Wind Farm Impacts Study

Review of the visual, shadow flicker and noise impacts of onshore wind farms

Final Report

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EXECUTIVE SUMMARY

Main findings

The majority of assessments presented at planning stage for the ten case study wind farms identified and mainly followed extant guidelines.

However, for some of the case study wind farms, extant guidelines were not consistently followed and/or the impacts predicted in the documentation submitted with developers' planning applications were not consistent with the actual impacts as assessed in this study or as reported by some local residents.

Assessments and public engagement activities had not always adequately prepared residents for the impacts of the operational wind farm in terms of visual, shadow flicker or noise impacts.

Main recommendations

The prediction, measurement, assessment and documentation of impacts across all sizes of developments need to be more consistent. For certain aspects of the impact assessment this has not always been the case, for example assessing residential visual amenity impacts.

The processes and procedures relating to retaining and accessing documentation need to be consistent across planning authorities, and throughout the consenting process, including post consent agreements, for example in respect of micro-siting.

Those making recommendations (planning officers, councillors, planning reporters) should consistently make clear in their reports whether they consider the relevant assessment to have been carried out in accordance with recognised guidance and whether they concur with the findings.

The implications of micro-siting need to be identified in assessments, in particular for visual and shadow flicker and, to a lesser degree, noise impacts, noting that there are also likely to be impacts for other environmental aspects not covered by the scope of this study, such as protected species, sensitive habitats or peat.

Our key recommendations are set out below. These are ordered following the sequence of chapters addressing the three separate impacts in this study, with general recommendations at the end, and a full list of recommendations is provided in Table 7-1:

1. guidance and methodology should be developed for residential visual impact surveys and also, where appropriate, the overall impact on residential amenity due to the combined visual, shadow flicker and noise effects of wind energy developments;
2. checklists are needed for planners at scoping and post submission stages of an LVIA to ensure consistency and consideration of key matters;
3. consistent and clear reporting on the landscape and visual design objectives for a wind farm should be set out in assessments;
4. guidance, definitions and significance thresholds should be developed for the assessment of shadow flicker, shadow throw and light effects, including their presentation in public consultations;
5. assessments should give fuller consideration to the experiential impacts of wind farm noise, including its character;
6. a review should be undertaken to establish whether the existing derivation of noise limits offers the appropriate balance between protection, simplicity and robustness;

7. good practice should be developed in terms of assessing modulated noise from wind turbines;
8. where noise issues are found to occur, these should be identified and assessed within clear timescales, and affected neighbours should be provided with regular and informative updates;
9. guidance should be developed to achieve consistency across competent authorities in respect of retention and accessibility of key documents throughout the consenting process, including post consent agreements; and
10. decisions about micro-siting should be taken by competent authorities and recorded, based on the specific implications for visual, shadow-flicker and noise impacts, alongside other potential impacts and in relation to stated design objectives.

The research

This study looked at whether the impacts predicted by wind farm developers in documentation submitted with their planning applications are consistent with the impacts experienced once the wind farm is operational. It aims to inform any future decisions on changes to Scottish Government online planning guidelines and good practice on managing the impacts of wind farms on local residents.

Site selection

Ten case study wind farms were selected for study to include a spread of wind farm sizes, wind turbine heights, environmental assessment process, landscape character, wind farm age, geographical location across Scotland, and consents process, as well as on the basis of having known complaints about visual, shadow flicker or noise impacts. The sites selected represented 4% of the total number of built onshore wind energy developments in Scotland in 2013.

Data gathering

Quantitative assessments do not necessarily account for the potential experiential response to wind farm developments. This study therefore used both an evidence review and a Residents' Survey to assess whether the impact from the wind farm case studies is as predicted by developers in documentation submitted with their planning applications.

The two main sources of information were:

- evidence of how local residents experience and react to visual, shadow-flicker and noise impacts, gathered through a Residents' Survey; and
- review of planning documentation, monitoring and as-built data, supported by site survey, predictions and mapping which was assessed by professional consultants.

Findings

Visual

Visual impacts on residents living close to the case study wind farms were assessed in documentation submitted with the planning applications for all sites with reference to extant LVIA guidance, although this was not always followed consistently. The case study wind farms all used representative viewpoint locations to assess impacts on residential receptors. In two instances, more detailed analysis of predicted visibility from individual residential locations was provided at the application stage.

The majority of the significant impacts on visual amenity identified at assessment stage for the case study wind farms corresponded with the significant impacts identified during the site visits for this study, with a small number of exceptions.

There was considerable variability in the Residents' Survey responses about visual impact. For people with a view of the wind farm, there was a range of opinion about whether they liked or disliked the wind farm as well as whether they felt the built wind farm was as expected or very different from the illustrations at the planning stage.

The impacts experienced by individual residents on a case by case basis were not necessarily reflected in the assessment of representative viewpoints in the LVIA. This points to the need for residential visual amenity surveys to be carried out to an agreed methodology for nearby residents likely to be affected by wind farm development.

The micro-siting of turbines in the built wind farms at the case study sites did not result in any changes to the significant effects identified at the assessment stage. But micro-siting can result in changes to the appearance of a wind farm which in some instances (a change from no visibility to visibility of turbines) would be significant, and how this is assessed needs to be consistent.

As good siting and design are the principal means by which visual (and landscape) impacts can be minimised, it is important that adequate attention is given to this part of the assessment process. The findings must be reported in a transparent way, identifying design and layout objectives as well as key constraints. This should assist in making any implications from micro-siting clearer.

Shadow Flicker

Shadow flicker was assessed at all of the case study wind farms for properties where it could occur based on the distance to the turbine(s). There was limited assessment of other potential shadow or lighting effects.

In the Residents' Survey some people recorded that they experienced shadow flicker even though they live in properties beyond the distance at which the current method for assessing potential shadow flicker predicts it to occur.

There are no standard significance criteria to assess shadow flicker impacts and no statutory limit or guidance to stipulate acceptable levels of shadow flicker.

Modelling of shadow flicker that includes data gathered through a house-by-house assessment of the potentially affected properties provides a more robust approach.

There appears to be a range of lighting effects impacting people living close to wind farms, none of which were found to be clearly defined. However, a clearer definition of all shadow and light effects with reference to parameters such as the distances, directions, light and weather conditions in which they can occur would help both assessments and public understanding of this particular impact.

In the process of developing new guidance, it would be beneficial to carry out further research to improve understanding of light and shadow effects on residents within 2 km.

Noise

Noise impact assessments were carried out at application stage for all of the case study wind farms. These referred to ETSU-R-97 guidance. However, there was some variability in interpretation of this guidance.

Following ETSU-R-97 with the Institute of Acoustics' Good Practice Guide (2013) should enable noise impact assessments to be carried out in a consistent manner. This Guide was published after all ten case study wind farms were consented and is recognised in Scottish Planning Policy. In about half of the case study wind farms, the planning stage assessments under-predicted the impacts of the operational wind farms compared with predictions for the same wind farms carried out following current good practice methods for the actual turbines installed.

There is limited guidance on assessment of certain characteristics of wind farm noise, such as amplitude modulation. Such characteristics have been shown through the Residents' Survey to heighten adverse experiential response to wind farm noise, and there is ongoing research on this subject.

The Residents' Survey results show that a small minority of residents who responded to the survey felt heavily impacted by wind turbine noise.

The results also highlight a few instances where people predicted to be exposed to similar noise levels reported very different experiences of the wind turbine noise. An individual's reaction to a particular noise is generally complex and difficult to relate to a single objective or quantified measure, and it was not possible to explore this further with respect to specific survey responses within the scope of this study.

Additional survey work (including systematic interviews and supporting recordings and/or measurements) at selected sites would assist in further understanding these variations in the responses and the character features experienced, but this was outside the scope of this study.

There was evidence that residents exposed to the higher end of the range of predicted turbine noise levels could experience significant impacts even in cases where the existing noise environment was expected to be relatively noisy. The potential masking effects of other sources of environmental noise on wind farm noise could therefore be investigated further.

Whilst most respondents reporting adverse impacts of wind farm noise experienced it outdoors, those who heard noise indoors and at night were generally located in areas predicted to experience higher wind farm noise and generally reported worse impacts.

There was some indication that respondents were unaware of the potential audibility of the wind farm. This was possibly due to audibility not being clearly addressed in the assessments and/or limited or no information being provided in public consultations.

In this study, modelling noise levels was a better predictor of the experienced impacts (as reported in the Residents' Survey) than distance alone.

Overall

The findings point to several possible improvements in planning guidance and best practice. Some have been implemented in the time between the case study wind farms being planned and built and the present. This is an encouraging sign that the planning process is getting better at predicting and presenting the impact from major developments like wind farms. Implementation of the specific recommendations made in this study should contribute to further improvements in the assessment, reporting, planning consideration and decision making for wind farm developments.

1.0 INTRODUCTION

Onshore wind farms in Scotland

1.1 Onshore wind turbines work by harnessing the kinetic energy from the wind and converting it into electrical energy. They were first consented in Scotland in the mid-1990s. Since then a considerable number of single turbines and wind farm developments at different scales have been built to make use of Scotland's wealth of wind resource. Wind energy is an important contributor to the renewable energy generation required under the Renewables Obligation (Scotland) and identified in the 2020 Routemap For Renewable Energy In Scotland (updated December 2013). Scotland's renewable energy targets are as follows:

- 100% domestic electricity demand equivalent from renewables by 2020;
- Interim target of 50% electricity demand equivalent from renewables by 2015;
- 11% heat demand from renewables by 2020;
- At least 30% overall energy demand from renewables by 2020; and
- 500 MW community and locally-owned renewable energy by 2020[1].

1.2 The majority of proposed multi turbine wind farm developments are subject to an Environmental Impact Assessment (EIA) by virtue of factors such as their size and potential effects on the environment (see The Town and Country Planning (Environmental Impact Assessment) (Scotland) Regulations 2011). If there are more than two turbines or the hub height exceeds 15 metres (Schedule 2 threshold in the EIA (Scotland) Regulations) this triggers an EIA screening process. Where the proposed development is under 20MW a screening process by the relevant planning authority will determine whether an EIA or Environmental Report is required. In practice, very few one- or two-turbine developments are required to submit an EIA.

1.3 The EIA comprises assessment of the proposed development against a range of existing baseline factors including landscape and visual amenity, ecology, hydrology, cultural heritage, socio-economics, noise, air quality, carbon emissions and traffic. The findings from these technical studies are provided in the form of an Environmental Statement (ES), a report submitted with the application. The ES identifies the predicted effects from construction and operation of the wind farm. The predictions are based on using established methodologies and guidance within each technical discipline, and are required to distinguish between effects which are significant and non-significant by the EIA Regulations.

1.4 The consenting process gives individuals and organisations an opportunity to put forward their view on a development by writing to the consenting authority[2]. If the proposed development is over 20MW[3] this would require a statutory 12 week pre-application consultation (PAC) for discussion and possible modification of the

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[1] Scottish Government 2013 and 2014: http://www.scotland.gov.uk/Resource/0044/00441628.pdf and http://www.scotland.gov.uk/Resource/0045/00457876.pdf

[2] For a wind farm of less than 50MW capacity application is made to the planning authority. Developments over 50MW capacity are known as Section 36 applications which are made to the Scottish Government's Energy Consents and Deployment Unit (ECDU)

[3] Megawatts of electricity output.

application. If the proposed development is greater than 50MW capacity it constitutes a Section 36 application determined by the Scottish Government. At this level PAC is a matter of good practice although it is not required.

1.5 Once the wind farm is consented and built, complaints may be made to the planning authority and/or Scottish Government. Depending on their nature, complaints may be investigated further, which may lead to changes in the operation of the relevant wind farm, in order to satisfy the consented planning conditions.

Wind Farms Impacts Study

1.6 Most wind farm applications go through a rigorous planning process. However, there has never been a multi-site study to compare the impacts of a wind farm assessed in the ES or supporting information provided as part of the planning process and the actual impacts once the wind farm is operational. Concerns about proximity of wind farms to dwellings, as well as overall practice and policy related to onshore wind farms were presented to the Scottish Government by Scotland Against Spin (SAS) in 2013.

1.7 The Wind Farms Impacts Study was therefore a research project looking at whether the impacts predicted by developers in documentation submitted with their planning applications are consistent with the impacts experienced once the wind farm is operational. The research used two sources of information:

- How local residents experience and react to visual, shadow flicker and noise impacts; and
- How the predicted impacts at the planning stage compare with the impacts when the wind farm is operating, as assessed by professional consultants.

1.8 The study was intended to assess whether methods and guidelines on the approval process for wind farms are sufficient to safeguard against unacceptable visual, shadow flicker and noise impacts on local residents. The aim of the study was to inform future decisions on changes to Scottish Government online planning guidelines and good practice on managing the impacts of wind farms on local residents.

Study Governance

1.9 The study was governed by a Project Steering Group (PSG) with representatives from various local and national interest groups representing both those living near wind farms and wind farm developers and operators, including Scotland Against Spin and Scottish Renewables, and representatives from local and national government planning interests. This PSG was put in place to ensure a balanced approach throughout the research and analysis.

1.10 The organisations represented in the PSG are listed below:

<u>ClimateXChange</u>

1.11 ClimateXChange is Scotland's centre of expertise on climate change. It provides a research, advice and analysis service to Scottish Government policy teams and associated public agencies. www.climatexchange.org.uk ClimateXChange acted as project manager for the study.

Scottish Government

1.12 Sponsoring teams within the Scottish Government on the steering group included:

- Onshore Renewables and Community Energy team which leads on the Renewables Routemap for Scotland http://www.scotland.gov.uk/Topics/Business-Industry/Energy/RoutemapUpdate2013;

- Planning and Architecture Division – representing onshore wind land use planning policy interests. Website http://www.scotland.gov.uk/Topics/Built-Environment/planning

Scottish Government teams that are supporting the study included:

- Energy Consents Deployment Unit, the team that deals with consents for wind farms under Section 36 of the Electricity Act 1989 http://www.scotland.gov.uk/Topics/Business-Industry/Energy/Infrastructure/Energy-Consents; and,

- the Air, Noise and Nuisance Team that provides advice in terms of noise and nuisance to Environmental Health Officers.

Heads of Planning Scotland (HoPS)

1.13 Heads of Planning Scotland (HoPS) is the representative organisation for senior planning officers from Scotland's planning authorities, national park authorities and strategic development planning authorities.
http://hopscotland.org.uk/

Scotland Against Spin

1.14 Scotland Against Spin is the independent alliance campaigning for the reform of the Scottish Government's wind energy policy.
http://scotlandagainstspin.org/

Scottish Renewables

1.15 Scottish Renewables is a member organisation dedicated to strengthening business relationships and committed to securing the best possible environment for the growth of renewable energy in Scotland.
http://www.scottishrenewables.com/about-us/

Scottish Natural Heritage (SNH)

1.16 SNH's vision is for a strategic approach in which renewable energy development is guided towards the locations and the technologies most easily accommodated within Scotland's landscapes and habitats without adverse impact. SNH is a statutory consultee for all wind farm developments in Scotland in terms of their impact on the natural heritage.
http://www.snh.gov.uk/planning-and-development/renewable-energy/onshore-wind/

RenewableUK

1.17 RenewableUK is the UK's leading renewable energy trade association, supporting the development of UK wind & marine energy. Renewable UK joined (March 2014) the PSG after Phase One and was therefore not involved in the site selection.
http://www.renewableuk.com/

Independent campaigners

1.18 Represented on the Project Steering Group by Ian Kelly MRTPI, Head of Planning, Graham and Sibbald (but acting in a personal capacity).
http://www.g-s.co.uk

Contractors

1.19 In June 2013 SLR Consulting Ltd (SLR) and Hoare Lea Acoustics (HLA) were contracted by ClimateXChange to undertake the study following a competitive tendering process.

1.20 The contractors for the study were:

SLR Consulting Limited

1.21 SLR is a leading international environmental consultancy that specialises in the energy, mining & minerals, waste management, planning & development, infrastructure and industrial sectors.
http://www.slrconsulting.com/

Hoare Lea Acoustics

1.22 Hoare Lea Acoustics is an independent acoustic consultancy and part of Consulting Engineers, Hoare Lea. HLA provides acoustic services for numerous types of development including wind farms, infrastructure, residential, commercial and industrial sites.
http://www.hoareleaacoustics.com/

Report structure

1.23 The report is structured as follows:

- Chapter 2 – Scope and Methodology;
- Chapter 3 – Phase One - Site Selection;
- Chapter 4 – Phase Two – Assessment of Visual Impacts;
- Chapter 5 – Phase Two – Assessment of Shadow Flicker Impacts;
- Chapter 6 – Phase Two – Assessment of Noise Impacts; and
- Chapter 7 – Overall Assessment, Conclusions and Recommendations.

2.0 SCOPE AND METHODOLOGY

Introduction

2.1 This section gives an overview of the scope and methodology of the project. The detailed methodology for component parts of the study is set out in the respective chapters addressing visual, shadow flicker and noise impacts contained in Chapters 4-6. Further detail with regard to the Residents' Survey methodology and analysis is provided in Appendix B.

Research Objectives and Scope of Study

2.2 The key objectives of the study were to identify whether:

- the significant environmental effects of wind farms assessed in the Environmental Statements (ESs) accompanying applications for energy consent or planning permission are consistent with the actual impacts from the built wind farms;
- Councils and consultees always rigorously examine ESs; and
- the actual effects, once the wind farms are operational, differ significantly from those identified in the ESs.

2.3 In order to address these objectives, the scope of the study was to review the visual, shadow flicker and noise impacts on local households of a selection of Scottish onshore wind farm developments, comparing the impacts identified at the pre-consent stage, the assessment of those impacts by the determining authority, the actual impacts of the operational wind farms, and the subsequent monitoring and enforcement actions taken by the planning authority.

2.4 The study was designed to provide evidence to inform Scottish Government thinking about planning advice and best practice guidance for all scales of wind farms. There is existing extensive guidance in respect of wind farm development. A list of key good practice guidance is provided in Appendix L.

2.5 Each of these different impacts is considered in the topic chapters 4 – 6 which follow and overall objectives are considered in the Overall Assessment, Conclusions and Recommendations in chapter 7.

Study Methodology

2.6 The study was conducted in two phases as follows:

Phase One – Site Selection

2.7 Ten wind farms, from a total of 252, were selected for this independent study and included a spread of wind farm sizes, wind turbine heights, environmental assessment process, landscape character, wind farm age, and geographical location across Scotland. The shortlist was itself based upon a longer list of all wind farm developments in Scotland since 2000 (single and multiple turbines over 50 m in height to blade tip) that have residential properties close by, and took into account information about any complaints that had been received by the relevant planning authority or the Scottish Government, about visual, shadow flicker or noise impacts. The PSG made the final selection from a shortlist of possible case study wind farms that SLR developed.

Phase Two – Impact Assessments

2.8 For each of the ten case study wind farm developments the study investigated how effective the assessment process was in determining the potential impacts of the wind farms. The research considered two main sources of information:

- Evidence of how local residents experience and react to visual, shadow flicker and noise impacts, gathered through a Residents' Survey; and
- How the predicted impacts at the planning stage compare with the impacts when the wind farm is operating, as assessed by professional consultants.

2.9 The local residents' experience was ascertained through a survey administered by post and online. The assessments made at the planning stage were reviewed through a combination of:

- An evidence review;
- The findings from the Residents' Survey;
- Site visits; and
- Modelling and/or prediction of impacts based on the known details of the as built wind farms.

2.10 The findings from this process were then analysed to evaluate the strengths and weaknesses of the assessment process and identify where improvements in good practice could be made. Finally, areas of further research were identified.

Box A – Interpreting data from the Residents' Survey

A survey of residents was included in the study to ensure that local residents' experience of impacts at the case study wind farms could be brought into the analysis. The purpose of the Survey was to gain an understanding of the extent to which residents experienced impacts and how they felt about those impacts. With that purpose in mind, the Survey was designed to capture: (i) quantitative data about how many people experienced different impacts and (ii) qualitative data about the nature of those impacts. The qualitative data are provided in 'free text' boxes, which allow respondents to explain what they experience in their own words. Bearing in mind the Survey's limited sample size and the small number of people who offered perspectives in the free text boxes, these qualitative data cannot be used to draw conclusions about the number of people experiencing a given impact. Thus throughout this report, we have provided quantitative findings only where these are supported by quantitative data, whilst insights gained from analysing the qualitative data have not been quantified.

2.11 A total of 2,303 households were invited to take part in the Residents' Survey, from which 390 responses were received representing 16.9%. Details of the survey methodology and questionnaire are included in Appendix B.

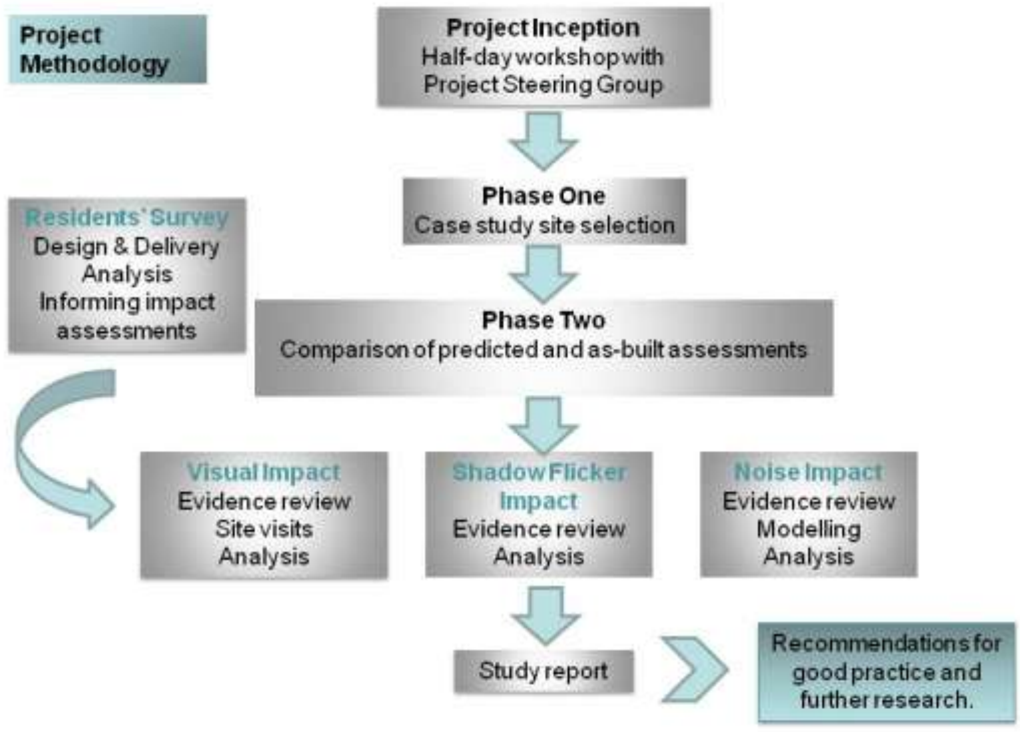
2.12 The Residents' Survey included quantitative and qualitative questions (see Appendix B). The study team designed and used the survey as an aid to its wider evaluation of the key research questions for the study. The study team analysed survey responses to inform its evaluation of the assessments of the three types of impacts covered by the study. However, it is important to note that it was not possible to check responses with respondents to ensure that questions were all understood and answered in the same way. For example, a respondent might record no impact at their residence but still record experiencing some types of impact. The limited number of residents, and related low number of respondents at some of the case study wind farm sites, along with the fact that only 30% of respondents answered all of the survey questions mean that the sample of responses for any given question is often very small. Additionally, although the response rate to the survey was generally good, ranging between 11% and 25%, a large majority of local residents did not respond.

2.13 The quantitative analysis of the responses to the survey questions is referred to in the impacts chapters (4, 5 and 6) and is provided in Appendix C. As noted, the case study wind farms comprised just under 4% of the total number of wind farm developments in Scotland in 2013, all of which were the subject of one or more complaints in respect of visual, shadow flicker and/or noise impacts. The scope of the Residents' Survey in this study has been necessarily tailored to the duration and cost of the project. Its limited extent means that it cannot be used to draw out any generally applicable, statistically robust conclusions in relation to the responses received. For all of these reasons, the quantitative analysis should be treated with caution in terms of the study and cannot be extended to the sector as a whole.

2.14 In the analysis of the Residents' Survey presented in chapters 4 – 6, the percentages given in respect of answers to specific questions are based on the number of respondents to that particular question and therefore do not take account of the number of people who submitted a completed survey, but chose not to respond to that particular question. In order to identify this group who chose not to respond to some of the survey questions, the quantitative analysis presented in Appendix C shows two sets of data: one which excludes the number of people who chose not to respond to any particular question; and a second set which includes this group. The study team agreed to present the percentages in chapters 4 – 6 based only on those who responded to the particular question rather than as percentages of the total number of respondents because it is not possible to identify the reasons why people chose not to respond to any given question. Some of the questions invited comment or description of the impacts experienced and this has been reported in a generalised way but these responses cannot be quantified.

2.15 A summary of the study methodology is presented in the flowchart below.

Figure 2-1
Summary of Study Methodology



Source: SLR Consulting Ltd

Data Protection

2.16 For the Residents' Survey all information gathered by the study was managed strictly in accordance with the provisions of the Data Protection Act. The Survey did not solicit personal details and survey responses do not contain names or addresses.

2.17 Information from the Residents' Survey responses was categorised by postcode using unique ID Codes and aggregated through the analysis process. Only the contractors' representatives, named University of Edinburgh academics involved in analysis of responses and the CXC Project Manager have access to the survey data. Information linking survey response ID Codes to postcodes has been held separately from survey responses and only the contractors' representatives, named University of Edinburgh academics involved in analysis of responses and the CXC Project Manager have access to this information.

2.18 The survey responses and information linking response ID Codes to postcodes will be held for six months by the contractors. After this time, all data will be provided to the CXC Project Manager to be held in a research archive at CXC to allow further analysis if required for the study or follow-on parts to the study. No copies of data will be held anywhere else.

2.19 The developers and operators whose sites were selected for the study provided valuable input and commercially confidential data. Based on the use of this data in the analysis, this study anonymises the site-by-site data and reports on the thematic findings to draw out good practice and lessons for future planning policy.

3.0 PHASE ONE – SITE SELECTION

Introduction

3.1 The purpose of Phase One of the study was to select between eight and ten appropriate wind farm developments for analysis in Phase Two. The selection was made with input from, and following the agreement of, the PSG. Following a data collection and screening process, a shortlist of sites for study was presented to the PSG. The requirements of the shortlist were to:

- Represent as broad a range of scale of development as possible, across a range of topographies and locations in Scotland;
- Include wind farm sites of different operational ages;
- Represent a range of spatial contexts, but at least 50% of the sample must comprise developments with turbines that are within 2 kilometres (km) of one or more dwellings, and with respect to noise impacts, an appropriate proportion of the sample should have non-financially-involved domestic properties within 1 km of the perimeter;
- Include sites that, though comparable in terms of size and proximity to dwellings, differ with respect to the scale of complaints raised by local residents about their visual, shadow flicker or noise impacts; and
- Include at least one development that was not subject to an EIA but for which noise issues were a material planning consideration (and therefore where a noise impact study was required).

3.2 At the outset of the study the aim was to develop a shortlist of at least ten and no more than 14 sites.

3.3 It was decided by the PSG that no ‘control’ or ‘best practice’ site would be included in the study as it would be impossible to select such a site due to the many variables and it would not necessarily provide insight in terms of the impacts to be studied. The sites were therefore selected on the basis of having known complaints about visual, shadow flicker and/or noise impacts, as the most effective way of informing the study objectives. They included less than 4% of the number of built wind energy developments in Scotland and are not necessarily representative of the nation’s overall wind farm sector.

Site Shortlisting Methodology

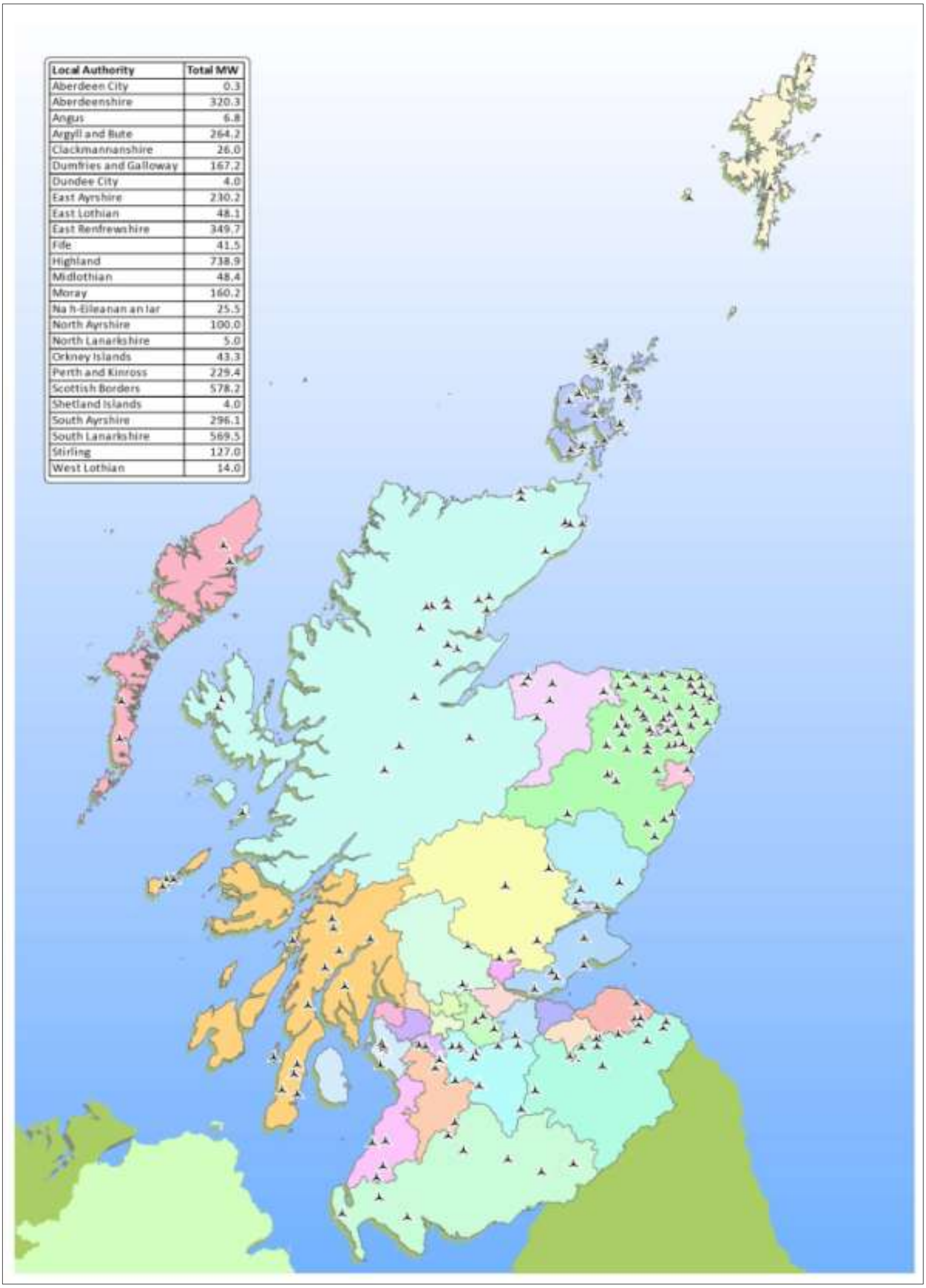
3.4 A stratified sampling approach was used to develop the shortlist of wind farm sites, i.e. the short list of sites was developed through a four stage process starting with the total list of wind farm sites and refining this through a further three stages (or strata) to meet the key selection criteria. This was the most efficient and objective approach for such a heterogeneous dataset.

3.5 The four stages of the short listing process were as follows:

Stage 1: Generate Long List

3.6 A long list of wind farms in Scotland built since 2000 was generated from data sources agreed with the PSG including RESTATS, SNH, Renewable UK and SLR’s own database. The total number of sites was 252. The locations of the sites on the long list are shown in Figure 3-1.

Figure 3-1
Wind farm sites on the long list



Local Authority	Total MW
Aberdeen City	0.3
Aberdeenshire	320.3
Angus	6.8
Argyll and Bute	264.2
Clackmannanshire	26.0
Dumfries and Galloway	167.2
Dundee City	4.0
East Ayrshire	230.2
East Lothian	48.1
East Renfrewshire	349.7
Fife	41.5
Highland	738.9
Midlothian	48.4
Moray	160.2
Na h-Eileanan an Iar	25.5
North Ayrshire	100.0
North Lanarkshire	5.0
Orkney Islands	43.3
Perth and Kinross	229.4
Scottish Borders	578.2
Shetland Islands	4.0
South Ayrshire	296.1
South Lanarkshire	569.5
Stirling	127.0
West Lothian	14.0

Source: SLR Consulting Ltd 2013

Stage 2: Collect key criteria data

3.7 Stages 2-4 involved SLR collecting data to fulfil a list of criteria devised jointly with the PSG to meet the requirements set out above. For Stage 2 the following data were collected for all sites on the long list.

- Name of development;
- Geographic location by site centre grid reference;
- Planning authority;
- Number of turbines;
- Height to blade tip of turbines;
- MW output of development;
- Whether it is within 3km of a residential settlement;
- Whether it is within 3km of residential properties;
- Date of consent/operation; and
- Name of developer/contact details.

3.8 Once key criteria data were available for the sites on the long list, Stages 3 and 4 were used to reduce the long list down to a shortlist of sites that SLR presented to the PSG.

Stage 3: Review any complaints

3.9 Stage 3 involved identifying whether complaints had been lodged with the relevant planning authority and/or Scottish Government in respect of any of the long list of sites. As this information was not necessarily easily accessible and may be documented in different forms within each planning authority a number of actions were taken to effectively capture this data as described below.

3.10 Planning authorities were requested via the Improvement Service to provide:

- A list of wind farms consented and built since 2000 (excluding applications pre-2000) within the planning authority area;
- From the above list an indication of any wind farms where complaints have been received (visual, shadow flicker, and/or noise), to identify wind farms not complainants;
- Whether GIS data are available for each wind farm including site boundaries and turbine locations; and
- A contact point in the planning authority for future enquiries on these data gathering matters.

3.11 All members of the PSG were asked if they were aware of any sites for which complaints had been made:

- Scottish Government reviewed evidence of concerns or complaints from the last 2 years of public letters to Ministers citing specific visual, shadow flicker and/or noise complaints or issues in respect of wind farm developments to identify any additional sites that may be included in the long list; and
- Scotland Against Spin (SAS) shared their knowledge of complaints from sites with new or pending statutory nuisance cases against turbine owners.

3.12 The OS Address Base dataset was used to identify the presence of residential properties and settlements with households within 3 km of a wind farm.

3.13 As described, the case study wind farms were selected on the basis of having been subject of one or more complaints in respect of visual, shadow flicker and/or noise impacts. However, it was not the purpose of this study to follow up on these complaints.

Stage 4: Consents process criteria

3.14 Stage 4 of the site short listing process was to identify the consents process associated with those developments which met all the key criteria above. Data gathered included the following:

- Small scale development;
- Large scale development;
- Section 36 application;
- Recommendation to decision making authority;
- Appeal via Local Review;
- Appeal via Local Inquiry;
- Appeal in respect of visual impact;
- Appeal in respect of shadow flicker; and
- Appeal in respect of noise impact.

3.15 Following collection of the consents process data, and taking account of interim feedback from the PSG, SLR drew up a short list of 46 developments which met the study objectives and key criteria as well as representing a range of consents processes. This was presented to the PSG on 28th August 2013.

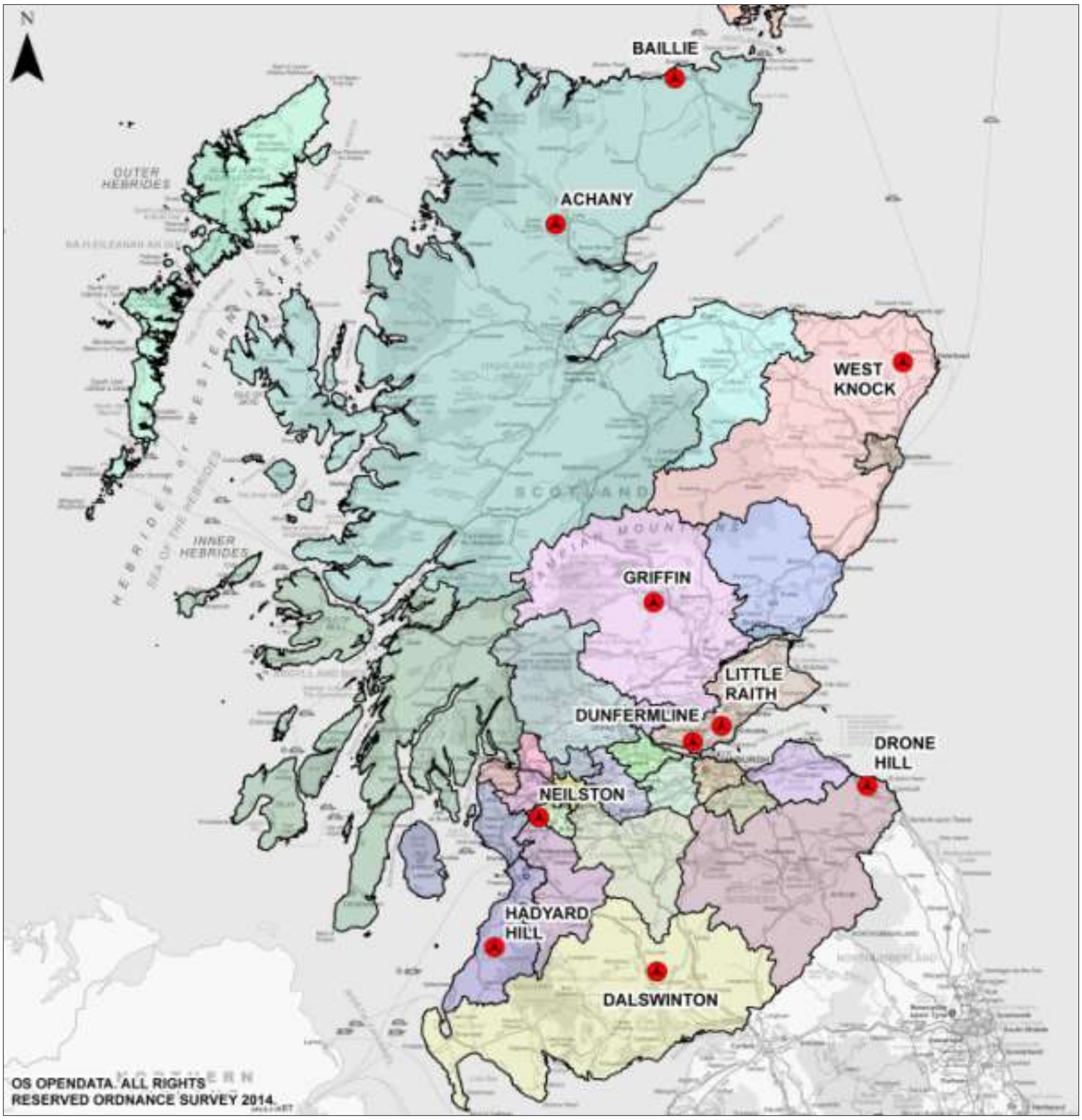
Final site selection

3.16 The final site selection rested with the PSG. As can be seen above, the final shortlist of 46 was longer than had been anticipated. It was therefore agreed that members of the PSG should individually score the sites to achieve a top ten ranking. The scoring guidance for this process included:

- A variety of scales reflected by:
    - number of turbines
    - turbine height
    - power output;
- The decision making authority, to ensure a spread of authorities;
- Landscape character, to ensure a mix of host landscapes;
- Date of application, consent and commissioning, to include a range of development dates;
- A range of the three issues of concern (visual, shadow flicker and noise); and
- A range of sizes of population within 3 km and less than 2 km.

3.17 The PSG’s scoring exercise was managed by the CXC Project Manager. It resulted in the final selection of case study sites as shown in Figure 3-2.

Figure 3-2
Final selection of wind farm case studies



Source: SLR Consulting Ltd 2013

3.18 The following Tables 3-1 and 3-2 show the key characteristics of the case study wind farms.

Table 3-1
Key location characteristics of wind farm case studies

Wind Farm	Local Authority	Site Centre Easting	Northing	Elevation (m) (at site centre)	Landscape Character Assessment
Achany	Highland Council	250900	904350	335m	Moorland Slopes and Hills
Baillie	Highland Council	302750	965400	102m	Mixed Agricultural and Settlement
Dalswinton	Dumfries and Galloway Council	294350	589250	282m	Foothills With Forest
Drone Hil	Scottish Borders Council	384100	668000	216m	Coastal Moorland
Dunfermline	Fife Council	310152	685380	68m	Urban
Griffin	Perth and Kinross Council	293700	744400	382m	Highlands Summits and Plateaux
Hadyard Hill	South Ayrshire Council	226450	597300	219m	Foothills
Little Raith	Fife Council	318750	691450	139m	Lowlands Hills and Valleys
Neilston	East Renfrewshire Council	345350	654000	217m	Rugged Upland Farmland
West Knock	Aberdeenshire Council	398550	844900	90m	Agriculture Heartland

Source: SLR Consulting Ltd

Table 3-2
Key planning characteristics of wind farm case studies

Wind Farm	Turbine number	Blade tip height	Power MW	Consent route	Application	Consent	Operation
Achany	19	105	38	Planning Authority/Public Inquiry	28/10/2005	13/10/2006	11/10/2010
Baillie	21	110	52.5	Section 36/Public Inquiry	13/07/2004	14/01/2010	29/03/2013
Dalswinton	16	125	30	Planning Authority	13/10/2003	21/11/2006	15/03/2008
Drone Hill	22	76	28.6	Planning Authority/Public Inquiry	04/03/2005	12/11/2007	01/09/2012
Dunfermline	1	100	1.5	Planning Authority	12/02/2009	22/12/2009	07/12/2011
Griffin	68	124	156	Section 36/Public Inquiry	27/04/2004	31/01/2008	28/02/2012
Hadyard Hill	52	101	120	Section 36	27/03/2003	29/12/2003	08/05/2006
Little Raith	9	126	25	Planning Authority	02/12/2004	11/02/2008	27/11/2012
Neilston	4	110	9.2	Planning Authority	26/05/2009	16/05/2011	13/05/2013
West Knock	3	84	2.4	Planning Authority	27/07/2009	21/04/2011	04/11/2010

Source: SLR Consulting Ltd

3.19 Following the confirmed case study site selection (October 2013) Phase Two of the study could commence.

4.0 PHASE TWO – ASSESSMENT OF VISUAL IMPACTS

Introduction

4.1 The main aims of this element of the research were to consider whether visual impacts on people living near the wind farms included in the study were accurately assessed at the application stage. This was identified by reviewing the Landscape and Visual Impact Assessments (LVIAs) in the Environmental Statements (ESs) or Environmental Reports (ERs) submitted with the applications. An assessment has also been made of whether the actual impacts of the operational wind farm are consistent with, or differ from, those predicted at the application stage.

Visual Impact Methodology

4.2 The main source of guidance in respect of the assessment of visual impacts is the publication Guidelines for Landscape and Visual Impact Assessment, 3rd edition (Landscape Institute and Institute of Environmental Management and Assessment, 2013), (henceforth referred to as GLVIA 3). This 3rd edition was published in 2013. All of the wind farms included in the study were planned and built while either the 1st or 2nd editions of this guidance were in place. There is a substantial volume of guidance produced by the Scottish Government and Scottish Natural Heritage (SNH) which is directed towards the development of wind farms, much of which aims to assist in achieving better design and layouts as well as implementation through the planning process. This guidance is listed in Appendix L. However GLVIA 3 is the current source of guidance on how to assess the visual impacts from wind farms.

Key Elements of LVIA

4.3 A summary of the current LVIA process is set out below, with the main differences between the previous editions of the guidelines in place during the assessment and construction of the ten case study wind farms noted. Further detail and a glossary of terms are provided in Appendix D.

4.4 The two key parts of the visual impact assessment process are firstly to identify the sensitivity of the people whose views and visual amenity will be affected as a result of a proposed development and secondly to assess the magnitude of change to these views that would occur from construction and operation of the development. The sensitivity to, and magnitude of, the changes are brought together to evaluate the overall impact. GLVIA 3 separates sensitivity into value, which is assessed at baseline stage, and susceptibility. These are combined to identify the overall sensitivity to change of any given receptor. Definitions of these various terms are provided in Appendix E.

4.5 The Town and Country Planning (Environmental Impact Assessment) (Scotland) Regulations of 2011 require that any impacts judged to be ‘significant’ should be identified. No definition is given in the Regulations for ‘significant’, but it is for each environmental methodology to set out the criteria and thresholds by which a judgement can be made on whether any impact is significant or not significant.

4.6 The first step in the process is to establish the context or baseline conditions against which to assess the changes that would occur as a consequence of a proposed development. This involves collecting data on the landscape character, identification of any designated landscapes and describing the nature of existing views within the area surrounding the proposed development.

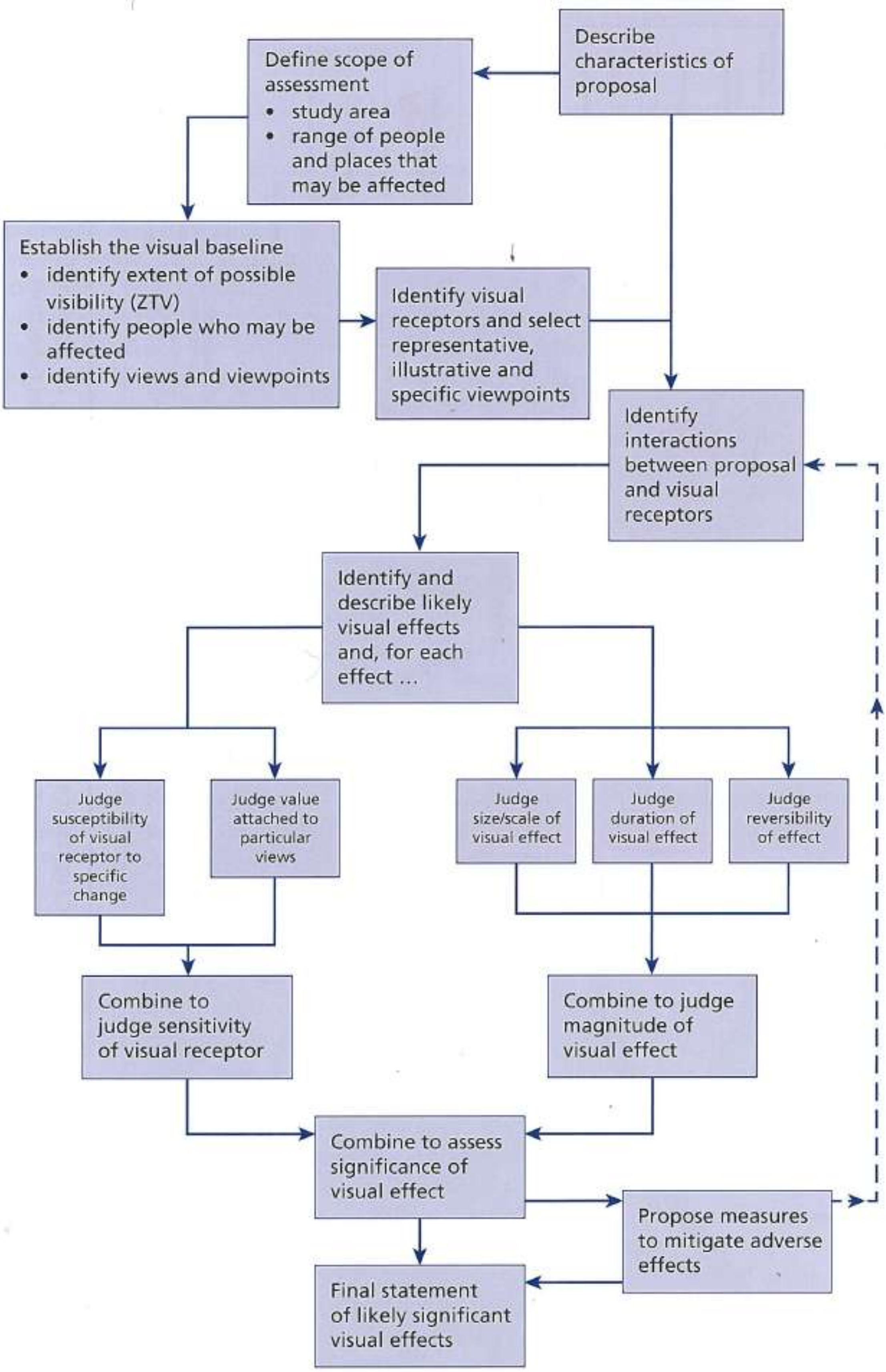
4.7 Visual impacts are defined as "*the effects of change and development on the views available to people and their visual amenity*" (para 6.1, GLVIA 3).

4.8 The sensitivity of people whose views are likely to be affected by a proposed development is assessed in relation to where they are and what they are doing in the landscape. The main groups of visual receptors most often identified in LVIA are people at their homes (often referred to as 'residential receptors'); people enjoying the landscape for recreational purposes such as hill walking, or following public footpaths through the landscape; and road or rail users. GLVIA 3 (and its predecessors) recommends that people in their homes should be considered to have a higher sensitivity to change in their views. "*The visual receptors most susceptible to change are generally likely to include residents at home*" (para 6.33, GLVIA 3). Previous versions of GLVIA also identified people at their homes as being of higher sensitivity to change in their views of the surrounding landscape.

4.9 The magnitude of change from a wind farm development that would occur at any given location is "*evaluated in terms of its size or scale, the geographical extent of the area influenced and its duration and reversibility*" (para 6.38 GLVIA 3). This requires considering of a number of criteria relating to:

- The height and number of turbines;
- The distance between the proposed turbines and the viewer;
- The amount of the available view that would be occupied by the turbines; and
- The degree of change or contrast of the likely changes in the landscape with the existing landscape and its key characteristics.

Figure 4-1
GLVIA Assessment process

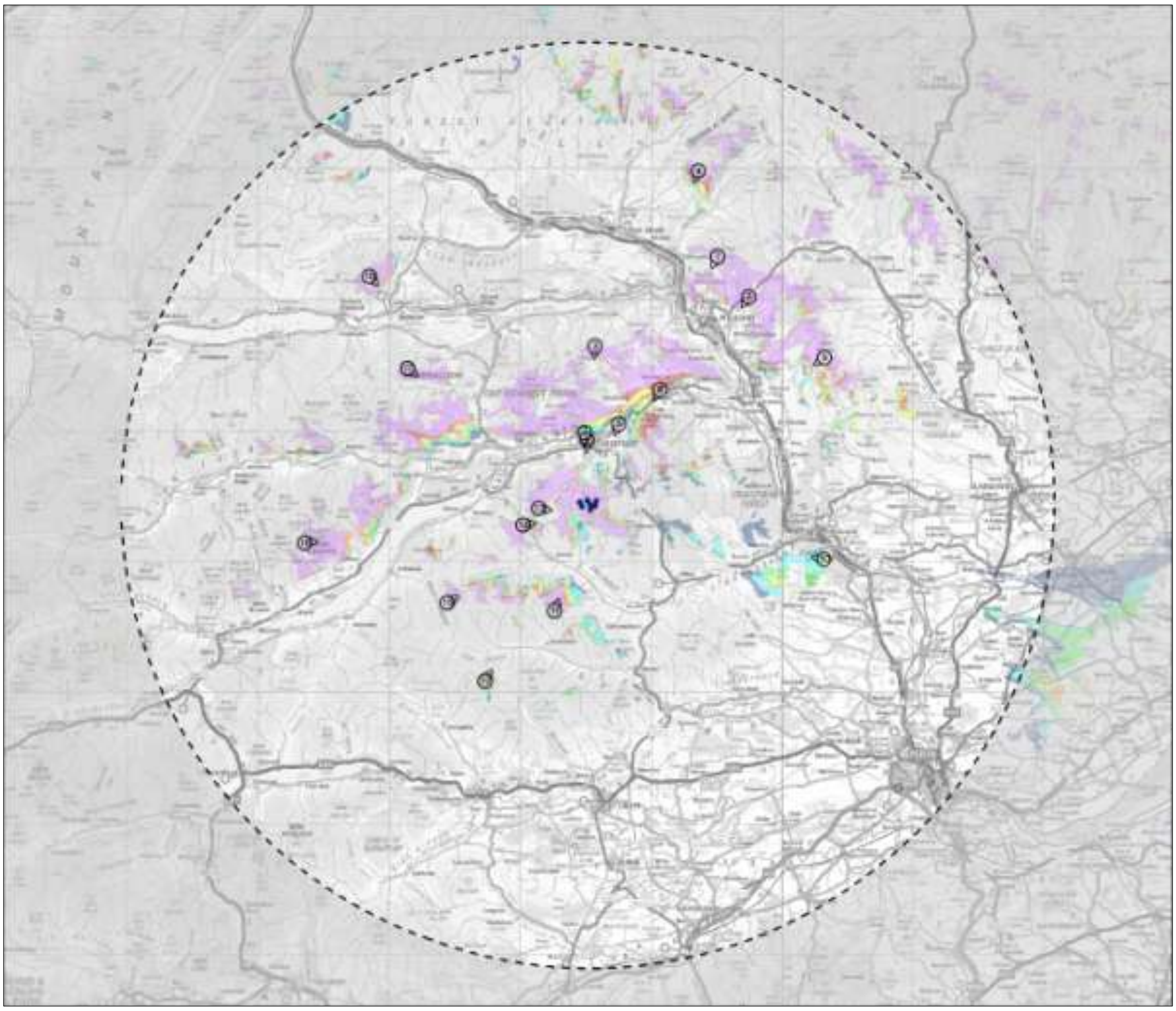


Source: GLVIA 3rd edition 2013

4.10 In order to explore the range of visual impacts which may occur from a development, a range of representative viewpoints is usually selected and agreed with the main consultees: the planning authority and SNH; during the scoping stage of the assessment. The aim is to select a proportionate number of locations which are representative of the range of people likely to be impacted, at a range of distances, directions and elevations relative to the proposed development.

4.11 LVIAs are generally accompanied by illustrative material. This usually comprises plans showing the area within which the proposed development may be seen, which is called the Zone of Theoretical Visibility (ZTV). ZTVs may be produced showing where any part of the turbine up to its blade tip may be seen (blade tip ZTV) or where any part of the turbine up to its hub height may be seen (hub height ZTV). Additionally, cumulative ZTVs can be produced to show where the proposed wind farm would be seen with other developments.

Figure 4-2
Example ZTV



Source: SLR Consulting Ltd. 2013 on behalf of I + H Brown NC Ltd for North Calliachar Wind Farm

4.12 Illustrations of the predicted view of the proposed development from the agreed representative viewpoints are also included in the LVIA which may be presented as photomontages or wirelines together with photographs of the existing view towards the proposed development. Photomontages consist of a model of the proposed development superimposed onto a photograph of the existing view. Wirelines comprise a computer generated 3D outline of a particular structure (in the case of wind farms, the wind turbines) placed on top of a 3D ground terrain model, which again is represented by a wireline.

Figure 4-3
Example Wireline

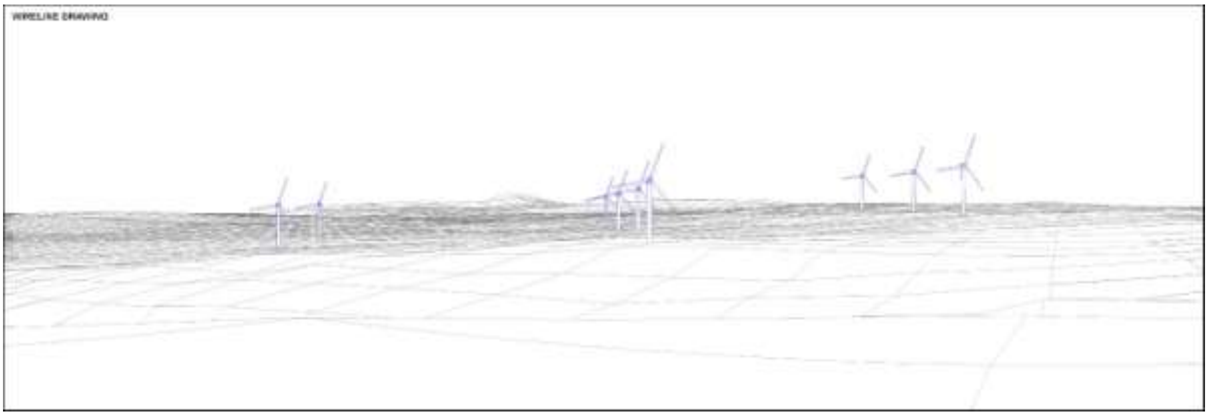


Figure 4-4
Example Photomontage

Source: SLR Consulting Ltd 2012 on behalf of RWE npower Ltd. in LVIA for Burn of Whilk Wind Farm

4.13 SNH published Visual Representation of Wind Farms Good Practice Guidance in 2006. This brought together the findings of research work carried out by several experienced professionals and provided comprehensive and detailed technical advice on the minimum and preferred requirements for illustrative material prepared for wind farm LVIAs. The assessments for seven of the case study wind farms were prepared before the first SNH guidance was published in 2006 and three were prepared after this date.

4.14 The SNH guidance was updated in June 2014 (with a further amended version published in December 2014). The new guidance recommends a suite of illustrations for each viewpoint for inclusion in LVIAs. This current SNH visualisation guidance applies to all assessments commenced after January 2015. Additionally, some local authorities (the Highland Council[4] and Perth and Kinross Council[5]) have published their own guidance on visualisations to accompany wind farm applications.

4.15 The Landscape Institute (LI) has produced an Advice Note on Photography and photomontage in landscape and visual impact assessment (Advice Note 01/11 LI) which refers to the SNH guidance.

4.16 Increasingly over the last ten years, planning authorities request that a residential visual amenity survey or report on residential visual impacts is submitted with the LVIA. This sometimes forms part of a Residential Amenity Survey covering other matters such as shadow flicker or noise. These surveys usually cover residential properties predicted to have views of the proposed wind farm within an agreed distance (usually up to a maximum of 5 km and more commonly between 2 and 3 km) and therefore in close proximity to the development. There is no standard methodology for undertaking such surveys or reports (see Appendix D).

Methodology followed for the Wind Farms Impacts Study

4.17 The methodology for the visual element of this study was designed to deliver the project Research Objectives, as set out in Chapter 2 and followed the key steps shown in Figure 2-1.

4.18 The approach taken in assessing visual impacts for the ten selected case study wind farms comprised the following key stages:

- An evidence review of the visual impacts predicted or assessed in the environmental information (ES LVIAs or ERs) submitted with the planning application/appeal for each of the selected case study wind farms;
- Two site visits to each of the ten case study wind farms to assess the actual visual impacts on residents in the area surrounding each development by reference to the viewpoints used in the application stage assessment, as well as locations identified in the Residents' Survey where respondents recorded that they "strongly dislike" or "dislike" the visual impacts of the wind farm;
- Comparison of the visual impacts predicted at the assessment stage with SLR's assessment of visual impacts at each case study site;
- A review of the reported visual impacts from the Residents' Survey for each case study wind farm, including a comparison of these reported impacts and those assessed at the application stage as well as those identified on site by SLR.

4.19 The methodology used by SLR in assessing the actual visual impacts from the ten case study wind farms has been based on GLVIA 3, which is the current guidance. The main tenets of this guidance remain unchanged from the previous editions used at the time of the case study wind farms' assessment. However, there is now a requirement to assess the value of the respective receptors as part of the baseline. The value of the view is then considered alongside the susceptibility of each receptor to change in order to assess their overall sensitivity to the type of development proposed (see Appendix D).

[4] The Highland Council 2013 Visualisation Standards for Wind Energy Developments

[5] Perth and Kinross Council 2013 Visualisation Standards for Wind Energy Developments

4.20 The focus of the study in relation to visual impacts was on impacts on people at their homes and therefore the group identified as residential receptors in GLVIA 3.

4.21 People place a high value on views from their homes and gardens and as they spend leisure time in their homes are likely to be highly susceptible to any change in these views. The high value of views from residential properties and high susceptibility of residents combine to give a high sensitivity to residential visual receptors (households). All residents were therefore assessed by SLR as being of high sensitivity.

4.22 The magnitude of change at any location was assessed by SLR in respect of the relevant criteria set out in GLVIA 3. These comprise the size or scale of the change that occurred in views as a result of the addition of the wind farm, as well as the geographical extent, duration and reversibility of the development. Size and scale were evaluated on the basis of the number and height of the turbines and their distance from the receptor. Geographical extent was evaluated on the basis of the extent of the view occupied by wind turbines, (sometimes referred to as the horizontal angle subtended). The duration of the visual impact from each of the case study wind farms was taken as being long term on the basis that the wind farms are likely to be in situ for up to 25 years. For the purposes of this study, reversibility was not considered. Although identified as a criterion to be considered in GLVIA 3, it was not taken into account because it is not known whether any of the case study wind farms would be repowered or decommissioned.

Evidence Review

Documents Reviewed

4.23 For each of the ten case study sites a review of the available planning stage documents was carried out. This focussed on identifying the aspects of the assessment and consultation process related to residential visual impacts. Eight of the study sites had Environmental Impact Assessments (EIAs) carried out, each of which included a LVIA. Two study sites did not require an EIA, but Landscape and Visual Impact Reports were produced. All of these documents were reviewed, as well as the visualisations accompanying the LVIAs.

4.24 Additionally, consultation responses from SNH and, where available, the planning authority's Landscape Advisor, were reviewed to identify whether residential visual amenity was identified by these consultees as being likely to be affected by the development. The Planning Officers' reports and recommendations to their respective committees were also reviewed where available. For one of the case study sites, it was not possible to obtain the Planning Officer's report and recommendation.

4.25 For the four applications subject to Public Inquiries, the Reporters' decisions and accompanying reports were reviewed.

Were residential visual impacts identified at the consultation and planning assessment stage?

4.26 On the basis of the available evidence, residential visual impacts were highlighted by some planning authorities but not for all at the pre-application stage. It is the responsibility of the planning authority to ensure that viewpoints are included in the assessment to provide adequate representative coverage of residential receptors. Although this is not SNH's responsibility, potential residential visual impacts were identified by SNH in three of the ten case study wind farms' pre-application consultation responses.

4.27 Whilst it is recognised that most planning officers have a good understanding of the range of environmental considerations relevant to wind farm applications, it was apparent from the evidence review that there was some variability in the way in which visual impacts were considered in the planning officers' reports.

4.28 Visual impacts on local residents were considered in respect of the majority of the sites in the planning officers' reports to committee available from the evidence review.

4.29 On the basis of the evidence obtained in respect of each of the ten wind farms included in the study, Residential Visual Amenity Surveys were not submitted as part of the LVIAs for any of the ten study sites. This is not surprising given the application dates of the case study sites, of which seven were submitted during or before 2005 and the remaining three were all submitted in 2009. As previously noted, in SLR's experience, Residential Visual Amenity Surveys were often produced at public inquiry stage in the first decade post 2000, but have been requested by planning authorities at application stage increasingly within the past ten years.

4.30 Tables were produced in the LVIAs for two of the case study sites at application stage providing more detailed information on the distance and direction to the proposed turbines, as well as the nature of views from individual residential properties within 2 km of the nearest turbine. Tables alone would not now constitute a Residential Visual Amenity Survey.

4.31 For one of the case study sites, a similar table was produced for all properties both up to 2.5 km and between 2.5 km and 5 km at the appeal stage. These tables identified the name and location of each property (Ordnance Survey grid references); the distance to the nearest turbine; and the number of blade tips and hubs that would be visible. However, these tables did not really provide any clear indication of whether the predicted impacts on views were considered to be significant or not. Of the two instances noted above where tables were produced at application stage, one of the sites was subject to a Public Inquiry and a more detailed Residential Visual Amenity Survey was prepared as part of the appeal documentation. This survey included the key components that would be anticipated in such a survey and appeared to SLR to have been carried out comprehensively. It is possible that similar surveys were completed for the other sites which went to appeal, but that the relevant documents were not found in the evidence review.

Methodology used in the Assessments

4.32 Based on SLR's review of the available documents, the methodology used to assess visual impacts on residential receptors within the majority of the submitted LVIAs and Environmental Reports generally followed guidance extant at the time the assessments were carried out (i.e. GLVIA, 2nd edition 2002). There were three sites for which the LVIAs were not completely consistent with extant guidance in all respects. In these instances, the sensitivity of change ascribed to residential visual receptors was inconsistently applied and therefore not always considered to be high, without reasoning provided as to why this should be the case. In one case, no threshold was identified for impacts considered to be 'significant'. This is a requirement of the EIA Regulations and clearly identified in GLVIA, 2nd edition of 2002.

Visualisations

4.33 The applications for seven of the ten case study sites were submitted prior to SNH's 2006 guidance on visualisations for wind farms being published, with three applications submitted in 2009, post publication. Nevertheless, the majority of the visualisations illustrating the LVIAs were considered in SLR's professional judgement to be reasonably consistent with the minimum requirements set out in SNH's 2006 guidance in terms of the size and scaling of the illustrations. However, in some instances the quality of the available printed illustrations submitted with the ES LVIAs was poor, and/or the quality of the photography was poor. It is not known whether the poor print quality would have applied to all the ES LVIA illustrations available to the public, consultees and/or decision makers.

4.34 For the majority of the case study sites, the illustrative material was considered by SLR's professional judgement to be of an adequate standard to inform the assessment, consultees and decision makers. In one of the case study wind farms, some of the illustrations did not show the full horizontal extent of the proposed turbines that would be visible, i.e. there were turbines visible to either the right or the left of the illustrated view which had not been included due to the presentation of a single A3 visualisation showing an approximate 75 degree view.

Viewpoint Selection

4.35 For each case study site, the number and location of representative residential visual amenity viewpoints assessed in the LVIAs or Environmental Report were recorded by SLR, as well as the number and location of these viewpoints predicted in the assessments to incur significant impacts on residential visual amenity. This was compared with the number and location of representative residential visual amenity viewpoints identified through SLR's desk review of the application stage assessments as being likely to incur significant impacts. The purpose of this mainly was to inform the subsequent site visits carried out by SLR, so that all locations considered likely to incur such impacts would be visited. This process also gave an initial indication of whether the number and location of representative viewpoints included in the assessments provided adequate coverage of high sensitivity residential receptors, particularly at close distances to the development.

4.36 For the majority of the case study sites, the number and location of residential visual amenity receptors included in the reviewed documents were considered in SLR's professional opinion to provide sufficient coverage to inform the assessment. There were three case study sites where additional viewpoints would have resulted in a more robust assessment of the impacts of the wind farm on residential receptors.

4.37 In respect of two of the case study wind farms, it was noted that some of the selected viewpoints which were on roads were assessed in respect of road users only, when these locations were quite close to residential properties which would have similar views towards the wind farm. In these instances, it would have been appropriate to assess impacts on residential receptors at these locations. This is because residential receptors are considered to be more sensitive to change than road users and therefore the overall effect identified for these locations would not necessarily reflect the level of impact for nearby residents. This highlights the challenge of selecting representative viewpoints for the purposes of LVIA, and it is not always the case that viewpoint locations on a road close to properties would have similar views. This may be due to screening around the properties by adjacent buildings, garden vegetation or in some instances small scale variations in landform not captured by the digital terrain model used to generate ZTVs.

Planning Officer's Reports

4.38 There was considerable variability in the extent to which visual impacts on residential receptors were identified and described in the available planning officer's reports at application stage. In one instance where the case study wind farm application was consented by the planning authority, the planning officer's report specifically considered visual sensitivity to be "low". No advice from a Landscape Advisor within the relevant planning authority was found in the evidence review for this site. It is not clear whether this sensitivity was ascribed to all visual receptors, or only residential visual receptors. The planning officer's report does not provide any reason for attributing a different sensitivity to residential receptors from that identified in the application stage assessment, or from normal best practice as set out in GLVIA. The application LVIA for this case study site identified receptors as being high sensitivity in the methodology but did not apply this consistently, which was justified on account of the context of the available view reducing sensitivity. In respect of this same site, SNH commented that the methodology used to undertake the assessment was not consistent with guidance and they disagreed with the LVIA conclusions in respect of visual impacts. There was no evidence in this instance of the Council having requested further information from the developer to address this concern prior to the development being consented.

4.39 In two instances, the planning officers in their reports to committee, appear to have arrived at conclusions on the acceptability of the case study wind farm developments in relation to landscape and visual impacts based on their review of the visualisations presented in the assessment, without any cross referencing to the findings of the respective LVIAs, or in relation to their own assessment.

4.40 In some instances it is not clear whether the planning officers' report text is recording the findings of the LVIAs; providing an endorsement of these findings; or providing his/her own assessment of the likely visual impacts of the proposed wind farm. It was also not clear whether planning officers had visited some or all of the viewpoints assessed in the LVIAs for the case study wind farms in the course of producing their reports.

4.41 At two of the case study sites, impacts on residential visual amenity were identified as a reason for refusal or objection by the respective local authorities.

Appeal Reports

4.42 In respect of the four case study sites for which Public Inquiries were held, objections to the proposed developments in respect of impacts on visual amenity were identified by all four local authorities, either in their reasons for refusal, or in reasons for objecting. In the Reports accompanying the appeal decisions, in one instance the Reporter referred to the "*visual impacts not being overbearing"* and in another, the Reporter referred to the fact that *"the wind farm would not result in the visual dominance of any houses*".

Site Visits

4.43 SLR's Landscape Architects carried out two site visits per case study wind farm: the first during summer months when deciduous plants were in leaf providing natural screening: and the second during winter months when there were no leaves on deciduous plants.

4.44 During each site visit, an experienced chartered Landscape Architect visited the residential viewpoint locations identified in the LVIAs/Environmental Reports predicted to incur significant effects within up to 5 km. Four of the ten sites were visited by two chartered Landscape Architects in order to calibrate SLR's assessment findings. The actual magnitudes of change and impacts on visual amenity assessed by the SLR Landscape Architect(s) on site were recorded and subsequently compared with the ES LVIAs/Landscape Report findings.

Predicted Visual Impacts

4.45 For the majority of the viewpoints visited (36 of 50), the findings of the site visits were consistent with the LVIA/Landscape Report assessment. However at just over a quarter of the viewpoints (14 of 50) the LVIA/Environmental Report findings were lower than those assessed in the field by SLR. Of these 14 viewpoints, SLR assessed the visual impacts as being significant at four viewpoints which were not considered to be significant in the submitted predicted assessments (two viewpoint locations in respect of one case study site, and one viewpoint at each of the other two case study sites). As previously noted, in one instance it was not clear whether the impacts were assessed as significant effects in the submitted LVIA.

4.46 At the other ten viewpoints where SLR identified a higher impact than the application stage assessment, the increased magnitude of change identified by SLR did not change the overall significance of the effect identified in the planning stage assessments (where this was clearly identified).

4.47 The difference in the assessment findings between the 'without leaf' and 'in leaf' site visits, was not sufficient at any of the viewpoints to alter the magnitude of change identified by SLR. This is considered to be largely due to the selection of representative viewpoints in the LVIAs/Environmental Reports which had relatively open views without intervening deciduous tree cover or vegetation between the viewpoint the wind farm. In respect of individual households and their views of the case study wind farms, a noticeable difference in effect was identified in the Residents' Survey due to 'in leaf' conditions. In SLR's professional opinion, this was probably due to the proximity of trees and/or vegetation to individual houses, whereas the representative viewpoints used in the LVIAs were all located at publicly accessible locations, i.e. outwith the curtilages of any individual properties, and therefore at locations with more open views less likely to be affected by intervening vegetation.

4.48 The second round of site visits was carried out after the Residents' Survey had been completed and comparisons were made between the Survey findings and the impacts assessed by SLR. This is reported in the subsequent section on Residents' Survey Insights.

Visualisations

4.49 SLR's Landscape Architects took the visualisations provided in the assessments to site and compared these with the appearance of the operational wind farm at each of the case study sites. In some instances, there were some differences between the appearance of the wind farm in the visualisations and the constructed development. These were mostly due to slight differences in the location of the turbines, or in some instances the number and/or height of turbines predicted to be visible. In one instance the visualisation predicted visibility of blade tips only whereas turbine hubs were visible from this location during the site visit. In some instances, forestry growth between the time of the application and related photography work used to illustrate viewpoints and the SLR site visits, resulted in slight reductions to the number and/or height of turbines visible.

4.50 Where possible, SLR checked this variability between the application stage illustrations and the actual appearance of the constructed wind farms, by comparing the application stage turbine grid references with the as-built turbine grid references supplied by the wind farm operators and checked by examination of aerial photography. In the majority of cases, SLR considered that these variations in the appearance of the wind farm were due to micro-siting of turbines during the construction stage. However it was not always possible to obtain evidence of post consent agreement between the developer and planning authority in respect of micro-siting. It was also not always easy to obtain as-built locations of the constructed turbines from either the local authorities or developers.

4.51 It is not unusual for a condition to be placed on consents for wind farm developments which approves a limit to the distance by which turbines can move during the construction stage from the locations identified in the application, usually up to 50 metres. In some instances no micro-siting allowance is given, but a requirement is placed on the developer to submit details of the final turbine locations for agreement with the relevant authority post consent but pre construction. Generally such a condition does not require reproduction of revised illustrative material to show the differences between the application stage locations and the revised construction stage locations.

4.52 This “leeway” in respect of final turbine locations is due to factors such as ground conditions which may not be fully known at the time of the application when no intrusive site investigation works are carried out. The results of site investigation post consent may mean that some adjustments to the exact locations of turbines are required to enable construction work to proceed.

4.53 In one instance there was a more marked difference in the appearance of the wind farm from the visualisations with fewer turbines at greater distance being visible on the ground than shown on the illustrations. For this site, SLR prepared wirelines based on the ‘as built’ turbine locations provided by the operator which matched with the appearance of the wind farm on the ground, but did not match with the only available visualisations from the evidence review. In this case, the change occurred prior to the appeal stage of the development and it was not possible to obtain copies of all the relevant appeal stage documentation.

4.54 At one other site, it appears that micro-siting of turbines has resulted in a greater height of turbine being visible from some locations than shown on the application stage visualisations.

4.55 It is apparent that, of the ten sites studied, there is considerable variation in the approach taken to micro-siting between their respective planning authorities (eight relevant to the ten case study wind farms), with some identifying a specified micro-siting distance by condition and others requiring this to be agreed post consent. There was no evidence of revised visualisations being requested by the competent authority to reflect the final micro-sited locations, and this has never been a requirement in the study team’s experience.

4.56 It is important to note that apart from the small number of instances where micro-siting results in a change from no predicted views of the development to it becoming visible, it is considered unlikely that the slight changes resulting from micro-siting would result in a material change to the predicted impacts, i.e. a change from non significant to significant effects, or vice versa.

4.57 In respect of single turbines, the difference between no visibility and some visibility which may occur with slight movement in the siting of the turbines could alter the difference between no effect and a significant effect occurring.

4.58 The greatest movement of turbine locations between the application stage layouts and as built layouts across the case study wind farms was a distance of 56 metres apart from the appeal sites where it is anticipated that a revised layout was submitted for which revised visualisations were not obtained.

4.59 In all instances the differences between the appearance of the wind farm from the viewpoints visited during the site visit and the illustrations provided in the assessments were insufficient to alter the magnitude of change resulting from the development as assessed by SLR's Landscape Architects. This is an important point because it means that despite the changes due to micro-siting, the significance or otherwise of the visual effects was not altered by these changes.

4.60 Nevertheless, there may be instances where micro-siting results in either visibility of the upper part of a turbine occurring where no visibility was predicted at the assessment stage, or conversely, no visibility occurring where previously visibility was predicted. These circumstances are only likely to occur at the edges of the ZTV, where slight movement of a turbine or turbines, particularly in the context of undulating topography, results in a change to the area from where they may be seen. No such circumstances were identified during the site visits.

4.61 Whilst the slight changes to the appearance of the wind farms which occurred as a result of micro-siting may not have altered the assessment of the significance or otherwise of predicted effects, such changes can alter the aesthetic appearance of a wind farm layout in ways which result in a departure from the originally intended design concept or objective. This is an important issue because the key mitigation in terms of (landscape and) visual impacts is the attention given to the relationship between the appearance of the turbines (their height, ratio of rotor to tower height and layout) and the landform of the site and surrounding area.

4.62 It may be that the public is not aware that small adjustments to the location of the turbines may occur as a result of micro-siting and it may be beneficial if this were made more clear in the public consultation process.

Residents' Survey Insights

4.63 The Residents' Survey questionnaires were distributed to a sample of households within 3 km (and 4 km for those with a low population) of the case study wind farms (see Appendix B). As 3 km is the distance within which significant impacts on visual amenity from wind farms are most likely to occur, the focus of the study of impacts on visual amenity concentrated on an area of 3 km from the nearest of the 'as built' turbine locations at each case study site. However all viewpoints identified as representing residential receptors in the ES LVIAs/Environmental Reports were visited within distances of up to 5 km, and the findings in the reports compared with the findings in the field. Additionally, the nearest publicly accessible locations to all households which had recorded a "strong dislike" or "dislike" in the Residents'

Survey in respect of the visual effects of the case study wind farms, were visited during the second ‘with leaf’ site surveys, which were carried out after completion of the household survey.

4.64 There were six questions in the Residents’ Survey that directly related to visual impacts (See Appendix B, Q11 – Q16). These covered:

- The extent of visibility of the wind farm from within the property;
- Whether there is visibility of the wind farm from external spaces;
- Residents’ responses to the visual impact on their property;
- Whether there is any seasonal variation in visual effects;
- Whether the development of the wind farm had resulted in any changes to the way people use their homes;
- Whether the appearance of the wind farm as built differs from any visual information that residents saw during the planning process; and the ways in which the wind farms looks any different from their expectations.

4.65 As described in Section 2.14, the analysis which follows is based on review of the responses provided to each of the questions and excludes those who chose not to provide a response in relation to the particular question.

4.66 In respect of the rooms in respondents’ houses affected by visibility of the wind farms, this varied considerably across the survey. For those who responded, 43% across all of the case study sites recorded that they did not experience visibility of the turbines from within their properties. However, there were some respondents at each of the case study sites who recorded that one or more of their public rooms have views of the wind turbines. Thus some respondents recorded having extensive direct views of the turbines from the majority of rooms whilst others recorded having no views from inside their properties.

4.67 Just under a half of those who responded (46%) recorded that the wind farm was visible from part of their garden or external property. Again, there is considerable variability in the responses as to the extent of visibility with some households experiencing extensive visibility and others limited or none.

4.68 Four out of the ten case study site surveys had no respondents who “strongly like” the visual impact of wind farm; with six recording some respondents who do “strongly like” the wind farm. Of the four case study sites where no respondents recorded that they “strongly like” the wind farm, two had some respondents who “like” the visual impact of the wind farm. Eight out of the ten case study Residents’ Surveys had some respondents (varied between 4% and 25%) who “like” the visual impact of the wind farm.

4.69 Conversely, some respondents (varied between 16% and 67%) at all ten case study sites recorded that they “strongly dislike” the visual impact of the wind farm and some respondents at eight of the ten sites recorded that they “dislike” the visual impact of the wind farms. A larger proportion of respondents across all the sites recorded that they “strongly dislike” (32%) the visual impact of the wind farm than “strongly like” (4%). However the numbers recording “dislike” and “like” were much more similar, (12% compared to 11%).

4.70 Overall, 15% of respondents recorded that they either “strongly like” or “like” the appearance of the wind farm; 45% recorded that they either “strongly dislike” or “dislike” the appearance of the wind farm, and 40% recorded being “indifferent” to its appearance.

4.71 During the second set of site visits, as well as visiting the ES/ER viewpoints, SLR also visited all the locations identified in the responses where residents had recorded “strongly dislike” and “dislike” in respect of views of the wind farm. SLR identified significant effects at 87 of the 122 instances where a “strongly dislike” or “dislike” response was recorded in respect of impacts on visual amenity. For seven of the case study sites, there were a few instances of respondents recording “strongly dislike” or “dislike” where there was no view of the wind farm. In one instance this occurred where the respondent’s property is located outside the Zone of Theoretical Visibility (ZTV), and, in all other instances, there was no view of the wind farm due to vegetation or intervening buildings immediately around the property which was identified during SLR’s site visits. It is possible that at some of these locations there may be filtered views of the wind farm in winter ‘without leaf’ conditions.

4.72 Some respondents at all ten sites recorded that they were “indifferent” to the visual impact of the wind farm. At six of the ten sites, the number of those who recorded being “indifferent” to the appearance of the wind farm was equal to, or greater than the number who recorded “strongly dislike” with 38% overall recording being indifferent to the visual impact of the wind farm.

4.73 Half of respondents at all of the sites (50%) recorded no variation in visual effects due to seasonal or weather changes. For the 21% of respondents who identified seasonal or weather variations in impacts, the main reasons given were the difference caused by trees in leaf close to properties (in their gardens or immediately adjacent vegetation) providing screening; poor weather conditions obscuring the turbines; and bright sunlight causing additional visual effects such as shadow flicker or ‘glinting’ of turbines.

4.74 A majority of respondents (68%) in respect of all ten sites recorded that they had not made any changes to the use of their residence due to visual impacts of the wind farm. However, slightly less than a quarter of respondents (23%) in one instance, and slightly less than a half (45%) in another, recorded that they had made changes to the use of their residence as a result of the visual impacts of the wind farm. These changes ranged from carrying out new garden planting; not using external areas; installing blinds; leaving curtains closed all day; changing seating; moving bedrooms; to re-planning extensions.

4.75 Overall, 38% respondents recorded that the wind farm appeared “as expected” or “broadly similar” to what was expected on the basis of the information presented during the planning process. Conversely, 32% recorded that the wind farm was “different” or “very different” from what they expected. The survey responses for four of the case study sites identify that between 24% and 38% of respondents recorded the wind farm as being “very different” from the planning process presentations. However, quite a large number of respondents to this question (30%) did not know how the wind farm as constructed compared to what was presented in the information provided during the planning process.

4.76 The ways in which respondents described the wind farm looking different from expectations based on the planning process illustrations varied from the turbines being more visually prominent in reality than the illustrations showed; the size of turbines appearing larger in reality; the turbines appearing to be closer than shown in the illustrations and photomontages not providing a “realistic” impression of the actual appearance of the operational wind farm. In one instance an increased number of turbines, more of the turbine towers, and hubs as well as blade tips were seen than predicted on photomontages.

4.77 A number of respondents recorded that they were unaware of what the appearance of the turbines would be once constructed. This also seems to be due to a range of factors from not having heard about the planning application or related public exhibitions, to not having seen or fully appreciated visual presentations of the appearance of the wind farm.

Summary of key findings from evaluation of the assessment process

4.78 There was considerable inconsistency across all of the case study wind farms sites in relation to the availability of documents regardless of the consenting route (planning application, Section 36 applications and sites subject to an appeal process).

4.79 All of the LVIAs for the case study wind farms referred to the relevant GLVIA methodology extant at the time of the assessments. However in some instances this appeared to have been inconsistently applied. For example, in some instances residential receptors were not always accorded a high sensitivity.

4.80 Not all of the assessments set a clear threshold for identification of significant effects. This is important because it is a requirement of the EIA Regulations and critical to inform the decision making process. In these instances, SLR was unable to establish whether the relevant competent authority had requested additional information to identify whether the effects identified in the assessment were significant or not.

4.81 Residential receptors were identified as a key group of people whose views would be affected by the proposed wind farms at all of the case study sites. SLR considered that the number and location of viewpoints representing residential receptors provided adequate coverage to enable the assessment and identification of likely impacts on residential receptors within the vicinity of the case study wind farms. However, at two of the ten case study wind farms, representative viewpoints for some nearby residential visual amenity receptors likely to be affected by the wind farm were not included in the assessment. GLVIA 3 does not require that all individual residential receptors are identified, but that representative viewpoints should be agreed to provide an assessment of the likely impacts on such receptors.

4.82 It was not possible to find records of the process applied through the consultation process at application stage, to ensure that the LVIA viewpoint coverage was representative and proportionate.

4.83 Responsibility for identification of residential receptors to be included in the LVIA lies with the planning authority, who in conjunction with SNH, usually make comments and provide recommendations on the representative viewpoints selected for inclusion in the detailed assessment. It is also the planning authority who makes the request for a residential visual amenity survey to be carried out and the responsibility for this lies with the landscape architects undertaking the LVIA.

4.84 At six of the ten case study sites, the magnitude of change and/or sensitivity of residential visual receptors recorded in the submitted assessment for a relatively small number of viewpoints were considered by SLR to have been underestimated in the LVIA. This was not always picked up by consultees in their response to the application, although in one instance SNH did note disagreement with the assessment findings in this regard.

4.85 SLR considered that the visualisations for the majority of the post 2006 case study wind farms were reasonably consistent with the extant guidance (SNH's 2006 guidance).

4.86 In all instances, SLR considered the visualisations were 'fit for purpose' insofar as they were accurately scaled in relation to the application stage turbine data and of an adequate standard to inform the assessment by a professionally trained Landscape Architect with LVIA experience.

Summary of key findings from effects from operational developments

4.87 Slightly less than a third of respondents (30%) to the Residents' Survey identified that they did not know how the illustrations of the proposed development compared with the built wind farm. Various reasons were given by some respondents as explanations for this including the fact that they had not seen any illustrations or been aware of the proposed development prior to its construction. Although 32% of respondents considered that the built wind farm was different or very different from the illustrations, a slightly greater number (38%) of those who responded recorded that the wind farm was "as expected" or "broadly similar" to what was anticipated on the basis of the information presented at planning stage. Of the respondents who recorded a difference, the reasons given mainly identified that the built turbines looked larger and closer than those shown in the illustrations.

4.88 Since all of the applications related to the ten case study sites were submitted, SNH has produced revised guidance on the production of visualisations to illustrate wind farm developments (Visual Representation of Wind Farms Good Practice Guidance 2014). SNH has commissioned research on the use of visualisations pre and post publication of the revised guidance.

4.89 In some instances review of the available documentation indicated that decision makers seem to have placed considerable weight on the appearance of a wind farm as presented in the visualisations in order to inform their decision making, without cross referring to the findings of the LVIA. It was not possible from the available evidence to identify whether the decision makers had visited the site and/or any of the representative viewpoints before making their decision. Although it is becoming increasingly common for planning authorities to arrange site visits for planning committees to a selection of viewpoints with the relevant visualisations, it is not known whether such visits are recorded in any way.

4.90 Visualisations are inevitably representative and cannot be expected to replicate the reality of the actual appearance of a development. Interpretation of visualisations can therefore be difficult without experience and/or professional training. SNH's revised guidance is intended to result in visualisations which more closely represent the perception of turbines in the landscape and therefore may be easier for the public to interpret.

4.91 In some instances some movement of turbines during the post consent micro-siting process resulted in a slight change to the appearance of the wind farm from that predicted in the LVIA illustrations. However, SLR did not consider that these amounted to significant changes to the visual impact of the development.

4.92 Nevertheless, for individual residents, any slight change, for example to the height or number of turbines visible which may result from micro-siting, may be a concern to them in terms of their attitude towards the development. This highlights the fact that there is a distinction between the generalised assessments of visual impacts on residential receptors within the LVIA process and the case by case, location by location experience of these impacts. The latter may be identified and assessed in a residential visual amenity assessment. However, as described in preceding sections of this report, these more detailed assessments of impacts on individual private views are not always required by the respective competent authorities or consultees, and there is no standard methodology for carrying out such assessments.

4.93 Micro-siting of turbines between application and construction stage can also result in changing the aesthetic appearance of the wind farm and may materially alter the original design concept or objectives. This can make a considerable difference to the relationship between the individual turbines, affecting the balance of the grouping, as well as the relationship between the turbines and the landscape where they are seen. Micro-siting changes to the location of turbines may also affect other impacts assessed such as shadow flicker and noise as well as other environmental considerations such as impacts on protected species, sensitive habitats or peat.

4.94 From review of the Residents' Survey, it is apparent that respondents hold diametrically opposed views about the visual impacts of the same wind farm developments. There are some people who live in close proximity who either "strongly like" (4% of those who answered this question in the survey) or "like" (11% of those who responded) the view of the wind farm in question whilst there are others who "strongly dislike" (32% of those who answered this question) or "dislike" (12% of those who answered this question) the view of the development. Interestingly a notable proportion of those who responded to this question (overall 38%, with the lowest being 18% and the highest 55%) recorded being "indifferent" to the visual impact of the development.

4.95 Based on the Residents' Survey findings and the second set of site visits which included locations adjacent to properties which had recorded "strongly dislike" and "dislike" in respect of the visual impact of the wind farm, there does not appear to be a direct correlation between the extent to which a wind farm is visible from within a property, or from its garden or external area, and the opinion of the respondents in respect of the appearance of the wind farm. Indeed there were some households at seven wind farms which recorded "strongly dislike" or "dislike" in respect of the visual impact of the wind farm, yet do not have any views of it from either inside or outside their property. This indicates that people are concerned about views within the locality of their homes as well as views from their homes.

4.96 There is some variation in terms of respondents' experience of visual impacts due to seasonal or weather conditions. No difference in visual impact was recorded by SLR between the "with leaf" and "without leaf" site visits. The difference between the individual experience at particular household locations and generic viewpoints selected to be representative of residential receptors illustrates the possible differences between the findings of a residential visual amenity survey or report and an LVIA. The former is more likely to identify the potential for seasonal variation as a result of for example, vegetation being in leaf.

Lessons for good practice

Pre-consent assessment

4.97 GLVIA 3 together with SNH's Visual Representation of Windfarms Good Practice Guidance provide the key sources of guidance on visual impact assessment methodology. Both sets of guidance post date the assessments included in this study. Adherence to this guidance is considered likely to reduce variability between different assessments and improve their robustness. It should also greatly assist in the scrutiny of such applications by planning authorities, other consultees and their associated specialists. There is a raft of other guidance which provides advice in relation to the siting and design of wind farms, cumulative impact assessment and other relevant considerations which is listed in Appendix L.

4.98 It is important that clear thresholds for significant effects are identified in LVIAs to comply with the EIA Regulations and thereby to assist decision makers.

4.99 The visualisations which accompany LVIAs should be produced in accordance with SNH's visualisation good practice guidance (2014) and other local authority standards where required. Following the revised SNH guidance, the illustrative material presented at public consultation events should be the same as that presented in the ESs/ERs.

4.100 The assessment process would benefit from greater consistency relating to storing and availability of documents by the relevant competent authorities; as well as requirements and methodology for residential visual amenity studies.

4.101 LVIAs should be reviewed by suitably qualified and/or experienced professionals at the consultation stage to provide robust advice to the relevant competent authority on the reliability or otherwise of the assessment. Where a LVIA does not follow extant guidance without adequate robust reasoning, the competent authority should request re-assessment.

4.102 GLVIA 3 (and its predecessors) identifies residential receptors as being of high sensitivity and it is therefore important that impacts on visual amenity for residents are thoroughly assessed. The use of representative viewpoints selected at the nearest likely affected settlements should provide a robust assessment of the likelihood of significant effects on visual amenity occurring, both at the particular location selected to be representative and, by extension, at other settlements or individual residential properties within the ZTV and at a similar distance from the proposed wind farm development.

4.103 Nevertheless, it is apparent from the increasing trend for planning authorities to request residential visual amenity surveys that the identification of whether a visual impact on residents is significant or otherwise, may not always provide the decision maker with sufficient information on the judgment to be made as to whether such an impact results in an unacceptable visual effect at any particular property location. The lack of an established methodology for such surveys exacerbates this problem.

4.104 A robust methodology for residential visual amenity surveys and subsequent consistent implementation, should "fill the gap" between the assessment of effects on residential receptors as a group and the effects which may occur for residents of all properties within a certain distance from any proposed wind farm development.

4.105 As siting and design of a wind farm provide the key means of minimising visual (and landscape) impacts, it is important that this process is carefully considered at the assessment stage and clearly reported and illustrated in the LVIA or ES/ER. Design objectives should be set out as well as key constraints so that the resulting layout can be considered against these factors.

4.106 It may assist in achieving a more consistent and transparent process, if planning authorities developed and agreed pre application and post submission check lists for processing wind farm LVIAs to cover such points as, by way of example:

- Do viewpoints to be included in the detailed LVIA provide adequate coverage of the people and places most likely to be affected the proposed development?
- Is a separate residential visual amenity report required (see below)?
- Has the LVIA been carried out in accordance with methodology stated and is it in accordance with best practice guidance?
- Are wind farm design rationale and objectives clearly set out?
- Do visualisations meet best practice guidance?
- If not, has applicant been asked for revised visualisations which do meet best practice guidance?
- Does the planning officer agree with the findings of the LVIA?

Public consultation

4.107 Whilst SLR's experience indicates that wind farm developers do carry out public consultation, the Residents' Survey indicates that developers do not always succeed in conveying relevant information to attendees. Following best practice guidance for this process could help to ensure that the public are well informed about consultation events and the ways in which they can engage with the planning process. Best practice guidance in respect of the public consultation process may be beneficial and the Scottish Government has published a consultation draft of Good Practice Guidance on Public Engagement for Wind Turbine Proposals in November 2014. This would supplement existing guidance[6].

4.108 The Residents' Survey responses indicate that there is some correlation between respondents finding the wind farm "as expected" or "broadly similar" to the illustrative material seen during the planning process and either "liking" or "strongly liking" the built wind farm. This suggests that good public consultation with accurate and clearly presented illustrative material may positively influence the public's subsequent attitude to the development. SNH's revised visualisation guidance (2014) recommends that the visual material presented at public consultation events is the same as that presented in the ESs/ERs.

4.109 The possibility of some movement to turbine locations happening as a result of micro-siting should be made clear to both consultees and the public.

Pre-application consultation response

4.110 It is important that planning authorities request a proportionate number/location of viewpoints to provide representative views of the receptors likely to be affected by the proposed development. SNH's guidance on visualisations does emphasise the need for proportionality. It is good practice that the planning authority and SNH agree the list of viewpoints to be included in the assessment prior to carrying out the detailed assessment.

[6] Scottish Planning Series Circular 4 2009 Development Management Procedures; and Planning Advice Note 3/2010 Community Engagement

4.111 Planning authorities should make clear in the Scoping Opinion and/or through the consultation process, whether a residential visual amenity survey is required, and agree the methodology to be used, distance to which it should be carried out, and the required output. This may be requested by the competent authority as part of a Residential Amenity Survey covering visual, shadow flicker and noise impacts.

Visualisations

4.112 SNH's recently published guidance should help to achieve clear, accurate and representative viewpoint illustrations. SNH also is currently carrying out research to assess the use of visualisations before and after publication of the revised visualisation guidance. SNH's guidance also makes clear that site visits with the relevant visualisations is recommended in order to gain a full understanding of the predicted views of any proposed development.

Post application response

4.113 Planning authorities and SNH should make clear in their consultation responses whether or not they agree with the key assessment findings in terms of the significance or otherwise of effects.

4.114 It would also contribute to greater transparency in the decision making process if planning and appeal reports identified where the report reflects the findings of the ES LVIA; where it reflects consultees' views; and/or where it provides the planner's own assessment of effects. In addition it would be helpful to know which of the viewpoints illustrated in the LVIA were visited by the decision maker.

4.115 It would be helpful if planning officers' and appeal reports could cross refer between LVIA findings and the visualisations, identifying any discrepancies, should these occur (i.e. if the planning officer's or Reporter's assessment of the effect differs from that predicted in the LVIA report and/or as represented in the visualisations).

4.116 Where an LVIA or accompanying visualisations are considered not to meet the current guidance, the planning authority and relevant consultees should require a re-assessment and/or revised visualisations to be submitted before considering the application further.

Mitigation

4.117 Visual impacts from wind farm development are mainly reduced by optimising the design. SNH has recently updated its guidance Siting and Designing Wind Farm in the Landscape (2014), which provides useful advice on the objectives and key considerations affecting wind farm design.

4.118 It is therefore important that the layout design process is given adequate attention during the assessment stage. It should be discussed and described in an open, transparent way within the LVIA/Environmental Report to demonstrate the key constraints and design solutions and overall design objectives in terms of the final submitted layout. This should assist the public, consultees and decision makers understanding the rationale for the proposed wind farm design and layout.

4.119 Having a transparent record of the design process would also help the micro-siting process so that any adjustments to turbine locations are consistent with the objectives design aims and objectives.

Micro-siting

4.120 A more rigorous and consistent process should be put in place to agree and record micro-siting of turbines post consent. Although there is a requirement to provide the Civil Aviation Authority with 'as built' turbine locations, this does not seem to have facilitated access to accurate 'as built' data. In SLR's experience, even when 'as built' turbine co-ordinates are provided by developers, these do not always accord with actual 'as built' locations.

4.121 As described above, a micro-siting allowance of up to 50 metres is the usual limit. It is important that whatever condition is placed on a wind farm consent in respect of micro-siting, is followed up by the developer in terms of providing details of the micro-siting adjustments required and consistency with the original design objectives and aims, as well as identifying any changes to impacts assessed. It is also important that the planning authority ensures that the micro-sited turbine locations are recorded and that they have sufficient information to judge whether the revised locations would result in any material changes to the submitted assessments. If this is the case, further assessment would be required.

Monitoring

4.122 Some planning authorities employ staff to carry out site visits post construction to ensure compliance with planning conditions. They may also check illustrations from key viewpoints to monitor whether the operational wind farm is similar to that illustrated in LVIA visualisations. This is valuable and should be done as far as resources allow.

Enforcement

4.123 It is understood that SNH intends to respond to LVIA submissions to achieve better compliance with their most recent visualisation guidance. Noting that their advice is guidance and not a mandatory requirement, this should encourage a consistent standard of visualisations. It should also be noted that SNH does not usually respond to small scale development, and consultation response is normally restricted to proposals that require an EIA, or where a protected area is likely to be affected.

5.0 PHASE TWO - ASSESSMENT OF SHADOW FLICKER IMPACTS

Introduction

5.1 The aims of this element of the study were to, evaluate whether shadow flicker impacts were accurately assessed at the application stage; whether these were identified by the consenting authority and/or consultees and to assess whether the actual effects when operational, differ from those anticipated at the application stage.

Shadow Flicker Impacts

5.2 The height and movement of wind turbine rotors means that in sunlight they cast shadows on the area around them. This can result in a range of light and shadow effects of which shadow flicker is commonly identified and assessed. There is no standard definition of shadow flicker. The Scottish Government's online information on onshore wind turbines, states that "*under certain conditions of geographical position, time of day and time of year, the sun may pass behind the rotor and casta shadow on neighbouring properties. When the blades rotate, the shadow flicks on and off, the effect is known as "shadow flicker". It occurs only within buildings where the flicker appears through a narrow window opening. The seasonal duration of this effect can be calculated from the geometry of the machine and the latitude of the potential site*."

5.3 The Scottish Government's advice states that where shadow flicker could be a problem, "*developers should provide calculations to quantify the effect. In most cases however, where separation is provided between wind turbines and nearby dwellings (as a general rule 10 rotor diameters) "shadow flicker" should not be a problem. However, there is scope to vary layout/reduce the height of turbines in extreme cases*".

5.4 Accordingly, "shadow flicker" generally is taken to mean shadow effects caused by the movement of rotors which occurs at distances of up to ten times the rotor diameter (10 x rotor diameter) of the relevant turbines. Shadow 'throw' is taken to mean shadow effects which occur beyond this distance. For properties in the area potentially affected, shadow flicker can have an adverse impact.

Planning Policy Guidance

5.5 Planning guidance in the UK requires developers to investigate the impact of shadow flicker. This guidance does not specify how to assess the impact, or how to assess the significance of the impact. Assessments were usually based on PAN45[7] and current guidance is available in the Scottish Government Specific Renewables Advice Sheet on "Onshore Wind Turbines" (revised December 2013) as quoted in the preceding section.

5.6 Other sources of guidance include:

[7] Planning Advice Note 45 – now revoked

- In England, the National Planning Policy Framework (NPPF), Planning Practice Guidance [8] identifies that:
    - "Flicker effects have been proven to occur only within ten rotor diameters of a turbine" and that "only properties within 130 degrees either side of north, relative to the turbines can be affected at these latitudes in the UK."
    - Within this distance, the extent and duration of shadow flicker effects are likely to be very limited:
    - "Modern wind turbines can be controlled so as to avoid shadow flicker when it has the potential to occur. Individual turbines can be controlled to avoid shadow flicker at a specific property or group of properties on sunny days, for specific times of the day and on specific days of the year. Where the possibility of shadow flicker exists, mitigation can be secured through the use of conditions".
- Guidance from Northern Ireland in Best Practice Guidance to PPS18: Renewable Energy (Department for the Environment, 2009) is sometimes adopted to identify what may be an acceptable duration of shadow flicker. This guidance states that: "*shadow flicker at neighbouring offices and dwellings within 500 metres should not exceed 30 hours per year or 30 minutes per day*". Therefore for the purposes of shadow flicker assessments significant effects are categorised to occur where expected shadow flicker results exceed a maximum of 30 minutes per day; 30 hours per year; or 30 days per year: whichever is greatest.

5.7 Similar to the UK there are no formal shadow flicker standards in the United States. As such, as well as the above referenced guidance, consultants performing shadow flicker studies tend to refer to the German standards or a German court decision. Based on limited research[9], these two German references specify the calculation of shadow flicker in two different ways.

- German Guidelines[10]" state that:
    - "A receptor should be subjected to shadow flicker a maximum of 30 hours per calendar year and a maximum of 30 minutes per day. These maximum limits are based upon a calculation of the astronomically maximum shadow, which is defined as the time sunrise and sunset during which theoretically, the sun will shine continuously cloudless sky."

5.8 In other words shadow flicker is calculated based on the worst case condition that the sun is always shining, that the wind is always blowing at sufficient velocity to spin the blades and in a direction which results in the blades being perpendicular to the receptor (maximum shadow flicker or worst case).

- In the case of the German court decision shadow flicker was defined as:
    - "Maximum of 30 hours per year based upon actual/real predicted values."

5.9 The German court ruled that the criteria to apply should be an actual or real case, not worst case shadow flicker values. This calculation takes into account the

[8] http://planningguidance.planningportal.gov.uk/

[9] Camp Dresser & McKee Inc. (2010). Memorandum of review of Shadow/Flicker Report dated August 9, 2010 prepared by Atlantic Design Engineers Inc. (ADE)

[10] WEA-Schattenwurf-Hinweise, (2002). Notes on the determination and evaluation of optical emissions from Wind turbines (WEA-shadows instructions)

probability of sunshine as well as site specific wind direction and speed data. As such, the real or calculated shadow flicker is likely to be considerably less than the worst case. However, in more northerly areas, such as the Scottish Highlands, shadow flicker can occur within a few sunny winter days. This can mean that although the total exposure might be less than 30 hours per year or 30 minutes per day it would occur over a concentrated period.

Shadow flicker impact methodology

5.10 In assessing the impact of shadow flicker, commercially available software programmes, such as, WindFarm 4, developed by ReSoft, are often used to calculate the expected number of hours that shadow flicker could occur at identified properties at their specific latitudes. The WindFarm 4 programme takes into account the movement of the sun relative to the time of day and time of year and, by accurately positioning the wind turbines and potentially affected properties, predicts the time and duration of expected shadow flicker at each window or doorway within each affected property. The modelling results are typically considered to be a worst-case estimation of the actual impacts experienced as it is assumed in the modelling that the sun constantly shines during the day and the turbines always turn.

5.11 The following assumptions are generally made in the modelling:

- All properties within the zone of influence are assumed to have a specified window size facing directly on to each turbine that has the potential to cause an impact;
- The wind turbine blades are assumed to be rotating for 365 days per year;
- The wind turbine blades are assumed to always be positioned so that their full face would be between the sun and each property;
- The sun always shines in a clear sky on every day of the year, i.e. there are no periods of cloud cover or low visibility due to fog, mist and haze etc;
- A human receptor is deemed to be present in all affected rooms at all times;
- No account is taken of the potential shielding effects of trees or vegetation; and
- Curtains or blinds are assumed not to be fitted to windows.

5.12 In some instances the model is run for each potentially affected property or for locations that represent groupings of properties with similar orientation/distance from the nearest proposed turbine. For the purposes of running the model, input data may be at the simplest level, making an assumption that the whole of the potentially affected facade at each property is covered by a window. Alternatively, data may be collected from review of the site and/or web based data is used to identify the actual number and sizes of windows on the potentially affected facade. At the most detailed level, site photographs and surveys are used to record the actual number and dimensions of windows on each potentially affected the property. Where there is an absence of any data collection regarding the dimensions of windows existing at any of the receptor locations, a standard measurement of a 1x1 metre window perpendicular to the Earth's Surface, is usually assumed.

5.13 The likelihood (and duration) of any shadow flicker from turbines occurring is often low as it depends on a number of factors including:

- the geographic location of any houses;

- the direction of the property relative to the turbine(s). In the UK only properties within 130 degrees either side of north relative to a turbine maybe affected as it has been shown that turbines do not cast shadows to their southern side[11];
- the proximity of any property to the turbine(s) (typically less than 10 x rotor diameters from the proposal);
- the number and size of windows facing the turbine(s); and
- the interactions between the above.

5.14 Shadow flicker does not occur when the sun is obscured by cloud, fog or by intervening objects; when the turbine is not operating; or when the rotor is turned parallel to a line between the receptor and turbine. These are sometimes referred to as *moderating effects* and are sometimes applied to reduce the predicted impact from *worst case* to *likely*.

5.15 In addition, the distance between the turbine(s) and a window affects the intensity of any shadow flicker that is experienced. The intensity of the shadow is greater at locations closer to the turbine. As distance from the turbine(s) increases, the intensity of the shadow is reduced.

5.16 The software model calculates the worst case scenario. In order to more accurately predict the potential for shadow flicker other factors may be taken into account including:

- Applying local average sunlight hours obtained from the nearest Met Office;
- Applying an average turning of rotor – e.g. 90% of the time;
- Applying actual[12] or estimated[13] wind speed ; and
- Reducing turning of rotor to 63% of the maximum possible if the wind turbine is assumed to be randomly yawed[14] relative to the sun position (Danish Wind Energy Association).

5.17 The only mitigating circumstances which reduce or eliminate the likelihood of shadow flicker occurring within the prescribed distance, would be factors such as there being no windows on the facade of the property facing the development, or there being some intervening screening such as trees, buildings or local landform variations. However, the nature of shadow flicker, i.e. that it is essentially considered nuisance and consequently an impact on amenity, means that defining significance is difficult. Additionally, the experienced effects of shadow flicker will vary from person to person.

5.18 In the absence of published guidance, no significance criteria have been established to assess shadow flicker impacts and there is no statutory limit or

[11] Planning for Renewable Energy – A Companion Guide to PPS22 Office of the Deputy Prime Minister (2004) – now superseded by NPPF Planning Practice Guidance

[12] Actual wind speed data can be measured by anemometer masts where these have been installed prior to consent at the site which record the prevailing wind direction from which the likely orientation of the turbines rotors can be interpreted;

[13] In the absence of measured wind speed data, a single 360 degree sector is assumed with 8760 hours of wind as a substitute for estimated rotor azimuth and wind speed, which is a conservative assumption.

[14] The yaw system of wind turbines can adjust the orientation of the wind turbine rotor towards the wind.

guidance to stipulate acceptable levels of shadow flicker. Instead the area of shadow flicker is assessed on a case by case basis to identify whether the extent and duration of the predicted effect is considered significant (major or moderate) or not (low or negligible).

5.19 Shadow flicker can be avoided by switching the turbine off at times when shadow flicker could be a problem. This will of course mean that the turbine is not producing any power at that time, and so will affect revenue from the wind farm.

Presentation of shadow flicker impacts

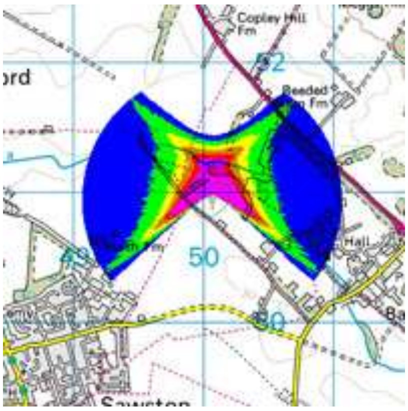
5.20 The assessment of shadow flicker is generally presented using tables, charts and interpretative text. For example, the computer modelling results may be presented in a table or plan similar to the examples below:

Table 5-1
Example Worst Case, Unmitigated Shadow Flicker Modelling results

House Name	Hours in year of potential shadow flicker (any window)	Max Hours Per Day of potential shadow flicker (any window)	Distance from nearest turbine
House A	54.6	0.92	686m
House B	16.1	0.52	646m

Source: SLR Consulting Ltd

Figure 5-1
Example Shadow Flicker Map



Source: www.redcotec.co.uk/renewable-energy/wind-turbine-feasibility-studies

Study methodology for shadow flicker impacts

5.21 The evaluation of whether shadow flicker impacts were appropriately assessed at the application stage and whether the actual effects of the operational wind farm differ from those anticipated at the application stage was made through:

- An evidence review of shadow flicker impact assessments for the case study wind farms;
- Analysis of Residents' Survey responses;
- Mapping of potential shadow flicker impacts for the case study wind farms; and
- A comparative analysis of findings.

Evidence review (data sources, findings, omissions)

5.22 The available planning stage documents for each of the ten case study wind farms were reviewed. This included consideration of how consistently the scope was defined, methodology identified and guidance applied, and a review of the assessment findings.

5.23 Shadow flicker assessments were carried out at the application stage for six of the ten case study wind farms. Five of the case study wind farm assessments of shadow flicker used computer modelling, typically, ReSoft's Wind Farm 4. Of those that were modelled, one involved carrying out a survey of the potentially affected property. One gave no evidence of methodology. The number of affected properties considered in the assessments ranged from seven at one case study wind farm site to seventeen at another of the five sites for which assessments were carried out. Sources of guidance referenced in the assessments included PAN45, PPS 22 and in some instances planning authority guidance. Significance criteria, where noted, referred to the German study (2002).

5.24 Four of the case study wind farms did not include a shadow flicker assessment in the respective ESs/ERs. This was because all of these sites were beyond 1.5 km from the nearest residential property and hence well beyond the 10 x rotor diameter threshold for shadow flicker occurring. Shadow flicker was therefore not considered an issue in these cases.

5.25 Planning, appeal and Reporters' decisions with the accompanying reports for the case study sites were reviewed. In one planning decision a shadow flicker management plan was requested which was required to include:

- A suite of all possible implementation measures that could be used to address shadow flicker in order to mitigate effects to an acceptable level and avoid nuisance complaints to the Council; and
- A practical procedure put in place to implement the mitigation measures if required.

5.26 The plan was required to cover a range of residential properties which were to be remotely monitored for one year from commissioning of the wind farm to study the effect that shadow flicker can have on amenity. It was not possible to ascertain from the evidence review carried out for this study whether this plan was executed and/or whether it successfully mitigated any identified impacts.

5.27 In another planning decision the predicted shadow flicker impact was deemed acceptable but it was noted that the authority was disappointed that the issue had not been assessed in more detail. In respect of one other case study site, one of the planning conditions stated that mitigation must be implemented by shutting down turbines during times and weather conditions when shadow flicker may occur. In the case of a complaint the condition stated that this would be investigated at the operator's expense. In one case the appeal decision confirmed that shadow flicker should not be an issue due to the site's distance from the nearest houses.

<u>Significance Criteria</u>

5.28 The lack of guidance with regards to significance criteria was noted in several of the assessments submitted at the application stage. In most cases the German guidance (2002), was used. In one case study the assessment also noted the judge's decision in the German court case, but added the criteria of waking hours, i.e. that the potential effect was less if during a period when it might be assumed the occupant would be asleep. In one case where a more detailed assessment was requested by the planning authority as an addendum to the ES, the significance criteria was refined to 100 hours for *worst-case* (i.e. modelled) and 30 hours for *likely* duration (i.e moderated effect). The resulting assessment identified some significant impacts.

Residential surveys

5.29 The majority of the assessments carried out at the application stage were conducted as a desk-based study. However, in the one case where an addendum to the ES was requested, a residential survey was undertaken in order to identify the numbers, sizes, positions and orientation of windows present on each identified property. Dates, times and durations of shadow flicker events were then predicted using ReSoft wind farm software.

Predicted impacts

5.30 For those sites that were assessed through modelling the potential shadow flicker impact at properties within 10 x rotor diameter of the nearest turbine, four predicted some level of impact and, of these, three concluded that shadow flicker would be unlikely to occur or would not be significant.

5.31 Of the cases that predicted some level of significant impact, these ranged from predictions of shadow flicker occurring for between 30 hours to 80 hours per annum.

Mitigation and monitoring

5.32 For those sites where a potential impact was predicted, the following range of mitigation measures was proposed:

- A turbine exclusion zone around sensitive receptors;
- Screening with coniferous planting (funded by the developer, in one case);
- A control system that automatically shuts down the turbine at times when shadow flicker occurs;
- A watching brief and constructive dialogue during the first year of operation to assess whether it is an issue.

5.33 Residual effects were considered at the application stage to be not significant if the control system was applied. However, it was also proposed that monitoring should be undertaken to assess the efficacy of the mitigation measures. Although mitigation measures were cited in the planning conditions for several of the case study sites, there was a general presumption to mitigate if shadow flicker was an issue, i.e. to wait until operation of the wind farm and liaise with residents to assess the effects.

5.34 In one case it was proposed that during the commissioning process of the newly constructed wind farm the visibility of each turbine would be checked from each window of the neighbouring nearest houses (with the co-operation of the householders). This would allow for turbines that do not have a clear line of sight to be excluded from the shut-down times that were to be applied for the benefit of that property. It was noted that a system is available for use with the candidate turbine proposed for the case study site which uses a device to measure the intensity of sunlight occurring at a particular moment, and uses this data, together with the date, time and, location of the wind turbines as well as the locations of nearby houses, to calculate whether shadow flicker will occur. The developer proposed to use this device to prevent shadow flicker affecting nearby properties. The developer also calculated that these measures would result in a loss of <1% of total annual generating time.

Financial interest

5.35 In two of the shadow flicker assessments there was a reference made to financial interests. In one case there was concern that a number of properties were within the zone of potential shadow flicker impacts and included those households with and without a financial interest. In another case it was noted that several properties identified as potentially experiencing significant shadow flicker effects were regarded as having a financial interest in the wind farm. In this latter case discussions were held with the occupants by the developer in order to ascertain their willingness to allow turbines to operate at times when shadow flicker had been predicted to occur and when the house is unoccupied (e.g. during working hours). Any such changes in operation were to be agreed with the planning authority's Environmental Health Department prior to their implementation.

Residents' Survey insights

5.36 There were five questions in the Residents' Survey that directly related to shadow and light effect impacts (see Appendix B, Q17-Q21). These covered:

- Whether the residents experienced light or shadow effects;
- Whether these were light, shadow throw and/or shadow flicker and how residents felt about these effects;
- Whether there was any seasonal variation in these effects;
- Whether the effects influenced any changes to the way people use their homes; and
- Whether the light and/or shadow effects as built differed from any information on this that residents saw during the planning process; and if so, in what way.

5.37 Within the Residents' Survey, shadow flicker, shadow throw and light effects were defined as follows:

- Shadow flicker occurs when the sun is low and the shadow of the turbine blades causes a flickering shadow to be cast;
- Shadow throw occurs when individual(s) outside a building are affected by the shadow cast by turbine(s) at frequent intervals; and
- Light effects may occur, for example, if light is reflected off the turbine blades or tower.

5.38 The majority of respondents to this question (66%) reported no light or shadow effects across all of the case study wind farms. In three of the case studies, 10% of those that responded reported that they experienced such effects; in six of the case studies this figure was between 17% and 30%, while in the remaining case it was 67%. A small number of residents reported shadow or light effects at each of the four sites where shadow flicker was not included in the planning stage assessments. When considering the responses for each site, only one site had no respondents reporting shadow flicker effects (but shadow throw was identified as an impact). Of the other nine sites, six of these had 1-5 residents reporting experience of shadow flicker and three sites had 12-19 experiencing shadow flicker.

5.39 Light effects which were described in the responses included light reflecting off the turbines into houses and lighting of the turbine at night; light from behind the turbines at night; and light bouncing off the turbines during spring and summer.

5.40 For those that experienced light and shadow effects including shadow flicker, 14% of respondents “disliked” or “strongly disliked” these effects. However, a few respondents (just over 2%) stated that they “liked” or “strongly liked” the effects, and 8% were “indifferent” to shadow flicker impacts. Some of the other concerns mentioned included claims that flicker may trigger migraines, cause dizziness and/or nausea and cause concerns with regards to epilepsy.

5.41 Several respondents commented that experiencing light and shadow effects when outside their properties, when working, or recreationally (e.g. walking or horse riding) was just as important in rural areas.

5.42 There was a variety of responses as to how light and shadow effects change with the seasons. These included that the lighting of turbines was more noticeable in the darkness of winter and that foggy conditions seem to carry this light further. Other light effects included the sun glinting off turbines. For shadow flicker there was a range of responses with several respondents identifying that impacts were more noticeable in spring and summer.

5.43 Some respondents mentioned very specific periods of time when they experienced shadow flicker for example mornings between late November and mid-January. Others said they can be affected by different turbines in different seasons, multiplying the impact. There were fewer comments regarding shadow throw and this tended to be associated with sites in more densely populated areas.

5.44 For those that experienced light and or shadow effects, some (28% of those who responded to this question) reported having made changes to the way they use their homes. This included:

- Closing curtains/blinds;
- Avoiding rooms where effects were occurring;
- Changing use of garden;
- Not being able to use television or computer;
- Sleeping in a different bedroom;
- Planting trees to block the view;
- Changing the times of using certain rooms and outdoor facilities;
- Not looking outside from the house; and
- Using window screening.

5.45 There were mixed responses to the questions concerning whether the light and/or shadow effects from the operational wind farm differ from any information on this that residents saw during the planning process; and if so in what way. Of those who responded to this question, approximately 31% considered that the effects were “as expected” or “broadly similar” to what they had anticipated on the basis of information provided. Approximately 36% of those who responded considered that the effects were “different” or “very different” from those anticipated and 33% “did not know”. In the cases where the effects were considered different to expectations reasons given included:

- No information was seen before construction of the wind farm;
- The turbines had been deemed too far away for shadow flicker to occur;

- The impacts were much worse than expected; and
- The promised mitigation had not happened.

5.46 In some cases shadow flicker was reported as being experienced at greater than the 10 x rotor diameter distance from the nearest turbine.

5.47 Several of the comments indicate that respondents may confuse shadow flicker impacts with visual impacts, commenting on the former when they meant the latter. It should also be noted that the responses to the questions on light and shadow effects (including shadow flicker) illustrate that there may be different understandings of what is meant by these terms, despite them being separately defined in the Survey.

Mapping of potential shadow flicker impacts

5.48 SLR mapped all the properties potentially affected by shadow flicker at each of the ten case study sites. This identified that there were four sites where no shadow flicker could occur since the nearest property was at a distance of more than the 10 x rotor diameter. This concurred with the sites that did not undertake shadow flicker assessments at application stage.

5.49 At the six sites where shadow flicker was predicted, between one and ten properties within the 10 x rotor diameter criteria were expected to experience shadow flicker impacts. The maps produced from this exercise were then scrutinised alongside the responses from the Residents' Survey. In some cases this indicated that responses reporting shadow flicker were well beyond the 10 x rotor diameter distance at which it would be anticipated to occur. It was not possible to identify the reasons for such responses to the questionnaire, but it may be that respondents were referring to experiencing impacts away from their residence (e.g. when driving or walking) or experiencing cumulative impacts from other wind farms. In a few cases properties were just outside the 10 x rotor diameter boundary and therefore the shadow flicker impacts were not assessed but it is possible that residents are affected.

5.50 The Residents' Survey also indicated that in some cases shadow flicker is experienced where it is not predicted from the applicant's or SLR's assessments. For three of the four sites where shadow flicker was not predicted (in the ES/ERs and by SLR) between two and fifteen residents responded that they experience shadow flicker. This included residents close to the boundary of the assessment but also in areas well beyond the boundary of potential impact, for example, over 1 km from the outer edge of the 10 x rotor diameter. In other cases where shadow flicker is anticipated on the basis of the assessment, it was not reported as an impact.

Summary of key findings from evaluation of the assessment process

5.51 As was the case for the visual impacts there was considerable inconsistency in the availability of relevant documents.

5.52 For the wind farm case studies considered in this study, it appears that the modelling of those residences within 10 x rotor diameter may not capture all those residences where people experience or believe they experience shadow flicker or similar effects once the wind farm is operational. There may be a case for reviewing the 10 x rotor diameter threshold, coupled with better definition of shadow flicker effects to provide a more comprehensive assessment and to make allowance for micro-siting of turbines.

5.53 In a few cases the more detailed assessment undertaken served to provide a more accurate understanding of the potential level of impact and how this could be mitigated. This was reinforced by planning conditions requiring mitigation and monitoring measures to be put in place.

5.54 A survey of residential properties combined with modelling the shadow flicker for the specific potential exposure to shadow flicker appears to be a more robust approach. It enables the wind farm developer to mitigate through design and/or through the operation of the individual wind turbines.

5.55 In general it was not apparent to what extent light and shadow effects featured in the pre-application consultation stage or whether sufficient information was provided to those potentially affected.

5.56 On the basis of the evidence review it appears that the Environmental Health Officers within the respective planning authorities were the main drivers for ensuring that residential receptors likely to be impacted by any proposed development were included in the assessments. In turn it appears that this was driven by the planning authorities seeking to minimise future complaints regarding the effects of shadow flicker from the development.

5.57 There is a lack of guidance in terms of assessing shadow flicker, shadow throw and light effects especially when considering the magnitude of change and/or sensitivity of residential receptors. In the assessments evaluated there were examples of sensitivity criteria based on a combination of level of exposure, with and without mitigation.

5.58 Shadow flicker impacts on residents at the majority of the case study wind farms that were assessed applied a combination of available guidance.

5.59 The manner in which shadow flicker impact assessments are presented could possibly be improved in order to show how residents may experience these impacts for an operational wind farm. This might include:

- Providing definitions of light and shadow effects to provide context for the shadow flicker assessment;
- Providing examples from operational wind farms including the typical periods of exposure, and
- Providing information in terms of mitigation measures through software control programmes for turbines.

Summary of key findings of effects from operational developments

5.60 Residents’ experiences from operational wind farms indicate that there could be a clearer definition of light and shadow effects including shadow flicker. The responses suggest that residents are experiencing a range of light and shadow effects which are not currently identified in the assessment process. A clearer definition would include the parameters of where, and in what weather conditions, these light and shadow effects might occur.

5.61 The Residents’ Survey responses indicate that there was potential under-assessment of impacts at the planning assessment stage in some of the case studies. In addition, where light or shadow effects are experienced (whether predicted or not predicted) there are some residents who are indifferent to this (8%) and some who strongly dislike the effects (10%), especially of shadow flicker.

5.62 Several respondents to the survey identified that they either did not see, or were not told about, the predicted shadow flicker effects of the proposed development. Some respondents found that the experience of the operational wind farm was very different or different (35% of those who answered this question) from what they anticipated, whilst a slightly smaller number (20%) considered the light and shadow effects to be broadly similar or as expected.

5.63 Monitoring and mitigation appears to have been at least partially successful in reducing the effect and related complaints. The most effective form of mitigation would be use of wind turbine software which modifies the operation of the turbine(s) during times when shadow flicker could occur, which addresses the impact at source.

Lessons for good practice

5.64 Developing clearer definitions of the light and shadow effects that can be experienced when living close to a wind farm would improve the understanding and assessment of shadow flicker. The definition would include the parameters of where and in what weather conditions these light and shadow effects might occur.

5.65 Once defined, an appropriate assessment methodology could be developed and provided as standard guidance. This would include the level of detail required: for example, residential surveys and how these should be combined with the computer modelling. It would also include definitions for the magnitude of change and/or sensitivity of residential receptors for shadow flicker, shadow throw and light effects as well as guidance on the identification of significance thresholds.

5.66 It would be beneficial to explore how shadow flicker impact assessments could be presented to community stakeholders possibly in a more transparent and engaging way. This might include providing:

- A context describing the range of potential light and shadow effects with shadow flicker being one of these;
- Examples from operational wind farms including the typical periods of exposure; and
- More information in terms of mitigation measures through software control programmes for turbines.

5.67 It is noted that the ten case studies wind farms were all assessed before 2009 and therefore it would be beneficial to review some of the current practice in shadow flicker impact assessments to inform any new guidelines.

6.0 PHASE TWO – ASSESSMENT OF NOISE IMPACTS

Introduction

6.1 This element of the work considered whether the noise impact of the wind farms on residential neighbours to the sites was accurately assessed at the application stage. This was identified by reviewing the noise impact assessments included with the ESs/ERs submitted with the applications. An assessment was also made of the noise impacts of the operational wind farms. This operational assessment involved consideration of both the modelled noise levels around the wind farms and the experiential reports of individuals from the Residents' Survey. Operational noise information was additionally available for five of the ten case study wind farms from post-completion noise measurements which had been undertaken previously by others. No new noise measurements were undertaken as part of the present project.

General Environmental Noise

6.2 In many areas of planning there is a need to set noise limits based on relatively simple and numerical measures of noise. These limits are generally aimed at restricting the potential impact of noise on people to an acceptable degree, whilst still allowing development. The most commonly used single figure measure of noise is termed the overall "A-weighted"[15] sound pressure level. Assessments of noise impact are frequently achieved by comparing the A-weighted level of the new noise, both with the existing noise environment and with benchmark levels, such as those associated with the onset of annoyance or sleep disturbance. Further details about the principles of general environmental noise assessment are presented in Appendix F.

6.3 However, an individual's personal reaction to a particular sound is generally complex and difficult to relate to a single objective measure. Factors which can affect an individual's response include:

- audible acoustic features to the noise (i.e. a particular character, such as impulses, whines, whistles, rumbles, etc.);
- how often the noise occurs;
- the variation of the noise over time;
- the time(s) of day, evening or night the noise occurs;
- whether the individual is ordinarily at home when the noise occurs;
- what the individual is doing when they are exposed to the noise; and
- the personal circumstances or attitude of the individual towards the source of the noise.

6.4 Such diverse factors encompass not just the physical properties of the sound itself, which numerical noise limits can address, but also the personal response of the exposed individual. Such personal responses are often found to vary depending on the context in which the sound is heard. Any or all of the foregoing factors may lead to a particular 'sound' becoming undesirable 'noise', where 'noise' is defined as 'sound that is unwelcomed by a particular individual in a particular situation'.

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[15] This metric was developed to reflect perceived loudness by accounting for the response of the human ear to sound, see Appendix F.

6.5 Meeting target noise limits does not therefore mean that everyone will experience the noise in the same way, and individuals may be differently disposed to either accept or object to the new noise. Also, a particular individual who finds a particular sound quite acceptable in one situation may find it unacceptable in another. There will be a range of responses to noise of a given level that, on balance, are considered to represent an acceptable overall impact. Where planning guidance recommends target noise levels, this is aimed at achieving the appropriate balance. Such recommendations frequently recognise that different sources of noise may have specific characteristics associated with them that may need to be accounted for, and also that there may be different sensitivities depending on the time of day or night.

Specific Characteristics of Wind Farm Noise

6.6 Wind farm noise is one specific example of an environmental noise. In common with most other forms of environmental noise its impact is ordinarily assessed in terms of its overall A-weighted noise level. However, noteworthy features specific to wind farm noise include:

- it can vary systemically[16] with changing wind speed or direction;
- it can occur at any time of day, evening and night, with the only controlling factor[17] being whether or not the wind is blowing; and
- it can contain a number of different acoustic characteristics.

6.7 Specifically, operational wind farms may emit two types of noise:

Aerodynamic noise is produced by the movement of the blades through the air. This is ‘broad band’ in nature, meaning that it is not of a very defined pitch but instead comprises a broader range of frequencies. It is sometimes compared to the sound of rushing wind[18]. However, it can sometimes be heard to rise and fall in level on a periodic basis. This rise and fall is associated with the rotation of the blades. For modern large scale turbines one rise and fall in level occurs at approximately every one to two seconds. The feature is generically often referred to as ‘amplitude modulation’, or ‘AM’ for short [19].

Mechanical noise is produced by machinery within the wind turbine. Because it is most often associated with rotating machinery such as gearboxes or generators it is

[16] The sound output of a wind turbine at source generally increases with wind speed, at least until it reaches a maximum in many turbine models. The propagation of sound from a wind turbine to a receiver location is affected by wind direction: it is generally the case that noise levels at a receiver located upwind from a turbine will be lower than when downwind from the same turbine.

[17] Some wind farms are subject to operational controls which limit their operation at certain times of the day and/or under certain wind conditions.

[18] When making this comparison it should be recognised that, whilst both types of noise are broad band in their general nature, they can nonetheless exhibit differing distributions of sound energy across their respective broader range of frequencies, as can different sources of noise within each of the categories of wind noise in trees and wind turbine noise.

[19] A modulation in amplitude means that the level of the noise changes regularly with time. Studies (RenewableUK, 2013) have revealed there to be at least two different source generation mechanisms for wind turbine AM noise, one of which is an inherent feature of the operation of all wind turbines (often described as ‘blade swish’) whilst the other only occurs under a specific set of conditions. The issue of AM is discussed in more detail in Appendix G.

often characterised by a tonal[20] character, meaning the noise is heard as a 'rumble', 'hum' or 'whine', depending on its source.

6.8 The construction of a wind farm can also generate noise and vibration which can represent a potential impact.

Noise Impact Methodology

6.9 The noise assessment process for onshore wind farms is guided by Scottish planning policy and supporting planning advice. This is detailed in Appendix G. In summary of this information, planning guidance requires the assessment of noise from onshore wind farms to be established through the use of the ETSU-R-97 report '*The Assessment and Rating of Noise from Wind Farms*' (Working Group on Noise from Wind Turbines, 1996), and recognises the good practice recommendations of the subsequently published by the Institute of Acoustics (IOA) Good Practice Guide (GPG) (IOA, 2013). The GPG was complemented by six technical Supplementary Guidance Notes in July 2014. The ETSU-R-97 assessment procedure specifies limits for the noise from the wind farm. These are set relative to the noise present during quiet periods prior to the construction of the wind farm: this is the "background noise". Background noise levels are measured at properties neighbouring the proposed wind farms. The ETSU-R-97 procedure reflects the variation in both background noise and the noise from the proposed turbine(s) with wind speed.

6.10 Appendix G sets out the steps for the ETSU-R-97 procedure and current good practice in the application of this method. Because this good practice has developed over the years, the procedures outlined do not necessarily reflect the situation at the time of preparation of the planning applications for the ten case study wind farms considered in this study.

Methodology followed for the Scottish Wind Farm Impacts Study - Noise

6.11 The methodology for the noise element of this study was driven by the project research objectives, as set out in Section 2.2.

6.12 The methodological approach adopted by HLA in assessing noise impacts across the ten case study wind farms comprised the following key stages:

- an evidence review of the noise related environmental information submitted in support of the planning applications/appeals for each of the selected wind farms;
- an evidence review of the available information concerning the as-built wind farms, including relevant operational information[21] where available, and also the results of any post-construction noise compliance measurements or noise complaint investigations;
- modelling work[22] to compare the predicted wind farm operational noise levels to the operational noise contours calculated for the as-built schemes, the latter

[20] A tone is the concentration of acoustic energy into a very narrow frequency range: see appendices F and G.

[21] For example, turbines operating in certain modes of operation or stopped in certain conditions.

[22] As considered below at 6.16, the project scope did not involve new noise measurements and the assessment of noise was made on a predicted basis but considered existing results.

being calculated by adopting a common calculation methodology across all sites in accordance with current recommended good practice;

- a review of reported noise impacts from the Residents' Survey for each case study wind farm, including the overlaying of these results on the calculated noise level contour maps to provide a visual representation of any 'clustering' of complaints or unexpected responses; and
- interviews with a limited number of respondents to the Residents' Survey to clarify their responses[23] - this element of the project supplemented the originally envisaged scope.

6.13 The methodology used by HLA in assessing the noise levels produced by the ten case study wind farms (as built) was based on the current good practice recommendations of the IOA GPG in predicting noise levels. For the reasons discussed below, no new measurements of wind farm noise were undertaken as part of the present project. Rather, the assessment of actual impacts was primarily based on the calculated noise levels obtained using a consistent (IOA GPG compliant) calculation methodology across all ten of the case study sites. Further explanation is provided below as to the reasoning behind two key aspects of the adopted methodology in responding to the project's core research questions.

Research Question 1: Do Actual Effects Differ Significantly From Those Identified in the ES?

6.14 The term 'actual effects' can be interpreted in both quantitative and qualitative terms, mirroring the distinction identified in Scottish Planning Policy, as set out in the Technical Advice Note (TAN): Assessment of Noise (2011).

6.15 The study team focussed the quantitative assessment of noise effects on the overall A-weighted level of the wind turbine noise for a number of reasons. Firstly because of the recognised importance of this measure in environmental noise assessment in general (see Appendix F) and, secondly, as it forms the basis of the relevant ETSU-R-97 methodology (see 6.9). The first part of this study therefore involved comparing the level of the noise assumed at planning stage with that calculated by HLA in accordance with current good practice for the wind farms as-built.

6.16 The only way to fully establish actual levels of noise at the case study wind farms would be to undertake long term noise measurements around each of these ten wind farms. However, the technical limitations and costs associated with such extensive measurements placed this option outside the scope of the current project (see Appendix H). A key consideration was that both wind farm noise and other forms of environmental noise are inherently variable, particularly under windier conditions. Robust analysis of wind farm noise data therefore requires both wind information and knowledge of the residual noise in the absence of the wind farm noise. These interacting features all combine to result in noise impacts which can vary significantly, as highlighted by some of the Residents' Survey observations.

6.17 HLA therefore concluded that operational noise levels suitable for the purpose of providing comparable analysis results between wind farms would, on balance, best

[23] The reason for these one-to-one approaches was to clarify cases in which the respondent(s) in question had reported a quite different response to neighbouring residents who were predicted to be subjected to a similar wind farm noise exposure.

be determined through the application of a common calculation methodology across all sites. The selected calculation methodology was that recommended in the IOA GPG. The application of this same methodology across all ten of the study wind farms allowed for the meaningful comparison of results. The results of these consistent calculations can then also be compared to the predictions made at the planning stage, the latter of which had been undertaken using a variety of differing calculation methodologies.

6.18 Some of the case study wind farms have been subject to post-construction noise monitoring. This study therefore sought information regarding these operational noise measurements[24] and used these results to inform the project as to actual, measured noise effects. Such measured noise data were available for five out of the ten case study sites. In these cases, the measurements were reviewed and compared to the calculated noise levels to further test the predictive approach taken. In addition to information about the overall level of the noise, as detailed later in this section, some of these studies provided information on the character of the noise.

6.19 The guidance in the above referenced TAN also sets out the use of a qualitative assessment to supplement a quantitative assessment. This is based on perception and how noticeable the noise impact is. This qualitative assessment can modify the conclusions reached from the quantitative assessment. It relates to experienced effects, including how an exposed individual perceives any audible wind farm noise and how its presence may have impacted on their day-to-day living. Potential noise impacts from any source on residential receptors are identified in the TAN as ranging from the noise being just noticeable on occasions but having little direct consequences, through residents changing their pattern of living to limit their exposure to the noise (such as using the garden less, closing windows on occasions or changing the use of rooms within their homes), to the noise leading to effects on quality of life and potentially also health, for example in terms of sleep disturbance, migraines, etc.

6.20 This study assessed experienced effects via the Residents Survey, which relies on the self-reporting of effects by those surveyed. Noise compliance measurement reports were also used where available, which included descriptions of the complaints and the noise experienced. The survey responses provide useful indications as to the features of the noise experienced, such as its prevalence or dependence on weather conditions, or the location of the respondent when most affected, as well as information relating to the acoustic character of the noise.

6.21 Notwithstanding the potential limitations of surveys which are reliant on the self-reporting of effects, the Residents' Survey responses usefully show the extent to which respondents report being personally affected by wind farm noise. In terms of health, the considerably more comprehensive study by Health Canada (2014) concluded that self-reported effects tended to be representative of those provided by objective physiological measures[25].

[24] Such measurements could have been undertaken either for the purpose of investigating a specific noise complaint or as part of a more general operational noise limit compliance check.

[25] The study included the collection of health-related objective end-point data such as sleep actimetry, hair cortisol levels, heart rate and blood pressure, as part of a more comprehensive survey design.

6.22 A final element of this study included directly approaching a limited number of Residents' Survey respondents to clarify their responses. These one-to-one interviews aimed to explore cases in which neighbouring respondent(s) reported quite different responses despite being expected to have a similar wind farm noise exposure, assuming of course a similar occupancy pattern of their homes.

6.23 In summary, the present study has been informed by a combination of estimates of the exposure of residents to wind turbine noise (based both on calculations and, where available, operational compliance measurements), the data gathered in the Residents' Survey and reported descriptions contained in operational noise investigations (when available). The Residents' Survey returns in particular allowed for the identification of qualitative issues, such as any specific character to the noise and also under what conditions and in which locations the noise is most negatively perceived.

Research Question 2: How has noise assessment practice been applied in the case studies?

6.24 One of the research objectives of this study was to review the noise assessments submitted in support of the planning applications for the ten case study wind farms. This objective was aimed at establishing whether additional good practice guidance from the Scottish Government could assist in more consistent and robust wind farm noise assessments. A similar dedicated exercise was undertaken in 2011 on behalf of the UK Government (Hayes McKenzie Partnership, 2011) for wind farms in England. It focused on noise and was considerably larger in scale, having been applied across a greater number of wind farm sites. The resultant report found evidence of significant variations in the manner in which ETSU-R-97 was being applied in practice. It consequently recommended the production of good practice advice which would lead to a more consistent application of ETSU-R-97. This led to the production of the previously mentioned IOA GPG in 2013.

6.25 This study included an analysis of the noise environmental information submitted for planning for each of the ten case study wind farms. Given the recommended adoption of the IOA GPG by the Scottish Government, in each case the submitted information was compared to this currently recommended good practice. This review was undertaken specifically to identify potential sources of variability between the noise assessments for the various case study wind farms in order to establish whether the consistent application of a common best practice methodology[26] could have reduced such variability.

Evidence Review

Documents Reviewed

6.26 For each of the ten case study sites a review of the available planning stage documents was carried out. This focussed on identifying the aspects of the assessment and consultation process related to noise impacts. Eight of the study sites had Environmental Impact Assessments (EIAs), each of which included a noise assessment. Two study sites did not require an EIA, but assessment reports were produced (with a noise section). Review of these identified the aspects of the assessment relating to noise effects and therefore of relevance to the project aims.

[26] In undertaking this exercise it is noted that current best practice was not fully developed/adopted at the time the planning applications for the case study wind farms were being prepared.

The information was not always available, however, or was incomplete, in which cases, efforts were made to obtain the missing information from planning authorities and/or site operators.

6.27 Additionally, consultation responses from the respective planning authority's Environmental Health Department were reviewed (when available) to identify whether noise impacts were identified by these consultees as potential effects of the development. The Planning Officers' reports and recommendations to their respective committees were also reviewed where available which was in all cases but one. The details of the technical scrutiny or communications underpinning the conclusions reached by the specialist consultees were not available. For the four applications which were subject to Public Inquiries, the Reporters' decision and accompanying reports were reviewed.

6.28 Review of the planning information was supplemented for each site by a review of information available for the as-built wind farm. For these as-built reviews the installed turbine types and their locations were generally determined from information posted either on public[27] or project-specific websites, or by information received direct from the case study wind farm operators. Where such information could not be directly gathered, coordinates were digitised from aerial photography using GIS methods.

6.29 In cases in which the scheme layout had been revised and/or the number of turbines was reduced prior to consent being granted, this led to revised or supplementary environmental information being submitted. In such cases the layout considered at the consent stage was adopted for this study and previous layout iterations disregarded.

Were noise impacts identified at the consultation stage?

Planning Officer's Reports

6.30 With all but one exception for which no information was available, it was possible to assess whether the planning authority had considered the information submitted on noise and provided comments. In six out of nine cases this was clear. In two other cases there was very limited consideration of noise by the planning authority. In one case consideration of noise was not set out in the planning report from the planning authority. In all the cases in which noise was explicitly considered, it was concluded that the proposal would comply with the requirements set out in planning policy. In all but two of these instances this referred explicitly to the established methodology of ETSU-R-97.

6.31 In limited cases, specific issues related to noise were raised during the consultation. In one case in which the planning authority expressed concerns regarding the potential impacts of cumulative noise, the planners considered this as a reason for refusal. In discussions by the planning authority and in the subsequent appeal this was dealt with through conditions imposed on the development, but it was not possible to evaluate the effectiveness of these conditions as part of the scope of this work. In another case the planning authority proposed different and more stringent limits than those of ETSU-R-97, but these were not applied as a condition in the subsequent appeal.

[27] http://www.thewindpower.net

6.32 The review found limited consideration by the planning authorities of other factors, such as audibility, beyond compliance with the requirements of planning guidance and ETSU-R-97, with exceptions listed as follows. In one case, the planning authority had commissioned a report from an independent specialist noise consultant which presented a detailed review of the scheme including consideration of standards other than ETSU-R-97. Low-frequency noise was either not considered or dismissed, with the exception of the potential for tones which were raised in two cases, and in these instances conditions were proposed to control tonality.

Appeal Reports

6.33 In respect of the four wind farm case studies which were subject to a Public Inquiry, there was more extensive evidence of consideration of noise impacts even though noise was generally not considered as a reason for refusal of the scheme. The appeal reports included, in two of the four cases, an outline of the scrutiny made by the Reporter of a variety of claims by third parties. Many of these claims were eventually dismissed by the Reporter, on the basis of the evidence presented, as being based on misunderstandings or representing deviations from standard planning advice.

6.34 This level of detail is consistent with HLA's experience of planning appeals. It does not necessarily mean that concerns raised by non-statutory consultees are not considered by planning authorities, but rather that as part of the inquiry process the consideration of these concerns is recorded in more detail. In contrast, details of the review process undertaken by the planning authority specialists are rarely publicly recorded. It is however possible that the Public Inquiry process leads to a more detailed scrutiny.

Noise Conditions

6.35 The planning consents and therefore the associated conditions were generally available for the case study sites (with one exception). In all cases but one these conditions were in broad accordance with the guidance of ETSU-R-97. The conditions prescribed noise limits (maximum noise levels) at neighbouring residential locations, defined partly on the basis of background levels measured prior to the wind farm being built (background levels, see Appendix G). In almost all cases (with one exception) where reference to "background noise" was made, the specific source of the data which should be referenced was not clear, but it would be reasonable to assume that the data reported in the EIA or ER should be used (as was made clear in one instance). However, as noted above, it was sometimes difficult to obtain these original assessments in the public domain. In one case only, a detailed table of noise limits was set out, which avoids problems with different interpretation of the conditions or obtaining the information included with the planning application.

6.36 The conditions also generally required operational noise measurements to assess compliance with these limits but, in accordance with ETSU-R-97, this was only to be done in the event of a specific complaint. In one case, however, noise compliance measurements were required following completion of the construction of the wind farm even in the absence of any complaint. There was in all cases no prescriptive methodology for dealing with the complaints and analysing the background noise, and no clear timescale set for monitoring. In contrast, the example of a "standard" condition which is included as an appendix to the IOA GPG (2013), is much more prescriptive, leaving little room for interpretation and providing clear steps and timescales for the investigation and measurement of the noise levels. This form of condition also includes a clear table of noise limits rather than making reference to measured baseline levels, which is now therefore good practice.

Methodology used in the Assessments

6.37 One of the objectives of the present project was to assess whether more specific guidance as to the good practice assessment of wind farm noise could be helpful. Appendix I contains a review of the submitted information for the ten case study wind farms and how this accords with what is now current good practice. As previously discussed, the published IOA GPG is recommended by the Scottish Government.

6.38 The main conclusion of Appendix I is that all assessments deviated to at least some degree from current recommended good practice. For example, only two of the assessments accounted for the potential effects of “wind shear”[28] by taking adequate wind speed measurements. Whilst there was some evidence that the more recent assessments tended to be more in line what is now current good practice, this was mixed. There was no clear evidence that the scale of the development or the assessment type (EIA or not) had an impact on the standard of the assessment. This is consistent with the results of a previous research study on the subject (Hayes McKenzie Partnership, 2011) which led to the development of the IOA GPG.

Scrutiny of Noise Assessments

6.39 Detail of the technical scrutiny undertaken by the local authorities was generally not available. However, information now required as part of good practice in order to facilitate such scrutiny (including details of the baseline survey and equipment or modelling parameters) was often not presented as part of the ES. On this basis it is considered likely that detailed technical scrutiny at the time of the application was not undertaken to current standards. This suggests that guidance on good practice can play an important role in driving improvements in noise assessments and their clarity.

6.40 The advice provided by the IOA GPG, which is the methodology specifically recommended for use by the Scottish planning system, provides a framework for consistency in approach to wind farm noise assessments themselves, including minimum requirements for the information submitted with an application. In turn this assists stakeholders by providing an equally structured framework for technical scrutiny, including the information required and the points to be examined as part of any consultation review.

[28] Differences in wind speeds experienced at different heights, for example between wind experienced close to the ground and stronger winds experienced by the turbine higher above the ground.

Noise Assessment Locations

6.41 In addition to their collation of data obtained by others as part of post-completion noise measurements, HLA also collated[29] the baseline background noise levels measured as part of the assessments of the ten case study wind farms. These data, which have all been extracted from the relevant environmental noise assessment information for each case study wind farm, are considered in detail in Appendix J.

6.42 In many cases only limited information was available from the reports for the actual locations at which background noise was measured, the equipment used, and other information that would allow an evaluation of the robustness of the survey. In some cases only the analysed overall results of the measured data were provided, with no information therefore being available relating to the distribution of the noise levels experienced.

6.43 The reported background levels in most cases allowed HLA to derive noise limits in accordance[30] with ETSU-R-97 and the specific terms of the relevant planning or appeal consent (if relevant). However, establishing definitive numerical noise limits that could be compared across the different sites was challenging. A number of specific difficulties are identified in Appendix J.

6.44 Notwithstanding the above, these noise limits represent the maximum levels of noise allowed in the planning consent for the turbines at the case study sites. As part of the study, these noise limit criteria were compared with the noise levels calculated by HLA for each of the case study wind farms (as built). This comparison was either based on predictions of the as built noise levels made by HLA (see 6.17) or with specific measurement results when available (see 6.18).

Other considerations

6.45 In addition to the requirement for wind farm noise to comply with the applicable standard of ETSU-R-97, the experiential effects in terms of audibility of the noise were often not set out as part of the planning application: the likely audibility of operational wind farm noise is specifically mentioned in only three of the ES reports, with the exception of the common statement of infrasound being inaudible. Only three of the applications for the ten case study wind farms considered the subject of AM noise, and when this was done, it was in quite general terms. Similarly, the potential for tones, although mentioned in six of the assessments, was not considered in detail: it was stated that such noise was unlikely to be an issue from modern technology wind turbines, and in one case it was considered specifically unlikely for the particular candidate machine considered. In these six cases, reference was made to the control procedures set out in ETSU-R-97 which impose a penalty should a tone arise.

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[29] No detailed re-analysis of the measured data was undertaken by HLA, but the measured levels were taken as reported in the respective assessments, as this was the basis on which the assessments were made.

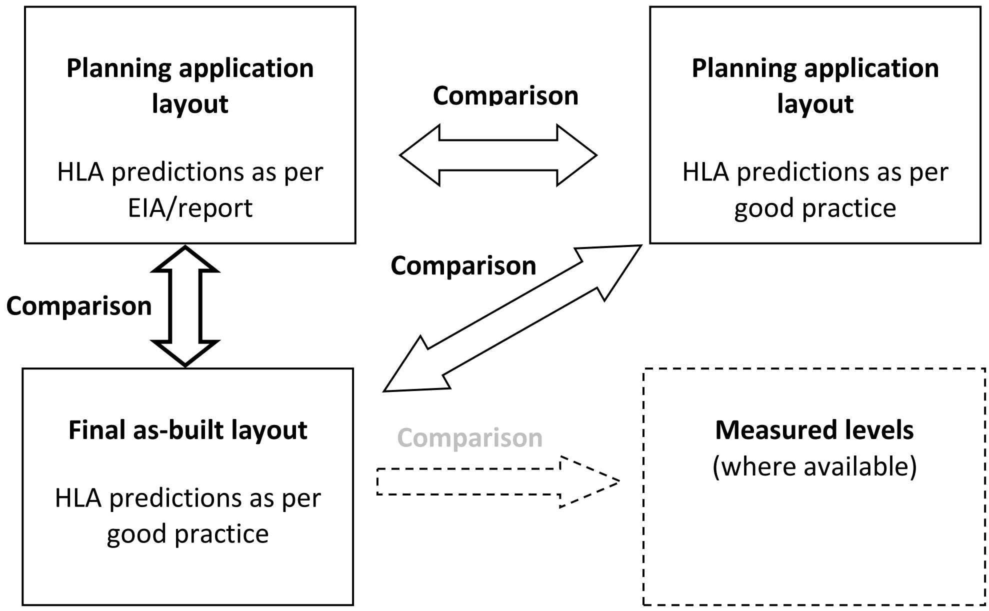
[30] In one case in which no ETSU-R-97 baseline background noise levels were available the consent specified a fixed noise limits in any case, allowing a limit to be defined.

Operational Noise

Noise Modelling

6.46 Based on the available information for each of the ten case study wind farms, noise predictions and contour plots were produced for each of the sites. These noise contour plots were used to illustrate the calculated spatial distribution of the noise levels in the area surrounding each wind farm as a result of its operation. These were then used as base-layer maps onto which the results of the Residents' Survey were plotted. This visual representation of results gave an overview of the relationship between the Residents' Survey responses, the proximity of the respondents to the wind turbines and the modelled noise levels. This process is illustrated in Figure 6-1 with further details and examples presented in Appendix K.

Figure 6-1
Noise Prediction Process



Source: HLA

6.47 For each of the ten case studies a total of four noise prediction scenarios were calculated:

1. **Planning layout and prediction method**: the first scenario adopted the information relating to the proposed turbine types and locations expected at the time of the planning application, and likewise adopted a noise calculation methodology representative of that adopted in the information submitted for planning;
2. **Planning layout and good practice prediction method:** the second scenario adopted the same input information as submitted for planning but HLA recalculated the noise contours using the noise propagation calculation methodology and turbine noise emission data in line with currently accepted good practice;
3. **As-built layout (good practice prediction method):** the third scenario again used the currently accepted good practice calculation methodology but HLA

adopted the locations and noise emission details of the actually installed turbines of the as-built wind farm; and

4. **Comparison of planning vs. as-built**: HLA compared the calculated noise levels under the first (submitted for planning) and the third (as-built) scenarios.

6.48 In addition, when actual measurements were obtained as a result of operational noise compliance measurements, the predictions for the as-built scenarios were compared to the measured results (see next section).

6.49 The calculations made in this study of the as-built noise contours all correspond to current good practice. Assumptions made in the supporting application documents sometimes differed from current good practice. In these cases, the HLA predictions for the first scenario used a similar method to that used by the applicant (see Appendix K).

6.50 In all but one case there was no information provided by the site operators regarding any operational mitigation being applied to the turbines. Therefore, with the exception of the one identified site, all turbines were assumed to operate with no mitigation applied. It is possible that turbines at sites other than the single identified site may be subject to operational mitigation. If this is the case then the calculations may over-state actual noise levels at those sites, but this remains an unconfirmed possibility.

Noise Measurements

6.51 Although no new noise measurements were undertaken by HLA as part of this project, post-completion operational noise measurements previously obtained by others for half (5) of the case study wind farms were considered from a range of sources. HLA sought the results of such measurements via direct approaches to the case study wind farm operators and/or the responsible planning authorities. In two cases the assessment was provided by the site operators, in two cases it was publicly available, and in the last case the report was provided by Scottish Government. This represented a total of ten measurement locations (as three out of the five assessments included measurements at multiple locations). HLA were not made aware of compliance measurements having been undertaken at the other five wind farms of the study. Whilst relevant information was requested in relation to all ten sites, for these five sites either no response was provided or it was confirmed that no such compliance exercise had taken place.

6.52 The resulting dataset of measured noise was not comprehensive in that it did not cover all sites or, for the 5 sites in question, all locations. The assessments mainly comprised the quantitative assessment of compliance with planning conditions. However, as detailed in the following section, in some cases additional qualitative evaluations of the noise were included. Such analyses provided useful information not only in terms of the overall level of the noise but also about its character.

6.53 Specifically:

- at three of these sites, measurements were initiated following complaints, whereas in the other two sites the measurements were started directly following construction of the wind farm as part of planning requirements;
- only in one case was the wind farm found to exceed the noise limits set out in its planning consent, whilst for the other four wind farms the requirements of the relevant planning condition(s) were met.

- in most cases the measurement locations (eight out of the total ten) could be related to respondents from the present study's residential survey who had registered a complaint; in one other case, the survey response described disliking the noise but did not record making a complaint, and the last location did not appear as one of the survey respondents.

- at three out of the five sites, a series of wind farm switch-off periods were undertaken (in one case at the specific request of the local authority) in order to assess the level of background noise present in the absence of turbine operation, whilst at the other two sites, measurements of background made prior to the construction of the site were referenced;

- the means by which the character of the noise was evaluated varied.

  - for one of the sites, the report does not consider the character but only the overall level of the noise: this was consistent with the planning requirements for that site, whilst at the other four sites, the character of the noise was considered in different ways;

  - in 2 cases, this was through the reporting of descriptions of the noise from affected residents (as noted in a complaint diary), combined with a subjective review by the report's author of audio recordings which in both cases identified audible swishing (*i.e.* AM), the magnitude of which was unclear although it was reported as being more pronounced at one of the two sites;

  - in the 2 other cases, a detailed analysis of tonality was undertaken using the methodology of ETSU-R-97: in one of these cases, the tonality identified was caused by other sources (it was present with the turbines switched off) but in the other case, tones clearly attributed to the wind farm were detected, thereby contributing to the conclusion that the wind farm was in breach of its planning consent and therefore mitigation steps were proposed.

6.54 No re-analysis of measured numerical data was undertaken by HLA but, in each case, the numerical results obtained in the report were reviewed and analysed in relation to measured background data and the HLA predictions. In doing this it is important in HLA's experience to recognise that measured levels can be influenced to a certain degree by the noise from other sources (background noise), and therefore not directly represent turbine noise levels, particularly at distant locations or at high wind speeds. A direct comparison with predicted levels may therefore be misleading. In comparing the measured levels to predictions, HLA therefore focused on the closest locations or the range of wind speeds (generally 5 to 8 m/s) in which the wind turbine noise was most clearly measured, showing for example the clearest difference between turbine on and turbine off periods. This represented a total of five locations at which, over the relevant range of wind speeds, HLA's predicted levels undertaken in accordance with the IOA GPG methodology (for the as-built layout and turbine model) were either similar (within 1 dB) to the measured turbine noise levels (2 locations) or were over-predicting these levels by 1 dB to 5dB or more (3 locations).

6.55 It was one of the initial aims of this study to establish actual levels of turbine noise from the wind farms studied but, for the reasons discussed above, a predictive approach was adopted rather than undertaking new measurements. However, the operational results obtained showed that the good practice predictions used to inform the present study were robust. These operation measurements also provided some additional information on noise character which was outside of the initial project scope.

Predictions: summary conclusions

6.56 The noise assessments reviewed generally did not fully accord with what is currently regarded as good practice (see Appendix I for details), which may be expected having regard to the application dates of the case study wind farms.

6.57 As detailed below, the predicted noise levels for the as-built wind farms calculated as part of the present study were in roughly half the cases similar to, or lower than, those presented at the application stage. However, in the remaining cases the good practice calculations made in this study strongly suggest that predicted noise levels at the application stage were underestimates, both in terms of what would be predicted for the assessment turbines following current good practice (five out of ten cases) and also relative to the final choice of turbine model installed in practice (four out of ten cases). Any such under-prediction has implications both for potentially affected residents and for wind farm operators who may subsequently have difficulties achieving the resultant conditioned noise limits in practice.

Table 6-1
Comparison of Noise Assessment Scenarios

Planning stage – difference between assumed methods versus good practice	**Changes between the planning and as-built layout/turbine model following planning (when assessed with good practice)**
ES/application under-predicted in 5 cases (by 1 to 6dB)	In 3 out of these 5 case this led to reductions (2-4dB), whereas the other 2 had changes which meant a further increase (2-5dB)
ES/application over-predicted in 3 cases	In these 3 cases this led to an increase (2-6dB)
Remaining 2 cases: limited differences (+/-1dB)	Little change at this stage in these cases.
Overall comparison between planning (as predicted in ES) and as-built (good practice)	
ES under-predicted as-built situation in 4 cases (by 1 to 5 dB)	
ES over-predicted as-built situation in 3 cases (by 1 to 4 dB)	
The remaining 3 cases had limited differences (+/-1dB)	

6.58 The analysis is summarised in Table 6-1 above. This shows that in three out of the five cases in which the ES under-predicted noise levels (at a key wind speed, according to IOA GPG guidance) there was also a corresponding reduction in noise for the as-built scenario. This reduction could be due, for example, to the choice of the actual turbine installed when compared to the model assumed at the planning stage, or to changes in the wind farm layout. It is possible that the imposition of conditions which provide a requirement to maintain the noise conclusions of the ES could have influenced this tendency, although there was no clear evidence to show this.

6.59 Overall, the as-built situation tended to be under-predicted by the planning assessment in just under half (four out of ten) of the assessments, whereas in six of the ten cases the as built predictions were similar to or lower than those made at the application stage. In only two of these four cases of under-prediction did HLA predict a risk of exceeding the noise limits derived at the planning stage. This was based on an analysis which did not assume any mitigation. In practice it is possible that curtailment of turbine operations may be being applied under some circumstances, but HLA does not have evidence of this.

6.60 The impact of turbine micro-siting in itself was minimal in the case studies reviewed, as the associated turbine movements represent differences in calculated noise levels of a fraction of a decibel. Such differences would not in practice be perceptible. Of much more potential significance, when present, are variations in noise levels arising from the final choice of turbine for the scheme and the associated variations in turbine noise emission levels (of the order of 3 dB to 5 dB), as well as potential penalties of up to 5 dB resulting from the presence of audible tones.

6.61 As considered in Section 6.38 and Appendix I, most of the assessments did not incorporate the potential effects of wind shear by referencing noise measurements to the wind speeds which the turbines would experience. In these situations, the IOA GPG provides guidance on accounting for the potential associated effects by applying a conservative correction to the predictions (section 4.5 of the GPG document). When this correction was applied it was found that there was no significant effect, in terms of causing a predicted excess of the noise limits. However, there were two exceptions for which a potential excess associated with wind shear was predicted. In one instance, actual compliance measurements were available and this predicted effect was not observed in practice. This observation is consistent with measurements undertaken at a number of sites in the UK for which detailed wind data are available. These have shown that wind shear effects tend to be limited in hilly or mountainous areas compared to flatter, coastal areas in which atmospheric effects can create conditions of enhanced wind shear[31].

6.62 Finally, comparisons made with measurements of noise from the operational wind farms at half of the case study sites supported the use of the predictive methodology for this study, and confirmed it to be sufficiently robust.

Residents' Survey

Methodology and Overall results

6.63 The following observations relate to the ten case study wind farms and those respondents who took part in the Residents' Survey.

6.64 The Residents' Survey is described in Appendix B. Questions 24 to 31 of the survey questionnaire requested information relating specifically to noise impacts. An initial summary analysis of the responses to the Residents' Survey was undertaken. This analysis highlighted a number of interesting features, albeit being based on a review which considered the responses and general trends observed but without considering factors such as distance from the turbines or predicted noise levels.

6.65 This initial summary analysis determined that the majority of respondents in the survey were largely indifferent to the developments. However, as detailed below, there were minorities in respect of each of the case study wind farms who reported experiencing considerable negative impacts of noise (with implications for their enjoyment of their homes and/or for their wellbeing).

[31] See IOA GPG, Supplementary Guidance Note 4: Wind Shear, July 2014.

6.66 There appear to be correlations between attitudes towards visual impact, light and shadow effects and noise (i.e. those who strongly dislike one usually feel the same about at least one of the others as well), though there are examples where respondents report being indifferent, or liking one and disliking another. Strong opinions (i.e. 'strongly dislike') are most likely to be felt in relation to two or three impacts, whereas less strong opinions lead to more variation in how individuals perceive different impacts/aspects of the development. For example, around 40% of respondents who disliked (not "strongly") the visual impact of the wind farm expressed a negative reaction to the noise. When the dislike of the visual impact was "strong", this proportion increased to 60%.

6.67 Where respondents report liking or being indifferent to visual impacts they tend not to report experiencing noise. However, those respondents who report strongly disliking the visual impact typically also report experiencing at least one other impact, and in some cases both (i.e. light or shadow effects and noise). Moreover, those who dislike or strongly dislike the visual impacts of a wind farm are more likely to dislike or strongly dislike the light or shadow effects and noise impacts where these are experienced. Conversely, those who report liking or being indifferent to visual impacts are more likely to report being indifferent to other impacts, where these are experienced.

6.68 Whilst some residents can experience more impacts (combined) than others, and be impacted upon in a number of different ways, the above relations suggest that perceptions of impacts can be related to each other. As developed below, some residents do report being impacted but not experiencing this negatively. This is consistent with other studies (see van den Berg, 2008). This does not, however, indicate which element(s) of the impact primarily caused the negative reactions, or whether the reactions are associated with other, non-acoustic, factors such as attitude, consultation effectiveness, construction disturbance, information availability, etc.

6.69 Across the case study sites the majority of respondents (about three quarters) reported either not hearing noise from the wind farm or, if the noise was audible, reported being indifferent to the noise. However, a significant minority (about a quarter) of respondents did report noise impacts. Experiences of noise also varied greatly between, as well as within, case studies. Some respondents reported hearing noise only occasionally whilst others reported this as constant. Respondents who reported hearing noise less frequently were also less likely to report this as a significant negative impact, whilst those who heard noise everyday were more likely to report this as being significant and intrusive.

6.70 Respondents were asked if they heard the wind farm and, if this was the case, whether this was outdoors or indoors and at what time of the day, evening or night. Overall, two thirds of respondents reported not hearing wind farm noise. About one third (35%) of all respondents at the case study sites stated they could hear the wind farm but with a variation between 17% and 74% for individual sites. Those that could not hear the turbines did not comment on their opinion of the noise.

6.71 Specifically, of those respondents (35%) that could hear the wind farm noise:

- 3% liked the noise (strongly or not), 25% were indifferent and 70% disliked it (strongly or not): those reporting dislike represented 24% of the total number of respondents. The dislike was rated as "strong" for about 73% of those that reported dislike.

- most reported hearing the noise outdoors (85% overall, with variations of 67% to 100% between sites) rather than indoors (43% overall, variation 25% to 61%);
- those that reported the noise as audible indoors tended to express more negative reactions to the noise;
- the time of day of reported audibility, when indicated in the responses, tended to be uniformly distributed;
- at those sites for which the noise was relatively less audible inside (with less than 20% of total respondents reporting hearing the noise indoors) the audibility tended to increase at night, possibly due to reduced background noise during night time periods; and,
- the noise was only rarely reported as being audible indoors when reported as not being audible outdoors (4% of responses).

6.72 The spectrum of opinions expressed about noise impacts therefore ranged from respondents not minding the noise to reporting a severe impact, although it is noted that the impact tended to be negative when perceived. Some reported a very severe impact from the noise. There were respondents who reported no involvement with the wind farm, who could hear noise, but who reported that they were indifferent to it.

6.73 Specific comments made by some respondents reported severe impacts supported by quite extensive descriptors of those impacts. These respondents added extensive comments to their surveys to explain the impact they felt, and described in detail feeling depressed because of constant noise, hating living in their homes because of it, not being able to sleep and experiencing health problems with headaches, and painful ears. Some highly personal comments were made about very specific impacts of noise (e.g. on quality of life, friendships, families, and relationships) in the free text boxes. These included in some cases the description of complaints made and their effect (see further analysis from paragraph 6.90 below).[32]

6.74 Those who reported indifference were very unlikely to substantiate or comment upon that opinion, but some of these comments compared wind farm noise favourably to other noisier man-made sources.

6.75 A loose correlation was observed between involvement with the wind farm (e.g. being a land owner, or community benefit recipient) and perception of impact. In a number of the case studies the survey responses suggest that those who were involved were less likely to perceive a negative impact; or if they did, for example, hear noise from the wind farm, they were less likely to be bothered by it than residents who indicated no involvement in the wind farm (see Appendix C, Figure C1-C4 for details). However, this correlation is by no means perfect; that is, across

[32] A clear distinction is made here between Residents' Survey responses that were provided in response to specific questions with a set choice of responses (e.g. 'like', 'dislike', 'strongly dislike', etc.) and descriptions arising from 'free text' comments (see Appendix B). It is meaningful to numerically analyse the former type of responses. In contrast, the latter type of free text comments are not amenable to such detailed numerical analysis: the fact that an individual respondent may not have made a personal comment on any particular matter does not necessarily mean that issue does not matter to them. The utility of any such individual free text comments in this project has therefore been to provide greater context and insight to individual responses to specific questions. It is for these reasons that information obtained from free text comments has specifically not been subject to any form of numerical analysis in this study.

the case studies there were residents who did not indicate an involvement in the wind farm, and who reported no impact or being indifferent to any impact that they did report. There were also respondents who were beneficiaries and who still reported impacts that they disliked or strongly disliked.

6.76 The picture that emerges from the above detailed analysis is that noise for the majority of the residents surveyed is an infrequent occurrence, if experienced at all, whilst for others it is a significant issue. However, this observation does not account for the critical parameter of the variations in exposure to noise of the respondents: this is considered in the next section.

Specialist review - method

6.77 In order to address the foregoing issue of the effects of likely noise exposure, HLA undertook a further detailed analysis of the noise specific questions. This focused on the noise questions, with additional consideration of responses to other questions when relevant.

6.78 HLA considered the location of each of the survey responses based on the unique identifier listed with each survey questionnaire which was linked to a database of associated addresses. The information on respondents' locations allowed the determination for each response of the distance to the nearest turbine. The coordinates also allowed calculations of noise levels to be undertaken for each of the survey locations using the models detailed in Appendix K of this report.

6.79 Instances where respondents described wind farm noise as audible and annoying, or where they reported having registered a complaint related to noise, were reviewed for each wind farm. The aim was to identify from these descriptions potential features which could have affected or increased the perception of the noise in addition to its overall levels. In each case, examples of the key descriptions provided in the responses were separated into different categories which comprised two main types: tonal (mechanical) noise and amplitude modulation (AM) noise. In some cases descriptors associated with general broadband noise were also identified. This was done on a case-by-case basis using HLA's experience of noise measurements and resident's descriptions.

6.80 HLA acknowledges that the analysis of qualitative noise descriptors in such self-reporting surveys is rarely straightforward. For example, regarding amplitude modulation, it was generally not clear whether the residents were objecting to a level of modulation or 'blade swish' expected as an inherent characteristic of wind farms under the ETSU-R-97 guidelines[33], or whether a more pronounced or marked modulation (sometimes referred to as enhanced[34] amplitude modulation, or (E)AM for short) was experienced at these locations. Thus these descriptors are not conclusive in themselves. Rather, they represent an indication of the potential for

[33] The ETSU-R-97 report specifically notes page 68 *"The noise levels recommended in this report take into account the character of noise described in Chapter 3 as blade swish. Given that all wind turbines exhibit blade swish to a certain extent we feel this is a more common-sense approach given the current level of knowledge."*

[34] The term 'enhanced' amplitude modulation is not precisely defined but has been used to describe amplitude modulation noise which is more pronounced, and therefore of potentially of greater experiential impact, than that expected of 'normal' blade swish. This more pronounced sound is sometimes described as a 'thump'.

features in the wind farm noise which may explain some of the responses and/or warrant further investigations.

6.81 Indeed, some of the follow-up interviews described below suggested that where the noise was described as a ‘hum’, this most likely referred to the general (broadband) and relatively constant noise from the turbine rather than a noise with a marked tonal character. The distinction of tonal characteristics, particularly at low frequencies of between around 50 to 200Hz[35], is considered in HLA’s experience to be especially difficult for non-trained listeners. In previous research (Delta, 2010) such tonal features were simply described as ‘low-frequency’ noise. The existence of low frequency tones could also be mistaken for ‘infrasound’[36], thus leading to potential confusion on the subject in the absence of the low frequency (but not infrasonic) tonal components being positively identified as such.

6.82 Also, in general, the degree of audibility of a specific noise (such as that resulting from the operation of wind turbines) will vary depending on ability of the underlying residual noise (i.e. the noise environment in the absence of the wind farm noise) to mask the wind farm noise. In the present analysis only limited account has been taken of the expected residual noise environments at the location of each respondent. This has only been possible in an approximate sense because such information is generally not available unless the original assessment reported baseline background noise levels measured at the particular location being considered. However, reference to the original baseline background noise assessments has allowed HLA to gauge whether the general environment around each wind farm is relatively ‘quiet’ or ‘noisy’. Whilst such terms may be defined relative to expectations, this approach can provide at least a guide to the residual noise in existence at the time respondents are most identifying wind turbine noise as an issue. The summary figures of Appendix J illustrate the range of reported background noise measured across the ten case study wind farms for the quiet periods of the day and night.

Specialist review – results

6.83 The tables below provide a simple overview of the results obtained from the Residents’ Survey in relation to the response to the noise from the wind farms. This combines the survey data across all sites in order to illustrate general trends observed. Firstly, the proportion of respondents able to hear the wind farm is considered. For those that can hear it, the proportion of respondents that expressed like, dislike or indifference is stated. For the respondents who noted they disliked the noise, the *relative* proportion of respondents for which the dislike was noted as strong is also shown. These statistics are shown first as a function of the distance from the respondent to the nearest turbine, and then as a function of noise levels calculated by HLA for the as-built wind farms in accordance with current good practice at a key wind speed of 8m/s. Additional charts are included in Appendix L.

6.84 Tables 6-2 and 6-3 show that the responses to the noise experienced were not clearly related to separation distance from the turbines, whereas the relation with calculated noise levels is much clearer. For example, the proportion of people

[35] The Hertz (Hz) is the unit normally employed to measure the frequency of a sound, equal to cycles per second for the fluctuation of the air particles.

[36] Infrasound refers to very low frequency sound (below 20 Hz), which is commonly assumed to be inaudible given that the threshold of audibility is very high at these frequencies.

reporting to hear the wind farm is similar for residents situated between 1 km and 2 km to those situated between 2 km and 3 km, and similar to that found less than 500 m from the turbines. The observed trends with separation distance are therefore unclear. In contrast, a very clear trend of decrease in audibility is observed as the noise levels reduce.

Table 6-2
Global analysis of all survey responses as a function of the distance to the nearest turbine

Distance to nearest turbine (m)	<500	500-1000	1000-2000	2000-3000	3000-4000
Percentage of total responses	6%	16%	38%	30%	6%
Cannot hear the noise	67%	41%	70%	70%	54%
Can hear the noise	33%	59%	30%	30%	46%
Of those that can hear the noise:					
Positive opinion	0%	3%	4%	3%	0%
Dislike (strongly?)	50% (83%)	60% (81%)	80% (72%)	64% (71%)	80% (50%)
Indifferent	50%	37%	16%	33%	20%

Table 6-3
Global analysis of all survey responses as a function of predicted noise levels at a key wind speed for the scheme (as-built)

Predicted as-built levels (L_{A90}, dB at 8m/s)	≥40	35-40	30-35	25-30	<25
Percentage of total responses	15%	29%	34%	14%	3%
Cannot hear the noise	0%	46%	64%	71%	87%
Can hear the noise	100%	54%	36%	29%	13%
Of those that can hear the noise:					
Positive opinion	0%	4%	2%	6%	0%
Dislike (strongly?)	75% (89%)	79% (86%)	68% (69%)	71% (59%)	25% (100%)
Indifferent	25%	18%	30%	23%	75%

6.85 The foregoing differences could reasonably be anticipated, as someone living 1000 metres from a small wind farm would be expected to experience a lower noise level than someone living the same distance from a large wind farm.

6.86 In terms of the responses as a function of predicted noise levels, wind farm noise is largely reported as not being audible at predicted levels below approximately 25 dB(A). Correspondingly, there are no reports of ‘dislike’ or ‘strong dislike’ at levels below 25 dB(A). Similarly, at predicted levels above approximately 38 dB(A) wind farm noise is almost universally reported as being audible. This reported audibility was associated with the reported dislike of the noise, and an increased dislike generally being reported within and above the 35 dB(A) to 40 dB(A) predicted noise level range. These observations are broadly consistent with previous research[37] on the subject.

6.87 Notwithstanding the presence of systematic trends in the foregoing relationships, there is considerable variation between individual responses for any given range of predicted noise levels. This is particularly so in terms of the reported strength of dislike and the reported consequential effects on the respondent.

6.88 Reference to the acoustical character of the noise is made in at least one survey response at each of the ten case study wind farms. This was categorised by HLA in terms of the two main potential character types described in Section 6.7 and Appendix G. At about two thirds of the case study sites, the descriptions provided by some of the respondents suggested the potential presence of a character such as tonality or modulation (AM) in the noise, but the nature or the magnitude of this character was not clear from the descriptions. This is complicated by the difficulties in interpreting such reported descriptions (as raised above).

6.89 In some of the case study sites the presence of character was more clearly apparent than others, with descriptions of tones at three of the sites and AM at three of the sites. This was considered clearer in these cases for one or both of the following reasons:

- an increased number of character-related descriptions; these descriptions being consistent and clear;
- in some cases the objective identification of the feature through measurements, recordings and/or qualitative analysis of measurements by specialist consultants (see 6.53).

6.90 Possible further work aimed at formally identifying and quantifying the character of the wind farm noise is proposed in the conclusions to this report.

Complaints Analysis

6.91 The respondents of the residential survey who described their involvement with the wind farm (question 6) as “I have lodged a complaint” were analysed in relation to responses made as to their opinion of the noise (question 26), with general comments made in response to question 30 also being considered where available.

6.92 Of all the survey responses received, 13% of respondents (51 in total) reported having made a complaint. The question was not specific to noise and in 22% of these cases (or 2% of the total respondents) the respondents could not hear the noise or were indifferent to it. In addition, in these cases general comments were more related to non-noise aspects of the scheme like visual impacts. However, the remaining 78% of the complainants reported disliking the noise, with a large majority (85% of that 78%) indicating a strong dislike. These results therefore suggest that for the majority of the reported complainants noise was an issue. This does not necessarily mean that noise was the only or main impact, with some of the general comments made reporting negative impacts from other, non-acoustic, aspects of the developments such as visual or shadow flicker effects.

[37] Project WINDFARMperception - Visual and acoustic impact of wind turbine farms on residents, Frits van den Berg, Eja Pedersen, Jelte Bouma, Roel Bakker, University of Groningen, 03/06/2008.

6.93 Information on compliance of the case study wind farms with their planning consent was obtained for five of the case study wind farms (see paragraph 6.51). For eight of the ten properties studied, the link was made to a respondent of the residential survey who had made a complaint, but this was not comprehensive, as this represented only 16% of the responses which reported complaining. Two individual complainants' responses specifically described noise compliance monitoring having been undertaken at their properties, but only one of these featured in the eight properties associated with the compliance reports obtained. Two other individual comments reported anger at complaints not having been investigated. This suggested that not all the details and results of operational investigations were made available to the study team. It is generally also not possible either to fully establish how each complaint had been investigated and possibly resolved, or to conclude on the effectiveness of the mitigation measures implemented (where relevant). Other general comments by respondents suggested to HLA that these specific responses referred to objections made at the planning or construction stage but not necessarily operational issues.

Additional Insights from the Residents' Survey[38]

6.94 The particular nature of people's reaction to noise was highlighted by the variations in results of the survey responses, with clusters of nearby properties predicted to be exposed to similar noise levels showing quite different responses. In some of the cases where residents described serious impacts from the wind turbine noise, other neighbouring or similarly exposed[39] residents described being either indifferent to, or having got used to, the noise, even for relatively elevated predicted levels. This was particularly the case, in line with previous studies (see Van Den Berg *et al.*, 2008), for residents financially involved with the wind farms, but not always.

6.95 Some of the cases for which a relatively large proportion of negative reactions were reported in the Resident's Survey related to the most noise-exposed residents and corresponded to situations in which a clear increase in noise was predicted between the planning situation and the as-built scenario, and/or potential excesses over the limits were predicted.

6.96 In no more than two of the study cases, however, as-built wind farm noise levels predicted in the study were either relatively low (in absolute terms) or predicted to be clearly below the noise limits and/or comparable with or clearly lower than measured baseline levels, yet instances of negative reactions and/or severe disruption were still reported. These situations were sometimes made more difficult to interpret because of the low number of properties involved (less than 5). In these cases it is possible that the residual audibility of the noise was considered problematic or unacceptable by these residents. As audible acoustic features of the noise were often reported in these cases, the presence of such features would have likely increased the audibility of the noise and its consequent experiential impact.

6.97 In some cases larger groups of respondents around a given wind farm responded negatively despite their being exposed (according to the calculations made in this

[38] This section presents observations determined from a review by HLA of general trends in the survey results, including a combination of both specific responses and free text comments. It was frequently the case that there was no clear demarcation between responses from the different case studies, which restricted the ability to precisely quantify the reported results.

[39] With similar predicted noise levels and with a similar position relative to the wind farm.

study) to lower predicted noise levels of between approximately 25 dB(A) and 30 dB(A). In these cases analysis of the survey responses has identified audible acoustic features (either tones or AM) as contributing to the negative responses.

6.98 In other cases, where higher predicted noise levels were calculated, it was difficult to establish from the survey responses what part the perceived character of the wind farm noise played in the reported dislike.

6.99 For a given predicted noise level, particularly towards the higher end of the range considered here, there does appear to be a link between the involvement of the respondent with the wind farm and their reported dislike, with reported adverse noise effects being generally lower for those respondents who had some involvement with the development.

6.100 There was little systematic evidence to suggest that the lack of community involvement directly had a negative impact on the survey responses, but several comments suggested to HLA that members of the community had little appreciation of the potential audibility in advance and the experiential impacts associated with the developments.

6.101 Where a specific condition for audibility was reported, this consistently related to the location of a respondent's property downwind of the wind farm for nine out of the ten case study sites. This was even found to be the case in situations of relatively low predicted wind farm noise levels or where the generally reported levels of background noise were higher and therefore masking effects would be expected to be greater.

6.102 It is a generally accepted premise that, due to propagation effects[40], downwind conditions lead to higher noise levels than cross-wind or upwind conditions. It is therefore in these downwind conditions that the wind turbine noise levels would be expected to be at their highest. The reporting of downwind conditions when wind farm noise is most audible supports this effect. It also strengthens the conclusions of the study relating to wind farm noise as opposed to other sources of noise which could have been unintentionally mistaken for the wind farm.

6.103 The effect of wind direction and (in some cases) dependence on wind speeds highlights the variability of wind farm noise and on the impact of changing weather conditions. Of those that commented on the changes in noise with weather conditions, the large majority (more than 75%) said there were changes. In the discussion in Appendix H on the approach used in the present study, the limitations of short-term measurements were stressed. This is supported by survey responses noting the variability in wind farm noise, thereby highlighting the limitations of shorter term noise measurements which may fail to capture the required range of noise exposures.

6.104 It is difficult to establish any clear relationship between survey responses and expectations based on the ES information, because such expectations are not easy to determine. As noted above, the potential audibility of the wind farm was generally

[40] In downwind conditions, the change of sound speed with height is such that sound tends to curve towards the ground. This this is called atmospheric refraction. This means it propagates well over distance, particularly compared to upwind conditions in which the sound will curve upwards and away from receivers.

not discussed in the application documents. It is therefore unclear as to what extent all neighbouring residents would have been aware of the potential audibility of the wind farm based on the ESs, non-technical summaries and/or consultations undertaken by the applicants, but this awareness was probably low (based on the above observations). If this is the case, then it is likely that audible wind farm noise (where no such audibility was expected) would lead to a heightened adverse response amongst at least some wind farm neighbours. It is not possible to conclude, however, that an awareness of likely audibility would necessarily have avoided such adverse responses in any particular case. The character of a source of noise is one additional factor that can lead to negative experiential reactions in practice, and it is conceivable that this situation could be exacerbated where such character is contrary to expectation.

6.105 Some of the specific comments made referred to increases over baseline as being an issue. Specific reference is made to increased impact when wind speeds close to the ground (and hence also wind-related masking noise in the vicinity of neighbouring dwellings) are low but the turbines are producing noise. According to current good practice this effect (resulting from the effects of “wind shear”) should be technically addressed by the adoption of suitable wind speed references both in noise calculations and noise measurements. However, no matter how the issue is dealt with technically, the potential significance of the impact of wind farm noise relative to the baseline noise environment remains an important factor in people’s response to wind farm noise.

6.106 Respondents were invited to comment on other issues they perceived as problematic. In only one case did a respondent comment on the impacts of noise during construction, but in doing so described noise as only one of a wider range of issues during this phase of the development. On this basis, construction noise was seen as a less important issue than the operational impacts identified. In most cases construction activities are located relatively distant from nearest noise-sensitive residences and are therefore unlikely to cause significant effects. Local authorities have powers available under the Control of Pollution Act 1974 to impose controls on a construction site with respect to noise.

Residents’ Survey Follow-up interviews

6.107 Based on the results of the above review, HLA selected a sample of 27 residents across six of the case study wind farms for which further investigations were considered useful. Some (20) of the selected properties represented clusters or individual properties predicted to be exposed to similar wind farm noise levels but expressing opposite responses; others (6) selected respondents expressed a similar dislike of the noise despite being predicted to be exposed to differing levels of noise. One resident was identified as the comments made were unclear. Letters were issued to all residents selected on this basis, requesting a response for a follow-up phone interview by HLA. The rate of response to these letters (30%) was not sufficient for the exercise to be conclusive, but some useful insights have emerged.

6.108 In one case, a respondent declared an indirect interest in the wind farm which had not been indicated in the survey and which helped to explain the lack of a negative response for that respondent. This reinforced the above conclusions on the effects of financial involvement.

6.109 The discussions in some cases were helpful to clarify remarks made in the survey, in particular with regards the character of the noise. This feedback has been incorporated in the discussion of the preceding sections.

6.110 Two respondents had specifically attributed some of the adverse health effects they had experienced, such as sleep disturbance or headaches, to the presence of infrasound or “low-frequency noise”. This was clarified in the interviews. These residents had no evidence or perception that they were exposed to high levels of infrasound, but expressed their concern that the health effects they experienced were caused in part or exacerbated by what they considered to be inaudible sound that could still affect their health. This expectation could have originated from information on this topic available on the internet and elsewhere, publicising claims that infrasound causes health effects. This is despite a large number of scientific studies on the subject which have reported findings to the contrary[41]. A similar expectation of symptoms regarding infrasound was observed in a controlled scientific study[42] following exposure to information available on the internet. Both the residents interviewed described audible noise from the wind farm which they found disturbing. This audible noise is considered much more likely to be associated with any reported adverse health effects.

6.111 Two of the interviewees mentioned measurements surveys done at their property, but considered that some features of the noise, such as its character, were not captured in these surveys. Only one of these two cases was part of the above review of available operational noise measurements (see paragraph 6.51). This reinforced the above observations that the data obtained on operational surveys was not fully comprehensive. Another interviewee described the lack of noise investigations or measurements despite complaints having been made to the local authority, but the reasons for this state of affairs was unclear.

6.112 To develop further insights and improve the rate of response, it would be necessary to conduct a more systematic one-to-one interview process (see Section 7.53). This would seek to more fully answer some of the questions raised, such as differences between respondents, and could in particular clarify the character of the noise described in some cases. This is also an area in which supporting targeted noise measurements, including audio recordings of the noise complained of, could usefully assist further investigation.

6.113 Every effort was made to identify those residents’ responses which distinguish noise character as much as noise level as leading to their adverse response to the noise. However, ambiguity in many responses prompted uncertainty over precisely what character of the noise was being complained of. This is further clouded by the fact that in some cases the presence of noise character is suggested when the calculated noise level is relatively high. In such cases it is difficult to conclude how much the character of noise is to blame as opposed to the absolute level of the noise. However, in other cases the calculated noise level is relatively low when the character of the noise is raised as an issue. In these cases it is more likely, but still

[41] See most recently the Health Canada study (2014) which is described above, or the 2006 UK study: *‘The measurement of low frequency noise at three UK wind farms’*, M. Hayes, Report W/45/00656/00 for the Department of Trade and Industry, which is referenced in Scottish Planning Guidance on onshore wind turbines.

[42] “*Can Expectations Produce Symptoms From Infrasound Associated With Wind Turbines?”,* F. Crichton et al, Health Psychology Journal, Vol 33(4), Apr 2014, 360-364.

not certain, that the character of noise may be having more of an effect in its own right. This represents a complex interaction between the level and character of the wind farm noise, further confounded by the fact that the level of background/residual noise at each of the respondents' properties at the times of occurrence of the reported noise issues is also not known.

Summary of key findings from evaluation of the assessment process

6.114 This was considered by considering the following three questions:

- were the noise levels pre-development and the maximum noise levels for the scheme derived according to the recommendations of Scottish planning policy;
- was the (objective) level of the noise produced by the operation of the case study wind farms predicted sufficiently robustly; and
- were the potential experiential effects of the noise on local residents considered and, if so, how?

Were the noise levels pre-development and the maximum noise levels for the scheme derived according to the recommendations of Scottish planning policy?

6.115 The level of information relating to the assessment of the noise environments pre-development (or baseline noise levels) generally fell short of what would now be good practice. It is therefore possible that the noise limits may have been over-stated in specific cases compared to what would now be good practice. There was no clear evidence of any such points being identified by planning authorities, or clarifications sought, at the time the applications were considered. In the opinion of HLA, had some[43] of these assessments been undertaken more in line with what is now good practice then this may have led to different results. This is important as the planning criteria for the maximum wind farm noise levels are generally based in large part on these baseline noise levels.

6.116 The ETSU-R-97 document provides a method for deriving noise limits from measured baseline noise as a function of the wind speed. This method is recommended in planning policy and was broadly followed in most cases. However, due to differing interpretations as to the exact implementation of ETSU-R-97, it was difficult to compare the resultant noise limits between the different case study wind farms.

Was the level of the noise produced by the operation of the case study wind farms predicted sufficiently robustly?

6.117 The predictions of the noise from the case study wind farms presented at planning stage were made using methods which often differed from what is now current good practice. In addition to this, the turbine layout and turbine model assumed at this stage were different to the final as-built situation, resulting in some cases in large variations. These variations are summarised in Table 6-1.

6.118 There was evidence in half the cases studied of turbine noise levels being underestimated at the planning stage. This was compensated in about half of these cases by changes in the final turbine model and layout which led to reductions in the noise levels predicted by HLA between the planning and as-built stages. This

[43] Due to the limitations in the information provided, it is not possible to quantify this further.

may have been influenced by the need to comply with planning requirements on noise limits generally imposed by way of conditions, although there was no direct evidence of this. Nevertheless, in just under half of the cases studied the wind farm noise levels were under-predicted overall, by 1 dB to 5 dB, at planning stage compared to the as-built situation. Conversely, in just over half the cases the wind farm noise levels were over-estimated over a similar range or little change was predicted.

6.119 The predicted influence of turbine location micro-siting on the predicted turbine levels was generally negligible, but the choice of the final installed turbine type led to differences of up to around 3 dB to 5 dB in the noise at different receptors when compared to the ES assessed candidate turbine type.

6.120 It is noted that the differences identified between the calculated noise levels at the application stage and the as-built scenarios for each wind farm relate to the reference wind speed of 8 m/s, selected by HLA as the main basis for this study. Additional variations between the application and the as-built scenarios for each wind farm were also found to exist across the wind speed range in which the turbines operate (see Appendix K).

6.121 Although the level of noise from the wind farms was not measured as part of this project, for half the case study wind farms results of operational noise measurements by third parties were obtained. These measured levels have shown good agreement with the noise levels predicted by the project team through adopting current good practice for the as-built scenarios. This observation supported the method used in the present study.

6.122 As the impact of wind turbine noise is assessed in the planning context by comparing turbine noise levels with derived criteria, if the turbine noise levels are under-estimated and/or the criteria are over-estimated at the planning stage, this represents a risk of under-assessing the future impact of the development. Indeed, the principal mitigation measure for wind farm noise at the nearest residential locations is through the adequate design of the wind farm. Obtaining robust information and assessment at the project outset and prior to the planning submission is crucial if suitably designed sites are to be proposed and appropriately assessed. It is therefore important that developers ensure that they adopt rigorous and verifiable means of obtaining robust information, in line with current good practice, and take advantage of the pre-application consultation process to identify an appropriate approach with the relevant authority.

Were the potential experiential effects of the noise on local residents considered and, if so, how?

6.123 The likely audibility and potential experiential impact of wind turbine noise were generally not considered in depth at the application stage. This is a direct reflection of planning policy on this point which recommends the setting of noise limits that are, in themselves, deemed to be ‘acceptable’ in planning terms. But general planning guidance requires the assessment of qualitative impacts in addition to this quantitative assessment. Compliance with the ETSU-R-97 derived noise limits does not necessarily relate to inaudibility of the wind farm noise for neighbouring residents. For some residents the fact that wind farm noise may be audible, regardless of its level, may be sufficient to elicit an adverse reaction to that noise.

6.124 At the application stage, the potential character of the noise was only discussed in general terms, and not considered at all in four out of the ten study cases. The potential noise features discussed included tones (“hum” or “whine”) and (in less cases) amplitude modulation (“swish” or “thump”).

6.125 The assessments reviewed either did not consider the subject of tonal noise, or that it was unlikely to be an issue from modern technology wind turbines. Standard measures were proposed to account for the presence of audible tones, should they occur, through a penalty procedure (see Appendix G).

6.126 Most of the applications (six of the ten case study wind farms) did not consider the subject of amplitude modulated noise (swish or thump) except in quite general terms. No penalty similar to that for tones was recommended to account for the effect of excessive amplitude modulation in the event that it should occur. This is consistent with current practice on the subject although, as previously discussed, this matter is presently under active review (Appendix G).

Is there evidence to suggest that Councils and consultees may not always rigorously examine ESs?

6.127 Based on the information available it has not been possible to firmly establish the degree of rigour and objective reasoning behind the decisions of Councils and consultees made in respect of the case study wind farms.

6.128 Wind turbine noise is a complex technical matter on which practice has evolved relatively rapidly over the effective assessment window of the present project. As a consequence the specialist knowledge required to enable its full appreciation has not necessarily been widespread. The reviews of the submitted applications undertaken by consultees may therefore not have identified potential deficiencies in the technical details of the noise assessment particularly as limited information was presented. It is therefore conceivable that different conclusions would have been reached by the consultees had the assessment been presented using the level of detail recommended under current good practice guidelines (which were not in place at the time).

6.129 Recognition (2013) by the Scottish Government of the IOA GPG clarifies the standard required of all wind farm noise assessments and should assist in the rigour and consistency applied to future scrutiny in this respect.

6.130 The application of noise planning conditions limiting the maximum levels of noise from sites can represent a safeguard to some extent against cases in which wind turbine noise levels are under-estimated at the planning stage. However if the noise limits (i.e. the planning criteria) derived are over-stated, for example due to un-representative elevated background noise levels, this cannot be subsequently remedied: this means that this aspect of the scrutiny of an application is particularly important.

Summary of key findings from effects from operational developments

Noise Impacts and Audibility

6.131 In addition to the detailed quantified analysis of the previous sections, the present section sets out an analysis of general trends identified by HLA based on their overall expert review of the results obtained.

6.132 Although a large majority of the residents surveyed were not affected by noise, some of the more noise-exposed residents expressed a range of impacts associated with noise. These responses ranged from a dislike of the noise to more significant impacts on their way of life. This situation is not unique to the case study wind farms: any audible source of noise may lead to a range of reactions depending on a wide range of factors, both acoustic and non-acoustic, including attitudinal.

6.133 There is an acceptance in planning policy that the development of wind farms means that some noise may be audible at some residential neighbours. Contrary to some other comparable sources, noise from wind turbines cannot be totally mitigated without effectively preventing development through the adoption of prohibitively large separation distances, just as some level of visual impact cannot be avoided. The potential for audible noise is not always clearly set out in the assessments or realised/expected by residents neighbouring a wind farm scheme. As recognised in ETSU-R-97 (p. 65), audible noise can create particular adverse reactions in cases in which inaudibility was predicted. There was no evidence that such strong claims of inaudibility were made at the planning stage of any of the case study sites considered, but neither was the potential audibility of each wind farm development clearly set out (see above) in the assessments presented.

6.134 Exposure to wind turbine noise can lead to annoyance, but there is considerable disparity between respondents. For most of the case study wind farms there were survey respondents with seemingly opposing views. Some were predicted to be exposed to very low noise levels but severely disliked the wind farm noise, while others were predicted to be exposed to higher noise levels but were indifferent about the noise. In a limited number of cases, direct involvement with the wind farm provided an explanation, but this was not true of most cases. In other cases respondents predicted to be exposed to similar levels of noise had polarised responses. This highlights the potential importance of a range of non-acoustic factors in shaping individual responses. This is consistent both with HLA's experience and according to the available guidance.

6.135 If a particular person were to be of the view that they do not under any circumstances find the sound of a wind turbine tolerable, they would perhaps consider that they suffer a loss of amenity merely through the fact that they may be able to hear the wind turbine sound. However, in the context of the planning framework, such quite real adverse impacts need to be balanced against other benefits that may accrue from the development. Thus even though the aim of the planning system, via the application of ETSU-R-97, is to control wind farm noise within 'reasonable' and 'acceptable' bounds, some loss of amenity may still be experienced by some neighbours. This is the case not just for turbine noise but also for other sources of noise such as minerals extraction or transportation. It must be recognised that, as for any noise source, even at low noise levels some people will always consider the level is unacceptable if it is audible. A qualitative assessment such as that prescribed in the 2011 TAN on the Assessment of Noise (as opposed to pure reliance on demonstrating that numerical noise limits derived in accordance with ETSU-R-97 will be achieved) could help decision makers be more aware of these factors. Any such qualitative assessment could be usefully informed by additional research into the effectiveness of the masking of wind farm noise by other sources of noise in the environment.

Noise Levels vs Distance

6.136 Analysis of predicted noise levels has helped explain general systematic differences in reported audibility or response to noise in the survey responses, though there were a few cases that did not fit the generally observed pattern.

6.137 In summary, reported audibility increased and reported acceptability decreased with increasing predicted as-built noise levels, (see Table 6-2 and Section 6.85). In comparison, the relationship with separation distance was much less clear. This is not surprising given the different noise levels that can be experienced at similar distances from wind farms due to differences in turbines types, layouts and topography between these wind farms.

6.138 In HLA's opinion, following an overall review of the evidence, instances of more widespread and consistently reported negative impacts from noise were due either to relatively elevated levels of the noise or to particular acoustic features. In cases in which the predicted turbine noise levels were high in absolute terms, and character was reported, it was not possible to establish to what extent the expressed dislike of the wind farm noise was due to the noise character or alternatively due to the overall level of the noise and/or its general audibility, or some combination of these factors. These two aspects are considered further below.

Noise character

6.139 Noise character, although not always fully clear on the basis of the available information, is an issue which appears to increase the negative reactions reported. This observation is in line with other types of noise. The acoustic characteristics identified were separated into tonality and amplitude modulation.

6.140 Responses to the residents' survey indicated the presence of audible tones could be a potential factor (to at least some degree) in some of the responses at about two thirds of the case study wind farms. However, the descriptions provided were generally not necessarily clear except at about one third of the case study sites. Such tones can be generated by operational turbines in some conditions, either because of faulty design or deficient components.

6.141 The assessment of such tones is subject to a clearly defined methodology contained in ETSU-R-97 which requires a character correction penalty to be added for audible tones. HLA's experience is that the ETSU-R-97 method is effective in practice in identifying and correctly rating tonality when present. In one of the ten case study wind farms in which complaints were identified in the residential survey, a tonal feature was positively identified as part of compliance measurements (whose results were obtained separately). This finding then initiated a mitigation process as it caused the limits to be exceeded. As a consequence, compliance with the planning conditions required either physical measures to the turbines themselves aimed at mitigating the tones at source, or operational constraints which reduce the overall level of the wind farm noise to compensate for the tone. In this case, standard enforcement procedures led to a mitigation strategy being implemented for this feature. The evidence on the effectiveness of this mitigation was inconclusive: one of the survey comments described the lack of satisfaction with the works but this was prior to the completion of the mitigation works.

6.142 Regarding amplitude modulation, when descriptions of the noise character suggested that this could be a feature (about two thirds of the case study wind farms), it was difficult to evaluate the magnitude of the actual modulation from the descriptions received. In about half of these cases, (i.e. about one third of the case study sites), the descriptions of this feature were clearer, thereby suggesting that it was more pronounced. Despite extensive research in recent years, which is leading to an increased understanding of the phenomenon, there is no generally agreed procedure for rating amplitude modulation, although several have been proposed.

More specifically, there exists no accepted means for accounting for particular amplitude modulation characteristics of the noise beyond those already calculated within the noise limits derived according to ETSU-R-97. Efforts are on-going to better establish an amplitude modulation assessment framework and practical methods for its control. This includes the recent publication of a consultation document by the Institute of Acoustics AM working group[44] as well as a contract due to be tendered by the UK Government for investigating suitable AM criteria[45]. Additional work beyond the scope of the present project to further analyse the case study wind farms in this respect was proposed above (6.112).

Audibility

6.143 The variability of impact with wind conditions was notable. When identified, audibility and/or adverse effects of noise were consistently greatest in conditions in which the wind blew from the turbines towards the resident. It is in these conditions that turbine noise levels are expected to be at their maximum, thereby supporting the validity of the responses received. This variability explains why conclusive measurements can in practice be time-consuming to undertake in an effort to capture the relevant conditions, and it supports the predictive approach adopted by the project team (based on predictions, see Appendix H). This also highlights the importance of considering not only the calculated noise levels but also the likely duration of noise exposure. This includes consideration of the locations of the potentially affected properties relative to the prevailing downwind direction from the wind farm development.

6.144 More than four out of five respondents who heard the wind farm noise did so outside of their homes. In comparison, less than half of respondents reported negative impacts within their homes. In these cases, however, the predicted levels were higher and the reported descriptions tended to be more negative. This suggests that the more widespread effect overall was on enjoyment of outdoor residential amenity, but with some severe impacts on indoor amenity possible. In line with HLA's experience, the latter impacts tend to be more the case at night.

Lessons for Good Practice

Pre-consent assessment and consultation

6.145 The Institute of Acoustics has relatively recently produced good practice guidance in the application of the ETSU-R-97 methodology (2013), which has been recognised by Scottish Government. HLA concluded that the application of the IOA Good Practice Guide recommendations would have resulted in more robust predictions, baseline derivations and assessments in general, with clearer presentation of the information necessary for different stakeholders to review or to interpret planning requirements. As the information is relatively technical in nature, non-specialists reviewers can find it difficult to identify basic discrepancies in

[44] Institute of Acoustics AM Working Group, Methods for Rating Amplitude Modulation in Wind Turbine Noise, Discussion Document, 22 April 2015, http://www.ioa.org.uk/publications/wind-turbine-noise

[45] Department of Energy and Climate Change, contract TRN 970/01/2015, Review of the evidence on the effects of and response to amplitude modulation (AM) from wind turbines, with a view to recommending how excessive AM might be controlled through the use of a planning condition, tender published 27 March 2015.

generic noise assessments. The current availability of good practice guidelines, which require in particular presentation of the information in a more consistent manner, is likely to assist this process.

6.146 For some of the case study sites reviewed more robust assessment and/or scrutiny at the planning stage could have resulted in reduced noise limits and would generally have resulted in more robust predictions. This could have affected the project design and therefore potentially reduced impacts in practice. It should nevertheless be noted that compliance with the terms of the IOA GPG would not be expected to eliminate all impacts and/or negative reactions.

6.147 General planning policy on noise in Scotland requires qualitative impacts to be assessed and considered at the application stage, in addition to objective criteria. For wind farms, this would include at least describing the potential for audibility of the wind farm noise. As noted above, this was generally not done for the case study wind farms, perhaps as a consequence of a specific methodology existing for the assessment of onshore wind farm noise. This sets out noise limits which aim to balance the impacts and the benefits of these developments. Further good practice guidance could consider more information relating to potential audibility in addition to simply demonstrating compliance with objective noise limit criteria, and how this can be specifically considered in the assessment. This could usefully be supplemented by further research into the effectiveness of other sources of environmental sound in masking wind farm noise.

Public consultation

6.148 The provision of information on the qualitative impacts of wind farms could be more generally publicised as part of the consultation process as there was limited evidence of awareness in this regard as part of the survey results.

6.149 It would therefore be beneficial to set out clearly, as part not only of the ES but the public consultation process that, where applicable, turbine noise may be audible and may exhibit specific character. This and the associated noise levels should be placed in the necessary context of both local and national noise policy. Such a qualitative assessment of noise impacts would supplement the quantitative assessment, in line with current planning policy.

Conditions

6.150 In terms of planning or consent conditions on noise, several of the examples reviewed were unclear or omitted key elements considered important.

6.151 It is clear that imposing clear planning conditions is beneficial in providing the necessary clarity for all parties. In particular, the following points are considered key:

- tabulated values of the noise limits or, if reference is made to background noise levels as is standard in setting ETSU-R-97 noise limits, the relevant source of this background level and wind speed reference used;
- reference to the ETSU-R-97 method to account and penalise for tonality;
- the locations at which the noise limits apply (i.e. residential dwellings) and when is an investigation of these levels required, and
- a clear mechanism by which local authorities can require operators to undertake such measurements in accordance with the ETSU-R-97 methodology, with clear timescales for undertaking these measurements and reporting.

6.152 The above points are addressed in the example condition provided as an annex to the IOA GPG.

6.153 Planning authorities could give consideration to imposing requirements on wind farm operators to undertake post-completion operational noise compliance measurements, even in the absence of complaints. Indeed, such an approach was identified as having been adopted for two of the case study wind farms. However, the weighing up of potential benefits against drawbacks is required on a case by case basis. Possible benefits include the identification of noise issues at the earliest opportunity, but the potential challenges to undertaking such measurements, including acquiring access to the properties and defining the range of conditions required for the study, should not be underestimated. In addition, the costs associated with acquiring such measurements need to be considered. These costs would be not only for the wind farm operators, both in commissioning the study and as a consequence of any required turbine shutdowns, but also for local authorities in monitoring the process. In contrast, assessments based on a robust prediction method that allows a reliable estimate of overall wind farm noise levels, combined with information demonstrating that efforts have been made to prevent the occurrences of specific features[46], and with standard conditions requiring investigations following complaints, in many instances may continue to offer the most appropriate means of controlling the likely occurrence of excess noise.

Mitigation

6.154 In addition to the above recommendations on the improvement of the robustness and clarity of the noise assessment itself, and therefore of the wind farm design, other measures may also help to reduce wind farm noise impacts in practice.

6.155 Enforcement action can result in operators reducing excessive noise levels or fixing an issue such as tonality or excessive amplitude modulation when found in practice. It is nevertheless recognised that it is beneficial for all parties that these issues should be prevented in the first place. Careful efforts at the turbine design and procurement stages should limit the risk of excessive noise levels occurring in practice, and minimise the risks of features such as tonality and amplitude modulation occurring in practice.

6.156 The presence of tonality depends on the design of mechanical elements in the turbines being effective at preventing or attenuating this potential feature. This can be queried by site operators at the turbine procurement stage and secured in practice by suitable warranties from the turbine manufacturer. No information was available on the commercial warranties obtained by the operators of any of the case study sites. However in HLA's experience, such warranty clauses on tonality are not always obtained, but they should form one measure which would assist in minimising the risk of audible tones arising in practice. This will require dialogue with turbine manufacturers to understand and manage these as part of the turbine design process.

6.157 The same could be done for amplitude modulation (AM) although there is more limited experience in this respect at this stage (see 6.143). The inclusion in turbine supply agreements (contractual requirements) of clauses on tonality and amplitude

[46] See comments elsewhere in this report regarding consideration of potential tonality as part of the turbine procurement process.

modulation that match the requirements for compliance with planning conditions (i.e. based on noise experienced at neighbouring residential dwellings as opposed to more traditional turbine supply agreements which focus on noise emissions measured at the turbine itself) would likely encourage the development of quieter turbines in respect of these noise types.

Enforcement

6.158 The process of monitoring noise levels is traditionally complaint-driven. The Residents' Survey and follow up interviews identified specific reports that complaints were not always followed by suitable investigations. The exact number of such situations was not clear from the limited information obtained as it could be higher than the limited instances identified. Drafting clear planning conditions on noise, as set out above, is recommended to provide a mechanism for enforcement of noise limits which is clear for all parties. In addition, clear communication between all parties, including the affected residents, is paramount and should be encouraged. Where issues are found to occur in practice, it is beneficial for these issues to be identified within sufficiently short timescales. It should also be recognised as good practice that affected neighbours are provided with updates on the actions of the planning authority and the wind farm operator.

7.0 OVERALL ASSESSMENT, CONCLUSIONS AND RECOMMENDATIONS

Introduction

7.1 This chapter summarises the study team's findings specifically in terms of the research objectives as set out in Chapter 2.2, with conclusions and recommendations. It should be noted that the observations made below are based on the findings in relation to the small sample of wind farms included in the study (4% of total wind turbine developments in Scotland 2013, all of which were identified as having incurred complaints).

7.2 The overall assessment of the study against the three key research objectives is reported for each type of impact: visual; shadow flicker; and noise.

Visual Impact Assessment

Is there evidence to suggest that significant environmental effects of the case study wind farms have been under assessed at the application stage?

7.3 For visual impact, this was addressed by considering the following questions:

- Was the assessment of impacts on visual amenity of residential receptors carried out in accordance with GLVIA extant at the time of the assessment?
- Were visual impacts on residents predicted sufficiently robustly?
- Were the potential visual impacts on local residents adequately illustrated by supporting visualisations?

<u>Was the assessment of impacts on visual amenity of residential receptors carried out in accordance with GLVIA extant at the time of the assessment?</u>

7.4 The application submissions for all ten case study sites were accompanied by LVIAs; two of which were included in ERs, and the other eight were submitted as part of ESs. All of the LVIAs included methodology sections which referred to the relevant extant guidance from the Landscape Institute and IEMA (GLVIA, 2nd Edition, 2002).

7.5 All of the LVIAs identified residents as a group of visual receptors which potentially would be impacted. All of the LVIAs assessed visual impacts on residents through inclusion of viewpoints chosen to be representative of views that would be obtained by residents of settlements close to the developments and with predicted visibility of the turbines.

7.6 This indicates that there was a consistent level of awareness across the case studies of the relevant source of extant guidance and awareness of the need to assess visual impacts on residents as one of the groups of receptors to be considered in the assessment.

7.7 A few of the case study LVIAs contained some departures from extant guidelines in carrying out the assessments.

7.8 GLVIA is not prescriptive, but it would be normal good practice if any departure from the methodology referred to in the LVIA is accompanied by an explanation with robust reasoning. This was not always done in respect of the small number of case study sites where the assessments carried out differed in some way from the stated methodology.

7.9 Thresholds for significant effects were not always made clear in the LVIAs and therefore it was not always apparent which of the visual impacts were considered to be significant effects. GLVIA is not prescriptive and GLVIA 3 states (para 6.42) that the "*significance of visual effects is not absolute and* can *only be defined in relation to each development and its specific location*." Nevertheless it is a clear EIA requirement to identify effects assessed as significant as part of the assessment process.

Were visual impacts on residents predicted sufficiently robustly?

7.10 Based on SLR's review of the submitted LVIAs, visual impacts on residents of settlements close to the case study wind farms were generally adequately assessed for the majority of the case study sites.

7.11 There were two instances where as a consequence of considering residents as being of moderate rather than high sensitivity, effects which were assessed by SLR's Landscape Architects as significant, were considered non-significant in the submitted assessments.

7.12 At just over a quarter of the LVIA viewpoint locations visited, SLR assessed slightly higher impacts than the submitted assessments. A small number of these resulted in effects being judged as non-significant in the submitted assessments rather than significant as assessed by SLR.

7.13 In three instances, the assessment would have been more robust if additional representative viewpoints had been identified for residents close to the wind farm and included in the assessment. However in two of these instances, the assessment considered effects on residential visual receptors at similar distances to where such viewpoints would have been located as being significant. So although there may have been a small number of additional locations which could have been included through identification of a nearby representative viewpoint, the fact that significant effects on residents close to the wind farm would occur was not overlooked and was clearly set out in the assessment.

Were the potential visual impacts on local residents adequately illustrated by supporting visualisations?

7.14 Guidance in respect of visualisations has evolved considerably over the past decade. The majority of the case study sites applications pre-date the publication of SNH's Visual Representation of Windfarms Good Practice Guidance in 2006. The 2006 guidance was updated in July 2014 with a revised version issued in December 2014.

7.15 Based on SLR's review of the available submitted illustrative material which accompanied the LVIAs for the case study wind farms, the visualisations appeared to be accurate in terms of size and scaling of the turbines. The quality of the prints available for view varied although it was not possible to know whether this also affected the set of prints which would have been available to the public, consultees and decision makers at the time of the application.

7.16 For four of the case study sites, there was some slight variation in the numbers and locations of turbines visible. This was attributed in one instance to a change in layout that occurred prior to, or during the appeal process and for which a final set of visualisations was not available, and in all other instances to micro-siting of the turbines at the construction stage. Details of micro-siting agreements were not readily available, and obtaining 'as built' turbine locations was not always straightforward.

7.17 Overall, the study team considered that the submitted visualisations were 'fit for purpose' and should have enabled a suitably qualified and/or experienced assessor to predict the impacts of the respective case study wind farms when viewed in conjunction with the related LVIAs, and thereby inform the relevant decision makers. In relation to whether the visualisations assisted local residents' appreciation of the likely appearance of the wind farms, across all the case study sites, slightly more than a quarter of the respondents (26%) recorded that the built wind farm was "as expected" or "broadly similar" to expectations, with 21% recording that it was "very different" or "different", and 20% recording that they did not know whether it was different or not.

Is there evidence to suggest that Councils and consultees may not always rigorously examine ESs?

7.18 Based on the information available in the evidence review, it has not been possible to establish the degree of rigour and objective reasoning behind the decisions of Councils and consultees.

7.19 In one instance the planning officer accepted the findings of the LVIA although SNH had noted their disagreement with this assessment's method and findings in their consultation response. In two instances the planning officers' recommendation seemed to be based on review of the visualisations without reference to the findings of the accompanying LVIA.

7.20 Outside of this study, SLR has experienced similar circumstances occurring in respect of decisions made by all of the possible consenting processes.

7.21 On the one hand there appears to be an over reliance on visualisations to inform the decision maker's judgement on the capacity of the site and surrounding area to accommodate the proposed development and, on the other hand, a reluctance to engage in the detail of the LVIA. SLR acknowledges that LVIAs have become very lengthy, often being the longest ES chapter. The length of the documents combined with what is often regarded as the qualitative nature of assessing landscape and visual impacts, may contribute to the problem. However the separation of examining and interpreting the visualisations from the detail of the accompanying assessment by consultees or decision makers is regarded as poor practice by professional Landscape Architects which may result in unsound decisions being made.

7.22 Visualisations are produced to help inform the assessment process and are therefore in the first instance one of the tools used by the assessor. Generally therefore they are used initially by professional Landscape Architects carrying out LVIAs who understand the limitations of visualisations in terms of the difference between the appearance of a wind farm in reality and its appearance in a visualisation. Visualisations can never completely replicate reality. However, visualisations clearly also are important in assisting the public, consultees and decision makers to understand the characteristics and appearance of the proposed development. SNH's revised guidance (2014) is intended to assist in the production of visualisations which more closely replicate the actual appearance of wind turbines in the landscape.

Is there evidence to suggest that the actual affects, during and after construction, can differ significantly from those identified in the ES?

7.23 Based on the findings of the site visits carried out by SLR, the overall visual impacts of the case study wind farms on residents of settlements close to the developments were mostly consistent with those identified at the assessment stage. Thus for the majority of case study sites where significant effects were identified by SLR during the site visits, significant effects on residential receptors close to the respective wind farm were predicted in the respective assessments.

7.24 However, in relation to the individual viewpoint findings, SLR assessed visual impacts on some residential receptors as higher than the submitted LVIAs. In a small number of instances this resulted in the impacts being assessed as non-significant in the LVIA, but considered significant by SLR. Due to the fact that in a small number of the case study assessments no clear threshold of significance was identified, it is not possible to provide the overall % of significant effects that were under assessed at the application stage across all of the case study sites.

7.25 Analysis of the Residents' Survey also provides a means of considering whether the impacts experienced by those living near a built wind farm correspond with the assessments included in the ESs/ERs. A higher percentage of respondents (38%) recorded that they found the information they saw before the wind farm was built to be either "as expected" or "broadly similar" to what they now see than the 32% who considered the wind farm to "very different" or "different". However, quite a large number (30%) did not know how the wind farm as constructed compared to what was presented at application stage. The reasons for this cannot be conclusively identified from the Residents' Survey. Where reasons were provided, these varied from respondents not having seen any visualisations at application stage, to not interpreting the appearance of the development in the visualisations.

7.26 Additionally, some respondents recorded that the wind turbines appeared larger or closer in reality than appeared in the visualisations and in one instance, recorded that more turbines were visible and/or a greater height of turbines appeared in reality than had been shown at the application stage.

7.27 It is evident from the study, that planning officers and Reporters are well aware of the need to consider visual impacts on residents near to wind farm developments. Residential visual amenity surveys are increasingly being requested by local authorities at application stage and one was provided at the appeal stage in respect of one of the case study sites. The absence of an agreed methodology for such surveys and in particular, the lack of any clear criteria for identifying whether the impacts assessed are unacceptable remains a difficulty. Preparation of these surveys could assist in 'filling the gap' between the assessment of visual impacts on nearby residents to a wind farm development as a generic group of receptors and the specific impacts which would occur at individual residents' properties.

Is there a need for more specific research?

7.28 It would be beneficial to develop a methodology for carrying out residential visual amenity surveys. Research could be carried out to review the range of residential visual amenity surveys submitted and identify the most appropriate methodology which is then developed for consultation and possibly endorsement by the Landscape Institute.

Shadow Flicker Impact Assessment

Is there evidence to suggest that significant environmental effects of case study wind farms have been under assessed?

7.29 This was addressed in relation to shadow flicker by considering the following questions:

- Was the assessment of impacts of shadow flicker carried out in accordance with clear guidance at the time of the assessment?
- Were shadow flicker impacts on residents predicted sufficiently robustly?
- Were the potential shadow flicker impacts on local residents adequately explained to residents?

<u>Was the assessment of shadow flicker impacts carried out in accordance with clear guidance at the time of the assessment?</u>

7.30 Of the six shadow flicker assessments that were conducted five were carried out using a computer model to assess the shadow flicker impacts. The model assessed which properties within 10 rotor diameters would experience shadow flicker and for how long per annum. However, the Residents' Survey responses indicated that there may be houses outwith the 10 rotor diameter that experience shadow flicker.

7.31 The assessment of the significance of these impacts relied on external guidance (Germany and Northern Ireland) and the magnitude of effect varied on a case by case basis. However, if the 30 hours per annum threshold supported by the German Guidance occurs within a few days, the shadow flicker impact is experienced more intensely over this time.

7.32 Four of the case study sites were not assessed as shadow flicker impacts had been scoped out due to the distance of the site from residences. SLR's assessment of these sites concurred with these findings.

7.33 The findings indicate that the assessments of shadow flicker impacts were carried out in accordance with the limited guidance that was available. However, the one more detailed assessment which included a survey of residential properties combined with the modelling was a much more thorough process tailored to the site and residences within the potential zone of influence.

<u>Were shadow flicker impacts on residents predicted sufficiently robustly?</u>

7.34 The modelling applied to assess shadow flicker impacts appears to be robust however the interpretation of the results in terms of significance criteria could be improved by development and consistent application of robust methodology. In some of the assessments the 'worst case' was presented alongside the 'likely' scenario which was reduced by moderating effects This involves assumptions in terms of operating times, weather conditions, direction of turbines, location of residences and size and aspect of windows. It is possible that this led to under-or over-representation of the results to residents but this could not be verified on the basis of the available evidence.

7.35 Where the shadow flicker impact was predicted to be significant, the Planning Conditions studied required that this would be mitigated by shutting down the turbine(s) causing shadow flicker during the times and weather conditions when this would occur. Thus predicted impacts tended to be mitigated through the operation of the wind turbines rather than relocation. This seems to be at least partially successful in terms of reducing effects and related complaints.

<u>Were the potential shadow flicker impacts on local residents adequately explained to residents?</u>

7.36 The Residents' Survey suggests that the awareness of potential shadow flicker impacts varied substantially across the case studies and within each case study. For example, at those sites where a shadow flicker assessment was not undertaken there were respondents who thought they had seen information about the predicted impacts. This possibly indicates some confusion around the questioning which included light and shadow effects as well as perhaps some variation in defining shadow flicker. For sites where an impact assessment was undertaken responses indicated a similar uncertainty about what had been seen pre-planning and how that compared with experience of the as built wind farm.

Is there evidence to suggest that Councils and consultees may not always rigorously examine ESs?

7.37 Based on the evidence that emerged from the different case studies it appears that for the case study wind farms where a shadow flicker assessment was carried out, the significance of the predicted impacts was examined rigorously by the competent authority. In two cases further demands were made on the developer to conduct a more detailed study and/or agree planning conditions including mitigation and monitoring. It was not possible within the context of this study to follow up on these cases and identify the efficacy of any mitigation put in place.

Is there evidence to suggest that the actual affects, during and after construction, can differ significantly from those identified in the ES?

7.38 There is evidence to suggest that residents are aware of a wider set of light and shadow effects than shadow flicker. This includes lighting, light effects and shadow throw. These different and variable lighting effects are not defined and were not assessed in the case study wind farms, except through the Residents' Survey. Perhaps due to the lack of clear definition and/or absence of assessment methodology, these other effects are not usually assessed within ESs/ERs. However, in terms of shadow flicker the actual effects do not seem to differ significantly from those assessed in the ESs.

Is there a need for more specific research?

7.39 In the process of developing new guidelines it would be beneficial to review a number (for example, ten) recent shadow flicker impact assessments to understand current best practice.

7.40 It was not possible to interview residents that experience shadow flicker in this study. However, follow up interviews could provide a more detailed understanding of the level and nature of light and shadow effects from the resident's perspective. There were a number of offers to be visited through the Residents' Survey which could be followed up.

Noise Impact Assessment

Is there evidence to suggest that significant noise effects of the case study wind farms have been under assessed at the application stage?

7.41 With regard to noise impacts, the study found that the case study wind farms had been assessed in general in accordance with the ETSU-R-97 methodology recommended by Scottish planning advice. However, there was considerable variability in the manner in which ETSU-R-97 had been applied across the study wind farms. In addition, the necessary supporting technical information required to assess the robustness of the assessment was not always produced. This had been noted previously in 2011, which led the UK Government to request from the IOA the production of good practice guidance (IOA GPG 2013).

7.42 The fact that Scottish planning advice now requires ETSU-R-97 assessments to be undertaken in accordance with the recommendations of the IOA GPG is expected to address many of the identified shortcomings in the cases of the ten study wind farms, all of which were undertaken prior to publication of the IOA GPG. The recognition by Scottish Government of the IOA GPG should assist in improving the rigour and consistency of assessments.

7.43 There was evidence of differences in the evaluation of turbine noise at the planning stage compared to what is now good practice. In about half the total case study wind farms the differences led to an under-estimate of impacts, but in about half of these cases this was compensated by changes to the final turbine model and layout. The combined effect of these factors was to result in under-prediction at planning stage compared to the as-built situation for about half of the case studies, with little change or over-prediction in the remaining cases.

7.44 The potential influence of turbine location micro-siting on the predicted turbine levels was generally negligible, but the final choice of installed turbine model and layout was more important.

Is there evidence to suggest that Councils and consultees may not always rigorously examine ESs?

7.45 Whilst available evidence was limited in relation to the review process engaged in by the responsible authorities, possibly including any additional information that may have been available at the time of processing the applications, it was considered that the lack of sufficiently detailed information is likely to have been a limiting factor in the rigour applied to the consultation reviews.

7.46 The IOA GPG recommendations clarify the standard required of all wind farm noise assessments and is expected to result in correspondingly more robust reviews by responsible authorities.

7.47 Underestimations of wind turbine noise at planning stage can be mitigated to some extent by the application of noise planning conditions which limit the maximum level of noise produced. However, if the noise limits are over-stated, this can be more difficult to remedy. This reinforces the importance of scrutinising this aspect of the applications.

7.48 The imposition of clear planning conditions, providing a mechanism for enforcement within clear timescales, following the identification of noise issues, provides clarity for all parties and is now recognised good practice. Affected neighbours should be provided with regular and informative updates.

Is there evidence to suggest that the actual effects, during and after construction, can differ significantly from those identified in the ES?

7.49 The considerable variability in the Residents' Survey from respondents expected to be exposed to similar wind farm noise made the interpretation of the adequacy of the existing noise limits difficult.

7.50 The responses received nevertheless tended to be related to the level of turbine noise predicted at each of the properties.

7.51 There was some evidence that absolute noise levels were associated with adverse effects even in cases where elevated background noise levels (and therefore masking effects) were expected.

7.52 Acoustic character features in the noise, when they occur, appeared to affect the response to, and acceptability of, wind farm noise. It is advised that greater efforts are made to prevent well understood characteristics such as audible tones from occurring, for example by increase focus on the turbine procurement process. There is also currently limited guidance on the evaluation of amplitude modulation from wind farms.

Is there a need for more specific research?

7.53 Additional systematic interviews and supporting noise measurements and/or recordings at selected sites considered in this study would assist in further analysing the range of responses in the Residents' Survey. This was outside the scope of this study but would help provide greater understanding of the range of impacts experienced, which in turn could help inform any future policy on achieving the balance between wind farm developments and the adverse impacts of the noise generated. This work could be linked to an assessment of wind turbine noise features using targeted acoustic measurements and/or recordings.

7.54 Whilst most respondents to the Residents' Survey indicated that the adverse impact of wind farm noise occurred when outdoors, those who heard noise indoors and at night were exposed to higher noise levels and generally reported worse impacts. There was also evidence of impacts being reported for residents exposed to elevated absolute turbine noise levels even in areas thought to be exposed to elevated background noise levels. The masking effects of background noise on wind turbine noise, and the effects of different absolute limits for wind turbine noise, could be investigated further, and particularly at night in view of the latest research on the subject (WHO 2009 for example). As part of this exercise, the relative merits between setting noise limits on an absolute basis and a relative to background basis could also be investigated.

7.55 Consideration could be given to providing further good practice/planning guidance in line with general planning guidance, of the qualitative noise impacts of wind farm developments, such as audibility, to supplement the assessment based on the recommended ETSU-R-97 guidelines. Further research may, however, be required in order to fully inform any such guidance.

7.56 More work is also required to better understand the occurrence and impacts of amplitude modulation, develop a technique for its measurement and objective quantification as well as investigate mitigation measures, in line with that already available in ETSU-R-97 for tones. This may emerge both from work presently underway through the IOA and a project due to be commissioned by the UK Department of Energy and Climate Change, and therefore engagement with this work is recommended.

General Observations from the overall study

7.57 Below some general observations are made in respect of the study findings in relation to the specific criteria that were agreed to be considered at the site selection stage.

- Evidence review – accessibility of documents/data
    - There was a wide inconsistency in the availability of information presented at the planning stage, and in particular of any subsequent consultation.
    - Many applications did not set out necessary general information such as the co-ordinates of the turbines, or technical assumptions such as for example, in the case of noise, details of the baseline survey or prediction assumptions, both of which are now required to be set out in accordance with current good practice.
    - Information relating to the post-consent phase was particularly difficult to locate, with information such as the micro-siting agreements, installed turbine locations or turbine model needing to be sourced from current site operators where possible. This has implications for any post consent monitoring, enforcement and/or follow up, if there are any complaints made to the relevant authorities post construction of a development.

- Consent processes – differences at national and local level?
    - No evidence was identified to suggest any correlation between the adequacy or otherwise of impact assessments and the consent route (planning authority, Section 36, appeal) for the proposed development. However, it was apparent that for the appeal sites, further detail was provided at the inquiry stage.

- Differences with scale?
    - There is no clear evidence to suggest any correlation between the adequacy or otherwise of LVIAs and the size of the development in terms of the number and/or height of the turbines. There was some indication that smaller scale developments in terms of the number and/or height of turbine were not as robustly assessed as larger scale developments. However, given the small number of case study wind farms included in the study and range of sizes, it is not possible to draw conclusive evidence on this.
    - No evidence was identified to suggest any correlation between the adequacy or otherwise of noise assessments and the size of the development.

- Differences with age of application?
    - There was no clear evidence to indicate that more recent applications were accompanied by more robust LVIAs or visualisations which more closely follow SNH's 2006 guidance. However, the applications which pre-date this guidance were not always illustrated by visualisations which would have met the minimum requirements of the 2006 guidance.
    - There was some evidence that later shadow flicker assessments were more detailed and include residential surveys.

  - There was some evidence that the noise assessment of more recent applications was closer in some respects to what is now current practice, although the evidence was mixed.

- Involvement of the community?
  - There was little systematic evidence to suggest that the lack of community involvement directly had a negative impact on responses, but several responses suggested that some respondents had limited understanding of the potential visual and shadow flicker impacts or the potential for audible noise from the wind farm.

- Where EIA is not required?
  - There was no evidence that non-EIA assessments were necessarily of a lesser quality than those subject to EIA. The necessity to comply with good practice guidance, commensurate with the scale of the development, is considered more important.

- Adherence to current guidance?
  - Whilst all reported LVIAs had referred to the extant GLVIA (2^{nd} edition 2002) as being the source for the methodology to be used, this was not always followed in carrying out the assessment. It is noted that where the assessment methodology was not followed, this was not always picked up by either the planning officer or SNH. In one instance where SNH did identify that current guidance had not been followed, there was no evidence of a revised assessment have been carried out
  - Whilst all reported noise assessments had followed the general procedure of ETSU-R-97, differences in the interpretation and application of this government recommended methodology were identified between the various applications, none of which fully complied with what is now considered current good practice. The subsequent recommendation of Scottish Government that the ETSU-R-97 methodology should be applied in strict accordance with the Good Practice Guidance provided by the Institute of Acoustics should address such interpretational issues and lead to more consistent and robust wind farm noise assessments.

Conclusions and Recommendations

7.58 The Wind Farm Impacts Study researched the visual, shadow flicker and noise impacts at ten case study wind farms across Scotland. It compared experienced and actual visual, shadow flicker and noise impacts of the operational case study wind farms to the impacts predicted in ESs or ERs submitted with the planning application for the ten Scottish case study wind farms.

7.59 The case study wind farms represent a small sample of the operational wind farms in Scotland in 2013 with known complaints and the assessments carried out at the planning stage for these developments were completed before 2009. Since this time there has been considerable development in the knowledge and understanding of wind farm impacts, with a raft of revised guidance (see Appendices L and M).

7.60 The findings from this study point to several improvements in planning guidance and best practice. Some have been implemented in the time between the case study wind farms being planned and the present. This is an encouraging sign that the planning process is getting better at predicting and presenting the impact from major developments like wind farms. However, there are still outstanding issues relating to the consistency of methodology for certain aspects of the assessments, and the procedures relating to documentation and the decision making process.

7.61 Additionally, a consistent theme identified across the visual, shadow flicker and noise impacts relates to the fact that the assessments carried out as part of the EIA process do not always capture the experience of wind farm impacts. This study used both evidence review and a Residents' Survey to assess whether the impacts from the wind farm case studies are as predicted by developers at application stage.

7.62 Residential Amenity Surveys which assess predicted visual, shadow flicker and noise impacts on residents at an agreed number of properties within a certain distance of proposed turbines can provide a more detailed level of assessment. Requests from planning authorities for such surveys are becoming more common, but there is no guidance or methodology for defining the scope and methodology.

7.63 In terms of the evidence review, there was a reasonable correspondence between the predicted impacts at application stage and the study team's assessment of the as built impacts. However there were some instances in respect of each of the topics where impacts were under assessed.

7.64 Whilst some of the discrepancies between predicted and actual impacts identified were attributable to inconsistencies in methodology or its application, some related to the fact that assessment methods do not necessarily account for the potential experience of, or response to, wind farm developments.

7.65 This divergence between objective measurement and experience of impacts was evident from the Residents' Survey which captured a range of responses. In respect of all three types of impacts considered by the study there were instances where no or limited impacts were predicted by the expert team, but residents reported experiencing adverse impacts. This finding points to the difficulties of predicting or assessing experiential responses. These often relate to people's responses to change in their local environment and their sense of, and relationship to, place. Place and place making are an integral part of Scottish Planning Policy (2014). It is therefore important that the assessment process and subsequent consideration of applications by relevant authorities takes account of this. Good project siting and design, rigorous and transparent impact assessments, and following the principles of public engagement are the main ways by which this can be achieved.

7.66 Consistent application of current guidance and methodologies should be a sound basis for assessment and as noted, this has evolved considerably even over the lifespan of this study. The study team has identified some ways in which assessments could be improved to better consider visual, shadow flicker and noise impacts from wind farms and specifically to capture some of the more experiential or specific impacts identified. These are set out in the Recommendations below.

7.67 Academic research has shown that community acceptance is heightened when technologies are interpreted by local residents to 'fit' with the place in which they are sited, working with the grain of place attachments and identities (NESC 2014).

Recommendations

7.68 Table 7-1 sets out our recommendations for each type of impact identified as a result of the study.

Table 7-1
Recommendations in relation to visual, shadow flicker and noise impacts

Recommendation	Action
Visual Impacts	
Guidance and methodology should be developed for residential visual impact surveys and also, where appropriate, the overall impact on residential amenity due to the combined visual, shadow flicker and noise effects of wind energy developments.	Research to feed into good practice/planning guidance
Prepare checklists for use by planning officers at scoping and post submission stages of an LVIA to ensure consistency and consideration of all key matters.	Develop, to feed into good practice/planning guidance
Consistent and clear reporting in LVIAs including setting out the design objectives for the wind farm development with key constraints considered.	Fully implement good practice guidance
Review of the use of SNH's revised guidance on visualisations.	Research underway
Shadow Flicker Impacts	
Guidance, definitions and significance thresholds should be developed for the assessment of shadow flicker, shadow throw and light effects, including their presentation in public consultations.	Research to feed into good practice/planning guidance
Develop guidance, definitions and significance thresholds should be developed for shadow flicker, shadow throw and light effects.	Research to feed into good practice/planning guidance
Conduct a small follow up study to understand more about the light and shadow effects on residents within 2km of wind turbine developments.	Research to feed into good practice/planning guidance
Develop clearer ways to present shadow flicker assessments and related light effects in public consultations.	Develop, to feed into good practice/planning guidance
Noise Impacts	
Further good practice/planning guidance could recommend more consideration of experiential impacts of wind farm developments, such as audibility, in line with general planning guidance.	Develop, to feed into good practice/planning guidance
A review should be undertaken to establish whether the existing derivation of noise limits offers the appropriate balance between protection, simplicity and robustness. This could comprise further investigation into the masking effects of background noise on wind turbines noise, and the effects of different absolute limits for wind turbine noise, particularly at night. As part of this exercise, the relative merits between setting noise limits as an absolute level or as relative to background level, or through a combination of the two as is presently done, could also be further investigated.	Research to feed into good practice/planning guidance
Good practice should be developed in terms of assessing modulated noise from wind turbines. This could include proactive involvement with other work in the UK to further this aim.	Research to feed into good practice/planning guidance
Where noise issues are found to occur, these should be identified and assessed within clear timescales, and affected neighbours should be provided with regular and informative updates.	Fully implement good practice guidance
Additional interviews and supporting noise measurements at selected sites included in this study to assist in further understanding the range of responses received and assessing the significance of acoustic features.	Research to feed into good practice/planning guidance
General	
Where appropriate, overall residential amenity should be considered through provision of a synthesising, collective analysis that brings together visual, noise, shadow flicker and other impacts.	Develop, to feed into good practice/planning guidance
Guidance should be developed to achieve consistency across competent authorities in respect of retention and accessibility of key documents throughout the consenting process, including post consent agreements.	Develop, to feed into good practice/planning guidance
Decisions about micro-siting should be taken by competent authorities and recorded, based on the specific implications for visual, shadow-flicker and noise impacts, alongside other potential impacts and in relation to stated design objectives.	Develop, to feed into good practice/planning guidance

APPENDIX A – AUTHORS' CREDENTIALS

Jean Welstead (MA Hons, MEd). Jean was one of the first wind farm planning co-ordinators in the UK in the early 1990s. She has observed the changes in the EIA process since this time with an interest in improving the effectiveness of this process. In addition to her work in the renewable energy sector she has over a decade of experience of delivering multidisciplinary environmental research projects. She was project manager for the Wind Farms Impacts study since its inception in June 2013. In terms of conflicts of interest she has not worked on any of the case study wind farms.

Lindsey Guthrie (MA Hons, MPhil, CMLI,): Lindsey has over 28 years' professional experience as a Landscape Architect in public and private sector in both the UK and overseas. She has specialised in Environmental Impact Assessment (EIA) and in particular, Landscape and Visual Impact Assessment (LVIA), having completed and managed LVIAs for a range of infrastructure projects including onshore substations, overhead lines, on and offshore wind energy, minerals and waste facilities. Lindsey has been involved in development of LVIA guidance having contributed to the 2nd edition of the Guidelines for Landscape and Visual Impact Assessment (GLVIA) (2006 Landscape Institute and Institute of Environmental Management and Assessment) and has been instrumental in revision to SLR's internal LVIA methodology to reflect the recently published GLVIA 3rd edition (2013). She has prepared and presented landscape evidence at 14 public inquiries.

When corroborating the LVIAs and undertaking the site visits for any of the case study wind farms which had previously been assessed by Lindsey, an alternate qualified Landscape Architect carried out the work.

Andrew Bullmore (BSc (Hons) PhD MIOA): Since gaining his first degree in 1983, Andrew has worked full time in acoustics, for the first seven years in academic research and subsequently in general acoustical consultancy and applied research. Andrew now specialises in the measurement, prediction and assessment of all types of community and environmental noise, with a particular expertise in wind farm noise, having been involved since the development of the earliest commercial wind farms in the UK in the early 1990s.. Andrew has provided expert witness evidence at a large number of wind farm planning hearings and inquiries. He is a member of the UK Institute of Acoustics.

Matthew Cand (|Dipl Eng PhD MIOA): Matthew has been involved at different stages, from inception to completion, on a wide variety of projects (including wind farms) throughout the UK. Matthew has provided expert witness evidence at several wind farm planning hearings and inquiries. Matthew joined the working group set up by the Institute of Acoustics which produced the Good Practice Guide on the assessment of wind turbine noise. He is a member of the UK Institute of Acoustics.

Hoare Lea Acoustics did not undertake the assessment at planning or appeal stage of any of the case study wind farms. Although the company has been involved with specific work with some of the operators of the wind farms considered, this was not the case for the authors. The conclusions of the study were solely based on the information collected as part of the project rather than information gathered through other sources or project work undertaken by the authors.

APPENDIX B – THE RESIDENTS' SURVEY

Introduction

A Residents' Survey was conducted for the ten case study sites as part of Phase 2 of the study.

The main purpose of the Residents' Survey was to inform the assessment of as built visual, shadow flicker and noise and compare these with the pre-consent assessments.

Methodology

Sampling Methodology

The first step in developing a sampling unit was to identify the number of properties within 3 km of each wind farm. They ranged from three dwellings to over 23,000 in Dunfermline. It was therefore not feasible within the scope of this project to survey every resident for all case study sites. However, for half of the sites 100% coverage was achievable and in the case of two sites the catchment was increased to 4 km to include more residents. For the remaining sites a proportional number of properties were selected.

Survey method

A quantitative self completion survey was used, as it was the most time and cost efficient method. Residents were sent the questionnaire, which had a series of pre-designed questions, covering a range of topics. They also had the opportunity in 'free text boxes' to add additional any comments. To make completion as easy as possible and to raise the return rate, a postal questionnaire with online option was employed to enable respondents to choose in the way in which they wanted to respond. Respondents could therefore either complete a paper copy of the survey (and were given a pre-paid envelope in which to post it back) or follow the link to an online version of the survey.

Development of the Survey

The proposed sampling methodology and questions for the Residents' Survey compiled by SLR and HLA were issued to the PSG for comment on 25 March 2014. Extensive comments were received which, following CXC and SLR review, were incorporated into revisions of the sampling methodology and questionnaire. The sampling methodology was revised to increase the percentages of residences in the within1 km and 1-2 km zones for three sites. In five of the ten cases, because of the small numbers of residences, 100% of the residents within the survey radius were approached. In the remaining case studies the majority of residents were randomly selected from the address data base within the survey area. However, the PSG requested that at four sites a small percentage (between 1 and 5%) of addresses were selected as likely to experience impacts due to their location or because a resident had requested to be included. At one of the more populated sites where a smaller percentage of total residents within the 3 km were invited to participate in the survey this percentage of selected addresses requested by the PSG was much higher (24%) due to the likelihood of impacts being experienced in this area.

The letter and questionnaire were distributed from mid-June until early July 2014.The survey was issued to residential addresses only (i.e. excluding business addresses). The table below shows the distribution of the survey for each case study. The survey was issued to residents with a return date stated on their individual letter which included their unique identifier code which enabled the research team to correlate their location with the potential impacts that could be experienced from the wind farm.

Table B-1
Survey distribution

Wind Farm	Number of households approached to complete study	Study Area	Percentage of Properties (%)
Achany	106	4km	100
Baillie	141	3km	100
Dalswinton	57	3km	100
Dunfermline	521	3km	2.3
Drone Hill	95	3km	100
Griffin	117	4km	100
Hadyard Hill	241	3km	55
Little Raith	512	3km	5.9
Neilston	261	3km	33
West Knock	252	3km	35

Source: SLR Consulting Ltd

Survey responses

It was noted in designing the survey that different approaches would also include built-in bias in terms of the type of people most likely to respond. It was also likely that those who had already registered a complaint or objected to the wind farm might be more likely to respond. The survey stimulated a good response rate for a postal questionnaire (typically 10%) of between 11.3% and 25.5% as shown in Table B-2 below.

Table B-2
Survey response rate

Wind Farm	Number of households approached to complete study	Number of Responses	Percentage response rate
Achany	106	12	11.3
Baillie	141	36	25.5
Dalswinton	57	11	19.3
Dunfermline	521	68	13.1
Drone Hill	95	19	20
Griffin	117	25	21
Hadyard Hill	241	32	13.3
Little Raith	512	62	12.1
Neilston	261	61	23.4
West Knock	252	64	25
Total	**2303**	**390**	**16.90**

Source: SLR Consulting Ltd

Analysis

The questionnaires asked a range of questions about the respondents' expectations of living near a wind farm, and their experiences since the wind farm has been built. A blank questionnaire is included at the end of this Appendix.

The analysis of the survey results was conducted on a case-specific base (i.e. survey results relating to each wind farm were analysed separately) and on an overall basis for all ten sites. However, given that in some instances the number of residents living near to particular developments is small, the analysis presented in this study represents a synthesis of the analysis from the ten case study wind farms.

The survey was completed by 390 respondents from a total of 2,303 households approached to complete the study relating to the ten case study wind farms. In order to protect the confidentiality of responses to the Residents' Survey, any potentially identifying information has been excluded from this report.

It is worth noting the potential limitations of surveys such as this, which include both participation and awareness bias, particularly with regards cross-sectional studies undertaken solely 'after the event' as compared to longitudinal studies which seek to compare responses both before and after the event. The scope of the Residents' Survey in this study has been necessarily tailored to the duration and cost of the project. Its limited extent means that it **cannot** be used to draw out any generally applicable, statistically robust conclusions in relation to the responses received. Furthermore, the targeted inclusion of a small number of specific respondents who were known to have complained in relation to impacts would most likely result in additional bias to any statistical interpretation of the results. The response rate itself is interesting in this respect. As stated above, it ranges from between 11%-25%, and although good, this is of course not a coverage of, or necessarily representative of, the local community as a whole (or even of the residents to whom surveys were sent). It is very often the case that respondents to surveys are those who have something very particular to say; and/or have the ability and the time to be able to complete the survey. From the findings of the surveys that were completed, general trends are clearly visible, but providing more specific quantitative detail may give a misleading impression of the coverage, scope, and representativeness of the survey. It is important to interpret the information provided in Appendix C with this in mind.

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XXXXXXXX wind farm, - Residents' Survey

Introduction

This survey is designed to capture your experience of living near XXXXXXX wind farm, near XXXXXX.

The research project is examining how well visual, shadow and noise factors were predicted during the planning process, before the wind farm became operational. This will provide evidence to the Scottish Government to help inform any future decisions on changes to planning guidelines and good practice on managing the impacts of wind farms on local residents.

While we can measure certain impacts of a wind farm, like visual appearance, we are dependent on you to tell us how these are experienced as a resident living close to the wind farm. We would be very grateful if you could spare approximately thirty minutes to complete this important survey about your experience of XXXXXXX wind farm.

The research is being done by SLR Consulting Ltd. The project is managed by ClimateXChange – Scotland's Centre of Expertise on Climate Change – and is funded by the Scottish Government. You can find out more about the project by visiting our website:www.climatexchange.org.uk/reducingemissions/windfarmimpactsstudy/.

A project report will be published on the ClimateXChange website in winter 2014-2015.

The survey can be completed on this printed version and returned by post using the Prepaid envelope supplied. To complete the survey, you will need your unique ID code, which is printed at the top and bottom of your letter.

If you have any questions about this research or would like any more information please contact: ragne.low@ed.ac.uk

Question 1

Please enter your unique code at the top of your invitation letter:

Question 2

How long have you lived in your current property?

Less than one year	1-5 years	6-10 years	10-15 years	More than 15 years
☐	☐	☐	☐	☐

Question 3

Is this your permanent address?

Yes	No	Other
☐	☐	☐

If other, please specify:

Question 4

Are you aware of the XXXXXXX wind farm?

Yes	No
☐	☐

If no, please return this survey in the Prepaid envelope without completing any other questions. Your response is still very valuable to us.

Question 5

When did you first become aware of XXXXXXX wind farm?

Before application	During planning and EIA	At start of construction	Once operational
☐	☐	☐	☐

Please describe how you became aware:

Question 6

Are you or have you been involved with the XXXXXXX wind farm at all?

Yes ☐ No ☐

If yes, how have you been involved with the XXXXXXX wind farm?

Planning process	I have lodged a complaint	Land ownership	Share ownership	Community Benefit governance	Community benefit recipient	Involved in nearby wind energy developments	Other
☐	☐	☐	☐	☐	☐	☐	☐

Please describe your involvement:

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Planning and Environmental Impact Assessment

XXXXXXX wind farm (*year*) was subject to an Environmental Impact Assessment (EIA) to assist the planning decision. An Environmental Impact Assessment (EIA) is a formal process to predict the potential environmental effects (positive or negative) of a proposed Development. We would like to understand your awareness and/or involvement in this process.

Question 7

	Yes	No
Were you aware of the Environmental Impact Assessment process before the wind farm received planning consent?	☐	☐

Question 8

Before the planning application was submitted, community consultations will have been held in your area by the developer, or sometimes by the Council or Community Council. These may have been in the form of meetings in the village hall, exhibitions in the public library or school and/or direct leafleting of households.

	Developer run	Council run	Other
Did you participate in any consultations run by the developers and/or council?	☐	☐	☐

If yes, what did this involve?

Question 9

	Yes	No
Did you raise any particular points with the developers or Council? For example, verbally at the meeting or by letter to the Council or developer?	☐	☐

Please explain the point(s) you raised:

Question 10

Did you receive feedback on the points you raised?	Yes ☐	No ☐

Please describe how your points were addressed:

Your experience of living near XXXXXXX wind farm

We are interested in understanding your experience of living near the wind farm in terms of visual, noise and shadow flicker impacts.

Visual Impacts

By visual impact we mean the extent to which the wind farm can be seen from your property, and your experience of this visibility.

Question 11

How many rooms have views of the wind farm?	One room ☐	Two rooms ☐	Three rooms ☐	Four rooms ☐
Not applicable ☐				
Which rooms have a view of the wind farm? Tick all that apply	Public rooms ☐	Kitchen ☐	Bathroom ☐	Bedrooms ☐

Please provide more details of where you can see the wind farm from inside your house:

Question 12

Can you see the wind farm from your garden or external property?	Yes ☐	No ☐

Please describe where you can see the wind farm from outside your house:

Question 13

How do you feel about the visual impact of XXXXXXX wind farm, viewed from your residence?	Strongly like ☐	Like ☐	Indifferent ☐	Dislike ☐	Strongly dislike ☐

Question 14

If you experience visual effects is there any seasonal or weather variation in your experience?	Yes ☐	No ☐

Please describe these:

Question 15

Have you made any changes in your use of your residence due to visual impacts of the wind farm?	Yes ☐	No ☐

If yes, please describe what changes you have made:

Question 16

If you were aware of the planning process, how does the information you saw before the wind farm was built, such as photomontages, compare with what you see now?	As expected ☐	Broadly similar ☐	Different ☐	Very different ☐	Don't know ☐

If the wind farm looks different to your expectations please describe in what way:

Light effects, shadow flicker and shadow throw impacts

Light effects may occur, for example, if light is reflected off the turbine blades or tower.

Shadow flicker occurs when the sun is low and the shadow of the turning blades causes a flickering shadow to be cast.

Shadow throw occurs when individuals(s) outside a building are affected by the shadow cast by turbine(s) at frequent intervals.

We are interested in whether you experience any of these from your residence.

Question 17

Do you experience light or shadow effects from XXXXXXX wind farm?	Light effects ☐	Shadow flicker ☐	Shadow throw ☐

Please describe where, when and how often?

Question 18a

How do you feel about the light effects of XXXXXXX wind farm viewed from your residence?	Strongly like ☐	Like ☐	Indifferent ☐	Dislike ☐	Strongly dislike ☐

Comments:

Question 18b

How do you feel about the shadow flicker of XXXXXXX wind farm viewed from your residence?	Strongly like ☐	Like ☐	Indifferent ☐	Dislike ☐	Strongly dislike ☐

Comments:

Question 18c

How do you feel about the shadow throw of XXXXXXX wind farm viewed from your residence?	Strongly like ☐	Like ☐	Indifferent ☐	Dislike ☐	Strongly dislike ☐

Comments:

Question 19

If you experience light or shadow effects, is there any seasonal or weather variation in your experience?

Yes	No
☐	☐

Comment:

Question 20

Have you made any changes in your use of your residence due to the shadow and/or light effects of the wind farm?

Yes	No
☐	☐

If yes, please describe what changes you have made:

Question 21

If you were aware of information about possible light and shadow effects before the wind farm was built, how does the information compare with your experience of light and shadow effects now?

As expected	Broadly similar	Different	Very different	Don't know
☐	☐	☐	☐	☐

If different, please explain in what way:

Noise impacts

We are interested in whether you hear any noise from the wind farm.

Question 22

Do you hear noise from the XXXXXXX wind farm?

No	Inside	Outside
☐	☐	☐

When do you hear any noise from the XXXXXXX wind farm?

Morning	Afternoon	Night	No noise
☐	☐	☐	☐

Please describe your experience of noise from XXXXXXX wind farm:

Question 23

How often do you hear noise from the wind farm on average?

Never	Less than 5 days per month	5-10 days per month	More than 10 days per month	Everyday
☐	☐	☐	☐	☐

Please add comments in relation to the noise(s) heard:

Question 24

Please describe the noise(s) that you hear:

Question 25

If you hear noise, is there any seasonal or weather variation in your experience of noise heard from XXXXXXX wind farm?

Yes ☐ No ☐

Comment:

Question 26

How do you feel about any noise from XXXXXXX wind farm, as experienced at your residence?

Strongly like ☐ Like ☐ Indifferent ☐ Dislike ☐ Strongly dislike ☐

Comment:

Question 27

Have you made any changes in your use of your residence due to the noise impacts of the wind farm?

Yes ☐ No ☐

If yes, please describe the changes you have made:

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SLR

Perception of the wind farm

Question 28

Has your perception, how you think and feel, of XXXXXXX wind farm changed over time?

Yes ☐ No ☐

If yes, please describe in what way:

Question 29

Within your household does everyone feel the same way about the wind farm?

Yes ☐ No ☐

If no, please describe the differences in how members of the household feel:

Question 30

If you have any other comments that you would like to make please use the space below:

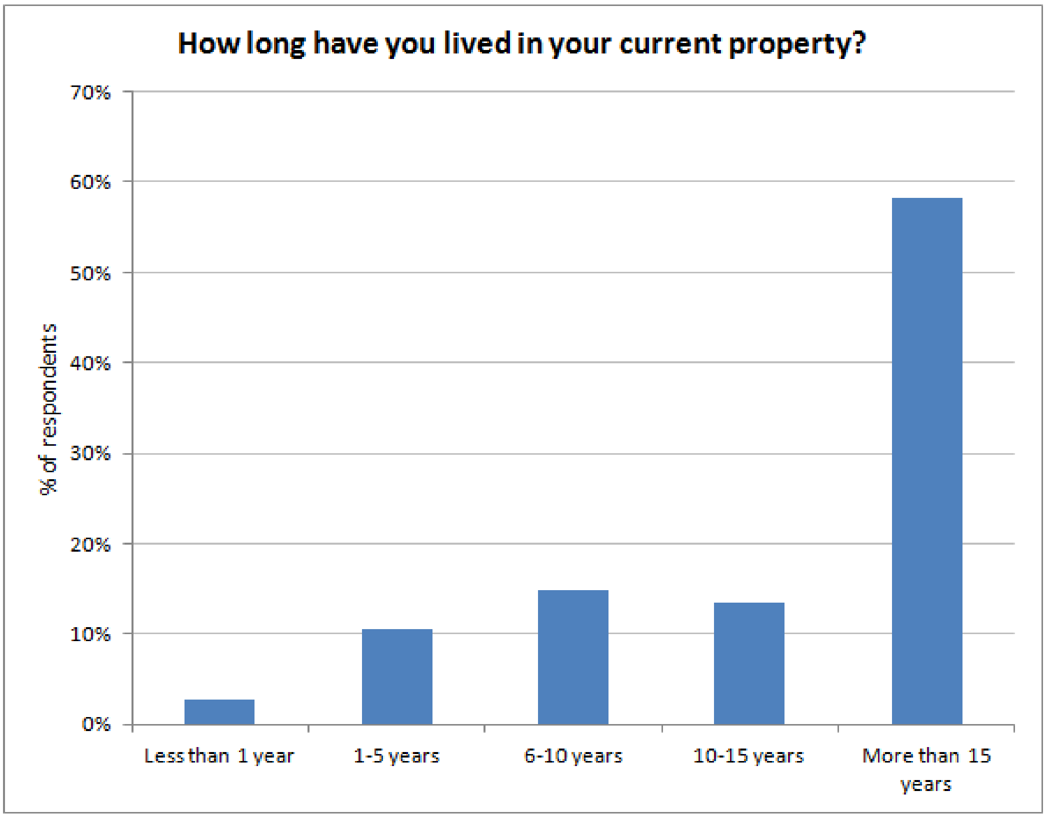
Thank you, we appreciate the time that you have taken to contribute to this survey.

APPENDIX C – GRAPHICAL REPRESENTATION OF QUANTITATIVE RESIDENTS' SURVEY DATA

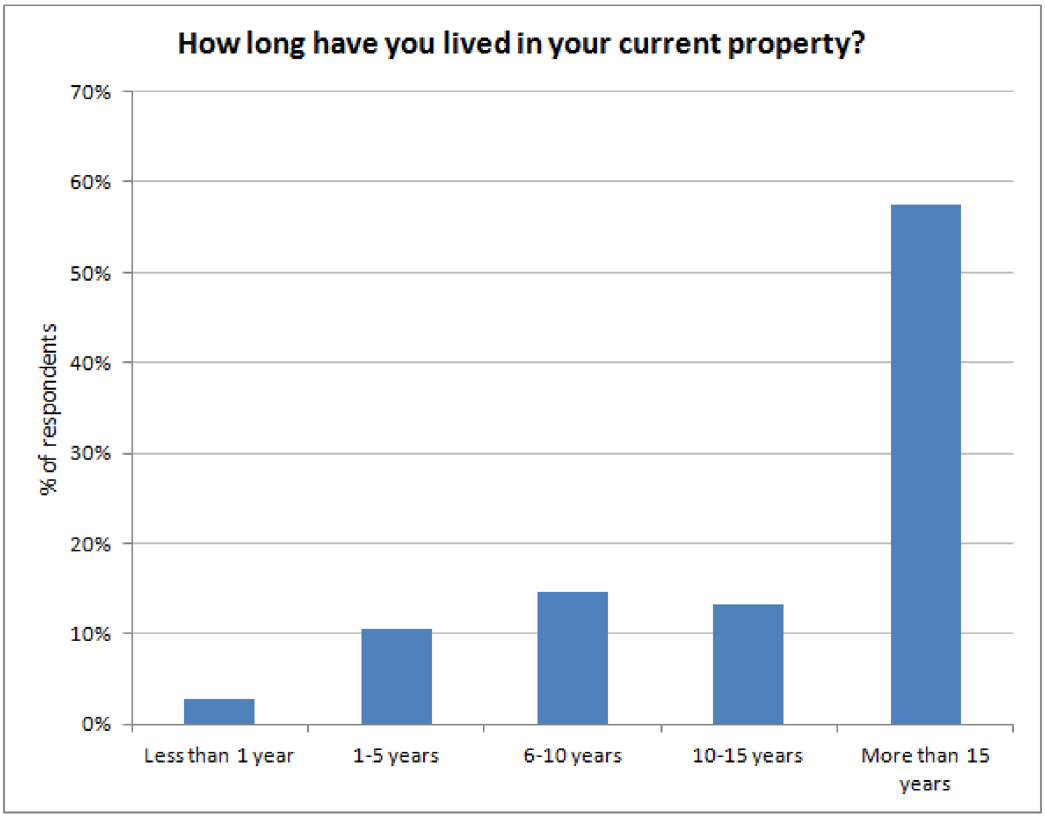
Due to the small number of households at some of the case study wind farm sites and varying response rates, as well as the fact that for any given survey question, some respondents did not provide an answer, quantitative interpretation of the data is challenging. The purpose of using a largely quantitative survey was to allow data to be collected from a large number of households in a cost-effective manner; more cost-effectively than a qualitative approach, with in depth interviews with householders. However the quantitative data only provide an overview, and it is not possible to know how residents interpreted the questions and whether they all will have interpreted them in the same way. Caution therefore needs to be exercised in the interpretation of the analysis, so that it does not suggest conclusive and specific findings that might be misleading. The benefit of having conducted the survey is to provide general trends from a large number of households, and this is what has been provided.

Question 2

No response excluded

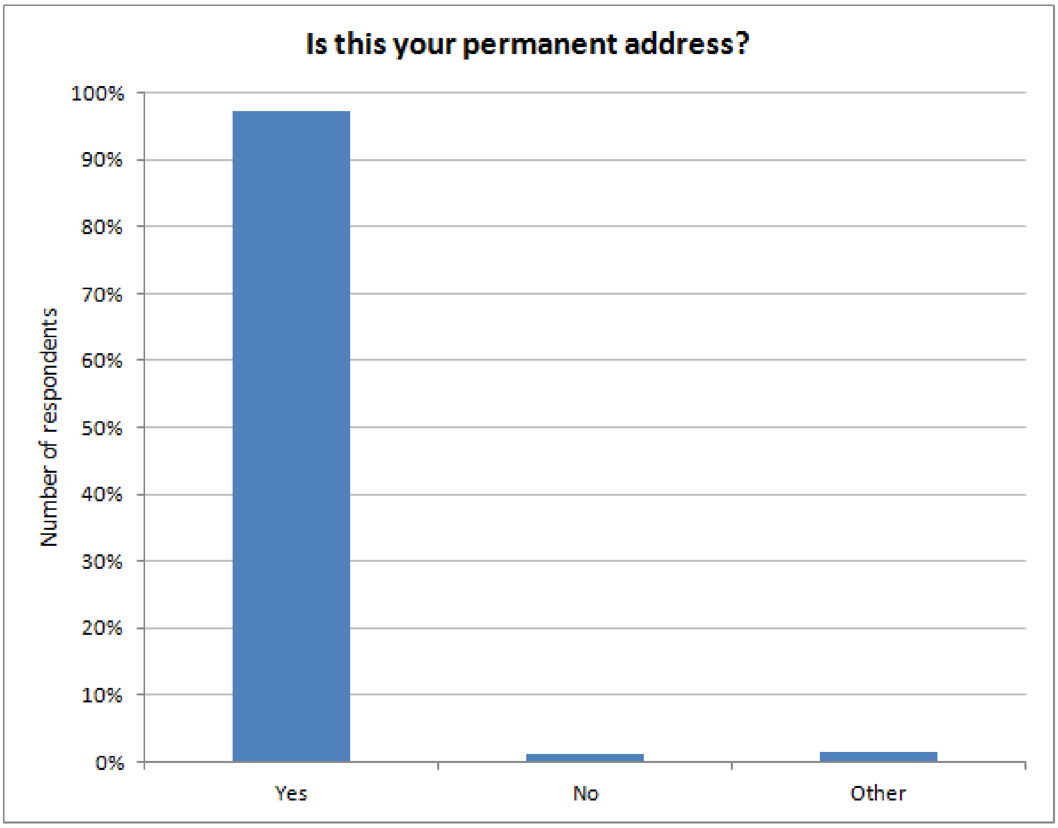


No response included

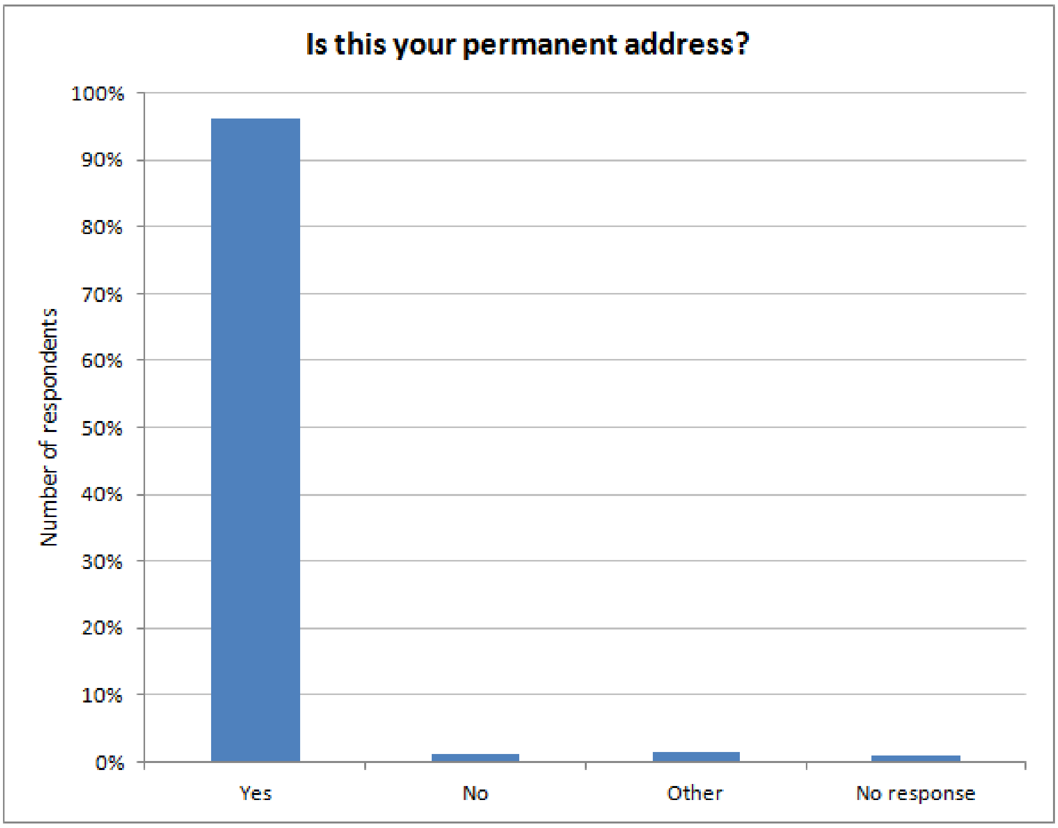


Question 3

No response excluded

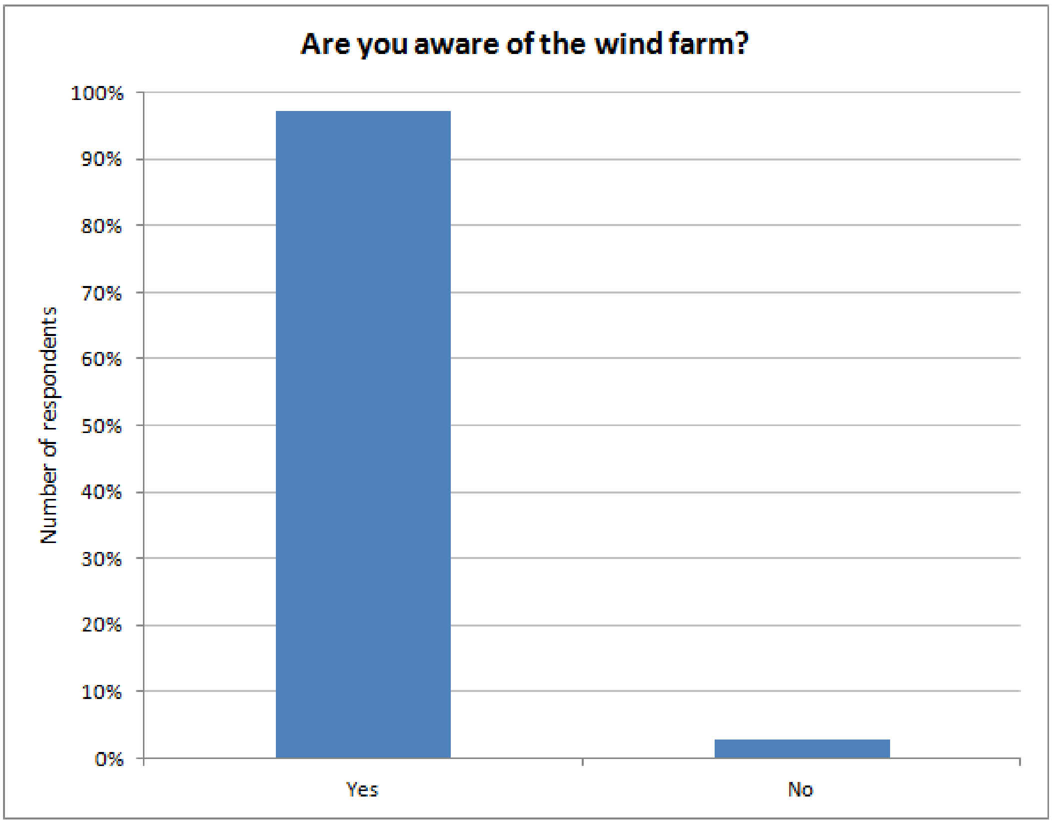


No response included

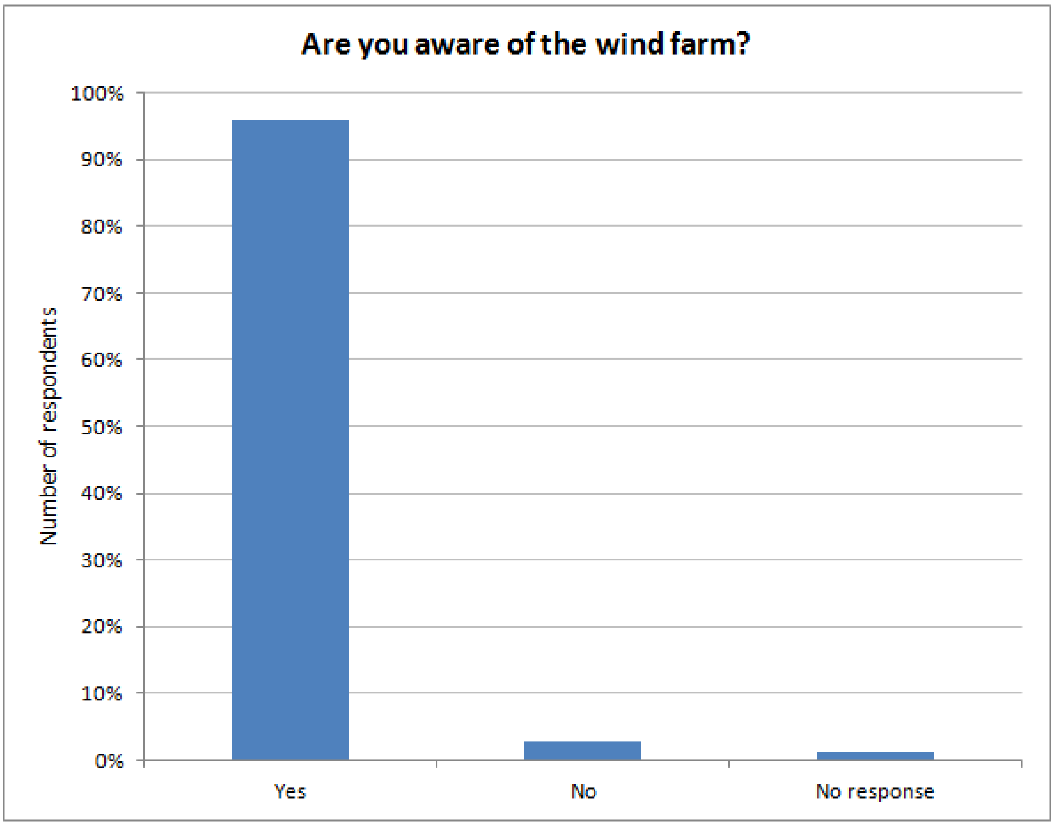


Question 4

No response excluded

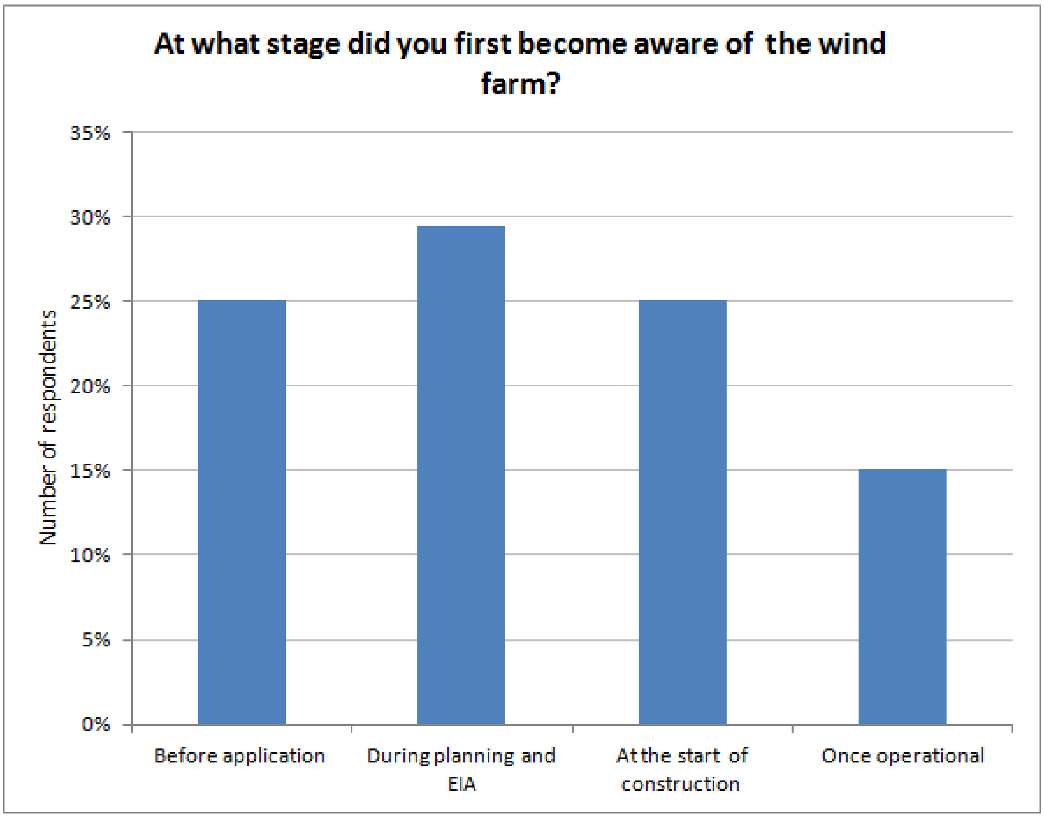


No response included

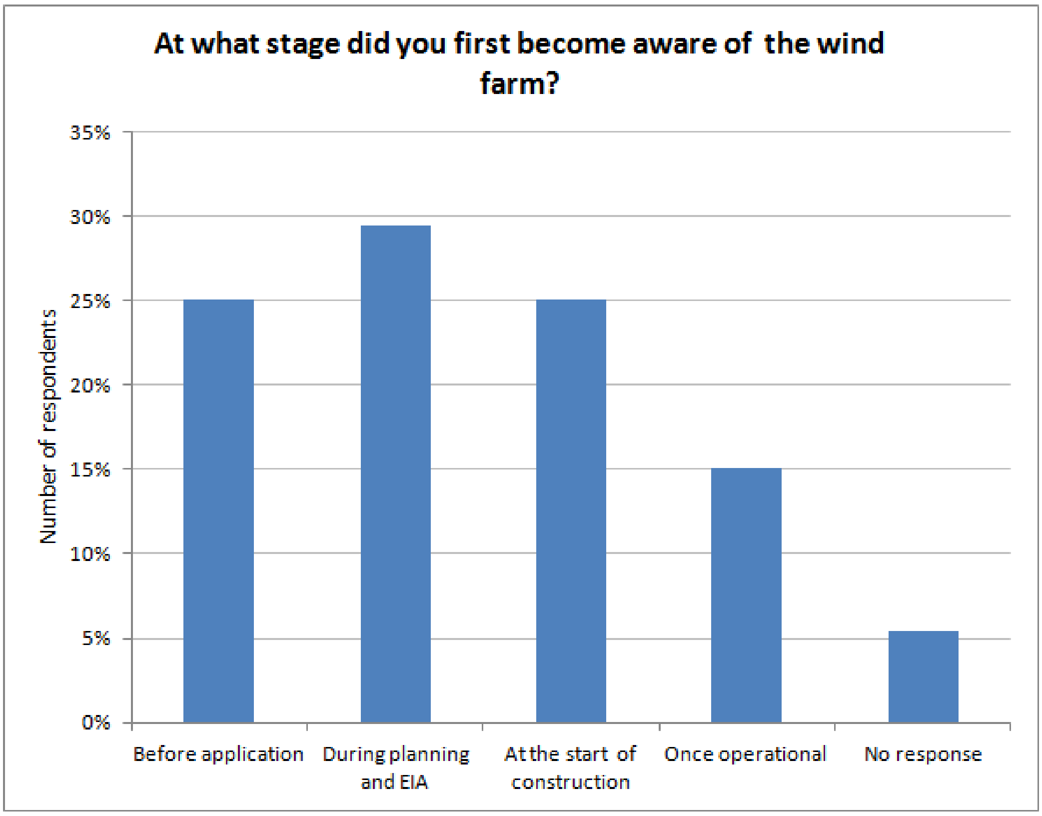


Question 5

No response excluded

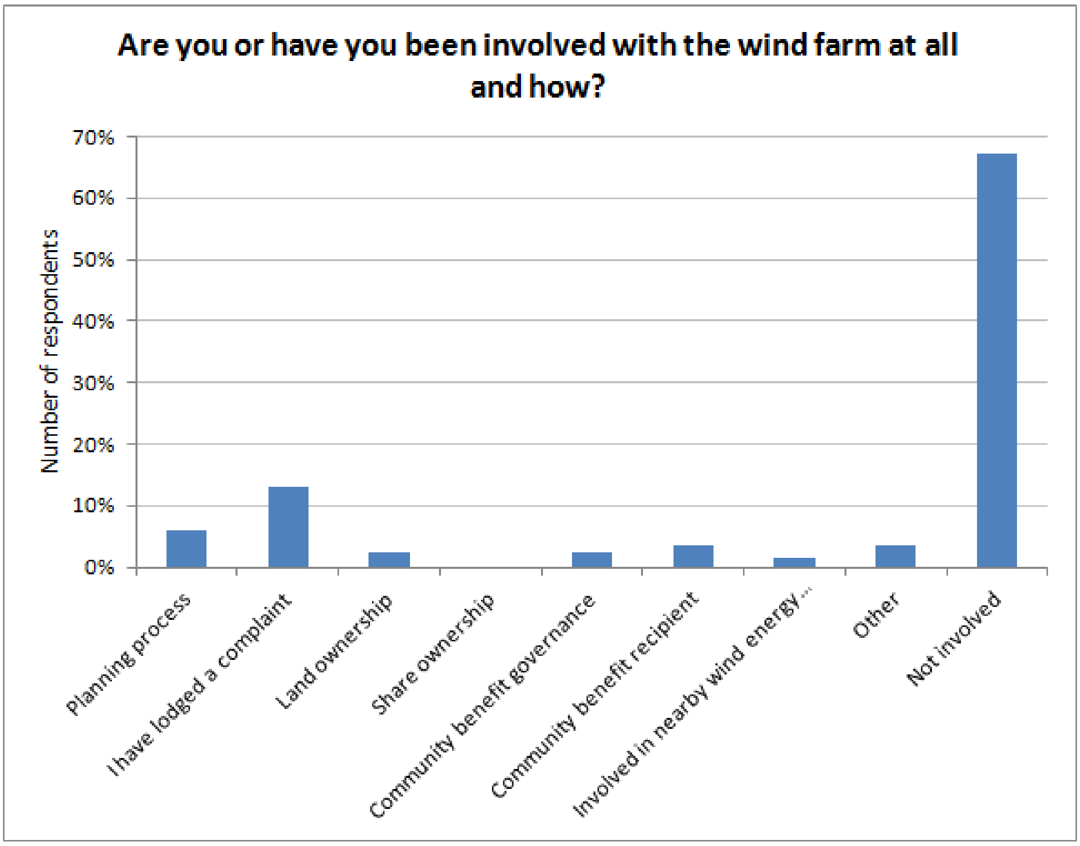


No response included

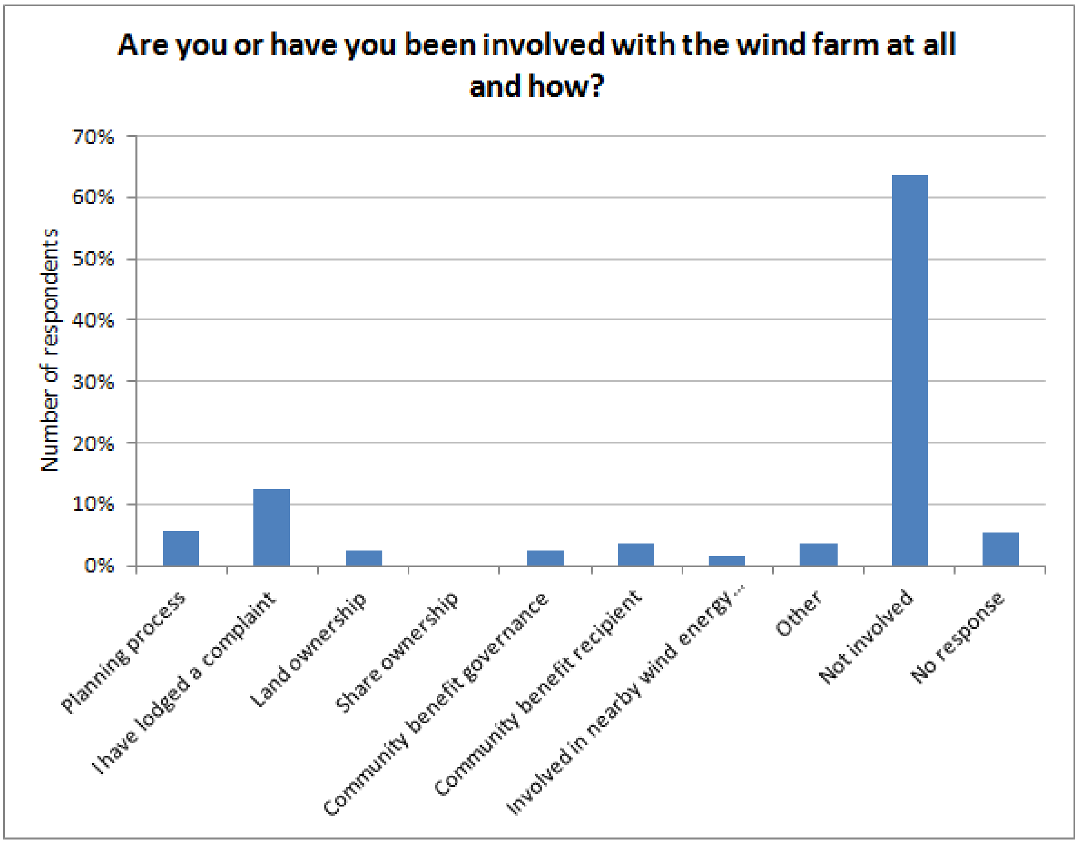


Question 6

No response excluded

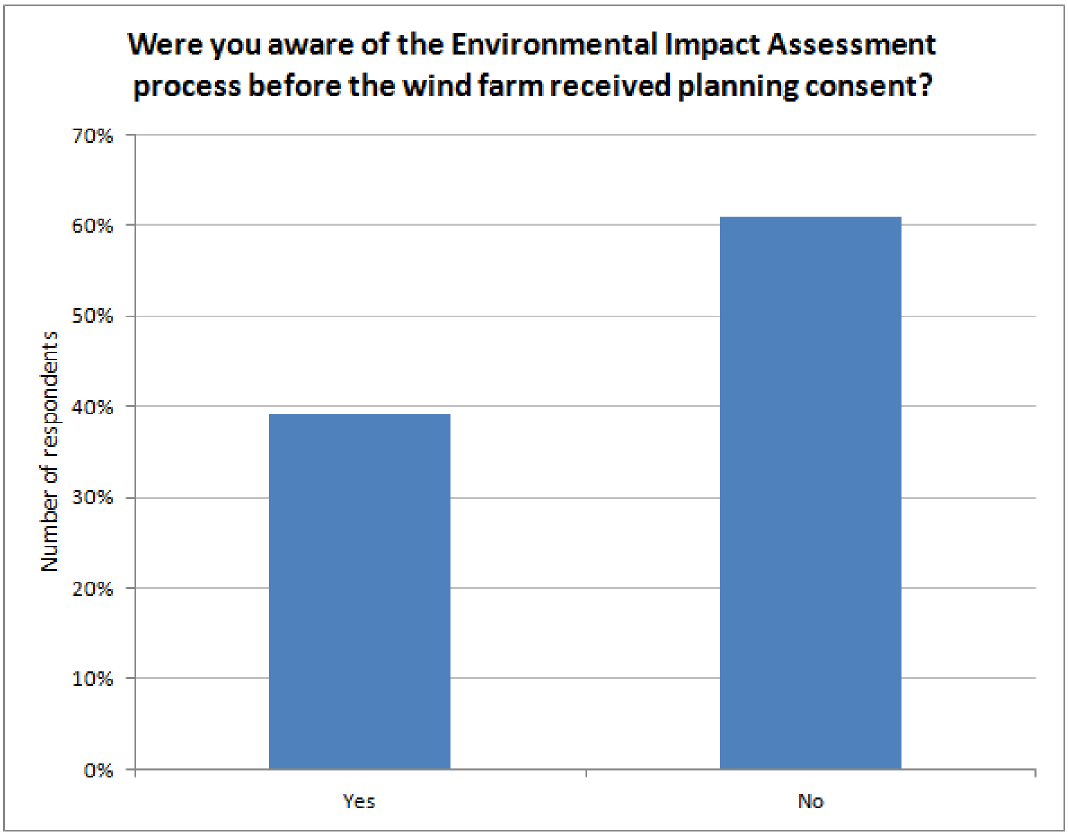


No response included

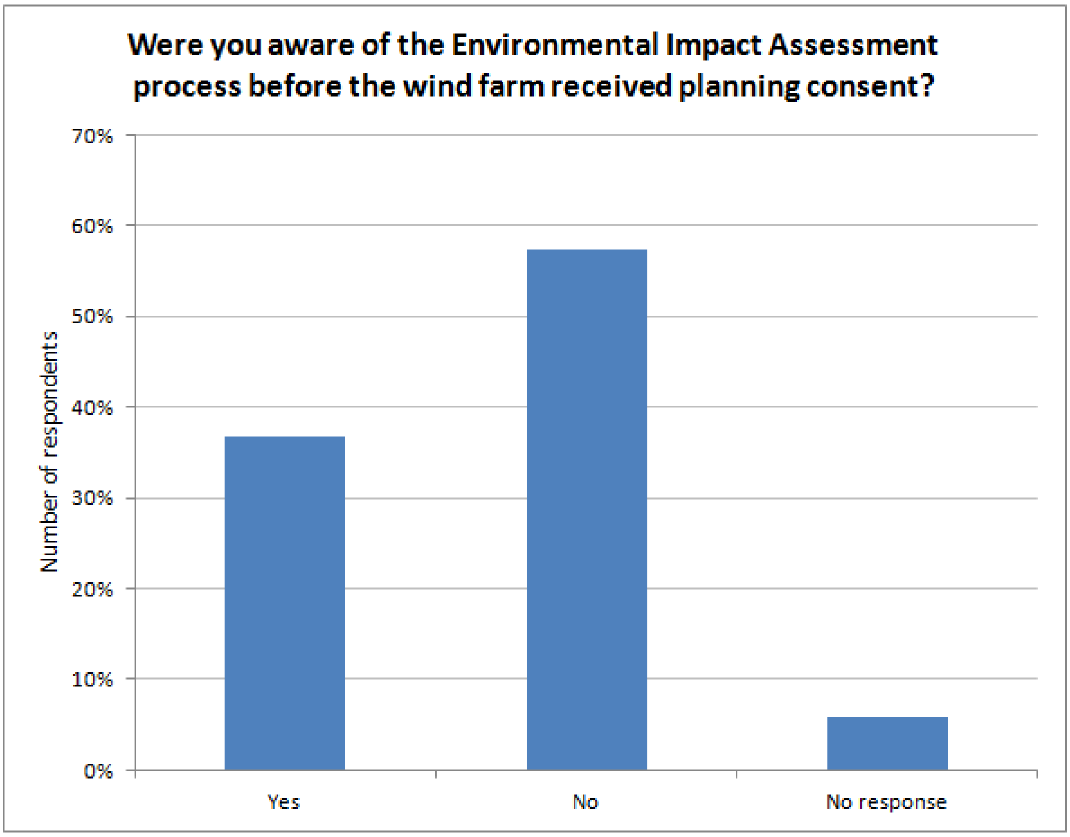


Question 7

No response excluded

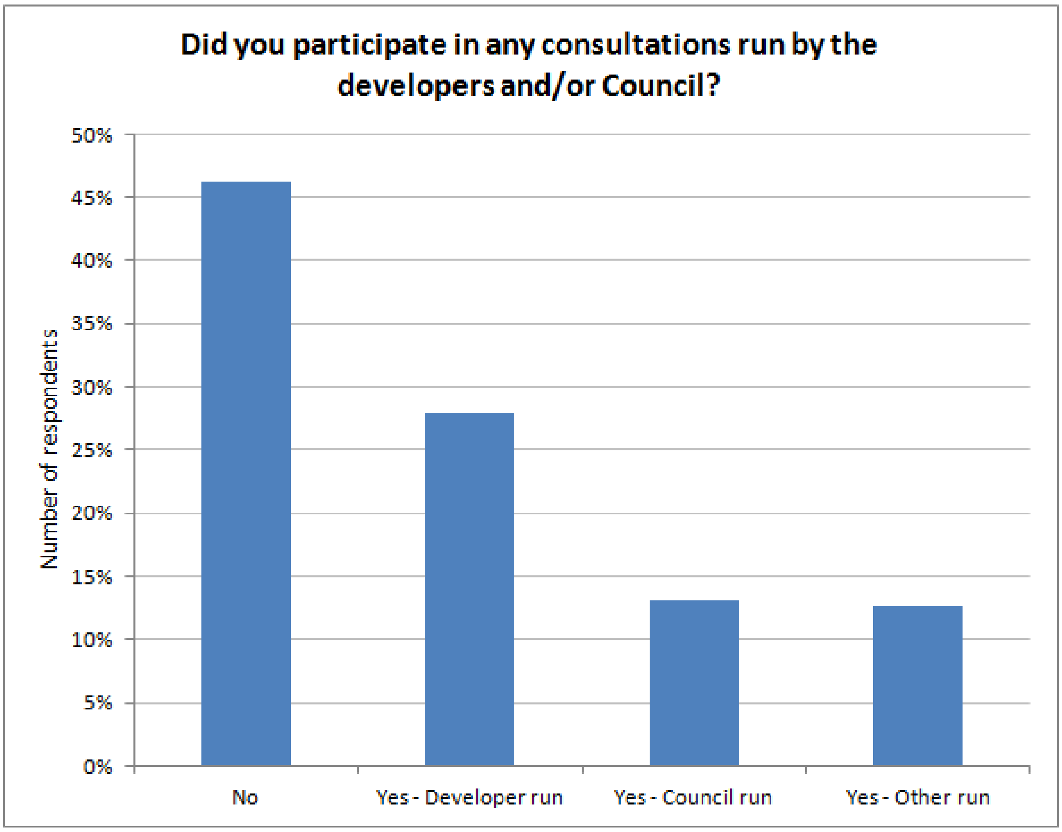


No response included

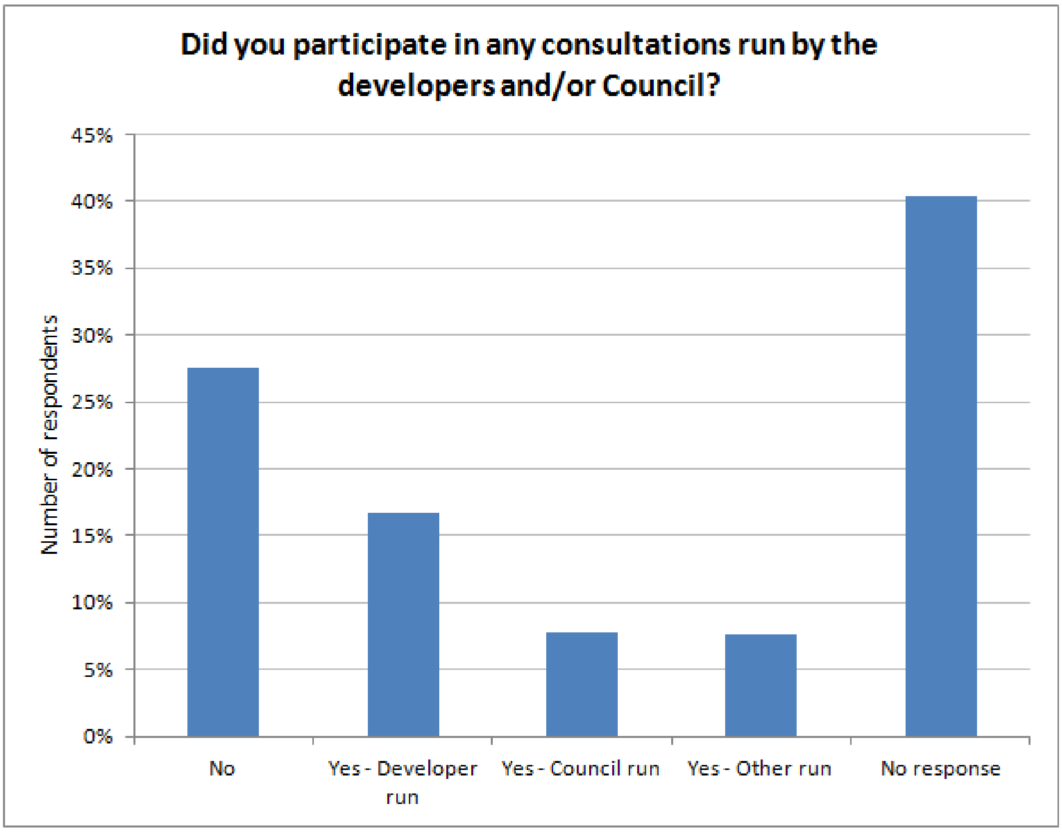


Question 8

No response excluded

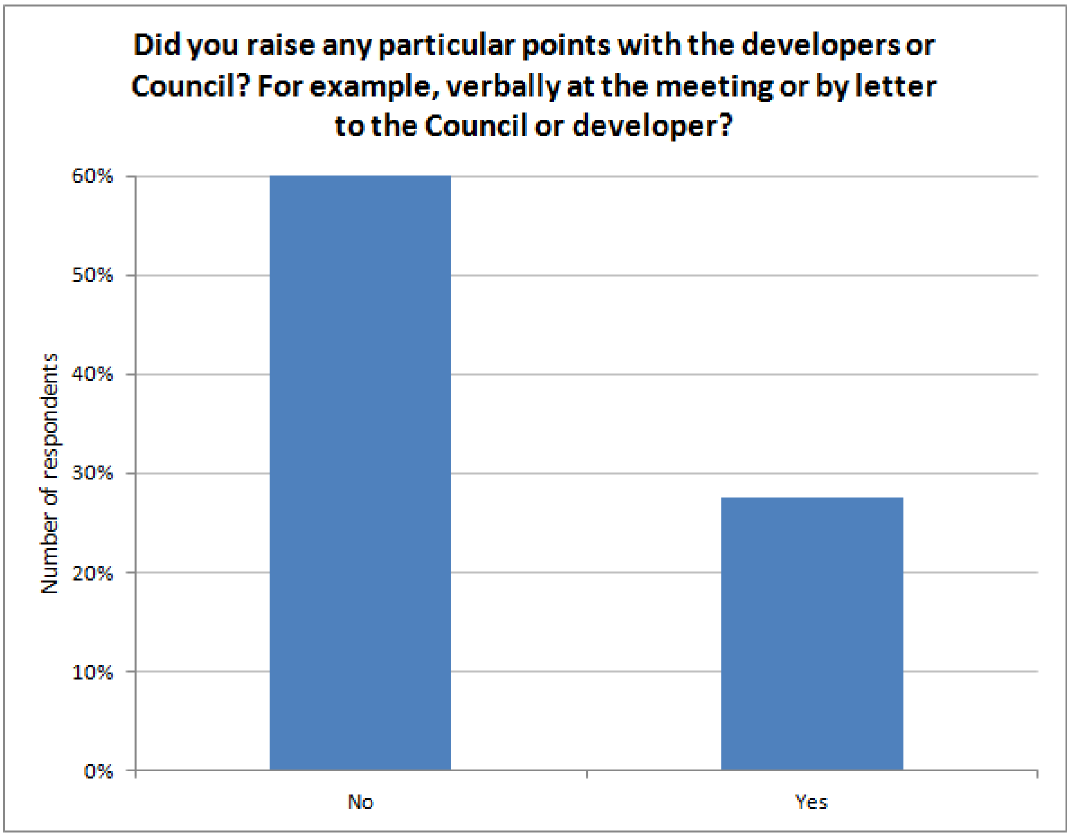


No response included

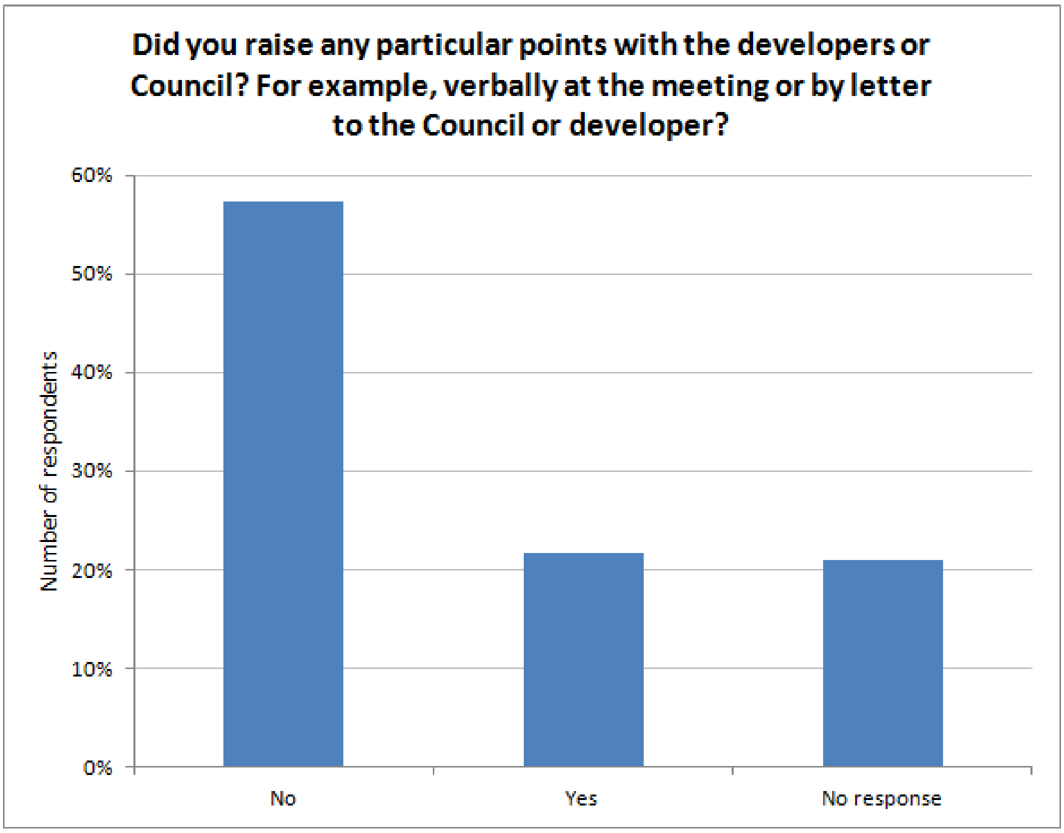


Question 9

No response excluded

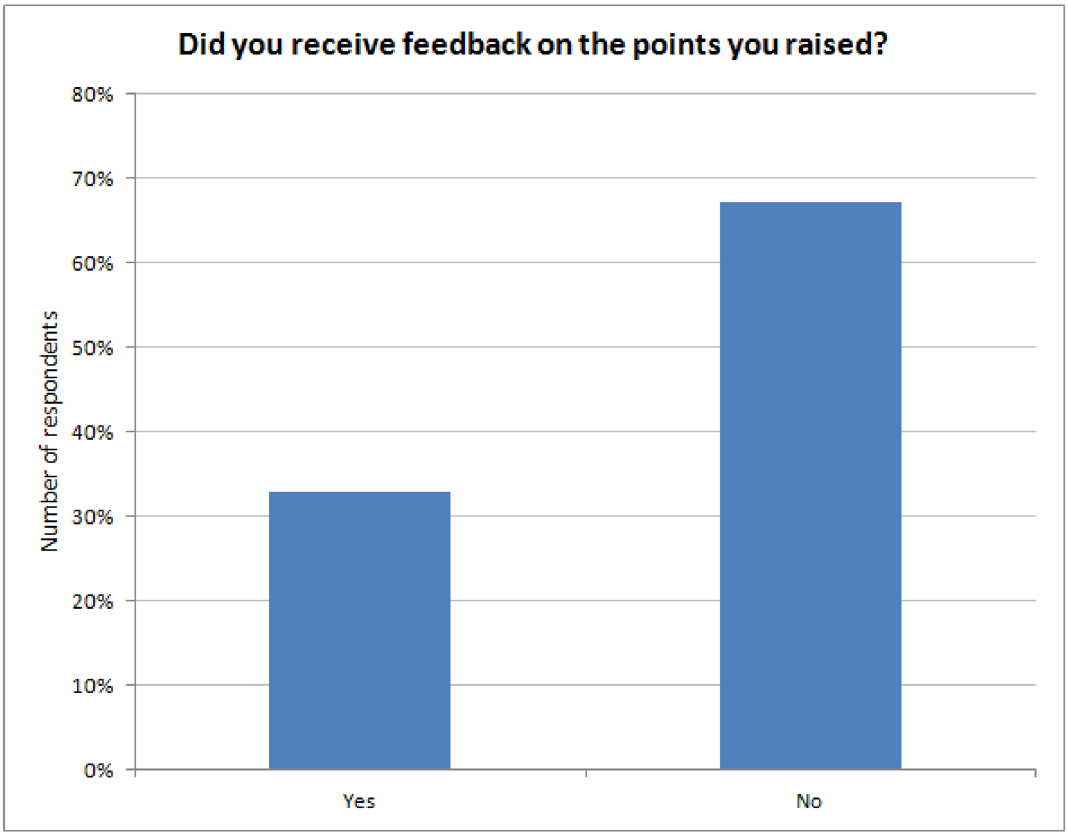


No response included

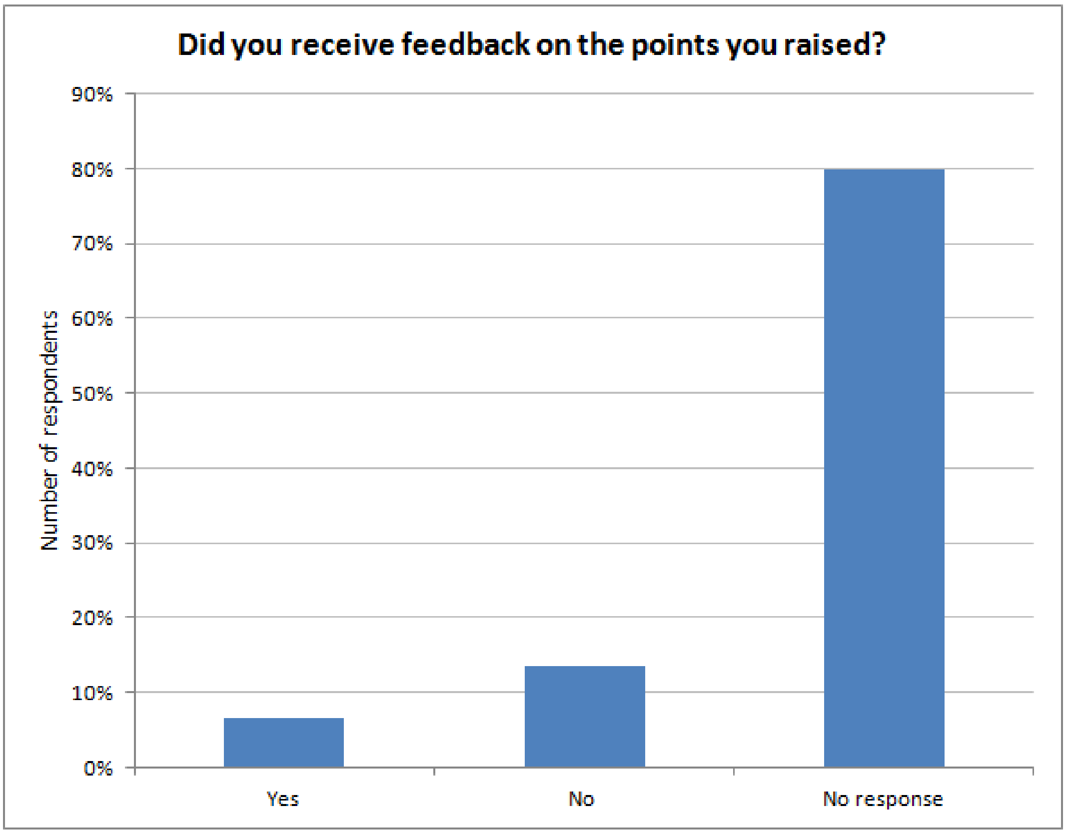


Question 10

No response excluded

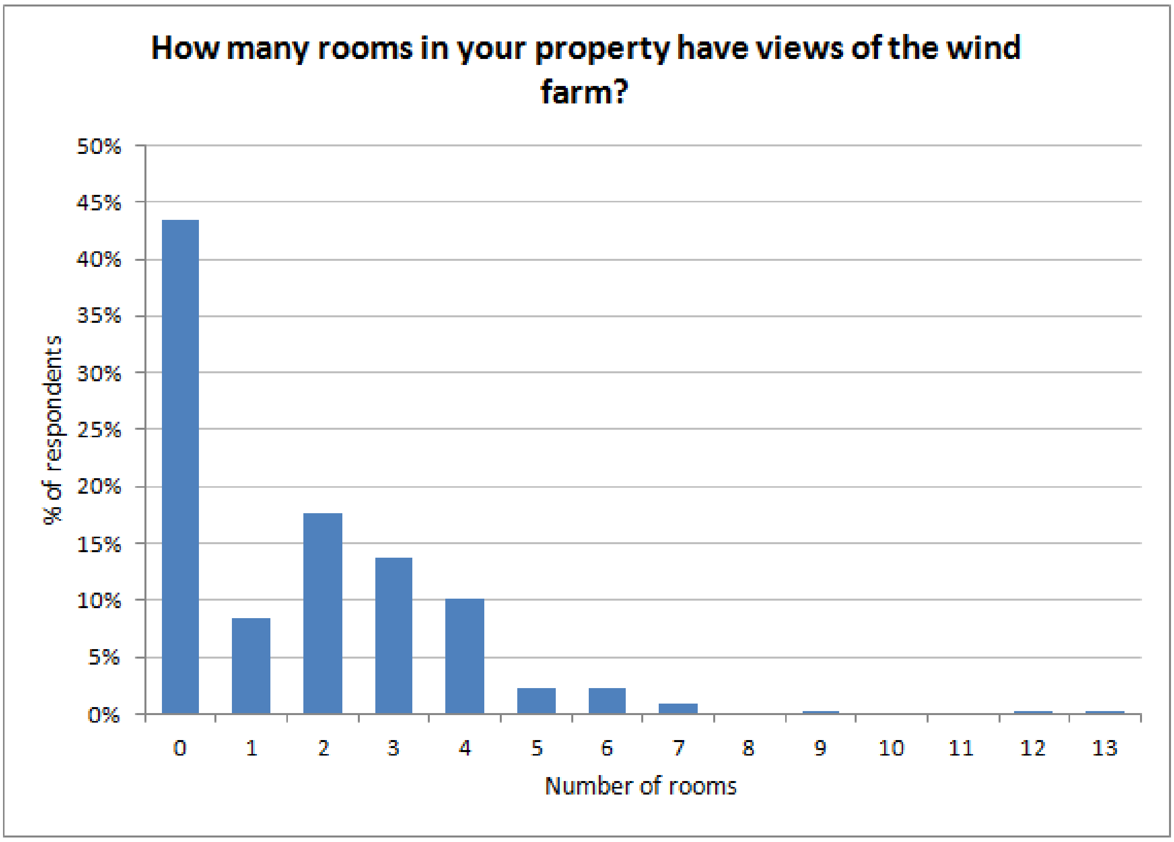


No response included

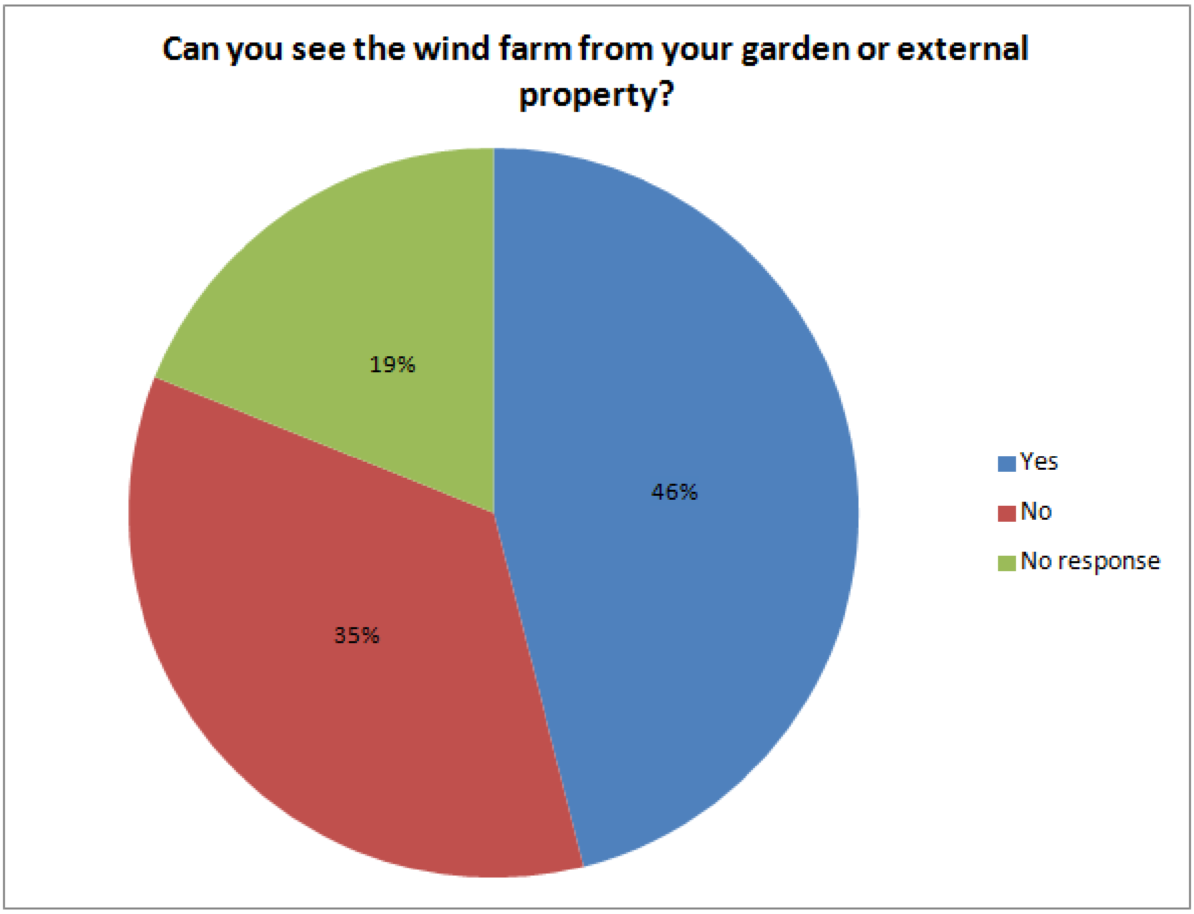


Visual

Question 11

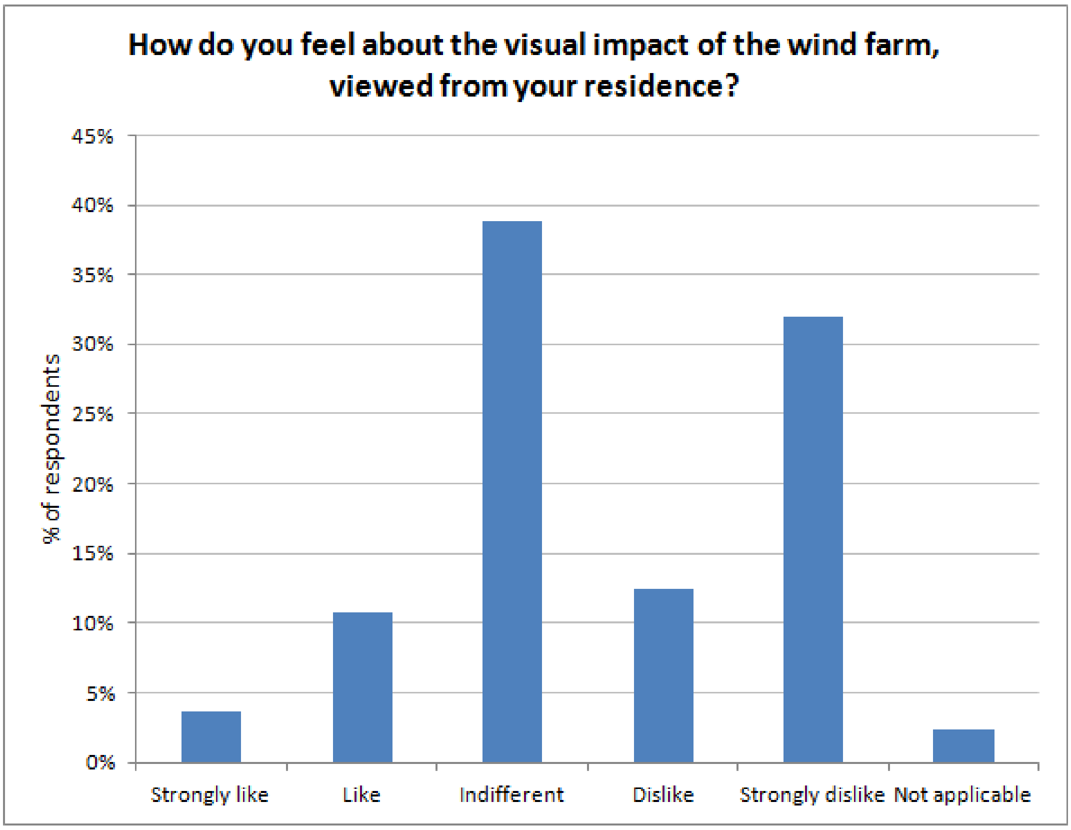


Question 12

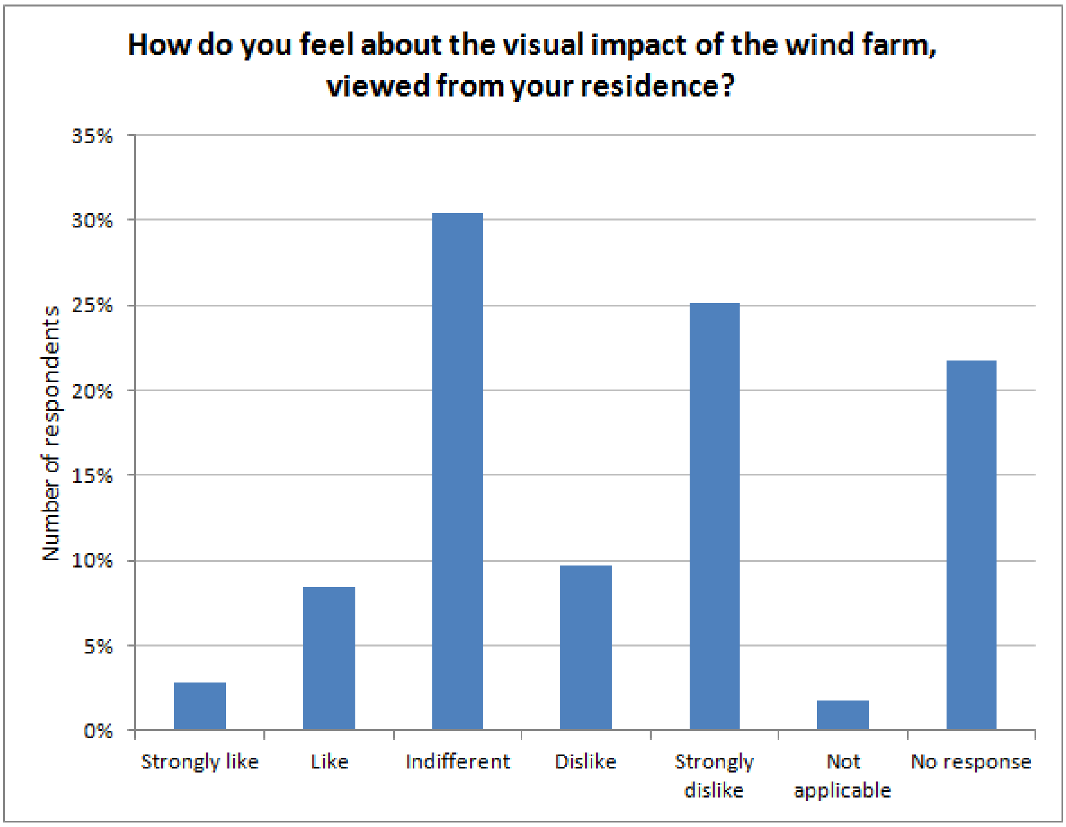

Can you see the wind farm from your garden or external property?
19%
46%
35%
Yes
No
No response

Question 13

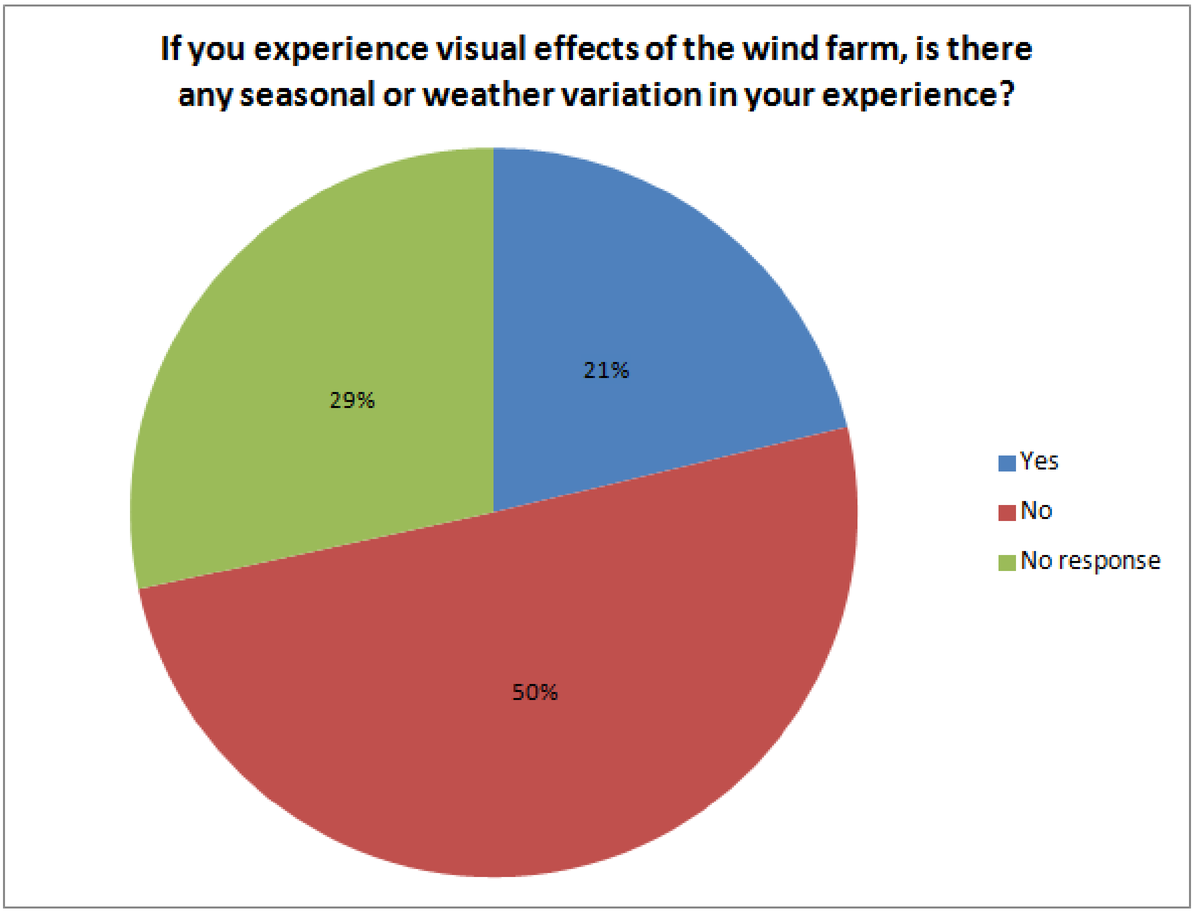
No response excluded



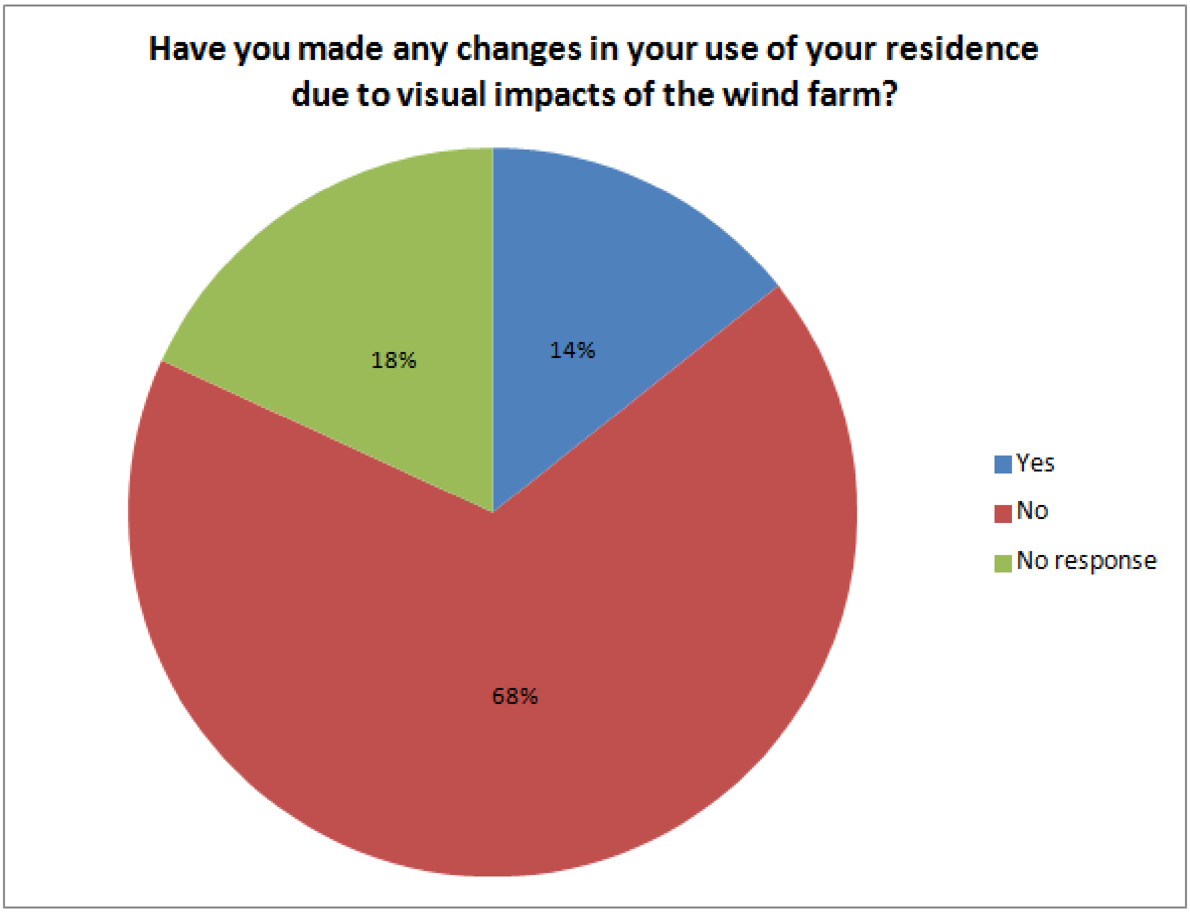
No response included



Question 14

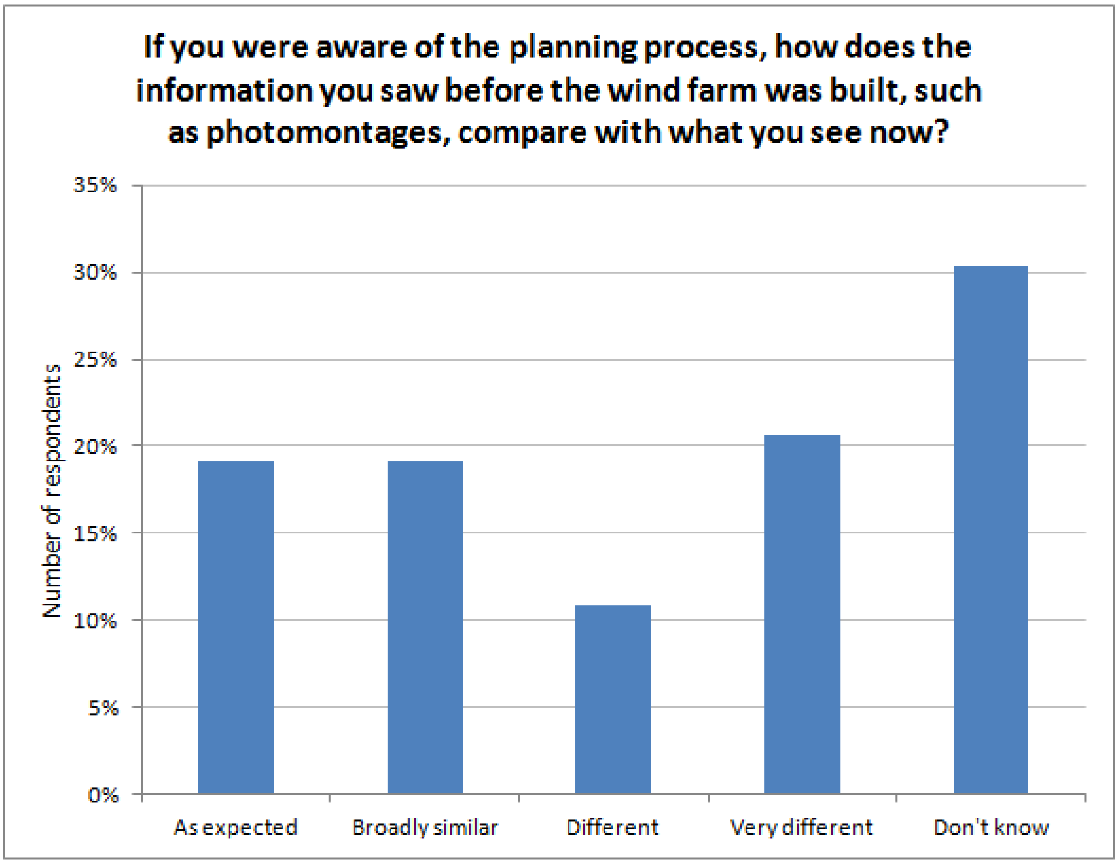

If you experience visual effects of the wind farm, is there any seasonal or weather variation in your experience?
21%
29%
50%
Yes
No
No response

Question 15

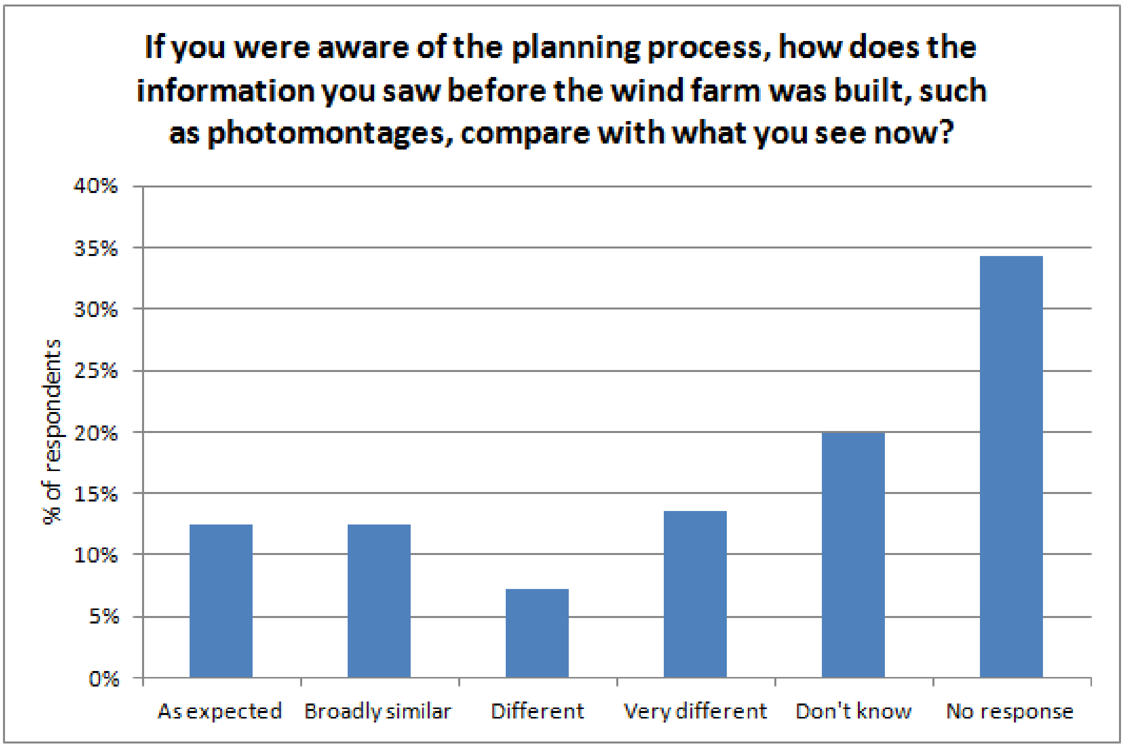

Have you made any changes in your use of your residence due to visual impacts of the wind farm?
14%
18%
68%
Yes
No
No response

Question 16

No response excluded

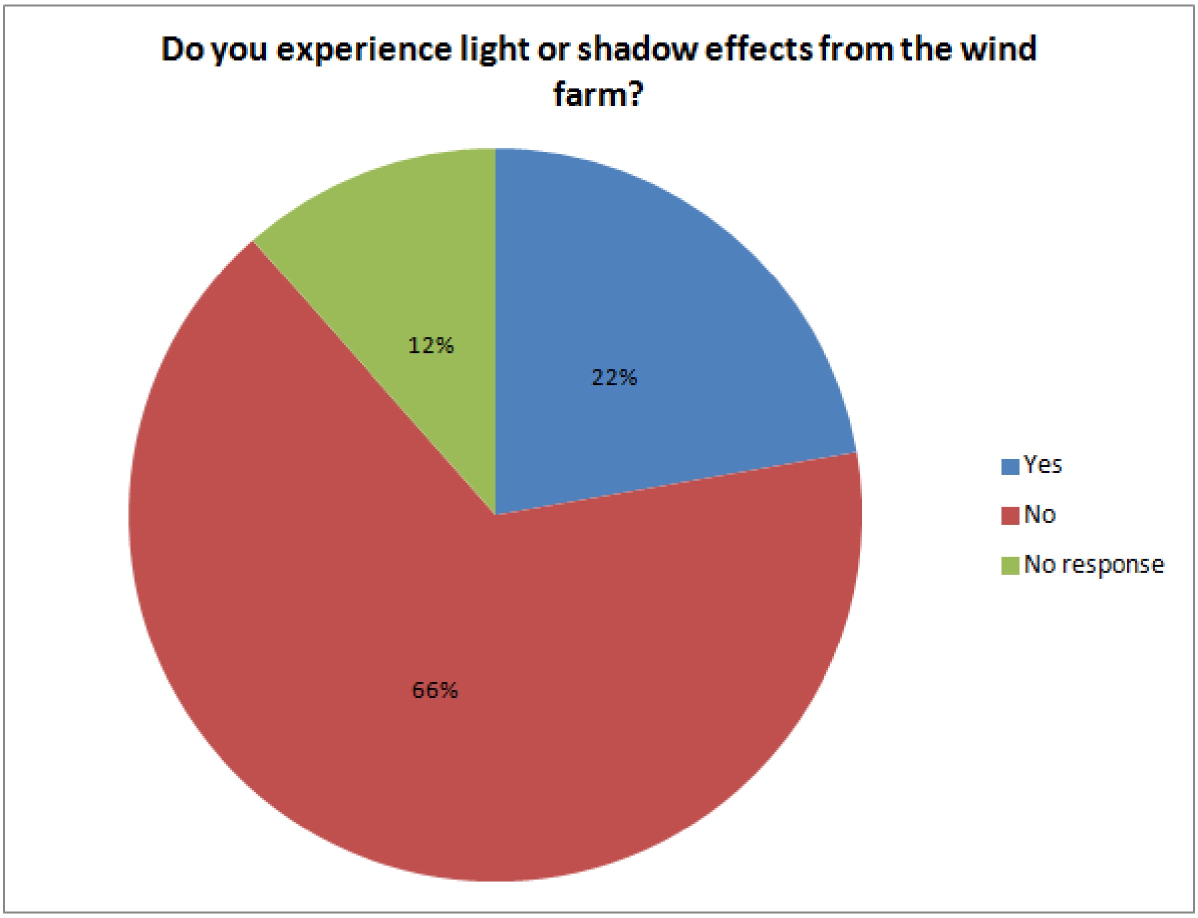


No response included



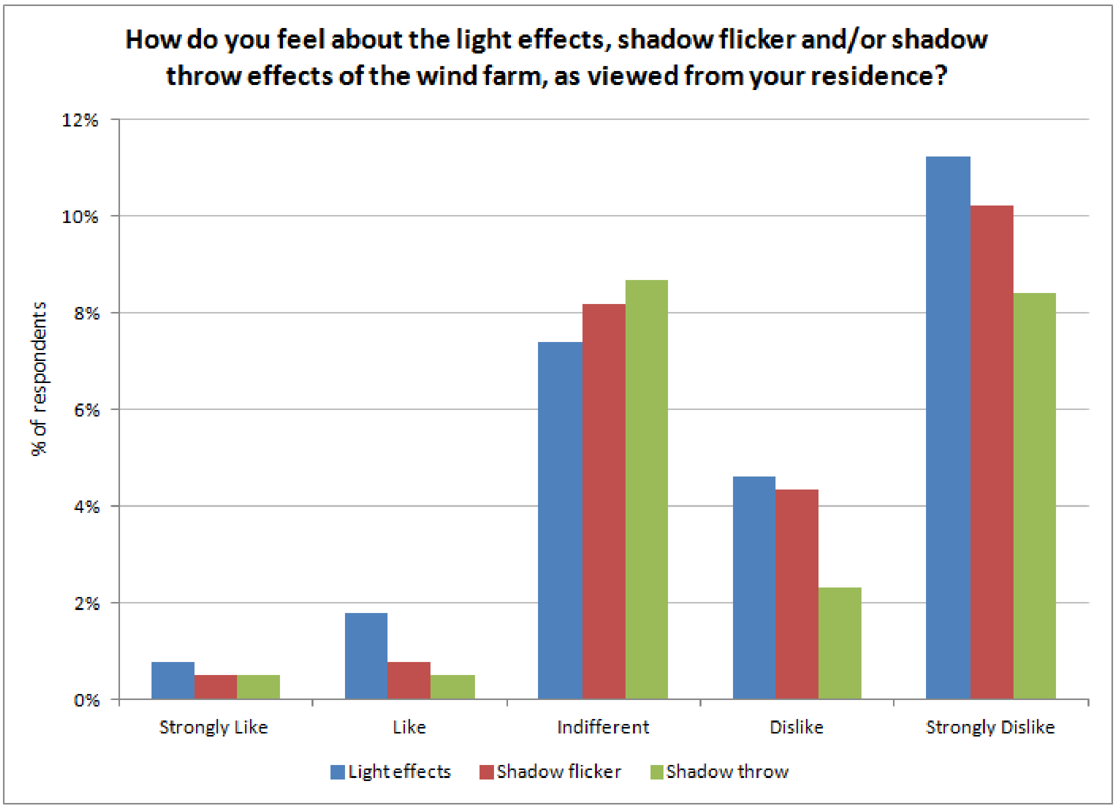
Light Effects

Question 17

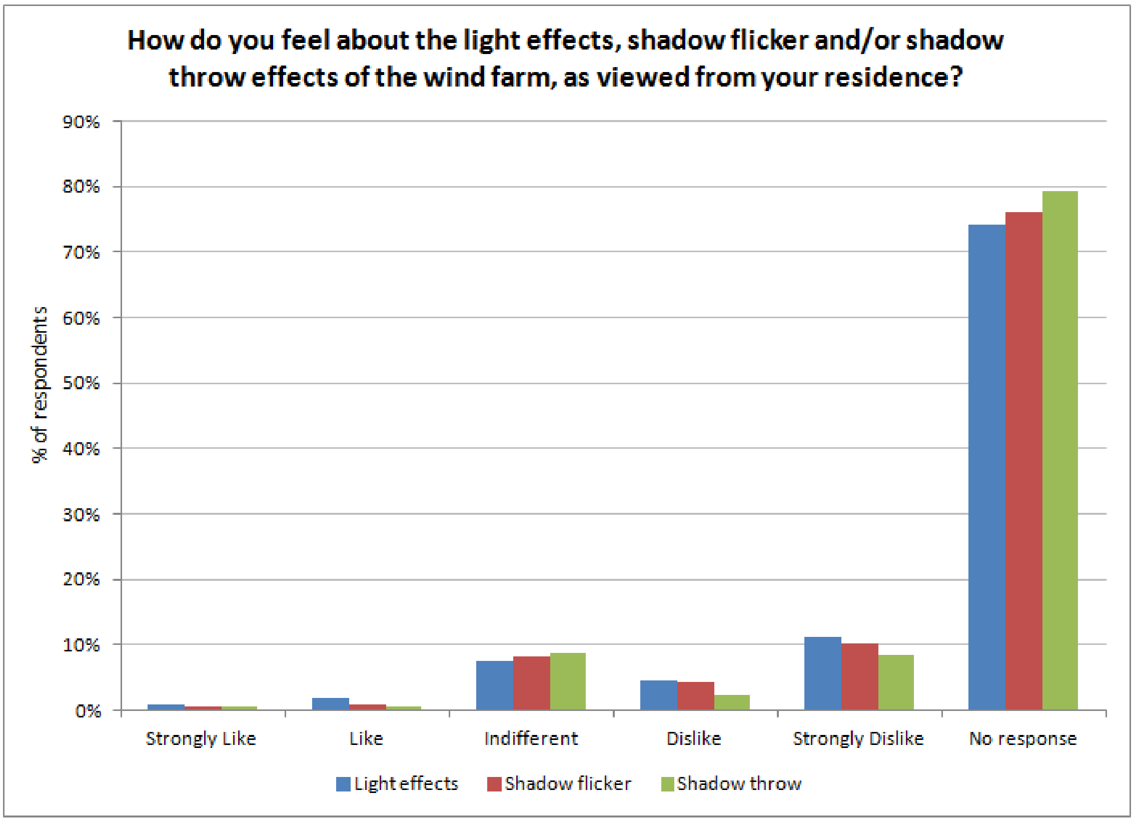


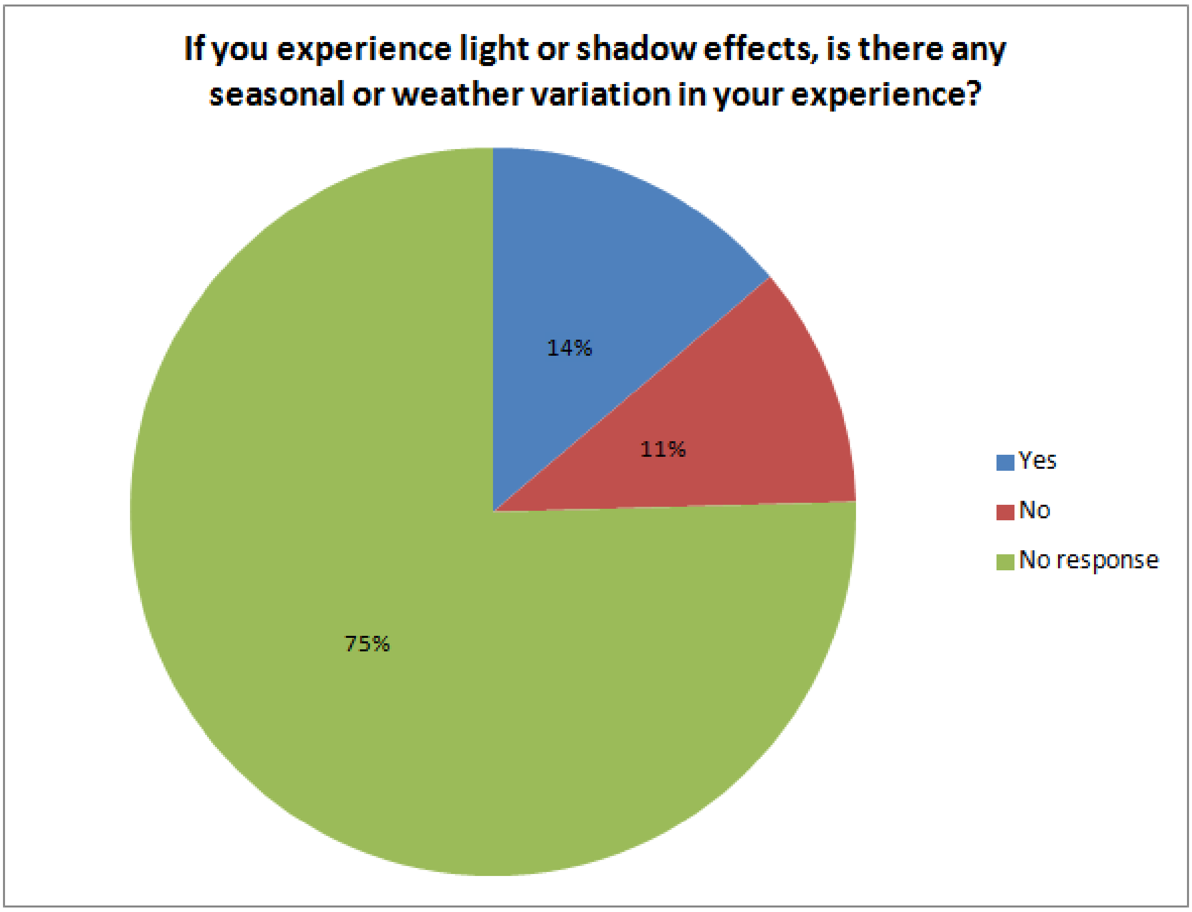
Question 18

No response excluded

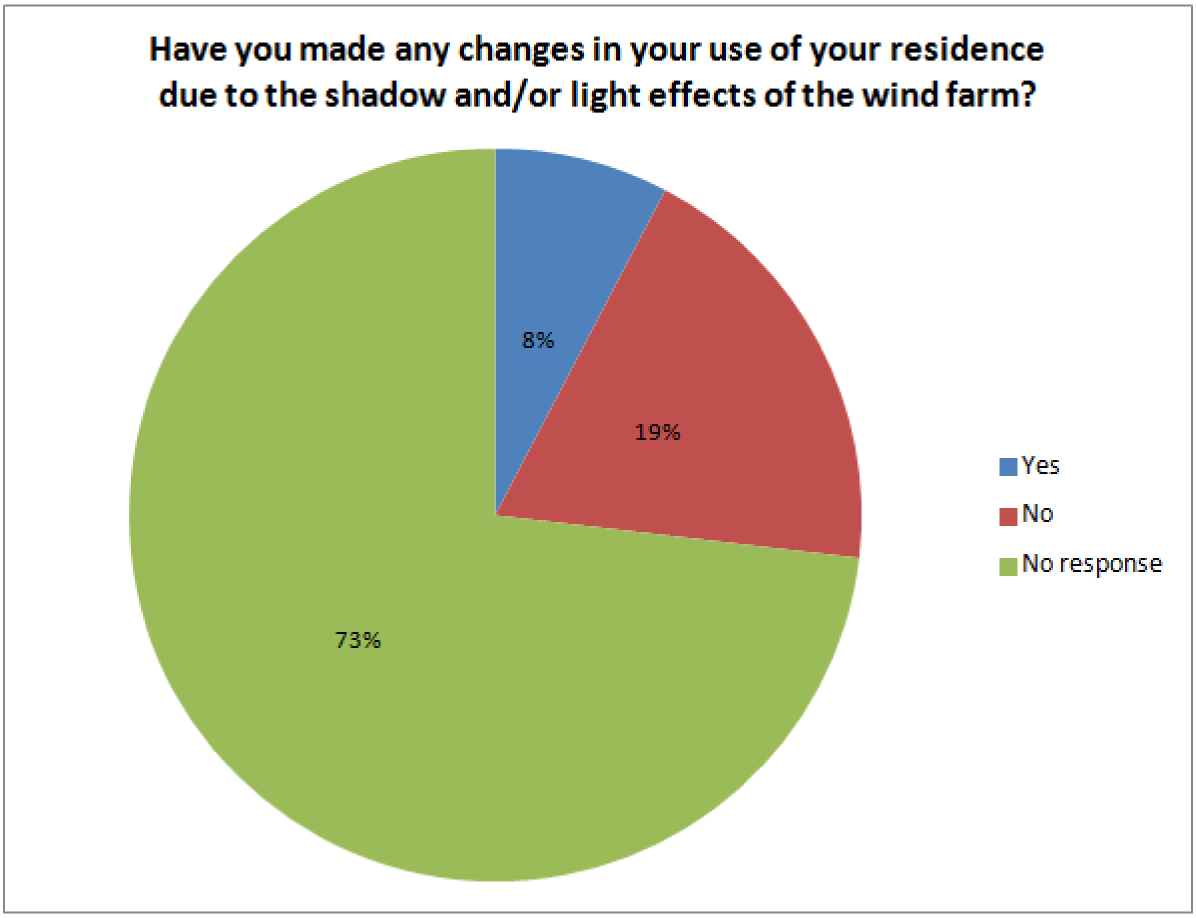


Question 19 No response included



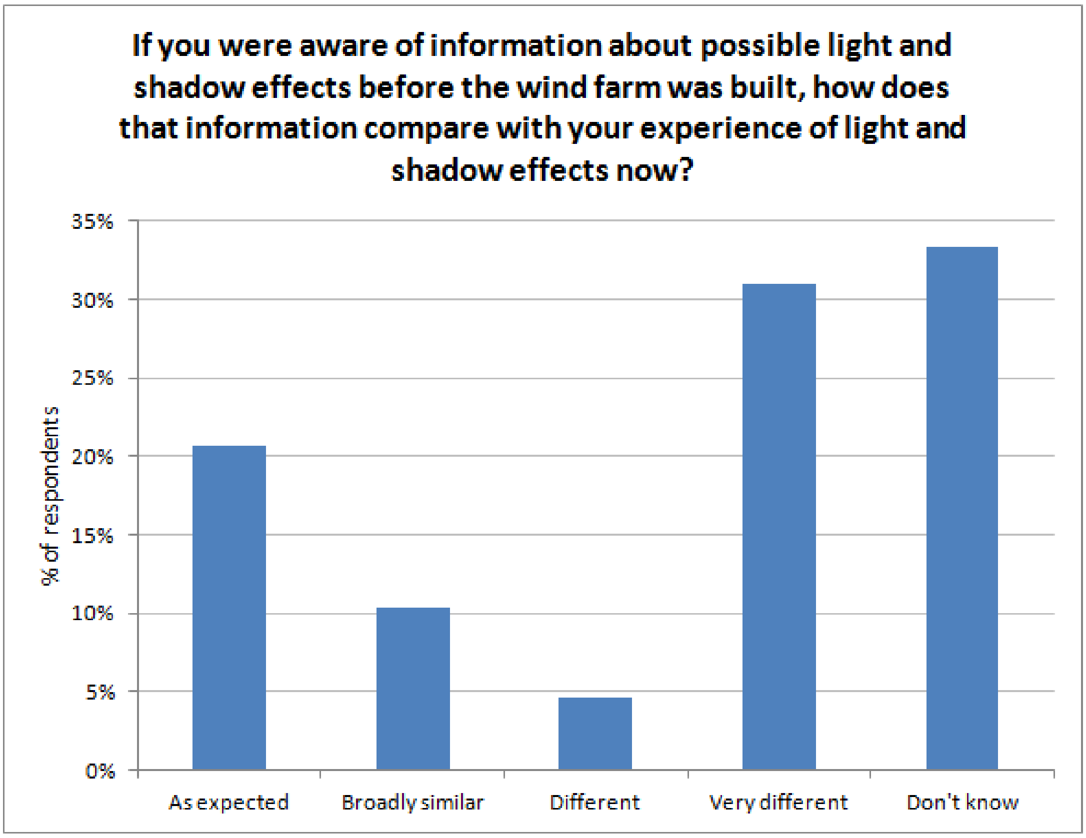

If you experience light or shadow effects, is there any seasonal or weather variation in your experience?
14%
11%
75%
Yes
No
No response

Question 20

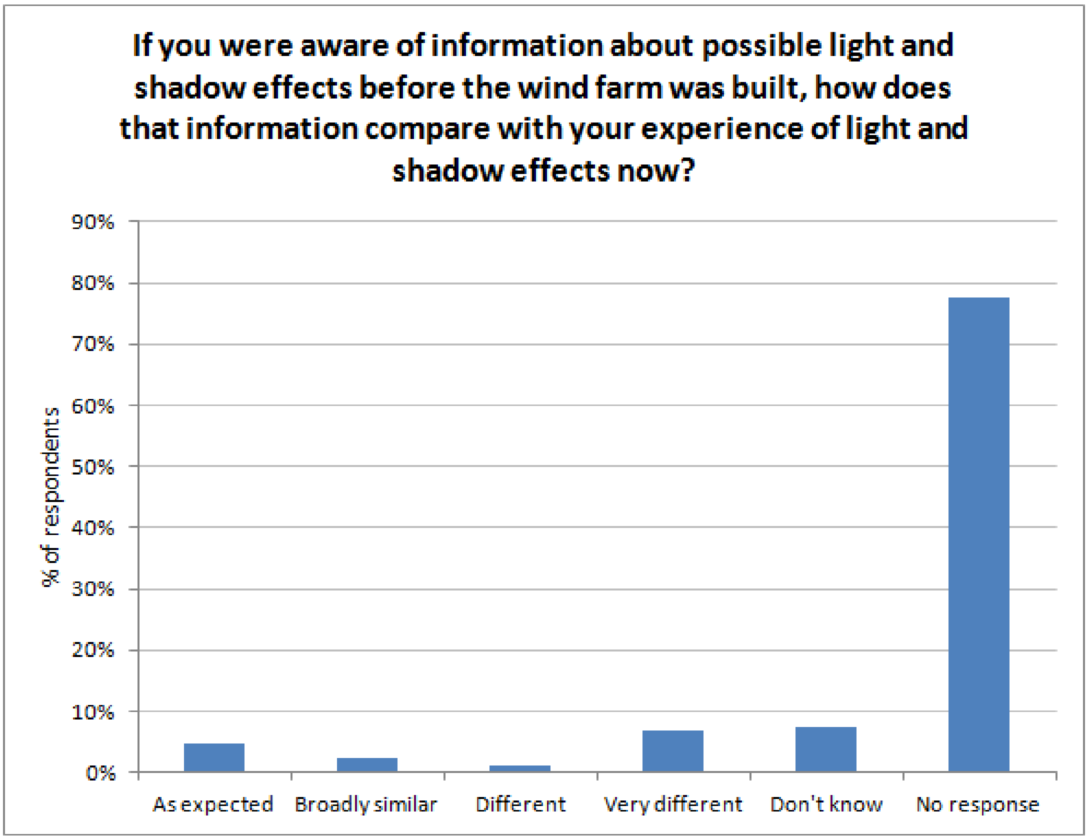

Have you made any changes in your use of your residence due to the shadow and/or light effects of the wind farm?
8%
19%
73%
Yes
No
No response

Question 21

No response excluded

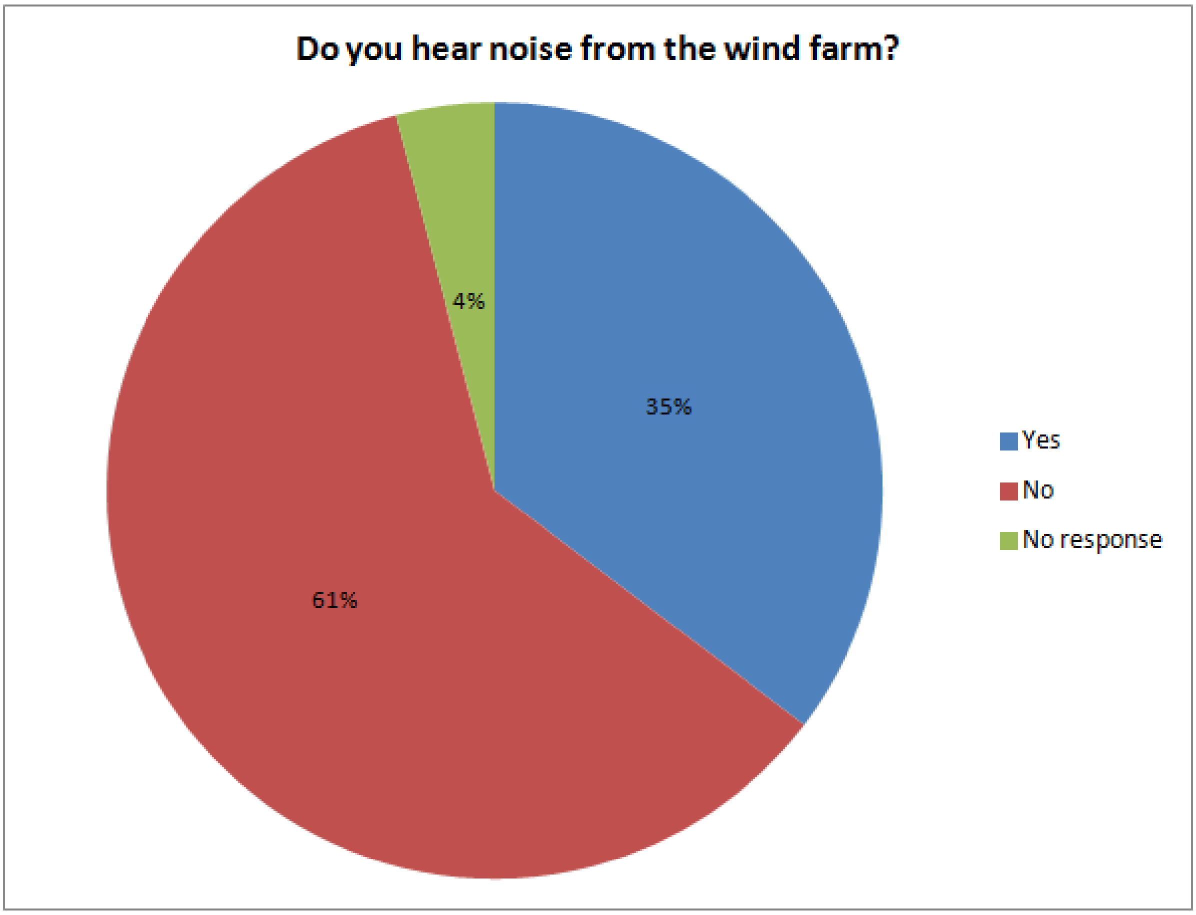


No response included

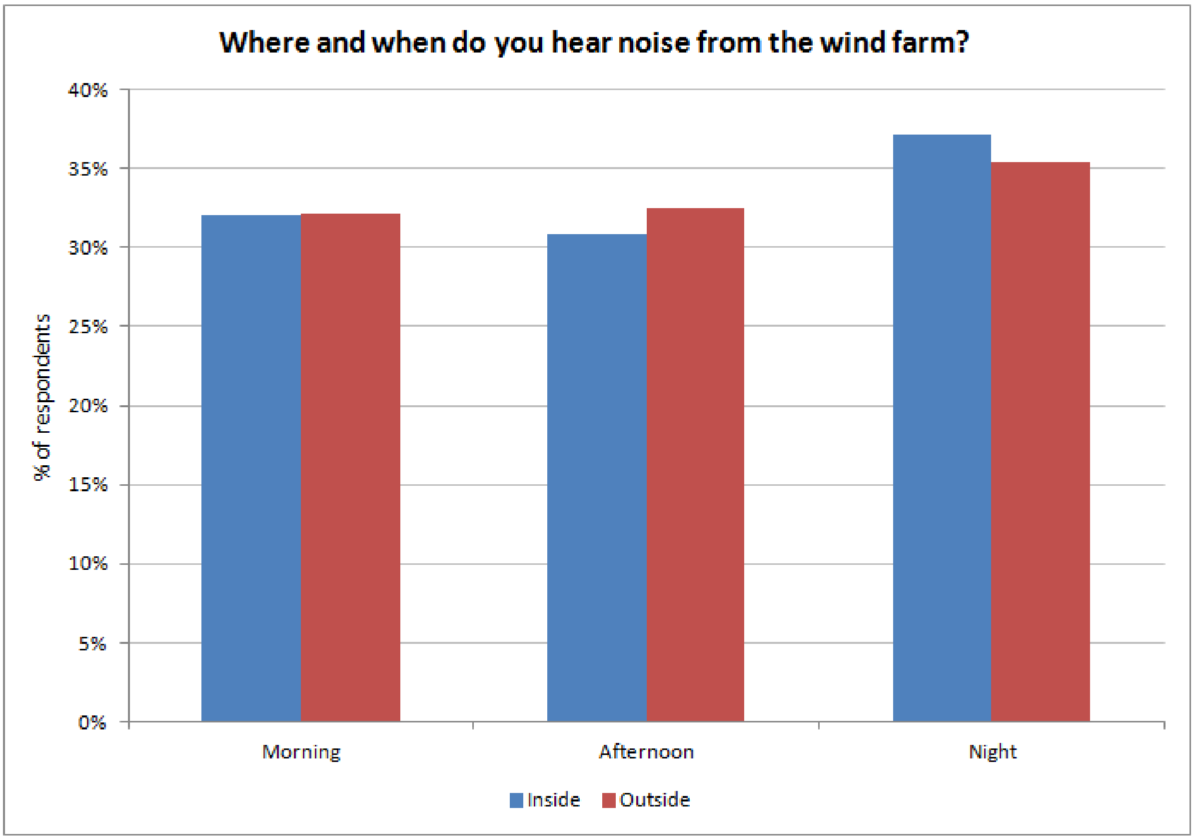


Noise perception

Question 22

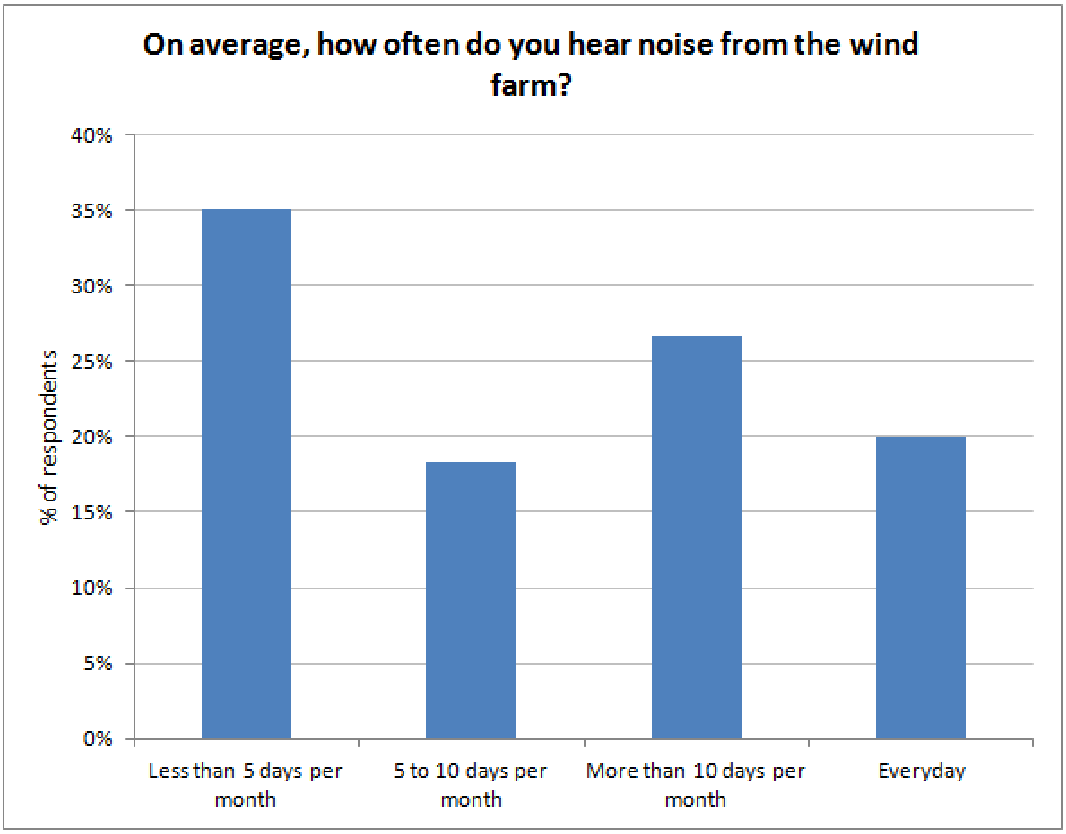


Question 22

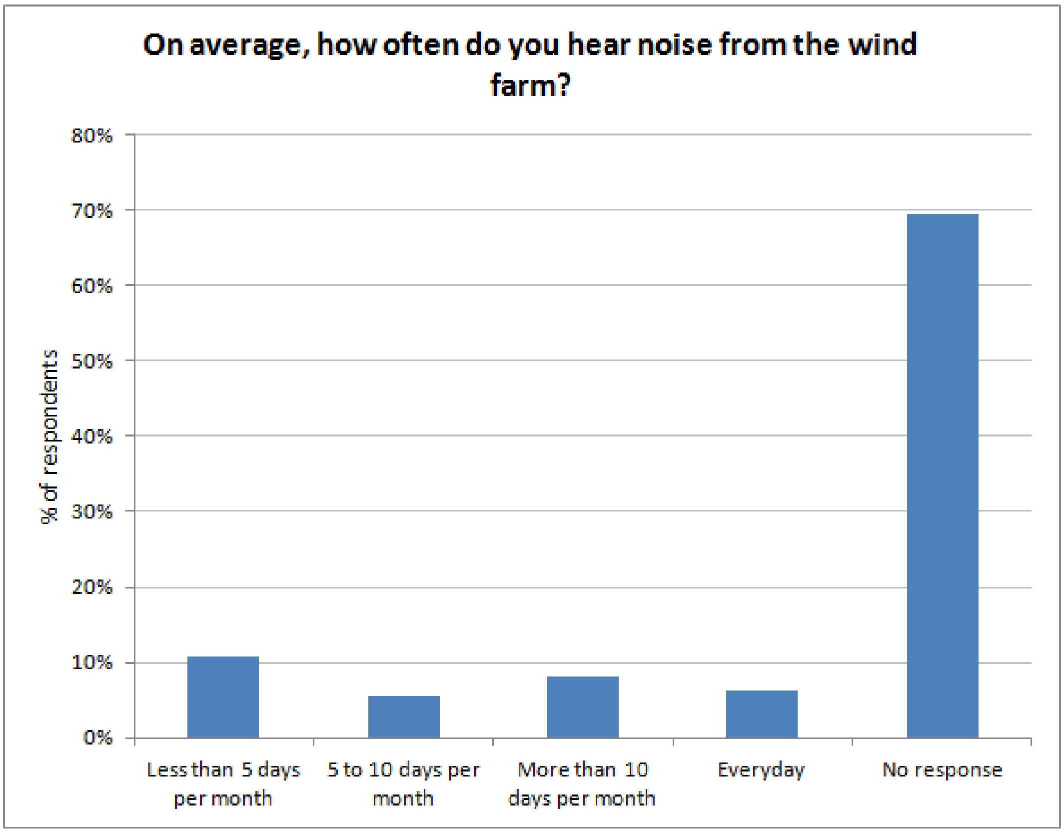

Where and when do you hear noise from the wind farm?
% of respondents
40%
35%
30%
25%
20%
15%
10%
5%
0%
Morning
Afternoon
Night
Inside
Outside

Question 23

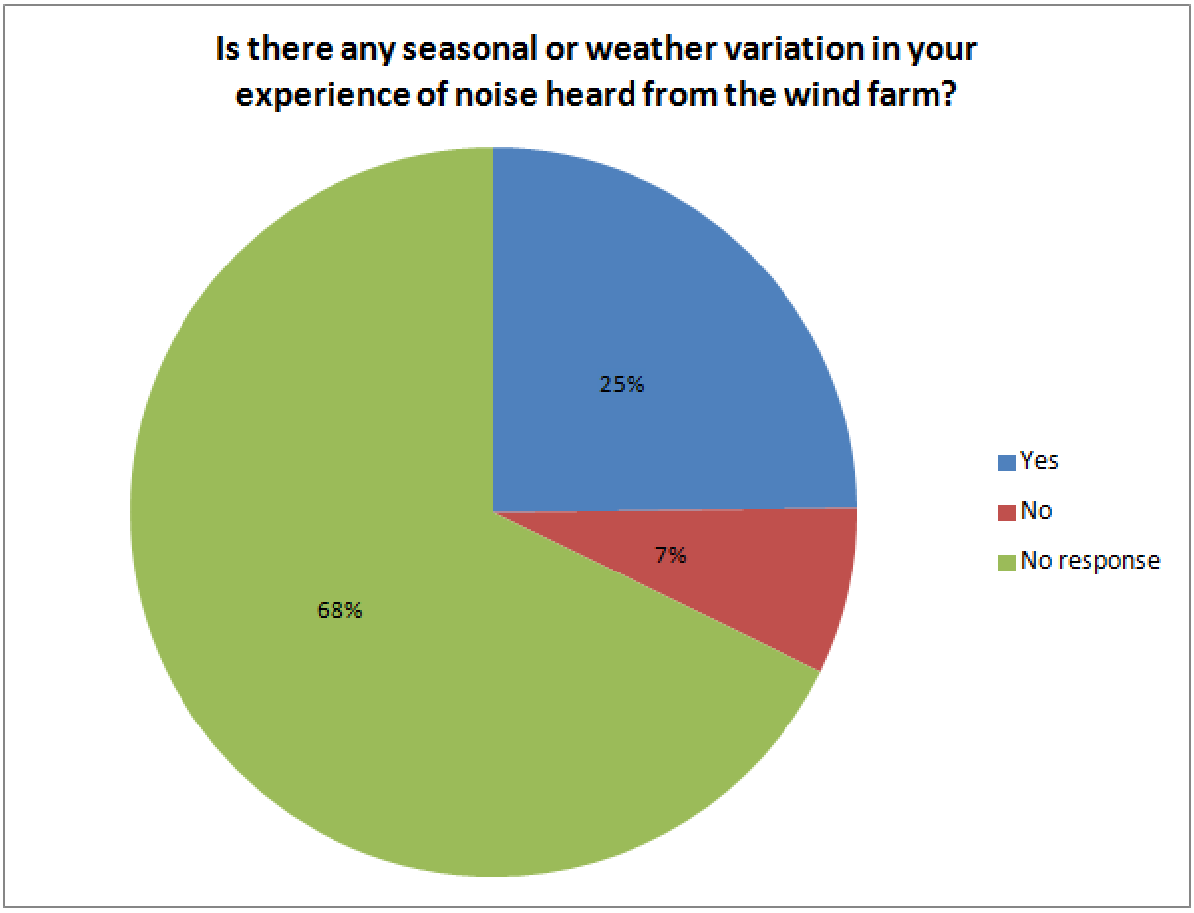
No response excluded



No response included

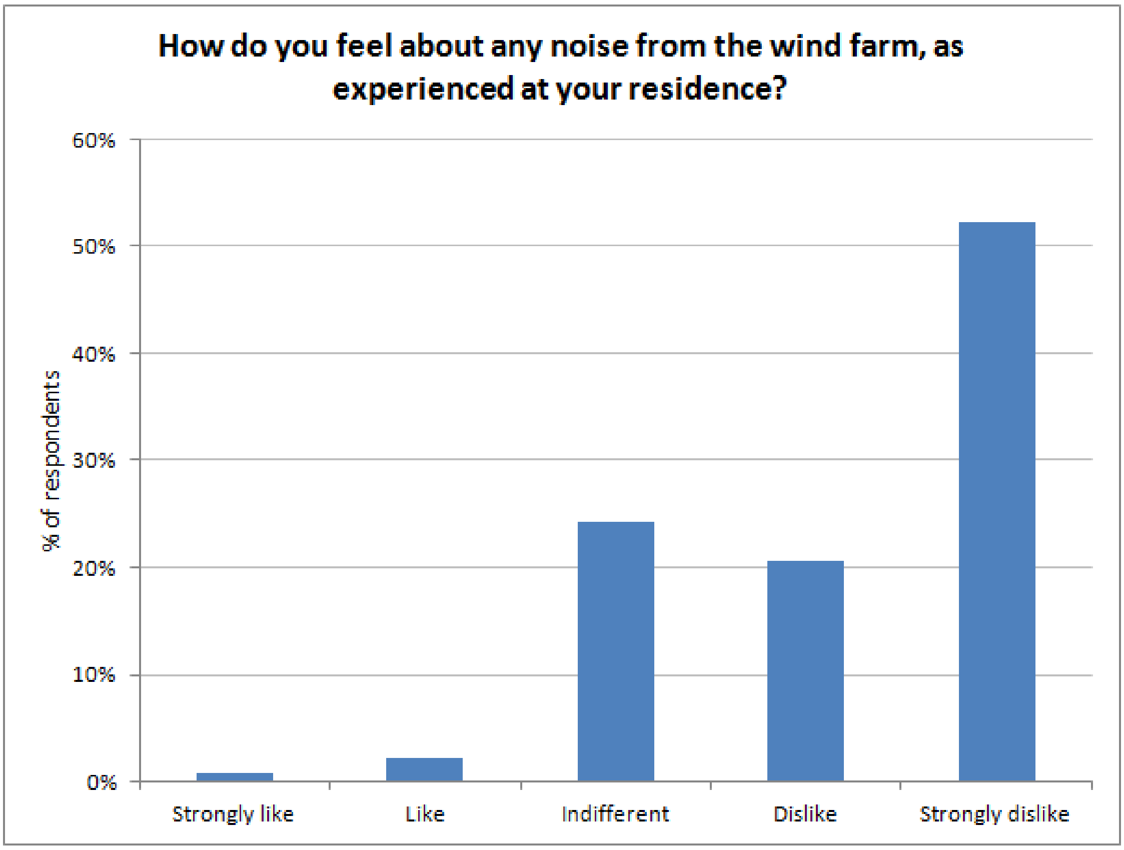


Question 25

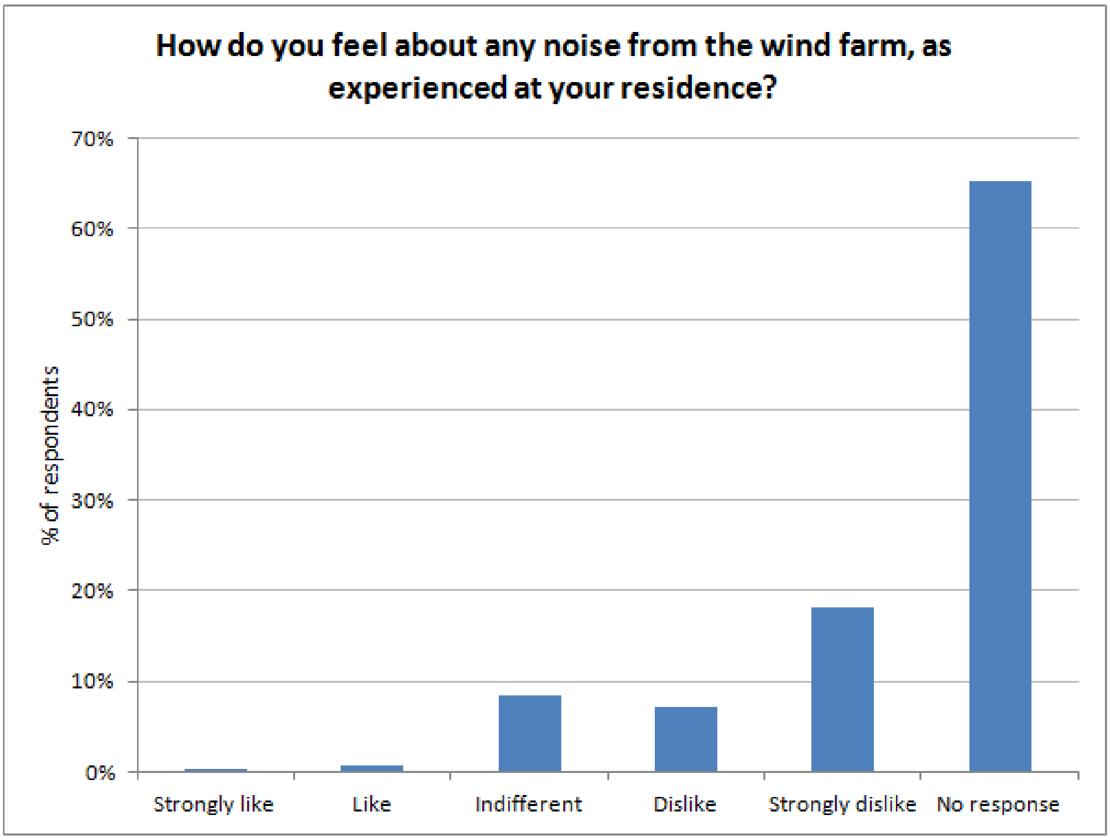

Is there any seasonal or weather variation in your experience of noise heard from the wind farm?
25%
7%
68%
Yes
No
No response

Question 26

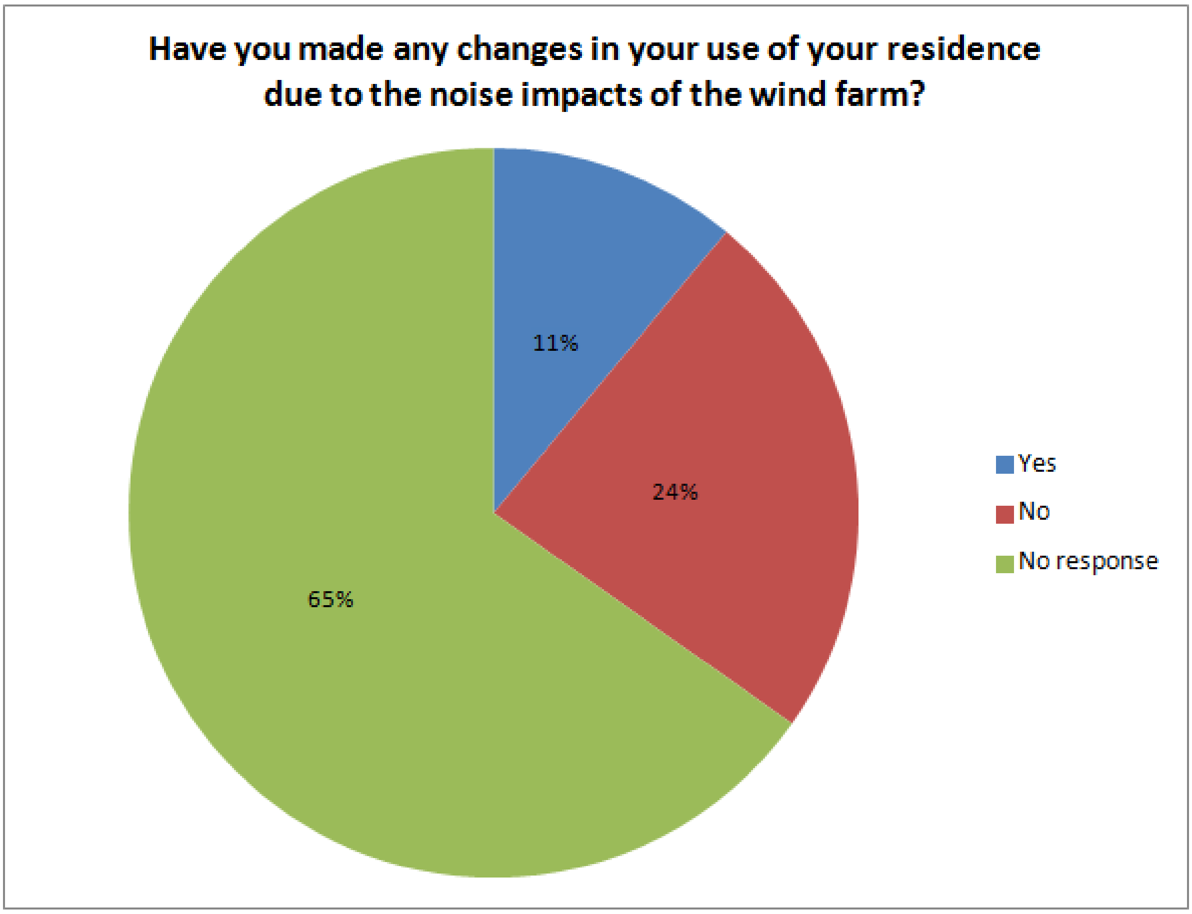
No response excluded



No response included

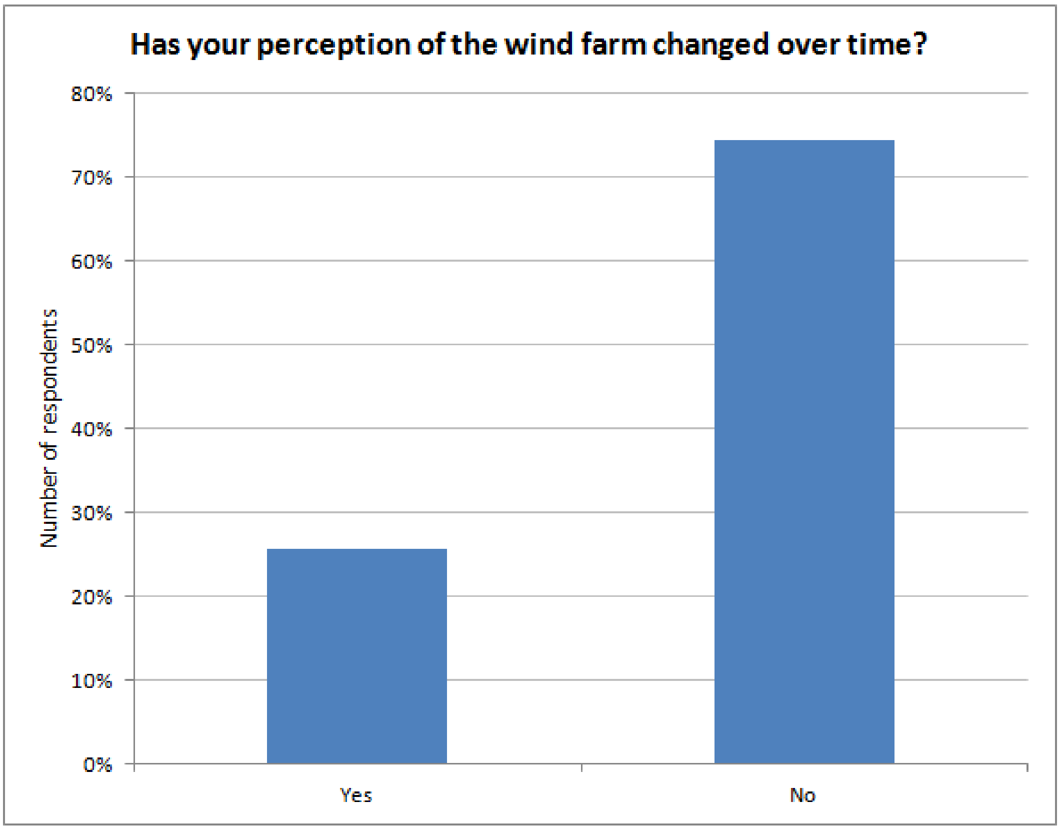


Question 27

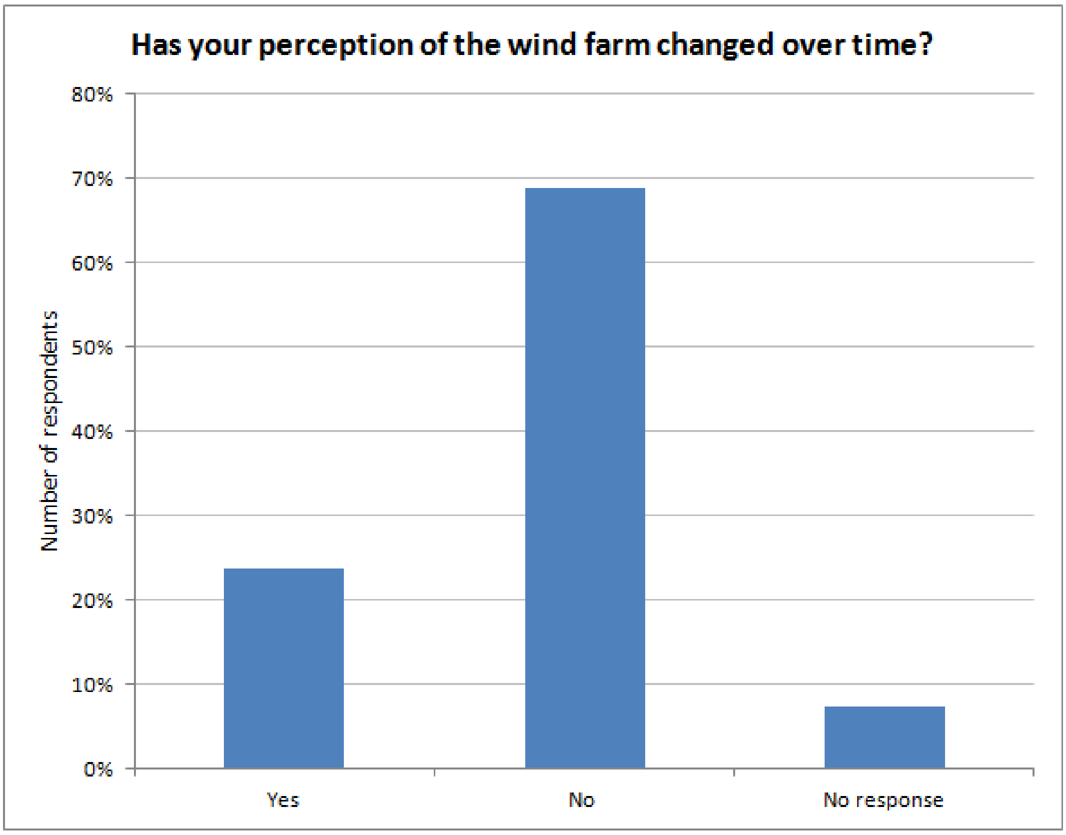

Have you made any changes in your use of your residence due to the noise impacts of the wind farm?
11%
24%
65%
Yes
No
No response

Perception
Question 28

No response excluded

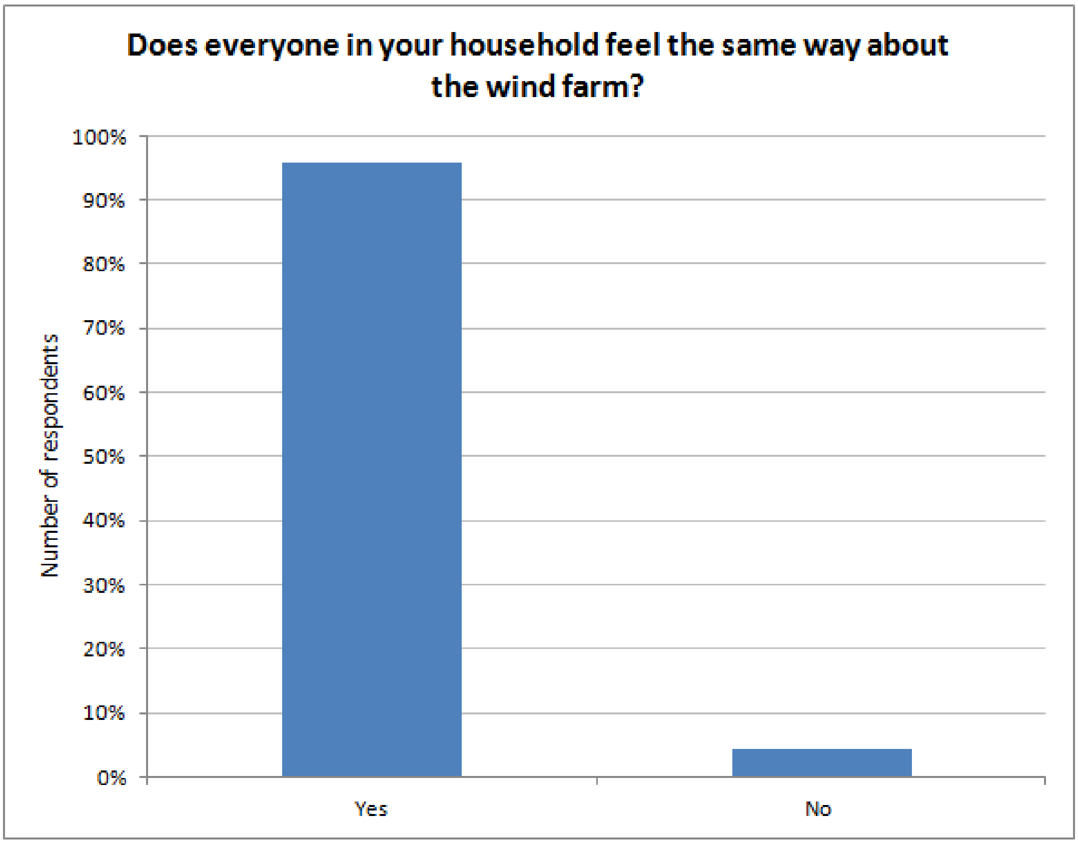


No response included

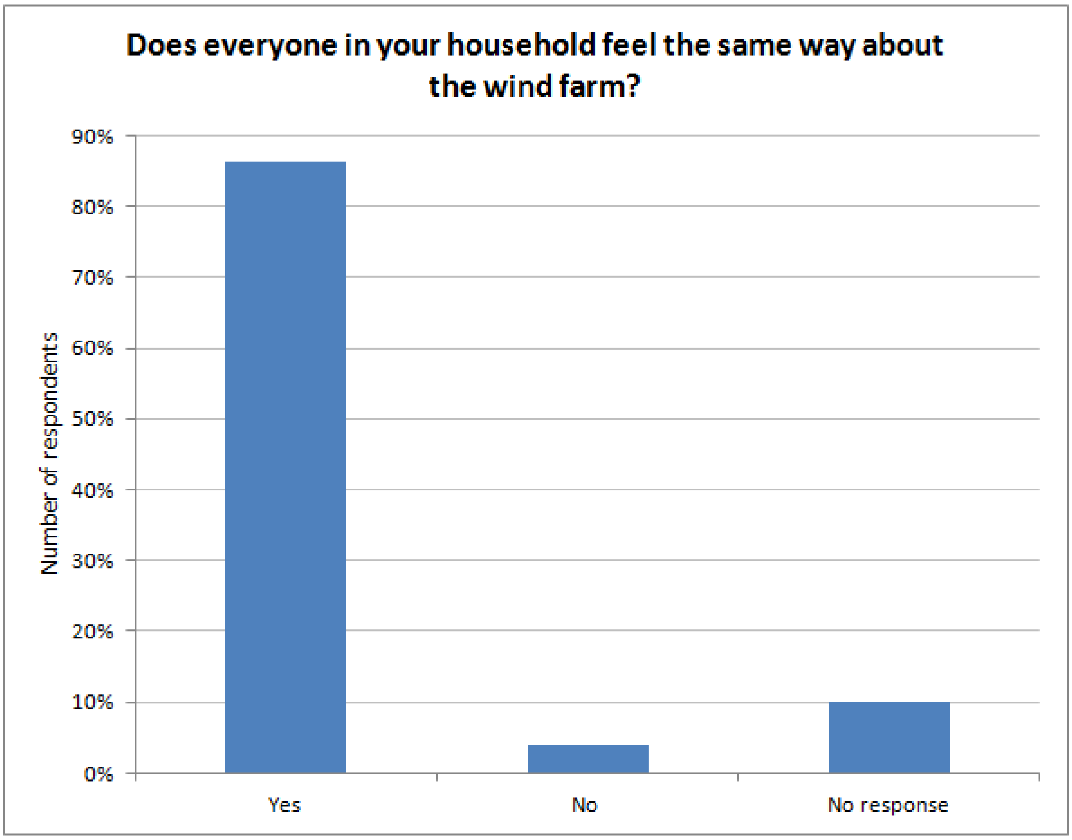


Question 29

No response excluded



No response included



Additional analysis

An additional graphical analysis of all results obtained was also derived by HLA as it was considered helpful in illustrating the relevance of both separation distance and calculated noise level to the responses.

Figures C1 to C4 show a graphical representations of the perceived audibility of the wind farm (rated as 0 (inaudible) or 1 (audible)). For each respondent for which the noise was audible, the opinion expressed regarding the noise was rated on a scale of 5, ranging from strongly dislike (-2), indifferent (0), to strongly like (+2). These audibility and attitude scores are shown plotted both as a function of the calculated as-built calculated noise levels at the respondent's property (see Appendix K) and as a function of the distance from the closest turbine.

Each dot on the figures corresponds to an individual response. In addition, the green curves show the numerical average of all the returned scores within given categories of distance or noise levels. The vertical bars associated with each point show the standard deviations around the average of the returned scores in each of the bands considered.

The plots shown as a function of distance from the closest located turbine show a lower correlation and a lack of systematic variation with both the reported audibility and attitude scores than do the plots as a function of calculated noise level. In other words, calculated noise level seems to be a better predictor of dislike of the noise than proximity alone.

Figure C1 Residents' Survey reported audibility of the wind farm as a function of the respondent's distance to the nearest turbine. The green curve represents the numerically averaged response (calculated from the two possible responses of inaudible at 0 or audible at 1) across the total number of respondents in each distance band.

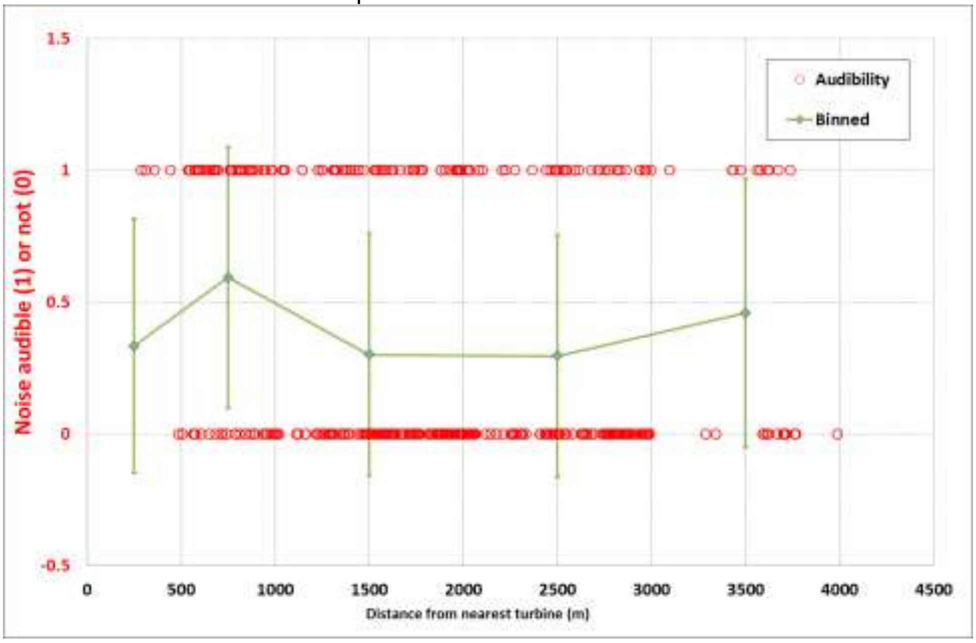


Figure C2 Residents' Survey reported opinion of the wind farm as a function of the respondent's distance to the nearest turbine. The green curve corresponds to the numerically averaged response (calculated from the five possible responses ranging from strongly dislike at -2 to strongly like at +2) across the total number of respondents in each distance band.

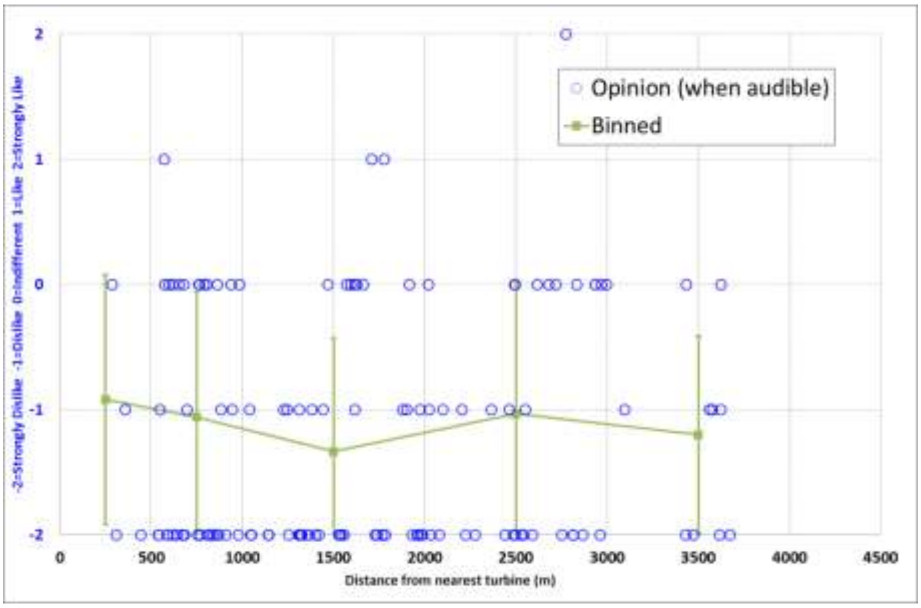


Figure C3 Residents' Survey reported audibility of the wind farm as a function of the calculated noise level. The green curve represents numerically averaged response (calculated from the two possible responses of inaudible at 0 or audible at 1) across the total number of respondents in noise level band, where the calculated noise level corresponds to that at an 8 m/s wind speed.

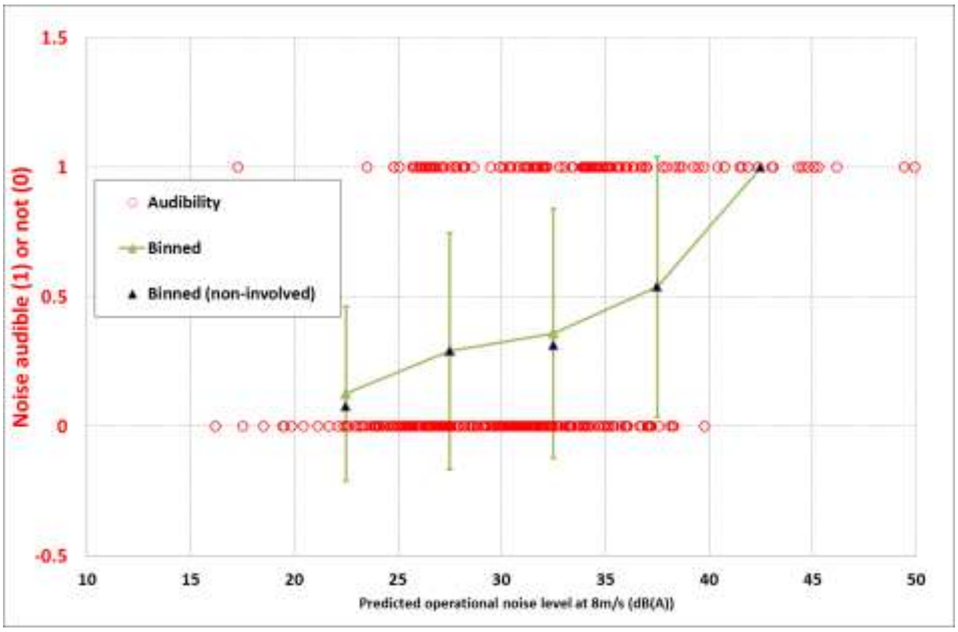
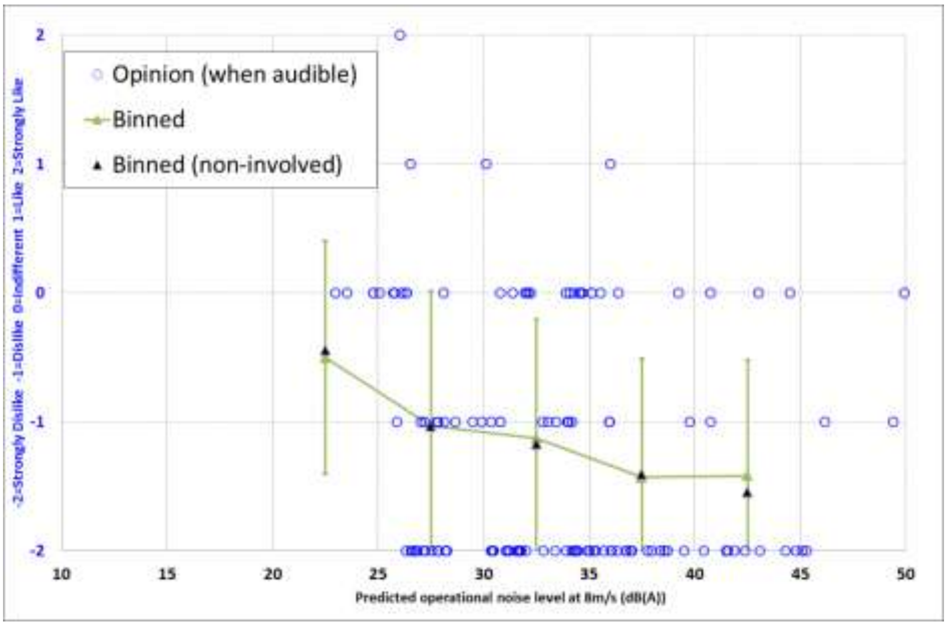


Figure C4 Residents' Survey reported opinion of the wind farm as a function of the calculated noise level. The green curve represents the numerically averaged response (calculated from the five possible responses ranging from strongly dislike at -2 to strongly like at +2) across the total number of respondents in each noise level band, where the calculated noise level corresponds to that at an 8 m/s wind speed.



APPENDIX D: - LANDSCAPE AND VISUAL IMPACT ASSESSMENT: SUMMARY METHODOLOGY

Key Steps

The key steps to carrying out a Landscape and Visual Impact Assessment (LVIA) as set out in GLVIA 3 are to establish the baseline landscape and visual context and identify the value of the existing landscape and visual resources which are likely to be affected by the proposed development. Value is identified initially by establishing if the landscape being considered is covered by any designation (national, regional or local) and then also by taking account of factors such as landscape quality or condition, scenic quality, rarity, representativeness, conservation interests, recreation value, perceptual aspects and cultural associations.

The overall sensitivity of the landscape and visual resources is assessed by considering the value identified at the baseline stage and the susceptibility of the resource to the type of change envisaged from the proposed development. Susceptibility of the landscape to change refers to the ability of the landscape receptor to accommodate the proposed development without undue consequences for the maintenance of the baseline situation. Susceptibility of visual receptors is mainly a function of the occupation or activity of people experiencing the view at particular locations and the extent to which their attention or interest may therefore be focused on the views and the visual amenity the experience at particular locations.

GLVIA 2 which was extant when all of the case study assessments were undertaken, stated (para 7.32) "*The most sensitive receptors may include occupiers (sic) of residential properties with views affected by the development*". The number of people likely to be affected is referred to in relation to the scale or magnitude of visual effect rather than the sensitivity of the receptors.

The magnitude of effect which would arise from the proposed development is then assessed in terms of its size or scale, the geographic extent of the area influenced as well as the duration and reversibility of the development.

GLVIA 2 (para 7.36) stated that the magnitude or scale of visual changes should be described by reference to, amongst other criteria: "*the scale of change in the view with respect to the loss or addition of features in the view and changes in its composition including the proportion of the view occupied by the proposed development*". GLVIA 3 repeats this same wording at para 6.39 and also refers to "*the nature of the view of the proposed development, in terms of the relative amount of time over which it will be experienced and whether views will be full, partial or glimpses*". This makes clear that factors which relate to the scale of the change in a view and/or restrict the extent to which that change would be visible should be considered in relation to magnitude of change and not receptor sensitivity.

GLVIA 3 recommends that the sensitivity of any visual receptor to change in their view derives from a combination of the value placed on the view by the receptor, and the susceptibility of the receptors to changes in their views and visual amenity. GLVIA 3 states that "*susceptibility of different visual receptors to change in views and visual amenity is mainly a function of: the occupation or activity of people experiencing the view and the extent to which their attention or interest may therefore be focused on the views and visual amenity they experience at particular locations*", (para 6.32 GLVIA 3).

The overall effect on landscape character, designations and visual amenity is then assessed by evaluating the overall sensitivity of each of these resources and the magnitude of change predicted to occur as a result of the proposed development.

Illustrative Material

GLVIA 3 does not prescribe what material is required to illustrate a LVIA but does set out the range of material that is usually considered useful to illustrate the written report. The guidance also makes clear that the amount and type of illustrative material should be proportionate and agreed with the competent authority (para 8.12 GLVIA 3). The competent authority is the organisation with responsibility for consenting the development: the local authority in respect of wind farms up to 50 MW in output and the Energy Consents and Deployment Unit (ECDU) of the Scottish Government in respect wind farms of over 50 MW which are referred to as Section 36 applications.

The Landscape Institute (LI) has produced an Advice Note on Photography and photomontage in landscape and visual impact assessment (Advice Note 01/11 Landscape Institute), as noted above. This Advice Note supersedes the previous LI Advice Note 01/09 and is referenced at para 8.15 of GLVIA 3. The LI's guidance on photography and photomontage in landscape and visual impact assessment in Appendix 9 of *Guidelines for Landscape and Visual Impact Assessment* 2nd edition (2002) was considered relevant until publication of GLVIA 3.

Residential Visual Amenity Surveys

GLVIA 3 para 6.17 states that "*in some instances it may also be appropriate to consider private viewpoints, mainly from residential properties. In these cases the scope of such an assessment should be agreed with the competent authority, as must the approach to identifying representative viewpoints since it is impractical to visit all properties that might be affected*". GLVIA 3 continues noting that "*residential amenity assessments are separate from LVIA although visual effects assessment may sometime be carried out as part of a residential amenity assessment*". GLVIA 3 para 6.17 also states that "*some of the principles set out here for dealing with visual effects may help in such assessment but there are specific requirements in residential amenity assessment*." GLVIA 3 does not go on to set out what these specific requirements are.

In SLR's experience, residential visual amenity surveys or reports usually comprise preparing a ZTV for the agreed distance from the wind farm; identifying all houses within the ZTV and then preparing wirelines and/or in some instances photomontages, showing the predicted view from each potentially affected property. Where there are groups of properties which would have similar views, a single representative location at each group may be chosen.

Generally the wirelines or photomontages are prepared for the nearest publicly accessible location to the property. Photographs of the view from the property towards the wind farm site are taken. In some instances, access to the external areas surrounding the properties is agreed in order that the viewpoint illustrations can be prepared for views from the individual house frontages which would have a view towards the proposed development. Additionally, sometimes access to the property itself is arranged, in order that detail can be provided of the existing views from various rooms in the house, against which to assess the predicted change that would occur from the construction of the proposed wind farm.

The wirelines and/or photomontages are taken to the site, where the Landscape Architect(s) record their assessment of the magnitude of change that would occur at each included property as a result of the proposed development. Additionally notes are usually made about the main orientation of the property in relation to the view to the wind farm, the direction and distance to the nearest turbine, likely views from any garden, whether the view is open and uninterrupted or whether there is any screening between the property and the proposed development.

A report is then produced setting out the findings of the survey or report with associated illustrations. The aim of these reports is to explore the nature of the visual impacts which would occur for residents living in close proximity to the wind farm in greater detail than provided within the LVIA, which describes visual impacts for representative groups of households rather than individual properties.

There is a growing body of evidence, largely from public inquiries across the UK, where impacts on individual houses have been explored in greater detail (Enifer Downs, 2009 Case Ref: APP/X2220/A/08/2071880; Baillie, 2009, IEC/3/105/3; Carland Cross, 2010, Case Ref: APP/D0840/A/2103026; Spittal Hill (Report 5/10/2011); and Fauch Hill Wind Farm and Harburnhead Wind Farm (Report 21/1/2014). The objective appears to be to establish whether the visual impact at any given property would be of such magnitude as to make the property an unsatisfactory place to live. There is often reference to what has become known as "the Lavender test" which derives from the Enifer Downs public inquiry (2009), where Inspector Lavender, stated in his report "*when turbines are present in such number, size and proximity that they represent an unpleasantly overwhelming and unavoidable presence in the main view from a house or garden, there is every likelihood that the property concerned would come to be widely regarded as unattractive and thus unsatisfactory (but not necessarily uninhabitable) place to live. It is not in the public interest to create such living conditions where they did not exist before*." Para 66 APP/X2220/A/08/2071880.

In response to this growing body of evidence, many residential visual amenity surveys aim to identify whether the effects at a particular property are considered to be "overwhelming" or "overbearing". This differs from the output from the LVIA which identifies whether effects on residential receptors as a generic group are significant or not significant at the agreed viewpoint locations or at identified settlements, as interpreted from the findings of the viewpoint assessment. It is not clear whether the responsibility for identifying whether effects are "overwhelming" or "overbearing" lies with the Landscape Architect(s) carrying out the residential visual amenity survey, or whether this judgement should be made by the competent authority. However, the lack of a clear methodology for carrying out residential visual amenity surveys and the subjective nature of the so-called "Lavender test" which may be applied by the planning authority or other competent authority determining a wind farm application, means that the objectives and findings of these surveys varies considerably.

APPENDIX E: LANDSCAPE AND VISUAL IMPACT ASSESSMENT: GLOSSARY OF TERMS

Aesthetic Aspects - The key aspects of the landscape which contribute to is appearance (previously composition), such as:

- scale
- enclosure
- diversity
- texture
- form
- line
- contour
- balance
- movement
- pattern.

Analysis (Landscape): The process of breaking the landscape down into its component parts to understand how it is made up.

Analysis (Visual): The process of identifying the nature of visibility in an area, which is determined through topographic analysis.

Assessment (Landscape): An umbrella term for description, classification and analysis of landscape.

Baseline: The landscape and visual character of the study area as it exists at the commencement of the assessment process – i.e. prior to the development proposal under consideration.

Classification: A process of sorting the landscape into different types using selected criteria, but without attaching relative values to the different types of landscape.

Constraints map; Map showing the location of important resources and receptors that may form constraints to development.

Cultural and social factors: The elements of the landscape which are the result of human activity, e.g.:

- Land use management
- Character of settlements and buildings
- Pattern and type of fields and enclosures
- Rights of way /footpaths
- Artistic/literary associations

Cumulative Effects: Effects arising from the additional changes to the landscape or visual character caused by a proposed development in conjunction with other developments (associated with it or separate to it).

Digital Terrain Model (DTM): Computer generated 3 dimensional model based on aerial survey of ground surface (e.g. Ordnance Survey *Profile data*). Often utilised as a basis for visibility modelling over large areas.

Diversity: Where a variety of qualities or characteristics occur.

Effect: The result of an impact on a landscape or visual receptor.

Element:	A component part of the landscape (e.g. roads, hedgerows, woods)
Enhancement:	Landscape or visual improvement through restoration, reconstruction or creation.
Environmental Fit:	The relationship of a development to identified environmental opportunities and constraints in its setting.
Field Pattern:	The pattern of hedges and walls that define fields in farmed landscapes.
Geographic Information System:	Computerised data base of geographical information that can easily be updated and manipulated.
Horizontal Angle Subtended	The angle measured in degrees from the left most visible part to the right most visible part of any development.
Key characteristics	The elements of the landscape and/or their inter relationship which form the defining components of the landscape
Impact:	The change arising for a landscape or visual receptor as a result of some form of alteration to the baseline.
Indirect Impacts:	Impacts on the environment, which are not a direct result of the development but are often produced away from it or as a result of a complex pathway. Sometimes referred to as secondary impacts.
Landcover:	Combination of land use and vegetation that covers the land surface.
Landform:	See Topography.
Landscape:	Human perception of the land conditioned by knowledge and identity with a place. An area, as perceived by people, whose character is the result of the action and interaction of natural and/or human factors;
Landscape Capacity:	The degree to which a particular landscape character type or area is capable of is able to accommodate change without unacceptable adverse effects on its character. Capacity is likely to vary according to the type and nature of the changes being proposed. The capacity of the landscape is derived from a combination of Landscape Character Sensitivity, Visual Sensitivity and Landscape Value.
Landscape Character:	The distinct and recognisable pattern of elements that occurs consistently in a particular type of landscape, and how this is perceived by people. It reflects particular combinations of geology, landform, soils, vegetation, land use and human settlement. It creates the particular sense of place in different areas of the landscape.
Landscape Character Type:	A landscape type will have broadly similar patterns of geology, landform, soils, vegetation land use, settlement and field pattern discernible in maps and field survey records.
Landscape Fabric:	Physical elements of the landscape or development site.
Landscape Factor:	A circumstance or influence contributing to the impression of the landscape (e.g. scale, enclosure, elevation).

Landscape Feature:	A prominent eye-catching element or landmark (e.g. church spire, wooded hilltop).
Landscape Impact	The change in the elements, characteristics, qualities and overall character of the landscape as a result of development.
Landscape Effect:	The consequence of change in the elements, characteristics, qualities and overall character of the landscape as a result of development. These effects can be positive, neutral or negative.
Landscape Evaluation	The process of attaching value (non-monetary) to a particular landscape, usually by the application of previously agreed criteria, including consultation and third party documents, for a particular purpose (for example, designation or in the context of an assessment).
Landscape Quality (or Condition):	Based on judgments about the physical state of the landscape and about its intactness. Also relates to the state of repair of individual features and elements which make up character in any one place.
Landscape Resource:	The combination of elements that contribute to landscape context, character and value.
Landscape Sensitivity (to a specific type of change):	The extent to which a landscape can accept change of a particular type and scale and is assessed in relation to the following: • Existing land use; • Pattern and scale of the landscape, including simplicity/complexity; • Landscape quality or condition including presence of any detracting features; • The nature of views – visual enclosure/openness of views, scale of views; • Value placed on the landscape – which may be expressed through designation; and • Scope of mitigation, which will be in character with the existing landscape.
Landuse:	The primary use of land, including both rural and urban activities.
Landscape Value:	The relative value or importance attached to a landscape (often as a basis for designation or recognition), which expresses commonly held national or local perception of its quality, special qualities and/or scenic beauty, tranquillity or wildness and cultural associations.
Magnitude of landscape change:	A measure of the amount of change to the landscape that would occur as a result of proposed development, generally based on the **scale** or degree of change to the landscape resource, the **nature** of the effect and its **duration**. This is based on a combination of largely quantifiable parameters, such as: • the distance to proposed development; • its visible extent; • degree of contrast with context;

	• extent to which proposed development would be visible, and • duration of an impact.
Magnitude of visual change	A measure of the amount of change to the visual context that would occur as a result of a proposed development. This is generally based on: • the scale of change to the view with respect ot the loss or addition of features in the view and changes in its composition, including the proportion of the view that would be occupied by the proposed development; • the degree of contrast or integration of any new features of changes in the landscape with the existing or remaining landscape elements and characteristics in terms of form, scale, mass, line, height, colour and texture; • duration and nature of the change, whether temporary or permanent, transient or persistent, etc.; • the angle of view in relation to the main activity of the receptor(s); • distance of the viewpoint from the proposed development; and • extent of the area over which the changes would be visible.
Methodology:	The specific approach and techniques used for a given study.
Mitigation Measures,	Measures including any process, activity or design process to avoid, reduce, remedy or compensate for adverse landscape and visual impacts of a development. Mitigation can also apply to the amelioration of existing adverse effects associated with existing developments/features in the landscape.
Natural Factors	The natural elements of the landscape which contribute to its character, e.g. • Geology • Soils • Landform • River and drainage pattern.
Perception (of Landscape):	The psychology of seeing and possibly attaching value or meaning to the landscape.
Perceptual Aspect	Elements of the landscape which evoke a response to the senses, such as; • Wildness • Remoteness • Sense of security • Tranquillity • Exposure**.**
Receptor:	Physical landscape resource, special interest or individual or group experiencing view liable to change as a result of the proposed development.

Receptor Location:	Location occupied by identified receptors.
Residual Effects:	Effect of development after mitigation proposals are taken into account.
Scoping	The process of identifying likely significant effects of a development on the environment – which may be carried out in a formal or informal way.
Significant Effect	An effect which is considered by the assessor to be "significant" in terms of the Environmental Impact Assessment Regulations which require the identification of significant effects.
Visual Amenity	Particular composition of landscape elements that contribute to a view, or views. The value of a particular area or view in terms of what is seen
Visibility Analysis	The process of identifying theoretical (based on digital modelling) and/or actual predicted areas from where any given development may be seen.
Visual Effect	The consequence of change in the appearance of the landscape as a result of development, which may be positive or negative.
Visual Impact:	The change in the appearance of the landscape and nature of views which may be adverse or beneficial.
Viewpoint Sensitivity	The extent to which a view would be altered by change of a particular type and scale, assessed in relation to the following: • Location and land use (receptor activity) at the viewpoint or context of the view; • Landscape character and quality at the viewpoint; • Landscape character and quality of the intervening landscape; • Importance of the view (which may be determined with respect to its popularity or number of affected people, its appearance in guidebooks, on tourist maps and the facilities provided for its enjoyment and references to it in literature and/or art.
Visualisation:	Computer generated simulation or photomontage or other technique to illustrate how the proposed development would appear.
Zone of Theoretical Visibility (ZTV)	The area predicted to have views of a proposed development on the basis of a digital terrain model or digital surface model, which may/may not take account of landcover features.
Zone of Visual Influence	The area within which a proposed development may be visible

APPENDIX F – THE ASSESSMENT OF ENVIRONMENTAL NOISE AND GLOSSARY

Some sound, such as speech or music, is desirable. However, desirable sound can turn into unwanted noise when it interferes with a desired activity or when it is perceived as inappropriate in a particular environment.

When assessing the impact of sound on humans there are two equally important components that must both be considered: the physical sound itself and the psychological response of people to that sound. It is this psychological component which results in those exposed differentiating between desirable sound and unwanted noise. Any assessment of the impact of sound relies on a basic appreciation of both these components. This appendix provides an overview of these topics.

The assessment of environmental noise can best be understood by considering physical sound levels separately from the likely effects that these physical sound levels have on people and on the environment in general.

Physical sound is a vibration of air molecules that propagates away from the source. As acoustic energy (carried by the vibration back and forth of the air molecules) travels away from the source of the acoustic disturbance, it creates fluctuating positive and negative acoustic pressures in the atmosphere above and below the standing atmospheric pressure. When acoustic pressure acts on any solid object it causes microscopic deflections in the surface. For most types of sound normally encountered in the environment, these deflections are so small they cannot physically damage the material. It is only for the very highest energy sounds, such as those experienced close to a jet engine for example, that any risk of physical damage exists. For these reasons, most sound is essentially neutral and has no cumulative damaging physical effect on the environment. The impact of environmental sound is therefore limited to its effects on people or animals.

Before reviewing the potential effects of environmental sound on people, it is useful first to consider the means by which physical sound can be quantified.

Indicators of physical sound levels

Physical sound is measured using a sound level meter. A sound level meter comprises two basic elements: a microphone which responds in sympathy with the acoustic pressure fluctuations and produces an electrical signal that is directly related to the incident pressure fluctuations, and a meter which converts the electrical signal generated by the microphone into a decibel reading. Figure F1 shows an illustrative example of the time history of the decibel readout from a sound level meter located approximately 50 m from a road. The plot covers a total time period of approximately 2 hours. The peaks in the sound pressure level trace correspond to the passage of individual vehicles past the measurement location.

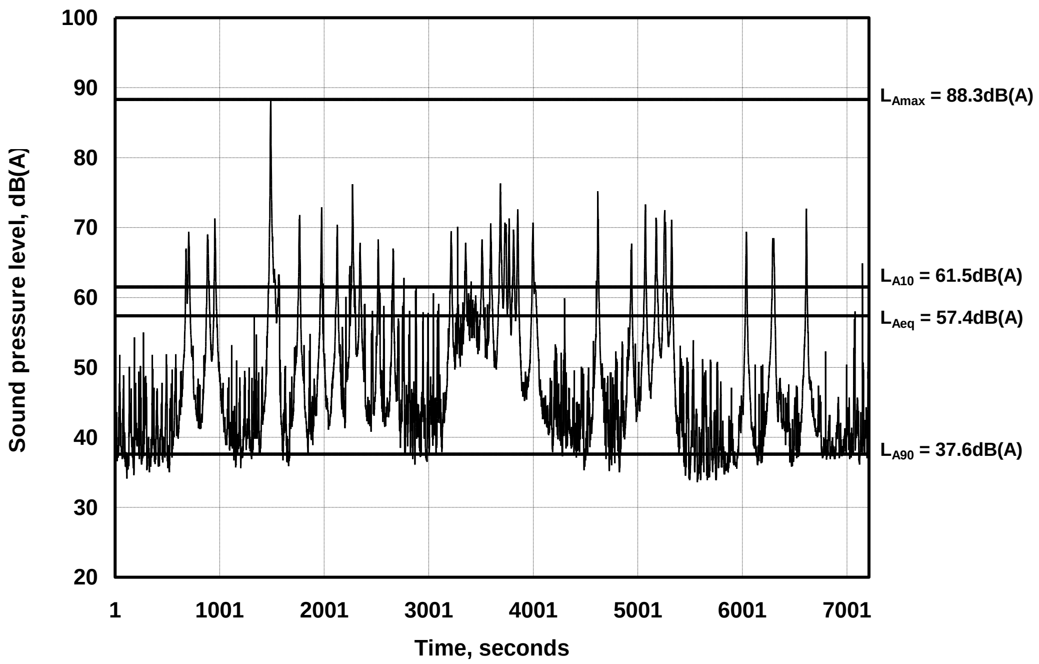


Figure F1 Sample time history of the sound pressure level measured close to a road

Assigning a single value to the time varying sound pressure level presented in Figure F1 is clearly not straightforward as the sound pressure level varies by over 50 dB with time. To overcome this, the measurement characteristics of sound level meters can be varied to emphasise different features of the sound that are thought to be most relevant to the effect under consideration.

Objective measures of noise

The primary purpose of measuring environmental noise is to assess its impact on people. Consequently, any sound measuring device employed for the task should provide a simple readout that relates the objectively measured sound to a human response. To achieve this, the instrument must, as a minimum, be capable of measuring sound over the full range detectable by the human ear.

Perceived sound arises from the response of the ear to sound waves travelling through the air. Sound waves comprise air molecules oscillating in a regular and ordered manner about their equilibrium position. The speed of the oscillations determines the frequency, or pitch, of the sound, whilst the amplitude of oscillations governs the loudness of the sound. A healthy human ear is capable of detecting sounds at all frequencies from around 20 Hz to 20 kHz over an amplitude range of approximately 1,000,000 to 1. Even relatively modest sound level meters are capable of detecting sounds over this range of amplitudes and frequencies, although the accuracy limits of sound level meters vary depending on the quality of the unit. When undertaking measurements of any particular type of noise it is important to select a measurement system that possesses the relevant accuracy tolerances and is calibrated to a matching standard.

Whilst measurement systems exist that are capable of capturing the range of sounds detected by the human ear, the complexities of human response to sound make the assessment of the experience of that sound a complex problem to resolve. Not only does human response to sound vary from person to person, but it can also depend as much on the activity and state of mind of an individual at the time of the assessment, and on the ‘character’ of the sound, as it can on the actual level of the sound. In practice, a complete range of responses to any given sound may be observed.

Sound levels and decibels

Because of the broad amplitude range covered by the human ear, it is usual to quantify the magnitude of sound using the decibel scale. When the amplitude of sound pressure is expressed using decibels (dB) the resultant quantity is termed the sound pressure level. Sound pressure levels are denoted by a capital 'L', as in L dB. The conversion of sound pressure from the physical quantity of Newton per square metre, or Nm^{-2}, to sound pressure level in dB reduces the range from 0 dB at the threshold of hearing to 120 dB at the onset of pain. Both of these values are derived with respect to the hearing of the average healthy young adult.

Being represented on a logarithmic amplitude scale, the addition and subtraction of decibel quantities does not follow the normal rules of linear arithmetic. For example, two equal sources acting together produce a sound level 3 dB higher than either source acting individually, so 40 dB + 40 dB = 43 dB and 50 dB + 50 dB = 53 dB. Ten equal sound sources acting together will be 10 dB higher than each source operating in isolation, whilst an increase of 20 dB requires a hundredfold increase in the number of similar sources and an increase of 30 dB requires a thousand times increase in the number of sources. Also, if one of a pair of sources is at least 10 dB quieter than the other, then it will contribute negligibly to the combined noise level. So, for example, 40 dB + 50 dB = 50 dB.

An increase in sound pressure level of 3 dB is commonly accepted as the smallest change of any significance. An increase of 10 dB is often claimed to result in a perceived doubling in loudness, although the basis for this claim is not well founded. As discussed in the preceding paragraph, an increase of 3 dB is equivalent to a doubling in sound energy, which is the same as doubling the number of similar sources whilst an increase of 10 dB is equivalent to increasing the number of similar sources tenfold.

Frequency selectivity of human hearing and A-weighting

Whilst the hearing of a healthy young individual may detect sounds over a frequency range extending from less than 20 Hz to greater than 20 kHz, the ear is not equally sensitive at all frequencies. Human hearing is most sensitive to sounds containing frequency components lying within the range of predominant speech frequencies from around 500 Hz to 4000 Hz. Therefore, when relating an objectively measured sound pressure level to loudness, the frequency content of the sound must be accounted for.

Sound outside the frequency range of 20 Hz to 20 kHz does exist, and can also be heard, particularly at the lower frequency end of the scale, although this may be difficult to interpret as such. However this requires levels to be very high, as the ear is particularly insensitive to these very low frequency sounds. As such high levels are generally not encountered in a natural setting or produced by most sources, this explains why these extreme sounds are generally considered inaudible. Sounds below 20 Hz are commonly referred to as 'infrasound' whilst sounds above 20,000 Hz are referred to as 'ultrasound'.

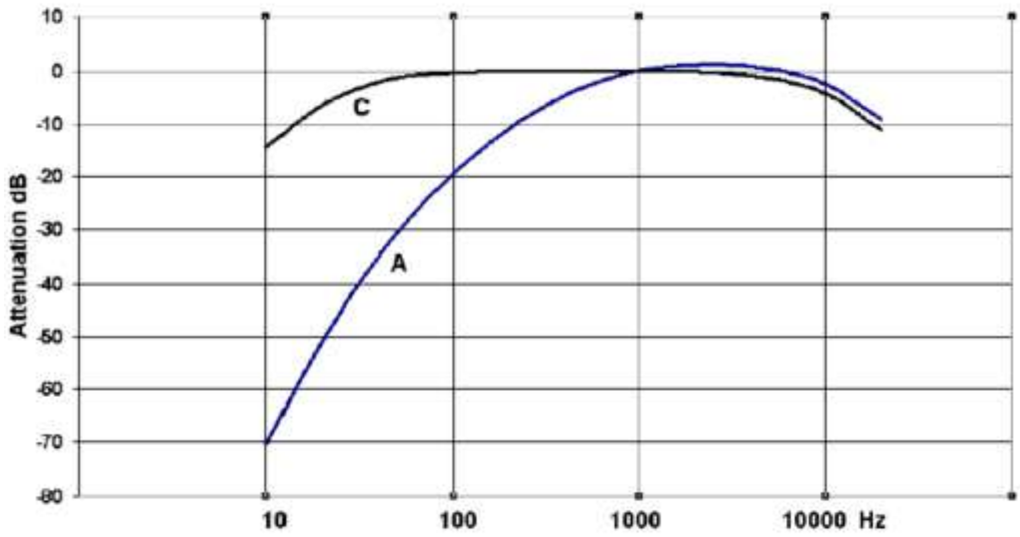


Figure F2 Comparison of the 'A' and 'C' weighting curves

When measuring sound with the aim of assessing an experiential response, the frequency selectivity of human hearing is accounted for by down-weighting the contributions of lower and higher frequency sounds to reduce their influence on the overall reading. This is achieved by using an 'A'-weighting filter, as shown in Figure F2.

Over the years, A-weighting has become internationally standardised and is now incorporated into the majority of environmental noise standards and regulations in use around the world to best replicate the response of the human ear. A-weighting filters are also implemented as standard on virtually all sound measurement systems.

Sound pressure levels measured with the A-weighting filter applied are referred to as 'A-weighted' sound pressure levels. Results from such measurements are denoted with a subscripted capital A after the 'L' level designation, as in 45 dB L_A, or alternatively using a bracketed 'A' after the 'dB' decibel designation, as in 45 dB(A). In order to provide some context as to the significance of different A-weighted noise levels, Table F1 shows some examples of typical noise levels associated with various different sources of everyday noise.

Source / activity	Indicative sound level (dB A-weighted)
Threshold of pain	140
Jet aircraft flyover	110
Food blender (1m away)	90
Urban environment with heavy traffic	80-90
Speech (1m away)	60-70
Urban environment	50-60
Inside a library	30-40
Quiet rural environment at night	20-30
Threshold of hearing	0

Table F1 Typical A-weighted noise levels associated with various different sources of everyday noise.

Temporal variation of noise and noise indices

The simple A-weighted sound pressure level provides a snapshot of the sound environment at any given moment in time. However, as is demonstrated by Figure F1, this instantaneous sound level can vary significantly over even short periods of time. A single number indicator is therefore required that best quantifies the human response to time varying environmental noise, such as that shown in Figure F1. The question thus arises as to how temporal variations in level should be accounted for. This is most often achieved in practice by selecting a representative time period and calculating either the average noise level over that time period or, alternatively, the noise level exceeded for a stated proportion of that time period, as discussed below.

Equivalent continuous sound level, $L_{Aeq,T}$

The equivalent continuous sound level averages out any fluctuations in level over time. It is formally defined as the level of a steady sound which, in a stated time period 'T' and at a given location, has the same sound energy as the actually received sound (which is most usually not steady but time varying) at the same location. It is a useful 'general' noise index that has been found to correlate well with the human response to most types of environmental noise.

The equivalent continuous sound level is expressed $L_{Aeq,T}$ in dB, where the A–weighting is denoted by the subscripted 'A', the use of the equivalent continuous index is denoted by the subscripted 'eq', and the subscripted 'T' refers to the time period over which the averaging is performed. So, for example, 45 dB $L_{Aeq,1hour}$ indicates that the A-weighted equivalent continuous sound level measured over a one hour period was 45 dB.

The disadvantage of the equivalent continuous sound level is that it provides no information as to the temporal variation of the sound. For example, an $L_{Aeq,1hr}$ of 60 dB could result from a sound pressure level of 60 dB(A) continuously present over the whole hour's measurement period, or it could arise from a single event of 96 dB(A) lasting for just 1 second superimposed on a continuous level of 30 dB(A) which exists for the remaining 59 minutes and 59 seconds of the hour long period. Clearly, the impact of these two apparently identical situations (if one were to rely solely on the L_{Aeq} sound level) could be quite different**.**

The aforementioned feature can introduce problems where the general ambient noise level is relatively low. In such cases the $L_{Aeq,T}$ can be easily 'corrupted' by individual noisy events. Examples of noisy events that often corrupt $L_{Aeq,T}$ noise measurements in situations of low ambient noise levels include birdsong or a dog bark local to a noise monitoring point, or an occasional overflying aircraft or a sudden gust of wind. This potential downside to the use of $L_{Aeq,T}$ as a general measurement index is of particular relevance to the assessment of ambient noise in quiet environments.

Despite these shortcomings in low noise environments, the $L_{Aeq,T}$ index is increasingly becoming adopted as the unit of choice for both UK and European guidance and legislation, although this choice is often as much for reasons of commonality between standards as it is for overriding technical arguments. However, it is often the case for quiet environments, or for non-steady noise environments, that more information than can be gleaned from the $L_{Aeq,T}$ index may be required to fully assess potential noise impact.

Maximum, L_{Amax}, and percentile exceeded sound level, $L_{An,T}$

Figure F1 shows, superimposed on the time varying sound pressure level trace and in addition to the $L_{Aeq,T}$ noise level, examples of three well established measurement indices that are commonly used in the assessment of environmental noise impacts. These are the maximum sound pressure level, L_{Amax}, the 90 percentile sound pressure level, $L_{A90,T}$, and the ten percentile sound pressure level, $L_{A10,T}$.

The L_{Amax} reading is suited to indicating the physical magnitude of the single individual sound event that reaches the maximum level over the measurement period, but it gives no indication of the number of individual events of a similar level that may have occurred over the measurement period.

Unlike the $L_{Aeq,T}$ index and the L_{Amax} indices, percentage exceeded sound levels provide some insight into the temporal distribution of sound level throughout the averaging period. Percentage exceeded sound levels are defined as the sound level exceeded by a fluctuating sound level for n% of the time over a specified time period, T. They are denoted by $L_{An,T}$ in dB, where 'n' can take any value between 0% and 100%.

The $L_{A10,T}$ and $L_{A90,T}$ indices are the most commonly encountered percentile noise indices used in the U.K.

The 10%'ile index, or $L_{A10,T}$, provides a measure of the sound pressure level that is present for 10% of the total measurement period. It therefore represents the typical upper level of sound associated with specific events, such as the passage of vehicles past the measurement point in the example of Figure F1. It is the traditional index adopted for road traffic noise. This index is useful because traffic noise is not usually constant, but rather it fluctuates with time as vehicles drive past the receptor location. The $L_{A10,T}$ therefore characterises the typical level of peaks in the noise as vehicles drive past, rather than the lulls in noise between the vehicles.

The $L_{A90,T}$ noise index is the noise level exceeded for 90% of the time period, T. It provides an estimate of the level of continuous background noise, in effect performing the inverse task of the $L_{A10,T}$ index by detecting the lulls between peaks in the noise. The $L_{A90,T}$ noise level represents the typical lower level of sound that may be reasonably expected to be present for the majority (90%) of the time in any given environment. This is usually referred to as the 'background' noise level.

Effects of sound on people

Except at very high peak acoustic pressures, the energy levels in most environmental sounds are too low to cause any physical disruption in any part of the body, just as they are too low to cause any direct physical damage to the environment. The main effects of environmental sound on people are therefore limited to possible interference with specific activities or to some kind of annoyance response. Some researchers have claimed statistical associations between environmental noise and various long term health effects such as clinical hypertension or mental health problems. Evidence in support of health effects other than annoyance and sleep disturbance is weak. However, the theory that psychological stress caused by these factors might contribute to so called 'indirect' or 'secondary' adverse health effects in otherwise susceptible individuals seems plausible. However, when considering health effects the World Health Organisation defines health not just in the context of direct physiological effects but in the wider context of:

'a state of complete physical, mental and social well-being and not merely the absence of infirmity'.

Within this wider context potential health effects of environmental noise are summarised by the World Health Organisation as:

- interference with speech communications;
- sleep disturbance;
- disturbance of concentration;
- annoyance;
- social and economic effects;

Due to the potential for acoustic features to increase the impact of a noise over and above the impact that would result from an otherwise ‘bland’ broad band noise of the same A-weighted noise level, it is common practice to add a ‘character correction’ to the specific noise level before assessing its potential impact. The resulting character-corrected specific noise level is often referred to as the ‘rated’ noise level. Such character corrections usually take the form of adding a number of decibels to the physically measured or calculated noise level of the specific source. Typical character corrections are around +5 dB(A), although the actual correction depends on the significance of the particular feature being accounted for.

The objective identification and rating of acoustic features can introduce a requirement to analyse sound in greater detail. To this point this Appendix has focussed on the use of the overall A-weighted noise level. This single figure value is derived by summing together all the acoustic energy present in the signal across the entire audible spectrum from around 20 Hz to 20,000 Hz, albeit with the lower and higher frequency contributions down-weighted in accordance with the A-weighting filter characteristics to account for the reduced sensitivity of the human ear at these frequencies.

However, in order to identify the presence of tones (which are concentrations of acoustic energy over relatively small bands of frequency), or in order to identify excessive levels of low frequency sound, it may be necessary to determine the acoustic energy present in the noise signal across much smaller frequency bands. This is where the concept of octave band analysis, fractional (e.g. 1/3, 1/12, 1/24) octave band analysis, or even narrow band analysis is introduced. The latter enables signals to be resolved in frequency down to bandwidths of 1 Hz or even less, thereby enabling tonal content to be more easily identified and measured. As standard, noise emission data for wind turbines is supplied as octave band data, with narrow band tests also being undertaken to establish the presence of any tones in the radiated noise spectrum. Figure F3 show examples of a narrow band analysis and a third octave band analysis of the same acoustic signal that contains tonal components.

Figure F3 shows the narrow band spectrum over a frequency range of 50 Hz to 2000 Hz with a frequency resolution of 2.5 Hz. Thus the apparently continuous spectral line is actually made up of individual data points equally spaced apart at frequencies of 50.0 Hz, 52.5 Hz, 55.0 Hz, 57.5 Hz, 60.0 Hz, and thereafter at 2.5 Hz increments up until 2000.0 Hz. The frequency of the analysed noise is marked along the horizontal axis. The level of the noise at each separate frequency is marked up the vertical axis. Tonal components in the noise are evident as the peaks centred at frequencies of 125 Hz and 1200 Hz, as indicated.

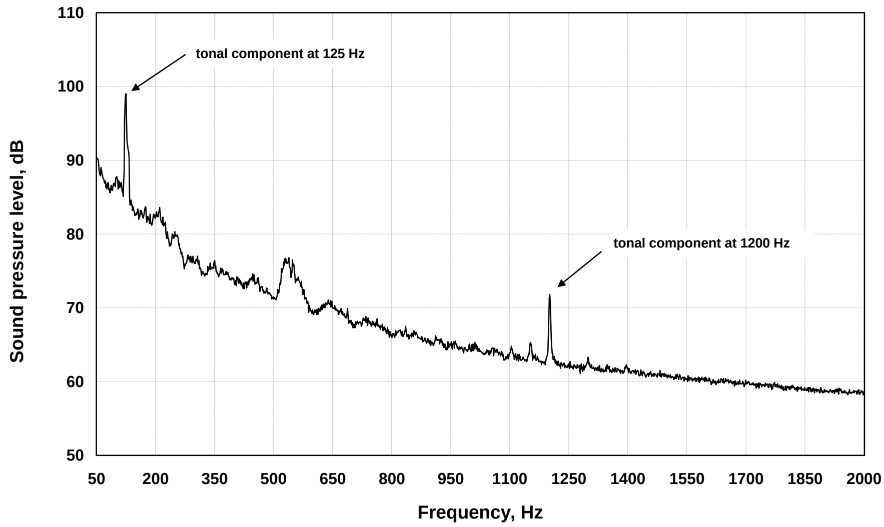


Figure F3 Sample narrow band analysis of an acoustic signal which contains tonal components at frequencies of 125 Hz and 1200 Hz.

GLOSSARY OF ACOUSTIC TERMINOLOGY

TERMINOLOGY	DESCRIPTION
A-weighting	a filter that down-weights low frequency and high frequency sound to better represent the frequency response of the human ear when assessing the likely impact of noise on humans
acoustic character	one or more distinctive features of a sound (e.g. tones, whines, whistles, impulses) that set it apart from the background noise against which it is being judged, possibly leading to a greater impact than the level of the sound alone might suggest
acoustic screening	the presence of a solid barrier (natural landform or manmade) between a source of sound and a receiver that interrupts the direct line of sight between the two, thus reducing the sound level at the receiver compared to that in the absence of the barrier
ambient noise	all-encompassing noise associated with a given environment, usually a composite of sounds from many sources both far and near, often with no particular sound being dominant
annoyance	a feeling of displeasure in this case evoked by noise
attenuation	the reduction in level of a sound between the source and a receiver due to any combination of effects including: distance, atmospheric absorption, acoustic screening, the presence of a building façade, etc.
audible sound	a sound that can be heard above all other ambient sounds
audio frequency	any frequency of a sound wave that lies within the frequency limits of audibility of a healthy human ear, generally accepted as being from 20 Hz to 20,000 Hz
background noise	the noise level rarely fallen below in any given location over any given time period, often classed according to daytime, evening or night-time periods (for the majority of the population of the UK the lower limiting noise level is usually controlled by noise emanating from distant road, rail or air traffic)
dB	abbreviation for 'decibel'
dB(A)	abbreviation for the decibel level of a sound that has been A-weighted

TERMINOLOGY	DESCRIPTION
decibel	the unit normally employed to measure the magnitude of sound
directivity	the property of a sound source that causes more sound to be radiated in one direction than another
equivalent continuous sound pressure level	the steady sound level which has the same energy as a time varying sound signal when averaged over the same time interval, T, denoted by $L_{Aeq,T}$
external noise level	the noise level, in decibels, measured outside a building
filter	a device for separating components of an acoustic signal on the basis of their frequencies
frequency	the number of acoustic pressure fluctuations per second occurring about the atmospheric mean pressure (also known as the ‘pitch’ of a sound)
frequency analysis	the analysis of a sound into it’s frequency components
ground effects	the modification of sound at a receiver location due to the interaction of the sound wave with the ground along its propagation path from source to receiver
hertz	the unit normally employed to measure the frequency of a sound, equal to cycles per second of acoustic pressure fluctuations about the atmospheric mean pressure
impulsive sound	a sound having all its energy concentrated in a very short time period
instantaneous sound pressure	at a given point in space and at a given instant in time, the difference between the instantaneous pressure and the mean atmospheric pressure
internal noise level	the noise level, in decibels, measured inside a building
L_{Aeq}	the abbreviation of the A-weighted equivalent continuous sound pressure level
L_{A10}	the abbreviation of the 10 percentile noise indicator, often used for the measurement of road traffic noise
L_{A90}	the abbreviation of the 90 percentile noise indicator, often used for the measurement of background noise
level	the general term used to describe a sound once it has been converted into decibels
loudness	the attribute of human auditory response in which sound may be ordered on a scale that typically extends from barely audible to painfully loud
masking	the effect whereby an otherwise audible sound is made inaudible by the presence of other sounds
noise	physically: a regular and ordered oscillation of air molecules that travels away from the source of vibration and creates fluctuating positive and negative acoustic pressure above and below atmospheric pressure. experientially: sound that evokes a feeling of displeasure in the environment in which it is heard, and is therefore unwelcomed by the receiver
noise emission	the noise emitted by a source of sound
noise emission	the noise to which a receiver is exposed
noise nuisance	an unlawful interference with a person’s use or enjoyment of land, or of some *right* over, or in connection with it
octave band frequency analysis	a frequency analysis using a filter that is an octave wide (the upper limit of the filter’s frequency band is exactly twice that of it’s lower frequency limit)
percentile exceeded sound level	the noise level exceeded for n% of the time over a given time period, T, denoted by $L_{An,T}$
receiver	a person or property exposed to the noise being considered

TERMINOLOGY	DESCRIPTION
residual noise	the ambient noise that remains in the absence of the specific noise whose impact is being assessed
sound	physically: a regular and ordered oscillation of air molecules that travels away from the source of vibration and creates fluctuating positive and negative acoustic pressure above and below atmospheric pressure experientially: the sensation of hearing excited by the acoustic oscillations described above (see also 'noise')
sound level meter	an instrument for measuring sound pressure level
sound pressure amplitude	the root mean square of the amplitude of the acoustic pressure fluctuations in a sound wave around the atmospheric mean pressure, usually measured in Pascals (Pa)
sound pressure level	a measure of the sound pressure at a point, in decibels
sound power level	the total sound power radiated by a source, in decibels
spectrum	a description of the amplitude of a sound as a function of frequency
third-octave band frequency analysis	a frequency analysis using frequency bands one third of an octave wide
threshold of hearing	the lowest amplitude sound capable of evoking the sensation of hearing in the average healthy human ear (0.00002 Pa)
tone	the concentration of acoustic energy into a very narrow frequency range

APPENDIX G- THE ASSESSMENT OF WIND FARM NOISE

Noise Impact Methodology

The noise assessment process for onshore wind farms is guided by Scottish planning policy and supporting planning advice. This policy and guidance has developed over the years. What is summarised below relates to current best practice. The policy and procedures outlined do not therefore necessarily reflect the situation at the time of preparation of the planning applications for the ten case study wind farms considered in this study.

Key Elements of Wind Farm Noise Impact Assessment

Scottish Planning Policy (SPP) and the Technical Advice Note (TAN) Assessment of Noise (2011)) present policy and guidance on noise associated with new developments in general. Guidance specific to the assessment of noise from onshore wind turbines is referred to in the web-based planning advice on onshore wind turbines. This guidance requires the assessment of noise from onshore wind farms to be established through the use of the ETSU-R-97 report '*The Assessment and Rating of Noise from Wind Farms*' (Working Group on Noise from Wind Turbines, 1996), as implemented in accordance with the good practice recommendations of the subsequently published Institute of Acoustics (IOA) Good Practice Guide (GPG) (IOA, 2013).

According to additional guidance set out in the above referenced TAN, assessing a new noise source involves considering the level of noise and the change in noise climate before and after the new noise is introduced. Such an assessment can be related to any measurable and quantifiable characteristics of the wind farm noise, including its overall level and also the presence of any acoustic features within the noise.

It was recognised early on in the development of the wind energy industry in the UK that methods more traditionally used in the context of planning for the assessment of noise impact, including the setting of appropriate noise limits, would not be directly applicable for the assessment of wind turbine noise. This was for various reasons, but not least the fact that wind turbine noise varies with wind speed.

The lowest wind speed at which energy generation can begin is referred to as the 'cut-in' wind speed. As the wind speed increases the rotational rate of the blades increases until the point at which the 'rated power' of the turbine is reached. Above the wind speed at which rated power is reached the rotational rate of the turbine blades is maintained roughly constant until a point at which, for design and safety reasons, the turbine blades are parked and power generation ceases. This upper wind speed is referred to as the 'cut-out' wind speed. The noise output of a wind turbine varies as a direct result of changes in rotational speed across its operational wind speed range[47].

A noise working group therefore formulated a dedicated methodology for assessing the impact of noise from wind farms on behalf of the Department of Trade and Industry. The

[47] For modern large-scale wind turbines the cut-in wind speed is typically around 4 m/s (~8 mph), and the rated power is generally reached at approximately 10 m/s (~20 mph) at hub height. The rotational rate of the blades for most large scale turbines typically varies from around 10 rpm (revolutions per minute) at 'cut-in' to around 20 rpm at 'rated power'. A typical cut out wind speed is approximately 25 m/s (~50 mph). For some older turbine models ("fixed speed" instead of "variable speed"), the speed of rotation will be fixed or less variable, leading to less variation in noise emissions, meaning relatively higher noise at low wind speeds.

group comprised a cross section of interested persons including, amongst others, environmental health officers, wind farm operators and independent acoustic experts. The outcome methodology from this working group resulted in the aforementioned report ETSU-R-97.

The ETSU-R-97 assessment procedure specifies that noise limits should be set relative to the noise present during quiet periods prior to the construction of the wind farm: this is the “background noise”. Background noise levels are measured at the properties nearest to the proposed wind farms. The ETSU-R-97 procedure then reflects the variation in both background noise and the proposed turbine’s source noise with wind speed. In common with other forms of environmental noise assessments, ETSU-R-97 assessments are based on the noise levels outside local properties.

Separate noise limits apply for daytime and for night-time. ETSU-R-97’s daytime limits were chosen to protect a property’s external amenity. Night-time limits were chosen to prevent sleep disturbance indoors. Fixed lower limits, different for day-time and night-time, should be applied where low levels of background noise are measured. If audible tones are present within the turbine noise (see previous section) then these are considered to effectively make the noise louder (experientially). They therefore attract a penalty of up to 5 dB which is added to the overall A-weighted noise level of the wind farm noise prior to its comparison with the ETSU-R-97 derived noise limits.

ETSU-R-97 requires the following steps to be undertaken, with reference to Figures G1/G2.

i) define the likely physical layout of turbines on the wind farm site, as shown by the dark blue markers towards the centre of Figure G1;

ii) identify the neighbouring noise sensitive locations to the wind farm, as shown by the numbered black markers in Figure G1;

iii) calculate the wind farm operational noise contours around the site (based on the adoption of a suitable candidate wind turbine model) to identify which neighbouring properties lie above the assessment threshold level of 35 dB(A); *(for example, in Figure G1 it may be determined that locations EX04, EX16, EX21 and EX23 lie within the 35 dB(A) assessment threshold noise contour line);*

iv) undertake background noise measurements outside the properties identified in step iii, or at least a representative sub-set of the identified properties, in order to separately derive for each location the typical quiet daytime[48] and night time background noise curves (see Figure 6.2) as a function of wind speed; *(for example, in Figure G1 it may be decided to undertake background noise measurements at only EX16 and EX04 as also being adequately representative of the background noise environments at EX21 and EX23 respectively);*

v) set the ETSU-R-97 noise limits at a fixed margin of 5 dB above the measured background noise curves, but set a lower absolute noise limit somewhere between 35 dB(A) and 40 dB(A) for the quiet daytime periods and at 43 dB(A) for the night-time periods, also identifying any financially involved noise sensitive properties where a less restrictive absolute noise limit of 45 dB(A) may be applied regardless of the time of day or night (see Figure G2);

[48] Quiet daytime is defined in ETSU-R-97 as being those periods when people are most likely to be at home using external amenity areas, and so includes all weekdays from 19:00 to 23:00, Saturdays from 13:00 to 23:00, and all day Sundays from 07:00 to 23:00. Night time is defined as 23:00 to 07:00 on all days of the week.

vi) the requirements of ETSU-R-97 are deemed to be satisfied provided the calculated (or measured, once in operation) wind farm noise levels at the residential location can be demonstrated not to exceed the derived noise limits (see Figure G2), having also accounted for any applicable tonal penalties.

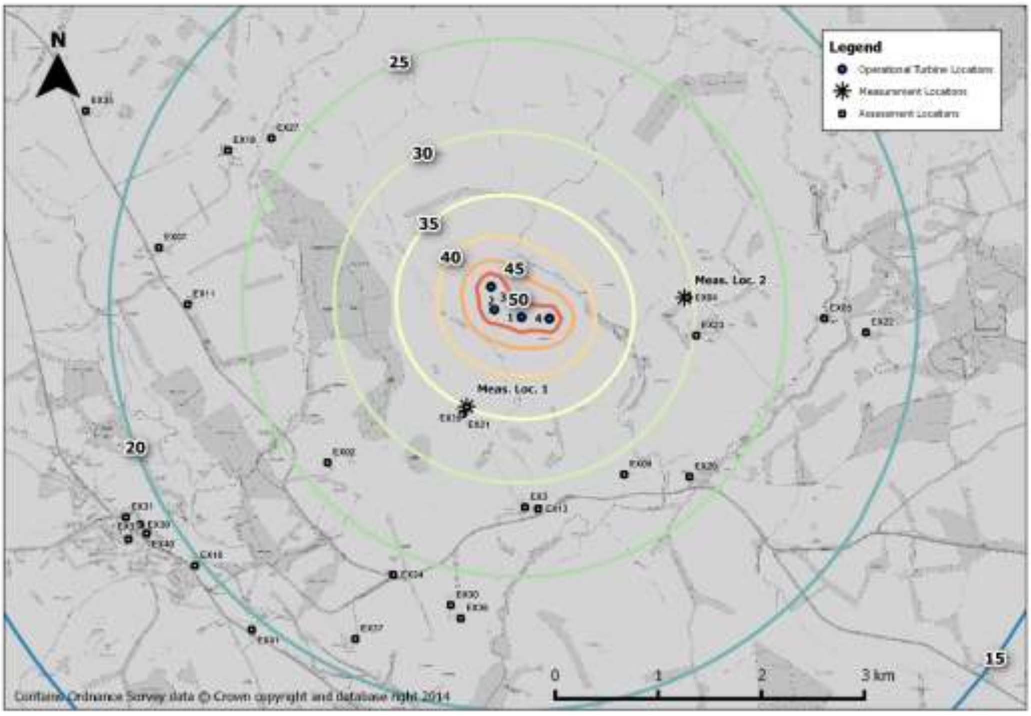


Figure G1 - Hypothetical wind farm layout illustrating the procedure of ETSU-R-97

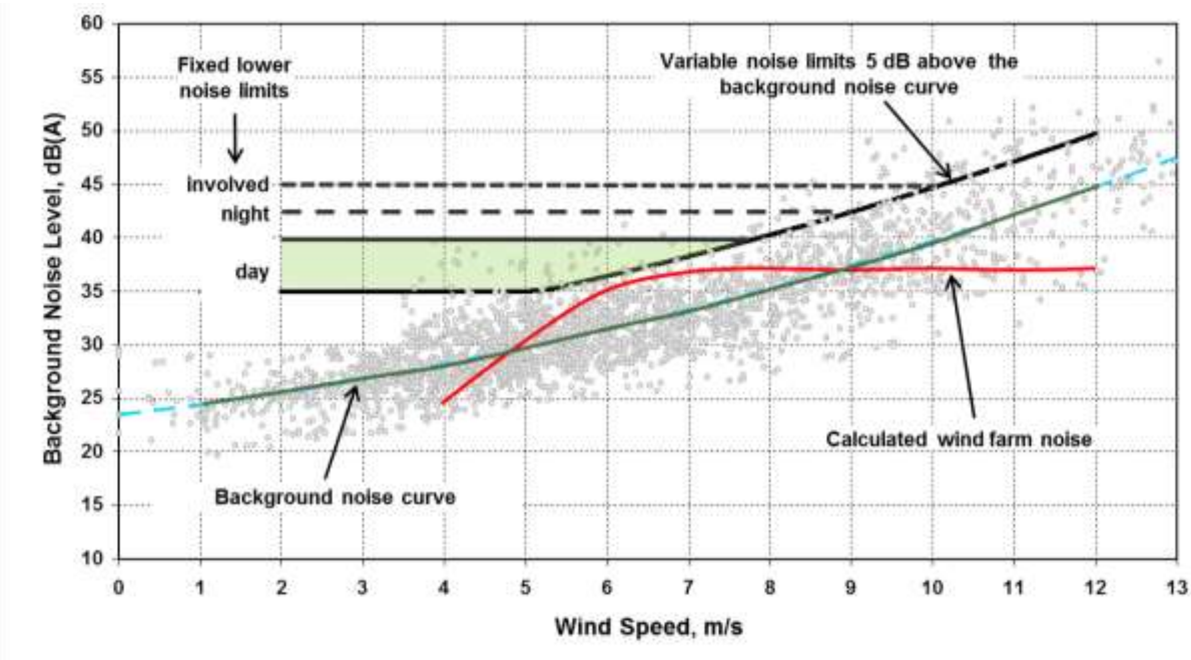


Figure G2 - Illustrative noise assessment under ETSU-R-97 at a residential location

Figure G2 illustrates the background noise curve (the green curve) derived as a 'best fit' to the scatter of measured background noise data points (the hollow grey circles), the resultant ETSU-R-97 noise limits (the various black curves, which feature a mix of fixed lower absolute noise limits and limits set at 5 dB above the background noise curve), and the calculated wind farm noise level (the red curve).

The recommended use of the ETSU-R-97 methodology results in defined levels of noise that are deemed to result in an 'acceptable' impact. Compliance with ETSU-R-97 noise limits does not therefore mean that wind farms will necessarily be either inaudible or have *no* negative noise impact.

Good practice in Wind Farm Noise Impact Assessment

Following concerns over differences in how ETSU-R-97 was being applied, the Government funded a study in 2011 to review the historical use of the ETSU-R-97 methodology across a wide number of wind farms in England (Hayes McKenzie Partnership, 2011). The report found evidence of significant variations in the practical application of ETSU-R-97. Good practice advice was therefore produced to secure a more consistent application of ETSU-R-97. That advice was contained in the Institute of Acoustics Good Practice Guidance, (IOA GPG) in 2013. IOA GPG provides specific advice in relation to ETSU-R-97, and in particular in the areas of:

- consultation & engagement;
- background noise surveys;
- wind and rain measurements;
- data analysis and noise limit derivation;
- noise predictions; and
- cumulative noise issues.

The key requirements for undertaking a wind farm noise assessment in accordance with current recommended good practice (i.e. using ETSU-R-97 and IOA GPG) are helpfully summarised in flowchart form in IOA GPG, repeated here as Figure G3.

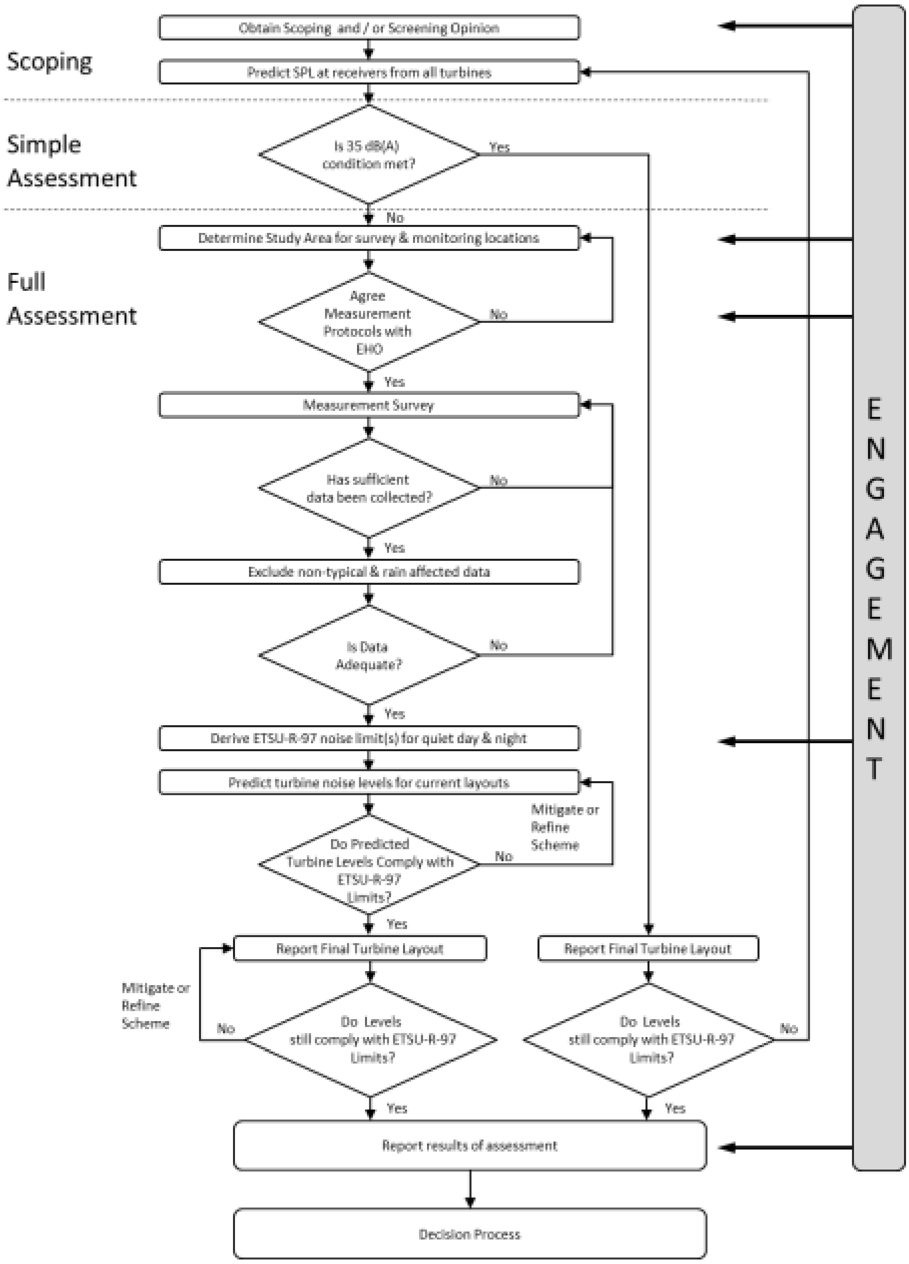
Conditions

Formal conditions are often attached to wind farm planning consents, requiring that the noise limits derived in accordance with the ETSU-R-97/IOA GPG procedures should not be exceeded. These are called conditioned noise limits, and will normally apply to all potentially noise affected properties and not just those at which background noise surveys were undertaken. For those properties where background noise data were not acquired, the noise limits are usually adopted from the property which is deemed to have the most representative background noise environment, as suggested by the ETSU-R-97 procedure.

In addition to the requirement that the overall noise levels arising from the operation of the wind farm shall not exceed the derived noise limits, ETSU-R-97 requires that any audible tonal characteristics in the noise are accounted for. These requirements are also usually included as a noise condition. ETSU-R-97 provides an objective procedure for assessing wind farm noise for audible tonal components, including for 'rating' tonal audibility and calculating a penalty of up to 5 dB(A) to account for it. Any applicable tonal penalty is added to the measured wind farm overall noise level prior to assessing whether or not the wind farm is operating in compliance with its conditioned noise limits.

Noise conditions also frequently require that, on receipt of a noise complaint, measurements should be done to establish whether or not the wind farm is operating within its consented noise limits[49].

Figure G3 - Flowchart illustrating the standard process for a wind farm noise impact assessment (taken from IOA GPG)



49 There has traditionally been no requirement for a wind farm to demonstrate it is operating in compliance with its conditioned noise limits except in the event of an actionable noise complaint.

Additional considerations

It is the experience of HLA that the adequacy of ETSU-R-97 for assessing the potential impact of wind farm noise has frequently been questioned. In particular, some observers have criticised the lower noise limits applied, particularly for night-time periods. These lower limits are considered to be adequate in absolute terms according to ETSU-R-97 regardless of baseline noise levels in the area. The adoption of such fixed minimum limits in areas of low background noise may result in the wind farm noise being permitted to be significantly above the existing background noise (see Figure G2, for example). This may especially be the case at lower wind speeds when there is enough wind for the turbines to operate but too little wind at neighbouring properties to generate local masking sound. The absolute value of the noise limit prescribed for night-time periods has also been criticised, particularly in the light of more recent guidance on sleep effects which has been published by the World Health Organisation (WHO Night Noise Guidelines for Europe, 2011).

Other factors may also affect the impact of wind farm noise. These include particular characteristics of the noise and also where it is experienced, as presented in the following section. The present project has aimed to secure information relating to these additional factors by way of questions included as part of the residents' survey.

The Character of Wind Farm Noise

The assessment of wind turbine noise according to the guidance outlined above focusses mainly on the overall level of the noise[50]. Generic research on the effects of noise from a range of different sources (see for example WHO, 2000) has established the importance of the overall noise level. This was also shown in research specific to wind farm noise (see Van den Berg and others, 2008). Any wind farm noise must also be audible relative to any pre-existing noise environment in order to elicit any reaction. For this reason both the *absolute* level of the noise being considered and the level of this noise *relative to the pre-existing noise environment* are taken together to form the main basis on which the acceptability of wind farm schemes is considered.

Notwithstanding the above, it is the experience of HLA that where complaints about wind farm noise arise they are not always associated solely with the level of that noise, be this in absolute or relative terms. Complaints can also arise from specific acoustic 'character' or 'features' of the noise which add to its impact.

The main acoustic feature associated with wind turbine noise has been tones (e.g. higher frequency 'whines', mid-frequency 'hums' or lower frequency 'rumbles') caused by the operation of turbine mechanical components. The typical requirement of noise conditions is that audible tones should attract a penalty of up to 5 dB(A). This means that compliance with the planning conditions would in practice be more difficult.

However, wind turbine noise can additionally rise and fall in level caused by the rotation of the blades. Traditionally it was assumed that this so-called 'blade swish' would decrease

[50] Environmental noise in general is most frequently quantified in terms of its 'overall' A-weighted level, as defined in terms of the dB(A) noise level. This is obtained by summing the sound energy across the entire range of frequencies which people can hear (usually taken to be between very low frequencies of around 20 Hz to very high frequencies of 20,000 Hz). The resultant dB(A) level provides a single number which is representative of the generally perceived overall loudness of the noise. Alternatively, the quantification of noise having particular acoustical characteristics can instead focus on a particular feature of that noise, such as the level of an audible tone at a specific frequency or, for a noise whose level is not constant, the amount by which the noise level varies with time. See Appendix F for more details.

with increasing distance from a wind farm. However, starting in around 2003 reports began to emerge of properties lying greater than 1 km from wind turbines sometimes experiencing a periodic ‘whoomphing’ or ‘thumping’ sound. Recent research (RenewableUK, 2013) has better identified the potential causes of this particular type of amplitude modulation noise as being different to that of normal blade swish, as referred to in ETSU-R-97. Blade swish is an inherent feature of the operation of all wind turbines, whereas this subsequently identified form of amplitude modulation noise has been associated with a quite different aerodynamic effect. Notwithstanding the different source generation mechanisms suggested for these two different types of noise, both share the same characteristic that the amplitude of the noise rises and falls (modulates) at a periodic rate equal to the blade rotation rate of the source turbine, which is typically around once every one to two seconds for modern large scale turbines. As a consequence both have generically become known as ‘amplitude modulation’ noise, or ‘AM’ for short.

Noise conditions do not commonly contain any requirements for the control of AM noise. There is currently no generally agreed method for assessing and rating the level of AM in wind turbine noise. Efforts are presently underway, however, to develop a robust objective AM assessment methodology (see, for example, the IOA Working Group on AM[51]). Such an objective test could then be incorporated in wind farm noise conditions to supplement the current practice of conditioning limits for overall noise levels and tonal penalties.

Wind Farm Noise Inside Properties

When considering the impact of wind turbine noise on residential neighbours the question as to whether the noise impact occurs when outdoors, indoors or both needs to be addressed. For practical reasons, and in common with other types of environmental noise, wind farm noise assessments focus on the setting of acceptable noise limits external to neighbouring properties. Internal noise levels are accounted for on the basis of an assumed typical reduction in noise from outside to inside. In the case of wind farm noise assessments this reduction standardly assumes that windows are open. However, wind farm noise can lead to complaints inside dwellings where it does not cause any issues outside the same dwelling. There can be a number of reasons for this, any combination of which may cause wind farm noise to be perceived differently indoors than outdoors. Examples of such reasons include:

- the general level of background noise which serves to ‘mask’ the wind farm noise is higher relative to the wind farm noise outside the property than it is inside the property;
- the presence of masking noise due to sources such as road traffic or human activities tends to decrease during the late evening and night-time periods, when residents will tend to be inside their property rather than outside; and
- sound inside a room can be perceived as having a different acoustic character when compared to how the sound arising from the same source is perceived outside.

[51] See terms of reference at: http://www.ioa.org.uk/publications/wind-turbine-noise

APPENDIX H- LIMITATIONS OF NEW NOISE MEASUREMENTS

The only manner in which the actual levels of noise present at the case study wind farms could have been fully established would be to undertake long term noise measurements at multiple locations around each of these ten case study wind farms. However, the technical limitations and costs associated with such extensive measurements placed this option outside both the time and financial budgets of the current project.

The aforementioned requirement for long term measurements arises from the inherent variability of wind turbine noise, where this variability is strongly dependent on the wind conditions experienced, not only wind speeds but wind directions. The importance of this variability was confirmed by the Residents' Survey responses which highlighted the importance of varying wind conditions to the impacts perceived by residents. In HLA's experience, unsuitable wind directions can for example prevail for periods of several weeks. It is this key dependence on the wind which separates wind farms as a source of noise from other sources of environmental noise, which are frequently more predictable with defined operational patterns. It is for this reason that longer-term measurements (of typically weeks or even months) are in practice required to obtain useful and robust information.

As these wind conditions are outside the control of practitioners, it is generally not possible to undertake meaningful noise measurements during short site visits. Such measurements will only provide a snapshot of an unknown range of potential noise levels which may occur over the longer term as wind conditions vary. Such sample measurements may therefore under-represent the impacts experienced during other conditions and times of day.

However, even if long term noise measurement data such as referred to above were to have been available to the project, two additional key limitations also need to be considered:

1. The noise data only becomes meaningful if the individual measured noise levels can be related to simultaneously measured wind speed, wind direction and wind farm operational data. Guaranteed access to such data could not be secured as part of the current project.

2. Any measured noise levels would necessarily relate to the combined contributions of the 'specific' noise from the wind farm plus any other sources of 'residual' noise, including natural wind noise, which happened to be present at the time of each measurement. The level of this residual noise is often close to or higher than the noise from the wind farm. The only means of establishing or evaluating the true level of wind farm noise would therefore require the controlled shutdown of the case study wind farms, and this was not possible as part of the current project. Without this capability it isn't possible to firmly establish the level of wind farm noise only. This is especially the case as wind farm noise levels are often similar to, or below, the level of naturally occurring (and also inherently variable) noise that would be present in the environment regardless of the presence of the wind farm.

The resulting noise levels, although measured, would therefore have been subject to a relatively large level of uncertainty which, in HLA's experience, would have made them of little worth in terms of the aims of the project.

Finally, the project considered a large number of properties at different distances from each of the cases study wind farms. Many of these would have different noise environments, levels of sheltering and exposure to a range of different noise sources. The results of the Residents' Survey showed large differences in responses for locations situated even in close proximity. Therefore the number of locations at which measurements would have been required would have been prohibitive. Also, the applicability of any measurement to other neighbouring locations would have been subject to considerable uncertainties. In contrast, the predictive approach retained for the project allowed consideration of noise levels and their variation over the entire study area, in a consistent way: see Appendix K for examples.

Finally, whilst consideration of noise levels were required as part of the project objectives, as discussed within the main text, noise features such as tones or AM represent another potential aspect of wind farm noise. But measurements and analysis of such features require additional specialist equipment capabilities, lengthy analysis and is subject (in HLA's experience) to similar or even higher levels of variability than overall noise levels.

Similar conclusions relating to the limited utility of noise measurements were also highlighted in another recent large-scale project (study commissioned by Health Canada, 2014). This study of the health effects experienced by residents neighbouring operational wind farms and investigated potential links with exposure to noise (including very low frequency noise or infrasound). This study had a wider scope and larger resources compared with the present project, and undertook approximately 4000 hours' worth of new noise recordings. Despite this, the study relied in preference on calculated noise levels rather than measurements to assess wind farm noise impacts, following consideration of similar practical limitations and complicating factors as those raised for the present study. Before this, other large-scale studies of responses to wind farm noise (as reported in van den Berg, 2008) were also based on calculated noise levels.

APPENDIX I - OVERVIEW OF SUBMITTED INFORMATION IN RESPECT OF NOISE IMPACTS

A review of the submitted information for the ten case study wind farms yielded the following results concerning whether or not their respective the noise impact studies had been undertaken and reported in line with what has subsequently become recommended good practice, as contained in the IOA GPG:

- in only 20% of the cases under study had the source sound power (SWL) data used for the modelling of wind turbines allowed for uncertainty (as is now current good practice, see Appendix K);
- in no case was the calculation of noise levels at residential properties made in accordance with the noise propagation calculation methodology which was subsequently recommended in the IOA GPG (see Appendix K). In some cases the deviations resulted in a method more conservative[52] than that of the IOA GPG and this compensated for the lack of a uncertainty margin considered in the category above;
- in only 20% of cases was relevant supporting information in relation to the background noise monitoring locations provided, and in one case no suitable baseline survey had been undertaken (guidance in IOA GPG section 2, 3 and 6);
- in 90% of cases noise limits were derived from measured background noise data in accordance with ETSU-R-97 (albeit subject to the uncertainties relating to the suitability of the background noise data arising from the preceding bullet point); and,
- in only 20% of cases was wind shear accounted for through the use of ‘standardised’ 10 m height wind speeds derived based on hub height wind speeds (IOA GPG section 2.6).

The foregoing results help to indicate, at least in part, the reasons behind the subsequently reported variability between assessment outcomes and actual effects calculated in accordance with current good practice. Had the current good practice advice been available at the time of the assessments for the ten study sites, then variability across the assessments resulting from different interpretations as to how ETSU-R-97 should be applied would have been minimised.

There was some evidence that the more recent assessments in the study tended to have been undertaken more in line with what is now current good practice in relation to the above points, although this observation was mixed. There was no clear evidence that the scale of the development or the assessment type (EIA or not) had an impact on the standard of the assessment.

[52] In this context, and in the remainder of this section, conservative means that the assessment is more precautionary, as it presents a higher predicted turbine noise levels or reduced criteria.

APPENDIX J- SUMMARY OF REPORTED BACKGROUND NOISE DATA

HLA extracted information relating to the reported measured background noise data from the relevant submitted environmental noise assessment information for each wind farm.

The resultant background noise curves are summarised in Figures J1 and J2 for the ETSU-R-97 quiet daytime and night time periods respectively. This represents the background noise curves for all the sites reviewed. In one case only no long-term or ETSU-R-97 compliant backgrounds were collected but a limited sampling approach was instead retained. These results are therefore not shown in the figures below.

In its review of reported background noise levels, HLA did not reanalyse any ‘raw’ noise data. What was considered of interest for the study were the ranges of background noise levels as derived and presented as part of the submitted assessments. Therefore the relevant information was accordingly extracted from the relevant documents, allowing these derived background noise curves to be plotted in Figures J1 and J2.

The derivation of this background data in most cases[53] allowed noise limits to be derived in accordance with ETSU-R-97, bearing in mind the terms of the relevant planning or appeal consent if relevant. However, establishing definitive numerical noise limits that could be compared across the different sites was a more difficult exercise than anticipated. A number of specific difficulties were identified as follows:

- First, considerable disparity was identified between the manner in which the noise limits had been specified across different case study wind farms. Whilst most had been specified in terms of permissible noise limits relative to the background, the relevant background noise level to be used was not always clear. In some cases only limited, or no, information was available as to the numerical values of the baseline background noise levels that should be used to set the noise limits.

- Where background levels were reported as a function of wind speed there were sometimes inconsistencies in the wind speed reference used, either because it was not specifically stated or, where it was stated, it differed between different assessments. As discussed elsewhere in this report, all the calculations reported herein for the as-built wind farms are based on turbine noise emissions referenced to a 10 m height standardised wind speed. Therefore, any attempted cross-referencing between calculated noise levels and the consented noise limits would lead to erroneous conclusions being drawn if the noise limits were not specifically referenced to the same standardised 10 m height wind speed. In these cases, assumptions were made in terms of the potential wind shear effects in accordance with the guidance of the IOA GPG (section 4.5 of that document).

- In the majority of cases the planning consent was available and included conditions on noise. These conditions typically set out maximum levels of noise from the wind farm. Compared to the extensive condition wording provided as Annex B of the IOA GPG, these were mostly in short form. In some cases clear reference was made to ETSU-R-97, including its tonal assessment methodology, whilst in other cases this was implied or omitted. It was common to see reference to a noise limit set to whichever is the greater of either a fixed level or to a margin above background. However, there was little clarity as to which background levels should be used to determine the noise limits,

[53] In one case in which no ETSU-R-97 baseline background noise levels were available the consent specified a fixed noise limits in any case, allowing a limit to be defined.

for example whether it should be the background levels presented in the ES or a new measurement specific to the complaint location at the time of investigation. In one case the condition deviated from the general approach of ETSU-R-97 for reasons which were not immediately clear.

Figures J1 and J2 show a wide range of variations in terms of the prevailing baseline noise levels obtained for both quiet day-time and night-time periods. At the higher end this could generally be attributed to the differences in the environment experienced at the properties arising from the relative influence of other non-natural sources, with some sites being situated next to major roads or motorways, or in urban areas. The majority of locations were situated in mainly rural areas in which mostly natural sources would be expected to dominate the background. In these situations different levels of sheltering and a range of minor sources could explain the residual variability.

Given the limited information and the lack of adherence to the recommendations of the IOA GPG, it cannot be excluded that the measured background noise levels may have been over-stated in some cases (as compared to what would have resulted from adherence to current good practice). This could in theory be due to use of inappropriate equipment, placement of the equipment, and/or the influence of unknown[54] or uncontrolled sources which were not eliminated as part of subsequent analysis. This would be more likely in cases where, excluding the obviously noisier environments raised above, the measured backgrounds were more elevated, although this is not necessarily the case as the presence of sources such as streams and rivers can elevate the noise levels whilst still being representative.

If lower background noise levels had been derived, this would have resulted in more stringent noise limits and differences in the assessment or wind farm design. The IOA GPG requires all details and results of a background noise survey to be reported in detail, allowing the required scrutiny to be undertaken.

[54] In one case, such an influence of unknown origin was raised but the resulting data was still used as part of the analysis.

Figure J1 Graphical comparison of the reported baseline background noise levels (L_{A90}, dB) across the study sites as a function of wind speed for the ETSU-R-97 defined quiet day-time periods. The levels have been derived from the relevant summary information contained in the various noise impact assessment documents submitted for each of the study sites (one site has been excluded due to a lack of available information).

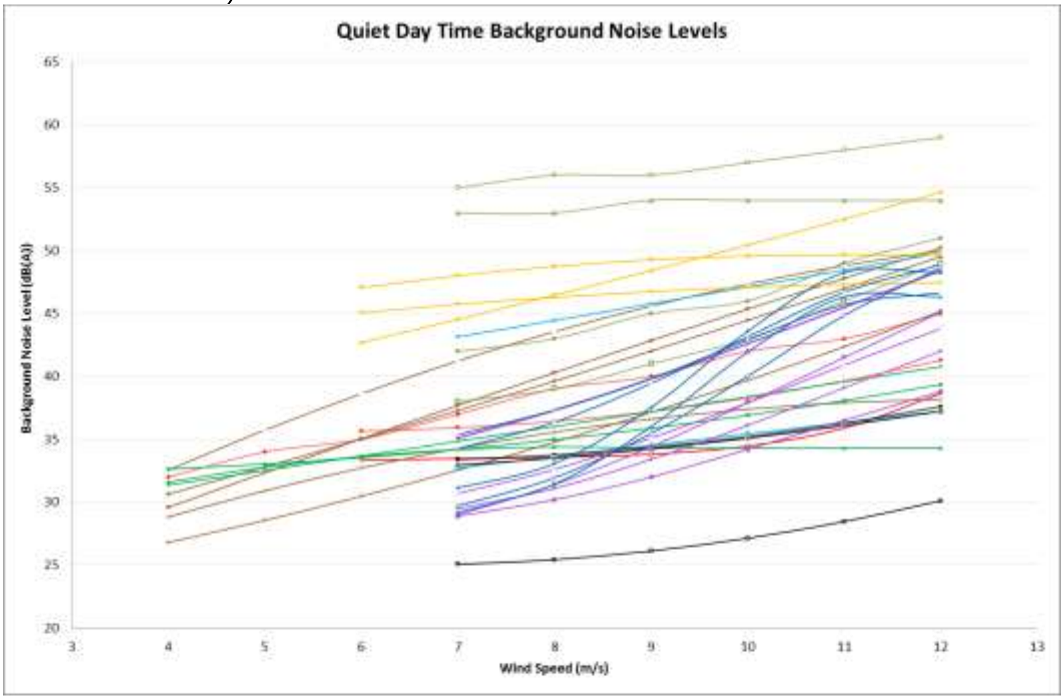
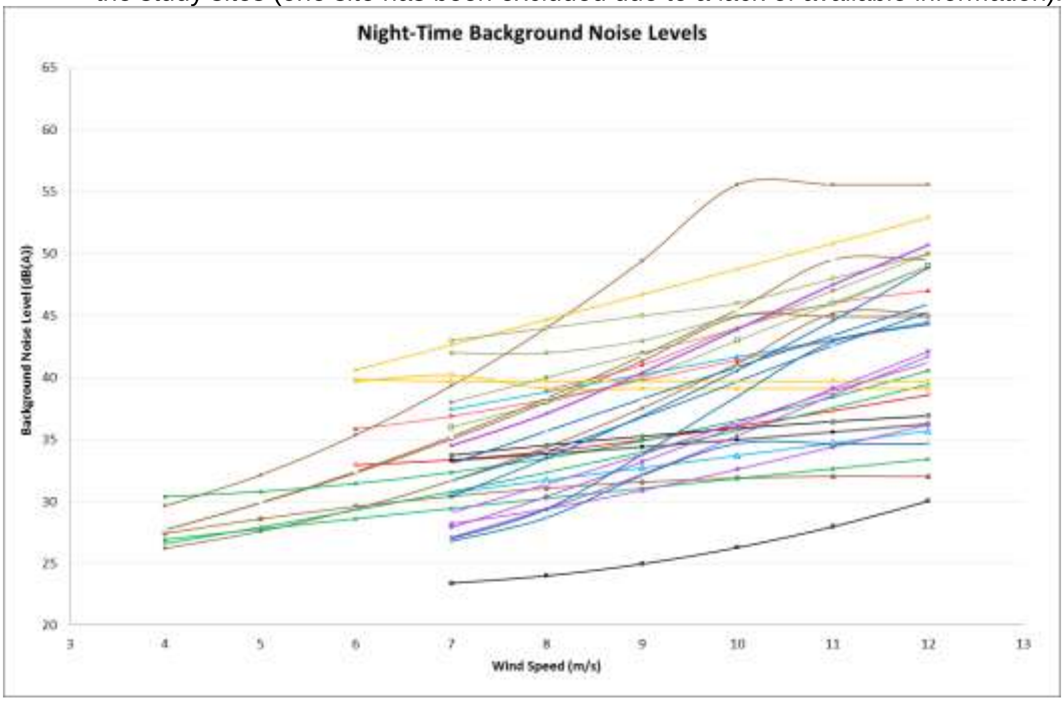


Figure J2 Graphical comparison of the reported baseline background noise levels (L_{A90}, dB) across the study sites as a function of wind speed for the ETSU-R-97 defined night time periods. The levels have been derived from the relevant summary information contained in the various noise impact assessment documents submitted for each of the study sites (one site has been excluded due to a lack of available information).



APPENDIX K- DETAILS OF WIND FARM NOISE LEVEL CALCULATIONS

Noise predictions and contour plots were produced for each of the sites at a reference wind speed[55] of 8 m/s. Such noise contour plots were used to illustrate the calculated spatial distribution of the overall A-weighted L_{A90} noise levels[56] in the area surrounding each wind farm as a result of the operation of that wind farm. These were then used as base-layer maps onto which the results of the subsequently discussed residents' survey were plotted. This visual representation of results allowed an overview to be gained as to the relationship between the survey responses, the proximity of the respondents to the wind turbines and the expected noise levels.

The single wind speed of 8 m/s adopted for all calculations corresponds to relatively windy conditions at which many modern turbines would be expected to have reached their maximum level at source. Therefore, at this representative wind speed, turbine noise levels at neighbouring residential properties would generally reach their maximum. On this basis it was considered to provide a useful common point of comparison. However, a detailed review of available data revealed that it does not paint a complete picture when comparing assessed and actual impacts. For some of the study sites, the actual installed turbines had very similar sound power levels to that of the originally assessed wind turbines at the wind speed of 8 m/s, but large variations of up to around 5 dB sometimes existed between the same turbines when comparing the sound power levels at other (lower) wind speeds. Therefore, whilst HLA considers that the selection of an 8 m/s wind speed for comparison of results across the study sites provided a reasonably pragmatic and representative approach, the potential limitations of this assessment methodology should also be borne in mind.

In terms of the calculation methodology adopted, the IOA GPG provides (section 4 2013) recommendations on the adoption of the ISO9613-2 calculation procedure when predicting wind turbine noise levels. For this reason, the ISO 9613-2 model with IOA GPG recommended variations was used to calculate the noise levels at the selected nearest residential neighbours. The model accounts for the attenuation due to geometric spreading, atmospheric absorption, barrier attenuation, ground effects and differing spectral content between different turbines.

The adoption of the ISO9613-2 methodology meant that the calculated noise contours did not represent the effects of wind directions: for each calculation point the ISO9613-2 predictions assume that the wind blows from the turbines towards the receptor[57]. Thus the calculated noise contours represent a level which would be expected to lie towards the upper end of the range of levels which would be experienced in practice at an 8 m/s wind speed. Under other 'upwind' conditions[58] and/or at lower wind speeds, noise levels could be significantly lower than those calculated using the adopted procedure. However, the key consideration here was the desire to derive all noise exposure levels on a like for like basis. The resultant noise contours therefore provided a conservative ('worst-case') but useful and

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[55] In accordance with relevant standards, wind speeds refer to that measured the turbine hub height and referenced (or "standardised") to a height of 10 m above ground using a standard correction factor.

[56] Wind farm noise is also measured and assessed using the 90 percentile (L_{90}) noise indicator, as it is relatively constant in nature and this limits the potential for corruption by other, louder sources of noise in the environment: see ETSU-R-97 report for details. The same report prescribes that L_{A90} noise levels are obtained by subtracting 2 dB from the noise levels obtained from manufacturer information, which are set out as energy-averaged L_{Aeq} levels.

[57] Downwind conditions.

[58] Wind blowing from the receiver towards the turbines.

meaningful comparison between different wind farms, properly accounting for key physical differences between them, including turbine layout, turbine types and the relative locations of residential receptors.

The IOA GPG recommendations include: using a receiver height of four metres above local ground level, a mixed ground factor[59] (G=0.5) and an air absorption based on a temperature of 10°C and 70% relative humidity. The IOA GPG also advises that the attenuation due to terrain screening accounted for in the calculations should be limited to a maximum of 2 dB, even where no line of sight exists between the receiver and the source. Additionally, in situations of propagation above concave ground, a correction of +3dB should be added: this is called the 'valley' correction.

It is the case for several of the study wind farms that the acoustic details submitted at the planning application stage used a simplified noise propagation model, as described in a document[60] from the Danish Ministry of the Environment, as this model is implemented in several commercial software packages. In these cases the ISO 9613-2 model using the G=0 parameter was used in this study to replicate these specific original assessments for comparative purposes. However, in cases where the Danish simplified propagation model was used but using only the overall A-weighted noise emission values for the turbines the Danish model is less conservative. In such cases the calculated noise levels are closer to the IOA GPG recommended implementation of the ISO9613-2 method, which was therefore adopted.

In terms of wind turbine noise emissions (i.e. their sound power output, at source), the IOA GPG notes that a variety of data sources are often available for a particular turbine model. A recently published IOA guidance note 3 (IOA, 2014) provides additional guidance. When using the parameters above there is "*a requirement of the noise assessment report to demonstrate that, whatever the data source, an appropriate allowance has been made for the potential uncertainty in the data*". This is often the case for wind turbine source data that is warranted by manufacturers, although care is required in the detailed interpretation of such data and adjustments are sometimes still required.

In summary, the calculations made in this study of the as-built noise contours consistently correspond to current good practice in terms of both the ISO9613-2 noise model used and the input parameters used in that model. This includes source emission data which incorporates an appropriate allowance for uncertainty in its specification. At the application stage assumptions made in the reviewed supporting documents sometimes differed from current good practice. Where this was found to be the case the identified differences were accounted for when calculating the noise contours corresponding to the application stage of each development.

As part of HLA's approaches with the case study wind farm operators, information was sought as to any specific operational constraints that may have been implemented on each wind farm. Many turbines models can incorporate noise control technology which allows their sound power output to be reduced across a range of operational wind speeds and/or wind

[59] For porous ground, which includes ground covered by grass, trees or other vegetation, and all other ground surfaces suitable for the growth of vegetation, such as farming land: G= 1. For hard ground, which includes paving, water, ice, concrete and all other ground surfaces having a low porosity: G = 0. Tamped ground, for example, as often occurs around industrial sites, can be considered hard. Mixed ground: if the surface consists of both hard and porous ground, then G takes on values ranging from 0 to 1, the value being the fraction of the region that is porous. G=0.5 is commonly used in wind turbine noise predictions.

[60] Description Of Noise Propagation Model Specified By Danish Statutory Order On Noise From Windmills (Nr. 304, Dated 14 May 1991).

directions and/or time periods, albeit with some loss of electrical power generation, in order to enable the best compromise to be achieved between noise immissions and electrical power generation. In some cases, turbines may also be shut down in specific conditions in order to achieve compliance with derived noise limits. Unless specific information in this regard was provided by the site operators (as requested but only obtained in one specific case) the wind turbines were assumed to be operating unconstrained.

As part of the study the derived noise limits were compared with the predictions for the 'as-built' scenario for each case study wind farm for comparative purposes. However, because of the above limitation, this was undertaken as an indicative exercise only with limited perceived value in assessing actual noise impacts.

For each of the ten case studies, a total of four noise prediction scenarios were calculated (as described in the main report). An example of the output of such calculations is shown overleaf in Figures K1 to K4 for a hypothetical situation (not based on an actual or potential wind farm) for illustrative purposes.

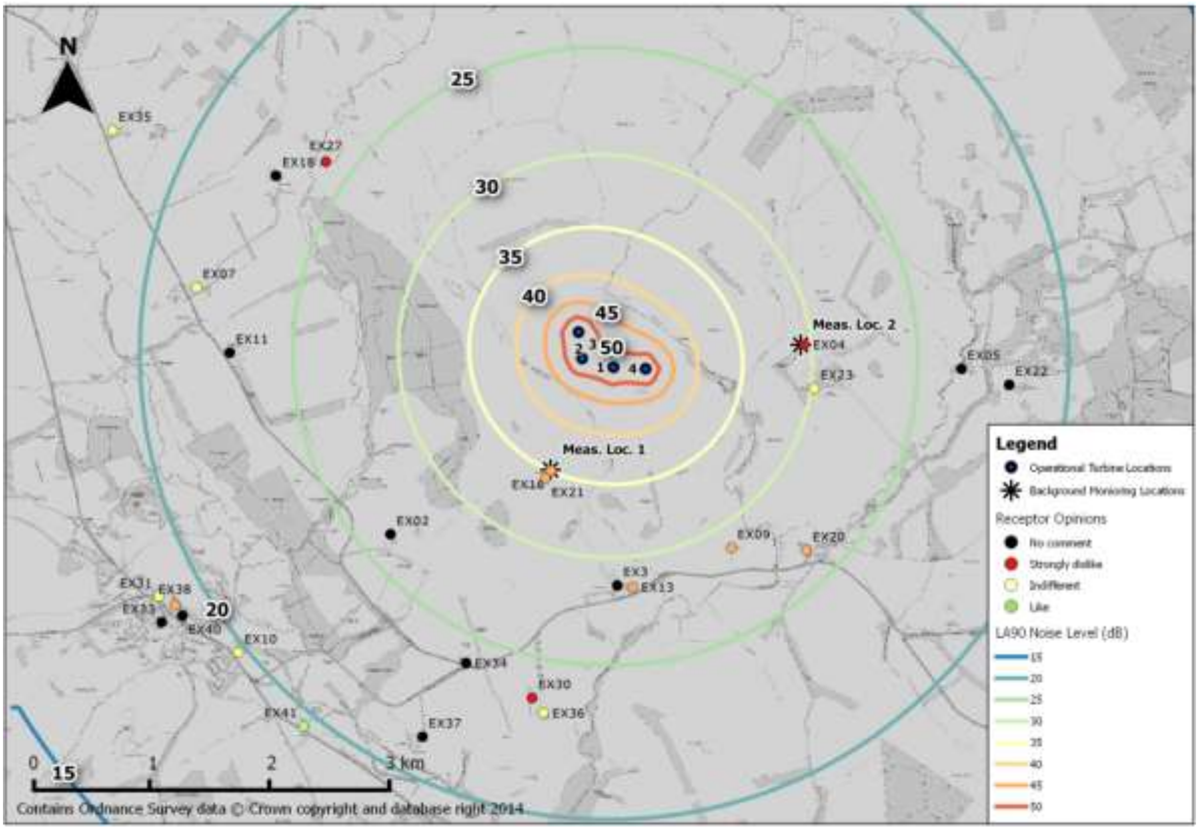

Figure K1 - Planning application layout - Predictions as per EIA/report [hypothetical example to illustrate the method used in this study]

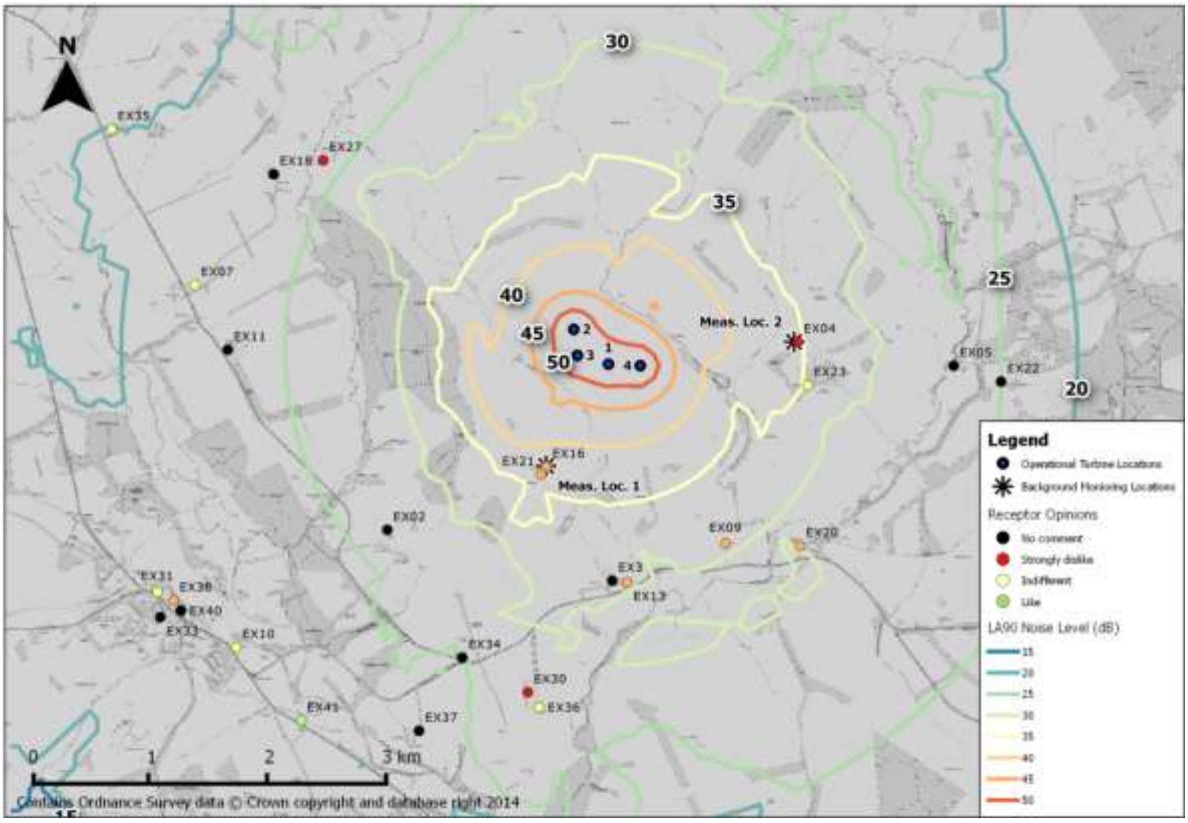

Figure K2 - Planning application layout - Predictions as per IOA GPG [hypothetical example to illustrate the method used in this study]

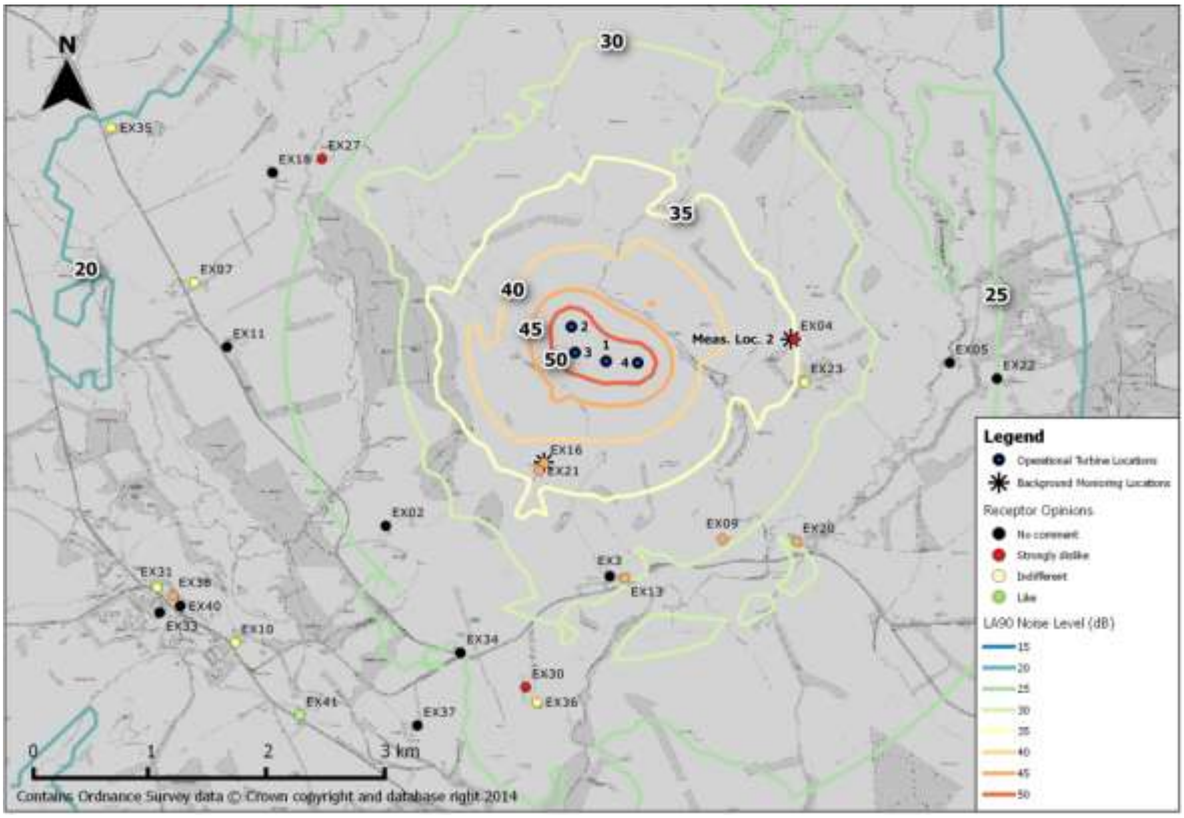

Figure K3 - Planning application layout - Predictions as per EIA/report [hypothetical example to illustrate the method used in this study]

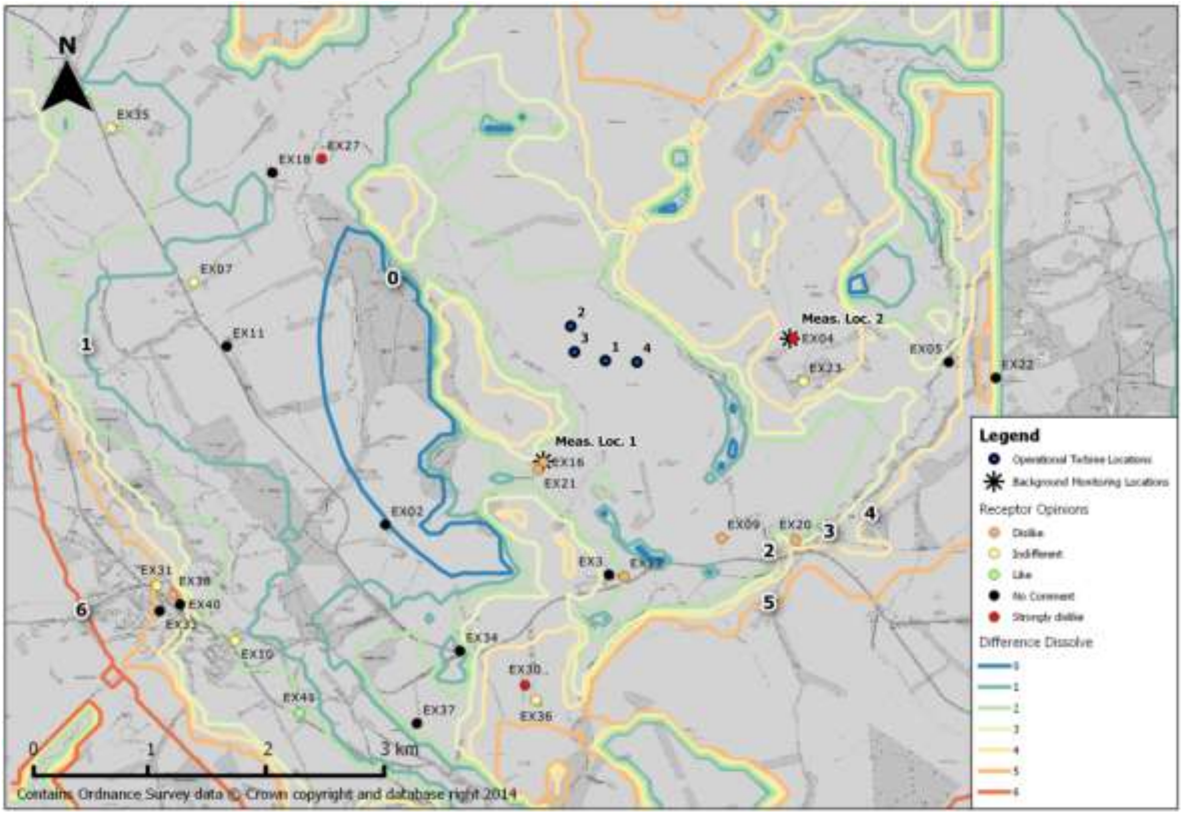

Figure K4 – Difference between the predictions of Figures K3 and K1. [hypothetical example to illustrate the method used in this study]

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Chapter 2 – Scope and Methodology

Chapter 3 – Phase One – Site Selection

Chapter 4 – Phase Two - Assessment of Visual Impacts

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