue (O'Neal et al., 2011, pp. 142-143, 157).

Their invocation of international noise standards also acts to conceal a real problem. Repeatedly, O'Neal and his colleagues state that they found that in relation to the turbines studied, "infrasound is inaudible", but low frequency sound above a certain level (40 Hz, 50 Hz, 31.5-40 Hz, and 63 Hz) "may be audible depending on background sound levels." (O'Neal et al., 2011, pp. 145, 147, 148, 151). It is precisely the "rumble/thump" of low frequency noise, audible in a quiet rural setting, above the low level of background noise, that is one of the things of which neighbours complain! O'Neal et al make this bland assertion, and then say no more of the matter, but change the subject to the fact that the noise levels comply with existing noise standards. If people are being seriously disturbed by low frequency noise, despite the levels complying with the noise standards, then the noise standards are inadequate, and need to be changed. Needless to say, this study, commissioned by the wind energy industry, does not discuss the matter.

It should be noted that this study only dealt with low frequency sound and infrasound between 12.5 Hz and 200 Hz (O'Neal et al., 2011, p. 135). So, infrasound below 12.5 Hz was not dealt with. Salt shows that inaudible infrasound can stimulate the Outer Hair Cells down to 1 Hz (Salt and Kaltenbach, 2011, p. 298). Alves-Pereira and Castelo Branco's research concerned infrasound levels down to 6.3 Hz. In this respect also, therefore, it cannot be said that O'Neal and his colleagues have addressed the issues raised by Salt, and by Alves-Pereira and Castelo Branco.

Finally, O'Neal and his colleagues ignore the matter of crest factor, raised by Bray and James, and by Swinbanks. A very high crest factor raises two issues: (i) it tends to lower the threshold of audibility, and therefore is likely to lower the threshold of annoyance, and to trigger sleep disturbance at lower levels; (ii) it may be of crucial importance, if (as Salt hypothesizes) amplitude-modulated infrasound signals tend to amplitude-modulate the higher frequency signals within the nervous system. These issues were only raised in 2011, and O'Neal and his colleagues were presumably unaware of them. But they now need to be addressed, and this is not done in the O'Neal study. (In relation to audibility, O'Neal et al cite studies by Møller and Pedersen (2004), and by Watanabe and Møller (1990).)

Sonus:

The Sonus study *Infrasound measurements from wind farms and other sources, prepared for Pacific Hydro Pty Ltd* (November 2010) also assumes that inaudible infrasound does not matter (Sonus, 2010b, pp. 3, 5). Salt's work is not discussed in the course of the study, and Salt's 2010 publication is not in the bibliography (Sonus, 2010b, pp. 36-37). So, like the O'Neal study, the Sonus study does not meet the challenge posed by Salt's work.

Salt has shown that inaudible infrasound stimulates the Outer Hair Cells of the cochlea, in the inner ear, at 60 dBG (Salt and Kaltenbach, 2011, p. 300). What is perhaps most significant about the Sonus study, in the light of Salt's research, is that the Sonus investigations found that infrasound immitted from the South Australian Clements Gap Wind Farm was measured at 61 dBG; while infrasound immitted from the Victorian Cape Bridgewater Wind Farm was measured at 63 dBG (Sonus, 2010b, pp. 4, 21, 26). Thus, infrasound levels above Salt's threshold were found in both cases.

However, the Sonus report argues, not only that the infrasound levels from these wind farms were below the audibility threshold of 85 dBG, but also that the infrasound levels from the wind farms are comparable to levels of natural infrasound in the vicinity of one of these wind farms (Sonus, 2010b, pp. 26). The levels were also of the same order as those measured at the beach, in the Adelaide Central Business District, and at a power station (Sonus, 2010b, p. 5).

This argument misses the point. The point of Salt's work, reinforced by that of Bray and James, and of Swinbanks, is that wind turbine infrasound is *amplitude-modulated, with a very high crest factor*. It is not only the case that the high crest factor tends to reduce the audibility threshold, and so to reduce the threshold for annoyance and sleep disturbance (Bray and James, 2011; Swinbanks, 2011). The wind turbine infrasonic signals, modulated with a high crest factor, will cause the higher frequency signals to become amplitude-modulated *within the nervous system*, raising the possibility that it is this *biological* amplitude modulation that causes, or at least helps to cause audible amplitude-modulated sound to be so annoying and disturbing. Moreover, infrasound may have a stronger effect on the ear mechanisms, in situations where ambient higher frequency sounds are low, as in a bedroom in a house in the vicinity of a wind farm. This is a subject on which Salt has called for more research (Salt and Lichtenhan, 2011).

Two other points about the Sonus study are worth noting. First, it states that the rate of attenuation of the infrasound measured was the expected 6 dB per doubling of distance (Sonus, 2010b, p. 3). This does not agree with the findings of Ambrose and Rand, who found that the rate of attenuation for the infrasound measured at their test site was 3 dB per doubling of distance (by cylindrical spreading) (Ambrose and Rand, 2011, p. 2). This disagreement suggests that at the least there is a methodological issue here to be investigated.

Second, the Sonus study asserts that it has confirmed that infrasound levels inside a dwelling will be lower than those outside a dwelling, for an external noise source (Sonus, 2010b, p. 5). However, Ambrose and Rand's research suggests that the situation may be more complicated. Ambrose and Rand found at their test residence a noise reduction of on average 20 dB for frequencies above 31.5 Hz, of about 15 dB at 31.5 Hz, and of 10 dB for the frequencies from 16 down to 8 Hz. However, "below 8 Hz there is no NR [noise reduction], but rather there appears to be amplification for the very lowest frequencies." (Ambrose and Rand, 2011, p. 38) Moreover, they found that the amplitude modulations of infrasound below 10 Hz were *stronger* indoors than outdoors (Ambrose and Rand, 2011, p. 2). In relation to this, they also found that the infrasonic sound energy below 10 Hz was "very-strongly coupled into the house interior", suggesting a "whole-house" *cavity response* of the interior house volume (Ambrose and Rand, p. 40). They associate this with the comment by neighbours, "It's like living inside a drum." (Ambrose and Rand, 2011, p. 39) They state:

> Despite the apparent increase in energy indoors, the wind turbine was almost inaudible indoors. The house envelope blocked most of the frequency content above 10 Hz, and amplified the remaining low frequency pulsations, *much like a drum*. (Ambrose and Rand, 2011, p. 42) (italics in original)

It seems that simple general notions about the reduction in infrasound levels, from outside to inside, are not adequate. Neighbours of NSW wind farms have already asserted that inside their houses it is like living inside a tumbler drier.

It can only be concluded that the O'Neal study and the Sonus study do not address the most serious and urgent problems associated with wind turbine infrasound. The NSW Department of Planning should not cite them in order to allay local residents' concerns.

Stable atmosphere and temperature inversion

In section 1.3 (d) there is a very brief mention of the so-called "van den Berg Effect". It is said that the "Noise Guidelines have been developed to provide greater clarity and rigour regarding the assessment and ongoing regulation of wind farm noise including:

- excessive amplitude modulation (including the van den Berg Effect)" (p. 5)

This is all that is said in section 1.3 (d). In Appendix B: *NSW wind farm noise guidelines*, there is a section of less than half a page on amplitude modulation, but the van den Berg Effect is not mentioned (p. 34). It is clear then that the NSW Department of Planning understands the "van den Berg Effect" as merely a kind of amplitude modulation, and as something that does not require any specific discussion. A general discussion of amplitude modulation will serve.

So far as I can see, the terms 'stable atmosphere' and 'temperature inversion' do not occur anywhere in the draft Guidelines.

These omissions, and the subsuming of the van den Berg Effect under amplitude modulation suggest that the Department of Planning does not understand what is involved in the van den Berg Effect. As what is involved is one of the most important features of wind turbine noise impacts in a rural area, the Department's superficial treatment of this issue is very unsatisfactory, and threatens to leave neighbours of wind farms unprotected from noise impacts that will almost certainly cause chronic sleep disturbance.

What is important here is to distinguish between (i) the effect of increased night-time noise due to a stable atmosphere, caused by temperature inversions, and (ii) an increasingly severe amplitude modulation ("thump-thump-thump"), caused by wind shear. The two do not necessarily go together. By assuming that they do, both the NSW Department of Planning and the NSW Land & Environment Court have fallen into error.

The van den Berg Effect, stable atmosphere and temperature inversion:

The van den Berg Effect is the phenomenon of increased night-time noise from wind turbines due to a "stable atmosphere", caused by temperature inversions.

During the day the air near the ground warms up, and becomes warmer than the air higher up. As a result, the warmer air tends to rise. This is called an "unstable atmosphere".

The situation is reversed on cold evenings and nights. On such evenings and nights the air close to the ground becomes colder than the air higher up. Hence the term "temperature inversion". In this situation there is no warm air to rise, and the colder and warmer layers of the atmosphere do not mix. Hence, this is called a "stable atmosphere".

The relevance of this to wind turbine noise is as follows. During the day, when the atmosphere is "unstable", the warm air rising carries away some of the turbine sound before it reaches a residence. But, on a cold evening or night there is no warm air to rise. The atmosphere is "stable". And the result is that more of the turbine noise reaches the residence.

Therefore, for any quantity of turbine noise coming from the turbine, it will be louder at the residence at night than during the day (assuming that there is a temperature inversion).

The above is the essence of the van den Berg Effect. Convenient summaries of the Effect will be found in Thorne (2011a), p. 17, and Dickinson (2010), pp. 186-189.

However, there is a complication. This complication turns on whether the terrain in which the wind farm and the residences are located is flat or hilly. Professor van den Berg's original research into the effect of stable atmosphere on wind turbine noise was conducted along the Dutch-German border, where the terrain is flat (van den Berg 2004b, 2006). His later research concerned how the Effect occurs in hilly terrain, including the hilly terrain of the Great Dividing Range near Taralga, NSW (van den Berg 2007).

In flat terrain there can be an additional characteristic to the Effect. This is as follows. Where a temperature inversion occurs at the wind turbine, the differences of temperature between the highest point of blade extension, and the lowest point of blade extension cause a turbulence of different wind speeds and directions through which the blades have to move. This turbulence causes the amplitude modulation of the turbine sound ("whoosh-whoosh-whoosh") to become more severe and loud ("thump-thump-thump"). This effect is an extra source of increased noise (van den Berg 2004b).

Therefore, in flat terrain the van den Berg Effect as a whole consists of two sources of increased noise: (i) the essential effect of increased noise due to a stable atmosphere, caused by temperature inversion, between the wind turbine and the residence; (ii) the incidental effect of turbulence at the wind turbine, caused by temperature inversion at the turbine.

By contrast, in hilly terrain there may only be one source of increased noise, namely, the essential effect of increased noise due to a stable atmosphere, caused by temperature inversion, between the wind turbine and the residence. It is possible that in hilly terrain the other characteristic, a severe thumping noise at the turbine due to temperature inversion at the turbine, may be absent, or only present to a slight extent. If the turbines are placed on a ridge, the high wind speed at the ridge may be sufficient to prevent a stable atmosphere from forming at the turbine. Consequently, there will not be turbulence at the turbine, and there will be no severe thumping sound.

Nonetheless, in such terrain, where the residences are down in the valley below the ridge, the cold down in the valley will cause a temperature inversion and a stable atmosphere, so that there is some increase of night-time noise due to this condition (van den Berg 2007).

How the NSW Land & Environment Court misunderstood the van den Berg Effect

The Taralga Case, NSWLEC 59 [2007]

In the judgment on the Taralga Wind Farm case (NSWLEC 59 [2007]) Chief Justice Preston defined the van den Berg Effect as follows:

> The Van den Berg Effect is an additional noise modulation described as a thumping noise which occurs, in limited circumstances, as a consequence of a temperature inversion between the tip of the rotor when it is at its most upward extension and the tip of the rotor when it is at its most downward extension. (para 229)

It will be seen that Chief Justice Preston defines the van den Berg Effect by reference to only one of its two characteristics in flat terrain, the incidental characteristic of the thumping noise produced by turbulence, due to temperature inversion at the turbine. And he ignores the essential characteristic of increased noise due to temperature inversion and stable atmosphere between the turbine and the residence. He then assumes that the incidental characteristic – in reality more relevant to flat terrain – is the only characteristic he needs to consider in the context of the hilly terrain of the proposed Taralga Wind Farm.

He thus makes a double error: (i) he assumes that the characteristic of thumping noise at the turbine is the only characteristic that he has to consider, when such a characteristic is more relevant to flat terrain than to hilly terrain; (ii) he ignores the essential characteristic of increased noise due to temperature inversion between the turbine and the residence, when it is precisely this characteristic, common to both flat and hilly terrain, that is relevant to the hilly terrain of the Taralga proposal.

Chief Justice Preston states that he does not feel that he is required to determine whether the van den Berg Effect will actually occur (para 236). Nonetheless, he assumes that there is only a low probability of its occurrence (para 238). This false assumption is based on the misconception that the van den Berg Effect is to be identified with the thumping at the turbine due to temperature inversion at the turbine. This identification is a misconception, because it confuses an incidental characteristic (the thumping), which is more likely to occur in flat terrain, with the essential characteristic of increased night-time noise due to stable atmosphere, caused by temperature inversion between the turbine and the residence – an essential characteristic common to both flat and hilly terrain.

Chief Justice Preston has thus based his judgment on an irrelevant consideration (the thumping), and failed to consider the truly relevant consideration (the increased noise due to temperature inversion between the turbines and the residence).

It may very well be so that in the hilly terrain of the Taralga Wind Farm there may be little or no thumping at the turbine at night. However, temperature inversion between the turbines and residences on cold evenings and nights will cause increased night-time noise. The Court has failed to protect residents against this, because it has failed to consider the issue accurately.

Before we leave the Taralga case, we must consider the assertion that, if the van den Berg Effect were to occur, the impact would be mitigated by the so-called "facade effect", according to which the turbine noise would be reduced by 10 dBA, as it passes from outside a residence to inside. This notion is inadequate, because it is simplistic. The reality is more complex.

By the time the turbine noise has reached the residence the proportion of sounds of different frequency will have changed in the overall sound mix from what it was when the sound left the turbine. This is due to the fact that low frequency sound attenuates less with distance than high or mid frequency sound (Sonus 2010a, p. 9). Consequently, even outside the residence low frequency sound will make up a bigger proportion of the sound mix than what it did at the turbine. If the turbine sound has passed through vegetation, e.g. trees, the high and mid frequency sound will be even more reduced in the mix (Sonus 2010a, p. 9).

As the turbine noise passes through the fabric of the residence, the high and mid frequency sound are reduced more than is the low frequency sound (DeGagne et al 2008, p. 116).

The final result is that the turbine sound heard within the residence is likely to be predominantly low frequency sound.

The appropriate units with which to measure low frequency sound are dBC, not dBA. This is acknowledged even by the Clean Energy Council and its consultants (Sonus 2010a, p. 9). If low frequency sound is only measured in dBA, the measurement will be inaccurate, underestimating the true magnitude of the sound level.

The assumption that the turbine sound will be reduced by 10 dBA by the “facade effect” is an inadequate notion, since most of the sound passing through the fabric of the residence will be low frequency sound, which cannot be measured accurately by dBA. The American noise experts George Kamperman and Richard James have stated that although the A-weighted sound level inside a residence may have been reduced by up to 15 dBA from its level outside the residence, nonetheless the low frequency sound level will have only decreased by 6-7 dBC (Kamperman and James 2008b, p. 5).

What is at stake here can be illustrated by reference to the work of the Australian noise expert Dr Robert Thorne, who has measured actual wind turbine sound inside a bedroom of a house about two kilometres from the turbines of the Waubra Wind Farm. One of Thorne’s graphs shows unweighted sound levels measured in dBZ. (dBZ are units which give an equal or flat response to sounds of all frequencies between 20,000 Hz and 1 Hz.) What the graph shows is high frequency sound no higher than 10 dBZ, but low frequency sound at a maximum of about 44 dBZ. Most of the sound in that bedroom is low frequency sound, and it is at a level to cause awakening from sleep (Thorne 2011a, p. 19; cf Hanning 2010, p. 9).

It can only be concluded that Chief Justice Preston’s reliance on the assumption that acceptable mitigation from the van den Berg Effect can be expected from a “facade effect” of a 10 dBA reduction was unsafe, since the notion of such a reduction is inadequate to the complex realities of sound propagation.

The Gullen Range Case, NSWLEC 1102 [2010]

In the Gullen Range Wind Farm case commissioners Moore and Fakes adopted Chief Justice Preston's definition of the van den Berg Effect as:

> ... an additional noise modulation described as a thumping noise which occurs, in limited circumstances, as a consequence of a temperature inversion between the tip of the rotor when it is at its upmost extension and the tip of the rotor when it is at its most downward extension. (NSWLEC 59 [2007], para 229; cited in NSWLEC1102 [2010], para 132)

In other words, the commissioners assumed the same misconception as Chief Justice Preston had assumed in the Taralga case. That is, commissioners Moore and Fakes, like Chief Justice Preston, assumed that what they had to consider in relation to the matter of the van den Berg Effect was the incidental characteristic of a thumping sound at the turbine due to temperature inversion at the turbine – a characteristic more relevant to flat terrain than to the hilly terrain of the Gullen Range proposal. The commissioners failed to consider the essential characteristic of increased night-time noise due to stable atmosphere, caused by temperature inversion between the turbines and the residence – the essential characteristic truly relevant to the hilly terrain of the Gullen Range proposal.

Basing themselves on this definition of the van den Berg Effect, and using meteorological data provided to the Court, the two noise experts in the Gullen Range case, Dr Tonin and Mr Turner, agreed "that the Van den Berg modulation is unlikely to occur at any relevant location, or if it does, it would occur infrequently. " (para 133) This inevitably led to the commissioners' conclusion: "We accept this uncontradicted expert evidence that the Van den Berg effect is unlikely to occur and it thus cannot be the basis for any modifications to the proposal." (para 133)

Being based on a misconception, the commissioners' conclusion that the "van den Berg Effect" is unlikely to occur in relation to the Gullen Range Wind Farm must be considered invalid, and an inadequate consideration of the matter of the van den Berg Effect.

And the commissioners' conclusion is in fact false. To confirm this I e-mailed Professor van den Berg at the University of Groningen in The Netherlands. I referred to the Court's finding that the "van den Berg Effect" in the sense of a thumping at the turbine was unlikely to occur. I then asked Professor van den Berg to consider whether the real situation was not in fact more complex. I wrote:

> Most of the residences around the site of the projected wind farm [i.e. Gullen Range] are below the level of the ridge, on which the turbines are to stand – from 50 to 150 metres lower than the top of the ridge. Also, we frequently get fog along and beside the ridge. Fog, as I understand, indicates temperature inversion. So, my question is: will the temperature inversion, indicated by the fog, cause the sound level immitted at the residences to be greater than any computer modelling would predict, because the turbine sound will be inhibited from dissipating upwards? I understand that this can happen where the terrain is flat. Can it also happen where the terrain is hilly, as with our situation? (Brooks, 4.5.2011)

Professor van den Berg wrote back:

> I have come across the situation you sketch. It is true that a stable atmosphere is less likely to occur on a ridge or a (high) hill. There is usually more wind higher up and so there is more mixing which counteracts the tendency of cold air to settle on the ground. Also, the cold air will flow downhill (or “downridge”), again preventing the cold air from settling on the higher ground. However, the second effect will add to cold air settling in the valley, thus strengthening a stable atmosphere there. In the end one has a situation similar to that over a flat terrain: high winds where the rotor is, less or no wind where the resident is – down below. The difference may be that beating is less likely to occur, if my explanation of beating in a stable atmosphere (changing wind speeds over the rotor) is correct. (van den Berg, 16.5.2011)

It is apparent, then, that Professor van den Berg confirms that in hilly terrain, such as that of the Gullen Range Wind Farm, there may be little or no temperature inversion at the turbines on the ridge, while there is temperature inversion below the ridge, between the turbines and the residences. So, there may be no condition of stable atmosphere at the turbines, with the result that there is no thumping at the turbines. But, there will be a stable atmosphere lower down, between the turbines on the ridge and the residences down below. In this situation the turbine noise heard at the residences must be increased.

It can only be concluded that the commissioners’ finding in the Gullen Range case, that “the van den Berg Effect is unlikely to occur”, is unsafe, both because it was deduced from a misconception, and because it is, as a matter of fact, false.

It is evident that the NSW Department of Planning holds the same view of the van den Berg Effect, based on the same misconception, as the NSW Land & Environment Court.

(I have Professor van den Berg’s permission to quote from his e-mails (Brooks, 30.5.2011, and van den Berg, 2.6.2011).

What is needed:

If NSW is to have adequate noise guidelines, in respect of the influence of a stable atmosphere and temperature inversion on night-time wind turbine sound, then the following are needed:

- **A distinction must be made between (i) a stable atmosphere and temperature inversion between the turbine and the residence, and at the residence, on the one hand, and (ii) a temperature inversion-induced wind shear at the turbine, causing a more severe amplitude modulation, on the other.**

- **The probability (and actuality) of a stable atmosphere, caused by temperature inversion, must be assessed for *both* the site of the turbines, *and* the site of the**

residence. This is the only way that the real probability of increased night-time noise can be assessed, especially if the turbines are located on a ridge, while the residences are down in the valley.

- **Separate assessments must be made for (i) increased night-time noise due to a stable atmosphere, caused by temperature inversion in and around the residence, and (ii) a more severe amplitude modulation at the turbine due to wind shear, caused by temperature inversion at the turbine.**

Without this kind of assessment (in dBA, dBC, dBG, and dBZ) wind farm neighbours in NSW will suffer chronic sleep disturbance, as in fact is already happening at the Crookwell One, Cullerin, and Capital Wind Farms, as well as at other wind farms in Victoria, South Australia, and New Zealand, and around the world.

Wind speed ratio

The draft Guidelines state:

> A unique characteristic of wind farms is that the noise level from each wind turbine rises as the wind speed at the site increases. *This is typically accompanied by an equal or greater increase in the background noise which may completely or substantially mask the wind turbine noise*. (p. 27; cf. p. 6) (italics added)

The first sentence in the above quotation is true. The second sentence is completely false.

The assumption that, as the wind speed at the turbine rises, the noise of the wind itself will mask the turbine noise at a residence is a false assumption that has been taken over uncritically from the *South Australian Noise Guidelines* (SANG, 2003, p. 2; 2009, p. 2). This was never more than wishful thinking, and experience has proved it to be false. It is now commonly accepted by acousticians that the wind speed can be high at the turbine, while being low or even zero at the neighbouring residence. This has been known since van den Berg first published his research in 2004 (van den Berg, 2004b, 2006, 2007; cf. van den Berg's e-mail quoted in the previous section; also, Thorne, 2011b, p. 266)

It is surprising that the NSW Department of Planning could allow this error to be in the draft Guidelines, since it has been known to be an error for a long time.

Appelqvist and Almgren:

The circumstance of wind speed being high at the turbine, but low or zero at the residence is an aspect of the van den Berg Effect, or the phenomenon of increased night-time noise due to a stable atmosphere, caused by temperature inversion (see previous section). However, it can also arise from the terrain, where the turbine is set higher than the residence, and the residence is sheltered by the terrain.

The National Swedish Environment Protection Board has proposed that wind farm sites with big differences in wind speed between the turbines and the residences should require a decreased guideline value, i.e. a lower noise limit. It has been proposed that the threshold wind speed ratio be 2:1 (Appelqvist and Almgren, 2011, pp. 1, 2). This issue has been researched by the acousticians Paul Appelqvist and Martin Almgren, who reported their results at the *Fourth International Meeting on Wind Turbine Noise*, in April 2011 (Appelqvist and Almgren, 2011).

Appelqvist and Almgren measured sound immissions from three wind farms, all set in hilly terrain, such that the measuring point was lower than the location of the turbines. In two of these cases, the measuring point was a residence, but in the third case it was only a sheltered location. In the first two cases, the wind farms had given rise to noise complaints (Appelqvist and Almgren, 2011, pp. 2-3, 6, 10).

In the first case, it was found that when the wind direction was such that the residence was downwind of the turbine, then for most of the measuring period the wind speed ratio was 2:1 or more. They found that very high ratios of 10:1 or more only seemed to occur in the evening and at night, between 10 pm and 7 am. They say: “This is also true to some extent for ratios down to 2:1, while the opposite holds for ratios below 2:1 which are more frequent during day-time.” They also say: “A high ratio is more likely to cause audible noise from the wind turbines due to the reduced masking effect from wind induced noise.” The measured noise levels were higher than what had been predicted. (Appelqvist and Almgren, 20011, p. 4, 6)

Similar results were obtained in the second case. The biggest wind speed ratios occurred in the evening and at night (10 pm to 6 am) (Appelqvist and Almgren, 2011, pp. 7-8).

In the third case, where there was no residence, the relation of the wind direction to the terrain gave rise to a partial masking effect of the turbine noise by the noise of the wind, at least for some wind directions (Appelqvist and Almgren, 2011, pp. 12-13).

Appelqvist and Almgren’s research confirms that where wind turbines are set on a hill or a ridge, higher than the location of neighbouring residences, the wind speed ratio can be extreme, and this can lead to increased noise at the residences. It is also important that their research confirms that of van den Berg in that the biggest wind speed ratios between turbines and residences occur in the evening and at night, suggesting the influence of a stable atmosphere, due to temperature inversions.

It is therefore imperative that the wind speed ratio be taken into account during the assessment and compliance monitoring stages of the planning process. But now we come up against the usual problems. Appelqvist and Almgren propose four methods by which to implement the Swedish Environment Protection Board’s proposal to require a lower noise limit for sites where the wind speed ratio is 2:1 or more. These are:

- Measurement of wind speed at both turbines and dwellings, with noise also measured at the dwellings
- Measurement of only wind speed or only noise
- Study differences of heights in the topography at the planned site, and compare with known cases of sheltered areas
- Calculate wind speed in the microclimate based on detailed wind analysis

Unfortunately, as Appelqvist and Almgren point out, there are problems with each of these methods. Methods 1 and 2 are said to be probably the most accurate, “but could lead to extensive measurement programs and also bring halt to the planning process and are probably also the most expensive.” Method 3 needs measurements at more locations for statistical certainty, and needs good altitude data. “Method 4 would most likely be the preferred method if a sufficiently good wind analysis method was available. No such method, with enough accuracy, is known to the authors." (Appelqvist and Almgren, 2011, p. 14)

So, the more accurate methods are more expensive, while the cheaper methods need further research if they are to have any accuracy.

From the standpoint of local residents it is essential that wind speed be measured both at the turbines, and at the residences, with noise also measured at the residences. This is possible, and it is necessary. If it is expensive for the proponent, so be it. As I have said before, wind farm developers have a state-guaranteed market, with state-guaranteed profits. This is enough of a privilege. Neighbours' health, well-being and amenity should not be sacrificed to developers' profitability.

It is surely clear that wind farm development has been premature, if not reckless. It has been promoted by state governments in Australia before all the necessary research needed for adequate environmental regulation has been done.

Increased night-time noise is one of the most important problems of wind farm development. It can lead to chronic sleep disturbance, with an increased long-term risk of contributing to multi-factorial diseases (see section on *Health*). The only solution to this problem is a moratorium with a research programme. If this is not implemented, and NSW's new guidelines remain inadequate, there will be a planning disaster, and a public health hazard. The moratorium is the only way that the disaster can be averted.

Measurements

As I have already indicated, wind turbine sound must be measured in 4 units:

- **In dBA: to measure the higher frequency sound**
- **In dBC: to measure audible low frequency sound**
- **In dBG: to test whether the inaudible infrasonic emissions exceed Professor Salt's threshold of 60 dBG**
- **In dBZ: this is necessary because dBG is only appropriate down to 10 HZ. Below 10 Hz dBZ is the appropriate unit**

All these units are necessary, because wind turbine sound is a broadband mix, comprising both higher frequency sound, and lower frequency sound, including infrasound. The sound energy present includes both audible and inaudible sound.

Sleep disturbance and annoyance have been associated with audible low frequency sound (requiring dBC). Sleep disturbance, annoyance, and other symptoms, such as tinnitus, ear pressure, ear fullness, vertigo, nausea, tachycardia, etc have been associated with infrasound (requiring dBG and dBZ). Vibro-acoustic disease has been associated with infrasound below 10 Hz (requiring dBZ).

The probability of increased noise due to blade stall or 'woomping', Heightened Noise Zones, synchronicity, and turbulence effects must be seriously estimated.

Turbines must be treated as a line source, not as a point source. Cylindrical spreading must be assumed, not spherical spreading.

Amplitude modulation at the blade pass frequency must be measured in dBA, dBC, dBG, and dBZ.

Amplitude modulation on a micro-time scale must be measured by the methods used by Bray and James (Bray and James, 2011). As Bray and James have pointed out, macro-time scale measurements such as L_{eq} conceal the real magnitude of micro-scale fluctuations, with a high crest factor, which are registered by the human hearing mechanism.

Temperature inversions at both the site of the turbines, and at residences must be measured, and their correlation with noise levels determined (using the appropriate units).

Wind speed at the turbines, and wind speed at the residences must be measured, and correlated with noise at the residences (using the appropriate units).

The 24 hour day must be divided into 3 periods, not two as suggested by the draft Guidelines. This is necessary because, as the research of Appelqvist and Almgren shows (see above), increased noise can occur in the evening between 6 pm and 10 pm, as well as during the night (10 pm to 7 am). The three periods, therefore, must be: 7 am to 6 pm; 6 pm to 10 pm; 10 pm to 7 am. (These are the periods already recognized by the New South Wales *Industrial Noise Policy* (NSWINP, 2000, p. 18).)

The measurements must be genuine measurements taken at the designated location. Proponents should not be allowed to substitute measurements at an intermediate location, with a sum. The substituted process can only be based on assumptions, and leaves room for abuse and misrepresentation.

Only if all these measurements are required will there be any real chance of estimating the probable, and actual noise immissions at neighbours' residences. If all these measurements are not made, then the real noise impact at residences will be misrepresented. Noise complaints and health complaints will be endless. When it is eventually proved, that noise impacts are excessive, intrusive, and dangerous to health, and turbines have to be turned off, capital will be wasted.

Noise limits and penalties

Noise limits:

The draft Guidelines set the following limits:

- 35 dBA, or background noise (L_{90}) + 5 dBA, whichever is greater (p. 27)
- 65 dBC (day) and 60 dBC (night)

Both these limits are unacceptable.

35 dBA is unacceptable, because background noise in a quiet country setting can fall below 25 dBA, or even below 20 dBA. If 5 dBA above background noise is supposed to be acceptable, then the acceptable limit would appear to be no more than 25 dBA, or 30 dBA, depending on the actual level of background noise.

'Whichever is greater' is unacceptable for the same reason. If background noise + 5 dBA turns out to be 25 dBA or 30 dBA, then to allow the wind farm to produce 35 dBA at a residence will guarantee annoyance, and possibly sleep disturbance.

I have already explained above why 65/60 dBC is unacceptable for low frequency noise (see above). 60 dBC equates to about 50 dBA. If background noise is 20 dBA outside, and perhaps virtually nil indoors at night, to allow low frequency noise in the 50s dBC into a bedroom would make life in that house unbearable.

***Outdoor noise limits*:**

We propose:

- **30 dBA (L_{eqA}), or background noise + 5 dBA, whichever is *lower***
- **The lower of the following:**
    1. **L_{eqC} - L_{90A} no greater than 20 dB**
    2. **A maximum not-to-exceed level of 50 dBC (L_{eqC})**

Note: I have changed Kamperman and James's 50 dBC (L_{90C}) to 50 dBC (L_{eqC}), because the difference between L_{eq} and L_{90} can be many decibels. See below under *Compliance monitoring*.

- **60 dBG**

***Indoor noise limits*:**

We propose:

- **20 dBA (L_{eqA}), or background noise + 5 dBA, whichever is *lower***
- **45 dBC (L_{eqC}), or (L_{eqC} – L_{90A} no greater than 20 dB), whichever is *lower***
- **60 dBG**

There should also be limits for outdoors and indoors in dBZ, but what they should be I cannot say. If there is not yet enough research to specify limits in dBZ, then that is another reason for a moratorium.

Penalties:

The draft Guidelines propose penalties for excessive amplitude modulation (greater than 4 dB), low frequency noise, and tonality.

The idea of adding 5 dBA penalties to a basic dBA measurement is a relic of the old noise assessment regime where *only* dBA measurements were made. If measurements are now to be made in dBA, dBC, dBG, and dBZ, as they should be, then what is needed is a set of definite limits along each of the weighting scales. This should include limits for amplitude modulation, low frequency noise, and tonality. All of the limits must be complied with. The limits should be set at levels to ensure that sleep disturbance, annoyance, and other adverse health effects do not occur for neighbours. If this cannot yet be determined, because research has not been completed, then there should be a moratorium and a research programme.

The philosophy implicit in the concept of penalties of a number of dB (5 dB) to be added to the estimated sound level also assumes that it is just the *level* of sound that is the problem. It should be apparent from all the research that has been done on wind turbine sound that the *character* of the sound is equally, if not more of a problem. Wind turbine sound is generally recognized now to be more annoying than other forms of industrial noise (Pedersen and Persson Waye, 2004). It is virtually certain that the explanation for this relates to the impulsive nature of the sound, and the relation of that to the 'startle' and 'alerting' mechanisms in the human nervous system. Whether this is directly related to audible low frequency sound or, as Salt hypothesizes, it is mediated by infrasonic stimulation of the inner ear, requires further – and urgent – research. But if it is the impulsive character of the sound that is the problem, then merely adding penalties of 5 dB to an already inadequate noise limit seems a very rough-and-ready kind of solution. **Presumably, the only genuine solution is to have a sufficient setback distance so that the physiological processes – whatever they are – are not set off. But, as all the medical research to determine such setbacks has not been done, we come back to a moratorium and a research programme. This issue really cannot be baulked.**

I note that the draft Guidelines set a maximum penalty of 5 dB, even though 5 dB is required for excessive amplitude modulation, another 5 dB for excessive low frequency noise, and another 5 dB for tonality (pp. 33-35). Since these penalties relate to different aspects of the sound, they should all be applied, if all the exceedances occur. To reduce the maximum penalty to 5 dB is an unjustifiable bias towards the wind energy industry, and against residents. (Even in the NSW *Industrial Noise Policy*, the maximum penalty is 10 dB (NSWINP, 2000, p. 28). So, why the reduction to a maximum of 5 dB, unless this is bias?)

I note that the section giving definitions of exceedances on p. 35 of the draft Guidelines is unrelated to its context. What the significance of the different kinds of exceedance is, is not stated. When exactly does each matter? Why has this not been explained? Are penalties due for a "repeated exceedance", or only for a "sustained exceedance"? Presumably not for a single exceedance. Why was this matter not thought through before the draft Guidelines were published?

This is a very important matter, as people's health is at stake. Is the Department of Planning really going to calculate how many nights' sleep disturbance people can endure without serious consequences to their health? How is 'serious consequence' to be defined?

If all this is too difficult, and if the Department of Planning left this unresolved, because it is too difficult, then let us have a moratorium and a research programme.

Ideally, noise limits should be related to the risk of adverse health effects. But existing noise limits are only based on annoyance curves, established through social surveys (Dickinson, 2010, pp. 194-196; Schultz, 1982). Moreover, these annoyance curves were themselves constructed in relation to transportation noise, which has been demonstrated to be less annoying at any given noise level than wind turbine noise (Pedersen and Persson Waye, 2004). So, the existing noise limits are doubly inadequate.

Noise limits should be set to ensure that neighbours do not suffer regular sleep disturbance, or other defined adverse health effects. But, health-effect based noise limits for wind turbines are impossible at present as the necessary research has either not been done, or not completed. This emphasises again how premature wind farm development has been. Only a moratorium and a research programme will do.

Compliance monitoring and Complaints

Compliance monitoring should be done in accordance with the stipulations set out under *Measurement* above.

In the draft Guidelines the 24 hour day is divided into 2 measuring periods: 7 am – 10 pm, and 10 pm – 7 am (p. 37). As I have already argued, there needs to be a threefold division, as increased noise can occur in the evening, as well as during the night: 7 am – 6 pm; 6 pm – 10 pm; 10 pm – 7 am. These are the periods recommended in the NSW *Industrial Noise Policy* (NSWINP, 2000, p. 18).

A full spectral analysis, of all frequencies from 0 Hz to 20,000 Hz, must be made.

No intermediate locations for measurements should be allowed (p. 37).

Monitoring must take account of the wind speed ratio between the turbines and the residences.

Monitoring must also take account of temperature inversions both at the turbines and at the residences.

Monitoring should occur regularly in order to check for mechanical noise from wear and tear. It should not be the task of neighbours to report noise from wear and tear to the proponent.

The concept that L_{eq} can be assumed to equal L_{90} + 1.5 dB cannot be allowed to stand, as it grossly underestimates the possibility of real difference (p. 37). Thorne has measured L_{Aeq} and L_{A95} levels inside a residence near a wind farm in Victoria. For a particular time-slice of his survey, the L_{A95} level was 17.4 dBA; the average L_{Aeq} level was 32.5 dBA (Thorne, 2011b, p. 269). This is a difference of 15.1 dB!

Thorne also cautions:

> The caution here is that sound levels vary significantly over very short (10 minutes, for example) periods of time. Thus, an assessment on an average longer-term level may not truly represent the short-term effect of varying sound character. (Thorne, 2011b, p. 270)

If it is difficult to distinguish the wind turbine noise from the ambient background noise, then there is only one method to be adopted. The turbines must be turned off, measurement taken, the turbines turned on again, another measurement taken, and the two measurements compared (Thorne, 2011b, p. 263). To avoid doing this by assuming that L_{eq} equals L_{90} + 1.5 dB is completely unacceptable. The inconvenience of turning the turbines off must be born by the operator, who has a state-guaranteed market, with state-guaranteed profits.

Thorne has pointed out the extreme difficulty of reaching a clear-cut determination as to whether a wind farm is in compliance with its noise limits, because wind turbine sound has such a pronounced tendency to fluctuate. He presents a table of measurements for a Victorian wind farm, taken over 11 days, and shows that sometimes the wind farm appeared to comply, and sometimes not:

> Table 1 shows the wide range in sound levels at the residence. The levels, at approximately 2000 meters from the turbines, show the impossibility of determining when or if the wind farm is exceeding a background level of 35 or 40 dBA. It can be inferred that for some of the time the wind farm is in compliance but at other times it might not. The situation becomes more difficult if there is sufficient breeze to cause a significant lift in background levels. (Thorne, 2011b, p. 266)

It can only be concluded that trying to impose conditions of consent on a wind farm, in the form of noise limits, is an impractical task, because compliance or non-compliance cannot be unproblematically determined. Where this is the case, it is unjust to continue with a pretence that noise guidelines will protect neighbours from adverse impacts. This being so, the only solution is to have an adequate setback distance to eliminate the possibility of neighbours suffering. But such a setback distance cannot yet be determined. It is therefore necessary that there be a moratorium and a research programme.

(On the problems of using L_{90} as a descriptor for measuring wind turbine noise impacts, see also Hansen, 2010.)

Protection of the Environment Operations Act, 1997, and EPA:

The NSW government proposes to amend the Protection of the Environment Operations Act, 1997, so that the body to receive noise complaints concerning wind farms is the Environment Protection Agency (p. 6). This is a long overdue reform, as hitherto neighbours of wind farms have been caught in a legal tangle. Wind farms were excluded from the schedule of industrial sources of noise in the PEOA, so that residents were legally obliged to make their complaint to the local council. The local council would probably not have the resources to investigate the complaint; it might refuse to investigate the complaint; and even if it did investigate, it would have no legal authority to impose conditions on a project approved at state level. This is already the situation of neighbours of the Capital Wind Farm, whose complaints to Palerang Council have been met with a refusal to investigate.

However, given the extreme reluctance of NSW government departments to listen to residents' complaints and concerns in the past, it must be questioned whether the EPA can be depended on to protect neighbours from real adverse impacts, or whether it too will exhibit a bias in favour of developers, and against residents. It would be preferable to establish an independent Compliance Authority, at a distance from government, to deal with the issue of compliance – insofar as it can be dealt with practically. Any institution associated with the Department of Environment must be in danger of a conflict of interest,

as the Department of Environment is charged with promoting wind farm development in NSW.

A permanent monitoring system:

It is now technologically possible to install a permanent noise monitoring system in all homes, work buildings, schools, or places of assembly around a wind farm. The sound monitoring equipment can be linked to a control unit, which can send instructions to the wind farm's control unit for turbines to be shut down, if there are exceedances of a set noise level (Waubra Foundation, 2011).

The use of such a system still presupposes that acceptable noise limits have been worked out, and that a decision has been reached as to what, over time, constitutes an unacceptable exceedance, necessitating the shutting down of turbines. This brings us back yet again to a moratorium and research programme. But at least when the research is completed, it will be possible to monitor emissions, and to end intrusive and health-affecting impacts.

Final remarks

A moratorium and research programme

Acousticians and medical researchers have abundantly testified that many aspects of wind turbine impacts require further research, if impacts are to be estimated accurately, and if adverse health effects are to be avoided. Further research is needed for the following: sound propagation from the turbine; the impact of multiple turbines; amplitude modulation and crest factor on a micro-time scale; the threshold of audibility; methods for dealing with the wind speed ratio; the health effects of wind turbine infrasound, both in relation to the symptoms of Wind Turbine Syndrome, and in relation to Vibro-acoustic Disease; other potential physiological processes in the nervous system, e.g. the frequency following response.

Given the need for all this research, continued wind farm development is premature and reckless. What is needed is not new guidelines, but a moratorium and a research programme.

The need for a moratorium and research programme is emphasised by the fact that the draft Guidelines show little sign of having paid any regard to current research. It still appears that the NSW Department of Planning is ignoring the bulk of independent acoustic and medical research, published in refereed journals, the proceedings of conferences, and in other refereed studies.

The draft noise guidelines, as they stand, will certainly not protect neighbours from adverse impacts. Complaints will be endless, when turbines are built. Capital will be wasted, when turbines have to be turned off to avoid non-compliance or demonstrable adverse impacts.

Curfew and setbacks

***Curfew*:**

The neighbours of Sydney airport enjoy a curfew at night, to enable them to sleep. Why cannot there be a curfew for wind turbines at night? Is it supposed that rural residents do not need to sleep? Why should city-dwellers be privileged over rural residents? This is especially important as wind turbine noise can continue all night, sometimes for several nights in a row, according to the wind. How can the Department of Planning consider this to be trivial?

***Setbacks*:**

As an adequate setback is the only way to deal with the intractable problems of wind turbine noise impacts, I will end this section on noise with the recommendation of Philip Dickinson, Professor of Acoustics at Massey University, New Zealand:

> **One easy solution for solving the noise problem and protecting public health, is a ruling that no wind farm sound emission shall exceed 30 dB ($L_{Aeq,\ 10\ mins}$) at any residence, nor exceed 20 dB ($L_{Aeq,\ 10\ mins}$) in total in the frequency bands 31.5 to 125 Hz. A very simple way of achieving this, and of eliminating the need for any further involvement by the territorial authority, would be to make a ruling that no wind farm shall be situated less than say 5 to 10 kilometres away from any residence unless the occupant agrees in writing for this condition to be waived. (Dickinson, [2011], p. 8)**

The NSW branch of the Australian Labor Party has proposed that no wind farm be located within 5 kilometres of any township. Why should urban dwellers be given this protection and not rural residents? Let there be at least a 5 km setback distance for both urban and rural residents, with a proviso that this may be extended, if further research justifies it.

Health

Grounds for concern

In the draft Guidelines *Health* is declared to be a key consideration in the assessment of wind farm proposals, and proponents are required to consider explicitly health issues (pp. 2,7). But there is very little discussion of health issues in Appendix A: *Meeting assessment requirements*, merely two brief paragraphs and four bullet points (p. 21). This being the case, how are proponents to know what constitutes a satisfactory consideration of the health issues related to wind turbines? The draft Guidelines ought to give some guidance in relation to specific issues, based on current research.

Proponents are advised to focus on health impacts at residences within 2 kilometres of turbines (p. 21). 2 kilometres is almost certainly too short a distance. The Australian acoustician Bob Thorne, who has a PhD in Health Science from Massey University, New Zealand, has stated:

> **Considering my own research, I conclude that a wind farm development has a high potential to cause adverse amenity, annoyance, sleep disturbance or health effects that are more than minor to residents within 3500 metres of the proposed wind farm.**
>
> **The effects may not extend to all persons within the locale and may extend approximately 3500 metres depending on wind farm design, weather conditions, ground conditions and topography. (Thorne, 2010e, pp. 132-133)**

Dr Sarah Laurie is a physician from South Australia, and Medical Director of the Waubra Foundation. Her investigations in Australia corroborate Thorne's findings:

> Preliminary results of investigations (24-hour blood pressure Holter Monitor) are showing that some people living adjacent to turbine developments **(distance of 3 to 4 km = 1.9 to 2.5 mi)** are getting episodes of hypertension (high blood pressure) at night, sometimes dangerously high, while they are asleep and while the turbines are operating. As this will mostly be asymptomatic, people generally will be unaware that it is happening to them until this investigation is done on a night when the turbines are operating.
>
> Notice, these patients do not necessarily have previously diagnosed hypertension; they and their family physician might think their blood pressure is normal, since it is normal when measured in the doctor's office, during the day, well away from the turbines. (Laurie, 2010) (bold added)

It would seem that the area to be considered by proponents in relation to health impacts should be at least 4 kilometres. But who knows how large an area this should be? If this is unknowable at present, then what is needed is a moratorium and a research programme.

In Appendix A of the draft Guidelines proponents are advised to consult the National Health and Medical Research Council's *Public Statement: Wind Turbines and Health* (2010). Proponents are also told that the Department of Planning may refer applications to the NSW Department of Health (p. 21).

The NHMRC *Public Statement* (July 2010) claims that "There is currently no published scientific evidence to positively link wind turbines with adverse health effects." But this document has a bibliography of only 13 items, at least 4 of which are studies sponsored by the wind energy industry. The bibliography does not include Dr Nina Pierpont's book, published in 2009, even though that book is peer-reviewed (see below). The bibliography also does not include the conference papers delivered by Professors Alves-Pereira and Castelo Branco in 2007 (see below). Those papers present evidence connecting wind turbine infrasound and the potential for Vibro-acoustic Disease.

The NHMRC document *Wind Turbines and Health: A Rapid Review of the Evidence* (July 2010) has a bibliography of 29 items, at least 7 of which are studies sponsored by the wind energy industry, or written in support of the wind energy industry. This bibliography also does not include the papers delivered by Alves-Pereira and Castelo Branco in 2007, nor the book *Wind Turbine Syndrome* by Dr Nina Pierpont in 2009.

The NHMRC cannot justify their exclusion of Dr Pierpont's book on the ground that it is not peer-reviewed, because it is peer-reviewed. The NHMRC cannot justify their exclusion of the book on the ground that it is not in the form of a journal article, because the NHMRC has included in its bibliographies other studies that are not journal articles, such as the Colby et al study *Wind Turbine Sound and Health Effects: An Expert Panel Review, prepared for the American Wind Energy Association and the Canadian Wind Energy Association* (2009).

Given the paucity of the bibliographies, and what the bibliographies include and exclude, it is impossible to avoid the suspicion that the NHMRC has aligned itself with the wind energy industry, and is unwilling to consider evidence from independent researchers who raise concerns about the potential adverse health effects of wind turbines.

It should be noted that the NHMRC *Rapid Review* is anonymous, and that there is no sign that it has been peer-reviewed. At one of the sessions of the Committee Professor Anderson, CEO of the NHMRC, claimed that the document was peer-reviewed (Community Affairs, 2011a, p. CA 85). But, the Committee's report does not name the authors of the *Rapid Review,* or the peer reviewers, if any (Community Affairs, 2011b, pp. 5-28). To the best of my knowledge, the identity of the authors, and of the peer reviewers, if any, remains unknown.

The NHMRC *Rapid Review* has been destructively criticised by the *Society for Wind Vigilance*, in a study approved by an advisory group that includes four distinguished physicians, and two distinguished acousticians. The Society's critique states:

> The "Rapid Review" is an incomplete literature review with no original research. The report is biased from the outset as it seeks to support a restricted and preconceived conclusion. The end result is a deficient public health document.

> NHMRC asserts it "... only uses the best available evidence, in the form of peer-reviewed scientific literature, to formulate its recommendations." The contents of the "Rapid Review" reveal a different reality. The list of reference omissions is immense.
>
> The "Rapid Review" places an inappropriate level of credence in wind energy industry produced and or sponsored material to support its assertions. To compound this bias the "Rapid Review" selectively cites references which favour the wind energy industry while inexplicitly omitting relevant citations which do not.
>
> The "Rapid Review" is characterized by persistent allusions that people experience adverse health effects due to "attitude", "negative opinions" and "worry". These speculative theories are presented while ignoring authoritative knowledge on the subject of noise and health. (SWV, NHMRC, pp. 3-4)

The *Rapid Review* explicitly claims that "there are no direct pathological effects from wind farms":

> This review of the available evidence, including journal articles, surveys, literature reviews and government reports, supports the statement that: *There are no direct pathological effects from wind farms and that any potential impact on humans can be minimised by following existing planning guidelines.* (NHMRC, 2010b, p. 8) (italics in original)

However, at a session of the committee Professor Anderson, CEO of the NHMRC, responding to Senator Fielding's reference to the *Rapid Review*'s claim that there are no adverse health impacts from living near wind turbines, stated:

> I know that the headline on that public statement [sc. the *Rapid Review*] says that, but *the document does not say that*. It did say that there was no published scientific evidence at that stage to positively link the two. That is a very different thing to saying that there are no ill effects and *we do not say that there are no ill effects. We definitely do not say it that way*. (Community Affairs, 2011a, p. CA 88) (italics added)

Professor Anderson's testimony is not accurate. As cited above, the *Rapid Review* quite clearly states: "There are no direct pathological effects from wind farms ...." (NHMRC, 2010b, p. 8) It seems that the NHMRC is backtracking on its published claim, and now does not say that there are no ill effects. This is effectively a repudiation of the claim made in the *Rapid Review*.

The position of the NHMRC outlined by Professor Anderson at the session of the Senate Committee is much more modest. He stated:

> We regard this as a work in progress. We certainly do not believe that this question has been settled. That is why we are keeping it under constant review. That is why we said in our review that we believe authorities must take a precautionary approach to this. (Community Affairs, 2011a, p. CA 87)

In view of Professor Anderson's testimony at the Community Affairs Committee that the (current) position of the NHMRC is that in their view there is no evidence to ascribe adverse health effects to wind turbines, but that the matter is being kept under constant review, and that authorities should adopt a precautionary approach, it is difficult to see what purpose is served by advising proponents of wind farm proposals to consult the existing public statements of the NHMRC. Professor Anderson's testimony could be summed up by saying, "We don't know." How will this help a developer word his application? How will it help a developer assess the potential health impacts of his proposal?

The draft Guidelines advise that the Department of Planning may refer applications to the NSW Department of Health (p. 21). It is hard to find any reassurance in this reference to the NSW Department of Health. I have a letter, dated 7 December 2011, from the Hon. Melinda Pavey MLC, Parliamentary Secretary for Regional Health, writing on behalf of the Minister for Health, concerning wind farm development in my local area. In part, Ms Pavey writes:

> I am advised by the NSW Ministry of Health that the National Health and Medical Research Council (NHMRC) conducted a rapid review of the evidence of adverse health impacts of wind turbines in July 2010. This review concluded that "*There are no direct pathological effects from wind farms and that any potential impact on humans can be minimised by following existing planning guidelines*". Of note is that the NSW Ministry of Health endorsed these NHMRC findings. (Pavey, 2011) (italics in original)

So, as late as 7 December 2011, the NSW Department of Health is still putting forward the *Rapid Review*'s claim that there are no direct pathological effects from wind farms, even though that claim was effectively repudiated by the CEO of the NHMRC on 31 March 2011, at the Committee session.

Minister Pavey also endorses the claim of the *Rapid Review* that any potential impact on humans can be minimised by following existing planning guidelines. But, if, as the NHMRC now holds, a precautionary approach must be taken, "because of the very early stage of the scientific literature" (Community Affairs, 2011a, p. CA 87), how is it possible to know that existing planning guidelines are sufficient to "minimise" potential adverse impacts? If it is correct that at present there is insufficient evidence to state categorically that there are adverse health impacts from wind turbines, *it is equally true that there is insufficient evidence to state categorically that there are no adverse health impacts from wind turbines*. Insufficient evidence means agnosticism *in both directions*. Therefore, the *Rapid Review*'s claim that existing planning guidelines will "minimise" adverse health impacts must be repudiated as well. It cannot be possible to know that this is true. (And what does "minimise" imply, when health effects are in question?!)

Local residents cannot take any comfort from the idea that the Department of Planning will refer the health-related issues of wind farm proposals to the Department of Health, as the Department of Health is still relying on claims made in the NHMRC's *Rapid Review*, which will not bear scrutiny. This is not encouraging.

It must be stated clearly here that it is untrue that there is insufficient scientific evidence to connect wind turbines with adverse health effects. On the contrary, there is sufficient evidence. I present it below.

Meanwhile, health concerns around wind farms continue to be raised by physicians as well as by the neighbours of wind farms.

Several Australian medical practitioners, practising in rural areas have publicly expressed their concerns about the serious health problems experienced by their patients, living in the vicinity of wind farms. They are Dr David Iser (2004), Dr Wayne Spring (2011), and Dr Andja Mitric-Andjic (2011). For details, see the media release put out by the Waubra Foundation (Laurie, 2011).

A recent editorial in the *British Medical Journal* calls for urgent independent research into the health effects of wind farms, especially in relation to noise impacts. The authors of the editorial are Dr Christopher Hanning, honorary consultant in sleep medicine at the Sleep Disorders Service, University Hospitals of Leicester, Leicester General Hospital, Leicester, UK, and Alun Evans, professor emeritus at the Centre for Public Health, Queen's University of Belfast, Institute of Clinical Science B, Belfast, UK. They write:

> A large body of evidence now exists to suggest that wind turbines disturb sleep and impair health at distances and external noise levels that are permitted in most jurisdictions, including the United Kingdom. Sleep disturbance may be a particular problem in children, and it may have important implications for public health. When seeking to generate renewable energy through wind, governments must ensure that the public will not suffer harm from additional ambient noise. Robust independent research into the health effects of existing wind farms is long overdue, as is an independent review of existing evidence and guidance on acceptable noise levels. (Hanning and Evans, 2012)

Wind turbines and adverse health effects

Before it can be determined whether there are adverse health impacts from wind turbines, the term "health" needs to be defined. The relevant sense for the consideration of wind turbine impacts on neighbours is that of the World Health Organization, which defines health as:

> A state of complete physical, mental and social well-being and not merely the absence of disease or infirmity.(WHO, 1948)

From the standpoint of this concept, the WHO regards both "annoyance" and sleep disturbance from excessive and intrusive noise as adverse health effects. See:

- *Guidelines for Community Noise*, ed. Berglund, B., Lindvall, T., Schwela, D. H., World Health Organization, 1999, sections 3.1, 3.3, 3.7

It should be noted that “annoyance” in this context does not just mean a passing irritation, but also “anger, disappointment, dissatisfaction, withdrawal, helplessness, depression, anxiety, distraction, agitation, or exhaustion” (WHO, 1999, section 3.7)

Griefahn and Basner testify that noise-induced sleep disturbances are regarded as adverse health effects by medical researchers, and that they can lead to impairment of performance, and in the long term contribute to multi-factorial diseases. See:

- Griefahn, B., and Basner, M., Disturbances of sleep by noise, Paper 107, Proceedings of ACOUSTICS 2011, 2-4 November 2011, Gold Coast, Australia, pp. 1-2 [This is a refereed conference paper.]

Since it is indisputable that wind turbine noise causes both annoyance and sleep disturbance for at least some neighbours, and since both annoyance and sleep disturbance from noise are regarded by the medical community as adverse health effects, *it follows necessarily that wind turbine noise causes adverse health effects.* This *general fact* does not have to be proved. It is already established. What is in question is the extent to which this phenomenon has been researched. This brings us to the topic of past, present and future research.

The state of research

It must be observed that there is far more research on wind turbine noise impacts by acousticians and noise engineers than by medical researchers. Why this should be so itself deserves to be investigated. One thing is certain. The explanation for the paucity of medical research is not because there are no adverse health effects to be investigated. As we have just seen, there is no doubt that there are such adverse health effects. The explanation must therefore be sought in a different direction. That topic cannot be pursued here.

According to Griefahn and Basner, systematic research into noise-induced sleep disturbances started at the end of the 1960s. But, most studies have focussed on transportation noise (aircraft, railways, road traffic) (Griefahn and Basner, 2011, p. 2). The bibliography to their conference paper lists 41 studies relating to noise-induced sleep disturbances, but none of them is focussed on wind turbine noise. They do, however, say:

> According to the studies performed so far, noise-induced sleep disturbances are to be considered as a health risk. The majority of noise-induced sleep disturbances is undoubtedly caused by transportation noise, and most studies focussed accordingly on these noises. As the extents and patterns of the respective effects were related to various acoustic features (such as maximum levels, rise times, duration, noise-free intervals, frequency spectra) as well as to situational conditions (such as time of night), *it is possible to transfer some knowledge to other noises that are not, or less intensively studied.* These are industrial noises that are significant on a rather regional level, and construction noises with a rather temporal significance**.** *Rather uniform noises are known to disturb sleep as well, namely church bells and wind turbines. With the increasing use*

> *of renewable energy the latter become more important, and need to be investigated more intensively.* (Griefahn and Basner, 2011, p. 6) [italics added]

Barbara Griefahn is a medical researcher specialising in the health effects of noise at the Leibniz Research Centre for Working Environment and Human Factors in Dortmund, Germany. Mathias Basner is a medical researcher specialising in noise-induced sleep disturbances at the Unit for Experimental Psychiatry, Division of Sleep and Chronobiology, University of Pennsylvania School of Medicine, Philadelphia, PA, USA. As the above quotation shows, they are calling for more intensive research on sleep disturbances caused by wind turbine noise. They do not feel obliged to prove that this is happening. It is obvious to them that it is happening, and so needs to be researched, just as sleep disturbances caused by transportation noise have already been researched.

The issues

It is necessary to distinguish between three questions:

(i) Can wind turbine noise cause adverse health effects, if turbines are inappropriately located, too close to neighbours' residences?

(ii) What are the precise circumstances in which adverse health effects are, or are not caused by wind turbine noise?

(iii) If there are adverse health effects from the noise from inappropriately located wind turbines, what are the physiological mechanisms that mediate them?

The answer to the first question is, yes, and this assertion no longer requires proof. The reason for this is simply that wind turbine noise is a form of industrial noise, and it is recognized by both medical researchers and acousticians that industrial noise generally does have the potential to cause, at least, sleep disturbance, with a long-term risk of contribution to multi-factorial diseases. Consequently, it is recognised that industrial noise requires environmental regulation. As we have seen, most medical research into noise-induced sleep disturbance has hitherto concerned transportation noise, but Griefahn and Basner call for intensive research into sleep disturbance induced by wind turbine noise, as government policy to promote renewable energy has led, and will continue to lead to the spread of wind farms (probably with larger and noisier turbines) (see above).

It is the second and third questions above that still require research. However, it needs to be said that acousticians have already provided an abundance of evidence in relation to the second question, i.e. what are the precise circumstances in which adverse health effects are, or are not caused by wind turbine noise? What is already known about sound levels, sound character, and the influence of wind speed, temperature, and terrain helps to determine markers for the probable occurrence of sleep disturbance and noise-induced stress, although further research needs to be done.

It is in relation to the third question above, where very little research has been done. That is, very few medical researchers have taken up the challenge of determining the precise physiological mechanisms that mediate adverse health effects from wind turbine noise.

The question of “Wind Turbine Syndrome”

The adverse health effects attributed to wind turbine noise by neighbours include not only annoyance and sleep disturbance, but also the cluster of symptoms that have been called Wind Turbine Syndrome. These symptoms include (apart from sleep disturbance) headache, tinnitus, ear pressure, dizziness, vertigo, nausea, visual blurring, tachycardia, irritability, problems with concentration and memory, and panic episodes associated with sensations of internal pulsation or quivering that arise while awake or asleep (Pierpont, 2009, p. 26). It is these symptoms that have aroused most controversy, since supporters of wind farms, including their hired consultants, assert that these symptoms are not due directly to turbine noise, but are rather the effect of negative feelings aroused by failure to stop a wind farm development, or not sharing in the revenue of a wind farm. Both the acoustic research that has been done, and the little medical research suggest that these claims have no validity.

Published research on the adverse health effects of wind turbines

In the section on *Infrasound* above I have already outlined the views of Professor Alec Salt and his colleagues, concerning the connections between wind turbine infrasound and potential adverse health effects. I have also outlined the views of Professors Alves-Pereira and Castelo Branco. To summarise:

Professor Salt has argued:

1. It is incorrect to assume that inaudible infrasound cannot affect human physiology.

2. Inaudible infrasound stimulates the Outer Hair Cells in the cochlea at 60 dBG.

3. There are physiological pathways from the OHCs to the brain that could transmit infrasonic signals, resulting in the symptoms of Wind Turbine Syndrome.

4. Amplitude-modulated infrasonic signals, originating from wind turbines, can amplitude-modulate the higher frequency signals *within the human nervous system*. This *biological* modulation may be responsible for the especially disturbing character of amplitude modulated sound.

Professors Alves-Pereira and Castelo Branco report that infrasound levels at a residence in the vicinity of a wind farm were higher than those at another residence in the vicinity of a port grain terminal, where there were documented cases of Vibro-acoustic Disease.

Note: the work of Professors Alves-Pereira and Castelo Branco has aroused controversy. At the 2009 NSW Legislative Council Inquiry into Rural Wind Farms Dr Eja Pedersen, the Scandanavian acoustician who has published much distinguished research on the noise impacts of wind turbines, disputed the relevance of Vibro-acoustic Disease to wind turbine impacts (NSW Legislative Council, 2009, p. 118). Professors Alves-Pereira and Castelo Branco did not give evidence to the Committee. Accepting Dr Pedersen's view, the Committee went so far as to state:

> The Committee acknowledges that some health impacts are supported by scientific research, such as the impact of noise annoyance. However, the Committee also notes that many purported impacts have created little more than unfounded fear in local communities, for example, Vibroacoustic Disease, wind turbine safety, shadow flicker and 'Wind Turbine Syndrome'. (NSW Legislative Council, 2009, p. 130)

It should be noted that Dr Pedersen is an acoustician, and not a physician or medical researcher. By contrast, at the NHMRC forum on Wind Farms and Human Health, held on 7 June 2011, Professors Alves-Pereira and Castello Branco presented further evidence concerning the residence (a farm) referred to in their 2007 papers. This evidence did not concern the human residents, as the wife and children had left the house. The husband was obliged to stay to look after the thoroughbred horses on the farm. His health is said to be deteriorating. The evidence concerned the horses. One feature of Vibro-acoustic Disease is that it is characterised by an abnormal production of organized collagen. The researchers found such an abnormal collagen growth in the four horses tested, and no such growth in a fifth horse that served as a control. (Alves-Pereira and Castelo Branco, 2011)

Mention should also be made here of the work of Dr Nina Pierpont, whose well known book *Wind Turbine Syndrome* is "peer-reviewed", despite claims to the contrary (see below).

Since it is commonly claimed by the wind energy industry and its supporters that there are no "peer-reviewed" studies connecting wind turbine noise with adverse health effects, I will now provide a list of such studies.

N.B. As long ago as 2009, Health Canada, the Canadian Department for Public Health, admitted that there are peer-reviewed studies linking wind turbines with adverse health effects:

> In fact, there are peer-reviewed scientific articles indicating that wind turbines may have an adverse impact on human health. For example, Keith et al. (2008) identified annoyance as an adverse impact on human health that can be related to high levels of wind turbine noise. In addition, there are several articles by Pedersen (and others) related to wind turbine annoyance .... The relationship between noise annoyance and adverse effects on human health is also further investigated in the manuscript by Michaud et al (2008).
>
> Health Canada advises that this statement [sc. that there is no peer-reviewed scientific evidence indicating that wind turbines have an adverse impact on human health] be

> revised to indicate that there are peer-reviewed scientific articles indicating that wind turbines may have an adverse impact on human health. (Health Canada, 2009, p. 2)

Why does this official pronouncement by Health Canada continue to be ignored?

Peer-reviewed studies of wind turbines and adverse health effects

The term “peer-reviewed” is ambiguous. Strictly speaking, it refers to the process that occurs *after* publication, when scientists try to duplicate another scientist’s results by carrying out similar investigations. The purpose is to discover whether the results are generally true, or whether they have been influenced by contingent factors. This sense of “peer-reviewed” has nothing to do with what is usually meant when commentators say, “there are no peer-reviewed studies of adverse health impacts from wind turbines.”

What is meant by the term in such claims is that the publications concerned have been *refereed.* All that means is that the study has been read by experts in the speciality, and approved as satisfying standards of professional discourse, and being worthy of consideration. It does not mean that the referees agree with what the study says, or that what the study says is true.

However, journal articles are not the only academic/professional studies that are refereed. Conference papers are refereed. So are scholarly/scientific books. So are PhD theses. So are some publications by professional consultancies. Journal articles are not necessarily more worthy than these other forms. To suggest that they are is disingenuous.

The following account of existing research does not claim to be comprehensive. But, it should be sufficient to disprove the claim that there is no “peer-reviewed” research on the adverse health effects of wind turbines.

N.B. The following account concerns only the noise impacts of wind turbines. It is well established that the visual effect of shadow flicker can be dangerous to health, and it is regulated by planning authorities. See:

- McBride, D., and Rapley, B., Blade Flicker, Shadow Flicker, Glint: Potential Hazards of Wind Turbines, pp. 79-92 of Rapley and Bakker eds, (2010)

McBride and Rapley conclude that the potential dangers from blade flicker and shadow flicker can be eliminated by siting wind farms more than 2.5 km from human habitation. They add that blade glint may require a greater setback distance. (McBride and Rapley, 2010, p. 91)

Medical research and medically related acoustic research

Articles in refereed journals

(i) Salt, A. N., and Hullar, T. E., 2010. Responses of the ear to low frequency sounds, infrasound, and wind turbines. *Hearing Research*, 268 (1-2): 12-21

Professor Alec Salt and Assistant Professor Timothy Hullar are medical researchers in the Department of Otolaryngology, School of Medicine, Washington University, St Louis, Missouri, USA. In this paper Salt and Hullar show that infrasound from wind turbines (or any other source) can impact on the human hearing system, even though it is inaudible. Inaudible infrasound stimulates the Outer Hair Cells in the cochlea. A-weighted measurements are inadequate to register the levels of such infrasound. They conclude: "The concept that an infrasonic sound that cannot be heard can have no influence on inner ear physiology is incorrect."

(ii) Salt, A. N., and Kaltenbach, J. A., 2011. Infrasound from Wind Turbines Could Affect Humans. *Bulletin of Science, Technology & Society* 31: 296-302

James A. Kaltenbach is a medical researcher at the Lerner Research Institute/Head and Neck Institute, Cleveland, Ohio, USA. In this paper Salt and Kaltenbach develop the thesis that inaudible wind turbine infrasound could impact upon the human hearing system. Inaudible infrasound stimulates the Outer Hair Cells in the cochlea at 60 dBG. Moreover, they point out: "Responses to infrasound reach the brain through pathways that do not involve conscious hearing but instead may produce sensations of fullness, pressure, or tinnitus, or have no sensation. Activation of subconscious pathways by infrasound could disturb sleep." (Abstract) They state: "We can conclude that based on well-documented knowledge of the physiology of the ear and its connections to the brain, it is scientifically possible that infrasound from wind turbines could affect people living nearby." (p. 301)

(iii) Bronzaft, A. L., 2011. The Noise from Wind Turbines: Potential Adverse Impacts on Children's Well-Being. *Bulletin of Science, Technology & Society* 31: 291-295

Arline L. Bronzaft, Ph.D. is Professor Emerita at the City University, New York, and a consultant in environmental psychology. In this paper she rehearses the research findings that "many studies have demonstrated that intrusive noises such as those from passing road traffic, nearby rail systems, and overhead aircraft can adversely affect children's cardiovascular system, memory, language development, and learning acquisition." On the basis of this research into the adverse health effects of transportation noise she argues the need for research into the potential adverse health effects of industrial wind turbines on children's health, and on the health of their parents. (Abstract)

(iv) Phillips, C. V., 2011. Properly Interpreting the Epidemiologic Evidence about the Health Effects of Industrial Wind Turbines on Nearby Residents. *Bulletin of Science, Technology & Society* 31: 303-315

Carl V. Phillips is an epidemiologist, currently Director of the epiphi Consulting Group, and Director and Chief Scientist of the laboratory TobaccoHarmReduction.org., and formerly Associate Professor in the Department of Public Health Sciences at the University of Alberta, Edmonton, Alberta. In this paper Dr Phillips states firmly: “There is overwhelming evidence that wind turbines cause serious health problems in nearby residents, usually stress-disorder-type diseases, at a nontrivial rate.” He argues: “The bulk of the evidence takes the form of thousands of adverse event reports. There is also a small amount of systematically gathered data. The adverse event reports provide compelling evidence of the seriousness of the problems and of causation in this case because of their volume, the ease of observing exposure and outcome incidence, and case-crossover data.” He rebuts the claims of wind energy supporters that this evidence does not “count”, that the outcomes are not “real” diseases, etc. He concludes: “The attempts to deny the evidence cannot be seen as honest scientific disagreement and represent either gross incompetence or intentional bias.” (Abstract)

(v) McMurtry, R. Y., 2011. Toward a Case Definition of Adverse Health Effects in the Environs of Industrial Wind Turbines: Facilitating a Clinical Diagnosis. *Bulletin of Science, Technology & Society* 31: 316-320

Robert Y. McMurtry, M.D., F.R.C.S.(C), F.A.C.S. is Orthopedic Consultant at St Joseph’s Health Centre, London, Ontario, Professor of Surgery at the University of Western Ontario, Member of the Health Council of Canada, and Member of the Canadian Index of Wellbeing Research Group. In this paper he comments: “Internationally, there are reports of adverse health effects (AHE) in the environs of industrial wind turbines .... The symptoms being reported are consistent internationally and are characterized by crossover findings or a predictable appearance of signs and symptoms present with exposure to IWT [industrial wind turbines] sound energy and amelioration when the exposure ceases. There is also a revealed preference of victims to seek restoration away from their homes.” McMurtry proposes a case definition “that identifies the sine qua non diagnostic criteria for a diagnosis of adverse health effects in the environs of industrial wind turbines.” (Abstract)

(vi) Shepherd, D., McBride, D., Welch, D., Dirks, K. N., and Hill, E. M., 2011. Evaluating the Impact of Wind Turbine Noise on Health-related Quality of Life. *Noise Health* 13: 333-339

Daniel Shepherd is a researcher in the Department of Psychology, School of Public Health, Auckland University of Technology, Auckland, New Zealand. David McBride is a researcher in the Department of Preventive and Social Medicine, University of Otago, Dunedin, New Zealand. David Welch and Kim N. Dirks are researchers in the School of Population Health, University of Auckland. In this paper Shepherd, McBride, Welch, Dirks and Hill report a “cross-sectional study comparing the health-related quality of life (HRQOL) of individuals residing in the proximity of a wind farm to those residing in a demographically matched area sufficiently displaced from wind turbines.” They find: “Statistically significant differences were noted in some HRQOL domain scores, with residents living within 2 km of a turbine installation reporting lower overall quality of life, physical quality of life, and environmental quality of life. Those exposed to turbine noise also reported significantly lower sleep quality, and rated their environment as less restful." They conclude: "Our data suggest that wind farm noise can negatively impact facets of HRQOL." (Abstract)

(vii) Rand, R. W., Ambrose, S. E., and Krogh, C. M. E., 2011. Occupational Health and Industrial Wind Turbines: A Case Study. Published online before print August 22, 2011, doi: 10.1177/0270467611417849, *Bulletin of Science, Technology & Society*, August 22, 2011

(viii) Shepherd, D., and Billington, R., 2011. Mitigating the Acoustic Impacts of Modern Technologies: Acoustic, Health, and Psychosocial Factors Informing Wind Farm Placement. Published online before print August 22, 2011, doi: 10.1177/0270467611417841, *Bulletin of Science, Technology & Society,* August 22, 2011

(ix) Havas, M., and Collig, D., 2011. Wind Turbines Make Waves: Why Some Residents Near Wind Turbines Become Ill. Published online before print September 30, 2011, doi: 10.1177/0270467611417852, *Bulletin of Science, Technology & Society*, September 30, 2011

(x) Pedersen, E., and Persson Waye, K, 2004. Perception and Annoyance due to Wind Turbine Noise: a Dose-response Relationship. *Journal of the Acoustical Society of America* 116 (6): 3460-70

Pedersen and Persson Waye are Scandanavian acousticians who have published much on wind turbine noise in the last decade. The above paper is now well-known, and much cited because it shows that wind turbine noise is more annoying than transportation noise (aircraft, railways, road traffic). N.B. It is in relation to transportation noise that most studies of noise-induced sleep disturbance have been carried out since the end of the 1960s (see Griefahn and Basner, 2011). This study also shows that 16% of surveyed respondents who lived where calculated outdoor turbine noise exceeded 35 dBA (L_{Aeq}) reported disturbed sleep.

(xi) Pedersen, E. And Persson Waye, K., 2007. Wind Turbine Noise, Annoyance and Self-reported Health and Well-being in different living environments. *Occupational and Environmental Medicine* 64(7): 480-486

In this paper Pedersen and Persson Waye report that the risk of perceiving wind turbine noise, and the risk of being annoyed by it both increase with increasing sound pressure levels. Also a rural area increased the risk of perception and annoyance in comparison with a suburban area. And in a rural area complex ground (hilly or rocky terrain) increased the risk compared with flat ground. They conclude: "There is a need to take the unique environment into account when planning a new wind farm so that adverse health effects are avoided." (Abstract)

(xii) Pedersen, E. And Larsman, P., 2008. The impact of visual factors on noise annoyance among people living in the vicinity of wind turbines. *Journal of Environmental Psychology* 28: 379-389

This paper has been much cited by supporters of the wind energy industry, because it finds a strong correlation between attitude to the visual appearance of wind turbines and the risk of noise annoyance. However, those supporters of the wind energy industry who cite it do not reveal that the authors state explicitly: "The proposed model was based on theoretical assumptions about causality and on the assumption that attitude towards the source influences noise annoyance. *However, we cannot exclude the possibility that the causality is directed the opposite way so that annoyance causes a negative attitude towards the source. Being annoyed by wind turbine noise in the home environment could initiate a negative attitude towards wind turbines.* There may also be a feedback loop between these variables." (italics added) What Pedersen and Larsman are admitting here is that their research establishes only a correlation, and proves nothing about the direction of causality.

(xiii) Pedersen, E., 2010. Health aspects associated with wind turbine noise – Results from three field studies. *Noise Control Engineering Journal* 59(1): 47-53

From studies made in relation to three sets of wind turbine noise data Pedersen establishes an association between wind turbine noise and both annoyance and sleep disturbance. Annoyance was associated with A-weighted sound pressure levels. Sleep disturbance was more common in rural areas than in suburban areas. She recommends adequate setback distances, and calls for further research.

(xiv) Pedersen, E., and Persson Waye, K., 2008. Wind turbines – low level noise sources interfering with restoration? *Environmental Research Letters* 3 (January-March 2008) 015002 doi: 10.1088/1748-9326/3/1/015002 [published online]

Pedersen and Persson Waye state: "It is hypothesized that low and moderate stressors such as wind turbine noise could have an impact on health. The risk seems to be higher if restoration is, or is perceived to be, impaired and also for certain groups of individuals." (Abstract) Inevitably, they call for further research.

Refereed conference papers

(i) Salt, A. N., and Lichtenhan, J. T., 2011. Responses of the Inner Ear to Infrasound. *Fourth International Meeting on Wind Turbine Noise*, Rome, Italy, 12-14 April 2011

Jeffery Lichtenhan is a medical researcher at the Eaton-Peabody Laboratory, Massachusetts Eye & Ear Infirmary, Boston, MA, and at the Department of Otology & Laryngology, Harvard Medical School, Boston, MA. In this paper Salt and Lichtenhan develop Salt's work on infrasound by showing, amongst other things, how an inaudible infrasonic signal can cause an audible signal of higher frequency to amplitude-modulate *within the human nervous system*. This is a kind of amplitude modulation that is *biological*, and internal to the human nervous system, and thus quite distinct from the external *acoustic* amplitude modulation that occurs as a result of the peculiar methods of sound generation at the rotor of a wind turbine. They write: "These findings are relevant to the perception of the "amplitude modulation" of sounds, and represent a biological form of modulation by low frequency sounds *that cannot be measured with a sound level meter*." (italics added) They conclude: "The complexity of the ear's response to infrasound leads us to the conclusion that there are many aspects that need to be better understood before the influence of wind turbine noise on the ear can be dismissed as insignificant." (Abstract)

(ii) Alves-Pereira, M., and Castelo Branco, N. A. A., 2007. In-home wind turbine noise is conducive to vibroacoustic disease. *Second International Meeting on Wind Turbine Noise*, Lyon, France, September 20-21, 2007

Alves-Pereira and Castelo Branco are Portugese medical researchers who have been studying the effects of infrasound and low frequency noise (ILFN) since 1980. In this study they compare two cases of ILFN impact. In the first case, documented instances of vibroacoustic disease (VAD) were ascribed to ILFN generated by a port grain terminal. In the second case higher levels of ILFN were found in a home neighbouring a wind farm. They observe: "ILFN levels contaminating the home of Case 2 are sufficient to cause VAD." They conclude: "ILFN generated by WT [wind turbine] blades can lead to severe health problems, specifically, VAD." (Abstract)

(iii) Alves-Pereira, M., and Castelo Branco, N. A. A., Public Health and Noise Exposure: the Importance of Low Frequency Noise. *INTER-NOISE 2007*, 28-31 August 2007, Istanbul, Turkey

This paper presents the same material as in (ii) above.

(iv) Griefahn, B., and Basner, M., 2011. Disturbances of sleep by noise. Paper Number 107, *Proceedings of ACOUSTICS 2011*, 2-4 November 2011, Gold Coast, Australia

I have already discussed this paper. See above, under **The state of research**.

(v) Thorne, R., and Shepherd, D., 2011. Wind turbine noise: why accurate prediction and measurement matter. Paper Number 73, *Proceedings of ACOUSTICS 2011*, 2-4 November 2011, Gold Coast, Australia

Robert Thorne is principal of the environmental consultancy Noise Measurement Services Pty Ltd. He holds a PhD in health science from Massey University, New Zealand. Daniel Shepherd is Senior Lecturer in the Faculty of Health, and Head of Postgraduate Studies in the

School of Public Health and Psychosocial Studies, Auckland University of Technology. This paper discusses methodological issues connected with the measurement and prediction of wind turbine noise, from the standpoint of public health.

Other refereed studies

(i) Pierpont, N., 2009. *Wind Turbine Syndrome: A Report on a Natural Experiment,* K-Selected Books, Santa Fe, NM

Contrary to the claims of the wind energy industry and its supporters, this book *is* refereed. The referees are named in the book, and their reviews are printed in the book (pp. 287-292). There can be no doubt of the distinction of the referees. They are:

- Jerome S. Haller, MD, Professor of Neurology and Pediatrics (retired 2008), Albany Medical College, Albany, New York
- Joel F. Lehrer, MD, Fellow of the American College of Surgeons, Clinical Professor of Otolaryngology, University of Medicine & Dentistry of New Jersey.
- Ralph V. Katz, DMD, MPH, PhD, Fellow of the American College of Epidemiology, Professor and Chair, Department of Epidemiology & Health Promotion, New York University College of Dentistry, New York
- Henry S. Horn, PhD, Professor of Ecology and Evolutionary Biology, and Associate of the Princeton Environmental Institute, Princeton University, Princeton, New Jersey

This is not the place to quote the whole of their reviews, but the following passage from Professor Horn's review is representative:

Dr Pierpont has gathered a strong series of case studies of deleterious effects on the health and well being of many people living near large wind turbines. Furthermore, she has reviewed medical studies that support a plausible physiological mechanism directly linking low frequency noise and vibration, like that produced by wind turbines, which may not in itself be reported as irritating, to potentially debilitating effects on the inner ear and other sensory systems associated with balance and sense of position. Thus the effects are likely to have a physiological component, rather than being exclusively psychological. (p. 291)

(ii) Rapley, B., & Bakker, H. (eds), 2010. *Sound, Noise, Flicker and the Human Perception of Wind Farm Activity,* Atkinson & Rapley Consulting Ltd (Palmerston North, New Zealand), in association with Noise Measurement Services Pty Ltd (NMS) (Brisbane, Australia)

This volume of essays on wind turbine impacts, including health impacts, is refereed. On the title page the "Head of Peer Review" is stated to be John Podd, BSc, PhD.

(iii) Shepherd, D., 2010. Wind Turbine Noise and Health in the New Zealand Context, pp. 15-68 of Rapley and Bakker (eds), 2010

(iv) Thorne, Bob, 2010. Hearing and Personal Response to Sound, pp. 69-78 of Rapley and Bakker (eds), 2010

(v) Thorne, Bob, 2010. Health, Wellbeing, Annoyance and Amenity, pp. 93-101 of Rapley and Bakker (eds), 2010

(vi) Thorne, Bob, 2010. Synopsis of Assessing Intrusive Noise and Low Amplitude Sound, pp. 111-125 of Rapley and Bakker (eds), 2010

(vii) Thorne, Bob, 2010. Wind Farms: The Potential for Annoyance, pp. 127-133 of Rapley and Bakker (eds), 2010

In this study Thorne remarks: "Considering my own research I conclude that a proposed wind farm will have a significant adverse effect on approximately 10% of the exposed population and a moderate adverse effect on approximately 20% of the exposed population. The adverse effects to some will be sleep disturbance and stress. To others it will be annoyance. The exposures are an adverse effect that is more than minor." (p. 132)

He also concludes: "Considering my own research, I conclude that a wind farm development has a high potential to cause adverse amenity, annoyance, sleep disturbance or health effects that are more than minor to residents within 3500 metres of the proposed wind farm."

"The effects may not extend to all persons within the locale and may extend approximately 3500 metres depending on wind farm design, weather conditions, ground conditions and topography." (p. 133)

(viii) van den Berg, GP, Pedersen, E, Bouma, J, and Bakker, R (2008). Project WINDFARMperception. Visual and acoustic impact of wind turbine farms on residents. Final Report, June 3, 2008. 63 pp. Summary at www.windaction.org/documents/16255 . Entire report at https://dspace.hh.se/dspace/bitstream/2082/2176/1/WFp-final.pdf

This survey was commissioned by the European Union. Amongst other things, it found that turbine noise was more annoying at night, and that interrupted sleep and difficulty in returning to sleep increased with (calculated) noise level.

Other items of relevant acoustic research

(i) Thorne, R, Rapley, B, and Heilig, J (2010). Waubra Wind Farm Noise Impact Assessment for Mr & Mrs Dean. Report No 1537, Rev 1, July 2010

In this study Thorne and his colleagues report on the noise impacts of the Waubra Wind Farm in Victoria, the Te Rere Hau Wind Farm in New Zealand, and the West Wind Wind Farm in New Zealand, in the context of the noise and health complaints reported by neighbours.

(ii) Ambrose, S. E., and Rand, R. W., *The Bruce McPherson Infrasound and Low Frequency Noise Study: Adverse Health Effects Produced by Large Industrial Wind Turbines Confirmed, December 14, 2011*

In this study the US noise engineers Stephen Ambrose and Robert Rand report on their investigations at a wind farm in Falmouth, Massachusetts. They found, amongst other things, that the wind turbine infrasound was correlated with observed adverse health effects, while the dBA and dBC measured audible sound did not correlate. The infrasound levels were above Professor Salt's threshold of 60 dBG.

(iii) Cooper, S., *Peer review of acoustic assessment, Flyers Creek Wind Farm, 41.4963.R1A:ZSC, 15 December 2011*

This review of the noise assessment for the Flyers Creek Wind Farm proposal includes a noise assessment of the Capital Wind Farm in NSW, in the light of the noise and health complaints made by neighbours. The report finds that the Capital Wind Farm generates sound at levels above what was originally predicted, that the wind farm is not complying with its conditions of consent, and that infrasonic levels reach the threshold of 60 dBG, as discussed by Salt.

(iv) Møller, H., and Pedersen, C. S., Low frequency noise from large wind turbines, *Journal of the Acoustical Society of America* 129 (6), June 2011, pp. 3727-3744

In this study of low frequency noise and infrasound from wind turbines Møller and Pedersen find that "the spectrum of wind turbine noise moves down in frequency with increasing turbine size." Although they do not mention Salt's research, they refer in the course of their discussion to instances of wind turbine infrasound at levels well above Salt's threshold of 60 dBG.

The Senate Committee's recommendation

One of the Senate Committee's recommendations was:

> The Committee recommends that the Commonwealth Government initiate *as a matter of priority* thorough, adequately resourced epidemiological and laboratory studies of the possible effects of wind farms on human health. This research must engage across industry and community, and include an advisory process representing the range of interests and concerns. (Recommendation 4) (Community Affairs, 2011b, p. ix) (italics added)

Recently, the Senate resolved to call upon the Commonwealth Government to implement the recommendations of the Committee’s report. As yet, neither the Commonwealth Government nor any of the State Governments has commissioned the needed health research programme. This is unacceptable, given the scale of potential public health impacts.

Moratorium and research

There is already sufficient evidence to give grounds for a serious concern that wind turbine impacts, especially noise impacts, have the capacity to have serious adverse effects on human health. There is as yet insufficient evidence to state that this matter has been thoroughly researched. Further research needs to be done before a setback distance adequate to protect human health, or a formula adequate to calculating such a setback distance in particular cases, can be determined. It follows that there must be a moratorium and a research programme. Not to institute a moratorium and a research programme is to gamble with people’s health. This is reprehensible.

The research programme must be commissioned by the public health authorities, i.e. government, as this is a matter of public health. It is unbecoming of government departments to dismiss the issue by claiming that there is no research to prove any adverse health effects from wind turbines, when it government itself that has the obligation to commission the research.

Individual rural residents, and community associations do not have the funds necessary to finance medical research programmes. It is necessary for the NHMRC and/or state departments of health to commission the research. There has already been too much delay. There is already enough evidence to justify it. And while the research is being done, let there be a moratorium. Residents’ health should not be put at risk while government, and government agencies delay.

Property value

The draft Guidelines stipulate that proponents shall consider potential impacts on property values (pp. iv, 8, 14, 22). It is hard to see what practical significance this can have, as the law does not recognize any principle of compensation for loss of property value as a result of an approved development. This was made very clear by the commissioners in the Gullen Range Wind Farm case in the NSW Land & Environment Court (NSWLEC 1102 [2010], paras 107-110). The most that the law recognizes is that the owners of properties deemed by the Minister or the Court to be unacceptably impacted should be granted acquisition rights. This means that the proponent is obliged to offer to buy the property, at a market price, as if there were no wind farm. The property owner then has to decide whether to sell and move, or not to sell, and to continue to live in a residence that the Minister or Court has deemed to be unacceptably impacted.

The fact that acquisition rights are granted to some owners, and that the property is to be purchased at a market price, *as if there were no wind farm*, is itself an indication that the vicinity of a wind farm is likely to lead to a loss of property value, as the NSW Legislative Council inquiry recognized (NSW Legislative Council, 2009, p. 140).

The reality is that many householders face the prospect of a considerable loss of property value from the vicinity of wind farms, as a result of noise, health and visual impacts. In some cases, the impacts may be so bad as to make properties unmarketable. The number of property owners thus affected is likely to be much greater than the number to whom acquisition rights are granted. Therefore, wind farm development, as currently carried on, will lead to injustice on a grand scale.

In response to this concern, the NSW Legislative Council inquiry did at least recommend that the issue of compensation be researched:

> Recommendation 11
>
> That the Minister for Planning commission research into compensation options for residents who are adversely impacted by wind turbines and wind farms in general. The research should investigate options including the purchasing of affected properties and/or the provision of monetary compensation by the developer. (NSW Legislative Council, 2009, p. 83)

To the best of my knowledge, no such research has been carried out by the NSW Department of Planning.

There are only two solutions to this problem. One is to have adequate setback distances so that the amenity and conditions for health and well-being at a residence are not destroyed by the vicinity of a wind farm. As this depends on the research that still needs to be done into noise and health impacts, it is premature for this issue to be determined now. Thus, the issue of property value also supports the need for a moratorium and a research programme.

The second solution is for proponents of wind farms to provide a guarantee to compensate residents, whose property suffers a loss of value due to the vicinity of the wind farm. Such property guarantees are given in some counties in the United States, as was recognized by the Senate inquiry into Rural Wind Farms (Community Affairs, 2011b, p. 59). The decisive argument here is that if, as wind farm developers claim, the vicinity of a wind farm will not cause any loss of property value, the developers have nothing to lose from agreeing to such a guarantee. On the other hand, if there is no such guarantee, and residents do suffer a loss of property value, then the proponent is imposing, unjustly, an externality upon the resident. The real cost of the wind farm includes the loss suffered by the resident, but the proponent does not have to bear this part of the cost. This is manifestly unjust.

It can only be concluded that there must be a moratorium, and a research programme to determine what is an adequate setback. These are needed on the ground of property value, as on the grounds of noise and health impacts. Failing this, let proponents of wind farm proposals give a property guarantee to all owners within 5 kilometres of turbines.

As Appendix F of the draft Guidelines cites the 2009 study *Preliminary assessment of the impact of wind farms on surrounding land values in Australia*, prepared for the NSW Valuer General, I will offer some comments on this document, and then discuss some other evidence on wind farms and property value, which seems to point in the opposite direction.

NSW Valuer General

The most recent official study of impact on property value by the vicinity of a wind farm, at least in NSW, is the *Preliminary Assessment of the Impact of Wind Farms on Surrounding Land Values in Australia*, prepared by Duponts in association with PRP Valuers and Consultants for the NSW Valuer General (August 2009). The report makes the following assertions in its Executive Summary:

> A review of wind farms currently operating in Australia revealed that they have been developed in locations generally removed from densely populated areas. As a result the small samples of sales transactions available for analysis limited the extent to which conclusions could be drawn....
>
> The main finding was that the wind farms [studied – 8 in all] do not appear to have negatively affected property values in most cases. Forty (40) of the 45 sales investigated did not show any reductions in value. Five (5) properties were found to have lower than expected sale prices (based on a statistical analysis). While these small number of price reductions correlate with the construction of a wind farm further work is needed to confirm the extent to which these were due to the wind farm or if other factors may have been involved.
>
> Results also suggest that a property's underlying land use may affect the property's sensitivity to price impacts. No reductions in sale price were evident for rural properties or residential properties located in nearby townships with views of the wind farm.

> The results for rural residential properties (commonly known as 'lifestyle prop's) were mixed and inconsistent; there were some possible reductions in sale prices identified in some locations alongside properties whose values appeared not to have been affected. Consequently, no firm conclusions can be drawn on lifestyle properties.
>
> Overall, the inconclusive nature of the results is consistent with other studies that have also considered the potential impact of wind farms on property values.
>
> Further analysis (with additional data and expansion of the study area to other states) [i.e. other than Victoria and NSW] may yield more comprehensive results. Notwithstanding this, further studies are also likely to be limited by the availability of sales transaction data. [Duponts, 2009, p. 2]

The above statements deserve some scrutiny and criticism. On the one hand, the summary asserts quite definitely that the wind farm sites studied "do not appear" to have negatively affected property values in most cases. On the other hand, the "overall" "nature of the results" is declared to be "inconclusive". How can both these assertions be true? Was there no impact on values, or was the evidence inconclusive? If the evidence was inconclusive, then the conclusion that there was no negative impact ought not to be drawn. The phrase "do not appear" is introduced to gloss over the contradiction.

The authors of the report desiderate further research in order to obtain "more comprehensive results", but they then go on to forecast that even with an expanded data base further studies will never reveal the truth! How could this be?

First, they suggest that future studies will have limited sales data to study, but they do not give the only possible explanation for this fact (assuming it to be a fact), namely, that adversely impacted people, wanting to move away from a wind farm, will be unable to sell their properties. Why else would there be a shortage of data as time passes?

Second, the methodology of the research must raise doubts as to its effectiveness. I cannot give a full analysis of the report here, but some obvious points can be made.

The report offers a literature review of previous studies, and implies that these studies are all inconclusive. But in fact, when one examines the detailed account of previous studies, one finds that different reports come to diametrically opposite conclusions. For example, the Jorgenson report (1996, Denmark) found that, on average, properties located close to a wind turbine sold for 16,200 DKK (about $3,700 AUD) less than those located further afield. Also, on average, properties located close to 12 or more wind turbines sold for 94,000 DKK (about $21,600 AUD) less than those located further afield. By contrast, a report commissioned by the US Renewable Energy Policy Project found that in the case of 6 out of 10 wind farm sites property values went up! What effect there was in the other 4 cases we are not told. (Duponts, 2009, p. 6)

Glaring contradictions of this kind between reports should not be hidden, but should alert us to the influence of interest on studies, and make us question methodologies.

The report also seems not to give full weight to the evidence it cites. For example, it cites a Western Australian survey according to which most respondents felt that wind farms were acceptable, *provided they were located over 5 kilometres from residences*. The survey also found that a quarter of respondents indicated that they would pay less for a property near a wind farm, and that of these 38% indicated that they would pay 1-9% less, while 22% indicated that they would pay 10-19% less. How could these sentiments not affect market price? And yet the compilers of the report disregard this survey when summing up their literature review. They conclude, “From the literature review, it is apparent that the perceptions of the negative effect on land values are not borne out by the statistical analysis of sales data, except in very few cases.” (Duponts, 2009, p. 9)

Another obvious fault of the report’s methodology is that it examines all sales transactions within *10 kilometres* of a wind farm (Duponts, 2009, p. 14). 10 kilometres is much too far, and in any case a distance should not be selected arbitrarily. If the purpose of the investigation is to test whether the presence of a wind farm is reducing the market value of properties, *or making them unsaleable*, then the investigators should determine an area within which noise and health impacts are likely to be felt, and then discover whether people, badly impacted, and who want to sell, have been able to sell, and at what price – or if they have been unable to sell at all. This is the only method that will enable the truth to be discovered.

The report is at fault in adopting the criterion of properties that have a *view* of turbines (Duponts, 2009, p. 15). It is not the view that is the main cause of annoyance, and it is not the view that is keeping people awake at night. To concentrate on the view, and therefore to include the transaction on properties as far away as 10 kilometres, because the turbines can be seen in the distance, is to avoid the real issue of any inquiry, namely, noise and health impacts.

I will mention only one other fault of the report. One of the wind farm sites studied is that of the Waubra Wind Farm. Waubra is the wind farm studied by the Australian noise expert Bob Thorne and his colleagues (Thorne et al., 2010). The NSW Valuer General’s report examines 6 transactions of properties around the Waubra site. It is remarkable that 5 of these 6 transactions took place *before the wind farm began to operate*! (Duponts, 2009, pp. 36-38) This is not rational. It is significant that in the case of the transaction that occurred *after* the wind farm began to operate, this is the transaction where the investigators find that there was a “possible” reduction in value. They calculate a 27% reduction in value, but decline to comment further (Duponts, 2009, p. 38).

Why did they not investigate further? Thorne tells us that the Waubra Wind Farm began to operate in its Ballarat section in March 2009, and in its Waubra section in May 2009. He also tells us that within a short time local residents were becoming concerned about noise, and that by August there were reports of adverse health effects (Thorne et al, 2010, p. 110). Why did not the NSW investigators visit the property in question, discover whether there were any adverse noise impacts, whether residents were able to sleep or not, whether the adverse impacts of the wind farm were common knowledge in the Waubra-Ballarat area, and what the opinion of local real estate agents was? They appear not to have done any of this. They remark: “There is generally little sales activity in the area surrounding the Waubra wind farm." But they do not say why. Could it be because of the wind farm? Why did they not try to find out? (Duponts, 2009, p. 38)

This kind of desktop, statistical analysis of transactions in an arbitrarily determined area will not discover the truth about the impact of a wind farm on property values. The only way for the truth of this matter to be discovered is by an 'on-the-ground' study, where badly impacted properties are visited, where impacted residents are interviewed, and where the experience and opinion of local real estate agents are drawn upon. Without this kind of close examination it will be impossible to conclude anything definite.

In any intellectual study the method adopted predetermines the *kind* of results that can be obtained. If one chooses to examine all sales transactions on properties within 10 kilometres of turbines, on the basis of a view of turbines, this method will guarantee that most transactions, at the outer distances, will show no impact. So, the result will inevitably be that a majority of instances of sales show no impact, and only a minority of instances, within a few kilometres of turbines, do show an impact. The cases where there is a real impact will be swamped by a mass of irrelevant cases that ought not to have been included in the survey. This will enable the inquirers to put forward the contradictory conclusion that wind farms have no impact on sales, and that the evidence is inconclusive.

As a counter to the NSW Valuer General's study, I will cite the evidence of real estate agents and property valuers who have had to deal directly with the problem of selling property badly impacted by a wind farm.

The Davis Case

First, I will cite the famous, perhaps notorious, case of the letter sent by Munton & Russell, Estate Agents to Julian and Jane Davis of Spalding, Lincolnshire in England. The Davises own a farmhouse 930 metres from the Deeping St Nicholas wind farm. Shortly after the wind farm began to operate in 2007 the Davises were compelled to abandon their home, as the noise was insupportable (Etherington, 2009, p. 118). Wanting to sell, the Davises contacted a local firm of estate agents, Munton & Russell. Russell Gregory, on behalf of the firm, wrote to the Davises:

> Further to your letter dated 26th April 2008 regarding the proposed selling of the above mentioned property. Whilst I understand the difficulty of the situation you are placed in with the problems caused by the wind turbines, until such problems have been resolved I am not able to place a current market value on the property as I do not believe any prospective purchaser would want to inhabit the property, or, indeed in the current climate, whether any mortgage lender would be prepared to lend on the property.
>
> I am therefore sorry to say that I find myself in the rare situation of having to decline any instructions to market the above property, until such problems have been resolved to the satisfaction of any prospective purchaser or their mortgage lender. (Gregory, 2008)

Mr Gregory is telling the Davises that their farmhouse is unsaleable, and worthless, and that it will remain so as long as the wind farm continues to operate. The Davises have lost all financial value in their home.

It is a relatively minor consideration, but worth mentioning, that the noise from the wind farm caused the local council to reduce the rates on the property on the grounds of "noise pollution externally and internal low frequency noise pollution from new wind farm 930m." (Etherington, 2009, p. 119)

Jane Davis has affirmed in a publicly available statement that she and her husband have been forced to find alternative accommodation 5 miles away in Spalding so as to be able to sleep. She also affirms that before the coming of the wind farm their property would have been worth about 180,000 English pounds, but can now only be sold as land at a price of about 35,000-50,000 English pounds (a reduction of between 81% and 72%). The house itself is unsaleable. (Davis, 2007)

This is a situation faced by all rural property owners in Australia, especially by the owners of what are called "lifestyle properties" or hobby farms. If such properties have to be sold as grazing land, they will suffer a reduction in value of around 70%.

The Davis case went to the High Court in England. Not long ago it was settled out of court with a confidentiality agreement. However, the latest news published by the online journal *Noise Bulletin* is that the Davis's farmhouse has been purchased by the wind farm company at a price which represents a 16% loss of value (*Noise Bulletin*, March 2012, Issue 60). It is unlikely that the Davises would have received even this amount, if they had not gone to court. It is unjust that innocent residents should be forced to the expense of going to court in order to protect their assets.

Shane McIntyre

Shane McIntyre is National Sales Manager for Elders Rural Services Australia Ltd. He has been a Licensed Estate Agent for thirty years, specialising in the sale of rural property, all over Australia, but especially in Victoria and the Riverina. He has held senior management positions with the largest rural real estate companies in Australia (McIntyre, 2011). He has made available an e-mail, in which he gives his judgment on the impact of wind farms on rural property values. He writes:

> Of significant importance, is the negative effect on the value of adjoining lands where wind towers have been erected. Visually, the towers are seen by the majority of the market as repulsive. Audibly, the towers effect the stillness a property enjoys, in particular the resonating tones in the night, invading the serenity of the adjoining lands.
>
> A proliferation of wind towers adjacent to a property has the same effect as high voltage power lines, rubbish tips, piggeries, hatcheries, and sewerage treatment plants, in that, if buyers are given a choice, they choose not to be near any of these impediments to value.

> The ultimate effect is that the number of buyers willing to endure these structures is significantly less than if the structures were not there. This logically has a detrimental effect on the final price of the adjoining lands.
>
> Experts assess the loss of value to be in excess of 30%, and sometimes up to half.
>
> My personal experience is that when an enquiry (potential buyer) becomes aware of the presence of wind towers, or the possibility of wind towers in the immediate district of a property advertised for sale, the "fall out" of buyers is major. Very few go on to inspect the property, and even fewer consider a purchase. On the remote chance they wish to purchase, they seek a significant reduction in the price.
>
> There is absolutely no doubt, that the value of lands adjacent to wind towers falls significantly in value. The ambience of a rural property is important, and oftentimes, the sole reason why a purchaser selects a particular area or district. The imposition of wind towers destroys this ambience forever. (McIntyre, 2011)

Derry Gardner

Derry Gardner is owner and operator of Gardner Appraisal Group Inc. & Gardner Ranch Sales LLC., a real estate appraisal firm, specialising in rural (farm and ranch) properties in Texas (www.gardnerappraisalgroup.com). On February 13, 2009 he made a presentation *Impact of Wind Turbines on Market Value of Texas Rural Land* to the South Texas Plains Agriculture Wind & Wildlife Conference.

Mr Gardner rejects the view of the (US) Renewable Energy Policy Project (REPP), expressed in May 2003, that wind turbines will not diminish property values. (I mentioned this study, with its extraordinary conclusion, on p. 6 above.) He criticises the study made by the REPP on two grounds: (i) it was funded by proponents of wind power, and displayed a built-in bias in its conclusions; (ii) its methodology lacked variables necessary for an adequate analysis. The variables lacking include: rising or falling market; number of days from listing to sale; residential property, not rural property; effect of noise, flickering and shadow; distances; possible change in highest and best use of land because of the presence of wind turbines.

Mr Gardner makes the following assertions:

- A view adds value to rural property.
- Take the view away – the added value goes away.
- Brokers in rural areas confirm that property values in areas of wind facilities are 10% - 30% less than property not in areas of wind facilities.
- Wind energy development creates an income stream, increasing a property's production value; but increased production value does not necessarily result in increased market value. [In other words, if a property hosts turbines, it may still fall in value on the market.]

Mr Gardner sums up the diminution of value from the impact of wind turbines as follows:

- Turbines on property: diminution in value 29-45%, average 37%
- Turbines within 0.2-0.4 miles [320 m – 640 m]: diminution 17-35%, average 26%
- Turbines within 1.8 miles [2880 m]: diminution 15-34%, average 25%

Mr Gardner's figures for diminution in value in Texas are not as high as Shane McIntyre's figures for Australia, or Jane Davis's from the UK, but they are high enough.

Mr Gardner adds that diminution of value may be increased by other factors, including wind turbine infrastructure; high-power transmission lines; substations; additional traffic for service of wind turbine and power lines; additional roads.

Mr Gardner sums up: "Market data and common sense tell us property values are negatively impacted by the presence of wind turbines." (Gardner, 2009)

Michael McCann

Michael McCann is a real estate appraiser and consultant. His company McCann Appraisal LLC is in Chicago [the "Windy City"!] (McCann, 2011).

On January 25, 2011 Mr McCann sent a letter about the adverse impact of wind turbines on the value of neighbouring properties to OttawaCitizen.com. He writes:

> For example, numerous families have been forced to abandon their homes due to the factual impacts to health, sleep disturbance and the like, which the Canadian Wind Energy Association and the American Wind Energy Association prefer to dismiss as "concerns". Many others have been unable to sell their homes due to the presence of nearby turbines, and which a growing list of realtors and estate agents report as being the deciding factor in would-be buyer's decisions to look elsewhere.
>
> There is a measureable and significant loss of values within 2 to 3 miles [3.2 to 4.8 km], and noise impacts have been broadcast as far as 5 miles [8 km] or more, in some instances, with 1 to 2 miles [1.6 to 3.2 km] being commonplace. Value losses have been measured at 20% to 40%, *with a total loss of equity in some instances*. [emphasis in original]
>
> Wind developers have been known to buy out the most vocal neighbours who refuse to roll over and play dead when they are initially ignored, and then turn around and sell those same homes for 60% to 80% below the appraised value – thus confirming value losses by their own actions.
>
> Other developers have avoided future liability by bulldozing the purchased homes.

> In fact, wind developers and the existing Canadian setback are even inadequate to protect neighbours from ice throw or from sections of turbine blades, which are documented as occurring up to half a mile from the turbines, and I have personally heard of a blade throw (piece) that went about 1 mile. . . .
>
> . . . . It is obvious what is happening here: *the wind industry is playing a numbers game, under the assumption or actuarial calculations that it is less costly for them to fight a number of lawsuits from citizens who do not have deep pockets, than it is to buy out the property they need to create huge projects.*(emphasis in original)
>
> The solution is simple, also: Mandate that all property they seek to encompass with industrial overlays be purchased outright, so people have an option as to whether they choose to live in a large, noisy industrial setting. (McCann, 2011)

Mr McCann tells us that he has spent about 2000 hours researching wind energy and its impacts (McCann, 2011). He drew upon this research and his own experience in June 2010 to make a submission to the Adams County Board, Illinois, when that Board was considering the issue of a setback distance for wind farms (McCann, 2010).

Referring to the US Appraisal Institute, he writes:

> The **Appraisal Institute** has developed methodology and techniques for evaluating the effects of environmental contamination on the value of real property. The three potential effects that contamination can have on real property: cost effects, use effects, and risk effects. All three effects are recognized as being present with utility-scale wind energy projects, as summarized in my written testimony.
>
> **Cost effects** can include neighbouring owner costs to attempt to mitigate against sound intrusion, shadow flicker, medical costs to deal with sleep deprivation related conditions, as well as, in some instances, the cost to rent substitute housing and potential legal costs incurred to protect individual owner's property rights, etc. . . .
>
> **Use effects** include the loss of peaceful use and enjoyment of their homesteads for many turbine neighbours, and there is evidence that livestock has been adversely impacted by the noise from turbines, ranging from death (*goats in Taiwan*) to reproductive disorders (*See Wirtz case in Wisconsin*) and behavioural changes and irritability of horses and cattle. These may also represent cost effects, in some cases, or other forms of financial impact.
>
> **Stigma effects** can range from loss of aesthetics, diminished views and character of neighbourhoods, to fear of health issues and noise disturbance, etc. This effect is often manifest in the lack of marketability of homes in the "footprint" and nearby properties most impacted by active turbines, and to varying degrees the known and unknown cost and use effects are also contributing factors to stigma effects. (McCann, 2010, pp. 2-3; bold and emphasis in original)

Mr McCann provides a summary list of his conclusions. I will quote those most relevant to your inquiry.

> Residential property values are adversely and measurably impacted by close proximity of industrial-scale wind energy turbine projects to the residential properties, with value losses measured up to 2-miles from the nearest turbine (s), in some instances.
>
> Impacts are most pronounced within "footprint" of such projects, and many ground-zero homes have been completely unmarketable, thus depriving many homeowners of reasonable market-based liquidity or pre-existing home equity.
>
> Noise and sleep disturbance issues are mostly affecting people within 2-miles of the nearest turbines and 1-mile distances are commonplace, with many variables and fluctuating range of results occurring on a household by household basis.
>
> Real estate sale data typically reveals a range of 25% to approximately 40% of value loss, with some instances of total loss as measured by abandonment and demolition of homes, some bought out by wind energy developers and others exhibiting nearly complete loss of marketability.
>
> Serious impact to the "use & enjoyment" of many homes is an on-going occurrence, and many people are on record as confirming they have rented other dwellings, either individual families or as a homeowner group-funded mitigation response for use on nights when noise levels are increased well above ambient background noise and render their existing homes untenable.

Emphasising the need for a 2 mile (3.2 km) setback, Mr McCann states:

> If Adams County approves a setback of 1,000 feet, 1,500 feet, or any distance less than 2-miles, these types of property use and property value impacts are likely to occur to the detriment of Adams County residences and citizens for which the nearest turbines are proposed to be located.

He also makes the following statement of principle, relevant to life in what is supposed to be a liberal democracy:

> The approval of wind energy projects within close proximity to occupied homes is tantamount to an inverse condemnation, or regulatory taking of private property rights, as the noise and impacts are in some respects a physical invasion, an easement in gross over neighbouring properties, and the direct impacts reduce property values and the rights of nearby neighbours. (McCann, 2010, pp. 5-6)

I will quote only one more of Mr McCann's statements:

> As a real estate appraiser with 25 years experience in evaluating zoning matters, I am unaware of any other land use in the 20 States in which I have worked that is permitted to

> cause such a nuisance that a property owner's rights are completely disregarded and protection of their property values marginalized to the point of meaningless and non-existent protection, via inadequate separation of incompatible uses based on industry-preferred setbacks. (McCann, 2010, p. 13)

This is the situation that is now facing Australia. Wind farm development here has not yet gone very far. There are already victims of noise impacts, adverse health impacts, and adverse impacts on property value, but these are only a small proportion of what the total number of victims will be, when the plans of the wind energy industry, and of state and federal governments are fully implemented. If people are to be protected, then the real impacts of wind turbines must be accurately assessed. At present, in Australia the assessments of the industry and of government are completely inadequate and inaccurate. I suggest that the evidence of experienced realtors like Shane McIntyre, Derry Gardner and Michael McCann, who have studied these impacts close-up, and "on the ground" is to be preferred.

The NSW Valuer General's report calls for further research (Duponts, 2009, p. 2). It is worthwhile briefly to compare the real need for more medical research into the effects of wind turbine noise and the need for further research into impacts on property values. In the case of medical research there is a genuine need for such research. There are important hypotheses concerning the physiological mechanisms that mediate the effect of wind turbine noise on the human body. These need to be investigated, and proved or disproved. There is also a need for epidemiological studies of what proportions of people are affected, in what conditions, and at what distances, and of what sub-classes of people are especially vulnerable – all this to be carried out in real time. All this research is very important indeed. By contrast, the sort of study carried out by Duponts for the NSW Valuer General is of dubious value, since the method adopted is unlikely to lead to any useful knowledge. All that needs to be done to discover the truth of property value impacts, is for badly impacted properties to be located, and for their loss of value on the market to be determined by consultation with independent real estate agents. This inquiry would not take much in the way of time or resources. It could be done very easily and rapidly. It is unfortunate that governments are not commissioning this kind of research.

Finally, it should be remembered that loss of property value or loss of marketability will presumably be suffered at residences where adverse noise impacts and adverse health impacts are also being experienced. The awareness that the family home is being devalued will only add to the stress suffered by the family, thus increasing the risks to health. In this way, the impact of property values cannot be dissociated from the issue of adverse health effects.

Decommissioning

The draft Guidelines do not insist on a bond in relation to decommissioning in all cases. The draft Guidelines only insist on a bond if the proponent's cost estimate and funding plan for decommissioning is deemed to be inadequate by the planning authority (p. 26). This is inadequate.

It must be remembered that ownership of a wind farm may be vested in a "$2 company", which can be sold any number of times over the lifetime of the wind farm (possibly 25 years, possibly 50 years). This being so, the only way to guarantee the necessary funds for decommissioning is to insist on a bond in all cases, as a basic requirement.

Other matters

Blade throw

Blade throw from disintegrating turbine rotors has recently been discussed in the online journal *Wind Energy* (Rogers et al, 2011). The authors present evidence that, amongst other things, a fragment of a turbine blade from a 1.5 MW turbine can be thrown, in 20% of cases, up to 700 metres from the tower (Rogers et al, 2011, Fig. 15). It should be remembered that such fragments can be several metres long. The authors demonstrate that "common setback standards based on turbine height and blade radius provide inconsistent and inadequate protection against blade throw." (Rogers et al., 2011, Abstract)

The section on blade throw in the draft Guidelines (p. 24) shows no sign that the Department of Planning is aware of current research, and the inadequacy of existing standards, or that the Department will expect proponents to take current research into account.

In view of the kind of evidence referred to above, we propose a setback of 1 kilometre from any property boundary.

Aerial spraying

Rural property owners are required by law to undertake weed control. For larger properties the most cost effective way of doing this is by aerial spraying. But, since for reasons of safety, pilots will not fly within 1 kilometre of a wind turbine, a setback distance of 1 kilometre from any property boundary becomes necessary, as for blade throw.

Exclusion zones

Wind turbines must be excluded from the following areas:

- **National Parks, and a 5 kilometre buffer zone around a National Park**
- **Any area where the presence of wind turbines would disrupt the habitat of endangered species**
- **Within 1 kilometre of a watercourse, 2 kilometres of a lake of more than 5 hectares, 1 kilometre of a road or highway**
- **Any fire-prone area, as defined by the Rural Fire Service**

Fire suppressors

All wind turbines should be equipped with fire suppressors. As bush fires are a major danger in rural Australia, this issue of fire suppressors should not be dismissed with bland, and unwise assurances that turbine fires are rare. It may only require one turbine fire to start a bush fire.

Independent review

The draft Guidelines allow for any neighbour of a wind farm to request from the Director-General an independent review of the impacts of a wind farm on that neighbour's land (p. 37). **Either (i) this independent review should be a right, not something in the discretion of the Director-General, or (ii) the request should go to an independent Compliance Authority.** Neighbours should not have to depend on the decision of the Department of Planning, given the extent of the bias in favour of wind farm developers shown by the Department until now.

The draft Guidelines state that the Director-General may require the proponent to commission an "independent" expert to carry out the review (p. 37). No expert commissioned by the proponent can possibly be considered independent. The choice of an independent expert must be at a distance from both the proponent and the Department of Planning. This is another reason for establishing an independent Compliance Authority. At the very least, the appointment of the expert should depend on the agreement of the impacted neighbour, possibly with the advice of the Acoustical Society of Australia.

Local council Development Control Plans

Local council DCPs should be adhered to. This is the only way to ensure some local democratic input into the planning process.

Project description

In the Environmental Assessment (EA) the proponent must specify the approximate turbine *capacity* proposed for the development, even if the proponent cannot specify a particular turbine model. Only if a reasonably definite turbine capacity is specified will it

be possible for a serious modelling of the wind farm's impacts, and its potential power output to be known.

If several turbine types are proposed, and if in the worst case scenario the wind farm does not comply with the guidelines, *then the proposal shall not be approved.*

Modification of the proposal

If the proponent proposes to modify the proposal in ways that require new modelling (e.g. tower height, blade length, turbine capacity, change of manufacturer, or *any* significant change to the dimensions of the turbine, or of the wind farm as a whole), then there must be a renewed application.

Conditions for approval

The proponent must obtain all necessary access approval from neighbouring landholders *before* approval is granted. The proponent must obtain all necessary access approval from neighbouring landholders, whose land will be used for transmission lines, *before* approval is granted.

Construction times

At present, the regulation of periods for commencing construction is a sham. It is possible for a developer to erect a demountable shed, and claim that construction has begun. This must end.

Genuine construction (e.g. the construction of roads; the pouring of concrete) should begin within 3 years of approval. If there is any modification of the proposal, a further 1 year, and no more should be all that is allowed. Then approvals should lapse. The entire project should be completed within 5 years of commencement.

Review of conditions of consent

Wind farms have already been built in NSW that are causing chronic annoyance, and chronic sleep disturbance to neighbours, despite formally complying with their conditions of consent. This can only mean that either the compliance monitoring procedure is inaccurate, and unreliable, or the conditions of consent are inadequate.

As a matter of fact, the conditions of consent based on the *South Australian Noise Guidelines* (2003), hitherto in use in NSW, are very inadequate. Any approval made in accordance with those guidelines is likely to be unsafe. This means that when all the wind farms already approved under those guidelines, such as Crookwell Two, Taralga, and Gullen Range, are built, hundreds of households will experience the chronic annoyance and chronic sleep disturbance already being endured by neighbours of Crookwell One, Cullerin and Capital.

The NSW Government must pass legislation to permit a review of the conditions of consent of any wind farm. This is the only way that innocent rural residents will get any real protection. It should be remembered that there is ongoing research into wind turbine impacts, and that Australian planning authorities have not even yet taken account of the research that has already been done. The draft Guidelines themselves are evidence of this. In the circumstances, a power of review must be legislated.

Zoning, setbacks and non-compliance

The basic problem faced by rural residents is that both the Department of Planning and the NSW Land & Environment Court interpret zoning regulations to mean that wind farms are permitted developments within the rural zones where residents live. That this is a matter of interpretation, rather than an obvious matter of fact, is indicated by the fact that wind farms are new kinds of development that have come on the scene long after the zoning regulations were devised. Wind farms change not only the landscape. They change the soundscape. The change to the soundscape is perhaps the more intrusive and obnoxious change, as human beings can always close their eyes. They cannot close their ears.

Once wind farms are regarded in law as permitted developments within rural zones, the residents really have no hope. The Land & Environment Court will proceed on this basis, and reason that the supposed public good of wind farms, and the requirements of legislated government policy must count for more than the needs and interests of a minority of citizens, i.e. the objecting residents. All this became very apparent during the Taralga case in the Land & Environment Court, and is quite explicit in the Court's judgment. The Taralga case then became a precedent for the Gullen Range case (NSWLEC 59 [2007], paras 67-160, esp. para 146; NSWLEC 1102 [2010], paras 107-110).

All this being so, if at the planning stage it is found or predicted that the project at certain points will not comply with its conditions of consent, and that neighbours will be unacceptably impacted by impacts that cannot be effectively mitigated, *then it is assumed as a matter of principle that the neighbours must move, rather than that the project be disallowed*. This is quite explicit, even in the NSW *Industrial Noise Policy* (NSWINP, 2000, pp. 6-7).

In the case of a wind farm, it has already become established that any unacceptable impact must be overcome through acquisition rights. That is, if certain turbines are predicted to have an unacceptable impact on certain neighbours, then the proponent must choose between removing the turbines, and offering to purchase the neighbours' property. This effectively leaves the power of decision with the proponent. The proponent will not choose to remove the turbines, since the profits to be derived from the turbines will be enormously in excess of the cost of purchasing the neighbours' properties. The result is that the neighbours are forced to move, or to continue to live in a residence that the Minister for Planning, or the Land & Environment Court has deemed liable to unacceptable impacts. All this is justified by the fact that the wind farm is in law a permitted development in the rural zone. The disruption to the lives of innocent residents counts for nothing.

The situation of neighbours who have not been granted acquisition rights may be even worse. Given the inadequacy of noise guidelines (both current and proposed), the remaining neighbours may find their life turned into a hell by continual excessive and intrusive noise impacts, resulting in adverse health impacts. They may be forced to abandon their homes, as has already happened in Victoria and South Australia.

All this has happened, because planning authorities have prematurely and recklessly allowed wind farm development to take place, before all the necessary research to determine adequate setbacks has been done.

The only solution to this problem is for there to be *a formal adequate setback so that turbines are definitely prohibited within a certain distance of residences*. Without such a setback, the established practice will prevail, such that if turbines do not comply with the guidelines, the neighbours must move, rather than the turbines.

But, since there is not yet sufficient research to determine accurately such a setback distance, there must be a moratorium, and a research programme. That is what is needed, not another set of inadequate, and inadequately researched guidelines. *The ultimate purpose of the research programme must be to determine an adequate setback distance, within which turbines will be prohibited.*

Applicability of the Guidelines

The NSW Government proposes that the Guidelines only apply in law to future proposals. With regard to existing applications and transitional projects, the Government will “recommend” the guidelines to proponents. With regard to wind farms approved and/or operating, the Department of Planning will “encourage” operators to adopt “relevant aspects of the guidelines” (Department of Planning, 2011b).

This is unacceptable. It is both irrational and unjust. It will mean that neighbours of some wind farms will enjoy protections that neighbours of other wind farms do not enjoy. This is blatantly inequitable, and offends against natural justice. Residents must take legal advice as to whether this absurdity and injustice would be upheld by the High Court.

As the “recommendation” and the “encouragement” will have no force in law, it is certain that wind farm owners and operators will ignore them. (And, what is a “relevant aspect”?)

It is therefore necessary that legislation be passed to impose the new Guidelines on *all* wind farm projects, whether existing, approved but not yet built, being assessed, or still to be proposed. Only this is consistent with rationality and justice.

Concluding remarks

As the acoustic and medical research, necessary to determine accurately adequate setbacks, has not been completed, there should be an immediate moratorium on further wind farm development in NSW, and on the construction of wind farms approved, but not yet built. There must be a curfew on the night-time operation of existing wind farms, and the conditions of consent of those wind farms must be reviewed, as must the conditions of consent of wind farms, approved, but not yet built.

When the research is completed, and it is possible to determine a setback distance adequate to guarantee protection for neighbours against chronic annoyance and chronic sleep disturbance and *other* adverse health effects, then that setback distance must be imposed on all wind farm projects, past, present, and future. In accordance with that setback, turbines of future proposals must be prohibited within that distance. Turbines of proposals being assessed must be prohibited within that distance. Turbines of projects approved, but not yet built must be prohibited within that distance. Turbines of existing wind farms must be shut down, if they fall within that distance.

If the NSW Cabinet declines to institute a moratorium, and a research programme, then two setbacks should be immediately resolved upon: a general setback of at least 5 kilometres from any residence, whether urban or rural; a setback of 1 kilometre from any property boundary. There must be a proviso that these setbacks will be extended, if that is justified by further research. These setbacks must be imposed on *all* wind farms, existing, approved but not yet built, being assessed, and still to be proposed, so that the construction and/or operation of wind turbines within those setbacks shall be prohibited.

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