Review of the 2Km separation distance between areas of search for onshore wind farms and the edge of cities, towns and villages

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Executive Summary

This report presents the results of a desk based analysis of peer-reviewed UK and international literature and policy reports on the evidence and rationale for separation distances for wind farms. Recent original research consists mostly of empirical investigations and case studies on the visual effects of wind turbines on local residents. Other studies present evidence for visual impacts on settlements; the separation distances set for wind farm search areas; and the rationale used by planning authorities to decide on particular separation distances.

The concepts of visual impact and adverse visual effects are both complex and contested and there are few studies that have explored the role of visual thresholds in multiple contexts. As a result there is little understanding of exactly what constitutes an adverse visual impact with respect to wind farms and how to determine their thresholds. Despite this, interest amongst planning authorities in adopting separation distances has increased in recent years, both in the UK and internationally.

We have not been able to trace the origin of the 2km separation criterion used in Scotland definitively to any specific study. We found no supporting data to justify this distance. Scotland has led in the use of a 2km separation distance, with other planning authorities then adopting it. The 2km criterion has however been queried both in Scotland and in other planning jurisdictions.

Our review of separation distances in over 15 countries found that most separation distances have in fact been set based on noise, shadow flicker or health considerations, with none specifically relating to visual impacts. In these cases, no reference is made to turbine heights.

In light of the recent publication of the revised draft Scottish Planning Policy (2013), three policy options for separation distances are explored. These are (1) retention of the 2km separation distance with clearer wording and definitions of key terms; (2) an increase in the distance to 2.5km to reflect the increasing size of onshore wind turbines; and (3) removal of a specific separation distance but the retention of visual impact as a criterion in the preparation of spatial strategies for wind energy by planning authorities.

1. Introduction

The Scottish Government has set an ambitious and challenging target to deliver at least the equivalent of 100 per cent of its electricity needs from renewable sources by 2020. Onshore wind is crucial to reaching this ambition and is already the country's fastest growing renewable energy sector (Scottish Government, 2013a; Scottish Renewables, 2013), as well as making up the largest proportion of Scottish renewable energy generation. The sector's steady growth is backed by some of the best wind resources in Europe, an attractive market for investors, advancements in technology and a balanced and robust planning framework (DECC, 2013).

While people in Scotland are reported to be generally positive about wind farms (Scottish Renewables, 2013), opposition has been recorded, much of which relates to the issue of visual impact (Pasqualetti, 2011; Cowell, 2010; Warren et al., 2005; Wolsink, 2000). Indeed, some authors have argued that visual impact is the most serious environmental impact of wind farms, usually because of the adverse effect that a new development can have on natural or 'unspoilt' landscape and the intense feelings of the public towards this subject (Cowell, et al, 2011; Jobert, et al., 2007; Krohn and Damborg, 1999; Coles and Taylor, 1993; Fortlage, 1990).

The Scottish Government provides planning policy and guidance to assist local planning authorities in development plan preparation and development management decision-making. With respect to the former activity, the current Scottish Planning Policy (SPP) 2010 recommends that authorities apply a 2km separation distance between areas of search for onshore wind farms above 20MW and the edge of cities, towns and villages. This 2km criterion was first set out in Planning Advice Note 45 (PAN 45) (revised in 2002 and now revoked) and later entered Scottish Planning Policy 6 (Renewable Energy) before being consolidated in SPP 2010. In practice there has been some debate surrounding the 2km separation distance, relating both to the height of turbine assumed and the nature of the relationship between visual impact and distance. In Scotland, the debate is documented in the consultation stages of the draft SPP to replace SPP 2010. The debate is also captured in the consultation documents reviewing separation distances in England (Regen SW, 2012), in North Yorkshire County Council (Bryant, 2012), and in the United states (Madison Wind Advisory Committee, 2013). Furthermore, the provenance of the 2km distance is unclear.

With bigger turbines expected onshore, up to 200m (to blade tip), existing policy needs to be reviewed. For example, is the existing separation distance flexible enough to accommodate increased turbine sizes? On the one hand, a blanket application of a prescribed separation distance would restrict all turbines on the basis of the theoretical maximum size. On the other hand, a differentiated calculation depending on the turbine height would introduce a 'sliding scale' which might be undesirable in policy terms and also in practice because it is perceived as introducing complexity.

The revised draft Scottish Planning Policy (SPP) document published for consultation in April 2013 (Scottish Government, 2013b), sets out new guidance to local planning authorities with respect to identifying spatial frameworks for wind turbines and wind farm developments. It includes a proposal to increase the community separation distance from 2km to 2.5km.

Reference to 20MW wind farms is removed. In the consultation, the draft SPP poses Consultation Question 16: “With reference to paragraph 218 and subsequent groups, do you think that the proposed increased community separation distance of up to 2.5km is appropriate?” (Scottish Government, 2013).

This report presents the results of a desk based analysis of UK and international literature on the use of separation distances with respect to onshore wind farms. It considers and synthesises the evidence and rationale for the current policy based on a 2km separation distance and explores whether there is evidence to support an increase to 2.5km. Specifically, the report aims to deliver on the study brief by:

1. Exploring the literature relative to visual impacts and separation distances;
2. Clarifying the provenance and rationale of the 2km separation distance;
3. Reviewing comparative experience from other countries;
4. Discussing the options for policy including the case for changing the separation distance from 2km to 2.5km given the trend to larger turbines;
5. Drawing conclusions and recommendations.

2. Method

The research was approached in three stages. Firstly, a review was carried out of the sources of evidence and rationale, if any, indicated in the policy documents supplied in the research brief. Secondly, this was supplemented by an examination of original studies published in peer reviewed academic journals, in order to identify empirical evidence on the topic. Thirdly, policy documents on wind farm separation distances and visual impacts were examined to identify separation distances and rationales applied in a range of contexts. Relevant publications were identified by applying the four most widely used multidisciplinary citation databases; ‘Google Scholar’, Thomson Reuter’s ‘Web of Knowledge’, Elsevier’s ‘Scopus’ and ‘IDOX’ (mainly for policy documents). The search terms included: “wind turbines and visual impacts”, “wind farms and visual impacts”; “distances wind turbines and settlements”, “wind farms and buffer areas”, "distances wind farms and settlements", “visibility perception of wind farms”, “separation distances wind farms”.

In addition to focusing on the Scottish literature, comparison has been made to other international sources, from within and without the EU. The report has been informed by over 20 policy documents and 6 policy review documents, and over 30 peer-reviewed papers covering experiences from over 25 countries. We also found over 10 published empirical studies directly exploring visual impacts and threshold distances.

3. Visual impacts and separation distances

The issue of visual impacts and separation distances is informed by three key considerations. One, the question of image and the way in which the visual attributes of the

environment are experienced by people. This is an area of study where environmental psychology and environmental behaviour have made a great contribution (see Devine-Wright, 2009, 2005; Wolsink, 2005; Gustafson, 201; Hayden, 1995; Canter, 1977; Craik, 1973; Dewey, 1958). Two, the concept of 'adverse visual effects' which is more complex, subjective, and has so far been under-researched in a way that can adjudicate appropriate separation distances in various contexts. Three, the purpose of planning policy with specific reference to visual impact and onshore wind farms (see for example Wolsink, 2007; CanWEA, 2007; Wester-Heber, 2007; Stanton, 1996). In summary, we found that although studies about understanding and assessing the visual impact of wind farms and human perception exist, there remains a dearth in those exploring thresholds, especially adverse ones, in various contexts. There is little understanding of exactly what constitutes an adverse visual impact; and indeed, how a systematic measure for comparison in various contexts can be derived. This may explain the challenges experienced in the topic of this report, i.e. the setting of separation distances based on visual impacts.

3.1 Image and visual attributes of the environment

Changes that can be perceived as visual intrusions in the landscape generally result from the introduction of visual contrast to the existing scene, based on differences in form, line, colour, and/or texture. How much a new facility could decrease the visual quality of a landscape (and thereby create an adverse visual impact) depends in part on the degree of visual contrast it introduces (Katsaprakakis, 2012). This can be categorised as referring to the objective component of factors that contribute to visual impacts. The other part of the visual impact equation involves viewer perception, referred to as the subjective component of the resultant visual impact. In most cases, however, the physical attributes of the wind turbines are the predominant source of visual contrast created by a wind energy facility (Sibille et al., 2009; Newcastle University Report, 2002; Bishop, 2002). These issues are explored further in the Appendix 1.

While the physical attributes of wind farms are basic measureable variables that affect visual impact, the main issue of human perception of visual effects is mainly in 'the eye of the beholder' and therefore cannot be easily established (Hillman and Brittan, 1990; Madanipour, 1996) or systematically and reliably aggregated (Bishop, 2002). New wind farms could be interpreted as a threat to the identity of place, especially when the technology is seen and symbolised by the community as contradictory to the local character (Brittan, 2001) or brand a place with a negative image (Wester-Herber, 2004).

3.2 Adverse visual effects

Whilst the term 'visual impact' is clearly defined as a change in the appearance of the landscape as a result of development which can be positive (improvement) or negative (detraction) (IEA and the Landscape Institute, 1995); the terms 'adverse visual impacts' and 'significant visual impact' remain variable across contexts (Bishop, 2002). This does not allow for comparisons between different contexts. More importantly, the treatment of thresholds in relation to visual impacts and settlements remains under-researched and can therefore not offer a robust evidence base for setting separation distances.

Visual and aesthetic impacts are amongst the most commonly expressed concerns about on-shore wind farms, but the determination of what constitutes an adverse visual impact is highly subjective because it depends on the values, beliefs, and experiences of individual

viewers (Turnbull, 2009; AWEA, 2008; Newcastle University Report, 2002; Shang and Bishop, 2000; Thayer and Freeman, 1987). Opinions about the aesthetic qualities vary greatly among different segments of the population and from one location to another. There is a widely held assumption that adverse visual impact is defined as an unwelcome visual intrusion that diminishes the visual quality of an existing landscape (AWEA, 2008 p8-1).

While visual impact thresholds and visual impact assessments are well recognised in the landscape literature (Bishop and Miller, 2007; Newcastle University Report, 2002; Stanton, 2001), the definition of an impact threshold remains more problematic (Sullivan et al., 2013; Shepherd and Zhang, 2011). Only a few empirical studies on thresholds have been undertaken since the dated Sinclair Thomas Matrix (see Newcastle, 2002) - see Sullivan et al., 2013; Ladenburg and Dahlgaard, 2012; Sibille et al., 2009; Bishop and Miller, 2007. These acknowledge that issues of separation distances and thresholds of visual impacts remain complex to analyse and compare between different contexts.

3.3 Planning policy and visual impact

In their paper evaluating the planning framework for renewable energy including wind power, based on Danish Municipalities, Sperling et al. (2013) argue that local planning authorities need to have the necessary means to enhance the siting and planning of wind turbines. Earlier, Turnbull (2009), highlighted that planners needed to be particularly cautious because a lack of understanding of perception and perceptibility of the visual impacts have led many planners to get visual assessments wrong.

However, Toke (2005) had already found a strong association between the outcome of local authority planning decisions, the opinions of local planning officers, and other stakeholders such as local parish and landscape protection groups. Latterly, Cowell (2010) described the role of planning in practice, showing how the Welsh Assembly Government developed a spatial planning framework for wind energy. In the paper, they argue that the planning framework can either promote or restrict the situation of wind farms. Toke (2005) then highlights how the tendency of the identified strategic search areas for wind reinforced the degraded status of afforested upland areas; the extent to which the planning framework rendered certain environmental qualities malleable; and how drawing boundaries may restrict the scope for future reflexivity in energy policy.

4. The provenance and rationale of the 2km separation distance

This section reviews both empirical and policy documents to identify the provenance of and rationale for the 2km separation distance for search areas, which has been used in Scotland since 2002. The first mention of the 2km separation distance goes back to the consultation draft of National Planning Policy Guidance (NPPG) 6 in 2000, a fact that was noted in a study for SNH by the University of Newcastle (Newcastle University Report, 2002). Our further search did not reveal any additional documentary trails, either in Scotland or elsewhere.

However, elements in a table in PAN 45 on the perception of wind farms in an open landscape, point ***to a possible awareness*** of two potential sources of the 2km distance. These are the publications by Stevenson and Griffiths (1994) and CPRW (1999). Stevenson

and Griffiths (1994) undertook a study of a sample of wind farms in England and Wales, analysed views from each site and from the results they devised a scheme of visual impact zones. One of their conclusions was that "in most situations turbines dominated the view up to a distance of 2 km". The CPRW paper (1999) contained details of the Sinclair-Thomas Matrix which categorised the potential visual impact of wind turbines by distance. It categorised visual impact as ranging from "dominant" at 2km to "negligible" at 20km.

There are several similarities between PAN 45 and these documents which suggest they may have been influential in the development of the Scottish policy. Firstly, the 2km figure sits within the distance for "significant impact" in both sources. Secondly, the use of the term "dominant" is a common factor; and thirdly, the use of four categories of visual perception by Stevenson & Griffiths is replicated in PAN 45 (Figure I).

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

Figure 1. General perceptions of a wind farms in an open landscape, from PAN 45

Furthermore, the chronology (Figure 2) allows for such a possibility. It is accepted that this conclusion remains tenuous and conjectural, however, and that other sources for the 2km distance cannot be ruled out; the PAN 45 table was not a carbon copy of material in both Stevenson and Griffiths (1994) or CPRW (1999); and the reference heights of turbines in PAN 45 are not clearly known.

While the Sinclair-Thomas Matrix (CPRW, 1999) provides very structured recommendations on visual impacts and separation distances, the Newcastle University Report (2002) found that the data on which the Sinclair-Thomas Matrix was based contained flaws. Interestingly, onsite assessments undertaken by the Newcastle University team agreed with the Sinclair-Thomas Matrix at two viewpoints: near to a wind farm and at long distances. However, they disagreed with respect to middle distance zones, where they either rated the visual effect as lower or were unable to reach a robust judgement because of a lack of differentiation in definition. They also found the Sinclair-Thomas Matrix difficult to use because of the imprecise terminology. The distinction between magnitude and significance was not always clear; and the Sinclair-Thomas Matrix did not account for the influences of different landscape character or visual context. An updated version of the Matrix based on current wind turbines (or wind farm) dimensions would be needed for today's purposes.

Author, Year	**Issue and findings relevant to this report**
US Dept of Interior, Bureau of	Uses Visual Resource Management (VRM) system of 3 distance zones: Foreground – middle ground 0 – 5.6km (where management activities may be viewed in detail; where changes are more noticeable and more likely to trigger public

Land Management (1984)	concern); background – 5.6 – 24km (; seldom seen – beyond 24. Indicate zone boundaries where texture and form of individual plants no longer apparent in the landscape.
Stevenson & Griffiths (1994)	Audited eight wind farms in England and Wales (turbines maximum height from 40.0 to 61.5m); devised an impact zoning schema of four categories as follows: *Zone i) Visually dominant – the turbines dominate the field of view and appear large scale; In* most situations turbines dominated the view up to a distance of 2 km (zone (i)). *ii) Visually Intrusive – The turbines appear fairly large in scale, and an important element in the landscape.* *iii) Noticeable – The turbines are clearly visible but not intrusive. The wind farm is noticeable as an element in the landscape.* *iv) Element within Distant Landscape – Turbines are indistinct and form minor insignificant elements within a broader landscape.*
EC (1995)	Earliest analysis of impact of distance on turbine visibility; Environmental statement for Penrhyddlan and Ilidarty facilities, Wales. Suggested 20km turbines invisible to naked eye in good visibility; 30m tower heights & rotor 28m; 103 turbine site; 20 km limit of visibility after examining 22 locations; became an early std;
SNH, (Started in (1996, finished 2001)	*Guidelines on the Environmental Impacts of Wind farms and Small Scale Hydroelectric Schemes;* produced . A map showing a Zone of Visual Influence. A wind farm is usually seen as a dominant focus when viewed from distances up to 2 km, although the entire wind farm may not be completely visible due to the obscuring of some turbines by the mid-ground landform
Thomas G (1996)	Planning Officer, Montgomeryshire, Wales; defined potential visual impact of wind turbines using descriptors which could be assessed in field under repeated observations; assumed good visibility; Thomas Matrix, 9 bands of VI form dominant to negligible. Turbine heights 41-45m.
CPRW (1999)	Revised Sinclair-Thomas matrix. Proposes dominant impact band A at 0-2.5km ht 52-55km.
SE (2000)	NPPG 6 consultations mention 2km for first time
SE (2002)	PAN 45 mentions 2km as a formal guidance for first time

Figure 2. Key publications and dates of some guidance on separation distances

5. International comparison of separation distances

The review of the literature on the use of separation distances other than in Scotland found recent interest in the issue from academics and planning agencies with a number of published sources on the topic (see Haugen, 2011; Mills and Manwell, 2012; Town of Madison Wind Advisory Committee, 2012; Canadian Wind Energy Association, 2007; Bryant, 2012; Regen SW, 2012). The documents focus on two main things: seeking evidence to justify separation distances, and trying to establish best practice. The key findings of these publications are summarised below; with the declared separation distances and the rationale for setting them indicated in Appendix 2. It must be noted that in the above documents, frequently, no reference is made to the turbine heights in association with the separation distances.

Haugen's (2011) report on the *International Review of Policies and Recommendations for Wind Turbine Setbacks from Residences: Setbacks, Noise, Shadow Flicker, and Other Concerns*, examined separation distances in over 14 countries and about 25 local planning

jurisdictions, excluding the USA. The report attempted to identify and clarify existing governmental requirements and recommendations regarding wind turbine setbacks from residences. This included identifying the rationale for setbacks and analysing whether or not they were based on public opinion or research findings. Haugen's (2011) report found that:

- Setbacks are claimed to be developed out of public concern for possible impacts to the landscape, health and quality of life, historical and cultural areas, the environment, and tourism;
- However, the evidence trail to support these setback distances is often lacking or unclear, with no statements of justification provided;
- There is no worldwide agreement on appropriate setback distances from homes;
- There was limited awareness of wind turbine setbacks in many countries, or why a particular setback distance was chosen;
- Frequently, separation distances were set not based on visual impacts, but on noise limits, health and shadow flicker concerns.

From the same report, it is clear that the leading on-shore wind generating countries such as Denmark and Germany do not have a standardised approach to setting separation distances. In Denmark, which has the highest wind energy capacity per capita, per land area, and per GDP in the world, a new regulation related to low frequency noise recommends a measured setback of 4 times the total height of the turbine (see also Mills and Manwell, 2012). In Germany, there is no national requirement or recommendation for wind turbine setback distances from residences; although the German states and local governments are responsible for guidelines determining setbacks. Five states in Germany use 1,000m, whilst the others used between 300 and 500m (see Appendix). However, state policies cannot be overly restrictive and must allow 20% of areas favourable to wind energy to remain open for wind facility development. In Germany, the average lower setback distance is approximately 450m and the average upper setback distance is approximately 700 meters. However, the turbine heights associated with the separation distances are not provide anywhere in the report.

In 2013, a report was commissioned by the Madison Wind Advisory Committee, USA, to review the siting of wind power facilities in relation to negative impacts. The report concluded that the larger the setback from residences and other structures, the less the negative impacts. Accordingly, they advised that a setback requirement for a large turbine is 3,560 feet (1,078m) from the property line of any non-participating owner, and 2.5 times the turbine height from any other turbine or house of a participating member. The rationale provided is that this is the minimum distance that would be safe in the event of potential equipment failure, ice throw and similar dangers. The review report was based on a relatively small sample of policy and empirical studies, mainly focusing on socio-economic factors. The turbine heights are not mentioned and, as in other reports, visual impact is not mentioned in the rationale.

In Canada, setbacks are decided at the provincial rather than federal level. The Canadian Wind Energy Association developed some guidelines regarding setback distances (CanWEA, 2007) for Ontario province. The aim was to provide guidelines for setbacks for various stakeholders in the wind energy industry, based on broad input from the industry,

technical experts and international research. CanWEA (2007) concluded that comprehensive setback guidelines for large-scale wind turbines should address a series of objectives including ensuring public safety, minimizing on and off-site impacts, and promoting good land use planning and practices while balancing the economics and viability of the wind project. It also stated that the definition of appropriate setbacks, at least for Ontario for which the report was commissioned, revolved around four main issues: public safety, noise levels, impact on radio, radar and telecommunications, and ensuring minimal impact on sensitive environments. However, the report also admitted to the challenges of setting fixed separation distances and recommended that setbacks be defined on a case by case basis through a site-specific study.

The report also offered some definitions and tried to clarify the issue of rationale for separation distances. For example, it defined "the minimum distance requirement" to mean the necessary distance between the wind turbine generator and residential premises. Furthermore, in a wind farm, the minimum distance requirement would apply to each wind turbine individually. It also defined "setback" as: the shortest horizontal distance measured at grade between a residential building, lot line, public roadway, or other identified feature and the nearest part of the wind turbine structure.

In England, North Yorkshire County Council commissioned a study to review setbacks in the UK and come up with evidence-based recommendations for policy options on separation distances in their planning jurisdiction (Bryant, 2012). The study was motivated by the existence of an earlier consensus seeking to secure a 2 kilometre minimum separation distance within North Yorkshire, a figure that was based on the Scottish national policy (Scottish Government, 2010). Further evidence-based research into the 2 km criterion was therefore requested. The published report in 2012, *Renewable Energy Policy – Proximity of Homes to Wind Turbines*, summarised approaches to minimum separation distances throughout the UK. Only three English authorities, i.e. Cherwell and Torridge District Councils and Milton Keynes Council, had introduced specified minimum separation distances to protect residential amenity. These minimum separation distances do not hold any formal planning status and are "encouraged rather than enforced".

The report states that "…the most reasonable updated evidence-based recommendations at this point in time can be summarised thus: at least 400m for visual amenity" (para 4.30). It is however not shown how the 400m is arrived at, neither is a further narrative or rationale provided. In the end, the report's recommendation on the separation distance was not adopted at least in part due to the absence of robust evidence for setting separation distances.

Another example from England is from The Local Government Association (1995) which aims to support and improve innovation in local government by developing and sharing good practice, through networking and working with councils. Their website, in the section under Planning and Regulatory Requirements, advocates: "A setback distance of at least 600-800 metres from residential properties for large wind turbines, which may be reduced for smaller projects". However, the supporting evidence for this criterion is not provided.

Regen SW (2012) also examined evidence for residential buffer zones for wind turbines in England and concluded that "policies that set standardised residential separation distances

are in conflict with Government policy and do not provide the best approach for addressing the impacts of wind turbines". Worthy of note is the fact that this report only addresses separation distances in terms of noise, health and shadow flicker. It recommends that "the imposition of standardised separation distances will artificially sterilise land that may be suitable for wind energy development" (p4). Moreover, in relation to England, the idea of a separation distance was rejected by Parliament in 2012: making clear that a case by case approach was preferable (House of Commons Briefing Note SN/SC/5221, 2011).

In England (see Bryant, 2012), the above mentioned unsuccessful Bill in the House of Lords "Wind Turbines – Minimum Distances from Residential Premises Bill" had proposed various turbine heights and separation distances, thus:

Turbine height	Proposed separation distance
From 25m and not exceeding 50m	1000m
From 50m and not exceeding 100m	1500m
From 100m and not exceeding 150m	2000m
Greater than 150m	3000m

This was another example where sources or derivations of the above figures were not provided.

Wales has a flexible policy in relation to the siting of wind projects. Its Technical Advice Note 8 (TAN 8) states that: "500m is currently considered a typical separation distance between a wind turbine and residential property to avoid unacceptable noise impacts. However, when applied in a rigid manner it can lead to conservative results and so some flexibility is advised" (Welsh Assembly Government, 2005).

Overall the following points emerge from our review of recent policy documents on the topic of separation distances:

- There is a lack of agreement on definitions – what constitutes a wind farm? (e.g. is it the capacity, number of wind turbines or the entire physical scope of the infrastructure); what is a separation distance, a minimum separation distance, a buffer and a setback etc? These terms are used without any clear and specific definitions attached to them;
- While separation distances at a national level are absent in many of the countries leading in wind energy, there is increased interest on the part of planning authorities to fully understand the rationale and evidence base for setting them;
- Existing empirical work and published material do not provide a robust evidence base to support the setting of, or selecting of specific, separation distances;
- In the reviews of separation distances, the heights of wind turbines upon which they are based is not usually mentioned, making it difficult for comparisons to be drawn across jurisdictions;
- In most countries other than Scotland, the separation or setback distances typically relate to noise and shadow flicker rather than visual impacts and they have been prepared in order to assist in the process of taking decisions on planning applications. Scotland is unusual in having a policy for identifying search areas as part of the plan-making process.

6. Discussion of policy options

Drawing on the review of academic and comparative practice, three possible policy options can be considered: retaining the 2km distance; increasing the separation distance for visual impact to 2.5km to take account of larger turbines; and, removing specific reference to a separation distance for visual impact.

6.1 Retaining the existing 2km distance

As noted above, Scotland is unusual in its current approach in specifying an area of search distance for larger wind farms based on visual impact. With the exception of those jurisdictions that have adopted 2km as a direct result of the Scottish policy, other countries set minimum distances, primarily relating to noise and shadow flicker, for use in assessing individual development applications. In Scotland, the 2km separation distance is part of a wider suite of advice given to Planning Authorities with reference to the preparation of Local Development Plans. The existing policy makes a link between the separation distance and the scale of wind farms (>20MW) although this does not give any indication of the number or size of turbines involved.

The review of the academic and policy literature has not identified any specific empirical material that can adjudicate or justify the 2km separation distance. But the 10 year existence of the 2km criterion in Scotland presupposes its inherent value. We examined a selection of recent Scottish development plan policies and supplementary guidance on wind energy development and found that authorities are complying with SPP by producing spatial frameworks and development management criteria for wind farm developments and that the 2km distance is mentioned in some but not all cases. An example where it has been used is the spatial strategy contained in Highland Council Supplementary Guidance: Onshore Wind Energy (Highland Council, 2012). This distinguishes three spatially distinct zones; 'areas requiring significant protection', 'areas with potential constraints' and 'areas of search'. A 2km distance from settlement development areas is one of the criteria used in establishing the boundaries of the middle zone. The Outer Hebrides Local Development Plan Supplementary Guidance, issued by Comhairle nan Eilean Siar in April 2013, also contains three spatial policy areas: 'broad areas of search', 'areas of potential constraint' and 'areas of significant protection' but in this case no specific reference is made to a 2km separation distance although 1.5km is mentioned. These differences suggest that there is already some flexibility in applying the policy as authorities are taking account of the particular geography and landscape characteristics of their plan area when identifying spatial frameworks.

6.2 Increasing the separation distance for visual impact to 2.5km

The case for increasing the separation distance to 2.5km, as proposed in draft SPP (Scottish Government, 2013) is related to the fact that turbines are becoming larger and will, as a result, have a greater visual impact. Since the 2km separation distance was *ab initio* not found to have been derived from empirical studies, using it as a reference for a 20% upward adjustment as suggested in the Newcastle University Report (2002) might seem logical but it is not supported by primary research.

As discussed earlier, visual impact has both objective and subjective aspects. The rationale that an X ratio increase in turbine height will necessarily correlate to an X ratio increase in separation distance makes an assumption that is yet to be corroborated by empirical evidence. Moreover, when turbine sizes are large e.g. 200m, the difference between 2km and 2.5km, as a visual separation distance, may need to be examined further in the field.

The draft SPP (Scottish Government, 2013) is different from the existing policy in other respects. Firstly the reference to wind farms of >20MW has been removed "to encourage all planning authorities to develop spatial frameworks for the full range of scales of wind farm development appropriate to their areas". No definition of what constitutes a wind farm or the size of turbines is given, however, and this is likely to lead to more rather than less confusion. Does the specification of a separation distance imply that no wind farms, irrespective of the number and height, should be located within 2.5km of settlements? This needs to be clarified. Secondly, the new policy distinguishes four groupings to be identified in spatial strategies. The separation distance is one of the criteria to be considered for Group 2 – areas of significant protection. Thirdly, the reference to a separation distance has been redefined as a 'community' separation distance although there is no discussion of what size of settlement constitutes a community. Given the reference to a community separation distance, it would be helpful to reword the policy to make it clear that the distance involved is taken from settlements rather than from the wind farms. This could be achieved by changing the wording as follows: "A separation distance of at least 2km (or 2.5km) from the edge of cities, towns and villages to wind farms is recommended".

6.3 Remove specific reference to a separation distance.

A third possibility is to remove the reference to a specific separation distance from the policy altogether, although the policy could still require planning authorities to take account of visual impact in drawing up their spatial strategies for wind energy and to include visual impact as a criterion in assessing individual development applications. In considering visual impact, factors of relevance would include turbine height as well as landscape character and other geographical features. The disadvantage of this might be the added complexity and diversity of approaches across different planning authorities. Removing the specific distance completely may also be unpopular with communities who could see it as a relaxation of the existing position. As the existing 2km for visual separation is greater than the distances used elsewhere in relation to noise and shadow flicker, removing it might also mean the necessity of defining distances for these issues in its place.

7. Conclusion and recommendation

This study sought to explore the origins and use in Scotland of a separation distance based on visual impact. The review of the literature relating to visual impact and adverse visual effects demonstrated the complexity of these concepts, an absence of robust research into threshold distances and the difficulty of applying them in practice across contexts.

While some conjectural allusion is made to the provenance of the 2km criterion in the SPP (Scottish Government, 2010), we nevertheless conclude that **no definitive evidence was found to establish the provenance of the criterion**; **neither was a justification or rationale found for it being 2km**; nor the precise size of wind turbines upon which the criterion was based.

While a seemingly logical approach for increasing the separation distance to 2.5km exists, as alluded to in the Newcastle University Report (2002), it is questionable to suggest that subjective aspects of visual impacts are directly proportional to physical distance.

In the absence of robust evidence to adjudicate appropriate separation distances in Scotland, a planning policy approach that integrates precaution while allowing maximum public education and engagement with wind energy issues (problems, challenges, benefits, costs etc.) is crucial to the setting and subsequent acceptance of separation distances. It is generally acknowledged that the existence of clear planning policies and guidelines is correlated to the successful deployment of wind turbines. There is thus an argument for either 1) given existing public acceptance, retaining the existing 2km separation distance as a criterion in identifying spatial frameworks for wind energy in Scotland but with clear definitions of relevant terms or; 2) removing the 2km distance from SPP altogether although retaining reference to visual impact as a criterion. In either case it would also be helpful if Scottish Government could further elaborate the descriptions of the criteria to be considered in identifying different zones (Para 190 in the current SPP) to help planning authorities in creating robust spatial frameworks.

Providing an evidence-based approach to inform what an appropriate buffer might be with reference to future bigger onshore turbines remains challenging in the absence of further relevant data and information. Information that addresses the following issues is needed:

- The extent to which current 2km has been influential (positively or negatively) in identifying search areas;
- Within a given context, the role of key parameters in determining visual impacts and their thresholds; and how their values change over time;
- What the underlying instruments for influencing visual impacts, which are largely based on subjective parameters, may be.

In a subject area that may end up being largely based on subjective parameters, perhaps the planning policy approach should be pragmatic and focus on ways to improve engagement requirements and procedures with stakeholders. Indeed, several peer-reviewed publications point to this being an effective approach for both onshore and off-shore wind farms eg Eltham et al. (2008) and Toke (2005).

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Appendix 1: Wind farms and visual impacts

Physical attributes are the stimuli of visual perception, and visual appreciation of the environment is a product of perception and cognition (Dewey, 1958). Behavioural science, and in particular environmental psychology, mainly focuses on analysis and understanding of the mechanisms involved in visual appreciation of the environment. The importance of visual quality and image has attracted the attention of many scholars in the field. In early studies, Canter (1969, 1977) shows that one of the major factors in response to the environment is pleasantness and satisfaction, which could be the result of aesthetic and visual evaluative factors. In another study, Lowenthal and Riel (1972) found that when people use their own judgment and descriptors of an environment, the visual variables, namely architectural quality and detailed design elements, are the most important data.

The visual character of the environment also has important impacts on human experience (Kaplan and Herbert, 1989; Kaplan and Kaplan, 1989). It can evoke strong emotions, and also influence human behaviour (Nasar, 2000). Psychological research can quantify responses to the physical environment (Russell and Snodgrass, 1987).

At the individual level, literature has little analytical explanation of differences in perception (Devine-Wright, 2005, 2009). From the perspective of environmental behaviour research, the relationship between people and the environment is the result of complex interactions amongst cultural, environmental and perceptual variables (Altman et al., 1980; Rapoport, 1994). Culture plays a significant role in the way environments are defined, transformed and owned (Moore, 2000). A large number of empirical and theoretical researchers within environmental psychology and behaviour agree that these properties are generally manifest in a set of related concepts, namely: sense of place, place attachment, place identity, place dependence, place memory, appropriation and personalisation (e.g. Altman and Low, 1992; Marcus, 1992; Hayden, 1995; Gustafson, 2001; Stedman, 2003; Jorgensen and Stedman, 2006). From an individual's perspective, when a wind farm is considered as a threat to the relationship with the environment, it first manifests itself with respect to visual attributes and changes to the image of the environment which the person is familiar with.

Wind farm projects also may compromise the sense of place continuity by changing the way people experience familiar places (Devin-wright, 2009). One important factor of the people / environment relationship, which may be influenced by wind farm projects, and yet has received limited research, is the way they change the sensory qualities of place. This is especially relevant to controversial energy technologies as 'competing claims about visual impacts of developments are a common attribute of public complaints' (Devine-Wright, 2005). Therefore it can be argued that visual impact should be explored in the context of 'place protective' measures (Devin-Wright, 2009) comprising tangible (physical) and intangible (sensual-symbolic) attributes of the environment.

There are studies identifying the key factors for local acceptance of wind farms. For example Jobert et al. (2007) explored five case studies in France and Germany and provided two categories of factors: institutional conditions, such as economic incentives and regulations; and site-specific conditions, such as the local economy, the local geography, local actors, and the actual on-site planning process (project management).

In terms of the literature on adverse visual impacts, some published empirical findings are worth noting. For example, Bishop (2002), tried to determine the thresholds of visual impacts by looking at cognitive and affective response on visual impacts. He observed that the question of impact thresholds was problematic. These must depend, to some extent, on the content of the intervening landscape: whether plain or picturesque, whether simple or complex. But, perhaps more importantly, impact depends on the particulars of the potential viewers. Earlier works on visual thresholds led to similar observation (see Shang and Bishop, 2000); based on studies to determine the estimation of visual contrast (Bishop, 1997) and on the effects of the atmospheric dispersion of colour (Cozman and Krotkov, 1997). Magill (1990) had tried to address the issue of landscape thresholds but failed to achieve systematic and robust quantitative measures of landscape attributes.

Appendix 2: A summary of the separation distances and rationale for them as reported in Haugen (2011), Bryant (2012) and Mills and Manwell (2013).

Country	**Region / local planning authority**	**Separation distance used / recommended**	**Rationale (e.g. visual impacts, noise, health)**
Germany		Variable, left to states and planning authorities	Noise, shadow flicker
	Saarland	None, or 550m to 850m depending on size of turbines	Noise, shadow flicker
	Lower Saxony,	1,000m recommended	Landscape, noise
	Thuringia	At least 1,000 meters, recommended	Noise
	Hesse	1,000m recommended	Noise, shadow flicker, light effects, public perception
	Bremen	500m	Noise, human health, shadow flicker
	Schleswig-Holstein	1,000m from towns and vacation areas, 500m from rural areas with a number of homes, and 300m from rural areas with 1-4 dwellings	Landscape, health and quality of life, historical and cultural areas, the environment, and tourism
	Hamburg	300m from individual dwellings, 500m from residential area	None given
	Saxony	Turbines 300m from nearby buildings, wind facilities should be 500m from buildings; Minimally, wind turbines set back a distance equal to their height from nearby structures, but it appears that possible effects should be examined out to 1500m	Possible impacts to the environment, landscape, shadow flicker, and noise
	Mecklenburg-Vorpommern	None	No specific guidance; refers to shadow flicker

	Rhineland-Palatinate	1,000m from residential areas based on a court decision to avoid negative impacts to residential areas; 400m from individual homes	Noise, shadow flicker, landscape, and the environment
	Berlin	None	N/A
Denmark		Wind turbines over 25 meters (82 feet) high must be placed at least four times their height from all residences, with no ability to waive this limit. Local authorities handle turbines of up to 150m height	Noise, shadow flicker
Spain	Regional governments are responsible for determining wind turbine setback distances	500m from residences and towns; recommended	Safety, noise
	Canary Islands,	150m from residences and 250m from towns,	Safety, noise
Italy		None	
France		500m from residential areas.	Noise
Canada		No national, regional, provincial	
	Ontario	550m away from all residences, workplaces, and recreational areas,	Health, noise
	New Brunswick	On crown lands, 500m or 5 times turbine height from residential areas	Noise
	Manitoba	500-550m from homes. In practice, from 300-800 meters from residences	Impacts to wildlife, the environment, and noise
	Alberta	None, but public participation involving people living within 800-2000m	Noise
	Quebec	None, but 500m common	
	Prince Edward Island	Minimum of 3 times turbine height from all residences; if developer owns the property, the wind turbine must be located at a distance at least the height of the wind turbine from residences on the property, and 3 times the turbine height from residences on bordering properties	Environment, public health and safety concerns
	Yukon, Nova Scotia, Newfoundland and Labrador	None	Sparsely populated areas
Portugal		200m widely used	Noise
USA	Maine	1.5 times height of turbine	Noise
Denmark		At least 4 times total height of the turbine; Typically, turbines over 25m be set at least four times their	Noise, shadow flicker, reflection, and housing values

		height from all residences	
The Netherlands		At least 4 times the height to the hub of the turbine from nearby homes	Noise, shadow flicker
Sweden		No national recommendations 400-1000m in Northern Sweden, sparsely populated	Noise limits
Australia		Decided by state and territory governments	
	Victoria	2km	Shadow flicker, impacts on local community
	South Australia, New South Wales, and Tasmania	None	Noise, shadow flicker
	Western Australia	1 km	Impacts on the environment and the community, noise
Ireland		500m or 10 turbine diameters, not very clear	Noise
New Zealand		None	Noise
Wales		500m, recommended	Noise
	Carmarthenshire	1.5km	Noise
	Torridge DC	600m	Noise, amenity
	Cherwell DC	800m	Noise, amenity
	Moray Council	Variable, 10 times rotor diameter	Noise
	Milton Keynes Council	800m	Noise, safety
	Aberdeenshire Highland Councils	Variabe; 10 times rotor diameter	Noise, safety
	Sth Cambridgeshire DC	2km	Noise, safety
Ireland		10 times rotor diameter; minimum distance not less than 500m	Noise, historical sites, shadow flicker, safety
England		None; a setback of height of the turbine plus an additional 10% in case of structure failures	Noise, safety
Northern Ireland		10 times rotor diameter to occupied property, with a minimum distance not less than 500m	