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Department of Planning & Infrastructure
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Re Environmental Assessment for the Crookwell Three Wind Farm Proposal

As I explained to a departmental official by phone this morning, I have lost my internet connection, and the internet service provider cannot restore it until Friday 8 February. I have in fact been without internet and e-mail since Friday 25 January. Consequently, I have been unable to access the Environmental Assessment for the Crookwell Three Wind Farm proposal, and I am unable to send in a submission by e-mail.

I intended to limit my submission to the noise assessment for the proposal. Unfortunately, I do not know whether the proposal is to be assessed under the *South Australian Noise Guidelines* (2003) or the NSW draft guidelines. However, it makes little difference, as both the existing guidelines and the proposed guidelines are inadequate to protect wind farm neighbours from adverse noise impacts, and associated adverse health impacts, including sleep disturbance, and stress-related symptoms such as headache, nausea, vertigo, tinnitus, racing heart, awakenings in panic, etc.

That both the existing guidelines and the proposed guidelines are inadequate to protect wind farm neighbours is demonstrable, and has been demonstrated. The proofs are already in the public domain. I give detailed references for these claims below.

It follows that any wind farm approval granted under either the existing guidelines or the proposed guidelines must be regarded as unreliable, and unsafe.

It must be concluded, therefore, that the proposal for the Crookwell Three Wind Farm should be rejected. There should also be a moratorium on all wind farm approval and construction in NSW, and existing wind farms should be shut down until it can be demonstrated that they are not harming neighbours' health.

The rest of this submission summarizes what is wrong with the noise guidelines used in, or proposed for NSW.

Deficiencies of the noise guidelines adopted, or to be adopted by NSW

Before I list the deficiencies in the noise guidelines, I should like to draw your attention to three recently published documents, which are relevant to this issue. You should study these, if you have not already done so. Given their contents, not to do so would be irresponsible.

They are:

- Steven Cooper, *Are wind farms too close to communities?*, The Acoustic Group Pty Ltd, [2012]
- Steven Cooper, *Review of Draft Wind Farm Guidelines* (42.4963.R2:ZSC), The Acoustic Group Pty Ltd, 14 March 2012
- Richard R. James, Wind Turbine Infra and Low-frequency Sound: Warning Signs That Were Not Heard, *Bulletin of Science, Technology & Society* 2012, 32(2) 108-127

Steven Cooper is a noise engineer of thirty years' standing, and principal of The Acoustic Group Pty Ltd. He is a member of the Australian Acoustical Society, and also of the (US) Institute of Noise Control Engineering. His report *Are wind farms too close to communities?* is a full and detailed criticism of the deficiencies of the various noise guidelines in use in Australia, including those in use in NSW. The report finds, amongst other things, that "Noise limits incorporated in the various State guidelines and used for assessment purposes have no scientific studies to support the basis of the limits." The report also finds that "The noise concepts used for wind farms in NSW ignore the fundamental premise of not creating 'offensive noise' as defined in The Protection of the Environment Operations Act." (Abstract)

Mr Cooper's *Review of Draft Wind Farm Guidelines* is a full and detailed criticism of the deficiencies of the NSW draft guidelines. It finds that the noise limits in the draft guidelines, like those in the existing guidelines, are not supported by scientific studies, and that the draft guidelines, like the existing guidelines, ignore 'offensive noise'. The *Review* also finds that "The Draft Wind Farm Guidelines set out measurement, assessment and compliance procedures which are likely to be unworkable in practice." (Executive Summary)

Richard R. James is a noise engineer of forty years' standing, currently with E-Coustic Solutions, Okomos, MI, USA. He is a member of the (US) Institute of Noise Control Engineering. His study 'Wind Turbine Infra and Low-frequency Sound: Warning Signs That Were Not Heard' "explores what was known about infra and low-frequency sound from wind turbines and other noise sources during the period from the 1970s through the end of the 1990s." (p. 108) It concludes:

> A review of the work of acoustical experts such as Swinbanks, Ebbing, Blazier, Hubbard, and Shepherd and others mentioned in this article shows that these problems

were reported at professional conferences and in research papers [i.e. in the period from the 1970s through to the 1990s].

There is sufficient research and history to link the sensitivity of some people to inaudible amplitude-modulated infra and low-frequency noise to the type of symptoms described by those living near industrial wind turbines.

This information should have served as a warning sign. . . .

The acoustics profession and individual acousticians should have recognized the early reports of symptoms by people living near wind turbines as a new example of an old problem. . . .

It is the author's opinion that had past experience and information, which was available prior to the widespread implementation of the modern upwind industrial-scale wind turbine, been incorporated into the government and industry guidelines and regulations used to siting [sic] wind turbine utilities, many of the complaints and AHEs [i.e. adverse health effects] currently reported would have been avoided. (p. 125)

The above studies by Cooper, and by James show not only (i) that the noise guidelines used in, or proposed for NSW are inadequate to protect the neighbours of wind farms from adverse noise impacts, or to achieve the aim of avoiding offensive noise, presupposed by the *Protection of the Environment Operations Act*, but also (ii) that these inadequacies of the guidelines could have been foreseen, on the basis of research conducted and published in the period from the 1970s through into the 1990s. This proves that there has been a substantial failure in the planning and regulation of wind farm development in NSW by both the Department of Planning, and the Department of Environment.

Moreover, it must be surmised that the Department of Health did not give correct advice on the potential adverse health effects of wind turbine noise to either the Department of Planning or the Department of Environment. If correct advice was given, it must have been ignored.

This failure of two, and possibly three departments of the NSW Government needs to be investigated by a Royal Commission.

Deficiencies of the noise guidelines

1. Measurements of wind turbine noise in **dBA** are inadequate, because dBA do not measure accurately low-frequency noise or infrasound, of which the turbine sound mix predominantly consists (Harrison, 2011; Dickinson, 2010; Sonus, 2010).

   A full spectral analysis of wind turbine sound is necessary. Measurements in dBA are necessary for high and mid frequency sound. Measurements in dBC are necessary for mid and low frequency sound. Measurements in dBG are necessary to test whether turbine infrasound immissions exceed Professor Alec Salt's threshold for Outer Hair Cell stimulation of 60 dBG (see below). Measurements in dBZ are necessary to measure infrasound levels between 10 and 0 Hz.

The *South Australian Noise Guidelines* (2003) require only measurements in dBA. Therefore, all approvals granted under these guidelines must be considered unreliable and unsafe.

The NSW draft guidelines make some provision for dealing with low-frequency noise, but the treatment of the issue is inadequate (see below).

2. The noise limit ***35 dBA, or background noise + 5 dBA, whichever is greater*** is inadequate for the following reasons. First, background noise at night in rural areas (away from main roads) can fall to below 25 dBA, or even below 20 dBA (Kamperman and James, 2008; Dickinson, [2012]; Cooper, 2011, 2012). Background noise of 20 dBA + 5 dBA = 25 dBA. Therefore, the greater level of 35 dBA would be the limit. 35 dBA is 15 dB higher than the background level of 20 dBA. This is by definition excessive, since the common understanding is that noise causes unacceptable annoyance when it is higher than 5 dBA above background (Cooper, [2012]).

   In addition, the regression line analysis conducted on the readings for background noise necessarily misrepresents the lowest levels of the background noise, since the regression line is necessarily higher than those lowest levels (Cooper, [2012]). This is particularly relevant to the issue of the wind speed ratio (see below).

   These criticisms apply to both the existing guidelines, and the proposed guidelines.

3. The descriptor $\mathbf{L_{eq}}$ is unsatisfactory for measuring wind turbine noise, because it time-averages the numbers for the amplitude of the sound. Thorne has shown that wind turbine sound fluctuates considerably even during as short a period as one minute (Thorne, 2011). It is likely to fluctuate even more over the standard measuring period of ten minutes. Consequently, the time-averaged $L_{eq(10\ mins)}$ figure will misrepresent the peak noise levels actually heard by neighbours, because it will average the sound levels recorded during the measuring period.

   This criticism applies to both the existing guidelines, and the proposed guidelines.

4. The descriptors $\mathbf{L_{90}}$ **and** $\mathbf{L_{95}}$ are also unsatisfactory for measuring wind turbine noise, as they register only the *quietest* 10% and 5% of the turbine sound, respectively. Consequently, they miss entirely the peak levels of the turbine sound, which neighbours actually hear (Hansen, 2010).

   This criticism applies to both the existing guidelines and the proposed guidelines.

5. It is inappropriate to assume that $\mathbf{L_{eq} = L_{90} + 1.5\ dB}$, since the variation between L_{eq} and L_{90} (or L_{95}) can be very much greater (Thorne, 2011).

   This false assumption is made in the proposed guidelines.

6. The **source of wind turbine sound is not a point**, as noise guidelines commonly assume. It is rather the whole area traversed by the turbine blades. If the blades are 45 metres long, then the area described (pi x r^2) = 6364 square metres. This is certainly

not a point. If there is vortex-shedding from the tip of the blades, then the area is even greater, perhaps twice as big (Dickinson, 2010).

Both the existing guidelines and the proposed guidelines ignore this issue.

7. Noise guidelines commonly assume that **wind turbine sound is propagated spherically**, from a point source. But research shows that the propagation may be cylindrical, and should be treated as a line source. Or, the propagation may change from spherical to cylindrical at some distance from the turbine (Thorne, 2011; Dickinson, 2010).

   The significance of this is that spherical spreading is commonly assumed to involve a rate of attenuation of 6 dB per doubling of distance, whereas cylindrical spreading involves a rate of attenuation of only 3 dB per doubling of distance. Consequently, if sound from a wind farm propagates cylindrically, but is modelled by a developer's consultant on the assumption of spherical spreading, the consultant's calculation will significantly underestimate the actual level of sound received by neighbours.

   The rate of attenuation can also vary according to frequency. Higher frequency sound attenuates at a greater rate than lower frequency sound (Sonus, 2010). Therefore, using only a single figure for rate of attenuation in modelling may lead to a significant underestimation of the levels of the lower frequencies. It should be noted that it is the low-frequency wind turbine sound that is the cause of much of the annoyance experienced by neighbours – at least as far as audible sound is concerned (see below).

   These matters are not discussed in either the existing guidelines or the proposed guidelines.

8. Because weather conditions can influence the magnitude of the sound energy impacting on a residence, it is necessary to take **separate measurements of wind turbine noise for the daytime (7 am to 6 pm), evening (6 pm to 10 pm) and night-time (10 pm to 7 am) periods.** These periods are recognised by the NSW *Industrial Noise Policy*.

   The *South Australian Noise Guidelines* (2003) require only one set of measurements for the whole 24 hour day. The averaging involved can only lead to misrepresentation of peak noise levels actually heard, especially at night.

   The NSW draft guidelines recognize only two measuring periods: day and night. Three periods are preferable, if evening noise is not to be underestimated by averaging.

9. Neither the existing guidelines nor the proposed guidelines recognize **the wind speed ratio**, i.e. the difference in wind strength between the wind at the turbines and the wind at the residence. Because of terrain, winds can be high and turbulent at the turbines (e.g. on a ridge), but low or non-existent at a residence (e.g. down in a valley). This means that there can be no reliance on wind at the residence masking the turbine noise, as both the existing guidelines and the proposed guidelines falsely suppose. (Thorne, 2011; Appelqvist and Almgren, 2011)

Moreover, as the wind rises at the turbines on the ridge, the noise limit rises, even though there may be little wind at the residence, and background noise at the residence may be falling. If the noise limit rises to, say, 45 dBA, while background noise at the residence falls to, say, 20 dBA, the turbine noise will be 25 dBA above background. When this noise enters the residence, it will be intolerable. At night it is certain to cause sleep deprivation. This situation comes about because (a) wind speed is measured at the turbine site but not at residences, and (b) regression line analysis of background noise levels at residences necessarily misrepresents the lowest background noise levels at a residence (Cooper, [2012]).

This disastrous situation is allowed by both the existing and the proposed guidelines.

10. The common assumption that the **noise of wind will mask the noise of turbines** is proved false by experience. Neighbours have reported that they can hear the sound of the turbines through the sound of the wind (Thorne, 2011; Bakker and Rapley, 2010; Dickinson, 2010).

    The explanation for this is simple. The noise of the wind is high and mid frequency noise. The sound of the turbines is predominantly low frequency noise. As low frequency noise can only be masked by another low frequency noise, the noise of the wind will not mask the turbine noise.

    Both the existing guidelines and the proposed guidelines make the false assumption that the noise of the wind will mask the turbine noise.

11. It has been proved conclusively that **most of the sound energy in the sound mix generated by wind turbines is low-frequency sound and infrasound** (e.g. van den Berg, 2004a; Kamperman and James, 2008; Dickinson, 2010; Bakker and Rapley, 2010; Thorne, 2011; Bray and James, 2011; Harrison, 2011).

    The predominance of the lower frequencies in the sound mix is even greater when the sound reaches a residence, because the higher frequencies attenuate at a greater rate than the lower frequencies, and because the higher frequencies will be more easily obstructed by vegetation (Sonus, 2010).

    Finally, the sound mix received inside a residence will be almost entirely low-frequency noise and infrasound, because the higher frequencies will be kept out by the fabric of the building, whereas the lower frequencies will more easily penetrate that fabric (DeGagne and Lapka, 2008).

    All this is most important because the sound of the lower frequencies can resonate inside rooms, and also inside the organs of the human body (Harrison, 2011; Ambrose and Rand, 2011; Berglund et al, 1996).

    It has also been demonstrated that as wind turbines get larger, and more especially taller, the characteristic 'note' of the turbine gets lower (Møller and Pedersen, 2011). Even the wind energy industry admits that this will require greater setback distances (Sonus, 2010).

The work of Bray and James (2011), and of Swinbanks (2011) shows that wind turbine low frequency noise and infrasound (being amplitude-modulated) have a very high crest factor, and that this will tend to lower the threshold of audibility.

I will deal with audible low-frequency noise in this section, and leave infrasound to the next section.

The *South Australian Noise Guidelines* (2003) do not concern themselves with low frequency noise at all. This is a grave omission, and serious failure.

The NSW draft guidelines state that "Analysis of wind turbine spectra shows that low frequency noise is typically not a significant feature of modern wind turbine noise . . . ." This statement is completely false, and is contradicted by all the independent research into wind turbine noise for the last decade, and indeed longer. It is impossible to have any confidence in a document that makes such a gross and elementary error.

The NSW draft guidelines propose that if the low frequency noise from wind turbines (above 20 Hz) exceeds 65 dBC during the day, or 60 dBC at night, further investigations are to be made. These limits are far too high. 60 dBC equates to about 50 dBA (personal communication from Bob Thorne). Pulsating low frequency noise in the 40s dBA in a bedroom at night would be intolerable, and cause sleep disturbance.

It should be noted that the US noise engineers Steven Ambrose and Robert Rand have proposed an outdoor limit of 55 dBC. This is to be a *maximum*, not an average (Ambrose and Rand, 2012).

It should also be noted that Denmark is to introduce an indoors noise limit for wind turbine low frequency noise. The limit is: 20 dBA for frequencies between 10 and 160 Hz (Møller et al, 2012). Møller and his colleagues point out that at low frequencies a much smaller increase in sound level is needed to produce any given increase in loudness. Consequently, it is crucial that the indoors noise level for low frequency noise be strictly observed, and that the limit be regarded as a definite *maximum*, and not as an average (Møller et al., 2012).

It can only be concluded that neither the existing guidelines nor the proposed guidelines takes the issue of wind turbine low frequency noise seriously. This no doubt explains the multitude of complaints from neighbours.

12. The wind energy industry maintains that **infrasound** from wind turbines is of no importance, because inaudible sound cannot affect human beings. This assumption is false, and has been authoritatively refuted by Professor Alec Salt and his colleagues. Professor Salt, a specialist in the physiology of the cochlea (in the inner ear) has shown that inaudible infrasound at 60 dBG stimulates the Outer Hair Cells in the cochlea, and that nerve fibres connect the Outer Hair Cells to areas of the brain associated with attentional control, arousal, startle, the sense of balance, and the monitoring of head and ear position. Salt also points out that the infrasound signals can cause a biological amplitude modulation of the higher frequencies within the

auditory/nervous system (Salt and Hullar, 2010; Salt and Kaltenbach, 2011, Salt and Lichtenhan, 2011, Salt and Lichtenhan, 2012).

Salt surveyed the infrasound levels produced by wind turbines, and found that they were typically between 60 and 70 dBG (Salt and Kaltenbach, 2011).

Salt has outlined his findings in language intelligible to laypeople on his website (http://oto2.wustl.edu/cochlea/wind.html).

It is clear that Salt's findings may constitute at least one explanation for neighbours' complaints of headache, nausea, vertigo, sleep disturbance, tinnitus, etc. And that is in fact his opinion.

The authors of the *South Australian Noise Guidelines* (2003) claim to be unaware of infrasound being present at any modern wind farm site. To the contrary, Hubbard and Shepherd (1990) show that even modern upwind wind turbines produce predominantly low frequency noise and infrasound (Hubbard and Shepherd, 1990, cited in James, 2012). Since 2003 abundant evidence from independent research has confirmed that modern upwind turbines produce predominantly low frequency noise and infrasound (van den Berg, 2004a; Kamperman and James, 2008; Dickinson, 2010; Bakker and Rapley, 2010; Thorne, 2011; Bray and James, 2011; Harrison, 2011).

The *South Australian Noise Guidelines* (2003), therefore, ignore infrasound. That they are still in use in NSW as a guide for approving wind farm proposals is reprehensible.

The NSW draft guidelines do not even mention infrasound. The NSW draft guidelines discuss "low frequency noise" down to 20 Hz, but do not discuss sound below 20 Hz, thus implying that infrasound can be ignored. This is especially reprehensible, as recent research has shown that enough was known about infrasound in the 1970s, 80s, and 90s to serve as a warning to officials drafting wind turbine noise guidelines that infrasound might be expected to be a serious problem (James, 2012).

Infrasound levels between 0 Hz and 10 Hz must be measured, as well as infrasound levels between 10 Hz and 20 Hz. The reason is that evidence is being gathered that shows that it is the levels between 0 and 10 Hz that may be causing the most serious adverse health effects (Ambrose and Rand, 2011; Ambrose, Rand and Krogh, 2012; Alves-Pereira and Castelo Branco, 2007). For this reason, infrasound levels must be measured in dBZ, as well as dBG.

13. The **amplitude modulation** of wind turbine sound occurs on both a macro- and a micro-time-scale. The macro-scale modulation occurs at the 'blade pass frequency', about once every second (Dickinson, 2010; Doolan, 2011; Bakker and Rapley, 2010). Recent research has shown that there is also modulation on a micro-scale, to be

measured in milliseconds, and that this form of modulation has a very high crest factor (Bray and James, 2011). A high crest factor tends to lower the threshold of audibility (Swinbanks, 2011).

Amplitude-modulated sound at frequencies of about 0.3 Hz to 10 Hz (i.e. at intervals of several seconds to about one-tenth of a second) tends to set off the 'alert mechanism' in the oldest and most primitive part of the human brain. Sustained stimulation of the alert mechanism can lead to anxiety, depression, sleep disturbance, tiredness, and nausea (Bakker and Rapley, 2010).

The meagre discussions of amplitude modulation in the *South Australian Noise Guidelines* (2003) and in the NSW draft guidelines are superseded by the work of Bakker and Rapley, of Bray and James, and of Swinbanks. Therefore, both the existing and the proposed guidelines must be considered inadequate in their treatment of amplitude modulation.

14. Where there is an array of multiple turbines **Heightened Noise Zones** can be created. The sound waves from several turbines can converge on a point, such that if there is a residence at that point, increased noise will be experienced (Bakker and Rapley, 2010)

    Neither the *South Australian Noise Guidelines* (2003) nor the NSW draft guidelines considers Heightened Noise Zones.

15. Again, where there is an array of multiple turbines **Wake and Turbulence Effects** can be created. These occur where a line of turbines is in line with a residence. If the turbines are too close together, or when the wind is gusting, the wake from one turbine can interfere with the wake of another turbine. And so on, down the line of turbines, increasing the noise transmitted from the turbines and received at the residence (Bakker and Rapley, 2010).

    In this connection, it is imperative to discover whether the turbines are separated by the distances recommended by the manufacturers.

    These matters are not considered by either the existing guidelines or the proposed guidelines.

16. Increased noise can also occur from **blade stall**, known in New Zealand as 'woomping'. Owing to the irregularity of the wind, it can happen that one blade has insufficient wind to move it, while the other blades still have sufficient lift. The blade with insufficient lift stalls, then starts again. This results in a thumping noise (Dickinson, 2010).

    Blade stall is not discussed in either the existing guidelines or the proposed guidelines.

17. Increased night-time noise can occur owing to a **stable atmosphere caused by temperature inversion**. This can take two forms. In flat terrain night-time temperature inversion, giving rise to a stable atmosphere, can cause different wind speeds at different heights of the wind turbine. These different wind speeds can produce a severe 'beating' of the turbine blades, generating higher night-time noise levels (van den Berg, 2004b, 2006). This phenomenon has come to be known as the 'van den Berg Effect'.

    However, in hilly terrain, where turbines are located on a ridge, with residences in the valley below, there may be no stable atmosphere on the ridge, because of the high winds, while there is a stable atmosphere in the valley, with cold air pouring down into the valley. The channel of cold air acts as a conduit for the turbine sound. Thus, there may be increased night-time noise at the residence, due to the stable atmosphere in the valley, even though there is little or no beating of the turbine blades, because of the absence of a stable atmosphere on the ridge (van den Berg, 2007). (This possibility is recognized in the NSW *Industrial Noise Policy*, where the conduction of sound by the channel of cold air is called 'drainage flow' (NSWINP, 2000).)

    The *South Australian Noise Guidelines* (2003) do not discuss either form of the effect of stable atmosphere and temperature inversion.

    The NSW draft guidelines treat the 'van den Berg Effect' as only a species of amplitude modulation, but they only discuss amplitude modulation in general. There is no discussion of the specific form caused by a stable atmosphere and temperature inversion.

    Moreover, the NSW draft guidelines do not discuss the situation where turbines are situated on a ridge with residences in the valley. There is no discussion of 'drainage flow'. In fact, the terms 'stable atmosphere' and 'temperature inversion' do not occur in the NSW draft guidelines.

    These are failures that could have disastrous consequences for neighbours.

18. **Indoor measurements** need to be taken as well as outdoor measurements. Outdoor measurements are insufficient, partly because (i) the extent of transmission through the fabric of a building varies according to frequency, and is still a matter of discussion; and (ii) low frequency sound and infrasound can resonate inside a room (see above), such that sound levels inside a residence may be higher than those outside a residence (e.g. Ambrose and Rand, 2011).

    Neither the existing guidelines nor the proposed guidelines considers the need for inside measurements.

19. The NSW draft guidelines allow measurements to be taken at **intermediate locations**, and a calculation to be made, according to the assumptions of a model. This should not be allowed, as the extent of sound transmission through the fabric of a building varies according to frequency, and is still a matter of discussion. Also, as noted above, low frequency noise and infrasound can resonate inside a building, such that the sound levels inside a residence may be higher than those outside a residence (e.g. Ambrose and Rand, 2011).

The above criticisms show that both the *South Australian Noise Guidelines* (2003) and the NSW draft guidelines are gravely deficient, and are incapable of protecting wind farm neighbours from adverse noise impacts, with the associated adverse health impacts.

(*En passant*, it may be noted that the proposed amendment to the *Protection of the Environment Operations Act*, by which wind farms are to be regulated by the EPA, will be undermined by the inadequacy of the noise guidelines, to which the Environment Protection Authority must refer. The Environment Protection Authority will be able to investigate noise complaints concerning wind farms, but only in relation to the assumptions, principles and categories of the noise guidelines. Since these guidelines are comprehensively inadequate, neighbours are unlikely to get any redress for their complaints, and will continue to suffer. This is unacceptable. Therefore, if the Crookwell Three Wind Farm proposal is approved, and the wind farm built, any complaints concerning noise impacts are likely to be dismissed by the NSW EPA, once it has determined that the wind farm complies with the (inadequate) noise limits stipulated in the noise guidelines. This is unacceptable.)

The Australian noise engineer Bob Thorne 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. (Thorne, 2010)

Thorne's opinion is borne out by the experience of residents living within 3.5 km of the Cullerin and Capital Wind Farms in NSW, and by residents living within 3.5 km of wind farms in Victoria, in South Australia, and in New Zealand.

It must be concluded that the neighbours of the Crookwell Three Wind Farm will experience the same adverse impacts as the neighbours of the above wind farms. Therefore, the Crookwell Three Wind Farm proposal must not be approved.

Yours sincerely

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