Visual Assessment of Windfarms: Best Practice

Report No. F01AA303A

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Summary

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BACKGROUND

The development process for many windfarms requires formal environmental impact assessment (EIA) and the incorporation of the results into an environmental statement (ES). SNH's experience is that there can be a great deal of variation in the way that visual impact assessment (VIA) is dealt with in EIA. This project involved: a review of relevant guidance, research and development work on visibility, visual impact and significance; an investigation of the visibility of eight existing Scottish windfarms; a comparison between as-built visibility and estimates of visibility in the ESs; evaluation of Zone of Visual Influence (ZVI) and other assessment tools; and generation of Best Practice Guidelines for VIA of windfarms.

MAIN FINDINGS

- Many guidelines on windfarm development appear to be based on first generation windfarms and need to be revised for second and third generation turbines.
- There is some research and a wide and diverse range of guidance and opinion on the detailed issues of ZVI, distance, visibility and significance for windfarms, explained by the complexity and the subjectivity of the issues, the desire of one set of windfarm interests to minimise the political, professional and public perception of the visual (and landscape) effects of windfarms and an opposing desire by another set of interests to maximise these perceptions.
- The magnitude or size of windfarm elements, and the distance between them and the viewer, are basic physical measures that affect visibility, but the key issue is human perception of visual effects, and that is not simply a function of size and distance.
- The influences on apparent magnitude are reviewed, including factors that tend to increase it and factors that tend to reduce it. A new conceptual model and schema for assessing visual effects is provided.
- Based on survey work at eight sites - Beinn An Tuirc, Beinn Ghlas, Deucheran Hill, Dun Law, Hagshaw Hill, Hare Hill, Novar and Windy Standard - an overall analysis is provided of the effects on visibility of the Size and Scale of the Development, Proportional Visibility, Lighting, Movement and Orientation, Distance, Colour and Contrast, Contrast, Skylining and Backclothing, Elevation of Windfarm and Human Receptor and Colour and Design.
- Zones of Visual Influence (ZVI) are never wholly accurate and other tools such as photomontage are never wholly realistic. Suggestions are made of ways to address these issues.

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1 INTRODUCTION

1.1 Concern for the landscape, visual and other environmental effects of tall, industrial or technological structures in the landscape is not new (e.g. Goulty, 1990). In the case of windfarms, however, there is universal acknowledgement that the potential landscape and visual effects are among the most important and to some extent the most intractable issues for obvious and well-rehearsed reasons (e.g. Coles & Taylor, 1993; Lindley, 1994).

1.2 Strategic approaches to the siting of windfarms are advocated through the use of tools such as Geographical Information Systems (GIS) (e.g. Sparkes & Kidner, 1996) and there are commercial software packages such as WindFarmer (Garrad Hassan, no date), WindPRO (EMD, no date) and WindFarm (ReSoft, no date) that combine GIS with procedures for calculating Zones of Visual Influence (ZVI) and producing photomontages. It is not clear if such software is in widespread use in the UK. Ultimately, however, the assessment of all but the smallest individual development project for a windfarm requires formal environmental impact assessment (EIA) and the incorporation of the results of that assessment into an environmental statement (ES).

1.3 Under the EIA Regulations, effects on landscape must be assessed. Established guidance (LI-IEA, 1995 and LI-IEMA, 2002) makes a distinction between landscape effects and visual effects, the latter being considered a specific subset of the former. *"Landscape effects derive from changes in the physical landscape which may give rise to changes in its character and how this is experienced. This may in turn affect the perceived value ascribed to the landscape. … Visual effects relate to the changes that arise in the composition of available views as a result of changes to the landscape, to people's responses to the changes, and to the overall effects with respect to visual amenity"* (LI-IEMA, 2002). In this report the focus is mainly on the visual effects for the reasons discussed below.

1.4 Scottish Natural Heritage's (SNH) experience is that there can be a great deal of variation in the way that assessment of both visual impact and the significance of visual impact are dealt with in EIA documents, including the appropriate distance for Zone of Visual Influence (ZVI) surveys. The latter attracts a degree of contention amongst some developers and landscape professionals. There is therefore a need for some independent opinion on all these aspects.

1.5 The brief for the current study (Appendix 4) therefore required that it address the following aims:

- to identify any relevant work on visibility, visual impact and significance
- to investigate visibility of existing windfarms
- to compare as-built visibility with estimates of visibility in ESs
- to draw conclusions about appropriate distances for ZVI in different circumstances

1.6 A series of research questions has therefore been posed in order to address these aims:

- What research, policy, guidance and opinions exist on issues related to the assessment of the magnitude and significance of the visual effects of windfarms?
- Is this literature consistent, and if not, what are the sources of and details of any differences?
- What are the key factors that affect visual effects and the assessment of those effects?
- What is the visibility of existing windfarms, and is this real-life visibility as predicted by the literature and as predicted in EIA? If not, why not?

- Based on the answers to those questions, can recommendations be made for best practice with regard to visual impact assessment within EIA?

1.7 This report is divided into six main sections as follows:

- The methodology and approach used for the study are described in section 2.
- Background research is described in section 3.
- Survey and analysis of eight case-study sites are described and analysed in section 4.
- An analysis of the overall survey is described in section 5.
- Discussion of the overall findings of the study appears in section 6.
- Recommendations for Best Practice Guidelines are summarised in section 7.

Table 1: Case Study Windfarms

Windfarm *	Local Planning Authority	SNH Office	OS Sheet/ Grid Reference	Location
(1) Beinn an Tuirc, Kintyre (2001)	Argyll & Bute Council	Argyll & Stirling	68/NR 753361	Centre/East of Kintyre
(2) Beinn Ghlas, Oban (1999)	Argyll & Bute Council	Argyll & Stirling	49/NM 980257	5km south of Taynuilt, 10 km east of Oban
(3) Deucheran Hill, Kintyre (2001)	Argyll & Bute Council	Argyll & Stirling	62/NR 760440	Centre/East of Kintyre
(4) Dun Law (Soutra Hill), Borders (2000)	Scottish Borders Council	Forth & Borders	66/NT 465575	South of Soutra and north west of Lauder
(5) Hagshaw Hill, Douglas (1995)	South Lanarkshire Council	Strathclyde & Ayrshire	71/NS 790307	4km west of Douglas
(6) Hare Hill, Ayrshire (2000)	East Ayrshire Council	Strathclyde & Ayrshire	71/NS 655098	Near New Cumnock
(7) Novar, Dingwall (1997)	The Highland Council	East Highland	20/21/NH 555715	6km north west of Evanton
(8) Windy Standard, Galloway (1996)	Dumfries & Galloway Council	Dumfries & Galloway	77/NS 615015	9km north east of Carsphairn and east of Loch Doon

* The date given is when the windfarm was built and/or commissioned.

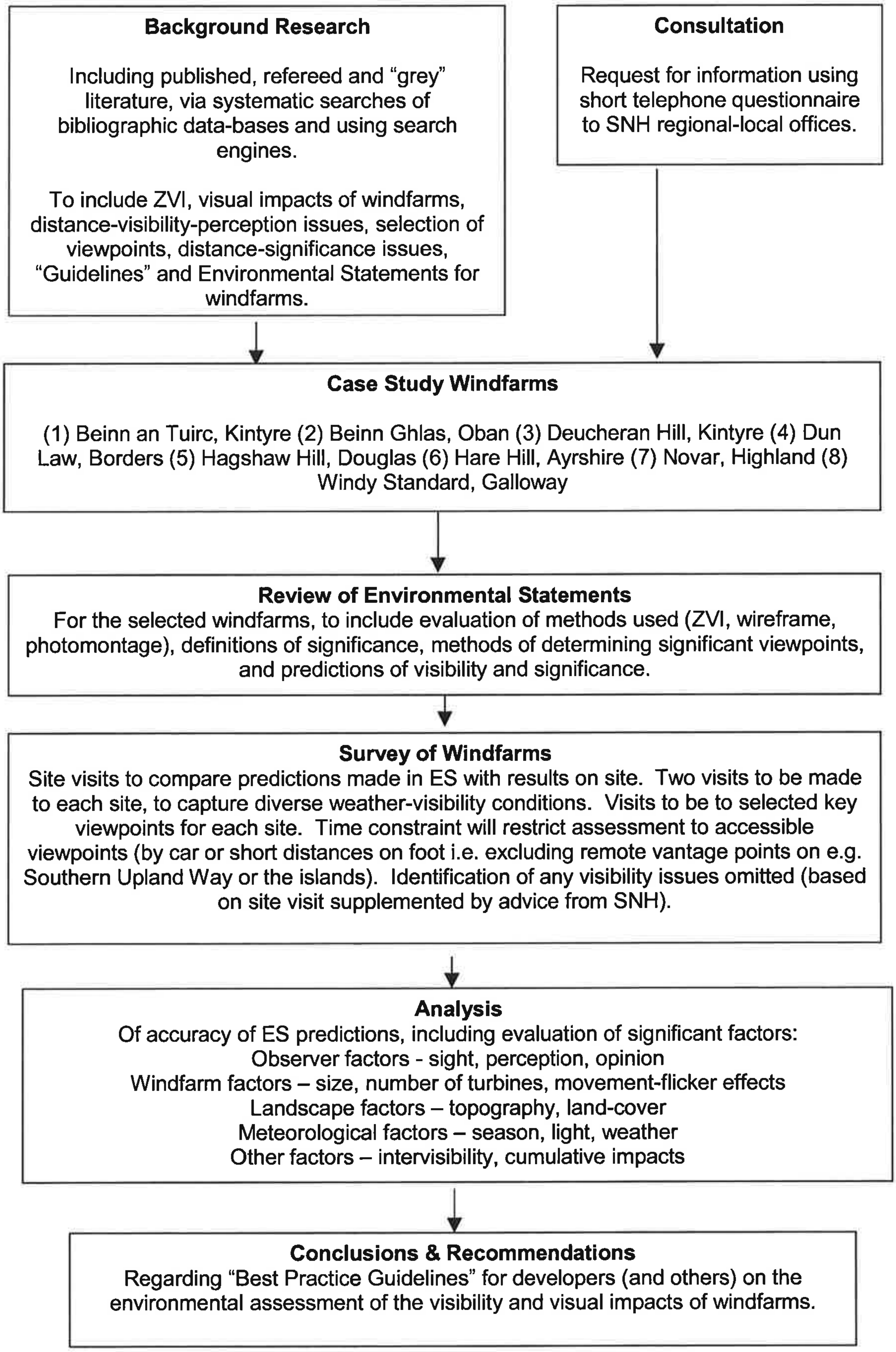
2 METHODOLOGY

2.1.1 The project has followed the requirements and guidance of the brief in all key respects and proceeded as follows (Figure 1).

2.2 Background Research

2.2.1 Both published and grey literature[1] on relevant topics was reviewed. The World Wide Web was searched for access to a wide range of unpublished guidance, opinion and comment. Although the primary focus was on Visual Impact Assessment (VIA), there are many other sources concerning renewable energy or wind energy that refer indirectly to technical detail concerning VIA and these have been included wherever relevant.

Figure 1: Project Methodology



2.3 Case Study Sites

2.3.1 The character of the landscape, weather and other environmental effects are important and so the study was required to focus mainly on Scotland. Selection of case study sites was iterative. A first short list was compiled from those windfarms built and operating in Scotland (Appendix to Brief), concentrating on the larger windfarms (in terms of numbers of turbines). Next, the age of the windfarms, the landscape character and the availability of Environmental Statements were examined. A final selection of eight sites was chosen, all in Scotland (Table 1). The ES for each windfarm was obtained through SNH[2] (Appendix 1).

2.4 Case Study Survey and Analysis

2.4.1 An identical survey and analytical procedure has been used at each case study site. First, the Environmental Statement and related or supplementary documents (Appendix 1) were analysed to extract basic information (if present) on the ZVI, viewpoints, visualisations (including photomontages) and terms used to define visual significance. The main focus was on the key elements of the Visual Impact Assessment (VIA) and not on the broader Landscape (including landscape character) Assessment.

2.4.2 Next, a contact within SNH (including some advisors who have since left the organisation) was telephoned to ask about the process of environmental assessment for each case study and to discover information not available from the ES, such as whether a public inquiry was held. Although we began asking for detailed recollection from each contact (for example: Did SNH advise on the precise radius of the ZVI? Were all viewpoints identified by SNH included or were any excluded?), this proved an unrealistic expectation. Contacts quite reasonably could not recall case details from several years previous and were only able to give general comments and recollections. Whilst case details could be extracted from archived SNH files, we did not pursue this due to time constraints. The contacts were able to comment on changes made between the windfarm *"as assessed"* and *"as built"*, but again could not provide site-specific details on turbine re-locations and similar adjustments. In some cases there are significant differences between *"as assessed"* and *"as built"* that have affected our ability to test the accuracy or otherwise of the ES.

2.4.3 Finally, site visits were made during which as many viewpoints as practicable were visited and a comparison made between the appearance of the windfarm on site and the verbal description and photomontage (if any) presented in the ES. Records of the weather, time of day, light levels, visibility etc were made. The site survey protocol was devised and field tested at Dun Law windfarm by all three surveyors, and then revised and refined before being applied at the remaining seven sites. Each site was visited by one of the professional landscape surveyors accompanied by an assistant. The numbers of visits to each viewpoint are noted in Section 4.

2.5 Timetable

2.5.1 Site visits to the case study sites were made on the dates shown in Table 2. Two visits were made to each windfarm, except at Novar where one visit was made.

2.6 Limitations

2.6.1 The study was constrained by time, and by time of year, and these factors must be borne in mind in the interpretation of the results. The whole project was executed over a short period of approximately 8 weeks. Field work was completed during January and February 2002 and so was not able to compare visibility or visual effects over four seasons and during a wide range of light and weather conditions. Although most sites were seen in contrasting weather conditions, it was not possible to ensure that every viewpoint at every case study site was observed in contrasting conditions (for example, overcast and clear skies).

Table 2: Fieldwork Timetable

DATE	DAY	KES	SPJ	JFB
30 Jan	Wednesday	Dun Law	Dun Law	Dun Law
3 Feb	Sunday	Beinn Ghlas		
4 Feb	Monday	Deucheran Hill Beinn An Tuirc		
6 Feb	Wednesday		Hare Hill Hagshaw Hill	
7 Feb	Thursday		Windy Standard	
9 Feb	Saturday			Novar
13 Feb	Wednesday		Windy Standard	
14 Feb	Thursday		Hare Hill Hagshaw Hill	Dun Law
17 Feb	Sunday	Deucheran Hill Beinn An Tuirc		
18 Feb	Monday	Beinn Ghlas		

2.6.2 It was not practical to visit every viewpoint in every ES; inaccessible or remote viewpoints (such as on islands, at the tops of mountains or hills or in remote walking terrain) were in general omitted from the study. Particular case study site limitations are mentioned in section 4 and may affect the comprehensiveness of the diagnosis for individual windfarms. Adverse weather conditions were a significant constraint in Kintyre. However, overall the study team assessed 70 viewpoints and made 113 individual viewpoint assessments; the more generalised diagnoses and conclusions from these pooled results are therefore more robust, limited only by the seasonal constraints.

3 BACKGROUND RESEARCH

3.1 Guidelines on Windfarm Development

3.1.1 We have reviewed a range of guidelines on windfarm development. There is universal acknowledgement that visual effects are important, that they depend on distance, size, visibility and other factors, and on both landscape and visual receptors. Whilst there is some evidence to suggest a degree of professional landscape consensus on VIA and significance, there is extremely diverse and subjective opinion among other stakeholder groups. Some guidelines quote specific distances for recommended ZVI or for the relative impacts (and by implication significance) of visual effects in relation to distance. Some guidance appears to be re-cycling guidance from other sources and justification for any specific distances quoted in these documents is rare. In most cases any distance-effect guidance is not related directly to or varied with the size or height of turbine towers, but appears to be based on first-generation windfarms with tower heights (to hub/nacelle) of 25-30 m approximately (40 – 55 m overall).

3.1.2 The latest version of National Planning Policy Guidance 6: Renewable Energy Development (Scottish Executive, 2001) sets out broad policy but contains no detailed technical advice concerning the assessment of landscape or visual effects (but see below). Similarly, Department of the Environment (1993)(Planning Policy Guidance 23) is generic but non-specific, although it does recommend light grey/white colours as most suitable for towers, nacelles and blades in Northern Europe. Department of the Environment (1995) quotes as an example that the zone of visual influence for a particular windfarm development in Britain has been calculated to be approximately 10 miles (16 km), but without any detail. Scottish Executive (2002)(Planning Advice Note 45) offers the following general guide (Table 3) to the effect that distance has on the perception of a windfarm development in an open landscape (without relating this to tower height, but having earlier referred to turbines of tower height >70m and rotor diameters of >80m):

Table 3: General Perception of a Wind Farm in an Open Landscape

	Perception
Up to 2 kms	Likely to be a prominent feature
2-5 kms	Relatively prominent
5-15 kms	Only prominent in clear visibility – seen as part of the wider landscape
15-30 kms	Only seen in very clear visibility – a minor element in the landscape

Source: PAN 45 (revised 2002): Renewable Energy Technologies.

3.1.3 A similar table appeared in the Draft NPPG6 Consultation Document (2000), and the comments made on that Draft are of interest. For example, the British Wind Energy Association (BWEA) asked for the term *"impact"* to be replaced by *"effect";* argued that the table of perceptions of impact was prejudicial and asked for its removal; and offered that *"significant visual effects of wind turbines are only experienced within 5 km; beyond 15 km wind turbines can generally only be seen in very clear visibility and even when visible are likely to be a minor element in the landscape"* (Powergen Renewables made essentially the same argument).

3.1.4 Other consultees referred to the fact that turbines are increasing in size; that the Novar windfarm is clearly visible at 30 km; preferred a recommendation of semi-matt to matt surfacing for towers; and raised the issue of cumulative effects. Several consultees referred to the Sinclair-Thomas Matrix (see section 3.7 and Table 4) without identifying its source, pedigree or publication. As a result of these consultations, almost all reference to particulars was removed from the final version of NPPG6. Some details do however reappear in PAN45, but the word *"dominant"* which appeared in the table in NPPG6 Consultation Draft is changed to *"prominent"* in the table in PAN45 (above).

3.1.5 Scottish Natural Heritage (2001) is the most detailed of any statutory agency guidance available or published. Whilst it contains detailed information on issues of siting and design, and the processes of site planning, it also contains a specific recommendation that a ZVI should usually extend to at least 25 km. The Countryside Council for Wales (1999) specifies a ZVI of at least 10 km from the site (for wind turbine proposals) and up to 20 km on the fringes of National Parks and Areas of Outstanding Natural Beauty (AoNB) and in areas likely to be seen from such distances. Countryside Commission (1991) suggests an outer limit of 10 – 15 km for ZVI. There is no up-to-date Countryside Agency guidance in existence but we understand it is in preparation.

3.1.6 It is likely that much local government guidance exists, but a comprehensive review would have required letters or questionnaires to each organisation; a small selection available on the www is noted here. Cornwall County Council (no date) is general development guidance and is based on Landscape Institute - Institute of Environmental Assessment (LI-IEA)(1995). It combines the concepts of impact magnitude and receptor sensitivity (both *"landscape"* and *"viewer"* for landscape and visual respectively) and then offers two matrix tables for evaluating landscape and visual significance.

3.1.7 Specifically for windfarms, Moray Council (2001) recommends the use in EIA of a ZVI map and viewpoint analysis based on wireline diagrams and photomontage without specifying any distance or technical detail for these. Cornwall County Council (1996) (Appendix A: Visual Impact Assessment of Delabole Wind Farm) describes how this project (which began operation in December 1991, comprising 10 No 400 kW turbines, each 40.4 m high inclusive), was assessed using a ZVI of 7.5 km and based on the nacelle height only (32 m).

3.1.8 South Norfolk District Council (2000) (Supplementary Planning Guidance) is more explicit, and contains the following specific guidance (extract)(although the South Norfolk topography and landscape character are very different to much of Scotland): *"The following seven general principles … should be met if the visual impact of any proposal is to be minimised: … ii) Where a proposal lies within 5km of the Broads Authority Executive Area boundary, it would only be acceptable if it was demonstrably capable of locating without visual intrusion to the Broads; … vi) Proposals should be spaced at not less than 5km intervals from each other in order to prevent substantial adverse cumulative impacts which might exceed the capacity of the landscape to accommodate wind developments; …"*. The SPG also recommends that any visual assessment is made on a 20km radius of the proposed large turbines in its zone of visual influence.

3.1.9 Cumbria County Council (1999) is the most detailed local government guidance we have identified. It is based on turbine heights to a maximum of 60 m and recommends a basic ZVI of 20 km and the visualisation of key viewpoints within 10 km. It also addresses cumulative effects, recommending such assessment for windfarms within 20 km of each other, and contains a range of further detailed guidance on both landscape and visual impact assessment.

3.1.10 The British Wind Energy Association (1994) suggests that the ZVI should be defined within a radius agreed with the local planning authority but contains no specifics concerning ZVI or other visual assessment tools.

3.1.11 The Campaign for the Protection of Rural Wales (CPRW)(1999) draws attention to the progressive increase in installed capacity and size of individual towers between 1991 to 1998 of from around 300 kW (41.5 m) to 600 kW (60 m) and notes that future increases will come from higher capacity machines of 1.5 MW (c 95 m) or more and that due to their extended threshold of visual intrusion, their impact would not be correspondingly diminished and would be considerably intensified at closer range. CPRW has argued that 95 m turbines could be visually intrusive at a 12 km radius and readily discernible at 22 km (Sinclair, 2001, discussed further at sections 3.7 and 6.2) so that CPRW recommend a *"radius of visual impact analysis of 30 km compared with 20 km for the current typical 55 m turbines"*. They note the potential siting of turbines offshore and call for this to be at non-intrusive distances from the coast (more than 10 km and preferably 15 km). CPRW state that 60 m turbines can be visually significant within a 15 km radius and forecast 20 km for 95 m turbines. Thomas (1996) argues for 20 km or more (ZVI) for large-scale developments and the landscape terrain of the Mid Wales upland plateaux.

3.1.12 Although the project has not been able to review international guidance, we did note that guidance from New Zealand (EECA, 1995) explicitly omits detailed recommendations for assessing visual effects and argues that *"each development will need to be considered on its merits in terms of site and locality-specific considerations such as distance, back-drop, landscape scale and number of potential viewers"*.

3.2 Research and Development Studies

3.2.1 Reference to ZVI and visual significance is contained in several national, supra-national and international research and development reports, some focused on wind power and some considering renewables in general.

3.2.2 AEA Technology plc (AEAT)(1998) is part of a study attempting to produce an overall valuation (or cost-benefit analysis) for the whole wind fuel cycle, including monetary estimates of the aggregate visual amenity damage of windfarms. It offers an *"Impact Pathway for Visual Intrusion"* and refers to the *"visual burden"* and the *"objective impact"* of that burden, and then contrasts this with the *"perceived impact"* which is influenced by attitudes and the existing land form and scenery. It refers to ZVI as zones of visual intrusion and notes that *"It can be concluded that there is unlikely to be any significant visual impact at a range of greater than 6 km"*, although this conclusion is not justified.

3.2.3 The International Energy Agency (IEA)(1998) uses similar language to AEAT (1998), emphasising the difference between the visual burden (comprised of the height, shape, form, colour and number of turbines themselves) and human responses to it. It goes on to state that beyond 20 km the turbines will not be visible to the human eye (apparently based on towers of *"40 m height with the blades adding another 20 m"*) and that in practice there are very small or negligible effects on visual amenity beyond 12 km. *"Between 6-12 km, the towers are indistinct and the rotor movement will be visible only in good conditions. Therefore, the visual amenity effects are generally concentrated within 6 km of the wind farm"* (the latter conclusions appear to be based on Eyre, 1995).

3.2.4 The European Commission (EC)(1997) (also based extensively on Eyre, 1995) states that *"a 1.5 MW turbine looks little different from a 500 kW machine, so the continuing trend towards larger wind turbines may, paradoxically, reduce the subjective visual effect of a given installed capacity"*. Although not explained, this may be a reference to the suggestion that any enlargement is very difficult to perceive if there are few comparable scale indicators in the landscape, although this ignores the effect of height on the visibility distance and also ignores the effects of magnitude near to a tower. It notes that *"two bladed rotors appear to tilt with respect to the horizon whereas three bladed rotors appear to revolve and are therefore more calm and pleasant to view"* but it makes no reference to distance effects.

3.2.5 Soerensen & Hansen (2001) focus on offshore windfarms and note that it is assumed that the visual impact to viewers at sea level is negligible when the farms are located more than 8 km from shore. With distances larger than 45 km, the visibility will be almost zero due to the curvature of the earth's surface. These distances will be greater where there are elevated viewpoints but may also be severely reduced depending on the atmospheric clarity. They quote a study in Germany where visual impact would not be regarded as a problem at all if the farms were placed 15 km from shore. CADDET (2001) reports briefly on studies for two offshore windfarms in Denmark. The Horns Rev windfarm (eighty 2 MW turbines in a grid pattern 14-20 km offshore) *"will be visible from shore on a very clear day"* but *"the dominance of the windfarm in the landscape as viewed from the shore will be so modest that the impact is likely to be minimal"*.

3.2.6 Quantitative research on ZVI, distance and visual impacts appears less common. Hull & Bishop (1988) examined the effects of electricity pylons on the landscape and in particular the relationship between distance and scenic impact. Based on the use of photographs and a rating of *"scenic beauty"* on a ten-point scale, they found that the visual impact decreases rapidly as distance increases. Most of the impact occurred in the 100 m to 1 km range, and the impact at 500 m was about 25% of the maximum, whilst at 1km it was 10%. The tower's scenic impact was also influenced by the landscape surrounding the tower. It appeared that towers had less impact in more complex scenes, especially at larger distances, presumably because the tower becomes less of a focal point and the observer's attention is diverted by the complexity of the scene.

3.2.7 Recent research by Bishop (in press) used animated computer simulations in paired comparisons of scenes, with and without a wind turbine, to test the ability of respondents (students) to first detect, then recognize, and then judge the impact of the turbine in relation to distance, contrast and atmospheric conditions (drawing on detailed equations from Shang & Bishop, 2000). The test turbine was 63 m in height (to rotor tip). His key conclusions (drawn from a Draft report by the Windfarm Steering Committee, Victoria, Australia, supplied by Nigel Buchan) are that:

- Recognition was only made by 5% of respondents at 30 km distance
- Recognition was only made by 10% of respondents at 20 km distance
- The most significant drop in recognition rates occurred at 8-12 km in clear air
- The most significant drop in recognition rates occurred at 7-9 km in light haze
- Visual impact drops rapidly at approximately 4 km and is <10% at 6 km in clear air
- Visual impact in light haze is not greatly different. A rapid decrease in visual impact begins at under 4 km and is <10% at 5 km
- Low contrast in light haze reduces the distance thresholds by 20%
- High contrast can dramatically increase the potential impact of white towers
- Ratings are highly sensitive to changing atmospheric conditions.

Given the size of the test turbine, these controlled and simulated findings are not dissimilar to the empirical results reported in Stevenson & Griffiths (1994) and Turnbull Jeffrey Partnership (1997)(Appendix 5), discussed below.

3.2.8 Research has been carried out, mainly in the USA and Denmark, into observer attitudes to the symbolism and meaning of wind energy (e.g. Thayer & Freeman, 1987; Wolsink, 1989, 1990), and into design issues such as scale, visibility, dominance, coherence, diversity, and the effects of site layouts (e.g. Bergsjo et al, 1982), but this research does not contain details that would inform the present study. For example, in some research smaller turbines appeared to have a lower effect than larger turbines, but this was a small preference compared to the effect of the number of units, so that people preferred fewer larger turbines. One potentially contradictory piece of research evidence is that on the one hand people find moving rotors more attractive than static ones, so that motion has been equated with lower perceived visual impact by some commentators, whilst elsewhere there appears to be agreement that movement makes the turbines more conspicuous than they would otherwise be.

3.2.9 Atkins Planning (1986) carried out a scoping study for the Energy Technology Support Unit on the visual impact of large wind turbines (up to 50 m high), which contains a range of sound, general observations and conclusions, although the penetration of such commissioned reports into wider circulation and practice is less clear. For example, we found no reference to that report, or Stevenson & Griffiths (1994), discussed below, in any of the ESs examined for the current study (except for an indirect reference to Stevenson & Griffiths in the Dun Law ES).

3.2.10 Stevenson & Griffiths (1994) carried out a comprehensive post-development audit of eight windfarms in England and Wales, visiting each windfarm on up to four occasions throughout the year. Six viewpoints were analysed at each site at distances up to 20 km, although in practice topography and visibility restricted views from 10 km and prevented views beyond 16 km for all sites. Photographs used a medium format camera (image area 4.5 x 6 cm) and a 80 mm focal length lens *"to provide an image closest to that of the human eye"*. The case study sites included turbines ranging in maximum height from 40.0 to 61.5 (but six were within the range 40.0 – 43.5 m) and in a variety of landscape settings.

3.2.11 Drawing on previous literature, and their own judgements, they devised an impact-zoning schema as follows:

> *"i) Visually dominant – the turbines dominate the field of view and appear large scale. The character of the immediate area is substantially altered and the movement of the rotor blades is obvious.*
>
> *ii) Visually Intrusive – The turbines appear fairly large in scale, and an important element in the landscape. However, they do not necessarily dominate the field of view. Blade movements are clearly visible and can attract the eye.*
>
> *iii) Noticeable – The turbines are clearly visible but not intrusive. The windfarm is noticeable as an element in the landscape. Movement is visible in good visibility but the turbines appear small in the overall view. Some change to the landscape setting is likely.*
>
> *iv) Element within Distant Landscape – Turbines are indistinct and form minor insignificant elements within a broader landscape. Movement of blades is generally indiscernible. The apparent size of the turbines is very small".*

3.2.12 Their main conclusions are that

- *In most situations turbines dominated the view up to a distance of 2 km (zone (i)).*
- *Turbines appear visually instrusive at distances between 1 and 4.5 km in average to good visibility (zone (ii)).*
- *Turbines are noticeable, but not intrusive, at distances between 2 and 8 km, depending on atmospheric conditions and other factors (zone (iii)).*
- *Turbines can be seen as indistinct elements within the distant landscapes at distances of over 7 km (zone (iv)).*

3.2.13 They also include further analysis and discussion concerning the effects of atmospheric conditions and seasonal variations, before analysing a number of VIA techniques. For ZVI, they recommend 10 km as suitable in most conditions. For photomontages, they make a number of straightforward recommendations, but in particular note that the size of the original photograph will affect the apparent size of the turbine image, stating that *"where photographs smaller than A3 are used, the turbines on the photomontage appear smaller than in reality"* and *"An A3 size print viewed from approximately 8 " [20 cm] gives an accurate rendition of scale".*

3.2.14 A recent study on ZVI, distance and visibility has been carried out at Hagshaw Hill windfarm for Scottish Power plc, as part of the preparation of the Beinn an Tuirc ES (Turnbull Jeffrey Partnership, 1997). Although we have not been able to examine the full report, we have reproduced a summary of it in Appendix 5 (from Scottish Power, 1997) because it covers similar issues to the present study.

3.2.15 It is evident that there is some research and a wide range of guidance and opinion on the detailed issues of ZVI, distance, visibility and significance for windfarms. Some of the differences identified might be explained by much of the early work having been based on first generation windfarms of a maximum height of from 40 to 55 m. Other differences can be attributed to both the complexity and the subjectivity of the issues, especially concerning visibility, perception and significance. A final influence is probably the desire of one group of windfarm interests to seek to minimise the political, professional and public perception of the potential visual (and landscape) effects of windfarms, and an opposing desire by another group of interests to maximise these perceptions. In practice, those differences must be resolved and decisions made.

3.3 Visual Effects and Design Issues

3.3.1 IEA (1998) notes that stroboscopic effects are minimised by keeping rotation rates below 50 rpm for three-bladed machines (75 rpm for two-bladed machines). The flicker effect (from the effect of sunlight streaming past the rotating turbine blades) has only a short potential duration each day and depends on a number of other criteria. In any event, effects should be minimal at distances greater than 300 m. It also states that *"Visual impacts are only normally important for residents and tourists up to a distance of about 10 km, with the main effects on amenity being concentrated within a few kilometres of the wind farm".*

3.3.2 The Danish Wind Industry Association (2000) offers some simple suggestions regarding design issues, similar to but much less comprehensive than SNH (2001). SNH (no date) remarks that *"experiments in blade colour have shown that pale blue, brown and grey rather than white appear to be more recessive, whilst a matt surface reduces the amount of glint"*, whilst Stanton (1996) argues that the colour used should be white rather than off-white or grey, arguing that this (white) represents a forthright design statement, rather than off-white or grey which may be seen as a form of deception. Stanton argues that white is associated with purity and neutrality, whilst grey appears technically primitive, linked with other industrial elements. Gipe (1995) reviews public opinion surveys and a range of design guidance, based on North American and European experience, to arrive at conclusions not dissimilar to the guidance contained in SNH (2001).

3.3.3 A recent study (European Wind Energy Association, 2000) has examined the colour issue afresh and has explored a wide range of colours, combinations and design approaches – including camouflage, blending and articulation – but the work was restricted to explorations using photomontage and we are not aware of any field testing of different colour combinations. *"The overall conclusion was that graduated colour schemes worked well in all situations, especially helping to "root" the turbines in their setting. In terms of actual colours, "earthy" colour schemes - browns, greens and oranges – were found to tie the turbines to their surroundings more effectively than "airy" blues and greys. Schemes using a range of different grey shades on different turbines in a group, and an idea for "false shadows" – three or four shades of grey in vertical irregular stripes up the tower - were both* *considered visually confusing".* It is not clear from this report whether the issue of visibility and perception in relation to distance was included in this study of colour.

3.4 Visibility and Perception

3.4.1 Viewed by the human eye 1.8 m from the ground across a *"flat"* surface such as the sea, the horizon will be of the order of 6 km distant, due to the curvature of the earth. Viewed at an elevation of 60 m, the horizon will be of the order of 32 km distant and from the top of a 1000 m mountain the horizon will be at a distance of approximately 113 km. A tall structure standing above the horizon would of course increase these distances significantly; for example, for an observer at 1.8 m who is viewing a man-made structure 50 m tall, the effective distance to the horizon is 34 km and for a 100 m structure the distance is 46 km (Miller & Morrice, no date).

3.4.2 However, actual human perception is affected by the acuity of the human eye. In good visibility (visibility is meteorologically defined as the greatest distance at which an object in daylight can be seen and recognised), a pole of 100 mm diameter will become difficult to see at 1 km and a pole of 200 mm diameter will be difficult to see at 2 km. In addition, mist, haze or other atmospheric conditions may significantly affect visibility (Hill et al, 2001). Assuming this relationship is linear, and assuming absolute clarity of view, this suggests that the outer limit of human visibility in clear conditions of a pole (e.g. a notionally cylindrical wind turbine tower) 5000 mm (5 m) in diameter (a representative figure for a 60+ m high tower) will be of the order of 50 km; and the absolute limit of visibility imposed by the limit of the horizon viewed across a flat plane is similar at approximately 46 km.

3.4.3 Although there is frequent reference in ESs to the effect of reduced visibility caused by atmospheric or weather effects, data is rarely used to quantify this effect (the Hare Hill ES is an exception among the case study sites, and Stevenson & Griffiths (1994) also use such data). Such data is available from the Meteorological Office.

3.4.4 Physical visibility is not, of course, the only issue. Human perception is equally important in considerations of if and how a windfarm will be seen. Whole branches of medicine, ophthalmology, psychology and many applied sciences are concerned with perception. Numerous text books provide illustrations of the complexity of perception, including many familiar optical illusions. These issues are critically important in areas such as the design of roads and signage, in the training of airline pilots, the analysis of accidents and the design of machinery. Whilst the thrust of much research is concerned with how people can be deceived or make perceptual misjudgements, there are several key points that we believe may be material to VIA for windfarms.

3.4.5 People perceive size, shape, depth and distance by using many cues, so that context is critically important. When people see partial or incomplete objects, they may mentally *"fill in"* the missing information, so that partial views of turbines may have less effect than imagined. Although people may be able to physically *"see"* an object, inattentional *"blindness"* caused by sensory overload, or a lack of contrast or conspicuousness, can mean they fail to *"perceive"* the object. In a contrary way, large size, movement, brightness and contrast, as well as new, unusual or unexpected features, can draw attention to an object. In all these effects, issues such as experience, familiarity and memory may have an important role to play. Therefore, perception depends on experience, the visual field, attention, background, contrast and expectation, and may be enhanced or suppressed.

3.4.6 Two important issues, depth perception and size constancy, deserve further discussion. At least six monocular cues (cues dependant on one eye only, compared to binocular cues that require both eyes) are recognized as being used in the perception of depth and relative distance. These include (i) interposition (one object partially obscuring another appears nearer), (ii) the relative size of the retinal image (an object of known size is perceived to be further away if the image is smaller), (iii) the height of an object relative to other objects (an object at a lower level is perceived to be nearer), (iv) objects that appear clearly visible are judged to be nearer than others which are less clear, (v) linear perspective (converging lines in the landscape can create this effect), and (vi) movement cues (fast movement is judged nearer than slow movement by a stationary observer). We can therefore surmise that these phenomena will act to increase or decrease the apparent distance of a windfarm from the observer in the landscape.

3.4.7 Constancy is the phenomenon in which the properties of familiar or well-known objects appear to be constant and stable irrespective of the circumstances in which they are viewed. In size constancy, objects are perceived as the same size even when viewed from different distances. This is often illustrated using photographs containing people, but applies with any familiar object – the perception of the size of the people is quite different to their actual size on the photograph. This effect appears to be based on factors such as the relative size of other objects, textures and familiarity (the phenomena of shape, colour and brightness constancy are also well-recognised). We can therefore surmise that on viewing a windfarm in the landscape, a human observer could perceive the turbines to be the same size over a potentially long distance range as their familiarity increases, even if the image sizes (on either the retina or a photographic film) are very different.

3.4.8 The general conclusions to be drawn are that the magnitude or size of windfarm elements, and the distance between them and the viewer, are basic physical measures that affect visibility, but the real issue is human perception of visual effects, and that is not simply a function of size or distance. We say more on factors that we believe increase perception of *"apparent size"*, and factors that decrease it, in sections 5 and 6.2.

3.5 Zone of Visual Influence[3] (ZVI)

3.5.1 The visibility of a windfarm is of course also affected by topography. The concept of the ZVI[4] in professional landscape work originated in the 1970s. Typically, topographic sections would be plotted and sight lines analysed at, say 10^0, intervals. This manual process was and is crude, slow and laborious. Faster and more refined manual techniques were developed using contour maps and templates or overlays. By the mid-1980s, Jarvis (1985) is describing the use of custom-written computer programs to produce ZVI and related visual assessment tools, but one is a program that takes six hours to execute 100,000 sections checking intervisibility; he gives an example of a ZVI covering 20 km^2 based on a 150 m grid.

3.5.2 The rapid development of computing power and capacity, and a parallel decline in relative costs, is of course familiar, so that a typical desk-top personal computer today might have many times the power of the Jarvis machine. However, the programs needed for calculating visual or landscape impacts over large areas have fallen into a no-man's land between Computer Aided Design (CAD) and GIS so that some companies such as TJP Envision (Turnbull Jeffrey Partnership, 1995; McAulay, 1997) have invested much in-house research and development effort in this area. The results are that today such ZVI calculations can be executed rapidly and relatively cheaply in terms of program costs and computing time (although it should be noted that program running times for ZVI calculations are counted in hours, not minutes, and these times increase linearly with the number of turbines and by the square (or worse) as the area of the ZVI increases).

3.5.3 The basic modules needed to calculate a ZVI are now an increasingly standard feature of much GIS software and integrated links to programs for producing wireframes and photomontages are commonplace. Use of a 50m grid, producing greater refinement and resolution, now appears common and standard. However, the rapid changes in the technology and tools that have taken place during the last 10 years inevitably means that some of the early ZVI in windfarm assessment (including the case study sites) are not as sophisticated or extensive as those appearing in current assessments, and this needs to be borne in mind in assessing aspects of the case study sites analysed later.

3.5.4 Hankinson (1999) describes three possible stages or components of a ZVI. First, a desktop study during which an experienced assessor can usually read the local contours from a 1:25,000 or 1:50,000 plan and gain a good idea of the likely extent of visibility. Next, an analysis (computer based) using a digital terrain model (DTM), cross-sections etc is carried out. Finally, site evaluation. She emphasises the distinction to be made between the ZVI (from the desk study and site evaluation) and what she terms the Zone of Theoretical Visibility (ZTV) derived from computer modelling (Hankinson, Box 16.7, page 367). There are two main sources of error in any ZTV.

3.5.5 First, data errors built into the computer program used include the contour intervals in the baseline data, which affect the degree of interpolation used in the program; and the accuracy and reliability of that data (other error refinements include whether the program takes account of the curvature of the earth etc)(Hankinson, Box 16.8, page 369). For example, a ZTV derived from a DTM based on 1:50,000 contour information (10 m contour interval) may be interpolated and rounded to the nearest metre in the program. The *"1 m interpolation"* assumes a straight-line slope between two contours and cannot take account of rocky terrain that can vary by up to 9.9 m without appearing on the 10 m contour base. Purchased data (from Ordnance Survey) and data digitised in-house also all contain inaccuracies or errors.

3.5.6 The second source of error arises because the ZTV is theoretical, that is it usually assumes a perfectly bare and smooth terrain unencumbered by houses, buildings or other structures, vegetation, hedges, woodland and forests. The site evaluation is the opportunity to take account of landform features that do not appear on the ZTV and landscape features that affect visibility such as trees, hedgerows, fences and buildings. Some programs are being developed that allow the introduction of surface features such as tree cover into the computation of ZVI (e.g. Turnbull Jeffrey Partnership, 1995 and illustrated in the Beinn An Tuirc ES). The key conclusion offered by Hankinson is that users and readers of ZTV/ZVI in environmental statements need to be alert to and explicit about the inherent sources of error, assumptions and limitations of the tools.

3.5.7 Current EIA DTM and ZVI calculations appear to be based on the use of Ordnance Survey (OS) topographic information, which is available for commercial and business use as Land-Form PROFILE (from 1:10,000 scale) or Land-Form PANORAMA (from 1:50,000 scale). The degree of detail, error and cost (at February 2002) of these products are significantly different. PANORAMA is available as 20 km x 20 km tiles (812 tiles cover Great Britain) that cost £10 each. Hence the digital or contour data for a windfarm in the centre of a tile might cost only £10 (to produce a 20 x 20 km ZVI), or £40 in the event that the proposed site fell at the corner of a tile. However, it should be noted that contour intervals are at 10 m and the error is ± 3 m, with a 50 m cell size. When details are stated in the case study ESs, the data set most commonly used is 1:50,000.

3.5.8 PROFILE has contour intervals at 5 m (±1 m) or 10 m (±1.8 m)(cell size 5 m) but each tile only covers 5 x 5 km and more than 10,000 tiles cover Great Britain. The cost per tile varies depending on quantity (e.g. decreasing from £100 - £70 - £42 - £25 per tile). The result is that 9 tiles cover an area 15 x 15 km, 16 tiles cover 20 x 20 km, 25 tiles cover 25 x 25 km and 36 tiles cover 30 x 30 km. The raw data costs are then, respectively, £900 - £1120 - £1750 - £2520. The practical result of this is that we are not aware that PROFILE data is used in ZVI for windfarms.

3.6 The Accuracy of ZVI Predictions

3.6.1 Fisher (1995) has analysed the effects of data errors on viewsheds calculated by GIS programs and shown that the calculations are extremely sensitive to small errors in the data, and to the resolution of the data and errors in viewer location and elevation. Other studies have shown that a viewshed calculated using the same data but with eight different GIS programs can produce eight different results. The direction of such errors – to either over or underestimate the ZVI – is unclear and is not obviously unidirectional. Such errors and effects are well researched and familiar in the detailed GIS technical literature but may not be highlighted in commercial programs or reported in practice reports, which reinforces the conclusion that the ZVI reported in most studies should be described as the Zone of Theoretical Visibility or the *"probable viewshed"*[5], and be subject to subsequent field testing and verification.

3.6.2 Prediction is at the heart of EIA and the general scarcity of detailed post-development audits by which the accuracy of impact predictions might be judged is surprising and regrettable, although some studies are now appearing. A general study by Wood et al (2000) across a range of project types and all (EU Directive) impact categories found that for landscape and visual effects, 40% of predictions were accurate, almost 40% were nearly accurate and approximately 20% were inaccurate.

3.6.3 Wood (1999) has made a detailed audit of the accuracy of a number of EIA predictions, including a ZVI for a clinical waste incinerator in Leeds. He discovered that for the incinerator stack, the ZVI overestimated the spatial extent of project visibility, due mainly to the use of a worst-case and simple topographic model that took no account of the heterogeneous and complex natural and man-made elements in the surrounding landscape.

3.6.4 In a further study (Wood, 2000) he audited the ZVI for four developed projects, including the Ovenden Moor windfarm near Halifax (ES dated 1991) in which the ZVI was determined by desk-study and not by the use of a topographic model or DTM. Overall he found a relatively close match between the predicted and actual ZVI, but including many errors of detail (large discrepancies were revealed for the other projects he analysed). He attributes the detailed errors in part to the fact that the ZVI was based on the tower height excluding the rotors, so that there was systematic under-prediction of visibility at the fringes of the ZVI; however, the general accuracy achieved using a coarse technique based on terrain only is probably due to the homogeneous landscape of the windfarm, dominated by open moorland with virtually no screening vegetation or buildings.

3.7 Visual Effect, Distance and Impacts

3.7.1 The most explicit and structured recommendations on the specific issue of the potential visual impact of wind turbines in relation to distance appears to be the self-styled Sinclair-Thomas Matrix (CPRW, 1999; Sinclair, 2001). This has its origins in a table produced in 1996 by a planning officer of Powys County Council (Thomas) and since revised and updated by a consultant (Sinclair). Assuming unimpeded, good visibility, Thomas defined 9 distance bands (A-I) and classified these with a visual impact rating from *"dominant"* (A) to *"negligible"* (I). This initial table was devised based on the 25 and 31 m hub machines built at Cemaes and Llandinam (Wales) in 1992. At that time, Thomas concluded that *"15 km is considered to be the appropriate radius distance for study"* and according to Sinclair, this became recognised as the norm for ZVI in EIA (apparently irrespective of turbine size).

3.7.2 Sinclair repeated the analysis, concluded that the Thomas distance bands were *"rather conservative",* and revised them upwards. Sinclair then extended the approach to viewpoints around other windfarms, including larger (72 m) turbines at Great Eppleton (Durham), and also projected or extrapolated the recommendations to encompass 90-100 m turbines. Both authors acknowledge that the Matrix is a general guide, especially at the margins of each band, and recognise the important influences of local conditions, viewing direction, turbine angle and the scale and nature of the landscape context. The resulting Sinclair-Thomas Matrix is reproduced in Table 4 (from Sinclair, 2001)(it is repeated in slightly different form in CPRW, 1999).

3.7.3 We have not been able to determine if this Matrix is in widespread use, or if it has been accepted, challenged or revised at public inquiries (although we are aware that it has been presented and used at public inquiries). It is not referred to in any ES we have examined (although many of these pre-date production of the Matrix) and it is not referred to in any of the literature we have examined, barring its citation in CPRW (1999) and Sinclair (2001) and mention in the consultation responses to Draft NPPG6.

3.7.4 Our initial diagnosis is that the Matrix raises several issues and difficulties of interpretation, including the fact that it is based on the professional (if experienced) opinion of two people, and that it sometimes conflates two separate points – magnitude and significance – for example in using the value-laden word *"intrusive"* in Band C. Such

Table 4: The Thomas and Sinclair-Thomas Matrices

THE THOMAS AND SINCLAIR-THOMAS MATRICES (section A)
to estimate the potential visual impact of different sizes of wind turbines

Overall height of turbines (m) >>>		41-45	41-48	53-57	72-74
Descriptors	Band	Thomas Matrix		Sinclair-Thomas Matrix	
		Original	Revised		
		Approximate distance range (km)			
Dominant impact due to large scale, movement, proximity and number	A	0-2	0-2	0-2.5	0-3
Major impact due to proximity: capable of dominating landscape	B	2-3	2-4	2.5-5	3-6
Clearly visible with moderate impact: potentially intrusive	C	3-4	4-6	5-8	6-10
Clearly visible with moderate impact: becoming less distinct	D	4-6	6-9	8-11	10-14
Less distinct: size much reduced but movement still discernible	E	6-10	9-13	11-15	14-18
Low impact, movement noticeable in good light: becoming components in overall landscape	F	10-12	13-16	15-19	18-23
Becoming indistinct with negligible impact on the wider landscape	G	12-18	16-21	19-25	23-30
Noticeable in good light but negligible impact	H	18-20	21-25	25-30	30-35
Negligible or no impact	I	20	25	30	35
Suggested radius for ZVI analysis		15	At least Junction of Band F and Band G; extended to reflect local circumstances or if cumulative impact may be involved		

THE SINCLAIR-THOMAS MATRICES (section B)
Potential visual impact matrix for wind turbines of 72-74m overall height (field observation) and 90-100m (extrapolated). Distances in km

Band		72-74m	90-100m	Magnitude (subject to other factors)	Significance
A	Dominant impact due to large scale, movement, proximity and number	0 - 3	0 - 4	High	Potential for independent significant impact
B	Major impact due to proximity: capable of dominating landscape	3 - 6	4 - 8	Medium/High	
C	Clearly visible with moderate impact: potentially intrusive	6 - 10	8 - 13	Medium	Potential for contributory significant impact
D	Clearly visible with moderate impact: becoming less distinct	10 – 14	13 - 18		
E	Less distinct: size much reduced but movement still discernible	14 – 18	18 - 23	Low/Medium	Potential for ancillary non-significant impact: only becoming significant if numerous or cumulative with other installations
F	Low impact, movement noticeable in good light: becoming components in overall landscape	18 – 23	23 - 30	Low	
Approximate recommended threshold for ZVI analysis					
G	Becoming indistinct with negligible impact on the wider landscape	23 –30	30 - 38	Negligible	
H	Noticeable in good light but negligible impact	30 -35	38 - 45		
I	Negligible or no impact	35+	45 +		

Source: Sinclair (2001)

confusion persists in the tables because Table section A does not have the same columns as Table section B, where in the latter, magnitude and significance are separated. However, we have attempted to apply the Matrix during the case study visits and this is discussed further at section 6.2.

3.8 Photomontage

3.8.1 The illustration of potential landscape or visual impacts using photographs, wireframes and photomontage is now commonplace and expected in EIA, and videomontage may soon become more widespread. The development of these and related visual or virtual reality techniques is now an area of major research and development interest. The issues are inevitably complex. Perkins (1992), for example, asks what influences *"perceived realism"*? Whilst image quality may be important, he points out that realism may be affected by the context or content of the image portrayed. A technically accurate and precise photomontage that placed Edinburgh Castle on Kintyre will not be perceived as realistic for obvious contextual reasons. Although less extreme, a proposed windfarm placed in a remote landscape may be perceived by a viewer as containing an element of incongruity and inappropriateness that will affect their evaluation of the visualisation.

3.8.2 It should also be obvious that the human eye sees differently than a camera lens, both optically and figuratively. The focusing mechanisms of human eyes and camera lenses are different; human eyes move, and the brain integrates a complex mental image; human vision is binocular and dynamic, compared to a camera that tends to flatten an image. These and related issues of perception have already been referred to in section 3.4.

3.8.3 It therefore follows that when the common recommendation is made that a 50mm standard lens (35mm camera) most closely approximates to the human eye, this *"standard"* or *"normality"* is relative and qualified (and this definition of *"normality"* is challenged in some specialised photographic literature). If a wide-angle lens is used, for example for panoramic effect, the size of the subject in the foreground will increase in relation to the background; in the case of windfarms in a landscape scene, the effect will be to under-represent the relative size of the towers and under-estimate their visual magnitude.

3.8.4 Cornwall County Council (1996) (Appendix A: Visual Impact Assessment of Delabole Wind Farm) notes that *"for photographs taken within 500 m of the site, a standard (75 mm) lens was used on a medium format camera. For all the others, a 200 mm lens was used. The combination of the two sizes of lens seemed to provide the most realistic image of the turbines/wind farm in the landscape".* This is an unusual set of conclusions that we have not been able to verify.

3.8.5 Shuttleworth (1980) is a relatively early example of a continuing body of work using photographs as surrogates for real landscapes, although the work is mainly concerned with landscape character and quality assessment, and not visualisation and realism *per se*. He points out the obvious differences and distortions between the two-dimensional image and the three-dimensional perception of a scene or viewpoint by a human observer. He stresses the need to insert aids in photographs to provide constancy scaling and perspective resolution. Perceptual ambiguity can be reduced if the field of view is as large as possible and if depth cues (paragraph 3.4.6) are deliberately included in the photograph. Interestingly, Shuttleworth found that photographic simulation was most reliable in dealing with the overall perception of the landscape, but less reliable when dealing with perception of detailed elements and characteristics in the landscape.

3.8.6 LI-IEA (1995)(and updated in LI-IEMA, 2002) contains general guidelines on photomontage (and CAD, including ZVI) but contains little technical detail for photographs or

ZVI. Sparkes & Kidner (1996) remark that photomontages are not cheap to produce, are fundamentally inflexible and of course cannot depict movement. They also suggest they can give a pessimistic impression of a development because for the turbines to be visible on the photograph, they tend to be painted in white or given a black outline, resulting in them having a high degree of contrast compared to expectations in reality. This was not our experience during the case-study research (paragraphs 6.1.16-6.1.21).

3.9 Significance

3.9.1 Prediction and then evaluation of significance are at the heart of EIA. All developments produce effects, which may be positive or negative. All developments produce effects which vary in size or magnitude and such variation may be spatial or temporal or both. It may or may not be feasible, technically or economically, to reduce or mitigate such effects. After mitigation, an effect may still be significant because of size, location, type, risk or related factors. Such significance may be temporary or permanent, reversible or irreversible. Significance is therefore always relative and context-specific, which may be local, regional, national, supra-national or international.

3.9.2 Ultimately, significant is whatever individuals, people, organisations, institutions, society and/or policy say is significant – it is a human evaluative and subjective judgement on which there may or may not be consensus. It is therefore important that two separate but critical characteristics of all effects – magnitude and significance – are clearly distinguished.

3.9.3 The wide diversity of opinion evident on the merits or otherwise of windfarms, including their visual effects, and the implicit expression of opinion on significance within that diversity of opinion, should not be surprising. It is therefore also important that in any ES, the foundations and assumptions on which significance is based must be clear and explicit.

3.9.4 Remarkably, perhaps, significance is little researched in relation to visual impacts. Exceptions are Bishop (in press), referred to at paragraph 3.2.7, and Stamps (1997), who offers a detailed review of the issue (including the related issues of design guidance and design review) and a theoretical and methodological model for assessment based on a statistical analysis of human preference ratings for before and after scenes. However, his focus, and his case-studies, are based on urban design issues in California.

3.9.5 The legal and regulatory starting points in Scotland are the Environmental Impact Assessment (Scotland) Regulations 1999 (Circular 15/1999) which require that *"the aspects of the environment likely to be significantly affected by the development"* are included in the ES, but offer no specific guidance on definitions of significant. The guidance states that impacts are more likely to be significant in sensitive locations, examples of which are listed. In the case of windfarms, the *"likelihood of significant effects will generally depend upon the scale of the development, and its visual impact ... EIA is more likely to be required for commercial developments of five or more turbines, or more than five MW of new generating capacity".* The complementary PAN58 (Environmental Impact Assessment)(Scottish Executive, 1999) does not offer specific guidance on definitions of significance.

3.9.6 Specifically for landscape and visual effects, the LI-IEA Guidelines (LI-IEA, 1995) are widely referred to and appear to have achieved status as a de-facto national standard. However, the Landscape Institute has produced an advice note[6] that emphasises that the Guidelines are general, non-prescriptive, and were not intended to offer a preferred methodology. In particular the note is at pains to point out that the examples given (Figure 3.1 [classification of sensitive landscape/visual receptors and impact magnitude] and 3.2 [the relationship between sensitivity and magnitude in defining significance thresholds]) are illustrative only. *"On no account should they be linked and then applied in the assessment of a proposed development. As paragraph 3.62 states: "... it must be stressed that this is only* *an example. Every project will require its own set of criteria and thresholds, tailored to suit local conditions and circumstances ...""*.

3.9.7 In the second edition of this guidance (LI-IEMA, 2002), the advice given is less prescriptive and stress is laid on "*informed and well-reasoned judgement supported by thorough justification*" as well as the need to consider issues, including significance, on a case-by-case basis (Box 7.3, LI-IEMA, 2002). Broad professional landscape consensus does exist, as the similarities in the examples given in Appendix 6 of LI-IEMA (2002) show, but detailed differences of interpretation are inevitable. Despite arguments to the contrary that appear in some of the ESs we have examined, there appears to be no statutory guidance on a definition or definitions of significance. Guidance states that potentially significant effects may occur in some sensitive locations (landscapes), with the implication that an effect of a defined magnitude in one location could be significant but that the same effect in another, less sensitive, location would not.

3.9.8 The value judgement of significance is played out through development control and the public inquiry system, in that decisions of re-design, re-siting of turbines, planning conditions and even refusal of permission can be said to be the result of statutory, public and political debate on which visual effects are and are not judged to be significant. It would be an interesting and informative study to test these ideas through a detailed examination of development control and public inquiry case-law, but this was beyond the scope of the current study.

3.9.9 It therefore follows that the definitions and judgements of significance contained within an ES are ultimately those of the developer and/or the consultant, even allowing for the existence of a degree of consensus among landscape professionals who would be expected to share some common standards and norms. Whilst no criticism of the honesty or professional integrity of the parties is intended concerning the case study examples in this project, it is a truism that a developer must want to minimise the number of significant impacts identified, and that a professional is torn between their role as an expert and their role as an advocate. Whilst there are examples in existence of patently biased and promotional Environmental Statements that developers have treated as little more than public relations documents, even in ostensibly fair, balanced and unbiased statements there can exist more subtle and entirely understandable nuances and judgements that can be challenged. Statutory consultees, other professionals and decision-makers are therefore free to accept or reject many definitions and judgements, unless consensus exists.

3.10 Public Attitudes

3.10.1 There is a little research, some survey and much anecdotal evidence that public attitudes to renewable energy, wind energy and windfarms are complex and dynamic. Krohn & Damborg (1998) review a range of international studies and show that (a) there is broad public support for renewable energy in general, (b) there is high (around 80%) public support for wind power, including similar levels of support in the UK based on thirteen surveys conducted between 1990 and 1996, but that (c) there are important and significant differences in attitudes and opinions in the particulars. In other words, there may be a significant difference between attitudes expressed (positively or negatively) in a general way, and actual behaviour in terms of opposition to new developments.

3.10.2 Whether such differences are labelled NIMBYism or invested with more subtle attempts to explain an apparent contradiction is a matter for research and debate (Wolsink, 1994, 2000). At a simplistic level, windfarms are not different from other developments such as hospitals, roads and waste disposal sites, in that the majority of the public accepts the necessity for these but may be vociferous opponents of local developments. Also, studies for windfarms show that human perceptions of potential noise and potential landscape or visual effects are the key issues. Windfarm interests have been interested to summarise and promote the results of such studies (e.g. BWEA, 1996), although it is worth stressing here that such summaries may show evidence of selectivity in interpretation, and most surveys have been of a type best described as general public attitude and opinion surveys that have not focused on the more detailed questions being examined in the current study.

3.10.3 Duddleston (2000) reports on a post-development survey (by telephone) of public attitudes and opinions concerning the Beinn Ghlas, Novar, Hagshaw Hill and Windy Standard windfarms. Residents within a 20 km radius of each site were sampled (the study used the following zonal definitions: 0-5 km – high proximity zone; 5-10 km – medium proximity zone; 10-20 km – low proximity zone). Perversely at first sight, perhaps, a slightly higher proportion of respondents in the medium and low proximity zones (11% and 12% respectively) said that they disliked the windfarm because it was unsightly or spoiled the view compared to those (8%) in the high proximity zone, but this bald result ignores detailed local visibility issues (for example, the Novar site is essentially invisible in the high proximity zone, except for specific and limited localised viewpoints, but more visible beyond this zone). This point is elaborated by Duddleston (Table 4, page 12), where she shows that a higher proportion of respondents in the medium proximity zone see the windfarm from their home or garden or when travelling on local roads compared to those in other zones, and they also see the windfarm more frequently (every day or most days). The survey then asked people to compare their anticipated and actual problems. For all effects including *"look of the landscape being spoilt"*, the results show actual effects to be around 15-20% of anticipated effects.

3.10.4 Whilst windfarm interests are keen to offer these (and other) results from public attitude surveys as evidence that public reaction and opposition to windfarms is exaggerated, it could equally be interpreted as evidence that detailed attention to the planning, impact assessment, siting and design processes is successful in minimising effects or mitigating potentially significant impacts. The Duddleston survey did not address specific visual questions, such as whether the windfarm as built appeared more or less prominent than they (the public) had expected or had judged from inspection of pre-project visualisations (the main sources for pre-project information were local newspapers, other media and word of mouth, with some consultation by developers in the high and medium proximity zones). It therefore offers no results to inform the detailed questions being asked by the current project.

3.10.5 We have not discovered any public attitude or opinion surveys that address the specific issue of the relationships between turbine size, distance, visibility and impacts.

3.11 Cumulative Effects

3.11.1 This general phenomenon is flagged or raised in many discussions and policy documents as an important issue. A relatively recent report is Energy Technology Support Unit (2000). This is generic guidance on principles and processes but contains little specification or technical detail on issues of magnitude, distance and significance.

3.11.2 Piper (2001) has analysed three cases of the cumulative effects of two or more projects, including windfarms in Holderness (Yorkshire) and Kintyre. In Holderness (study for East Riding of Yorkshire Council), the boundary of the study area was seen as the maximum distance (about 20 km) from which the windfarms might be seen (in a coastal region of very flat topography). The basic approach involved defining landscape character and determining the sensitivity of the landscape (based on potential change, intrinsic character and potential visibility). The study defined several visibility thresholds as follows: 0-2 km: turbines a prominent element in the local landscape – high visual impact; 2-5 km: turbines would appear as clearly visible element in landscape – high-medium or medium visual impact. In terms of best practice for cumulative effects assessment, Piper rates the Holderness study as limited and partial; for example, no cumulative zone of visual influence map was produced to show overlapping affected areas within different dominance thresholds. For the Kintyre project (study for Scottish Natural Heritage) the study area was defined as a radius up to 30 km, assuming turbine heights to blade tip of up to 68 m, and based on five projects or potential projects at various stages of resolution. As for Holderness and in terms of best practice for cumulative effects assessment, Piper also rates the Kintyre study as limited and partial; for example, landscape character assessment was not used and no explicit assessment of significance in relation to distance is made.

3.11.3 MosArt Associates (2000) have prepared an analysis of landscape character and sensitivity to windfarm development for Cork County Council, but this was an area based study akin to the similar capacity studies being carried out in Scotland and elsewhere, and contains few detailed technical recommendations on aspects of VIA. With regard to cumulative effects, however, it recommends the use of overlapping ZVI and, pending a further study, that the outer limit of cumulative effect is set at 10 km separation, with any larger separation not considered as having a cumulative effect. For individual applications, it recommends a basic ZVI of 20 x 20 km and, for large turbines (a height of more than 60 m), a ZVI of 30 x 30 km.

3.11.4 Information on a current research study on cumulative impact of wind turbines, commissioned by the Countryside Council for Wales, is at Macaulay Land Use Research Institute (2002). At present the material available here is largely literature review, much of which is general and non-specific for windfarms. For example, it reviews controversies over the differences between professional and lay public preferences for landscape and scenic quality; it reviews several studies (largely drawn from the USA and the Netherlands and much from the late 1980s) on perceptual studies of windfarms (but much of this is focused on attitudes and symbolism, and general design issues) and it reviews a familiar range of tools for VIA, including ZVI and viewpoint analysis.

4 CASE STUDY SITES

4.1 Introduction

4.1.1 The following sections provide a short description of each windfarm, followed by a condensed analysis of each Environmental Statement (Appendix 1), concentrating on key aspects of the VIA [7]. For each viewpoint visited we provide a brief summary of the prediction or judgement made in the ES, and then a brief comment based on our site appraisal. An overview of the site appraisals is then presented, followed by some brief conclusions.

4.2 Beinn An Tuirc

The Windfarm

4.2.1 The windfarm was constructed in 2001. The original proposal was for 50 turbines with a hub height of 40.5 m and a total height of 62.5 m. As built the windfarm consists of 46 turbines with height to hub of 40.5 m and total height of 62.5 m. Viewpoints were selected by negotiation with the local planning authority and SNH. The site moved south during negotiations because of ornithological interests and the layout also changed for this and visual reasons. There are significant locational differences between as assessed and as built.

The Environmental Statement

4.2.2 The ES material available to us was varied and complex and it proved difficult to cross-match, collate and test the documentation. The main statement (no date) is based on layout G (layouts D, E, F and G are referred to). The ZVI radius (study area) is declared as 15km, but is actually 16.6 km to accommodate the spread of the windfarm layout of 3.3 km. Chapter 9 in the ES includes a detailed discussion of the basis for the selection of 15 km. The basic ZVI is a zone of theoretical visibility (bare-ground or worst-case scenario). Computer calculations are also made of the zone of actual visibility taking account of trees rendered in the program as standardised forestry blocks. Relative visibility in the ZVI is based on a hub height of 40.5 m, not the maximum height, but this decision is not explained.

4.2.3 Eighteen viewpoints were selected based on site survey and consultation with SNH, Argyll & Bute Council and North Ayrshire Council (Arran). Site assessments were made based on visualisations (photographs and wireframes), not photomontages. The effects on both stationary viewers and moving viewers are distinguished and analysed and a long list of factors considered in assessment is provided. Orientation of the turbines in relation to the prevailing winds is considered. Separate reports exist containing *"Wireframe Overlay Illustrations"* (May 1998)(viewpoints 1, 2, 5, 11, 12, 13 and 15 only) and *"Photomontages"* (no date)(prepared for viewpoints 2, 5, 11, 12, 13 and 15 only). The recommended viewing distance for visualisations is 24 cm. It is not clear if these separate reports refer to the 18 viewpoints in the main ES.

4.2.4 At the end of each viewpoint assessment (descriptive), a statement is made as to the anticipated effect (e.g. *"moderate adverse effect on visual amenity"*) and the significance (e.g. *"significant"*). The ES makes reference to the Environmental Assessment Regulations and concludes that minor effects are not significant, but moderate and major effects are significant. The basis for the assessment of significance does not appear in the main ES (layout G), but is described and discussed in detail in a supplementary report, *"Assessment of Landscape and Visual Effect Layout F, Draft 2"* (1997), as is the technical detail of the ZVI, DTM etc. We also obtained a packet of visual material (ZVI, site layout, wireframes) dated 1999 that in one case referred to layout H. We assume that layout H is close to the as built windfarm.

4.2.5 Although based ultimately on professional judgements by more than one assessor, this ES is explicit in listing and discussing the factors taken into account in judging very significant, significant and not significant or no effect. The details in the ES are long and relatively complex and are not repeated here for that reason. The supplementary report (1997) is effectively a second version of the ES, based on Layout F, but concerned only with the landscape and visual effects. A full set of ZVI, visualisation, photomontage and related materials is presented.

Site Survey

4.2.6 There are 19 viewpoints in the ES. Seven are on the islands of Gigha or Arran and 2 are in the sea; these were not visited during this study. Of the 10 remaining, 5 were not visited due to their remoteness. To assess them would have involved some hill walking which may have been feasible in better weather but was not practical due to the time constraints of the project and the poor weather conditions. Therefore only five out of 19 viewpoints were assessed.

4.2.7 We made a total of 9 visits to the 5 viewpoints (viewpoint 6 involved walking 2 miles so we visited it only once when the weather was good) but were only able to make 5 useful assessments of 4 viewpoints due to the weather.

Table 5: Viewpoint Analysis for Beinn an Tuirc

VP	Distance (km)	No of Visits	ES Description (main ES)	Site assessment	Photomontage/wireframes (main ES)	Wireframes (supplementary)
1	5.85	2	States 11 turbines visible.	None visible. This may be due to layout changes.	Totally inaccurate, looks like layout change.	
2	4.35	2	States 35 turbines visible over 2 hills. States 'moderate adverse impact'.	23 then 11 visible over 1 hill. Although the number and layout were not accurate, 'moderate adverse impact' is correct.	Inaccurate in number and position. Turbines looked bigger in reality than in photomontage.	Called viewpoint 1. Wireframe shows 23 turbines with extreme tips of three more (which were obscured by vegetation in reality). The individual positions are reasonably accurate. The overall position and size of the farm is accurate.
3	7.8	2	States 30 turbines visible. States 'new visual focus' and 'moderate adverse impact'.	15 visible. "Moderate adverse impact' may be too strong as there are already many manmade elements in this landscape.	Not accurate in position or number. Size looked bigger in reality.	Called viewpoint 2. Two wireframes, one without vegetation and one with blocks of trees. The former shows 15 turbines with the tip of one more. The overall position and size is accurate. The latter wireframe shows only 11 turbines and the tip of one. As we saw more it would appear that the screening effect of the trees has been overestimated.
6	6.6	1	ES states 21 turbines visible and 'low adverse impact'.	7 visible (although light conditions poor). 'Low adverse impact' is correct.	Not accurate in number or position.	Called viewpoint 5. Shows 8 turbines.