SUBMISSION

Rye Park Wind Farm Modification 1 SSD-6693 – Mod 1

1. I write as the owner of “Wattle Vale”, to object to proposed Modification 1 to Development Consent SSD-6693 for the Rye Park Wind Farm. My objections are on the grounds of visual impacts, noise impacts and biodiversity impacts as set out below. This submission has been prepared with the benefit of advice of senior and junior counsel specialising in environmental and planning law.

Visual Impacts

2. The Rye Park Wind Farm Modification 1 is supported by a Visual Impact Assessment (**VIA**) by Green Bean Design, dated March 2020.

3. At the outset, I query the decision not to assess the modification against the Visual Performance Objectives of the NSW Wind Energy Visual Assessment Bulletin (**Visual Assessment Bulletin**) on the grounds that this bulletin does not contain any specific objectives relevant to modification applications.[1] There appears to be no reason why a modification should not be assessed against these objectives as well as an original application, especially given that the Visual Assessment Bulletin states expressly that it is to apply to any modification application that involves a significant reconfiguration or increase in height to the approved turbines.[2]

4. The VIA at Fig 1 and 2 contains a plan of the turbines which are to be deleted. However, this actually shows the difference between the Response to Submissions proposal and the modified proposal, rather than between the approved and modified proposal. Thus, it gives the impression of more turbines being deleted as part of the modification application than is actually the case.

5. The VIA concludes that there is no change in the visual impact rating for most non-associated residences as a result of the modification,[3] but this quantitative analysis may overlook qualitative changes in the views experienced by the most-affected residences in the moderate to high category. The wind turbines which can be seen from these residences will obviously be larger, and therefore more prominent.

6. In the Rye Park Wind Farm Assessment Report (**the Assessment Report**), the Department of Planning (**the Department)** expressed serious concerns about the visual impacts of the approved proposal on some residences, and only accepted these impacts on the grounds that they could not be ameliorated without threatening the viability of the project.[4] None of these dwellings appear to have benefited significantly from the deletion of turbines. The prominence of individual turbines and risk-benefit analysis for these residences is likely to have changed, now that advances in technology have resulted in a preference for fewer, larger, turbines. The photomontages in the VIA do not demonstrate these impacts, as they only address views from public roads. In the circumstances, careful consideration should be given

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[1] VIA p 16. See NSW Wind Energy Visual Bulletin Table 2, p 20.

[2] See Visual Assessment Bulletin at page 2.

[3] p 98.

[4] Moderate to high impacts not ameliorated by the deletion of turbines from the original proposal were those produced by the Northern Precinct discussed in the Assessment Report at p 23, the North Eastern and Central Precincts at pp 30-31 and the Southern Precinct at p 35.

to the acceptability of the impacts of the modified proposal on the most affected residences.

7. It is also concerning that the VIA contains no assessment of the visual impact of night-time hazard lighting.

8. At the time when the original project was assessed, the Department received advice from the Civil Aviation Safety Authority (**CASA**) that the proposal was not considered to be a hazard to aviation safety, and therefore that hazard lighting was unlikely to be required.[5] As a precaution, the PAC imposed Condition 5 which required that "any aviation hazard lighting complies with CASA's requirements". However, in the circumstances, there was a low probability of that condition being triggered, and so the impacts of night-time lighting received little attention. That has changed with the proposal to increase the maximum height of the turbines.

9. The Aeronautical Impact Assessment lodged in support of the modification application explains that "for structures more than 110 AGL, the proponent should expect that obstacle lighting will be required unless there are unusual circumstances", and that any variation of this standard will be subject to a hazard risk assessment.[6] It obviously would have been much easier for the approved project, with a maximum tip height of 157 metres, to obtain an exemption from this requirement than the modified project, with a maximum tip height of 200m.

10. Therefore, it should be assumed that the modification is likely to require night-time hazard lighting where none was required for the approved project, making a visual impact assessment of night-time hazard lighting necessary.

11. In February 2018 the Department recommended refusal of the Jupiter Wind Farm for reasons which included the visual impact of night lighting. The Department observed in that context that "there are limited existing light pollution sources in the vicinity and many residences value the dark night skies as a feature of the area".[7] The same is true of the majority of residences in the vicinity of Rye Park, which are located in rural areas currently subject to no light pollution. The substitution of a night sky with no man-made lights, for one containing a series of rotating red lights at heights of up to 200 m constitutes a major and permanent intrusion of an industrial element into a previously pristine vista.

12. There seems to be no reasonable prospect that this impact can be ameliorated by conditions, as the lights will need to be visible for long distances in order to fulfil their aviation safety function. Partial shielding may assist to reduce the impacts of lights on stationary hubs and masts, but is unlikely to reduce the impact of rotating blade-tip lights.

13. Therefore, a visual impact assessment which ignores the impacts of night-time hazard lighting is inadequate and does not permit the consent authority to properly consider the visual impacts of the proposal.

14. In the assessment of the original proposal, the Department obtained advice from an independent expert on visual impacts, which led to a number of important changes to the proposal and the imposition of conditions to ameliorate visual impacts. Visual

[5] Assessment Report p 39.
[6] Appendix C.
[7] p 36.

impacts are also a critical impact of the proposed modification. Therefore, the Department should not rely solely on the proponent's assessment, but should also obtain an independent report on this aspect of the proposed modification addressing all relevant impacts including night-time hazard lighting.

Noise Impacts

15. The Modification Environmental Noise Assessment, March 2020 (**MENA**) shows that the increase in the size of the proposed turbines will change the impacts of the development from barely compliant to non-compliant at a number of sensitive receivers.[8] The proponent should not be permitted to modify the proposal so as to exceed state-wide standards designed to protect rural communities from the adverse impact of wind farm noise.

16. The proponent claims that it can achieve compliance by adopting a strategy of operating selected turbines in a reduced noise mode.[9] However, it has not provided any evidence to support the effectiveness of such a strategy. Nor is it offering to accept a condition which would oblige it to put this strategy into practice in specific circumstances. To permit the proponent to construct infrastructure which is predicted to produce unacceptable impacts and then to leave it to the proponent's discretion to curtail operation of the facility so as to avoid those impacts is not a robust regulatory approach. In those circumstances, the community will be highly exposed to the risk of non-compliance, and once the wind farm is operational, non-compliance will be very difficult to assess let alone enforce.

17. The MENA at Table 3 compares the predicted noise impacts of the modified proposal to noise criteria rather than comparing it to the predicted impacts of the original proposal. This underrepresents the extent of the predicted noise increases, because some of these residences were previously well below the criterion. For many residences there will be an increase in the predicted impact in the order of 5dB(A), which is significant in such a quiet rural area.

18. Furthermore, the predictions in the MENA appear to be based on incorrect assumptions. L Huson & Associates have carried out a Review of the MENA, which is attached to this submission at Appendix A. This shows that the MENA has not used the correct parameters for modelling noise impacts, leading to a likely under-estimation in the order of 4dB(A).[10] Of particular concern is that the MENA fails to take account of the fact that the turbines in the modified proposal will be inadequately spaced for their size.[11] If the noise predictions in the MENA are adjusted upwards by 4dB(A), then there will be non-compliance at several more non-associated residences.

19. The assessment of construction noise in the MENA is not informative, because it does not consider the extent to which construction noise, both in volume and duration, is likely to increase as a result of the modification. For example there is no consideration of whether the construction of larger turbine components will require the use of large and noisier machinery, or more earthworks to create larger hardstand areas. It seems likely that there will be an increase in all of these

[8] MENA p 15.
[9] MENA p 15.
[10] Review by L Huson and Associates, p 10.
[11] MENA p 8.

parameters, given that the modification will more than double the area of ground disturbance.[12]

20. The increase in the size of the turbine elements and disturbed areas is likely to result in a proportionate increase in the level and duration of noise produced by the two concrete batching plants which were approved as part of the original proposal. Yet there is no detailed assessment of the amount of noise likely to be generate by those plants, or how their noise impacts will be mitigated. These batching plants are likely to be very substantial operations which, if approved in isolation, would require a high level of assessment. Given the magnitude of increase in works proposed as part of the modification, the management of impacts from the batching plants should not be deferred to post-approval management plans. Rather, the proponent should be required to model the actual impacts of these plants and to provide plans and specifications for any proposed mitigation works (such as screening and earthen bunds) before the modification is approved.

Biodiversity Impacts

21. In relation to the assessment of biodiversity impacts in the Biodiversity Assessment Report (**BDAR**), the first point to note is that in spite of a reduction in the number of turbines, the proponent is seeking approval to more than double the disturbance area. The original assessment was based on an estimated a disturbance area of only 254 ha.[13] The indicative development footprint for the modified project (not including external roads) is now estimated at 542 ha.[14] This suggests that the original assessment may have drastically underestimated the extent of roads and hardstand areas actually required to construct the proposal.

22. The impacts of an increased disturbance area should not be treated as non-existent because they arise from errors in in the design of the original footprint rather than from the headline changes proposed in the modification application. The original Consent requires that the development be carried out generally in accordance with the Environmental Impact Statement[15] which allows for a development footprint of 254 ha. If the proponent, on more detailed consideration, finds that it actually needs a footprint of 542 ha to construct the development, then it must either obtain a modification to allow for that increased footprint, or walk away from the Consent. Therefore, the impacts of the proposed increased footprint should be treated as a direct impact of the modification application.

23. As part of the overall increased footprint, the proposal to increase the clearing of White Box Yellow Box Blakely's Red Gum Woodland Endangered Ecological Community (**White Box EEC**) to a total of 38 ha is a very serious matter. This community is currently listed as an Endangered Ecological Community, but there is a pending determination which is likely to change this listing to critically endangered.[16] An ecological community is only eligible to be listed as critically endangered if it is facing an extremely high risk of extinction in the immediate future.[17] In light of the extreme threat level facing this community, it is unsatisfactory for the proponent to rely on the avoidance of 28 ha within the development corridor as a mitigation

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[12] See the discussion of biodiversity impacts at [21] below.
[13] Assessment Report, March 2017, p 46.
[14] Modification Report p 11.
[15] Development Consent SSD 6693, 22 May 2017, Schedule 2 [2](a).
[16] BDAR p 170.
[17] *Biodiversity Conservation Act 2016* s 4.5.

measure for the clearing of 38 ha.[18] The objective of maintaining the quality and diversity of ecosystems[19] is not going to be achieved by allowing the piecemeal destruction of remnants of such rare communities.

24. This State-listed community is almost entirely co-extensive with the Commonwealth-listed White Box-Yellow Box-Blakely's Red Gum Grassy Woodland and Derived Native Grassland Critically Endangered Ecological Community (**White Box CEEC**) on the site.[20]

25. Given that these communities are practically the same, the assertions in the BDAR that the modification will decrease the impact of the proposal on the White Box EEC while increasing the impact on the White Box CEEC,[21] misstate the real impact.

26. What appears to have happened is that the State was willing to approve clearing 50 ha of this community as originally proposed by the proponent, whereas the Commonwealth was only willing to approve clearing of 9.5 ha. If this is correct, then the overall outcome of the original approval process was that the proponent was required to refine its development footprint to clear a maximum 9.5 ha of the White Box community. Measured against this outcome, the modification is proposing a real increase in clearing of this community in the order of 17 ha, not a reduction of 11 ha as asserted in the BDAR.

27. We understand that the proponent is offering to offset these impacts, but offsetting does not create more of an ecological community. Nor does it provide any warrant for the consent authority to ignore the biodiversity impacts of a proposal which remain part of the environmental impacts of the proposal, to be considered under s 4.15(1)(b) of the *Environmental Planning and Assessment Act 1979.* All that offsetting does is to offer protection or improved management in another area. This only creates a 'net gain' if one assumes that the second area would otherwise have been subject to clearing or mismanagement, which is not a valid assumption in the case of a protected ecological community.

28. Before allowing clearing on such a scale, the consent authority should consider how much White Box EEC remains in the local area, and whether clearing of up to 38 ha is likely to adversely affect survival of this community in the locality and in the region. In undertaking this consideration it should not assume that the White Box EEC will remain untouched everywhere else that it occurs in the region, but rather that it will be subject to a range of cumulative threats. The Commonwealth listing advice for this community notes that it mainly persists on land with steeper slopes which was less likely to be cleared for grazing.[22] This seems to make it particularly susceptible to clearing for wind farms. At the time of approval of the original proposal, there were 14 operational, approved or proposed wind farms within 60 km of the project site.[23] The proponent has not provided any information in the BDAR to enable the consideration of these kinds of cumulative impacts.

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[18] BDAR p 261.

[19] *Biodiversity Conservation Act 2016* s 1.3.

[20] The BDAR at Fig 3.2 shows only two small roadside areas (less than 2 ha) where the state-listed community is not co-extensive with the Commonwealth-listed community. The Assessment Report, March 2017 (for the original proposal) at p 46, Table 13 assumes that the two communities are the same.

[21] BDAR Executive Summary and p 179.

[22] *Advice to the Minister for the Environment on the White Box – Yellow Box – Blakely's Red Gum Grassy Woodland and Derived Native Grassland.*

[23] NSW Planning Assessment Commission Determination Report Rye Park Wind Farm, p 1.

29. The direct impacts of the modified proposal on hollow-bearing trees will also be very significant. An estimated 4,047 hollow bearing trees will be removed,[24] including 231 suitable for the Superb Parrot.[25] This represents a four-fold increase compared to the overall 893 hollow-bearing trees[26] under the approved project. For threatened owls and raptors, the impact of the loss of hollow-bearing trees will be felt not only through the direct loss of nest sites, but also through a reduction in the availability of nest sites for prey species. The BDAR does not consider whether this could contribute significantly to the decline of hollow-dependant species in the locality, particularly in light of the cumulative effects of other wind-farms in the region.

30. The BDAR does not contain enough information to enable the consent authority to consider the potential impacts of habitat fragmentation. These impacts could be especially significant for species such as the Squirrel Glider which prefer to travel between trees, rather than across the ground. The modified proposal will create gaps of up to 200 m through existing vegetation patches.[27] No consideration is given to whether this fragmentation will reduce the habitat value of the remaining patches, or sever important wildlife corridors.

31. Assurances that the proponent will seek additional opportunities to avoid biodiversity values in the detailed design phase should not be relied upon.[28] At present, it is in the proponent's interests to seek to avoid threatened species habitat and threatened ecological communities in its indicative development footprint, to maximise its chances of approval. It will not have any incentive to further minimise habitat loss after approval. Rather, past experience suggests that the disturbance footprint is likely to increase rather than decrease as the practical requirements of construction become clearer. Therefore, the consent authority should assume that the proponent will clear the full area permitted under the conditions of consent.

32. The Bird and Bat Assessment (**BBA**) lodged in support of the modification application is a flawed document. It does not disclose the number, duration or method of the surveys used to make predictions about bird behaviour. Nor does it explain how the observers estimated the height at which bird were flying. It does not appear to account for the difficulty of identifying small birds flying at heights over 30m above ground level (**AGL**).[29] Therefore, it is highly likely that it underestimates the proportion of flights over 30m AGL. In addition, Umwelt's assertion that certain species "only very rarely fly" above 20m AGL[30] is not supported by any scientific evidence.

33. In the case of several of the threatened species actually observed during site surveys by Umwelt, the BBA relies on a sample size of less than 5 observations. So even assuming that these surveys accurately represent the number of flights 30m AGL, it is not valid to make generalisations about species behaviour based on this data. A more rigorous approach would have been to examine the scientific literature for information about the flight patterns of these species.

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[24] This figure is not expressly stated in the BDAR, but represents the total of the numbers stated for each community in Table 5.3, at pp 255-256.
[25] BDAR p 274.
[26] BDAR p 271.
[27] BDAR pp 266-268.
[28] For example BDAR 241.
[29] p 10.
[30] p 11.

34. The BBA only assesses the risk to threatened birds actually observed on the site by the proponent's consultants. Even with a high level of survey effort, the presence of other species cannot reasonably be excluded on this basis. The rarer a species is the less likely it is to be observed on any given site. Therefore, species presence should be assumed where suitable habitat exists.

35. The BBA also fails to consider the possible impacts of the increased rotor size on the Wedge-tailed Eagle. This species, although not threatened, nevertheless forms an iconic part of the natural ecosystem. As a large, high-flying raptor, it will be impacted by the full extent of the proposed 49% increase in total rotor swept area.

36. The potential impacts of wind turbines on Wedge-tailed Eagles were given weight by Preston CJ in *Taralga Landscape Guardians Inc v Minister for Planning and RES Southern Cross Pty Ltd* [2007] NSWLEC 59. Although the impact on eagles was found not to warrant refusal in that case, that decision was made 13 years ago in relation to a wind farm comprising only 69 wind turbines to a maximum height of approximately 100m. In the present case, the impacts on Wedge-tailed Eagles are likely to be greater and less acceptable, considering the proposed increase in turbine size, and the cumulative impacts of approximately 14 other wind farms (either operational or proposed) in the surrounding region.

June 2020

APPENDIX A COVER SHEET

Rye Park Wind Farm Modification 1 SSD-6693 – Mod 1

Review by L Huson & Associates Pty Ltd dated May 2020

L HUSON & ASSOCIATES

REPORT

REVIEW

Rye Park Wind Farm
Planning Permit Amendment
May 2020
Application # SSD-6693-Mod-1

CLIENT:

D. S. T. Legal

Job No LHA427
May 2020

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REVIEW

Rye Park Wind Farm Planning Permit Amendment

EXECUTIVE SUMMARY

I have reviewed the documentation provided to support an amendment to the Rye Park Wind Farm planning permit with regard to acoustics. The amendment (no. SSD-6693-Mod-1) has been submitted to Major Projects, NSW Department of Planning, Industry and Environment, to cover an "Increase in maximum tip height to 200 m, decrease in maximum number of turbines to 80 and determine a single transport route for construction traffic."

The documentation to support the requested amendment included a report by Sonus Pty Ltd, dated March 2020, referenced in Appendix G.3 – Noise Report that was sourced from: https://www.planningportal.nsw.gov.au/major-projects/project/26241

Construction noise impacts have been assessed with tables of predicted construction noise levels being listed in Table 8 of the Sonus report of March 2020. However, it is difficult to review these predictions when sound source locations, sound power levels and noise model have not been described.

The noise impact assessment for the selection of a Preferred Transport Route has not been considered in the Sonus report.

This review shows that the changes proposed by Rye Park Renewable Energy Pty Ltd will exceed target noise limits imposed for the development.

I do not consider that the candidate wind turbine used in the new wind farm layout will achieve compliance with the required noise limits at some dwellings surrounding the Rye Park Wind Farm. The use of G=0.5 and an alternative 4m receiver height in the noise modelling is inappropriate and the justification for its use by Sonus Pty Ltd is found to be lacking.

The NSW Planning and Environment's "Wind Energy: Noise Assessment Bulletin for State significant energy development", December 2016 (WENAB) requirements in respect of certain modelling parameters that can significantly alter predicted sound levels have not been applied.

The noise modelling completed by Sonus has not followed the WENAB noise modelling requirements. Instead, optimistic noise model parameters have been used. With the correct noise model inputs to ISO9613-2 our review demonstrates non-compliance with the permitted noise targets.

The noise model used to prepare data for the Sonus report does not account for site conditions such as inflow turbulence from other upwind turbines. These effects can increase sound emissions from wind turbines to an extent largely determined by the proximity of the wind turbines to each other. Inclusion of these effects will further exacerbate the degree of non-compliance with permitted noise limits.

A larger rotor diameter (up to 158m) for a new candidate wind turbine would normally require an increase in spacing between wind turbines to minimise this adverse effect. The proposed new layout retains the same wind turbine spacing described in the current planning permit that was based on a wind turbine having a 112m diameter rotor. The result for the new proposed GE158 5.5MW wind turbine will be a decrease in efficiency of the wind farm and an increase in noise emissions, even if test results (always measured to minimise inflow turbulence during testing) show that the sound power of the smaller and the proposed larger wind turbines are similar.

Amplitude modulation increases for larger wind turbines is a distinct probability and if the modifications sought are approved I recommend that an appropriate noise condition to protect residents from adverse amplitude modulation effects be issued. Uncertainty over potential acoustic amplitude modulation / beating adverse impacts can be addressed by issuing a noise condition similar to the one described for the Den Brook Wind Farm (Condition 20).

I do not give any weight to wind turbine noise guarantees and suggest that it is preferable to rely upon conditions that require robust assessment against licensed noise limits. Different sound power test results for the same wind turbine model are common and appropriate uncertainties should be considered in noise predictions. Turbulence Intensity (TI) can increase sound emissions and an increase in TI is inevitable for a larger wind turbine on the same turbine layout footprint.

This review has shown deficiencies in the method used to predict wind farm operational noise levels. The predicted wind farm noise levels from the candidate wind turbine are shown to be at least 4 dB too low.

If the noise model is corrected and re-run it should be possible to identify additional wind turbines that need to be removed from the proposal to ensure that the project meets the extant development consent noise limits.

The extant Schedule 3 Environmental Conditions do not require any noise prediction modelling to demonstrate compliance with approved noise limits if a different turbine to the candidate is used. I see this as a deficiency which can be remedied with a condition to require on site testing of any alternative wind turbine to that used as a candidate. The test results can then be incorporated into a properly constructed ISO9613-2 noise model to demonstrate that compliance with the noise limits can be met. If on site test results and new noise model predictions show that non-compliance is likely then the project construction can be halted until such time that an appropriate noise reduction strategy is devised and approved.

Ancillary equipment attached to and part of each wind turbine can operate below cut-in wind speed at the Rye Park Wind Farm that is not covered by the WENAB and operational noise limits in Condition 11. I recommend that a target noise limit from any such ancillary equipment be included with those applicable to ancillary infrastructure noise conditions in Condition 12.

Prepared by [signature] ***25 May 2020***

W Les Huson BSc MSc CPhys MInstP MIoA MAAS MEIANZ (CV included as Appendix A)

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INTRODUCTION

I have been commissioned by D. S. T. Legal to review an application by Rye Park Renewable Energy Pty Ltd to amend the Development Consent (granted in May 2017 for Application Number SSD 6693) for up to 92 wind turbine generators (WTGs) with a tip height of up to 157m at the Rye Park Wind Farm, with regard to noise.

This report has been prepared by William Leslie Huson.

RYE PARK WIND FARM DEVELOPMENT

It is useful to review the past environmental noise reports that led up to Development Consent and their relevance to the current Environmental Noise Assessment by Sonus Pty Ltd for the Rye Park Wind Farm Modification since these are referenced in the report (ref. S3200C17, March 2020).

The Rye Park Wind Farm was originally conceived by Epuron Pty Ltd which organised the preparation of an Environmental Assessment in accordance with the Director-General's Requirements originally coined on 14 February 2011 and supplemented on 16 August 2011.

Epuron Pty Ltd commissioned SLR Consulting Australia Pty Ltd to prepare an assessment of environmental noise (report 640.01808-R1, August 2013, Revision 5). This report states that it was prepared for Rye Park Wind Farm Pty Ltd with a proposal to build 126 wind turbines using the Vestas V112 3MW turbine as a representative candidate.

Rye Park Renewable Energy Pty Ltd was formed on 29 August 2014, being a subsidiary of Epuron Pty Ltd, which retained ownership of the Rye Park Wind Farm development. Epuron then completed the sale of the Rye Park Wind Farm project to Trustpower Limited (NZ) via its subsidiary Rye Park Renewable Energy Pty Ltd in November 2014. Rye Park Renewable Energy Pty Ltd then became responsible for the future development of the Rye Park Wind Farm project.

An environmental noise assessment of the operation and construction stage was completed after minor wind farm modifications by Sonus Pty Ltd (report S3200C9 dated February 2016) for a wind farm layout containing 109 wind turbines, again using the Vestas V112 3MW candidate.

Tilt Renewables was demerged from Trustpower Limited (NZ) in October 2016, with Tilt Renewables (an Australasian company, dual listed on the New Zealand stock exchange and the Australian stock exchange) taking ownership of all operational wind assets and the wind development pipeline.

Development Consent was given on 22 May 2017 for up to 92 wind turbines after specifically removing wind turbine numbers 16, 29, 44, 45, 47, 90, 93, 94, 95, 96, 97, 98, 99, 101, 133, 134 and 144. I am not aware of any revised environmental noise assessment for the final approved 92 wind turbine layout.

The current proposed modification is for a wind farm layout change to remove a number of wind turbines (numbered 6, 35, 28, 52, 53, 56, 77, 102, 103, 104, 140 and 149) that will leave a total of 80 wind turbines, each being of a type represented by a candidate GE 158 5.5MW wind turbine. The physical locations of the 80 wind turbines remain as detailed in the May 2017 Development Consent.

ENVIRONMENTAL NOISE ASSESSMENT REPORTS

Environmental noise assessment reports for the Rye Park Wind Farm were all to be prepared in accordance with NSW planning guidelines that reference the South Australian Wind Farm Guidelines (SA Guide), originally from 2003 and later from the 2009 version. The 2009 SA Guide relaxed rural noise limits compared to the 2003 version but NSW planning have retained the lower target noise limits as described in the NSW Planning and Environment's "Wind Energy: Noise Assessment Bulletin for State significant energy development", December 2016 (WENAB).

The SA Guide of 2009 was current during each of the noise assessment reports for the Rye Park Wind Farm. This SA Guide describes the approach that should be used when predicting noise from a proposed wind farm, as follows:

"It is recommended to use noise prediction methods in accordance with ISO9613−2 or CONCAWE.
A conservative approach should be used for predicting wind farm noise by calculating noise levels in octave bands from at least 63 to 4,000Hz to determine an overall predicted level and using the following inputs:

- atmospheric conditions at 10ºC and 80% humidity,
- weather category 6 (if CONCAWE method is utilised),
- hard ground (zero ground factor)."

The WENAB states that 'The Department and the EPA will assess the noise assessment report to determine whether it has been undertaken in accordance with the requirements of SA 2009 and this Bulletin, and whether the predicted noise levels comply with the applicable criteria.'

SLR CONSULTING NOISE PREDICTIONS

The noise predictions in SLR Consulting's report 640.01808-R1, August 2013, Revision 5 used the ISO9613-2 noise model with hard ground (G=0). The atmospheric conditions and receiver height used in the model were not described. The noise model used 1/3 octave band sound power data obtained from IEC61400-11 test reports. Two different IEC61400-11 test report results are presented in Appendix B of their report, one dated 16 August 2011 containing overall A-weighted sound power levels and another dated 28 June 2012 containing 1/3 octave sound power data.

Unfortunately, the overall A-weighted sound power from the earlier official Vestas approved test report is approximately 1.5 dB higher than the later test report from GL Garrad Hassan that shows the 1/3 octave band values.

Given that 1/3 octave band sound power data was used by SLR Consulting in their noise model it is most likely that an optimistic sound power level being approximately 1.5 dB lower than the specification data provided by Vestas was used. Furthermore, no IEC61400-11 test result uncertainty was applied to the sound power levels used in the noise model despite there being an uncertainty of 2dB shown in the GL Garrad Hassan test result.

It would be expected that the reported noise model results were 1.5 dB too low from reported test results and a further 2dB too low if IEC61400-11 test result uncertainty were to be applied.

The noise model did correctly use hard ground to determine ground absorption effects, as required in the SA Guide of 2009.

An estimate of the noise model uncertainty is given as +/- 3dB, although greater uncertainty is expected from ISO9613-2 beyond a 1 km prediction range.

Included in the SLR Consulting report is a section on Amplitude Modulation. This section (9.2.3) describes how Draft NSW Wind Farm Guidelines at that time were suggesting that an unacceptable amount of amplitude modulation is a peak to trough A-weighted sound level exceeding 4 dB. Below 4 dB the amplitude modulation would be considered to be a normal part of reasonable wind farm characteristics that are included in setting the target noise limits.

The current WENAB does not cover amplitude modulation.

SONUS NOISE PREDICTIONS

FEBRUARY 2016 REPORT

The Sonus noise model described in their February 2016 report SC3200C9 is the CONCAWE method.

Input parameters to the CONCAWE noise model include weather category 6 and atmospheric conditions at 10ºC and 80% humidity, as required by SA Guide 2009. However, a major departure from the SA Guide is the use of fully absorbent ground, rather than hard ground. The effect of this model input variation is significant with predicted results being too low by 6.6 dB for residence R38, for example.

The sound power data used in the February 2016 CONCAWE noise model match the Vestas IEC61400-11 test report data from 16 August 2011 (the higher of the two test report results shown in Appendix B of the SLR Consulting report).

No uncertainty account has been provided to the sound power levels used in the noise model and no estimate has been provided of the CONCAWE model uncertainty.

If an uncertainty correction had been applied to the sound power levels used and if the correct ground absorption had been used then the noise model would have shown non-compliance with the required target noise limits at multiple properties even with the suggested noise reduction modes available for the candidate Vestas V112 wind turbines.

In such circumstances, the development would not have been approved in the form proposed and may be the reason that a number of wind turbines were refused development consent.

MARCH 2020 REPORT

The Sonus noise model described in their March 2020 report SC3200C17 utilise the ISO9613-2 method.

Unlike their previous noise modelling in 2016 this noise model included an addition of 1.5 dB to the sound power test results for the candidate GE 158, 5.5MW wind turbine. Other departures from their previous noise model is the use of a receiver height of 4m and 50% ground absorption (G=0.5), which again, do not comply with the requirements of the SA Guide 2009.

In common with the SLR Consulting and previous Sonus noise assessment reports; this report suggests that if approval be granted that the final wind turbine selection and layout will be assessed prior to construction of the Rye Park Wind Farm. Unfortunately, the current Development Consent conditions are silent on this issue and do not require any further noise modelling or test result verification if another wind turbine is chosen or to verify if the sound power from the wind turbine batch being installed meet the sound power levels used in the noise model.

Sound Power Data

Input data to the ISO9613-2 noise model has been suggested for a candidate wind turbine. The sound power data for this particular wind turbine has presumably been included in the noise model from test report data. It would be useful if Sonus had referenced the test report used and noted the uncertainty that will be contained in that report.

Sound power levels for wind turbines are measured in accordance with IEC61400-11. Inaccuracies from IEC61400-11 measurements translate directly into uncertainties in model predictions.

The generally accepted uncertainty with the IEC61400-11 measurement is 2 dB for controlled conditions such as minimal inflow turbulence to the rotor. However, the Sonus report shows that a 1.5dB margin was used to account for uncertainties.

Sloth[1], a Vestas wind turbine manufacturer and installation employee and co-author of the Joule study, suggested that IEC61400-11 “is a fairly good tool for verification of warranties, but not a good tool for predicting noise at imission points where people actually can get annoyed”.

Sloth also suggests that if the ISO9613-2 noise model is used then hard terrain (G=0) should be used and that installed sound power results from measurements using IEC61400-11 should be corrected for actual inflow angles, actual air density, actual wind shear and actual turbulence intensity, each being known to influence the sound emission of a wind turbine.

Sound power test data for a wind turbine is measured having regard to minimising inflow turbulence to the rotor (turbulence intensity). Increased inflow turbulence will increase sound power and this effect is described in Annex C of IEC 61400-11 v2.1 as follows: “Turbulence is a natural part of the wind environment, and as it passes through the rotor disk, it causes unsteady pressures on the blades that radiate noise. Studies suggest that at high power levels or wind speeds, noise due to inflow turbulence can become the dominant source of aerodynamic noise emission from a wind turbine.” In a real wind farm turbulence is generated by each wind turbine. The location of each wind turbine and the spacing between them influence the amount of turbulence at a wind farm site (site effects).

The Basic Aspects for siting of Wind Farms is described in the following from Suzlon Energy:

[1] Erik Sloth, et al, Problems related to the use of the existing noise measurement standards when predicting noise from wind turbines and wind farms, AUSWEA Conference, 2004

Original sourced from http://www.wwindea.org/technology/ch02/en/2_4_1.html.

This reference is included in Appendix B and contains the following:

> "We have to distinguish between two different sources of turbulence. Turbulence is generated by terrain features – which is referred to as ambient turbulence intensity - as well as by neighbouring wind turbines – which referred to as induced turbulence (Figure 1). Sources of ambient turbulence are for example forests, hills, cliffs or thermal effects. Thus ambient turbulence can be reduced by avoiding critical terrain features. But the wake-induced turbulence has far more impact than the ambient turbulence intensity /2/.
>
> Decreasing the spacing increases the turbulence induced by the wakes of neighbouring wind turbines meaning that there are limits to how close you can space the turbines.
>
> As a general rule the distance between wind turbines in prevailing wind direction should be a minimum of the equivalent of five rotor diameters. The spacing inside a row perpendicular to the main wind direction should be a minimum of three rotor diameters."

The larger rotor diameter of 158m for the new wind turbine translates to a minimum spacing recommendation of 790m. The average spacing between an adjacent wind turbine in the current wind farm layout is 459m. 85% of the wind turbines in the proposed modification will have adjacent spacing to another turbine less than 510m apart. The larger 158m diameter rotor proposed will contravene the minimum spacing of turbines suggested by Suzlon Energy which has extensive experience in wind farm design.

Wake turbulence will be a significant site effect that will increase sound power values compared to those reported in IEC61400-11 tests. Accordingly, the sound power data used for the Sonus report is overly optimistic.

I have long held the view that "A number of variables such as: turbulence, wind shear, inflow angle and air density may differ at an installed site compared to the idealised sound power measurement results obtained using IEC 61400-11. These effects can alter the sound power level of a WTG and should be considered in the noise model." This extract is from a peer reviewed paper I presented at the joint Australian and New Zealand Acoustics 2006 conference titled "Review of the application of NZS6808 to wind farms in Australia".

A paper recently published by the Institute of Physics[2] quantifies the effect on time-averaged sound pressure levels, for a typical 2.75 MW single wind turbine having an 80 m rotor diameter, by changing wind shear and inflow turbulence [turbulence intensity (TI)]. The results show that for both upwind and downwind sound propagation the sound pressure level at 700m for a TI of 3% and 10% produced a difference of between 8dB and 9dB (increase from 3% to 10% TI increases the sound level up to 9 dB). The increase in sound pressure level from 0% TI to 10% TI is greater at 11dB to 12 dB. The paper states in the conclusion: *"First of all, higher ambient turbulence intensity results in increased sound source power levels, particularly at the low frequency content (31.5 Hz - 300 Hz). This directly affects the far field noise (up to 2500 m), as the atmospheric absorption is negligible for this frequency range. To the authors' knowledge none of the noise mapping tools take into account the increased source levels due to ambient or wake induced turbulence. Neither the standards demand turbulence dependent noise curves. We believe that this can be one of the reasons for inaccurate far field noise predictions."*

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[2] Barlas, E. Zhu, W. J. Shen, W. Z. Andersen, S. J. "Wind Turbine Noise Propagation Modelling: An Unsteady Approach" Journal of Physics: Conference Series 753 (2016) 022003 (TORQUE 2016)
Available at: *iopscience.iop.org/article/10.1088/1742-6596/753/2/022003/pdf*

Another consequence in increasing the size of the Rye Park wind turbines is that the wind shear across the rotor will increase. The second point from the conclusions in the IoP paper[2] is: "*Second of all, it is observed that under low incoming turbulence the wind shear has significant effect on downwind propagation*" and that: "*Further investigation of the SPL modulation due to wake deficit showed that particularly the low incoming turbulence levels (0 % and 3 %) result in increased spectral energy of the low acoustic frequency content over wide spread propagation distances. This can lead to beating noise at far field*."

Beating noise is a form of amplitude modulation that will be discussed below.

The ISO9613-2 noise propagation model has proven to be an acceptable noise model if it is used within its design constraints. Acoustic consultants working for wind farm developers invariably use a single source for each turbine located at hub height (sometimes the sound source is located at maximum rotor height). Unfortunately, wind turbines are complex sound sources that do not readily conform to the stated limitations of ISO9613-2. For example, a wind turbine emits sound for each blade, approximately 85% from the hub towards the tip, in a cyclic manner forming an arc and there are wake and turbulence effects that influence sound propagation.

There are effectively three rotating sound sources for each wind turbine and standard propagation models such as ISO9613.2 are generally applied for wind farms using a single point source per turbine without inclusion of a directivity correction term that is available in the ISO9613-2 method.

Wind turbine manufacturers are knowledgeable about the effects of wake induced and site affected inflow turbulence on the sound emissions and performance of their wind turbines, not least because such turbulence can increase equipment fatigue. It is customary to first request the minimum turbine spacing that the manufacturer is willing to provide a guarantee for, in terms of power output and sound emissions. In this instance, the turbine locations are fixed in the current permit so a written comment on the suitability of the suggested candidate wind turbines could be provided by the manufacturer of any final wind turbine choice in respect of guarantees.

It should be noted that a wind turbine of a given name such as a GE158 5.5MW can have many variants and can have different electronic controls, blades or gearboxes fitted that can influence sound power output.

The inclusion of independent tests on any chosen wind turbine could be included in consent conditions, which is now common practice in Victoria, for example.

Ground Absorption and Receiver Height

The Sonus report references good practice guidelines from the UK for a justification to use G=0.5. Given the climate in the UK, it may be reasonable to use a 50/50 mixed ground terrain value of G=0.5 for an ISO9613 noise model in the UK to compare with ETSU[3]. However, in South Australia and New South Wales this model input parameter is not considered appropriate. For example, the SA Guide 2009 referenced by the NSW EPA require wind farm noise models to use G=0 if CONCAWE or ISO9613 is used.

[3] Energy Technology Support Unit Working Group on Noise from Wind Farms. ETSU-R-97: The Assessment and Rating of Noise from Wind Farms. UK Department of Trade and Industry. 1996

The ISO9613-2 noise model will predict typically 4 dB extra noise at imission points around the Project site if G=0 is used in the noise model using a receiver height of 1.5m instead of the G=0.5 value used in the Sonus report of March 2020. Any noise compliance checks will also use a measurement height of 1.5m rather than at the suggested prediction elevation of 4m.

Changing the prediction or compliance measurement height to 4m will also make previous Background noise measurements that were taken at 1.5m height invalid.

The implications of these adjustments to the noise model in the Sonus report are significant when compliance margin levels under curtailed mode of 0dB are predicted for four dwellings in Table 6 of their report.

The predicted sound levels at the dwellings requiring noise agreements with the project developers will also be higher and may not comply with the agreement noise targets. For example, Table 3 in the Sonus report shows a compliance margin of only 1 dB for Associated Residence R02.

Amplitude Modulation

The World Health Organisation released their revised Environmental Noise Guidelines[4] in 2018 which included reference to wind farm noise. Page 85 from this guideline describes the known characteristics of wind turbine noise:

> "The noise emitted from wind turbines has other characteristics, including the repetitive nature of the sound of the rotating blades and atmospheric influence leading to a variability of amplitude modulation, which can be a source of above average annoyance (Schäffer et al., 2016). This differentiates it from noise from other sources and has not always been properly characterized. Standard methods of measuring sound, most commonly including A-weighting, may not capture the low-frequency sound and amplitude modulation characteristic of wind turbine noise (Council of Canadian Academies, 2015)."

The Draft NSW Planning Guidelines – Wind Farms, December 2011 was a consultation document that considered adverse noise impacts from amplitude modulation. Penalties for undue amplitude modulation were formulated in the New Zealand Standard 6808:2010 that is currently used to assess wind farms in Victoria. The current WENAB includes a section on 'Special noise characteristics' that narrowly considers only tonality and fails to mention amplitude modulation.

With the advent of ever increasing wind turbine size it has been recognised that amplitude modulation and beating at distances in the far field can cause a significant adverse noise impact.

A protection mechanism for residents surrounding a wind farm that addresses potential amplitude modulation was coined in the UK for the Den Brook Wind Farm. The limits for amplitude modulation were included in the Planning Approval noise conditions for this wind farm. Subsequently, after many appeals against the noise conditions by the wind farm developers, the matter was decided in the High Court.

The three Lord Justices agreed in the Approved Judgment[5] that the condition specifying the quantum of AM (Condition 20) is a requirement correctly imposed that must be adhered to.

4 World Health Organization. Environmental Noise Guidelines for the European Region; WHO Regional Office for Europe: Copenhagen, Denmark, 2018.
5 *Hulme v Sec State for Comms and Local Govt & Ors* [2011] EWCA Civ 638

Furthermore, the method proposed by the developer and accepted by the local council to meet Condition 20 requirements was deemed to be unfit since it conflated the AM assessment with the ETSU analysis process.

It was deemed inappropriate to treat AM as a penalty in the same way that tonality was considered in ETSU (a procedure to apply a penalty similar to that used in the SA Guide 2009). The AM conditions were to stand alone irrespective of noise conditions relating to ETSU recommended limits[6]. NZS6808:2010 also allows for the independent assessment of amplitude modulation nuisance through application of the NZ Resource Management Act.

Condition 20 is complaint driven and is a simple time series analysis method described as follows:

> At the request of the local planning authority following the receipt of a complaint the wind farm operator shall, at its expense, employ a consultant approved by the local planning authority, to assess whether noise immissions at the complainant's dwelling are characterised by greater than expected amplitude modulation. Amplitude modulation is the modulation of the level of broadband noise emitted by a turbine at blade passing frequency. These will be deemed greater than expected if the following characteristics apply:
>
> > a) A change in the measured LAeq, 125 milliseconds turbine noise level of more than 3 dB (represented as a rise and fall in sound energy levels each of more than 3 dB) occurring within a 2 second period.
> > b) The change identified in (a) above shall not occur less than 5 times in any one minute period provided the LAeq, 1 minute turbine sound energy level for that minute is not below 28 dB.
> > c) The changes identified in (a) and (b) above shall not occur for fewer than 6 minutes in any hour.
>
> Noise immissions at the complainant's dwelling shall be measured not further than 35m from the relevant building, and not closer than within 3.5m of any reflective building or surface, or within 1.2m of the ground.

The Local Council subsequently approved the use of LAeq, 100 milliseconds in lieu of LAeq, 125 milliseconds and this is the parameter used in the Institute of Acoustics Preferred Method[7] for quantifying amplitude modulation. Unlike Condition 20 described above, the IoA Preferred Method does not set a compliance target for their derived metric.

Ancillary Equipment

Different wind turbine designs are available where the switch gear and hydraulic equipment can be housed within the tower or external in a separate enclosure.

An energised wind turbine waiting for sufficient wind to 'cut-in' will have equipment operating yaw drives, transformers and fans and this equipment does not get masked by changes in wind speed below cut-in. The SA Guide wind turbine assessment methodology is only applicable to the operating wind turbine in which case ancillary operating equipment could fall within the sound power testing described in IEC61400-11. However, below cut-in it would be appropriate to assess noise emissions from ancillary equipment housed internally and/or externally to the tower using standard NSW EPA industrial noise guidelines, rather than use the SA Guide 2009.

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[6] *Hulme v Sec State for Comms and Local Govt & Ors* [2011] EWCA Civ 638 [38] (Lord Justice Elias)

[7] Institute of Acoustics Amplitude Modulation Working Group. (2016). AMWG Final report. Available from: http://www.ioa.org.uk/sites/default/files/AMWG 20Final 20Report-09-08-2016_1.pdf

REVIEW CONCLUSIONS

Construction noise impacts have been assessed with tables of predicted construction noise levels being listed in Table 8 of the Sonus report of March 2020. However, it is difficult to review these predictions when sound source locations, sound power levels and noise model have not been described.

The noise impact assessment for the selection of a Preferred Transport Route has not been considered.

It should be confirmed that the location of the substations and batching plants remain unaltered.

This review has shown deficiencies in the method used to predict wind farm operational noise levels. The predicted wind farm noise levels from the candidate wind turbine are shown to be at least 4 dB too low.

If the noise model is corrected and re-run it should be possible to identify additional wind turbines that need to be removed from the proposal to ensure that the project meets the extant development consent noise limits.

Uncertainty over potential acoustic amplitude modulation / beating adverse impacts can be addressed by issuing a noise condition similar to the one described for the Den Brook Wind Farm (Condition 20).

It has been noted that the extant conditions do not require any new noise modelling or testing on site for any wind turbine that differs from the proposed candidate. This can be corrected with a new noise condition requiring confirmation of sound power levels for any new, or even the candidate, wind turbine that is tested on site prior to construction of the whole project.

The test turbine(s) can be constructed in locations remote from sensitive locations to ensure that there will be no adverse noise impact if the sound power results prove to be higher than expected. This new condition will also allow the Developer to submit a noise reduction strategy for approval prior to completing full project construction.

APPENDIX A

CURRICULUM VITAE

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QUALIFICATIONS

BSc (Hons) Applied Physics, UK 1975

MSc Noise and Vibration Studies, Institute of Sound and Vibration Research, Southampton, UK 1977

PROFESSIONAL AFFILIATIONS

Chartered Physicist, UK

Member of the Institute of Physics, UK

Member of the Institute of Acoustics, UK

Member of the Australian Acoustical Society

Member of the Environment Institute of Australia and New Zealand

Member of the AV003 and AV004 acoustics working groups for Standards Australia

Australian representative for the International Institute of Noise Control Engineers (I-INCE) Technical Study Group 5 A GLOBALAPPROACH TO NOISE CONTROL POLICY (Now disbanded after completion of the scope of work defining this group – see http://www.i-ince.org/data/iince061.pdf)

My company, L Huson & Associates Pty Ltd, is a member firm of the Association of Australian Acoustical Consultants and the Association of Noise Consultants (UK)

EXPERIENCE

Since graduating I have been involved in a number of scientific areas of research and development. My early experience was in constructing a microwave device to measure the temperature of plasma inside a nuclear fusion experimentation device at the UKAEA, Culham Laboratory in the UK. I then worked in research and development of thermal imaging devices prior to completing my Masters in Sound and Vibration Studies. My work since then (1977) has been primarily associated with acoustics and vibration both terrestrial and underwater.

For the past 30 years I have worked in Australia as a noise and vibration consultant and have operated through my own consultancy firm for the past 24 years. I am experienced in modelling acoustic propagation from a variety of sources such as railways, roads, aircraft, underwater ordnance, pile driving, blasting and numerous types of industry.

Of particular relevance to the evidence provided here is the work I completed for the Toora Wind Farm which involved detailed analysis of pre and post construction noise data using NZS6808 1998 to check compliance with license conditions. My experiences in the analysis of wind farm noise data led to a paper that was presented at the joint Australia and New Zealand Acoustics conference in 2006 titled "Review of the Application of NZS6808 to wind farms in Australia." This paper highlighted the sources of error that were implicit and allowed in the NZS6808, 1998 standard. The latest version of the NZS6808 standard (2010) addresses a number, but not all, of the data analysis error concerns described in my paper. Over the past eight years I have been independently gathering sound data in the audible and infrasound parts of the acoustic spectrum at numerous wind farms in Australia, the UK and Ireland. A summary of some of this research work on infrasound was presented in a peer reviewed paper: Huson, W. Les."Stationary wind turbine infrasound emissions and propagation loss measurements." 6th International Conference on Wind Turbine Noise, Glasgow 20-23 April 2015.

APPENDIX B

Siting of Wind Farms: Basic Aspects

When searching the internet for the definition of the word “layout” I came across following:

Layout in word processing and desktop publishing refers to the arrangement of text and graphics. The layout of a document can determine which points are emphasised and whether the document is aesthetically pleasing. While no computer program can substitute for a professional layout artist, a powerful desktop publishing tool can make it easier to lay out professional looking documents (source: www.webopedia.com)

In principle the same is valid for wind farm planning: The term layout in wind industry is used for choosing optimal locations for wind turbines. Tools like flow models help to identify the best positions, but cannot replace the engineer making the final decision by balancing interests.

So what is that engineering experience, what factors influence the decision?

Jessica Rautenstrauch, wind energy consultant from Anemos, Germany, at work.
© Paul Langrock (www.unendlich-viel-energie.de)

Wind resource

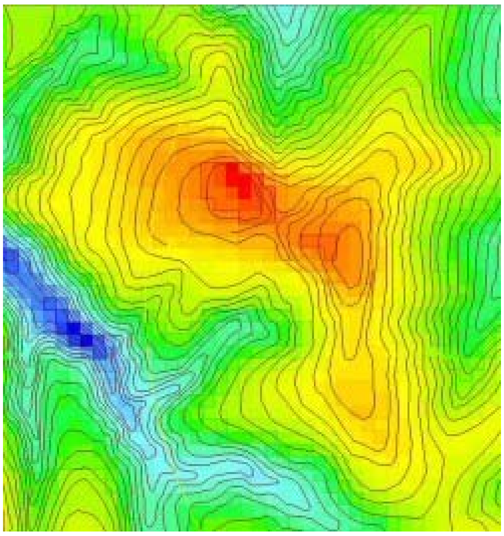
The wind resource is the most obvious factor to concentrate on when choosing a wind turbine location. We have a wide range of options to determine the wind resource of the site. The quality of the tools varies significantly and so does their price.

Common sense is a good starting point. Nature itself helps to guide us to suitable sites. Flagging of trees – permanent flagging and not the temporary bending in the wind – shows us the prevailing wind direction and is a good indicator for the strength of the wind.

However because of the uncertainty involved, using common sense as the only tool is of course insufficient. For any bankable estimate of the energy yield on-site wind speed measurements are required. The number of measurement masts required for a specific site depends next to the size of the project mainly on the complexity of the terrain. The measurement height should be minimum 2/3 of the expected future hub height. An increase in measurement height beyond this leads to a reduction of the uncertainty in the energy estimate. The measurement period must be one year or more to avoid any seasonal bias. Since the wind speed varies also inter-annually typically up to +/-12% a long-term correction is highly recommended.

The measured wind regime is extrapolated across the site to derive a resource map of the site using different flow models /4, 5/. A wind map like the one in Graph 1 can then be used to identify the windiest locations.

However additionally technical constraints should be taken into account when developing a layout /3/. A number of site specific wind load parameters can be extracted from the wind speed measurement. They are used to optimize the technical suitability of the chosen layout and the wind turbine type for the site specific wind regime.



Graph 1: Example Wind Resource Map. The colours denote the energy content of the wind, red high and blue low energy content.

Technical restrictions

Wind turbines are designed for specific conditions. During the construction and design phase assumptions are made about the wind climate that the wind turbines will be exposed to. In rough terms: For very complex sites with high wind speeds "heavy-duty" versions of wind turbines are available, which are sturdier but also more costly. Low wind speed sites in flat terrain do not put so high demands on the on the wind turbine structure, hence the construction can be more light-weight and hence cheaper. The different turbines have been classified by the IEC, class 1 being the highest wind speed class. The following table is a simplified summary of the IEC classification /1/.

IEC class	I	II	III	IV
V_{ave} (m/s) annual average wind speed at hub height	10	8.5	7.5	5
V_{ref} (m/s) 50-year maximum 10-minute wind speed	50	42.5	37.5	30

Table 1: IEC classes

But not only the wind speed but also other parameters play a role and have to be checked, when developing a layout for a specific turbine.

One of the most important parameters is the turbulence intensity. Turbulence intensity quantifies how much the wind varies typically within 10 minutes. Because the fatigue loads of a number of major components in a wind turbine are mainly caused by turbulence, the knowledge of how turbulent a site is of crucial importance.

We have to distinguish between two different sources of turbulence. Turbulence is generated by terrain features – which is referred to as ambient turbulence intensity - as well as by neighbouring wind turbines – which referred to as induced turbulence (Figure 1). Sources of ambient turbulence are for example forests, hills, cliffs or thermal effects. Thus ambient turbulence can be reduced by avoiding critical terrain features. But the wake-induced turbulence has far more impact than the ambient turbulence intensity /2/. Decreasing the spacing increases the turbulence induced by the wakes of neighbouring wind turbines meaning that there are limits to how close you can space the turbines. As a general rule the distance between wind turbines in prevailing wind direction should be a minimum of the equivalent of five rotor diameters. The spacing inside a row perpendicular to the main wind direction should be a minimum of three rotor diameters.

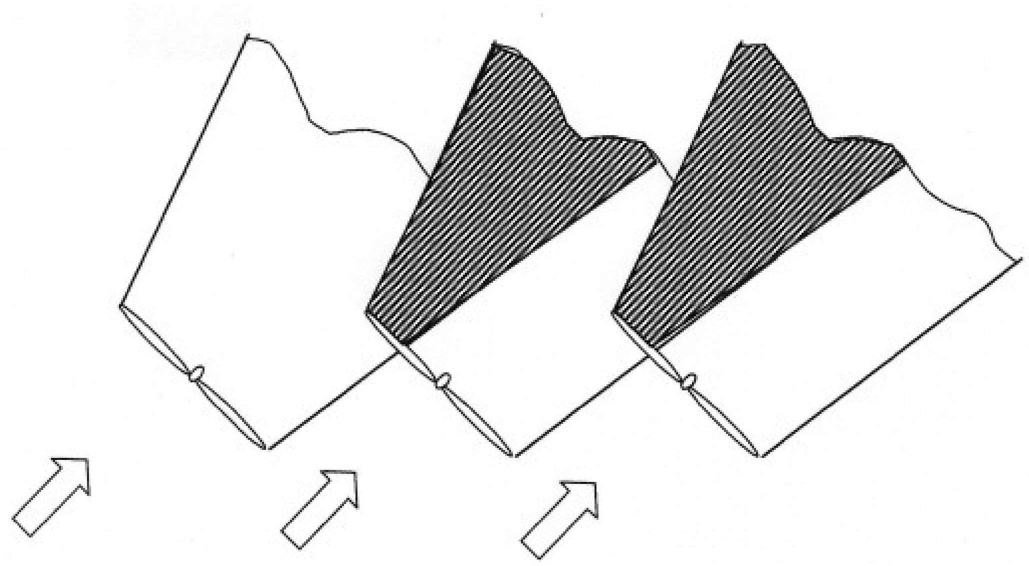


Figure 1: Shadowing in wind farm

If a layout is too close the resulting fatigue loads might be too high. In order to then ensure the lifetime of the main components wind sector management might have to be applied, meaning that some wind turbines might have to be switched off when they are operating in the wake of the neighbouring wind turbine.

Another parameter which has to be checked when developing a layout is the flow inclination, velocity tilt or in-flow angle. When wind turbines are to be placed on steep slopes or cliffs the wind might hit the rotor not perpendicular but at an angle. This angle is related to the terrain slope. With increasing height above ground level the effect of the terrain slope is normally reduced such that the terrain slope is only of indicative use to estimate the velocity tilt. A large in-flow angle will not only reduce the energy production but will also lead to an increased level of fatigue of some of the mayor components.

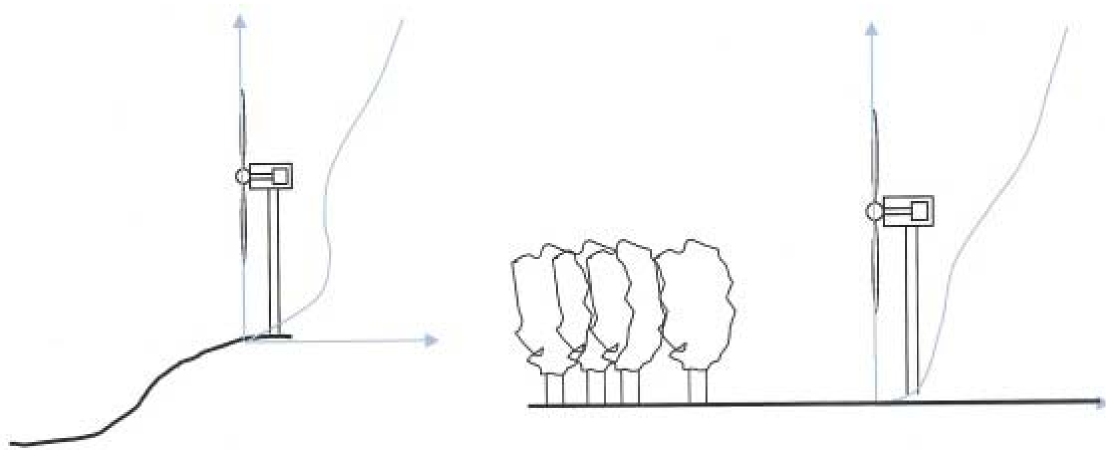


Figure 2: Distorted wind profile at steep slope (left) and behind a forest (right)

Furthermore a steep slope might cause a negative gradient across some parts of the rotor (Figure 2).

Normally the wind speed increases with increasing height. In flat terrain the wind speed increases logarithmically with height. In complex terrain the wind profile is not a simple increase and additionally a separation of the flow might occur, leading to heavily increased turbulence. The resulting wind speed gradients across the rotor lead to high fatigue loads particularly on the yaw system.

Obstacles like forest can have a similar effect on the wind profile and should be thus avoided.

Planning constraints

Next to the wind resource and technical considerations a good layout should also take planning constraints into account. The visual impact is course the most obvious. A layout that follows the shape of the terrain rather than straight rows of wind turbines appears to be less intrusive. Noise is another important parameter to take into account. Next to noise also the impact due to flicker at the nearest inhabited houses should be estimated. The accepted levels vary from country to country.

Electro-magnetic interference can cause problems. Hence placing wind turbines in a transmission corridor should be avoided.

Some areas on site might have to be excluded from development due to other factors related to fauna, flora and archaeology.

Jessica Rautenstrauch, wind energy consultant from Anemos, Germany, at work.
© Paul Langrock (www.unendlich-viel-energie.de)

Summary

A large number of parameters have to be taken into account when developing a layout. Some work can be done using tools, but in the end the balance between financial, technical and planning constraints can be best done by an experiences engineer.

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