VISUAL IMPACT ASSESSMENT OF WIND FARMS IN SOUTH AUSTRALIA

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ABSTRACT

The paper presents the results of a study of the visual effects of wind farms in South Australia. As a green industry and given community concern about their effect on perceived scenic quality, the wind energy industry has particular responsibility to locate wind farms sensitively in respect of scenic quality.

The paper briefly examines reactions to wind farms internationally and in Australia.

Photographs of proposed and potential wind farm sites were used in the study and participants shown each scene in random order, once with and once without a wind farm. The perceived scenic quality of each scene was rated on a 1 (low) to 10 (high) scale.

Wind farms had greatest negative effect on landscapes perceived as highly scenic and progressively less effect on landscapes rated as lower in scenic quality where wind farms actually enhanced scenic quality.

Tables indicate the likely visual effect of wind farms on coastal and inland landscapes of known scenic quality.

Distance to the wind farm did not appreciably reduce their visual effect. Varying the number of turbines indicated no clear trend. Colour of turbines slightly affected perceived scenic quality. Further research of these factors will be necessary.

Wind farms should avoid areas of high perceived scenic quality, particularly on the coast and be located in areas of low to moderate scenic quality.

1. INTRODUCTION

Wind farms have been rapidly established in Australia over recent years. A key community concern has been their effect on perceived scenic quality. This paper addresses people’s perceptions of the scenic quality of selected South Australian landscapes and the effects of wind farms on that perceived scenic quality.

The paper reviews briefly the reaction to wind farms overseas and in Australia. It describes the design, conduct and results of a survey to measure their visual effect. Finally, the application of the results to the development and planning of wind farms is discussed.

2. CONTEXT

2.1 International reactions to wind farms

The rapid growth of global wind generating capacity to 59,000 MW at the end of 2005 (WWEA, 2006) has been accompanied by a massive increase in the size of turbines, and hence the visual impact they have on the landscape (Pasqualetti *et al*, 2002). Typical turbines in 1990 stood 65 m high (hub height and rotor) but ten years later in 2000 were over twice that height - 135 m high (World Wind Energy Association, 2003). A 135 m turbine with a rated power of 1.5 MW has fifty times the output of a 1980 turbine of 45 m height. With the greater scale, their visual impact has grown accordingly.

Wind farms can present a range of effects: noise, blade glint, bird strike, soil erosion, however these can generally be mitigated. Due to the turbine size, visual intrusion is not so easily addressed (Thayer and Hansen, 1988).

Surveys in Canada, the Netherlands, United Kingdom and Denmark indicate that the community support higher priority being given to wind power (Krohn and Damborg, 1999).

The United Kingdom experience is particularly interesting given the English love of their countryside:

> More than their poets, their art, or their architecture, the English love their landscape, and woe betide any who would threaten it. This protectionist attitude has brought wind development in England nearly to a standstill. (Short, 2002)

The Economist (1994) described wind farms as a 'new way to rape the countryside' and Sir Bernard Ingham described a wind farm in Yorkshire as 'lavatory brushes in the air' (Pasqualetti, 2001). Ann West, vice Chair of Country Guardian, has described them as "industrial-size blots on the landscape" (West, 2004).

Between 1993 and 1998, 16 out of the 18 planning applications for wind farms in Wales failed because of local objectors (Garman, 2004). Short (2002) noted that only one in four of wind farm applications had been approved in the UK, such was the success of organized opponents.

Although there has been a move to offshore wind farms in the UK, partly to avoid local opposition, these also have not been immune to criticism. For example, a proposed 30 turbine project at Scarweather Sands near Port Talbot was opposed by a petition of 8,000 signatures.

Despite many proposals failing to win approval, the general UK community has been supportive. During the 1990s, many surveys of residents near wind farms and of tourists to the area were held in the UK and these provide the most extensive resource of community attitudes available. Table 1 summarises these surveys following construction of wind farms (excluding surveys held at open days).

By far the majority of participants in these surveys indicated support for the wind farms – none indicated a strongly negative view.

Table 1 Summary of Findings from UK Wind Farm Community Attitude Surveys

Location	Positive	Neutral	Negative	Source
Resident Surveys – post construction of wind farm				
Delabole, Cornwall ~300 interviewed	81% turbines made no difference	3% neutral	16% turbines made some difference	Exeter Enterprises, 1994
Cemmaes, Wales ~ 130 interviewed	92% not bothered by visual impact 86% in favour of wind farm 53% supported more wind farms in area		7% concerned about visual impact	Market Research Assoc., 1994
3 wind farms in Wales ~270 interviewed	63% in favour of wind farm		37% oppose	BBC Wales, 1994
Kirkby Moore ~250 interviewed	82% supported development of wind farms in area	61% not concerned about wind farm	10% opposed wind farm development	Robertson Bell Assoc. 1994
Coal Clough, Lancashire 50 interviewed	80% positive about wind farm	16% uncertain	4% against wind farm	Anon. 1996
Taff Ely, Wales ~400 intereviewed	63% support wind farm 29% - "scenery more interesting"	32% neutral 51% "its all right"	4% oppose wind farm 17%- "spoil scenery"	Robertson Bell Assoc. 1997
Novar, Scotland ~200 interviewed	68% support wind farm 11% - "scenery more interesting"	29% neutral	3% oppose wind farm	Robertson Bell Assoc. 1998a

			12% - "spoil scenery"	
Stroud, Gloucestershire ~400 interviewed	67% support wind farm 70% support more turbines 43% - "scenery more interesting"	30% - "hardly noticeable"	7% oppose wind farm; 16% oppose more turbines 17% "spoil scenery"	Robertson Bell Assoc. 1998b
Lambigg, Cumbria ~230 interviewed	74% support wind farm 24% - "scenery more interesting"	18% no opinion	8% opposed wind farm 26% "spoil scenery"	Robertson Bell Assoc. 2002
4 wind farms in Scotland 430 interviewed	67% favour wind farms 74% - nothing disliked about wind farms 21% liked appearance		10% "spoils view" 11% nothing liked	Dudleston, 2000
10 wind farms in Scotland ~1800 interviews	20% - wind farms have positive impact on area	51% neither positive or negative impact 23% not opinion	7% negative impact on area	Braunholtz, 2003
Tourist surveys				
Argyll & Bute, Scotland, ~310 interviews	43% - wind farm has positive effect	43% equally positive & negative, 6% don't know	8% wind farm has negative effect	MORI Scotland, 2002
Scotland, 1800 interviews	75% positive about wind farms 63% - wind farms make no difference to visiting area		21% negative about wind farms 25% would avoid area	NFO System Three, 2002

The British Wind Energy Association (BWEA) monitors opposition to wind farms including letters to the press. Hill (2001) traced the results of 27 UK opinion polls on attitudes to wind energy from 1990 to 2001. She found an average of 74% support. Hill also examined the content of press articles, features and letters to the press for 1996 and 2001 and found that articles and features became far more positive over this period while the majority of negative coverage derived from letter pages. However over this period, supportive letters had increased and the proportion of negative letters decreased from 60% to 50%. Widespread support by the majority has often been rendered mute by vociferous opposition by a minority, often not from the affected area. The BWEA website includes the results from 11 surveys.

In 1991 the German Parliament passed the Electricity Feed Law which guaranteed payment of 90% of the retail price of electricity and wind farms proliferated (Schwahn, 2002). Renewable energy was further reinforced by the Renewable Energies Law in 2000. Wind farms were seen as "government-sponsored money-making machines" (ibid). In Germany where half the operators of wind farms are farmers, local residents were generally supportive. Community attitudes towards wind farms were influenced more by the decision making process and the players involved than by the size of the project (Erp, 1997).

However landscape publications in Germany described the destruction of scenic beauty as a "catastrophe" and "the beauty of our landscape is in danger". (Hoppe-Kilpper & Steinhäuser, 2002) The German Association for Landscape Protection (BLS) generally opposed wind farms.

In Sweden, communal ownership was recognized as the key to support and many farmers viewed wind farms as contributing to their livelihood. Hammarlund (2002) believed that the "development of a wind power site is out of the question if it has not been socially anchored in the local society".

With Denmark's flat landscape, so flat the "wind's strength hardly diminishes between the North Sea and the Baltic Sea" (Nielsen, 2002), its 6000 wind turbines are particularly conspicuous. Their scale "often exceeds all other elements in the landscape" (ibid). As in Germany and Sweden, there is a tradition of community ownership of wind farms in Denmark with wind farm cooperatives being funded by several hundred small investors. Among residents at Sydthy in northern Denmark, Anderson *et al* (1997) found that people with shares in wind farms were significantly more positive about wind power than those without an economic interest. They found that residents near to the wind turbines did not consider their visual impact significant. Supporting Hammarlund's view about community support, Nielsen believed that the removal of Denmark's wind farms would result in a public outcry.

During the 1990s, Danish power companies sought to build larger wind farms comprising 20 to 50 turbines rather than the usual arrays of three to five turbines but met strong local resistance and were abandoned. These companies are now turning to offshore arrays which involve fewer private interests (Nielsen, 2002).

From these surveys the following conclusions are drawn:

- Economic participation in wind farms ameliorates adverse reactions to wind farms. As noted by Thayer and Hansen (1988) with reference to Cordelia Village in California which opposed a wind farm: "the residents … could make little symbolic or real connection between their own electricity demand and the energy to be produced by the proposed wind farm. Had they possessed even a degree of symbolic ownership or investment in the turbines, the entire visual meaning of the landscape might have changed, and the outcome might have been different." Thayer and Hansen suggest enfranchising their "visual consumers", involving them in the wind farm development and compensating them for scenic "damage".

- While the majority of the local and wider communities are generally supportive and positive about wind farms, there is usually a vocal minority with legitimate concerns about the industrialisation of rural and natural landscapes and whether the energy significance of wind farms compensates for their visual impacts. This minority may include local land owners but more often appears to be drawn from the wider community of people who have a close attachment to the countryside. Wind energy developers ignore their concerns at their peril as opponents are generally well organized, well networked and effective in advocating their view;

- High standards of wind farm design, layout and operation are essential, aiming 'to minimize the conspicuousness of wind turbines' (Gipe, 2002).

2.2 Wind Energy in Australia

The rapid growth of wind farms in Australia in recent years has been stimulated by the Commonwealth Government's Mandatory Energy Renewable Target (MRET). The target aims to increase Australia's renewably generated electricity by 2%, from 10.5% to 12.5%, by 2010 (Prime Minister, 1997). Most of the existing renewable is hydro generated. The target has been defined as a further 9,500 gigawatt hours of electricity from renewable sources, which is sufficient power for the households of four million people. MRET applied from April 2001.

By Nov, 2006, 817 MW of wind farms had been installed and, according to the Australian Wind Energy Association (AusWEA), a further 5962 MW proposed (AusWEA, 2006). If each turbine was rated at 1.5 MW, these would total an additional 4000 turbines.

The MRET Review Panel (2003) recommended the target be increased to 20,000 GWh by 2020. However the Howard Government's energy statement of June 2004 countered that the costs of such an increase ($5 billion NPV) could not be justified (Prime Minister, 2004). Instead, the Government provided funds for the development of low emission technologies and for improved wind forecasting which "could allow wind (sic) to locate in a wider range of sites away from sensitive landscapes."

2.3 Australian Reactions to Wind Farms

Victoria has witnessed the strongest opposition to new wind farms. In 1997, 95 wind turbines were proposed on the coast near Portland, an area identified by the Victorian Coastal Council as of 'outstanding scenic quality requiring special landscape protection' (VCC, 1998). On appeal, the proposal was rejected on grounds that the wind farm would have a "disturbing visual impact on the significant landscape values of the Cape" (VCAT, 1999).

Subsequently Pacific Hydro proposed a four cluster, 120 turbine wind farm near Portland and at Yambuk. The Planning Panel appointed to report on the project recommended qualified approval of the proposal with amendments (PPV, 2002) and the Planning Minister approved it with modifications.

A number of groups campaigned actively against Portland and other wind farm proposals in Victoria. Coastal Guardians Victoria was formed as an umbrella group representing wind farm opponents. The National Trust (Victoria) called for a State-wide assessment of landscapes (2002). In August 2002, the Victorian Government released new policy and planning guidelines for wind farms (SEAV, 2003).

On 27 July, 2003, the Australian Council of National Trusts and the Australian Wind Energy Association (AusWEA) announced an agreement to work together on a joint *Wind Farms and Landscape Values Project* to ensure landscape protection during the growth of the wind industry (AusWEA/ACNT, 2003). The objective of the agreement was to "determine and promote an agreed upon means for assessing landscape values in order to ensure that the planning and siting of wind energy developments can proceed, and that significant landscapes can be identified." Planisphere, consultants engaged by AusWEA and the ACNT, prepared and released a series of discussion papers (AusWEA/ACNT, 2004) and in June 2005 following lengthy forums around Australia, released their stage one report (Campbell, 2005):.

The media release accompanying the release of the report stated:

> The central finding of the Report is that, although there is this large body of methods and guidelines relating to landscape assessment, none of these assessment methodologies have yet been universally adopted, resulting in confusion and uncertainty about best practice in the community.
>
> "Landscape values are already an essential consideration for any wind farm development and ensuring that the methodologies to assess these values are standardized across the country is an increasing priority for the wind energy industry," said Ian Lloyd-Besson, President of AusWEA.

To date the project has not advanced to the next stage of methodological development pending funding.

The research described in this paper provides a means of determining community landscape values.

3. STUDY DESIGN

3.1 Objectives

The study examined the effects of wind farms on selected landscapes in South Australia. Specifically the objectives of the study were to:

- Assess, using community preferences, the likely visual effect of wind farms in a range of South Australian landscapes;
- Develop the means to predict the likely visual effect of wind farms;
- Assess the influence of distance, number of turbines and colour of turbines on the visual effects;
- Develop guidelines for wind farm development based on the findings.

3.2 Methodology

The methodology measured differences in ratings of the perceived scenic quality of a scene with and without a wind farm indicating whether it had a positive or negative influence (Hull and Bishop, 1988). Landscape quality could be enhanced by the presence of a wind farm, or it could detract from landscape quality.

Photographs rather than field assessment of scenic quality were used. Studies have shown that colour photographs can give similar ratings as field studies (Brown *et al*, 1988; Dunn, 1976; Kellomaki

& Savolainen, 1984; Shuttleworth, 1980; Stewart *et al,* 1984; Trent *et al,* 1987; Zube *et al,* 1975) provided the photographs met the following criteria:

- The photographs were in colour;
- A sufficient number of photographs covered the area and range of features;
- The photographs were in standardised format (i.e. horizontal), non-artistic composition, provided good lateral & foreground context to scenes, covered a single landscape unit and showed typical representative scenes.

The use of photographs as surrogates offered obvious advantages over transporting a large group of people around South Australia to rate scenes. Photographs enabled widely separated locations and scenes separated by time to be rated on a comparable basis. Photographs were particularly appropriate to the needs of this study to evaluate hypothetical alterations to the landscape such as those posed by wind farms.

A 10 point rating scale was used (1 – very low, 10 – very high) and over 300 adult participants who were broadly representative of the community.

4. STUDY IMPLEMENTATION

4.1 Photographs

AusWEA's (2002) *Best Practice Guidelines* identified the following "five crucial technical criteria for successful development" for wind farms.

- Potential wind resource
- Potential size of site
- Electrical connection
- Land ownership and current usage
- Construction issues

Of these, the first two factors were the main considerations in the selection of potential sites. Scenes were selected to represent both the proposed and potential wind farm sites in similar numbers.

Scenes were selected to represent both proposed (35 scenes) and potential (33) wind farm sites. They were located on the coast and on agricultural land. South Australian landscapes where wind farms had been proposed or in which suitable wind regimes exist (AusWEA, 2002) were photographed using a Nikon SLR F60 camera with 50mm lens. The photographs were scanned and standardised digitally with Photoshop™ to show blue skies so that the presence of clouds would not influence ratings.

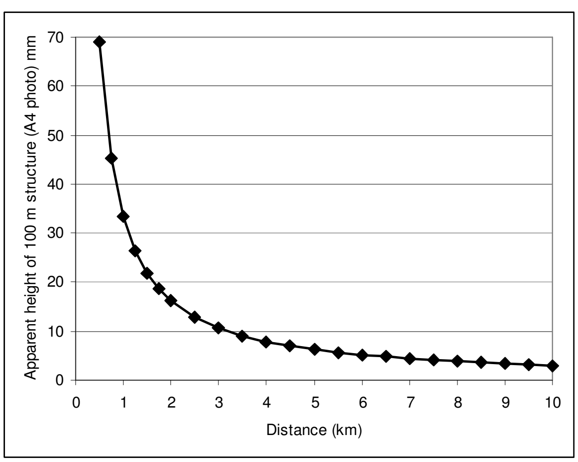


Figure 1 Relationship of height & distance of 100 m high structure

Photomontages were prepared, inserting standard wind turbines into the original photographs using Photoshop™. Whereas Hull and Bishop (1988) used similar scenes, the use of digital methods allowed the same scene to be used with and without the turbines. The turbine size was scaled appropriately with distance based on a formula developed from measurements of a structure of known height (Torrens Island Power Station chimney) at distances from 0.5 – 10 km. The exponential formula used for measuring the height of a 100 m wind turbine was $y = 33.46X^{-1.0446}$ where y = height in mm on A4 photograph and x = distance in kilometers (Figure 1).

The visual prominence of a wind farm diminishes rapidly within 3 – 4 km distance and it then diminishes linearly, reducing only gradually with distance. The height of the turbines in the photomontages was calculated based on their distance from the observer.

The turbines shown were coloured white except in three scenes where a range of hues was applied: white, grey, blue, and tan. In two separate scenes, the turbines were coloured in the following order: red, orange, yellow, green, blue, indigo and violet (rainbow colours). The scenes were of flat agricultural land.

In three scenes, the number of turbines was varied between six and thirteen to examine the influence of frequency on visual impact. Again, scenes of agricultural land were selected. Although the number of scenes used to examine the influence of colour and turbine numbers was small, the results could indicate an area for further research.

To assess the influence of distance on visual impact, the distance to the mid point of turbines from the observer was measured in all scenes.

4.2 Survey instrument

The survey comprised 150 scenes:

Scenes without wind farm	68
Same scenes with wind farm	68
Extra scenes for colour and distance	14
Total	150

The scenes were arranged in random order. Because viewing wind farms may be novel for participants, the first ten scenes were replicated at the end of the 150 scenes and the first ten ratings discarded. Thus a total of 160 scenes were rated but only 150 scenes analysed.

The rating instrument listed the scenes from 1 – 160 with a column for ratings. It was headed with a rating scale from 1 (very low) to 10 (very high) together with brief instructions. Information about the participants was sought covering: age, gender, education, birthplace, familiarity with regional South Australia and whether the participant had seen a wind farm and if so where. The survey was anonymous.

4.3 Survey conduct

The wind farm survey was carried out using three means:

- Sessions at which the scenes were shown to groups of participants;
- The survey was placed on CDs with instructions, distributed to worksites and undertaken by participants at their PCs;
- The survey was placed on an Internet site and invitations sent to 65 individuals invited them to participate and to forward the invitation to others in their worksite[1].

1. The Internet site was developed using ColdFusion web scripting language with a 95 compression rate for JPEG downloads. Lower compression rates can be used if participants have broadband or high speed modem internet access.

Sessions involving groups of participants and the CD were undertaken by tertiary students and various professionals. Sessions gained 134 participants and the CD surveys 37. The Internet survey was the most rapid and efficient gaining 280 participants in 7 days when it was terminated.

Conduct of the survey comprised the following steps.

1. The instructions thanked the participants, provided a brief outline of its purpose and asked them to rate each scene on the basis of its perceived scenic quality. The survey comprised a Powerpoint™ slide show with each scene displayed for 7 seconds.
2. Six scenes were then shown of a range of typical agricultural and coastal landscapes without wind farms and then six scenes with wind farms; these were not rated.
3. All 160 numbered scenes were then shown.
4. Following completion, rating sheets were collected and participants thanked. Internet surveys were forwarded automatically to the database immediately after rating each scene.

Total participation numbered 454; however some Internet participants did not complete the entire survey. In all, 161 participants rated all 160 scenes and a further 150 completed between 150 and 160 scenes; the 311participants which completed 150 or more scenes were selected for analysis.

4.4 Survey Participants

The respondents' characteristics were compared with 2001 Census statistics for South Australia (ABS 2002).

Age
Compared with the State population, the survey participants were generally younger. The differences were significant ($\chi2$ = 95.1, df = 1, 5, p = 0.000).

Gender
About 6% more males than females participated in the survey. The difference was significant ($\chi2$ = 4.62, df = 1, p = 0.03).

Education
The education level of participants was higher than the community; 76% held degrees or higher degrees compared with 10.7% of the community. The difference was significant ($\chi2$ = 2270, df = 1, 3, p = 0.00).

Birthplace
The majority of respondents, 80.4%, were Australian-born, slightly higher than the community's 75.4%. The difference was not significant ($\chi2$ = 3.4, df = 1, p = 0.065).

4.5 Comparison with State Population

The main differences were that there were fewer older people and more younger people in the sample compared with the State population, and far better educated people in the sample as well.

Table 2 Ratings by Participant Characteristics

	Categories of Participant Characteristics					
	1	**2**	**3**	**4**	**5**	**6**
Age	5.61	5.77	5.68	5.79	5.71	5.62
Gender	5.69	5.73				
Education	5.67	6.08	5.63	5.76		
Birthplace	5.67	5.85				

Although the survey participants differed significantly from the South Australian community, if there was little change across the range of a given characteristic, e.g. education, then it would be apparent that the influence of the characteristic was minimal and acceptable. An analysis of the ratings based on each of the participant characteristics (e.g. education) found that there was minimal difference across the characteristics (Table 2). Except for one item (education – certificate/ diploma), the ratings varied by only 2.4%. This suggests that although the survey sample differed from the population, this would generally not affect the ratings.

Tests of significance indicated that the only characteristic which had a significant effect on ratings was education. The differences in ratings across the other participant characteristics were not significant.

Interestingly a high 56.5% of participants indicated that they had seen a wind farm. Around two-thirds of these wind farms were in Australia – mainly on the Victorian coast at Codrington, or at Starfish Hill in South Australia. Those overseas were mainly in Europe, UK and the US. Many identified wind farms in several locations, including overseas.

5. RESULTS

The overall mean of scenes without wind farms was 6.15 (SD = 1.23) but the presence of wind farms reduced this to 5.49 (SD = 1.28). The difference of 0.66 was significant: ANOVA F = 11.44, df 1. 134, p = 0.001. The ratings for *without wind farm* and *with wind farm* were both normal distributions.

The coastal and inland scenes were analysed separately.

5.1 Coastal Scenes

The presence of wind farms reduced the mean perceived scenic quality rating of the 21 coastal scenes by 1.52, from 7.61 to 6.09, a significant difference: ANOVA F = 35.78, df 1, 41, p = 0.000.

Coastal scene with wind farm (rating 6.63 – rating without wind farm 8.68

The difference in the ratings is evident by arranging them in descending order of rating difference (Figure 2). This indicates the rating of each scene without and with the wind farm. The largest gap occurred where the landscape quality rating was high and reduced as the landscape rating decreased. Figure 3 shows the trend lines for the data.

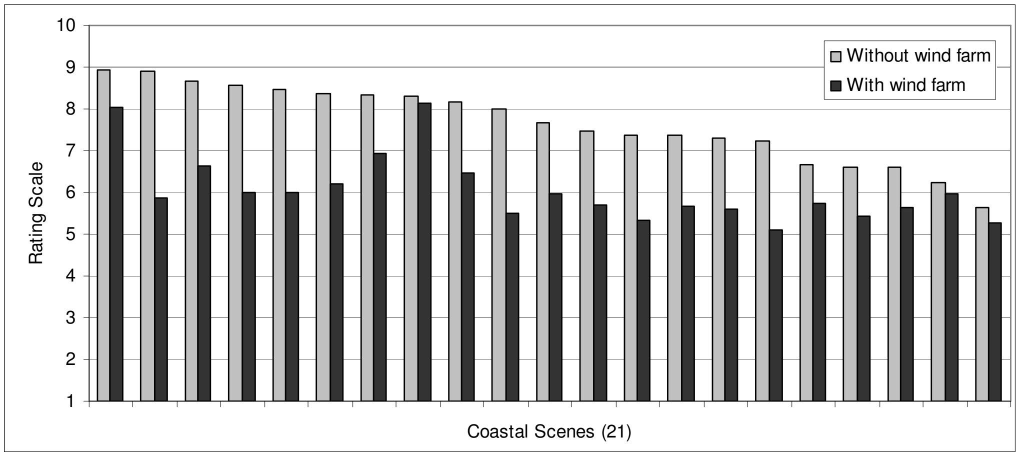


Figure 2 Coastal scenes – arranged in descending order of rating difference

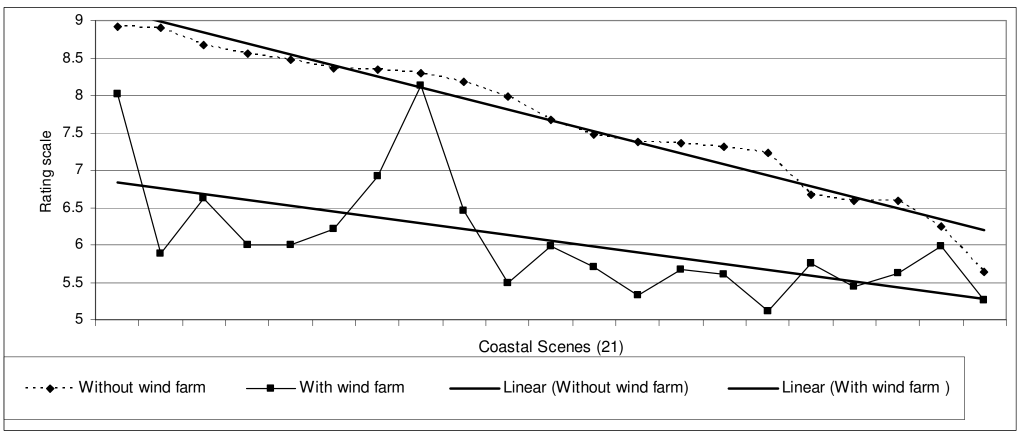


Figure 3 Trend lines for coastal scenes

Equation for trend line for scenes without wind farm: $y = -0.146x + 9.27$, $R^2 = 0.96$
Equation for trend line for scenes with wind farm: $y = -0.078x + 6.92$, $R^2 = 0.36$
where y = rating and x = scene number.

Table 3 Predicted effect of wind farms on coastal scenic quality

Rating without wind farm	Rating with wind farm	Difference
10.0	7.31	-2.69
9.5	7.04	-2.46
9.0	6.77	-2.23
8.5	6.51	-1.99
8.0	6.24	-1.76
7.5	5.97	-1.53
7.0	5.71	-1.29
6.5	5.44	-1.06
6.0	5.17	-0.83
5.5	4.91	-0.59
5.0	4.64	-0.36

Table 4 Description of generic landscape ratings for coastal scenes

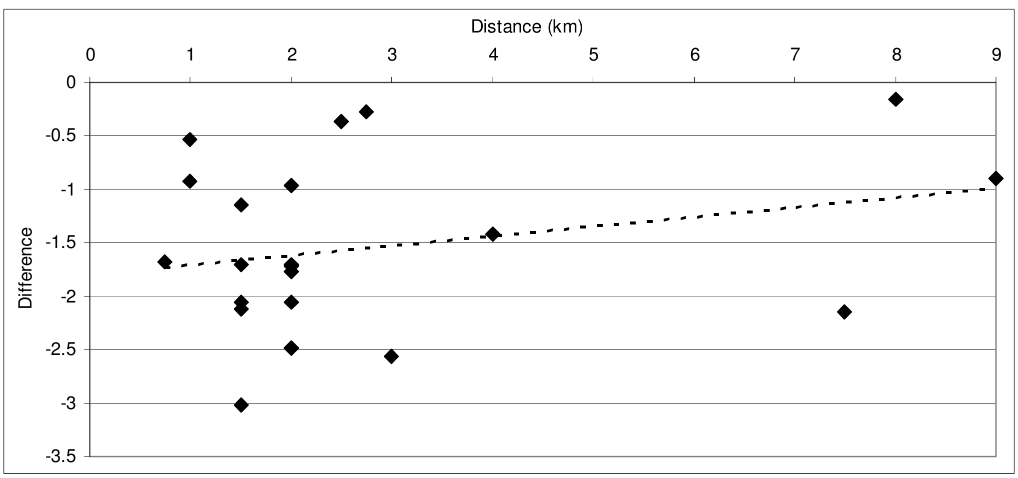
Rating 8	**Rating 7**
High, sheer or very steep cliffs, frequently indented coast (maximum edge), reefs, islands, pronounced wave motion, beaches backed by steep cliffs or high land. Overall contains a high vertical element and strong awe inspiring effect.	Headlands, long wide beaches, sloping cliffs, extensive dunes, wave motion, low rocky cliffs, reefs, some islands, smoother coastline – less indented. Overall, a lower vertical element, sloping cliffs and less coastal indentation.
Rating 6	**Rating 5**
Beaches, low hinterland, no cliffs, islands, mangrove flats, low dunes, little wave motion. Overall very little vertical element.	Flat hinterland used for agriculture or other non-natural uses, coastline lacking indentation, rocks or other features of interest.

Note: A rating of a given unit, say 6, covers the range 6.00 to 6.99.

Based on the known rating of a given landscape, Table 3 may be used to predict the likely effect of wind farms on perceived scenic quality in South Australian coastal areas. In South Australia a map of landscape quality is available based on the author's survey (Lothian, 2000; See South Australian Atlas: www.atlas.sa.gov.au/products/other/ a3qual.pdf). Table 4 describes scenes by their landscape rating as derived by Lothian (2000).

5.2 Effect of distance - coast

Bishop (2002) found using computer generated images of 15 wind turbines adjusted for distance that the visual effect dropped at 4km, was below 10% at 6 km, and at 30 km only 5% of people recognized the objects. The wind farms would be expected to diminish perceived scenic quality with distance.



Note: Trend line y = 0.089x – 1.80, r^2 = 0.07

Figure 4 Effect of distance on wind farm effect in coastal areas

The differences in the landscape quality rating without the wind farm and with it were compared with the distance (Figure 4). The scenes below 3 km showed the greatest negative effect on scenic quality ratings: up to -3. The negative effect of one of the distant scenes (> 7 km) was comparable with that of scenes < 2 km.

There were three scenes in which the turbines were more than 7 km from the viewpoint. The scenic quality of all three scenes was affected negatively by the presence of the wind farm. In one of these scenes, the negative effect was comparable with that of some scenes within 2 km distance, causing a reduction in rating of 2.2. However, the scenes located within 1 to 3 km showed the greatest negative effect on scenic quality ratings, with reductions of between -2.5 and -3.

The scattered data yielded an almost horizontal trendline with a low correlation coefficient. Overall the negative effect of the wind farm did not reduce appreciably with distance.

5.3 Inland Scenes

The presence of wind farms reduced the mean perceived scenic quality of the 47 inland scenes by 0.26, from 5.47 to 5.21, a small difference which was not significant: ANOVA F = 1.74, df 1. 93, p = 0.19

Inland scene with wind farm (4.94 – rating without wind farm 4.26)

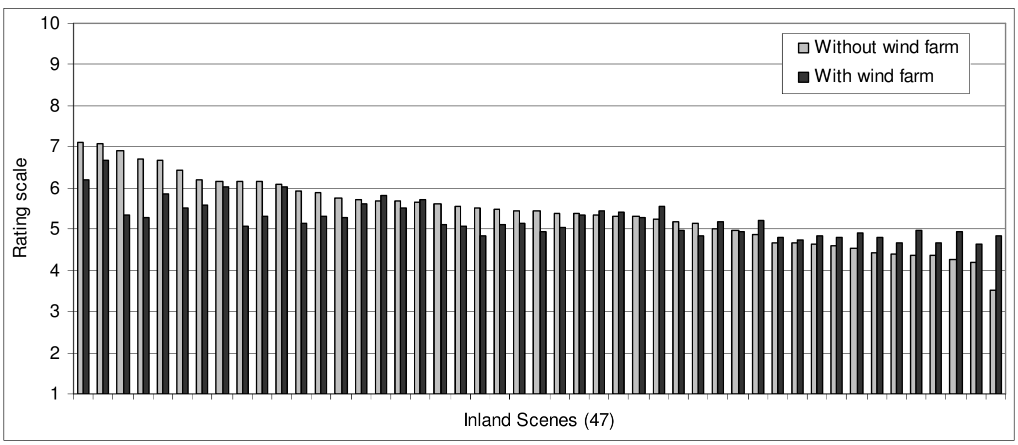


Figure 5 Rating of inland scenes in descending order

Equation for trend line for scenes without wind farm: $y = -0.058x + 6.81$, $R^2 = 0.96$
Equation for trend line for scenes with wind farm: $y = -0.024x + 5.819$, $R^2 = 0.56$
where y = rating and x = scene number.

Where the scenic quality rating of scenes without wind farms was close to 5 or below (Figure 5), the rating with the wind farm was always higher. Figure 6 indicates trend lines for the two data sets. The trend lines cross at a rating of 5.1; above this the wind farm generally detracted from scenic quality while below it the wind farm generally enhanced scenic quality. Table 5 indicates the likely effect of a wind farm in an inland scene of known landscape quality rating.

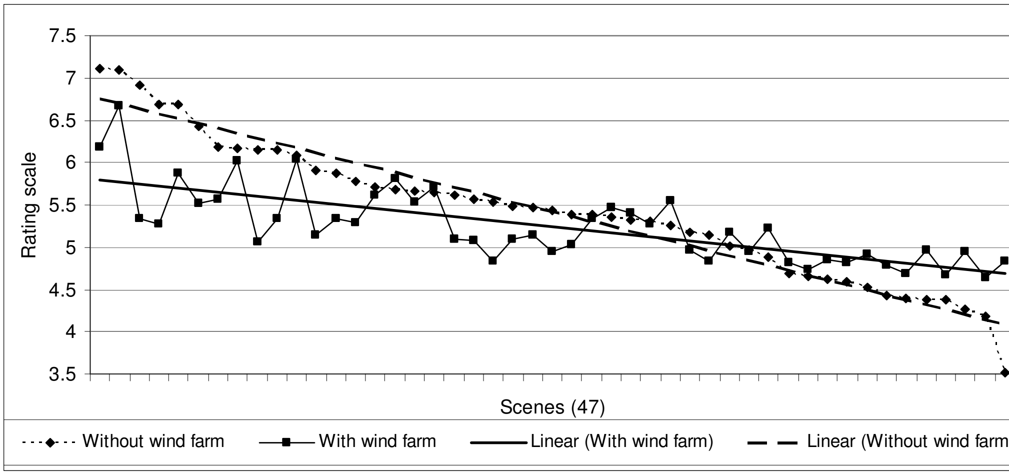


Figure 6 Trend lines for inland scenes

Table 5 Effect of wind farms on inland landscape quality

Rating without wind farm	Rating with wind farm	Difference
7.0	5.90	-1.10
6.5	5.69	-0.81
6.0	5.48	-0.52
5.5	5.28	-0.22
5.0	5.07	+0.07
4.5	4.86	+0.36
4.0	4.66	+0.66
3.5	4.45	+0.95
3.0	4.24	+1.24

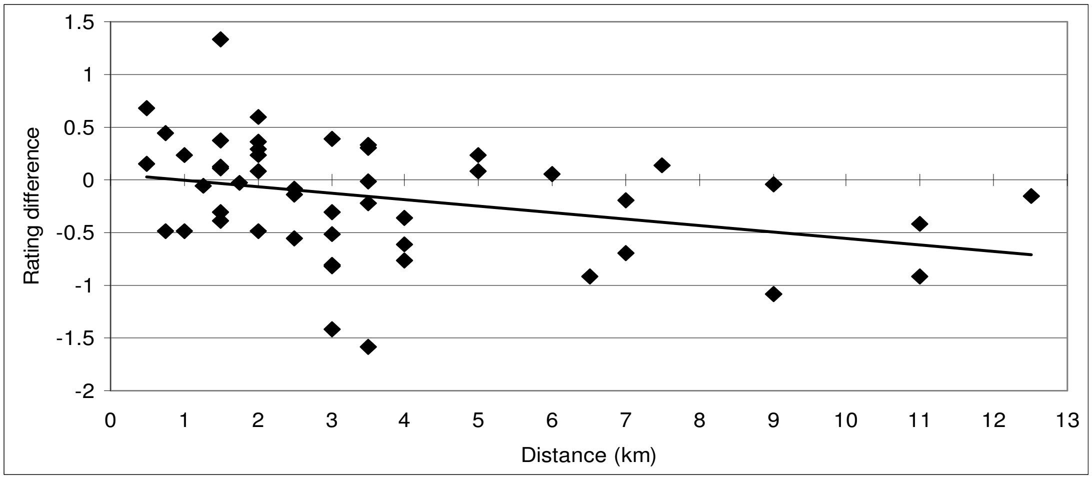
Use of Table 5 requires the rating of the landscape quality prior to the wind farms to be determined. Table 6 describes South Australian scenes by their landscape rating.

Table 6 Description of generic landscape ratings for inland scenes

Rating 7	**Rating 6**
Highly natural scenes, very hilly or mountainous, thickly vegetated with tall trees, cliffs or rocks may be prominent	Hilly or steeply undulating land, tall scattered trees, orchards, grassland
Rating 5	**Rating 4**
Broad flatter undulating hills & valleys, grazing land, scattered vegetation, savannah woodland with tall scattered trees on grassland, dams	Flat or gentle slopes, distant ridgelines or hills, fairly treeless or widely scattered vegetation or distant trees, cereals, grazing, no dams
Rating 3	
Flat, treeless, cereals, bare ground	

5.4 Effect of Distance - inland

Hull and Bishop (1988) stated that “intuition suggests that visual impact decreases as distance … increases”. A comparison of the ratings with and without the wind farm, arranged by the distance (Figure 7) suggested however that the negative effect actually strengthened with distance. Up to 7 km, wind farms had both a positive and negative influence but beyond this distance, the effect was almost wholly negative. The trend line ($y = -0.06x + 0.055$, $R^2 = 0.10$) had a negative slope but its correlation coefficient was too low to be definitive. The differences in the ratings by distance were significant ($p = 0.000$) in all but one distance category – that near the viewpoint, 1 – 1.99 km.



Note: Trend line y = -0.06x + 0.05, r^2 = 0.1

Figure 7 Effect of distance on visual effect of wind farms in inland areas

The effect of the wind farm at 3 km and 11 km was compared for the same scene in the southern Flinders Ranges (Table 7). The results indicated that the effect was greater at the farther distance, similar to that suggested above.

Table 7 Influence of distance on Flinders Ranges scene

Distance (km)	Without wind farm	With wind farm	Difference	p
3	6.43	5.52	0.91	0.000
11	6.69	5.28	1.41	0.000

A possible explanation of the apparent greater impact at greater distances is that in the nearby scenes the wind farm added interest to the landscape, but at a greater distance they merely appeared to be structures in the landscape. As structures they were considered to detract from the landscape, perhaps similar to electricity transmission pylons.

Additional testing and possible consideration of the influence of other factors visible in the scene would be necessary to establish any clear pattern regarding the effect of distance on the visual effect of wind farms in the landscape.

5.5 Number of turbines

In three scenes the number of turbines in each scene was varied from six to thirteen (Table 8, Figure 8).

Table 8 Influence of turbine number on landscape quality

	0 turbines	6 turbines	7 turbines	9 turbines	11 turbines	13 turbines
Sheringa1	4.97		4.95			4.75
Sheringa2	4.66		4.74		4.89	
Tungketta	6.59	5.45		6.06		

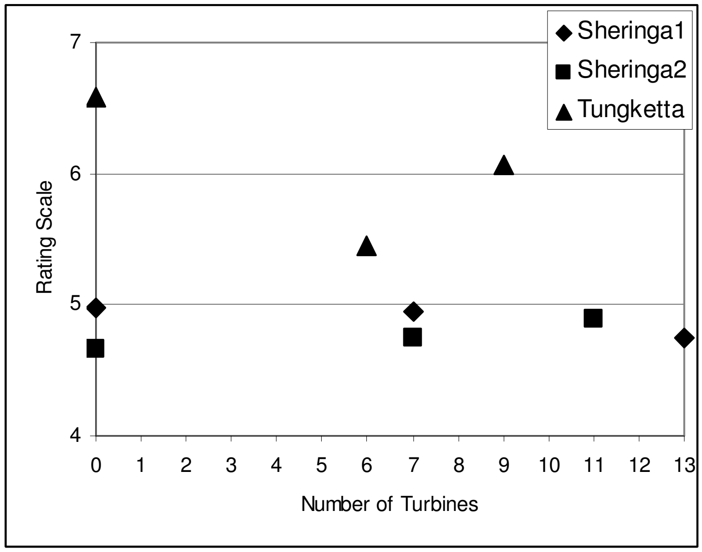


Figure 8 Influence of turbine numbers on ratings in three scenes

The results indicated that for Sheringa1, the greater number of turbines reduced scenic quality more than the lesser number. However, in Sheringa2 the larger number of turbines enhanced scenic quality. In the Tungketta site, where scenic value was enhanced by a glimpse of the sea, the presence of 6 turbines depressed scenic value by more than 1, but where 9 turbines were present, scenic quality decreased by a lesser amount, 0.53. The differences in ratings across the scenes showing differing numbers of turbines was not significant: ANOVA, F = 0.378, df 1, 11, p = 0.55.

These results indicate no clear trend and further sampling of sites with various numbers of turbines would be required in order to establish the influence, if any, of turbine numbers on visual impact.

5.6 Colour of Turbines

To test the effect of different colours on the perception of turbines, a range of colours were used in three scenes (Table 9, Figure 9). The background hues of each scene were a similar straw colour with blue skies.

Table 9 Ratings of Turbine Colours

Colour	Green Point	Nth L. Alexandrina	Woakwine
None	4.62	4.43	5.71
White	4.85	4.79	5.62
Blue	4.80	4.87	5.62
Grey	4.89	4.38	5.44
Tan	4.50	4.61	4.84
Rainbow	3.46	3.51	

Blue was the preferred hue in two scenes (equal with white in one) and grey in the other scene. White, blue and grey were similar in two scenes and white, blue and tan in the third scene. Most marked were the rainbow hues which rated well below the other colours. The differences between the colours were significant: ANOVA, F = 6033, df 4, 13, p = 0.012.

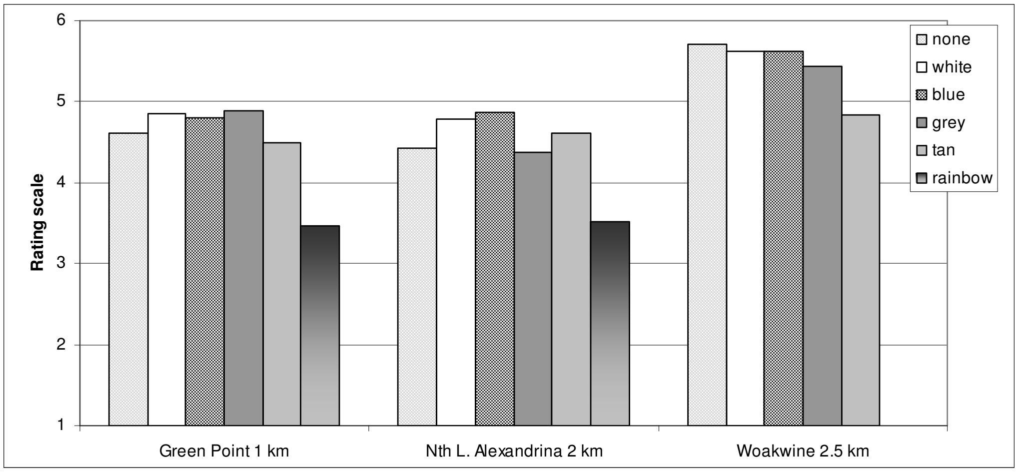


Figure 9 Rating of Turbine Colours

Shang and Bishop (2000) found the size of the object multiplied by its contrast percentage to be a key factor in determining visual effect. The contrast of the wind turbines against the sky and the land was assessed on a three grade scale of contrast: low, medium and high based on black and white prints. The ratings were averaged for each level of contrast and a low level of correlation between ratings and contrast was detected (r = 31). The highest contrasting scenes were those within 1 km, whereas the more distant scenes, 2.5 km, were either of low or medium contrast.

Overall the results suggested a preference for white, blue or grey coloured turbines, with the differences between these very small. The tan hue was less preferred and the rainbow coloured turbines were definitely least preferred. The contrast the colour presented against its background indicated a slight correlation between ratings and the degree of contrast. The highest contrasting scenes were closest and the more distant scenes offered less contrast.

These findings must be regarded as tentative, being based on a small sample of scenes, but indicates an area for further research.

6. CONCLUSIONS

This research on people's scenic perceptions of the effects of wind farms has indicated the following conclusions:

1. Wind farms generally had a negative effect on South Australian landscapes of moderate to high perceived scenic quality (i.e. rated approximately 5.1 – 10 on a 10 point rating scale).
2. Wind farms generally had a positive effect on landscapes of moderate to lower perceived scenic quality (i.e. approximately 0 – 5.0 on a 10 point scale).
3. The effect of varying the number of wind turbines on perceived scenic quality indicated no clear trend.
4. Negative visual effects of the wind farm did not reduce appreciably with distance.
5. The colour of wind turbines and towers affected perceived scenic quality. White, blue or grey coloured turbines were preferred with very small differences. The tan hue was less preferred and rainbow coloured turbines were least preferred. There was a slight indication that ratings increased with the contrast presented.

Because of the small samples involved in examining the effect of the number of turbines, their distance and colour, further research of these aspects will be necessary.

The effect of other landscape dimensions as variables on perceived scenic quality (e.g. atmospheric conditions) and in combination with wind turbines was not tested.

Based on the study findings, it appears likely that negative visual effects of wind farms would be diminished if:

- The most scenic locations, which are often coastal, are avoided;
- Wind farms are located so as to be not visible from the water's edge in coastal settings or in association with the sea from key viewpoints;
- Wind farms are located in inland areas of low to moderate scenic quality;
- Inland areas of higher scenic quality are avoided.

It is acknowledged that locating the wind farm slightly inland from the coast may reduce the wind speed and hence the viability of the project, however this balance may need to be considered to protect scenic quality.

Scenic resources are important to manage and protect in the process of developing wind energy generation. 'World experience (in the USA, Denmark, UK and the Netherlands) suggests that landscape will normally be the single most strongly argued issue in any wind farm permit decision' (PPV, 2002, Vol 2).

For the wind energy industry, the findings are particularly significant. As a green industry, whose credentials rest on its generation of pollution-free and greenhouse-friendly electricity, it is particularly critical that the industry not cause environmental impacts. The findings of this study suggest that it should avoid the selection of sites which, although having excellent wind resources, are also of high scenic value to the community. Many of the cases of opposition to wind farms derive from the poor site selection by the industry. As a green industry, it must display greater sensitivity to scenic values than it has in the past.

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