Annexure A

# Parameters of Human Vision and Viewshed Definition

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# ANNEXURE A PARAMETERS OF HUMAN VISION AND VIEWSHED DEFINITION

## A.1 WIND TURBINE VIEWSHED BASED ON THE PARAMETERS OF HUMAN VISION

The viewshed can be determined by measuring the extent to which an object fills an observer's static field of view. The viewshed in a man-modified landscape is limited to that area in which an object takes up at least 5% of the full field of view.

The measurement of the field of view is based upon the parameters of human vision outlined below. These provide a basis for assessing and interpreting the impact of a development by comparing the extent to which the development will intrude into the central field of vision (both horizontally and vertically).

### A.1.1 *Horizontal Field of View*

The central field of vision for most people covers an angle of between 50° to 60°. Within this angle, both eyes observe an object simultaneously. This creates a central field of greater magnitude than that possible by each eye separately.

This central field of vision is termed the 'binocular field' and within this field images are sharp, depth perception occurs and colour discrimination is possible.

These physical parameters are illustrated *in Figure A1.*

The visual impact of a development will vary according to the proportion in which a development impacts on the central field of vision.

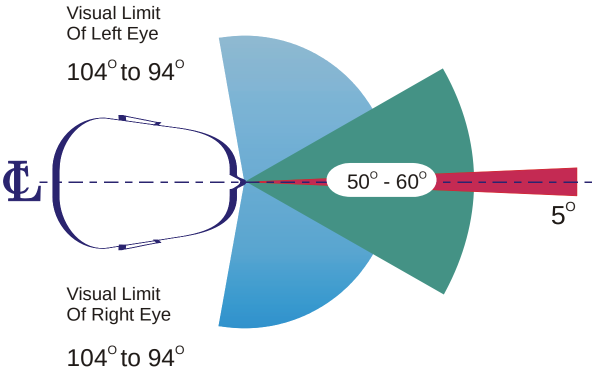


***Figure A1 Horizontal Field of View***

Developments, which take up less that 5% of the central binocular field, are usually insignificant in most landscapes (5% of 50° = 2.5°).

### A.1.2 *Vertical Field of View*

A similar analysis can be undertaken based upon the vertical line of sight for human vision.

These physical parameters are illustrated in *Figure A2*.

As can be seen in *Figure A2* the typical line of sight is considered to be horizontal or 0°. A person's natural or normal line of sight is normally a 10° cone of view below the horizontal and, if sitting, approximately 15°.

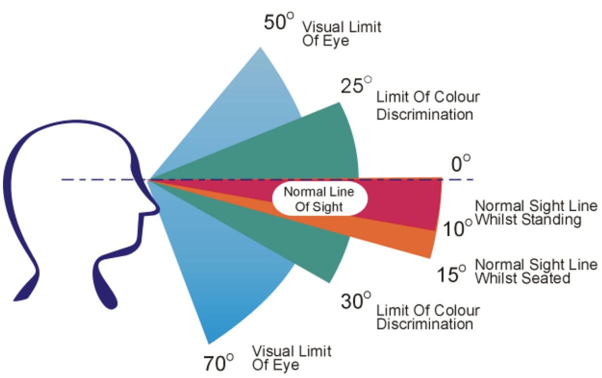


***Figure A2 Vertical Field of View***

Objects that take up 5% of this cone of view (5% of 10° = 0.5°) will only take up a small proportion of the vertical field of view, and are only visible when one focuses on them directly. However, they are not dominant, nor do they create a significant change to the existing environment when such short objects are placed within a disturbed or man-modified landscape.

### *A.1.3 Viewshed Based on the Horizontal Field of View*

The viewshed of a single wind turbine is calculated on the extent to which a single wind turbine (in this example the widest section is the swept path of the rotor) would intrude into the 60° central field of vision.

The table below analyses' the extent to which a swept path of a single rotor would interrupt the horizontal field of view.

*Table A.1 Viewshed based on the degree a swept path of a single rotor would take up in the horizontal field of view*

| Horizontal Field of View | Visual Impact | Distance from an observer to a rotor with 92 m diameter |
|---|---|---|
| <2.5° of view (5% of 50° = 2.5°) | Insignificant<br>The swept path of the rotor would take up less than 5% of the central field of view. The rotor, unless particularly conspicuous against the background, will not intrude significantly into the view. The extent of the vertical angle will also affect the visual impact. | > 2290 m |
| 2.5° – 30° of view (60% of 50° = 30°) | Potentially Noticeable<br>The swept path of the rotor may be noticeable and its degree of visual intrusion will depend greatly on its ability to blend in with its surroundings and particularly the sky. | 173 m-2290 m |
| >30° of view | Potentially Visually Dominant<br>At this distance the swept path of a single rotor will fill more than 50 percent of the central field of vision and will always be noticed and sympathetic treatments, such as paint colours to blend against a sky, will only be able to partially mitigate visual effects. | < 173 m |

These calculations suggest that the impact of a 92 m wide rotor would reduce to insignificance at approximately 2,290 m, as the swept path of the rotor would, at this distance, form less than 5% or 2.5° of the horizontal field of view. At distances less than 173 m, a 92 m wide rotor, would be visually dominant.

These calculations do not take into account the height of the wind turbines, nor do they allow for the placement of multiple wind turbines within the landscape. The distances suggested by the analysis, based upon horizontal field of view of a single rotor, are far less than experience would suggest to be reasonable.

### A.1.4 *Viewshed based on the vertical field of view*

The previous calculation is based on the visual impact of a single rotor in the horizontal field of view. A single wind turbine has the same height as many wind turbines sited across several kilometres, and the intrusion into the vertical field of view may better determine the viewshed for a wind farm.

The point from which the wind farm becomes an indistinct line on the landscape, better determines the viewshed. That is the point at which the vertical size of a range of wind turbines diminishes to an imperceptible component within the vertical field of view.

The sketch below shows how the viewshed of a long horizontal object is determined by its height and not by its width.

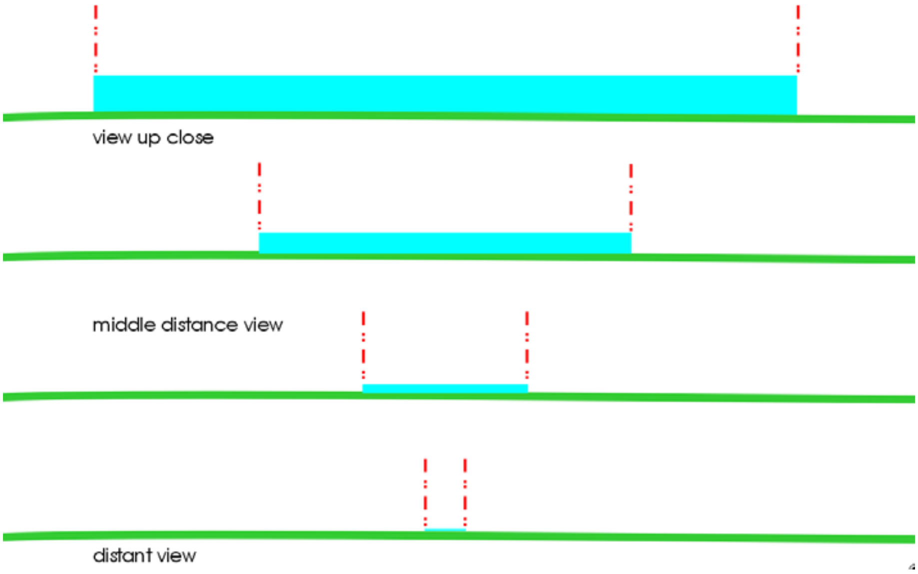


*Figure A3 The diminution in visibility with distance from a long horizontal object*

As an observer moves further away from a horizontal object the width may still be apparent, however the vertical dimension reduces to insignificance

This effect can also be demonstrated by the example of a farm fence that may be several kilometres in width, yet as one moves further away, it becomes less apparent, until at some distance it is not possible to separate this element from the horizontal plane of the landscape. Similarly, the viewshed of a long horizontal object such as a wind farm can also be determined by its height.

As wind farms are comprised of many tall slim towers with rotating blades, wind farms are different to a solid structural mass such as buildings. At greater distances, the rotating blade becomes the most visible element and at closer distances, it is the overall height of the wind turbine that becomes most apparent.

The table below shows the relationship between impacts based on the proportion that a wind farm comprising of many wind turbines will occupy within the vertical field of view, which in the table below is assumed to be 10°.

Objects that take up 5% of this cone of view (5% of 10° = 0.5°) are considered visually insignificant. That is not to imply that the objects become invisible at this distance, rather they become such a minor element in an already man modified landscape that their visual impact can be considered to be insignificant.

Once objects take up at least 10% of the vertical field of view, they can be more readily discernible (10% of 10° = 1°) and this visibility increases as the wind turbines increasingly take up a greater proportion of the vertical field of view.

When the wind turbines take up 25% of the vertical field of view, they become visually evident and when they take up 50% of the vertical field of view, they will dominate the view.

*Table A.2* Visual impact based on the vertical field of view to a wind turbine

| **Vertical Line of Sight** | **Visual Impact** | **Distance from an observer to a - 146 m high wind turbine** |
|---|---|---|
| < 0.5° of vertical angle (5% of 10° = 0.5°) | Insignificant<br>A thin line in the landscape. | 16785 m |
| 0.5°-2.5°of vertical angle | Potentially noticeable<br>The degree of visual intrusion will depend on the development's ability to blend in with the surroundings. | 3355-16785 m |
| 2.5° – 5° of vertical angle | Visually evident<br>Usually visible, however the degree of visual intrusion will depend of the width of the object and its placement within the landscape. | <3355 m |

The table above shows the distance at which a wind turbine approximately 146.5 m high with a 92 m diameter swept path of a rotor diminishes with distance within a vertical field of view.

In some lighting conditions, the rotor stands out in distant views and for this reason it is calculated separately for the outer edge of the viewpoint. As this calculation is intended as only a guide to setting the viewshed, all figures have been rounded to the nearest appropriate kilometre).

**Insignificant visual impact & the limit of the viewshed** occurs at approximately 17 km, at which point a 146.5 m high wind turbine is no longer a significant visible element in a man modified landscape except for the most sensitive of locations. The swept path of the rotor also becomes the only visible element in some lighting conditions as the supporting tower becomes imperceptible and possibly this could reduce the viewshed to 10 km in these lighting conditions.

The 17 km viewshed is based on a conservative assumption that the wind turbines are a solid mass 146.5 m high, similar to a building. In reality the wind turbines are widely spaced and the wind farm is a far more visually transparent object than a solid building mass some 146.5 m high and several kilometres in width. However, it is also to be noted that the turning of the rotor also attracts the eye, extending the viewshed.

It is stressed that these calculations attempt to locate the distance at which a wind farm becomes imperceptible within a man-modified landscape. This is not to say that wind turbines at 17 km, or even at 27 km are invisible. Wind turbines of this height will be discernible in good lighting conditions to an observer who knows where the wind turbines are located and therefore focuses in that direction. However the visual impact within a man modified landscape is not considered significant beyond this distance, aside from exceptional circumstances.

**Potentially noticeable** visual impact occurs between 3 km to 8.5 km where the entire wind turbine is visible and lighting does not alter the visibility of the tower versus that of the rotor. Foreground vegetation and intervening landform can reduce the degree to which the wind turbines are noticeable.

**Visually evident** occurs at distances between 1.5 km and 3 km where the wind turbines have increased in visibility and are evident and potentially dominant in the landscape. Landscape is less effective at screening wind turbines unless it is close to the viewer.

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Annexure B

# Community Perception Studies

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# ANNEXURE B COMMUNITY PERCEPTION STUDIES

The results summarised in 'Chapter 3 – Community Perception Studies' are also supported by many other studies undertaken in Australia, NZ, the UK and the USA. Some of these studies are summarised below in *Annexure A*.

## B.1 GULLEN RANGE WIND FARM– COMMUNITY PERCEPTION TOWARDS WIND FARMS

A study to ascertain the regions view towards wind farms was conducted from the 27th of July and concluded on the 2nd of August 2007. This study was previously quoted in the Planning Application Report for the Gullen Range Wind Farm. The study area included the Goulburn – Crookwell – Yass regions, which are located within the Southern Tablelands area in NSW. This area is known to high wind speeds and therefore has potential for wind energy projects.

The respondents in this study were located in small urban and rural locations within the immediate vicinity of the proposed Gullen Range Wind Farm; however the study also selected residents further to the west around Gunning and Yass, to the North West at Binalong, to the east towards Crookwell and to the south east towards Goulburn.

Within the study area, an existing wind farm, known as Crookwell I, is located to the immediate east of Crookwell Township and an approved wind farm (Crookwell II), to the immediate south of Crookwell I. Further approved wind farms are located to the south east known as Walwa-Gunning and Cullerin Range. Located further to the west, to the west of Yass, is the approved wind farm at Conroys Gap.

At the beginning of the study, it wasn't known just how much respondents knew of these wind farm projects, what they knew of wind farms, what the wind turbine that populated and powered them looked like, or know what it actually did. This study examines community perceptions towards renewable wind energy, derived from wind farms, for the region of south east NSW and establishes baseline data on community perceptions in the study area.

Results have shown an approval rating of almost 9 in 10 (89%) respondents in favour of wind farm projects being developed in the Southern Tablelands. With over 9 in 10 (96%) of respondents agreeing 'wind energy is a good alterative energy source', see *Figure B.0.1*.

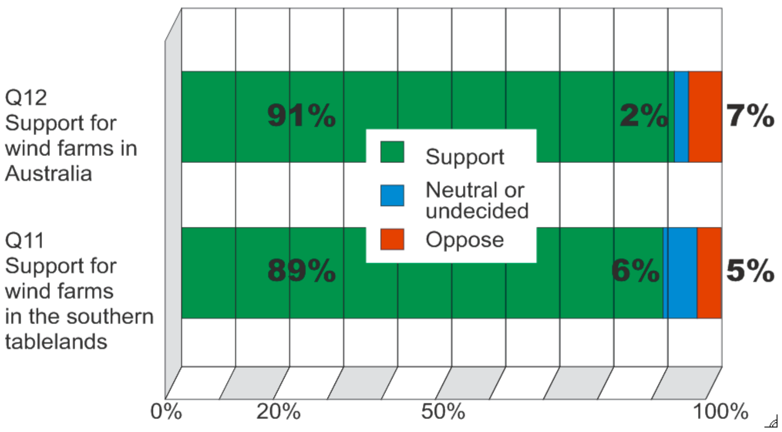


*Figure B.0.1 Support for wind farms*

Further to this, most respondents (83% favour, 8% opposed) were accepting of a wind farm set back 10 km from their home, with a slight decrease to 7 in 10 respondents (71% Favour, 19% opposed) accepting a wind farm set one kilometre from their home, see *Figure B.0.2*. This is a very similar level of acceptance that has been identified in other studies.

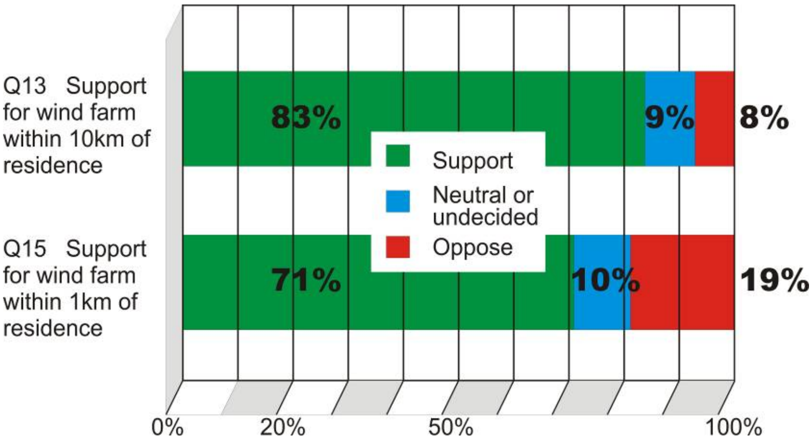


*Figure B.0.2* *Support for wind farms near respondent's residence*

As well as the statistical similarity in the level of support between sites in Victoria and NSW, there is also a similarity ion the level of support when a wind farm is proposed within 1 km of a respondent's residence and if it is located on some of the most scenic of Victoria's coastline (Kanos & Quint, 2000, cited in Section 2.2.1).

In response to introducing the concept of multiple 'typical' (15 to 80 turbines) wind farms in the local rural area, respondents accepted 76% (19% opposed) one typical wind farm, with three typical wind farms accepted by 64% (27% opposed) see *Figure B.0.3*.

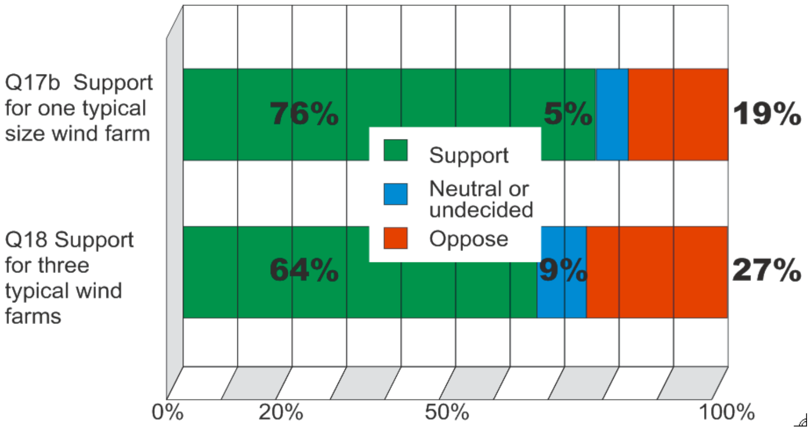


*Figure B.0.3* *Support for multiple wind farms*

*Figure B.0.3* again highlights the remarkably consistent levels of approval for one or more wind farms in the area. The lowest level of acceptance at 64% for three wind farms is again very similar to the levels of support shown for the most sensitive of locations, weather with one kilometre of the respondent's house or on coastal headlands along Victoria's coast.

The study also found that the community has no clear preference between a few clusters, close together, or spread out at reasonable intervals along the highway. Therefore it would seem that this landscape can absorb future wind farm developments, as the community has not a strong preference.

This study shows the adult residents in the survey area are concerned about global warming and are aware of the alternatives available. The study also shows respondents know and understand what a wind turbine is, how wind farms appear in the landscape and are supportive of them.

Moreover when it comes to locating wind farms, respondents are not averse to having them in their immediate locality, and a majority still approving of a wind farm within one kilometre of their home.

It is suggested that respondents feel the creation of wind farms is positive and this study shows that many are prepared to embrace them in their local area.

These outcomes are remarkably consistent with results from other surveys conducted both within Australia and overseas and a clear pattern is emerging on the acceptance of wind farms in rural communities.

## B.2 *OTHER AUSTRALIAN COMMUNITY PERCEPTION STUDIES*

The following section builds upon ERM's discussion of perception issues in past visual assessments of other wind farms and is pertinent to the visual and landscape assessment of the proposed Ararat Wind Farm.

### B.2.1 *Coastal Headlands*

In 2000, a study was undertaken for the Department of Natural Resources and Environment (Kantos & Quint, 2000) on the many issues concerning the Victorian Coastline including the construction of wind farms on coastal headlands.

*Figure B.0.4* summarises the results of this particular component. The study involved a series of nine workshops as well as telephone interviews (n = 700).

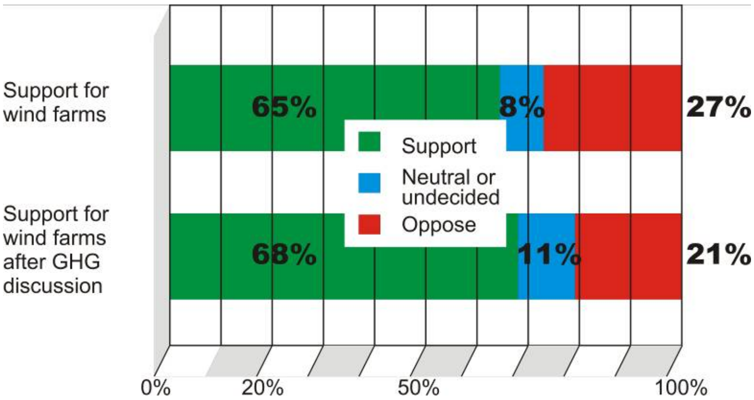


***Figure B.0.4*** ***Wind farms on Coastal Headlands – Participant Responses***

Study participants initial support or opposition to the construction of wind farms on coastal headlands was measured. After being exposed to arguments on renewable energy, greenhouse gas emissions and climate change issues their responses were measured again. This study found that there was only a slight increase in participants' acceptance of wind farms on coastal headlands, from a 65% acceptance level before arguments on greenhouse gas emissions to 68% acceptance after these arguments were presented. However opposition reduced from 27% to 21%.

### B.2.2 *Nirranda Wind Farm*

Similar figures have been found in a 2002 visitor survey undertaken for Stanwell Corporation Limited (Offer Sharp & Associates 2002) on the possible visual impacts of the proposed wind farm on the Bay of Islands viewing platform that is located adjacent to the Nirranda site, in the Shire of Moyne approximately 250 km west of Melbourne.

Approximately 80% of people were generally in support of wind farms, however when presented with a proposal for a wind farm visible from a scenic coastal lookout (the Bay of Islands) the support for a wind farm at this location reduced to approximately 71%, whilst opposition to the presence of a wind farm at this location increased from 3% to 12%.

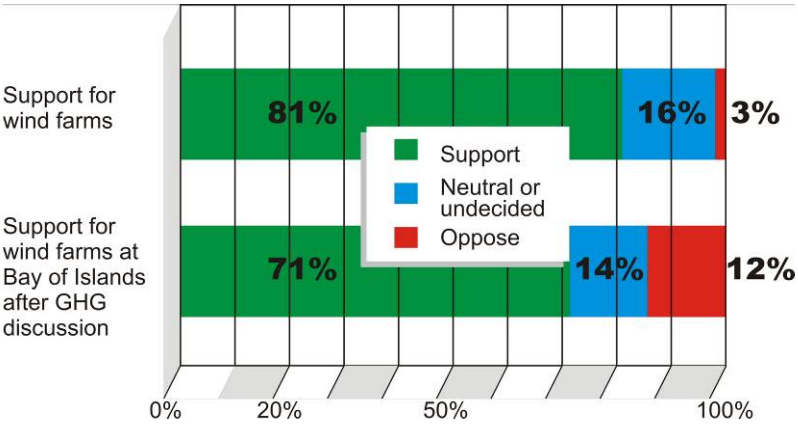


***Figure B.0.5 Nirranda Wind Farm Respondents Attitudes to Wind Farms***

*This figure of 71% support for wind farms is similar to the Kantos & Quint result of 68% reported previously for wind farms on exposed coastal headland.*

### *B.2.3 Yaloak Wind Farm*

Research undertaken by Offer Sharp & Associates, 2004 presented at the Yaloak Wind Farm panel hearing in 2005 showed a similar level of community acceptance to wind farms on this inland site near Ballan, Victoria.

The study assessed community reaction to images of a wind farm in the Yaloak landscape as well as at another site at Crowlands in Western Victoria. Neither location was identified, however the Yaloak proposal had been publicised for some time before the survey and the landscape may have been recognised by some, and particularly local, respondents. Community reaction to the siting of wind turbines in these landscapes was based on interviews with 200 respondents from each of Melbourne, Bacchus Marsh and Ballarat.

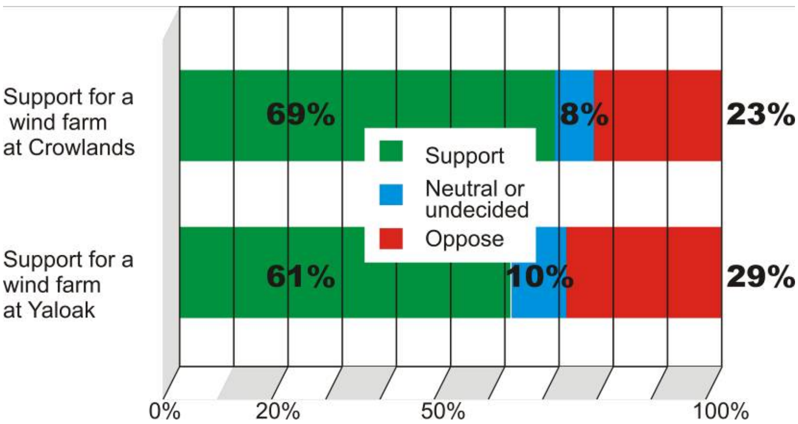


***Figure B.0.6 Level of Support for Potential Wind Farms at Yaloak and Crowland***

This data has been extracted from *Table 15 Crowlands* and *Table 19 Yaloak* in the Offer Sharp & Associates 2004 report and illustrates the acceptance levels for wind farms of each of these sites. The study also found slight differences in levels of support at Crowlands (67%, 66% and 73%) for respondents from Melbourne, Bacchus Marsh and Ballarat respectively, and slightly larger differences (61%, 55% and 68%) in support for the proposed wind farm at Yaloak.

However, the overall findings are similar of the earlier studies from the earlier Kantos & Quinn 2000 and Offer, Sharp 2002. All these Australian studies continually show a level of acceptance greater than 60%. Overseas studies show similar results.

## B.3 OVERSEAS STUDIES

Community perception studies have also been undertaken overseas to gauge levels of community support and opposition to wind farms.

### B.3.1 United Kingdom

A paper presented at the 20th British Wind Energy Association Conference (Anne Marie Simon Planning, 1996) gives an overview of thirteen studies undertaken between 1990 and 1996 by wind power proponents, opposition groups, the BBC, statutory authorities and a Liverpool University dissertation found that in all these studies:

- The overwhelming majority of respondents support the principal of development of wind power in the UK, and they also support their local wind farm;
- Those with direct experience of an operating wind farm are more supportive and positive than those without experience;
- Once wind farms are in operation, concerns about noise and visual impact decrease;
- The majority of people find the wind farms acceptable in the landscape and more find the wind turbines graceful than ugly; and
- A strong majority support and a small minority oppose wind farms, with more expressing no opinion than opposition (Freris 1998).

A summary of the results for eleven of these studies, which is taken from this paper (*Anne Marie Simon Planning, 1996*), are reproduced below.

***Table B.1*** ***Summary of Eleven Studies Conducted in the United Kingdom into Attitudes to Wind Power from 1990-96***

| Location | Sponsor/Organiser | Date | In favour | Against | Don't know |
|---|---|---|---|---|---|
| Delabole, England | DTI | 1992/3 | 84% | 4% | 11% |
| Cemmaes, Wales | DTI | 1992/3 | 86% | 1% | 13% |
| Llandinam & Llangwyryfon, Wales | CCW | 1992/3 | 83%<br>78% | 3%<br>8% | 14%<br>14% |
| Llandinam<br>Rhyd-y-Groes<br>Taff Ely, Wales | BBC | 1994 | 76%<br>61%<br>74% | 17%<br>32%<br>9% | 8%<br>7%<br>17% |
| Kirkby Moor, England | National Wind Power | 1994 | 82% | 9% | 9% |
| Bryn Titli, Wales | NWP (pre construction)<br>NWP (open day) | 1996 | 68%<br>94% | 14%<br>3% | 19%<br>3% |
| Trysglwyn, Wales | NWP (open day) | 1996 | 96% | 4% | - |
| Coal Clough, England | Liverpool University Dissertation | 1996 | 96% | 4% | - |

**Notes**
NWP = National Wind Power (a wind farm developer).
CCW = Countryside Council for Wales (a statutory body)
BBC = BBC (Wales) and the University of Wales

In all these studies between 61% and 96% of survey respondents were supportive of wind power.

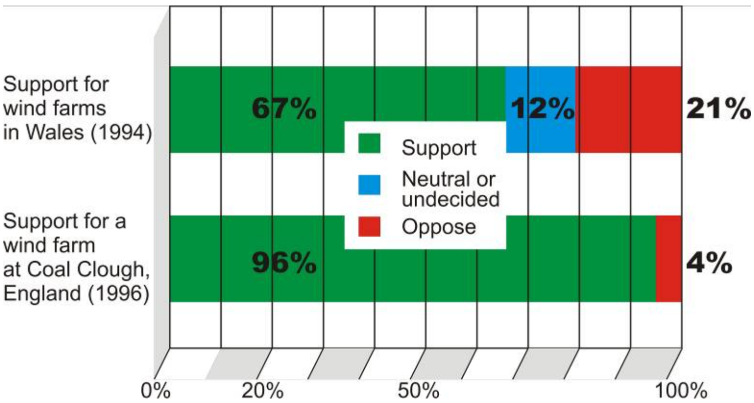


***Figure B.0.7*** ***Comparison of Selected Wind Farm Community Perception Studies in the United Kingdom***

The lowest level of acceptance was one area within the BBC 1994 study which looked at attitudes towards wind farms in Wales (Interviews with 268 respondents, conducted in two stages; stage one being just after the wind farm was built and stage two one year later). The BBC study also looked at three locations, Llandinam, Rhyd-y-Groes and Taff Ely) with the lowest support for the wind farm at Rhyd-y-Groes with 61% support and 32% against, whilst overall the BBC study found that 67% of respondents were in favour of the development of wind power in Wales, and 21% were opposed.

The highest approval was that reported in the Coal Clough (Lancashire, England) study (Questionnaire completed by face to face interviews, sample of 50) with 96% approval and 4% opposition.

These figures are similar to those reported in the Australian studies.

### B.3.2 *Scotland & Ireland*

A recent study (November 2005) on community perception of wind farms in Scotland and Ireland also has similar, but higher approval ratings. (found at http://www.your-energy.co.uk/pdf/windfarmpaper121205.pdf).

***Table B.2 Comparison of levels of acceptance between wind farms in Scotland and Ireland***

| | Strongly support | | Support | | Neutral | | Oppose | | Strongly oppose | |
|---|---|---|---|---|---|---|---|---|---|---|
| | DL (%) | BH (%) | DL (%) | BH (%) | DL (%) | BH (%) | DL (%) | BH (%) | DL (%) | BH (%) |
| A. Wind power is Scotland | 55 | 55 | 35 | 22 | 6 | 16 | 2 | 0 | 2 | 7 |
| B. Local wind farm | 63 | 47 | 25 | 16 | 3 | 20 | 3 | 4 | 5 | 13 |

DL = Dun Law (operational site). BH = Black Hill (proposed site).

(from *Public Perceptions of Wind Power in Scotland and Ireland*, Charles R. Warren, Carolyn Lumsden, Simone O'Dowd & Richard V. Birnie, Journal of Environmental Planning and Management, Vol. 48, No. 6, 853 – 875, November 2005, Table 4, p862).

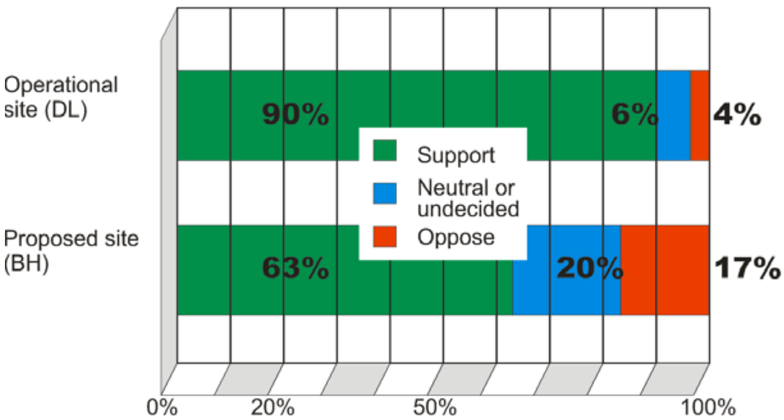


***Figure B.0.8 Acceptance levels - Scotland and Ireland***

Once again this reconfirms that the high level of acceptance, and this report also goes further and shows the increased level of acceptance within a community following construction. This is discussed in the next section of this report.

### B.3.3 *North Carolina, USA*

Reported attitudes in a study from North Carolina (NC) in the USA are also similar. A paper prepared on public attitudes (Grady 2004) towards wind energy in eastern NC, which included coastal areas, and western NC, which includes mountainous areas, presented to the 'Efficient NC Conference' also found similar degrees of approval. Note: There was no information in this paper on the sample size.

*Table B.3* *Public Attitude to Placement of Wind Farms in Eastern NC*

| Placement | % Prohibited | % Not prohibited | % Don't know |
|---|---|---|---|
| Mainland | 11.9 | 72.8 | 15.3 |
| Mainland clustered | 14.1 | 69.6 | 15.1 |
| Sounds | 16.6 | 63.6 | 19.8 |
| Sounds clustered | 28.0 | 50.2 | 20.5 |
| Offshore | 13.9 | 68.6 | 17.6 |
| Offshore clustered | 14.4 | 68.6 | 15.8 |

*Table B.3* shows the level of acceptance for clusters of wind turbines reduced to 50% for the Sounds which are the coastal areas along the eastern seaboard of North Carolina. The level of acceptance for clustered groups of wind turbines in the mainland area rose to 69.6%.

This paper (Grady, 2004) also presented levels of acceptance within the more mountainous areas of Western NC.

*Table B.4* *Public Attitudes to Wind Farm Placement – Western NC*

| Placement | % Prohibited | % Not prohibited | % Don't know |
|---|---|---|---|
| Ridge tops | 20 | 64 | 17 |
| Ridge tops clustered | 28 | 57 | 15 |
| Ridge tops with other towers | 16 | 75 | 10 |

The western area of Northern Carolina is mountainous; many parts are uncleared and show few signs of human intervention. The level of acceptance for clustered groups of wind turbines on ridge tops in this area is less (57%) than the level of acceptance reported for the mainland areas of Eastern NC (69%), however if there are other towers on the ridge tops (i.e. there are obvious signs of human intervention) then the level of acceptance rises to 75%.

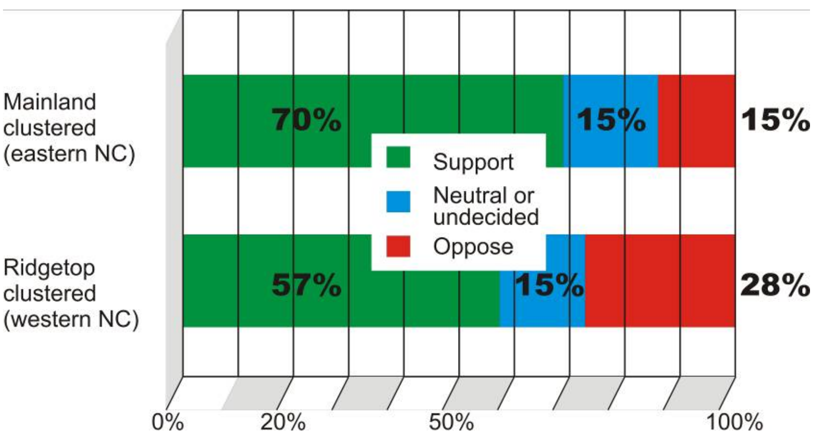


*Figure B.0.9* *Acceptance Levels - Northern Carolina, USA*

In summary this paper reported that:

- *"Within groups of middle aged, middle class, pragmatic, year round residents of the mountain and coastal regions of NC, there is support for developing renewable energy as a future source of fuel for electricity generation.*
- *More than 3 out of 4 would prefer to see more future electricity derived from solar and wind*
- *Less support for turbines in sounds or national forests*
- *2 out of 3 support turbines visible from home*
- *Over 80% support turbines for residential use."*(Grady, 2004)

The degree to which the respondents believe that wind farms on mainland sites should not be prohibited is very similar to the previously cited United Kingdom and Australian studies; with between 69-73% believing that wind farms should not be prohibited.

## *B.4 PERCEPTION ALTERATION AFTER CONSTRUCTION*

There has been no research done on the visual impact of wind farms in Australia after construction, however overseas studies suggest greater acceptance levels by people who live in the vicinity of wind farms after their construction (Gipe n.d.)

Anne Marie Simon Planning and Research in the previously cited study also found that all studies that looked at perceptions before and after construction, reported an increase in acceptance after the Wind Farm was completed.

It is also interesting to note that the study on Scotland and Ireland (cited above) also shows a 27% increase in acceptance following construction, although the greatest proportion of people who changed their mind were in the "neutral or undecided" group, there was still a significant reduction from 17% to 4% in the group that opposed the wind farms.

This study supports the view that familiarity does not increase opposition to a wind farm, but rather increases acceptance and support for wind turbines in the landscape.

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Annexure C

# Photomontages