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Final Draft Report for PSG

Wind Farms Impacts Study

Review of the visual, shadow flicker and noise impacts of
onshore windfarms

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THE UNIVERSITY *of* EDINBURGH

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EXECUTIVE SUMMARY

Main findings

The majority of information presented at planning stage for the ten case study wind farms followed extant guidelines.

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

Community engagement is a crucial element in preparing residents for the impacts.

Main recommendations

How the impacts from wind farms are predicted, measured and documented needs to be standardised and consistent across all developments. 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.

Our specific recommendations are:

- guidance and methodology should be developed for residential visual impact surveys;
- check lists are needed for planners at scoping and post submission stages of an LVIA to ensure consistency and consideration of key matters;
- consistent and clear reporting on the design objectives for a wind farm should be set out in assessments;
- guidance and definitions should be developed for shadow flicker, shadow throw and light effects;
- shadow flicker assessments need to be presented more clearly in public consultations;
- assessments should give fuller consideration to the subjective impacts of wind farm noise, including its character;
- a review should be undertaken to establish whether the existing derivation of noise limits offers the appropriate balance between simplicity, robustness and protection;
- good practice should be developed in terms of modulated noise from wind turbines;
- 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
- decisions about micro-siting should be taken based on the specific implications for visual, shadow-flicker and noise impacts.

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, and geographical location across Scotland. This represented 4% of the total onshore wind energy developments in Scotland in 2013.

Data gathering

Objective assessments do not necessarily account for the potential subjective experience or 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 and mapping which was assessed by professional consultants.

Findings

Visual

Visual impacts on residents living close to the case study wind farms were assessed for all sites with reference to extant LVIA guidance.

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 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 (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 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 too far away for shadow flicker to potentially 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 are clearly defined, or possibly definable. However, a clearer definition of shadow flicker with reference to parameters such as the distances and weather conditions in which it can occur would help both assessments and public understanding of this particular impact.

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 robust and rigorous noise impact assessments to be carried out. This Guide was published after all ten case study wind farms were consented.

There is limited guidance on assessment of certain characteristics of wind farm noise, such as amplitude modulation.

In the Residents' Survey some people predicted to be exposed to similar noise levels reported very different experiences of the noise. 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. 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 features experienced, but this was outside the scope of the current project.

An individual's reaction to a particular noise is generally complex and difficult to relate to a single objective or quantified measure.

There was some evidence that absolute turbine noise levels were of importance, 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 worst impacts.

Modelling noise levels was a better predictor of the experienced impacts than distance alone. This suggests that distance is not a robust way of representing noise impacts.

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.

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 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.
- 1.2 The majority of proposed 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 where the hub height exceeds 15 metres (Schedule 2 threshold) this would trigger 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.
- 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 along 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 is required to distinguish between effects which are significant or 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 authority². If the proposed development is over 20MW³ this would require a statutory 12 week pre-application consultation (PAC) for discussion and possible modification of the application. If the proposed development is greater than 50MW it constitutes a Section 36 application determined by Scottish Government. At this level PAC is a matter of good practice although it is not required.

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 In the case of Section 36 consent this would be Scottish Government, for an application less than 50MW capacity this would be the planning authority.

³ Megawatts of electricity output.

- 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 Wind farms are major infrastructure projects that go through a rigorous planning process. However, there has never been a multi-site study to look at the match between the impacts of a wind farm as assessed in the Environmental Statement or supporting information provided as part of the planning process and the actual impacts once the wind farm is operational. Concerns about proximity of, 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 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 the 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 has been 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 Steering Group 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:

ClimateXChange

- 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.climateexchange.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 provide 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 – 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.

Objectives and Scope of study

- 2.2 The key objectives of the study were to identify whether:
- The significant environmental effects of wind farms may be under assessed in the Environmental Statements (ESs) accompanying applications for energy consent or planning permission;
 - Councils and consultees may not always rigorously examine ESs; and
 - The actual effects, during and after construction, can 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. 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.
- 2.4 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.

Methodology

- 2.5 The study was conducted in two phases as follows:

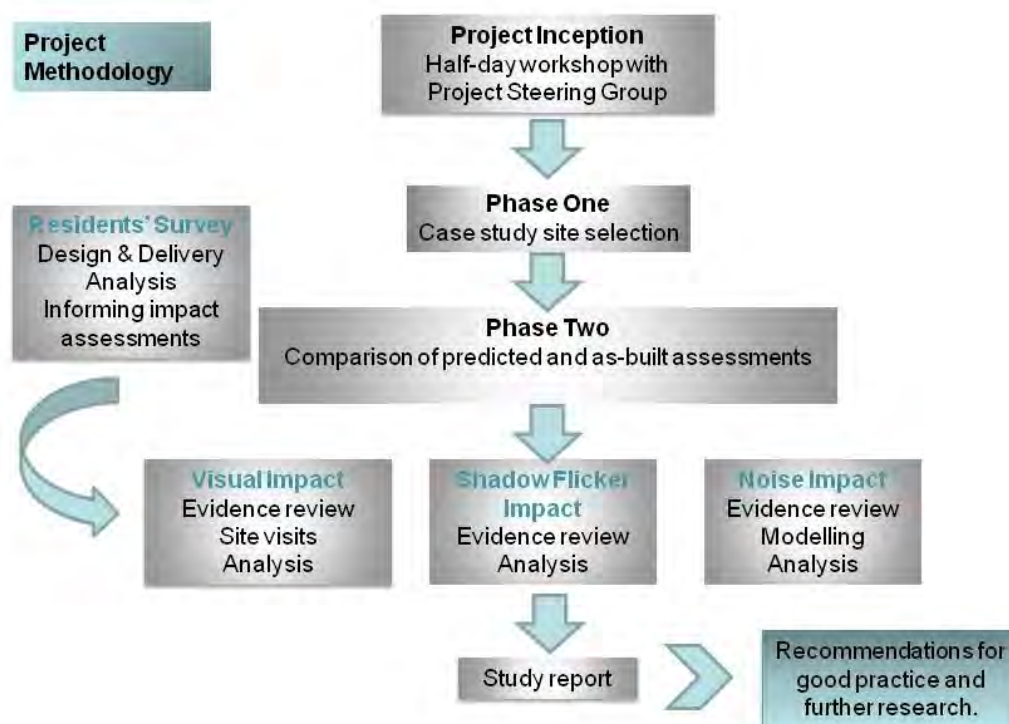
Phase One – Site Selection

- 2.6 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 PSG made the final selection from a shortlist of possible case study wind farms that the consultants developed. The shortlist was itself based upon a longer list of all wind farm developments in Scotland since 2000 (single 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.

Phase Two – Impact Assessments

- 2.7 For each of the ten case study wind farm developments the study investigated how effective the assessment process had been 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.
- 2.8 The local residents' experience was ascertained through a survey administered by post and online. The survey questionnaire is included in Appendix B. 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.
- 2.9 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.
- 2.10 The analysis of the Residents' Survey findings on visual, noise and shadow flicker impacts has been made in respect of the numbers of respondents to each question, rather than in respect to the overall number of people completing the survey for each site. Thus if a respondent did not answer any particular question, this has not been taken into account in the analysis of responses to that question set out in chapters 4 - 6. Non response may be understood as indifference. In order to reflect this, two sets of analysis of the findings are presented in Appendix C, one set which excludes non responses and a second set which includes non responses as "indifferent" to the question under consideration.
- 2.11 The limited number of residents and related low number of respondents at some of the case study wind farm sites means that the % findings which are reported in the study must be treated with caution.
- 2.12 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

- 2.13 During the research process there has been some media interest in the study. As the study aims to draw out good practice and lessons for future planning policy, the PSG decided that the report would anonymise the site by site findings and report on the thematic findings. In terms of the Residents' Survey all information gathered by the study has been 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.
- 2.14 Information from the 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.
- 2.15 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.

- 2.16 The developers and operators whose sites had been selected for the study provided valuable input and data under confidentiality agreements.

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 perimeters 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 noise and visual 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 to include wind farms with known impacts as the most effective way of informing the study objectives. They included less than 4% of wind energy developments in Scotland and are not necessarily representative of the nation’s overall wind farm sector.

Site Shortlisting Methodology

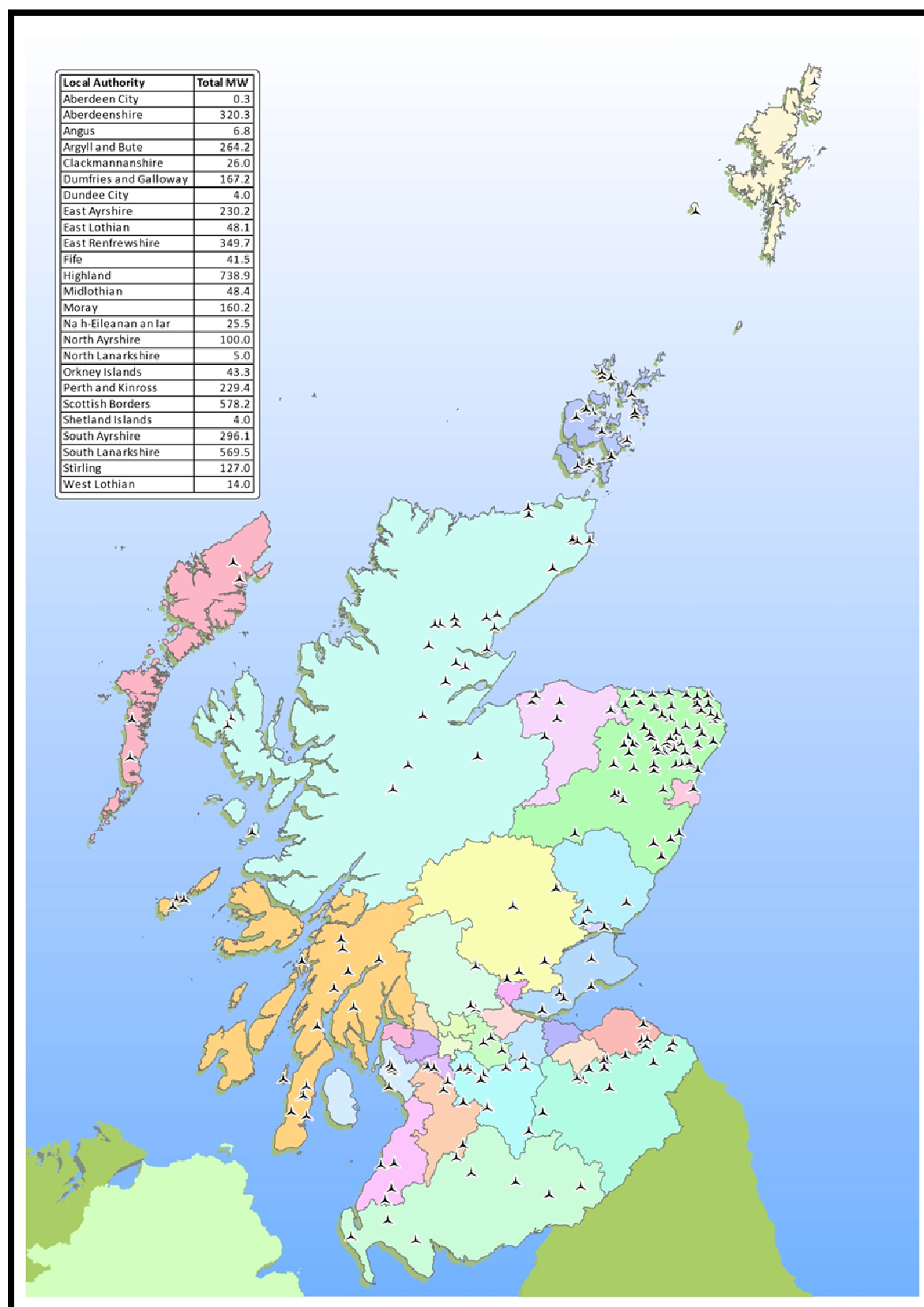
3.4 A stratified sampling approach was used to develop the shortlist of wind farm sites, i.e. the short list of sites was developed through a four stage process starting with the total list of wind farm sites and refining this through a further three stages (or strata) to meet the key selection criteria.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

3.5 The four stages of development 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



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. This included:

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.

Stage 4: Consents Process criteria

3.13 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.

3.14 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.

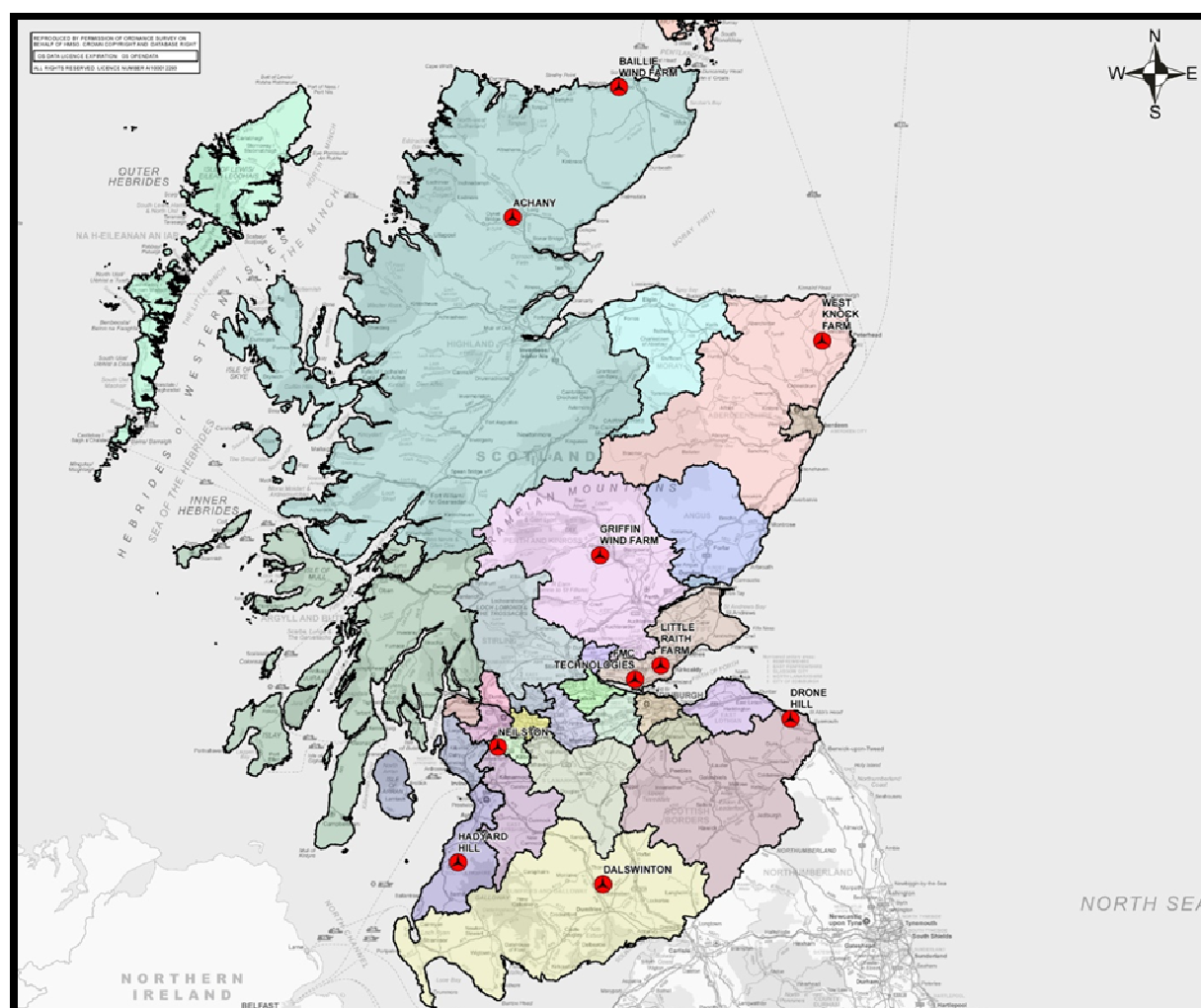
Final site selection

3.15 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.

3.16 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

3.17 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		Elevation (m) (at site centre)	Landscape Character Assessment
		Easting	Northing		
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 Hill	Scottish Borders Council	384100	668000	216m	Coastal Moorland
Dunfermline	Fife Council	310152	685380	38m	Urban
Griffin	Perth and Kinross Council	293700	744400	382m	Highland Summits and Plateaux
Hadyard Hill	South Ayrshire Council	226450	597300	219m	Foothills
Little Raith	Fife Council	318750	691450	139m	Lowland Hills and Valleys
Neilston	East Renfrewshire Council	245350	654000	217m	Rugged Upland Farmland
West Knock	Aberdeenshire Council	398550	844900	90m	Agricultural 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	29/12/2003	29/12/2003	08/05/2006
Little Raith	9	126	25	Planning Authority	02/12/2004	11/02/2008	27/11/2012
Neilston	4	121	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

- 3.18 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

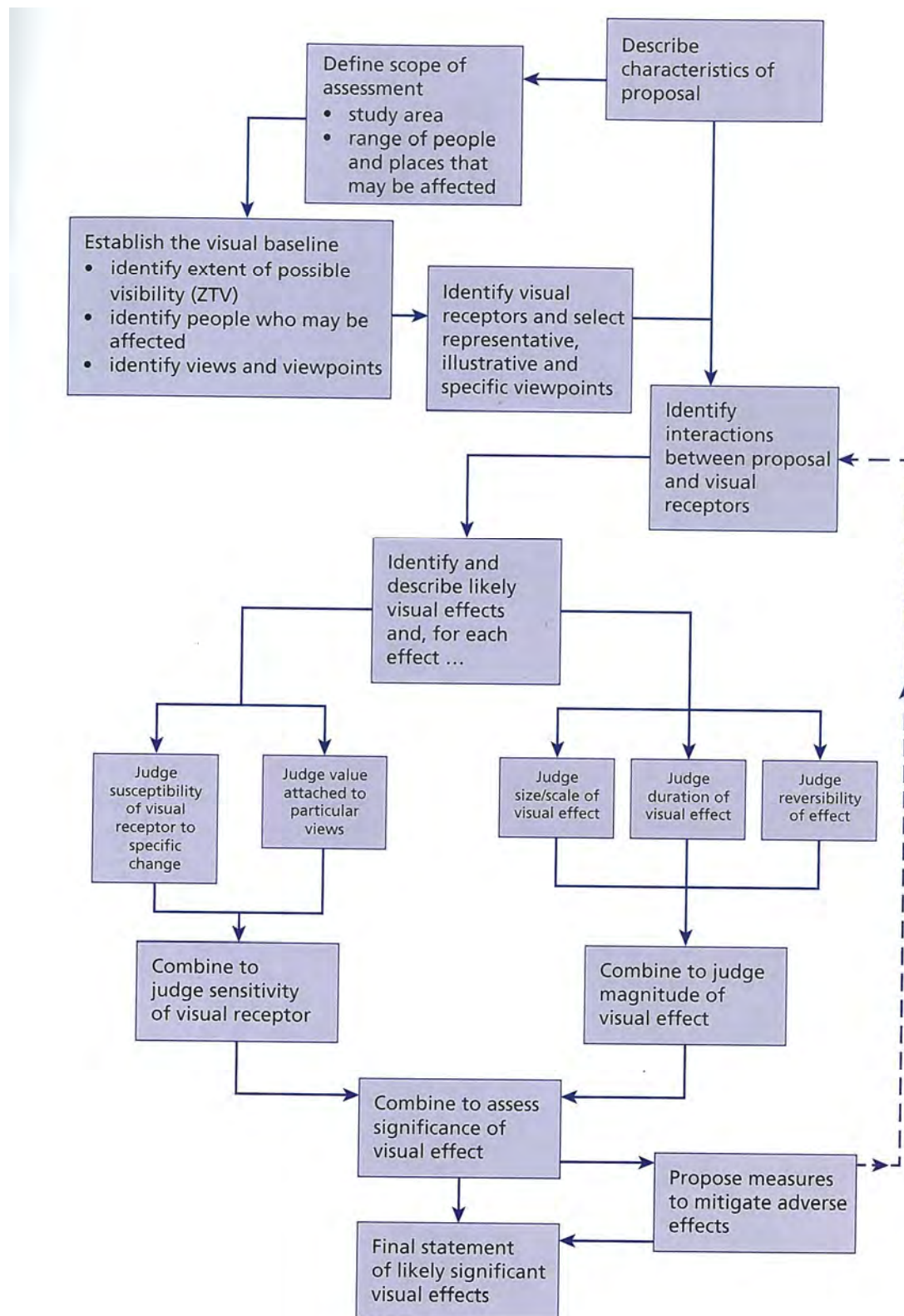
- 4.2 The main source of guidance in respect of the assessment of visual impacts is the publication *Guidelines for Landscape and Visual Impact Assessment*, 3rd edition (Landscape Institute and Institute of Environmental Management and Assessment, 2013), (henceforth referred to as GLVIA 3). This 3rd 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 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 is provided in Appendix D.
- 4.4 The two key parts of the visual impact assessment processs 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. GLVIA3 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.
- 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.

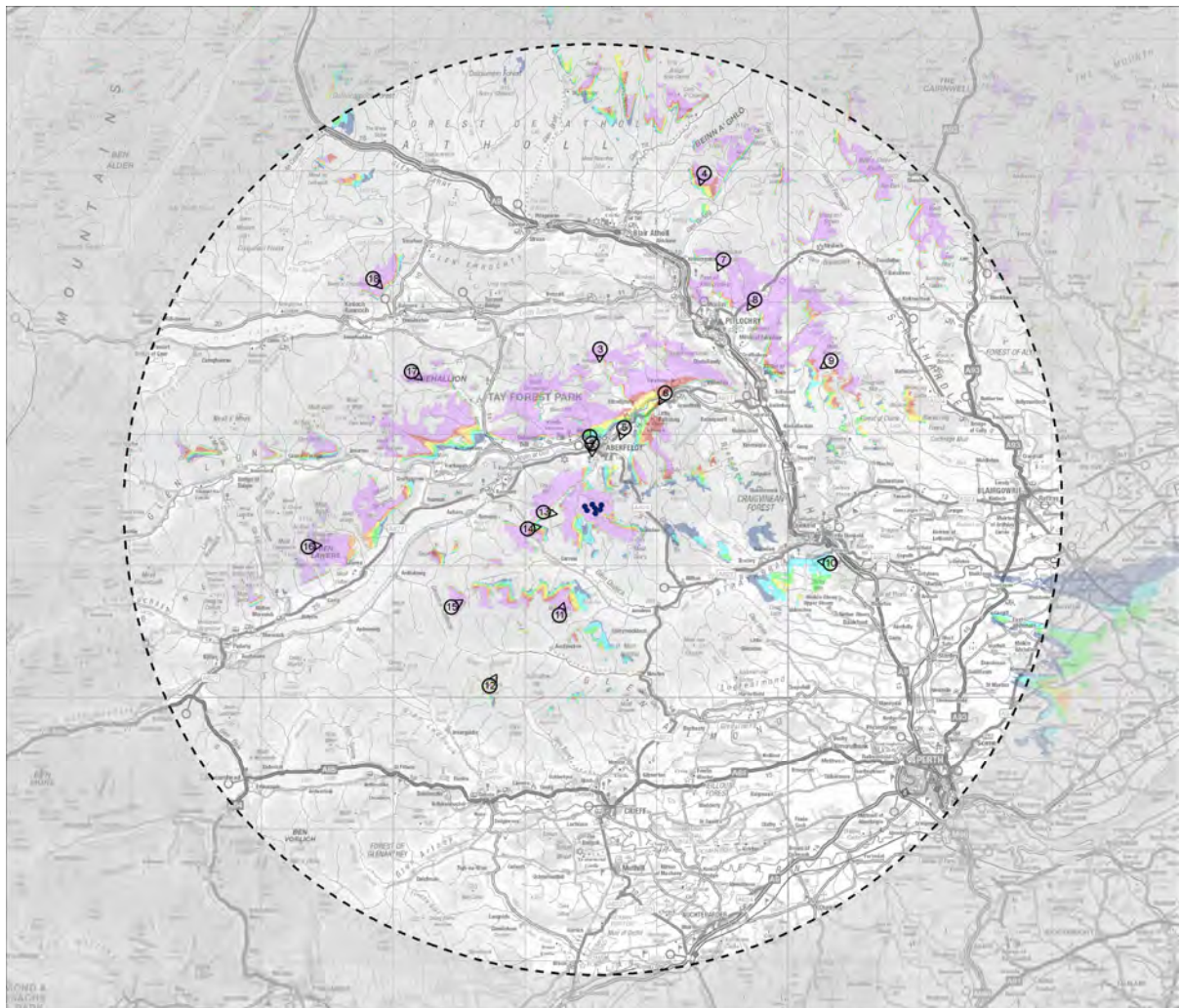
Figure 4-1
GLVIA Assessment process



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 usually 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.

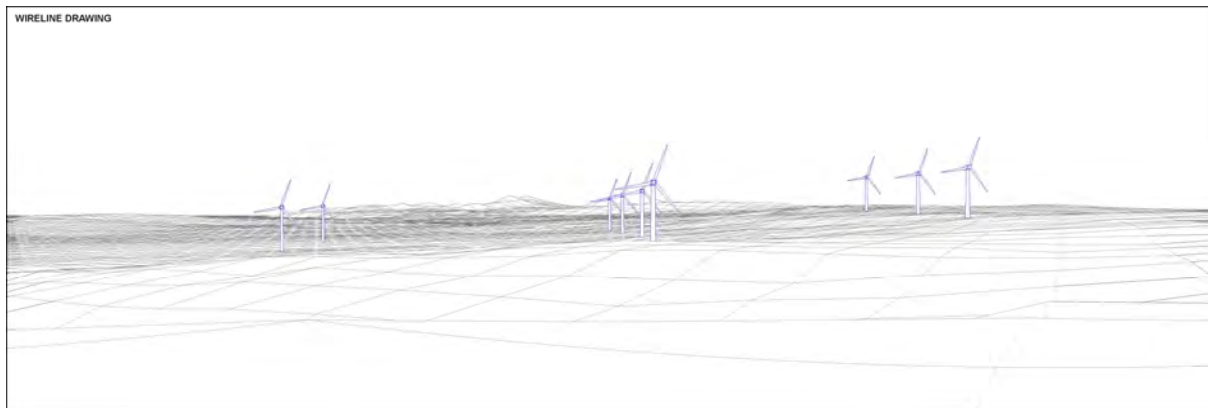
Figure 4-2
Example ZTV



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 Council⁴ and Perth and Kinross Council⁵) 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 is produced to accompany LVIA's for wind farm developments. 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 derived to follow 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 LVIA 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 (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 is 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 by considering 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 has been taken as being long term on the basis that the wind farms are likely to be in situ for up to 25 years. Reversibility has not been considered, as 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 LVIA.
- 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 stage?

- 4.26 Residential visual impacts were highlighted by SNH in three pre-application consultation responses but not for the remaining seven sites.
- 4.27 Similarly, 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.
- 4.28 Whilst it is recognised that most planning officers have 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.
- 4.29 Visual impacts on local residents were noted in respect of the majority of the sites in the planning officers' reports to committee available from the evidence review.
- 4.30 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 LVIA's 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.
- 4.31 Tables were produced in the LVIA's for two of the case study sites at application stage providing more detailed information on the nature of views from individual residential properties within 2km of the nearest turbine. For one of the appeal stage 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. 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. Additionally, they did not identify whether the effects on the respective properties were considered to be 'overwhelming' or render them unsatisfactory places to live, as described in the so-called 'Lavender test'⁶. Of the two instances where these 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 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 LVIA's and Environmental Reports followed guidance extant at the time the assessments were carried out (i.e. GLVIA, 2nd edition 2002). There were three sites for which the LVIA's were not completely consistent with extant guidance in all aspects. In these instances, either 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, or no threshold was identified for impacts considered to be 'significant', which is a requirement of the EIA Regulations.

⁶ "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 an unattractive and thus unsatisfactory (but not necessarily uninhabitable) place to live" Enifer Downs Public Inquiry Report 2009 APP/X2220/A/08/2071880

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 by SLR 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 this was considered not to be the case, and additional viewpoints would have resulted in a more robust assessment of the impacts of the wind farm on residential receptors.
- 4.37 In other instances, 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. 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 consideration of the findings of the respective LVIA's, or in relation to their own assessment.
- 4.39 In some instances it is not clear whether the planning officers' report text is recording the findings of the LVIA's; 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 LVIA's for the case study wind farms in the course of producing their reports.
- 4.40 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

- 4.41 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

- 4.42 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.

- 4.43 During each site visit, an experienced chartered Landscape Architect visited the residential viewpoint locations identified in the LVIA/Environmental Reports predicted to incur significant effects within up to 5 km. They took copies of the relevant visualisations from the assessments. Four of the ten sites were visited by two chartered Landscape Architects in order to calibrate the 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 LVIA/Landscape Report findings.

Predicted Visual Impacts

- 4.44 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 4 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 so no comparison can be made.
- 4.45 At the other 9 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).
- 4.46 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 LVIA/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 LVIA 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.
- 4.47 A 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

- 4.48 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 slight 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.

- 4.49 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.
- 4.50 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.
- 4.51 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.
- 4.52 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.
- 4.53 At one other site, it appears that micro-siting of turbines has resulted in a greater height of turbine being visible from some locations.
- 4.54 It is apparent that, of the ten sites studied; there is considerable variation in the approach taken to micro-siting between their respective local 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 team’s experience.
- 4.55 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.
- 4.56 In respect of single turbines, the difference between no visibility and some visibility which may occur with slight movement of the turbines could alter the difference between no effect and a significant effect occurring. No single turbine developments were included in this study.
- 4.57 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 m apart from the appeal sites where it is anticipated that a revised layout was submitted for which revised visualisations were not obtained.
- 4.58 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.
- 4.59 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.
- 4.60 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.
- 4.61 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

- 4.62 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 are most likely to occur, the focus of the study of impacts on visual amenity concentrated on a 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 LVIA's/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 location 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.
- 4.63 There were seven questions in the Residents’ Survey that directly related to visual impacts (See Appendix B, Q11 – Q17). 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 are 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.
- 4.64 In respect of the rooms in respondents’ houses affected by visibility of the wind farms, this varied considerably across the survey. At all of the case study sites, some public rooms at some of the properties are identified as having views of the turbines, with 43% of respondents across all of the case study sites recording that they did not experience visibility of the turbines from within their properties. 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.
- 4.65 Just under a half of respondents (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.
- 4.66 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.
- 4.67 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 majority of respondents across all the sites recorded that they “strongly dislike” (38%) 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%).
- 4.68 Overall, 15% of respondents recorded that they either “strongly like” or “like” the wind farm; 45% recorded that they either “strongly dislike” or “dislike” the wind farm, and 40% recorded being “indifferent” to its appearance.
- 4.69 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 the appearance 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 acknowledged that at some of these locations there may be filtered views of the wind farm in winter ‘without leaf’ conditions.
- 4.70 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 40% overall recording being indifferent to the visual impact of the wind farm.
- 4.71 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.
- 4.72 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.
- 4.73 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.
- 4.74 The ways in which respondents described the wind farm looking different from expectations based on the planning process illustrations varies 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.
- 4.75 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

- 4.76 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).
- 4.77 All of the LVIA's 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 accorded a high sensitivity.
- 4.78 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.
- 4.79 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 was generally proportionate. 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.
- 4.80 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.
- 4.81 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.
- 4.82 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.
- 4.83 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).

- 4.84 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

- 4.85 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. However, respondents mainly recorded that the built turbines looked larger and closer than those shown in the illustrations. Although 32% of respondents considered that the built wind farm was different or very different from the illustrations, a slightly greater number (38%) 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.
- 4.86 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 July 2014 guidance.
- 4.87 In some instances decision makers appeared 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.
- 4.88 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.
- 4.89 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.
- 4.90 Nevertheless, for individual residents, any slight change, for example to the height of, 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, 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.
- 4.91 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.

- 4.92 From the responses to 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" or "like" the wind farm in question whilst there are others who "strongly dislike" or "dislike" the development. Interestingly a notable proportion (overall 38% with the lowest being 18% and the highest 55%) of respondents recorded being "indifferent" to the visual impact of the development. This spectrum of opinion about wind farm developments is consistent with most of the public attitude surveys about wind farms which have been carried out over the last ten years (Department of Energy & Climate Change Public Attitudes Tracker February 2015).
- 4.93 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.
- 4.94 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 e.g. vegetation being in leaf.

Lessons for good practice

Pre-consent assessment

- 4.95 GLVIA3 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
- 4.96 It is important that clear thresholds for significant effects are identified in LVIA's to comply with the EIA Regulations and thereby to assist decision makers.
- 4.97 The visualisations which accompany LVIA's should be produced in accordance with SNH's visualisation good practice guidance (2014). Following the revised SNH guidance, the illustrative material presented at public consultation events should be the same as that presented in the ESs/ERs.

- 4.98 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.
- 4.99 LVIA should be reviewed by suitably qualified and 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.
- 4.100 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.
- 4.101 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.
- 4.102 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.
- 4.103 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.
- 4.104 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 LVIA 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?
 - Do visualisations meet best practice guidance?

Public consultation

- 4.105 Whilst SLR's experience indicates that wind farm developers do carry out public consultation, the Residents' Survey indicates that a 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 guidance⁷.

- 4.106 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 beneficially influence the public's subsequent attitude to the development. SNH's revised visualisation guidance (December 2014) recommends that the visual material presented at public consultation events is the same as that presented in the ESs/ERs.
- 4.107 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

- 4.108 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.
- 4.109 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.

Visualisations

- 4.110 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 July 2014 revised visualisation guidance.

Post application response

- 4.111 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.
- 4.112 It would also contribute to greater transparency in the decision making process if planning 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.
- 4.113 It would be helpful if planning officers' reports could cross refer between LVIA findings and the visualisations, identifying any discrepancies, should these occur

⁷ Scottish Planning Series Circular 4 2009 Development Management Procedures; and Planning Advice Note 3/2010 Community Engagement

(i.e. if the planning officer's assessment of the effect differs from that predicted in the LVIA report and/or as represented in the visualisations).

- 4.114 Where a 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

- 4.115 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.
- 4.116 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.
- 4.117 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 design aims and objectives.

Micro-siting

- 4.118 A more rigorous and consistent process should be put in place to agree and record micro-siting of turbines post consent. As described above, an allowance of up to 50 m 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 these do not alter the submitted assessments.

Monitoring

- 4.119 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

- 4.120 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, it will encourage a consistent standard of visualisations.

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 had been suitably assessed at the application stage, as part of the ESs/ERs accompanying the application, and whether these have been highlighted 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. For properties in this area, shadow flicker can have an adverse impact.
- 5.3 Shadow flicker happens as a result of the sun passing behind the rotors of a wind turbine, casting a moving shadow over nearby properties. It happens when the sun is low in the sky and shines on a building from behind the blade of a turbine. When the sun is high, any shadows will be confined to the wind farm area, but when the sun is lower in the sky, the shadow of the turbine blades may be cast onto buildings in the surrounding landscape. These shadows will appear to flick on and off as the blade rotates. Whilst shadow flicker is generally not considered a problem outdoors as light is reflected in all directions, a moving shadow cast inside a building through a narrow opening, such as a door or window, could have a more pronounced effect. The effects of shadow flicker can vary depending on the size of opening, its orientation to the turbine and sun, the frequency of flicker and the duration of the effect, either as a single event or averaged over a year.

Planning Policy Guidance

- 5.4 Planning guidance in the UK requires developers to investigate the impact of shadow flicker. This guidance does not specify how to assess the impact, nor how to assess the significance of the impact. Assessments were usually based on PAN45⁸ and the Scottish Government Specific Renewables Advice Sheet on “Onshore Wind Turbines” (revised December 2013).
- 5.5 Other sources of guidance include
- The Companion Guide to Planning Policy Statement 22 (PPS22): Renewable Energy. It 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:
 - “a single window in a single building is likely to be affected for a few minutes at certain times of the day during short periods of the year.”
 - Guidance from Northern Ireland in Best Practice Guidance to PPS18: Renewable Energy (Department for the Environment, 2009) is sometimes

⁸ Planning Advise Note 45 – now revoked

adopted to identify what may be an acceptable duration of shadow flicker. This guidance states that: “*shadow flicker at neighbouring offices and dwellings within 500m 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.

5.6 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 rely upon the German standards or a German court decision. Based on limited research⁹, these two German references specify the calculation of shadow flicker in two different ways.

- German Guidelines¹⁰ 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.”

5.7 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.”

5.8 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 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 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

5.9 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 WindFarm4 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-

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)

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.

5.10 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.

5.11 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 survey 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 1x1m window perpendicular to the Earth's Surface, is usually assumed.

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

- the 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 side¹¹;
- the proximity of any property to the turbine (typically less than 10 rotor diameters from the proposal); and
- the interactions between the above.

5.13 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*.

5.14 In addition, the distance between the turbine and a window has an impact on the intensity of any shadow flicker that is experienced. The intensity of the shadow is

¹¹ Planning for Renewable Energy – A Companion Guide to PPS22 Office of the Deputy Prime Minister (2004)

- greater at locations close to the turbine. As the distance becomes greater the intensity of the shadow is reduced.
- 5.15 The UK does not have any standard significance criteria to assess shadow flicker impacts and there is no UK statutory limit or guidance to stipulate acceptable levels of shadow flicker.
- 4.121 Analysing the potential for shadow flicker is dependent on actual wind speed data¹² or estimated wind speed¹³.
- 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; and
 - Reducing turning of rotor to 63% of the maximum possible if the wind turbine is assumed to be randomly yawed¹⁴ 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. The experienced effects of shadow flicker will vary from person to person. In the absence of published guidance, no significance criteria have been established to assess shadow flicker impacts. 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 (high or moderate) or not (low or negligible).
- 5.18 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

- 5.19 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 similar to the example below:

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 turbine 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 very conservative assumption.

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

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

Figure 5-1
Example Shadow Flicker Map



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

Study methodology for shadow flicker impacts

5.20 The assessment of whether shadow flicker impacts have been appropriately assessed at the application stage and whether the actual effects of the operational wind farm differ from those anticipated at the application stage has been 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)

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

5.22 Five of the assessment used computer modelling, typically, Resfot's Wind Farm 4. Of those that were modelled, one carried out a survey of the affected property. One gave no evidence of methodology. The number of affected properties ranged from seven to 17. 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).

- 5.23 Four sites 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.
- 5.24 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.
- 5.25 The plan was required to include a range of residential properties to be remotely monitored for one year from commissioning of the wind farm to study the effect that shadow flicker can have on amenity.
- 5.26 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.

Significance Criteria

- 5.27 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 hrs for *likely* duration (i.e. moderated effect). The resulting assessment identified some significant impacts.

Residential surveys

- 5.28 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

- 5.29 For those sites that were assessed through modelling the potential shadow flicker impact at properties within 10 rotor diameters of the nearest turbine, four predicted

some level of impact and three concluded that shadow flicker would be unlikely to occur or would not be significant.

- 5.30 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

- 5.31 Of those sites where a potential impact was predicted, the following mitigation measures were 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.

- 5.32 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 it was an issue, i.e. to wait until operation and liaise with residents to assess the effects.

- 5.33 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 site 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 and, time and, location of the wind turbines and as well as the locations of nearby houses, is used 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

- 5.34 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 has 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

- 5.35 There were seven questions in the Residents' Survey that directly related to shadow and light effect impacts (see Appendix B, Q18-Q24). These covered:
- Whether the residents experienced light or shadow effects;
 - Whether these were light, shadow throw¹⁵ and/or shadow flicker;
 - How they 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.
- 5.36 The majority of respondents reported little or no light and shadow effects. 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 experiencing shadow flicker and three sites had 12-19 experiencing shadow flicker. Light effects 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.
- 5.37 For those that experienced light and shadow effects, the majority "disliked" or "strongly disliked" these effects, in particular shadow flicker. However, a few respondents stated that they liked or were indifferent to shadow flicker impacts. Some of the other concerns mentioned included claims that flicker may be triggering migraines, causing dizziness and/or nausea and causing concerns with regards to epilepsy.
- 5.38 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.
- 5.39 There were a variety of responses as to how these 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 which in one response was thought to cause an effect similar to lightning. For shadow flicker there was a range of responses including:
- More profound in spring and summer,
 - Worse as days get longer, spring and autumn (evenings), two weeks either side of the shortest day, and
 - Moon light causing night time flicker.

¹⁵ There is no standard definition of "shadow throw" but it generally is taken to mean shadow effects caused by the movement of rotors which occur beyond the 10 x rotor diameter of shadow flicker.

- 5.40 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.
- 5.41 For those that experienced light and or shadow effects some 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;
 - Using window screening; and,
 - In one case, leaving their property temporarily to escape.
- 5.42 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. These ranged from “as expected” to “very different” with a high number of “don’t knows”. In the cases where the effects were considered different to expectations responses included;
- No information was seen before construction of the wind farm;
 - They were deemed too far away for shadow flicker to occur; that
 - The impacts were much worse than expected; and
 - The promised mitigation has not happened.
- 5.43 In one case shadow flicker was reported as being experienced at greater than the 10 rotor diameters distance from the nearest turbine.
- 5.44 Several of the comments indicated 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) illustrated that there may be different understandings of what is meant by these terms, despite them being specifically defined in the survey.

Mapping of potential shadow flicker impacts

- 5.45 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.
- 5.46 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 boundary where it would occur. 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 of the ten rotor diameter boundary and therefore the shadow flicker impacts were not assessed but it is possible that residents are affected.

- 5.47 Of the six sites where SLR did predict a potential shadow flicker impact, between one and ten residences across the sites have the potential to experience shadow flicker. This broadly concurred with the applicants' assessments. However, there were residents who reported experiencing shadow flicker impacts but also some who stated no impact within the zone of impact and several who did not respond to the survey.
- 5.48 The responses from residents also indicated that in some cases shadow flicker is experienced where it is not predicted from the applicant's and 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 ten times rotor diameter. In other cases where shadow flicker is anticipated on the basis of the assessment, it is not reported as an impact.

Summary of key findings from assessment process

- 5.49 As was the case for the visual impacts there was considerable inconsistency in the availability of relevant documents.
- 5.50 For the case studies considered here, it appears that the modelling of those residences within 10 rotor diameters may not capture all those residences that experience or believe they experience shadow flicker or similar effects once the wind farm is operational. There may be a case for widening the assessment to 11 rotor diameters or a set distance, such as, 1 km to provide a more comprehensive assessment and to make allowance for micro-siting of turbines.
- 5.51 In a few cases the more detailed assessment 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.
- 5.52 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.
- 5.53 In general it is 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.
- 5.54 On the basis of the evidence review it appears that the Environmental Health Officers 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 local authorities seeking to minimise future complaints regarding the effects of shadow flicker from the development.

- 5.55 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.
- 5.56 Shadow flicker impacts on residents at the majority of the sites that were assessed applied a combination of available guidance.
- 5.57 The manner in which shadow flicker impact assessments are presented could possibly be improved in order to show how residents may experience this for an operational wind farm. This might include:
- Broadening the assessment to light and shadow effects;
 - Providing examples from current wind farms including the typical periods of exposure, and
 - Providing more details in terms of mitigation measures through software control programmes for turbines.

Summary of key findings of effects from operational developments

- 5.58 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 necessarily currently included 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.
- 5.59 The Resident 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 (predicted or not predicted) there are some residents who are indifferent to this and some who strongly dislike the effects, especially of shadow flicker.
- 5.60 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. They then found that the experience of the operational wind farm was very different from what they anticipated.
- 5.61 Monitoring and mitigation appears to have been at least partially successful in reducing the effect and related complaints. The findings indicate that mitigating through use of wind turbine software is more successful than modifications by use of blinds or changing the use of rooms within households.

Lessons for good practice

- 5.62 Developing a clearer definition of the light and shadow effects that can be experienced when living close to a wind farm would improve the assessment of shadow flicker. The definition would include the parameters of where and in what weather conditions these light and shadow effects might occur.
- 5.63 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.

- 5.64 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 all light and shadow effects with shadow flicker being one of these;
 - Examples from current wind farms including the typical periods of exposure; and
 - More details in terms of mitigation measures through software control programmes for turbines.
- 5.65 Public consultation with regards to light and shadow effects could be improved by provision of clearer definitions, how assessments should be carried out and presented in an accessible way.
- 5.66 It must be noted that the ten case studies wind farms all went through the consenting process before 2011 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 actual noise impacts of the operational wind farms.

General Environmental Noise

- 6.2 In many areas of planning there is a need to set target noise levels based on relatively simple and objectively quantifiable measures of noise. These target levels are generally aimed at limiting to within an acceptable degree the potential impact of noise on people, whilst still allowing otherwise necessary or desirable development. The most commonly used single figure measure of noise is termed the overall “A-weighted”¹⁶ 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 noise 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 attitude of the individual towards the source of the noise.
- 6.4 Such diverse factors are effectively encompassed in the definition of ‘noise’ as: ‘sound that is unwelcomed by a particular individual in a particular situation’, thereby requiring some element of response on the part of the individual who hears the noise, and not just reliance on the level of the sound.
- 6.5 Meeting target noise levels 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

¹⁶ This metric was developed to reflect perceived loudness by accounting for the response of the human ear to sound, see Appendix F.

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 with changing wind speed or direction;
- it can occur at any time of day, evening and night, with the only controlling factor¹⁷ being whether or not the wind is blowing; and
- it can contain certain acoustic features.

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 wind¹⁸. But 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 short¹⁹.

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 often characterised by a tonal²⁰ 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

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 whilst the other only occurs under a specific set of conditions. The issue of AM is discussed in more detail in Appendix G.

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

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 Institute of Acoustics (IOA) Good Practice Guide (GPG) (IOA, 2013). 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 Scottish Wind Farms Impacts Study - Noise

- 6.11 The methodology for the noise element of the present study was driven by the project Research Objectives, as set out in Section 2 of this report.
- 6.12 The methodological approach adopted by HLA in assessing noise impacts across the ten case study wind farms selected for the final study 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 information²¹ where available, and also the results of any post-construction noise compliance measurements or noise complaint investigations;
 - modelling work to compare the predicted wind farm operational noise levels to the operational noise contours calculated for the as-built schemes, the latter being calculated by adopting a common calculation methodology across all sites in accordance with current recommended good practice;
 - a review of subjectively 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 responses²² - this final element of the project supplemented the originally envisaged scope.

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

²² 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.

- 6.13 The methodology used by HLA in assessing the actual noise impacts from the ten case study wind farms was based on the current good practice recommendations of the IOA GPG. 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 and robust (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 objective and subjective terms. This mirrors the separation between quantitative and qualitative assessments in Scottish Planning Policy, set out in PAN 1/2011.
- 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. This is first because of the recognised importance of this measure in environmental noise assessment in general (see Appendix F) and, second, because this is the basis of the relevant ETSU-R-97 methodology. 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 manner by which actual levels of noise occurring at the case study wind farms could be fully established 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. 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)²³.
- 6.17 HLA and the project team therefore concluded that likely 'actual' noise levels would, on balance, best 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 consistent application of this methodology across all ten of the study wind farms allowed for the meaningful comparison of results. These calculations can then be compared to the predictions made at the planning stage.

²³ Health Canada undertook a study (2014) 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 (Appendix H).

- 6.18 Some of the study wind farms have been subject to post-construction noise monitoring. The present project therefore sought information regarding these operational noise measurements²⁴ 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 predicted noise levels to further support the approach taken.
- 6.19 The guidance in PAN 1/2011 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 subjective 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 PAN 1/2011 as ranging from the noise being just noticeable on occasions but having little direct consequences, to 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), through 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 The present study assessed actual subjective 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 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 accepted potential limitations of surveys of self-reported effects, the Residents' Survey responses usefully show the extent to which respondents report being personally affected by wind farm noise. In this regard, the considerably more comprehensive²⁵ study by Health Canada (2014) concluded there was a significant correlation between self-reported and objectively measurable effects. However, even that larger scale and more closely controlled study reported the caveat that its conclusions could strictly only be applied to the 18 wind farms and ~1200 respondents that made up its sample population. This underlines some of the challenges inherent in translating such research findings into practical guidance.
- 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 approaches 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.

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 It included the collection of health-related objective end-point data such as sleep actimetry, hair cortisol, heart rate and blood pressure, along with a more comprehensive survey design.

- 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 subjective 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 the present 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 The present 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 adherence to a common agreed best practice methodology could have reduced such variability. However, it is fully acknowledged that what is now best practice was not necessarily so at the time the planning applications for the study wind farms were being prepared and there is therefore no implied criticism of any of the noise assessments in this regard.

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. 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 public²⁶ 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 some cases, scheme layouts had been revised and also the number of turbines possibly 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 In most cases where information was available, 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. 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.
- 6.32 There was in general limited consideration by the local authorities of other factors, such as audibility, beyond compliance with the requirements of planning guidance and ETSU-R-97. 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 generally dismissed with the exception of the potential for tones which were raised in at least two cases, and in these instances conditions were proposed.

²⁶ <http://www.thewindpower.net>

Appeal Reports

- 6.33 In respect of the four wind farm case studies which were subject to a planning 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 planning inquiry process leads to a more detailed scrutiny by its nature.

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 environmental report 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: this is now considered good practice.
- 6.36 The conditions also generally required 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.

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 current good practice²⁷. As previously discussed, the IOA GPG now exists and is recommended for use 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 with 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.

Scrutiny of Noise Assessments

- 6.39 Detail of the technical scrutiny undertaken by the local authorities was generally not available. However, information now required to be provided 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 or their associated technical appendices. This suggests that guidance on good practice can play an important role in driving improvements in noise assessments and their clarity, and as a result assist the scrutiny of such assessments by consultees.
- 6.40 The advice provided by the IOA GPG provides a framework for consistency in approach to wind farm noise assessments themselves, including minimum requirements for the information provided in the assessment submitted with an application. In turn this assists stakeholders by providing an equally structured framework for technical scrutiny, including the information required to be presented and the points to be examined as part of any consultation review.

Noise Assessment Locations

- 6.41 In addition to their collation of data obtained by others as part of post-completion noise measurements, HLA also collated²⁹ 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 in terms of the actual locations at which background noise was measured, the equipment used,

²⁷ The purpose of having undertaken this analysis is not to imply any criticism of the assessments done at the time, but rather to assess whether those assessments may have been more consistent and robust had they been undertaken in accordance with the good practice guidance that is currently available

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.

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.

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 accordance³⁰ 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 subjective 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, this being 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 generally not considered in detail except by reference to the procedures set out in ETSU-R-97. When tonal noise was specifically considered it was stated that such noise was unlikely to be an issue from modern technology wind turbines.

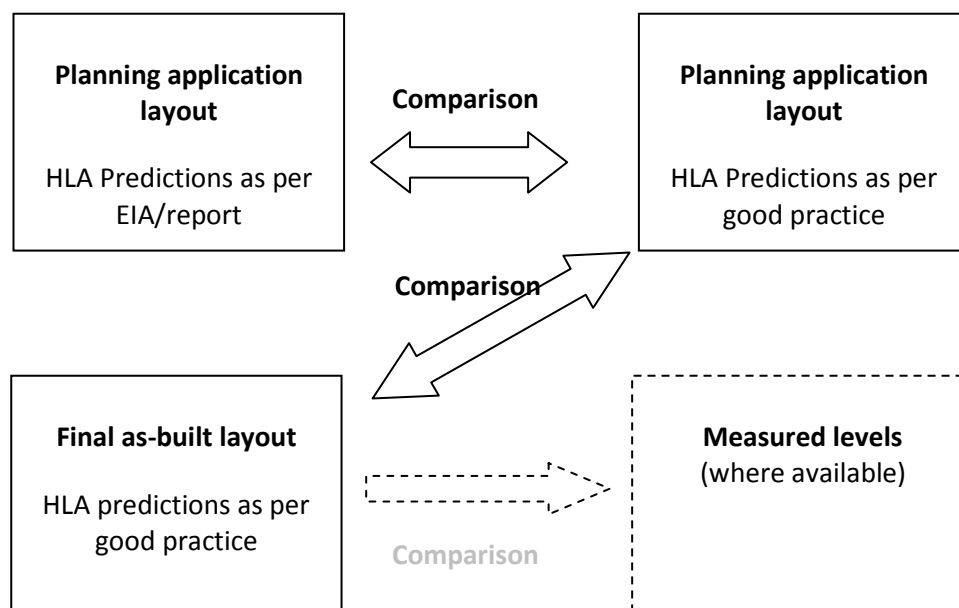
Operational Noise

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 by HLA 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 expected noise levels. This process is illustrated in Figure 6.1 with further details and examples presented in Appendix K.

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.

**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 results of the measurements (see next section).

6.49 The calculations made in the present study of the as-built noise contours all correspond to current good practice. Assumptions made in the supporting application stage 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 operational mitigation applied. It is possible that turbines at other sites 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 In addition to baseline information extracted from the planning and supporting documents, five of the selected wind farms were subject to post-completion operational noise measurements. These measurements were generally undertaken either as part of a requirement to demonstrate operational compliance or as a result of complaint driven investigations. HLA sought the results of such measurements via direct approaches to the case study wind farm operators and/or the responsible planning authorities.
- 6.52 Therefore, although no new noise measurements were undertaken by HLA as part of this project, noise compliance measurements were in the end obtained for half of the case study wind farms considered (50%) from a range of sources. This represented a total of ten measurement locations. No re-analysis of measured numerical data was undertaken but, in each case, the results obtained were critically reviewed and analysed in relation to the measured background data at the planning stage (where relevant) and the predictions based on the as-built model.
- 6.53 Although this dataset of measured noise was not comprehensive, it provided useful information in terms of both:
- **Overall levels:** it was one of the initial aims of the present research 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 wind farm noise compliance measurements obtained from others usefully showed that the good practice predictions that HLA used to inform the present study were robust. For the five locations at which wind turbine noise was most clearly measured, and over the range of wind speeds where turbine noise was clearly identifiable above the background noise of other sources, HLA's predicted levels were either equal to the measured turbine noise levels (2 locations) or were over-predicting these levels by 1 dB to 5dB or more (3 locations).
 - **Character:** the compliance measurements in some cases presented evidence of the specific character of the noise. This evidence was either through objective identification of features (for tonality) or through the reporting of subjective descriptions of the noise from affected residents or the measurement practitioners (in the case of amplitude modulation). This highlights the difference between tonality, for which an objective rating method is described in ETSU-R-97, and AM for which no such method currently exists. For three of the noise reports reviewed however, no consideration of the character of the noise was undertaken, as this was not a requirement of the planning conditions for the wind farm.

Predictions: summary conclusions

- 6.54 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.

- 6.55 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 by HLA 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 in terms of 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 not only for potentially affected residents but also for the 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 (20%): 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 5dB)	
ES over-predicted as-built situation in 3 cases (by 1 to 4 dB)	
The remaining 3 cases had limited /differences (+/-1dB)	

- 6.56 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 it could be due 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.
- 6.57 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 the former situation (under-prediction), in only two of these four cases did this under-prediction lead to a predicted 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 any evidence of this.
- 6.58 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. 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) and potential penalties of up to 5 dB arising from the presence of audible tones would be much more significant when present.

- 6.59 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. When this correction was applied it was found that this generally did not have a 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 of these two cases, actual compliance measurements were available and this predicted effect was not observed in practice in the measurements. This observation is consistent with measurements undertaken at a number of sites in the UK for which detailed wind data are available and which 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 higher wind shear conditions³¹.
- 6.60 Finally, comparisons made with measurements of noise from the operational wind farms at half of the case study sites supported the use of the methodology for this study, and confirmed it to be sufficiently robust.

Residents' Survey

Methodology and Overall results

- 6.61 The following observations strictly relate to the ten case study wind farms and those respondents who took part in the Residents' Survey. The findings cannot necessarily be applied to specific situations that may exist at other wind farms, although they may be used in conjunction with other studies to further the general understanding as to how wind farm noise may differently affect residential neighbours to such developments.
- 6.62 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 by the University of Edinburgh. 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.
- 6.63 This initial summary analysis determined that the majority of respondents in the survey were largely indifferent to the developments. However, 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).
- 6.64 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

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

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%.

- 6.65 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.
- 6.66 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.
- 6.67 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.
- 6.68 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.
- 6.69 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%);

- the time of day of reported audibility, when indicated in the responses, tended to be uniformly distributed;
 - those that reported the noise as audible indoors tended to express more negative reactions to the noise;
 - 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).
- 6.70 The results did not therefore support the possibility raised in Appendix G that noise impact is necessarily more prominent indoors rather than outdoors. However, this observation cannot be used to necessarily conclude that night time noise impact indoors is necessarily less significant than daytime impact either indoors or outdoors.
- 6.71 The range 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 reported that they could hear noise, and who reported that they were indifferent to it.
- 6.72 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 because of the noise, experiencing health problems, with headaches, and painful ears. One resident described the noise as pervasive and from which there was no escape. 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 below).
- 6.73 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.
- 6.74 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 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. However, this correlation is by no means perfect; that is, across 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.
- 6.75 The picture that emerges from this overall review 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.

Specialist review - method

- 6.76 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 focussed on the noise questions, with additional consideration of responses to other questions when relevant.
- 6.77 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.
- 6.78 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.
- 6.79 HLA acknowledges that the analysis of subjective noise descriptors in such self-reporting surveys is rarely straightforward. For example, the identification of descriptors associated with amplitude modulation could be representative of the general, inherent modulation present in any turbine noise as much as it could describe particularly marked or enhanced³² amplitude modulation. Thus these descriptors are not conclusive in themselves. Rather, they represent an indication of the potential for features in the wind farm noise which may explain some of the responses and/or warrant further investigations.
- 6.80 Indeed, some of the follow-up interviews described below suggested that in some cases in which the noise was described as a 'hum' then this most likely referred to the general broadband 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 200Hz³³, 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'³⁴, 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.

³² 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 subjective impact, than that expected of 'normal' blade swish.

³³ 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.

³⁴ 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.

- 6.81 Regarding amplitude modulation, it was generally not clear whether the residents were objecting to a general or moderate level of modulation or swish, which is expected to some extent from wind farms under the ETSU-R-97 guidelines³⁵, or whether more pronounced or specifically marked modulation or (E)AM³⁶ was experienced at these locations.
- 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 as 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 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.

³⁵ 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.*"

³⁶ The term EAM has historically been used to signify 'Excess AM' or 'Enhanced AM', although this presumes a knowledge as to what constitutes 'non-excess' or 'non-enhanced' AM, for which there is no agreed definition.

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 m 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. The finding illustrates the potential limitations of setting planning constraints in terms of noise merely through the use of minimum setback distances.
- 6.86 In terms of the responses as a function of predicted noise levels, wind farm noise is largely reported as being not 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 again corresponds with the reported dislike of the noise, with an increased dislike generally being reported within and above the 35 dB(A) to 40 dB(A) predicted noise level range. These observations are consistent with previous research³⁷ 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

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.

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 to each of the ten case study wind farms. This was categorised by HLA in terms of the main two 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 so clear from the descriptions. This is complicated by the difficulties in interpreting such subjective descriptions (as raised above).
- 6.89 In some of the case study sites the presence of character was more clearly apparent than others, with tones at three of the sites and AM at three of the sites. This was considered clearer in these cases for one or more 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 subjective 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 Of all the survey responses received, 13% of respondents reported having made a complaint. This was not necessarily about noise. For example, in 22% of these cases (or 2% of the total) the respondents could not hear the noise or were indifferent to it, and the reported comments were more related to other aspects of the scheme like visual impacts. However, for the remainder of the reported complainants a large majority (85%) reported strongly disliking the noise, with the others disliking it. With such responses noise was clearly a relevant factor in these cases, but it was not necessarily the only or main impact, with negative comments also being made in relation to other, non-acoustic, aspects of the developments.
- 6.92 Some of the comments relating to respondents having complained suggested to HLA that they may have been referring, in some cases at least, to objections made at the planning stage rather than specific complaints made following the commencement of the operation of the wind farm. This possibility may have influenced the above results. However, other reports were more clearly related to operational complaints. Two individual complainants' responses reported noise compliance monitoring having been undertaken at their properties. This followed reporting complaints to the planning authorities. They describe the site operator putting in place mitigation measures, but not being convinced that these measures would or had mitigated the issue. Comments sometimes referred to experiencing residual impacts, either concerning noise or other aspects such as shadow flicker. Two other individual comments reported anger at complaints not having been investigated.

Additional Insights from the Residents' Survey

- 6.93 The subjective nature of people's reaction to noise was highlighted by the variations in results of the survey responses, with some respondents exposed to similar noise levels showing quite different responses. In some cases where residents described serious impacts from the wind turbine noise, other neighbouring or similarly exposed³⁸ 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.
- 6.94 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.
- 6.95 In one or two 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. In these cases it is possible that the residual audibility of the noise was considered problematic or unacceptable by the 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 subjective impact.
- 6.96 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 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.
- 6.97 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.
- 6.98 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.
- 6.99 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 and the subjective impacts associated with the developments.
- 6.100 Where a specific condition for audibility was reported, this consistently related to when the respondent's property was located downwind of the wind farm for nine out

³⁸ With similar predicted noise levels and with a similar position relative to the wind farm.

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.

- 6.101 It is a generally accepted premise that, due to propagation effects³⁹, 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 as being when wind farm noise is most audible supports this effect. It also strengthens the conclusions of the study as relating to wind farm noise as opposed to other sources of noise which could have been unintentionally mistaken for the wind farm.
- 6.102 The effect of wind direction and (in some cases) dependence on wind speeds highlights the variability of wind farm noise and its dependence on 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. These survey responses support this by noting how variable wind farm noise can be, thereby highlighting the limitations of shorter term noise measurements which may fail to capture the required range of noise exposures.
- 6.103 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 not discussed in the application documents. It is therefore unclear as to what extent 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. The character of a source of noise is one factor that can lead to worse subjective reactions in practice, and it is conceivable that this situation could be exacerbated where such character is contrary to expectation.
- 6.104 In terms of increases over baseline, several respondents refer to this 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 subjective response to wind farm noise remains.
- 6.105 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

³⁹ In downwind conditions, the change of sound speed with height is such that sound tends to curve towards the ground 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.

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

- 6.106 In some cases neighbouring respondents who would be expected to be exposed to similar wind farm noise levels expressed opposite responses; or in some cases, residents expressed a similar dislike of the noise despite being predicted to be exposed to differing levels of noise. Where this occurred, follow-up telephone interviews were planned to try and establish the reasons behind these opposing views. Letters were issued to 27 residents selected on this basis, requesting a response for a follow-up phone interview. The rate of response at the time of writing (30%) was not sufficient for the exercise to be conclusive, but some useful insights have emerged.
- 6.107 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.
- 6.108 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.
- 6.109 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 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 contrary⁴⁰. A similar expectation of symptoms regarding infrasound was observed in a controlled scientific study⁴¹ following exposure to information available on the internet. Both the residents interviewed as part of the present study 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.
- 6.110 It was noted by some of the residents interviewed that some features of the noise, such as its character, were not necessarily captured by the noise surveys which could have been, or had been, in some cases undertaken.

⁴⁰ 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.

⁴¹ *"Can Expectations Produce Symptoms From Infrasound Associated With Wind Turbines?"*, F. Crichton et al, Health Psychology Journal, Vol 33(4), Apr 2014, 360-364.

- 6.111 To further confirm these and develop further insights, it would be necessary to conduct a more systematic one-to-one interview process to improve the rate of response (see further work proposed). 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.
- 6.112 Every effort was made to separate out those residents' responses which identify noise character as much as noise level as leading to their adverse response to the noise. However as expected there was ambiguity in many responses leading to uncertainty as to 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 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

- 6.113 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 subjective 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?

- 6.114 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 overstated in specific cases compared to what would currently 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 some⁴² of these assessments been undertaken more in line with current 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.
- 6.115 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

⁴² Due to the limitations in the information provided, it is not possible to quantify this further.

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?

- 6.116 The predictions of the noise from the case study wind farms were made using a range of different methods, and based on certain assumptions as to the turbine layout and turbine model to be used. These were often different from what is now current good practice, in some cases resulting in large variations.
- 6.117 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 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.
- 6.118 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.
- 6.119 It is noted that identified these differences 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).
- 6.120 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.
- 6.121 Both over-estimated criteria and under-estimated wind farm noise levels (or a combination of both) at the assessment stage represents a risk of excessive impact. 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.

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

- 6.122 The likely audibility and potential subjective impact of wind turbine noise was 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 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.

- 6.123 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").
- 6.124 The assessments reviewed generally considered that tonal noise was unlikely to be an issue from modern technology wind turbines. They either did not consider the subject or proposed that standard measures could be applied to account for the presence of audible tones, should they occur, through a penalty procedure (see Appendix G).
- 6.125 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?

- 6.126 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.
- 6.127 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. It is therefore conceivable that different conclusions may have been reached even in cases in which a rigorous evaluation of the wind farm noise impact assessments and the necessary consultations were undertaken.
- 6.128 The more recent recognition (2013) by Scottish Government of good practice produced by the Institute of Acoustics 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.
- 6.129 Whilst underestimations of wind turbine noise at the planning stage can be mitigated to some extent by the application of noise planning conditions, if the noise limits (i.e. the planning criteria) derived are over-stated, this cannot be subsequently remedied, which reinforces the importance of this aspect of the project scrutiny.

Summary of key findings from effects from operational developments

Noise Impacts and Audibility

- 6.130 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 subjective reactions depending on a wide range of factors, both acoustic and non-acoustic, including attitudinal.
- 6.131 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.
- 6.132 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. There were some who were exposed to very low noise levels who severely disliked the wind farm noise, and some exposed to higher noise levels who were indifferent about the noise. This was not always explained by direct involvement with the wind farm. In other cases respondents exposed to similar levels of noise had polarised responses. This highlights the potential importance of non-acoustic factors in shaping individual responses.
- 6.133 Differences in personal reactions to (any) audible noise are generally to be expected, both in HLA's experience and according to the available guidance. Some of these variations are due to non-acoustic factors such as differences in attitudes towards the source of the noise in question. Some of the above results could therefore be explained in part by differences in perceptions of wind farms within the public at large.
- 6.134 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 subjective 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 PAN 1/2011 (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

- 6.135 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. In summary, reported audibility increased and reported acceptability decreased with increasing predicted as-built noise levels. In comparison, the relation 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.
- 6.136 The foregoing observation therefore supports the consideration of calculated noise levels at the planning stage rather than the adoption of a recommended minimum separation distance alone, which does not effectively represent the potential noise effects.
- 6.137 In HLA's opinion, following an overall review of the evidence, instances of more widespread and consistently reported negative impacts from noisewere 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

- 6.138 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.
- 6.139 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.
- 6.140 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 a tonal feature was positively identified as part of compliance measurements, 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, although the subjective effectiveness of this mitigation could not be established within the scope of this study.

- 6.141 Regarding amplitude modulation, when descriptions of the noise character suggested that this could be a feature, which was in 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, so in about one third of the case study sites, the descriptions of this feature were clearer, thereby suggesting a more pronounced feature. Despite extensive research having been undertaken in recent years which is leading to an increased understanding of the phenomenon, there is no generally agreed procedure for rating amplitude modulation. More specifically there exists no accepted means for accounting for particular amplitude modulation characteristics of the noise beyond those already accounted for within the noise limits derived according to ETSU-R-97. Further work is therefore proposed on this subject, subject to the outcome findings of current efforts to better establish an amplitude modulation assessment framework and practical methods for its control.

Other points

- 6.142 The variability of the 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.
- 6.143 More than four out of five respondents who heard the wind farm noise heard it outside 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 subjective reactions were 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

- 6.144 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

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.

- 6.145 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 however, that compliance with the terms of the IOA GPG would not be expected to eliminate all impacts and/or negative reactions.
- 6.146 General planning policy on noise in Scotland requires subjective impacts to be assessed and considered at the application stage, in addition to objective criteria. For wind farms, this would include 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 objective methodology existing for the assessment of onshore wind farm noise, which 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

- 6.147 The provision of information on the subjective 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.
- 6.148 It would therefore be beneficial to set out clearly as part of not only 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

- 6.149 Robust predictions of noise levels appear to provide a better indication of impact than separation distance alone. The imposition of clear planning requirements in the form of planning conditions provides a mechanism for inducing and enforcing these levels in practice as well as providing the necessary clarity for all parties.
- 6.150 In terms of planning or consent conditions on noise, several of the examples reviewed were unclear or omitted key elements considered important. 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.
- 6.151 The above points are addressed in the example condition provided an annex to the IOA GPG.
- 6.152 Planning authorities could give consideration to imposing requirements on wind farm operators to undertake post-consent operational noise compliance measurements after completion of a project, even in the absence of complaints. This would allow identifying at the earliest opportunity issues such as tonality. However, the difficulties associated with this, such as acquiring access to the properties and defining the range of conditions required for the study, should be recognised. The costs for the wind farm operators associated with such measurements, not only in commissioning the study itself but also in terms of the wind turbine shutdowns which may be required as part of any measurement campaign, would also need to be considered. Furthermore, the present study has shown that an assessment based on a robust prediction method can allow a suitably robust estimate of overall wind farm noise levels in the cases considered. Combined with information demonstrating that efforts have been made to prevent the occurrences of specific features⁴³, this may be sufficient in many cases in reducing the likely excess of prescribed noise levels in practice.

Mitigation

- 6.153 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 impacts in practice.
- 6.154 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.
- 6.155 The presence of tonality depends on the design of mechanical elements in the turbines being effective at stopping 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. This is not always done in HLA's experience but would assist in minimising the risk of this feature arising in practice. This will require dialogue with turbine manufacturers to understand and manage these as part of the turbine design process.
- 6.156 The same could be done for amplitude modulation (AM) although there is more limited experience in this respect. The inclusion in turbine supply agreements (contractual requirements) of clauses on tonality and amplitude modulation that match the requirements for compliance with planning conditions (i.e. based on noise experienced at neighbouring residential dwellings as opposed to more

⁴³ See comments elsewhere in this report regarding consideration of potential tonality as part of the turbine procurement process.

traditional turbine supply agreements which focus on noise emissions measured at the turbine itself) would encourage the development of quieter turbines in respect of these noise types.

Enforcement

- 6.157 The process of monitoring noise levels is traditionally complaint-driven. The Residents' Survey identified claims that complaints were not always followed by suitable investigations. Drafting clear planning conditions on noise, as set out above, would assist in this regard. In such situation 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 updates as to the actions of the planning authority and the wind farm operator.

7.0 OVERALL ASSESSMENT, CONCLUSIONS AND RECOMMENDATIONS

Introduction

- 7.1 This chapter sets out 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).
- 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?

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

- 7.4 The application submissions for all ten case study sites were accompanied by LVIA's; two of which were included in Environmental Reports, and the other eight were submitted as part of Environmental Statements. All of the LVIA's 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 LVIA's identified residents as a group of visual receptors which potentially would be impacted. All of the LVIA's 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 LVIA's 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 LVIA's 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 LVIA's, 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, being 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 LVIA's 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.

- 7.17 Overall, the study team considered that the submitted visualisations were ‘fit for purpose’ and should have enabled a suitably qualified and 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 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 subjective 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 LVIA. 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 (26%) 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 21% who considered the wind farm to "very different" or "different". However, quite a large number 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?

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

- 7.30 Of the six 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. An extended study area of 11 rotor diameters might be used to take account of this and also allow for micro-siting and ground to blade tip allowances.
- 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.

Were shadow flicker impacts on residents predicted sufficiently robustly?

- 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-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.

Were the potential shadow flicker impacts on local residents adequately explained to residents?

- 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 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 those that undertook a shadow flicker assessment, the significance of the predicted impacts were examined rigorously by the competent authority. In at least two cases further demands were made on the developer to conduct a more detailed study and/or agree planning conditions including mitigation and monitoring.

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 effects than just 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. 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 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 the latest practice.
- 7.40 It was not possible to interview residents that experience shadow flicker in this study. However, this could provide a more detailed understanding of the level and nature of the effect 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 Institute of Acoustics the production of good practice guidance (IOQ 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. Adherence to the IOA GPG recommendations is expected to result in more robust noise assessments and correspondingly robust reviews by responsible authorities.
- 7.43 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 to the final turbine model and layout. Nevertheless, in just under half of the cases studied, the turbine noise levels were under predicted at planning stage. Conversely, in just over half the cases noise levels were over estimated at planning or little change was predicted.
- 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 recognition by Scottish Government of good practice produced by the Institute of Acoustics clarifies the standard required of all wind farm noise assessments and should assist in the rigour and consistency of assessments.
- 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 cannot be subsequently remedied, which 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 results of the present study nevertheless supported the use of robust predicted noise levels to assess wind farm noise impacts rather than separation distances.
- 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 features, when they occur, appeared to affect the subjective response to, and acceptability of, wind farm noise. It is advised that greater efforts are made to prevent well understood features such as audible tones from occurring, for example by increase focus on the turbine procurement process. There is 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 the present project.
- 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 reports worst impacts. The masking effects of background noise on wind turbine noise, and the effects of different absolute limits for wind turbine noise, particularly at night, could be investigated further, in the light of the latest research on the subject (WHO 2009 for example). As part of this exercise, the potential benefits and drawbacks of setting absolute noise limits only, as opposed to including noise limits set relative to the background noise, could also be assessed.
- 7.55 Further good practice/planning guidance could additionally recommend more consideration of subjective impacts of wind farm developments, such as audibility, in line with general planning guidance. 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 from work presently underway through the Institute of Acoustics and therefore engagement with this work is recommended.

General Observations

- 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.
- 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. However 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.
 - 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 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 the 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 be 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 LVIA's had referred to the extant GLVIA (2nd 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.
 - 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. 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 Farms 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 Environmental Statements or Environmental Reports 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 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 objective assessments carried out as part of the EIA process do not always capture the subjective 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 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.
- 7.63 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 subjective experience or response to wind farm developments.

- 7.64 This divergence between objective measurement and subjective 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 subjective 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.
- 7.65 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 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 subjective or specific impacts identified. These are set out in the Recommendations below.
- 7.66 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

- 7.67 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	Current status
Visual Impacts	
Develop guidance and methodology in respect of residential visual amenity surveys.	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.	Good practice/planning guidance
Consistent and clear reporting in LVIA's including setting out the design objectives for the wind farm development with key constraints considered.	Good practice
Review of the use of SNH's revised guidance on visualisations.	Research underway
Shadow Flicker Impacts	
Develop guidance on the definitions of shadow flicker and throw, and light effects.	Research to feed into good practice/planning guidance
Develop guidance on significance criteria for shadow flicker to be applied in future assessments.	Research to feed into good practice/planning guidance
Conduct a small follow up study to understand more about the	Research to feed into

Recommendation	Current status
light and shadow effects on residents within 2km of wind turbine developments.	good practice/planning guidance
Develop clearer ways to present shadow flicker assessments and related light effects in public consultations.	Good practice/planning guidance
Noise Impacts	
Further good practice/planning guidance could recommend more consideration of subjective impacts of wind farm developments, such as audibility, in line with general planning guidance.	Good practice/planning guidance
Focus on the turbine design and procurement stages to reduce the risk of noise features.	Good practice/planning guidance
Where noise issues are found to occur in practice, these issues should be identified and assessed within clear timescales. Affected neighbours should be provided with regular and informative updates.	Good practice/planning guidance
Additional systematic interviews and supporting noise measurements at selected sites considered in this study to assist in further understanding the range of responses received and assessing the significance of acoustic features.	Subject to addition costs for survey, measurement and analysis work
Consideration as to how amplitude modulation noise should be incorporated within the assessment, application and consenting process, including proactive involvement with other work in the UK to further this aim.	Potential further consideration or research
Further investigation into the masking effects of background noise on wind turbine noise, and the effects of different absolute limits for wind turbines noise, particularly at night. As part of this exercise, the potential benefits and drawbacks of setting absolute noise limits only, as opposed to including noise limits set relative to the background noise, also could be assessed.	Potential further consideration or research
General	
Develop guidance to achieve a level of consistency across competent authorities in respect of retention and accessibility of key documents throughout the consenting process.	Good practice/planning guidance
Identify of implications of micro-siting on visual, shadow flicker and (to a lesser extent) noise impacts.	Good practice/planning TBD

APPENDIX A – AUTHORS’ CREDENTIALS

Jean Welstead (MA, 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 research and for the past fifteen years 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 development and analysis of the survey drew on expert advice from Dr Mhairi Aitken (Centre for Population Health Sciences) and Dr Claire Haggett (School of Social and Political Science) both at the University of Edinburgh.

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. The results are shown in Table 1. 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 4km 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 within-1 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 4.2 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

8.2 Analysis

This section reports on the analysis of questionnaires sent to local residents. 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 (which follows). The overall analysis of the questionnaires is not based on factors such as distance from the turbines, as this is covered in the respective impact chapters. 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). Before analysis, the data was also separated from information about the respondents (and the data from a small number of cases where residents had been approached to take part was included in with all the other data, and analysis conducted on the data as a whole). However, given that in some instances the number of residents living near to particular developments is small, and in order to ensure that no individuals could be identified, the following discussion represents a synthesis of our analysis from each of the case study sites but does not identify individual cases.

The survey was completed by 385 respondents relating to 10 wind power developments located throughout Scotland. In order to protect the confidentiality of respondents to the survey, any potentially identifying information has been excluded from this report.

It is worth noting the potential limitations of studies 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 is was never expected to be able to draw out any generally applicable statistical 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.

XXXXXX Wind Farm Residents' Survey

Introduction

This survey is designed to capture your experience of living near XXXXX wind farm.

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 XXXXX 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.climateexchange.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 XXXXX 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 XXXXX 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 XXXXX wind farm at all?

Yes
☐

No
☐

If yes, how have you been involved with the XXXXX 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:

Planning and Environmental Impact Assessment

XXXXX wind farm (XXXX) was subject to an Environmental Impact Assessment (EIA) or Environmental Report (ER) to assist the planning decision. The EIA/ER is a study of the potential impacts of a proposed development. We would like to understand your awareness and/or involvement in this process.

Question 7

Were you aware of the Environmental Impact Assessment process before the wind farm received planning consent?

Yes
☐

No
☐

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.

Did you participate in any consultations run by the developers and/or council?

Developer
run
☐

Council run
☐

Other
☐

If yes, what did this involve?

Question 9

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?

Yes
☐

No
☐

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 XXXXX 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

☐

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 XXXXX 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 XXXXX 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 XXXXX 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 XXXXX 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 XXXXX 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
XXXXX wind farm?

No
☐

Inside
☐

Outside
☐

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

Morning
☐

Afternoon
☐

Night
☐

No noise
☐

Please describe your experience of noise from XXXXX 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 XXXXX wind farm?

Yes
☐

No
☐

Comment:

Question 26

How do you feel about any noise from XXXXX 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:

Perception of the wind farm

Question 28

Has your perception, how you think and feel, of XXXXX 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:

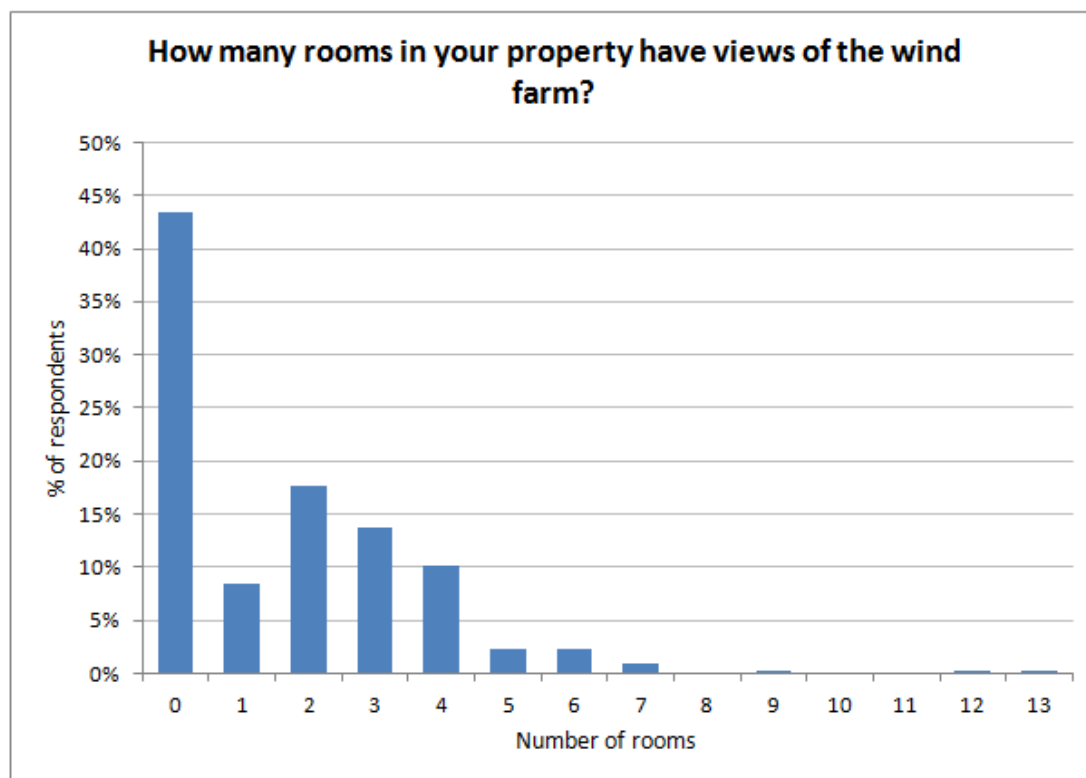
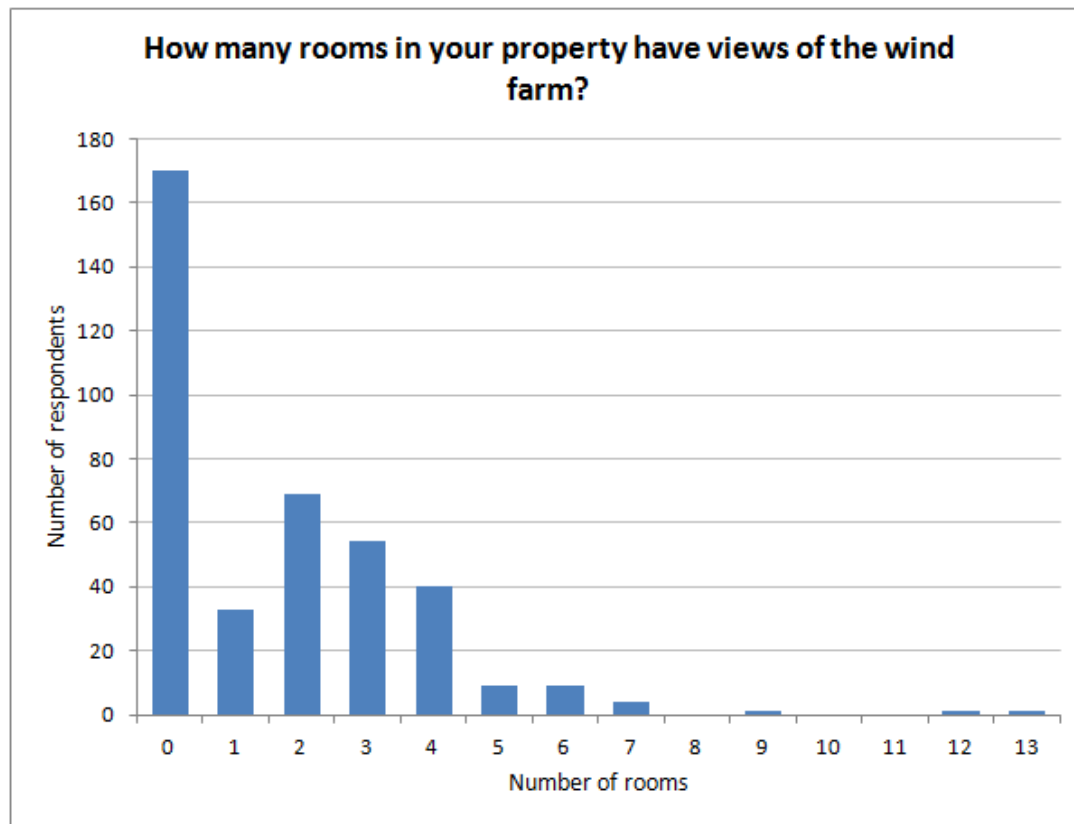
Question 30

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

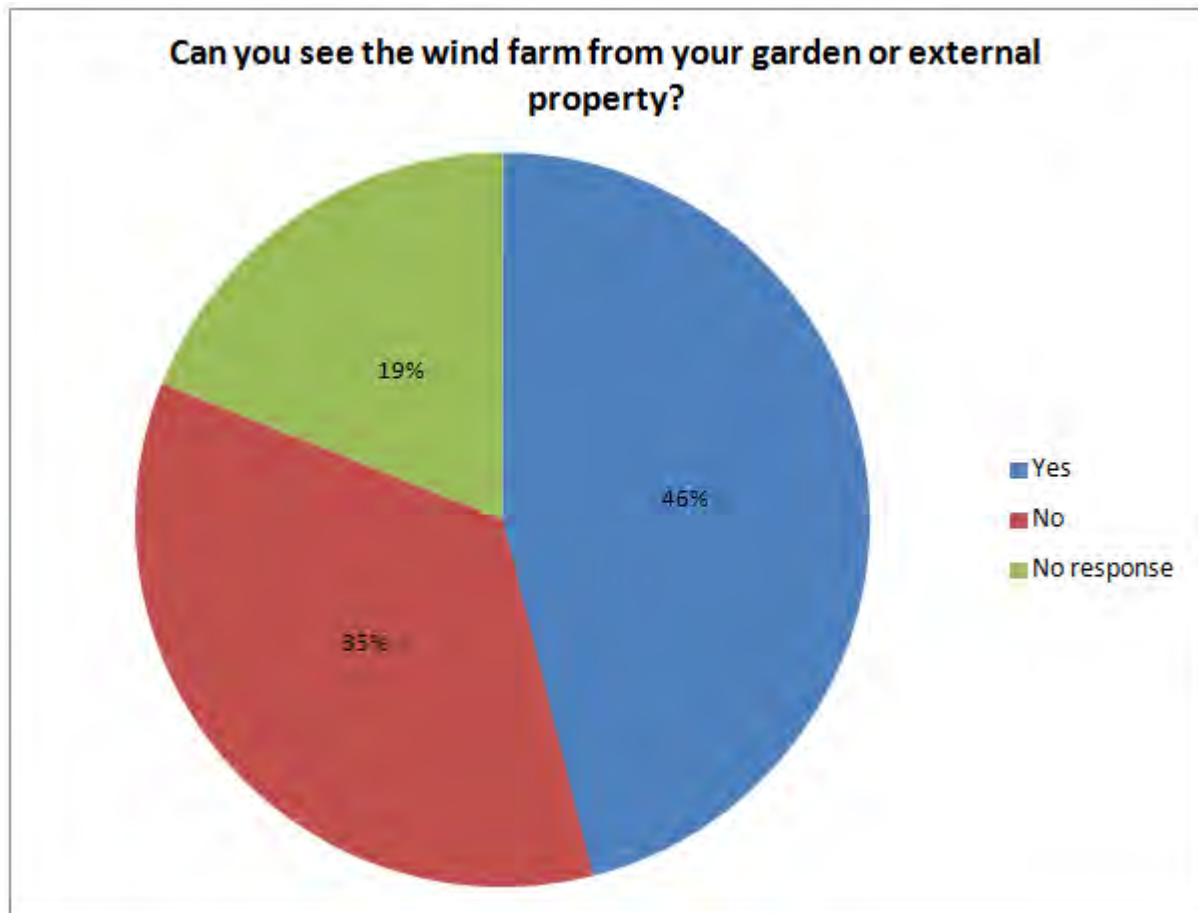
Thank you, we appreciate the time that you have taken to contribute to this survey.

Appendix C – Graphical Representation of Residents' Survey Findings

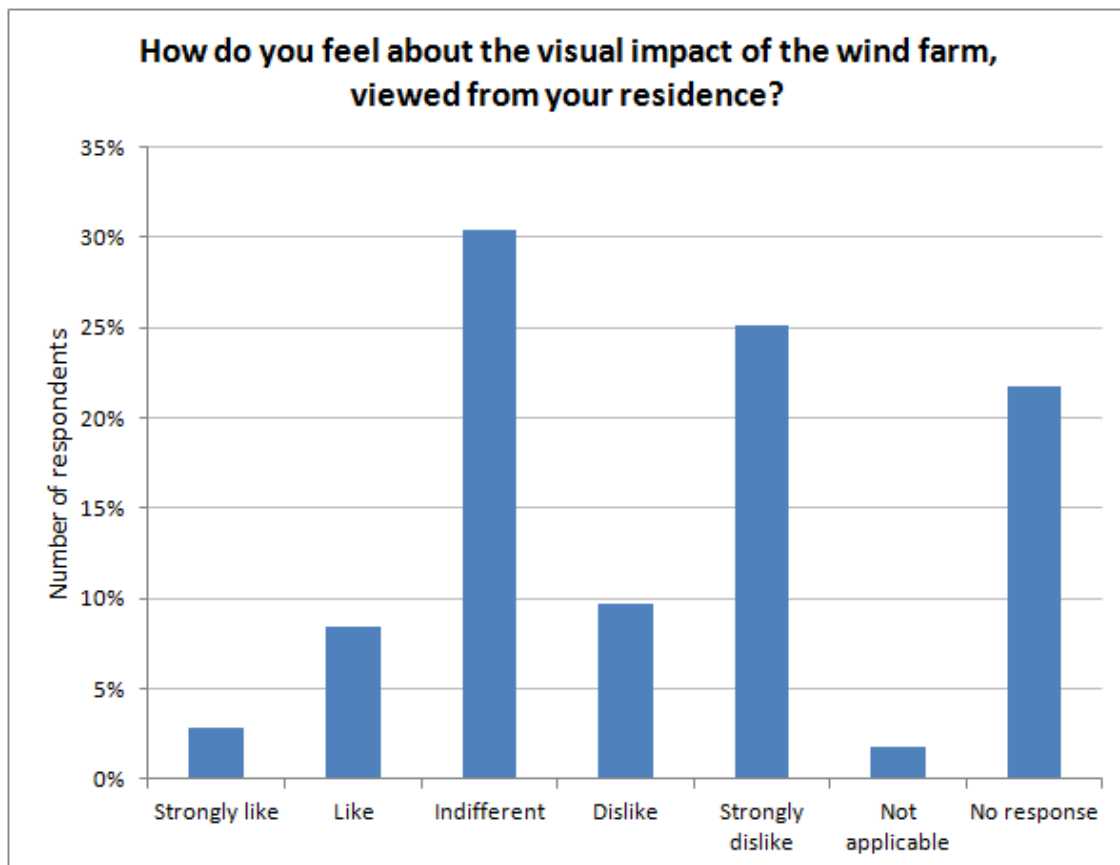
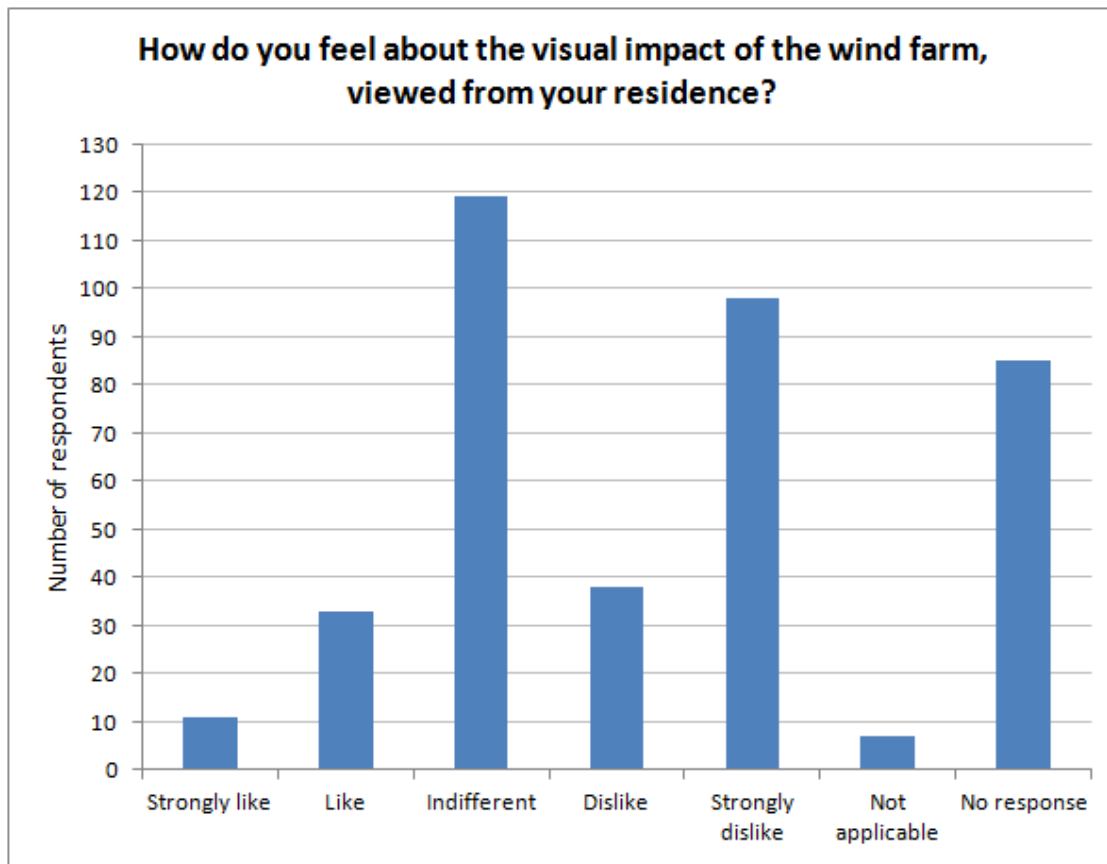
Visual Q11



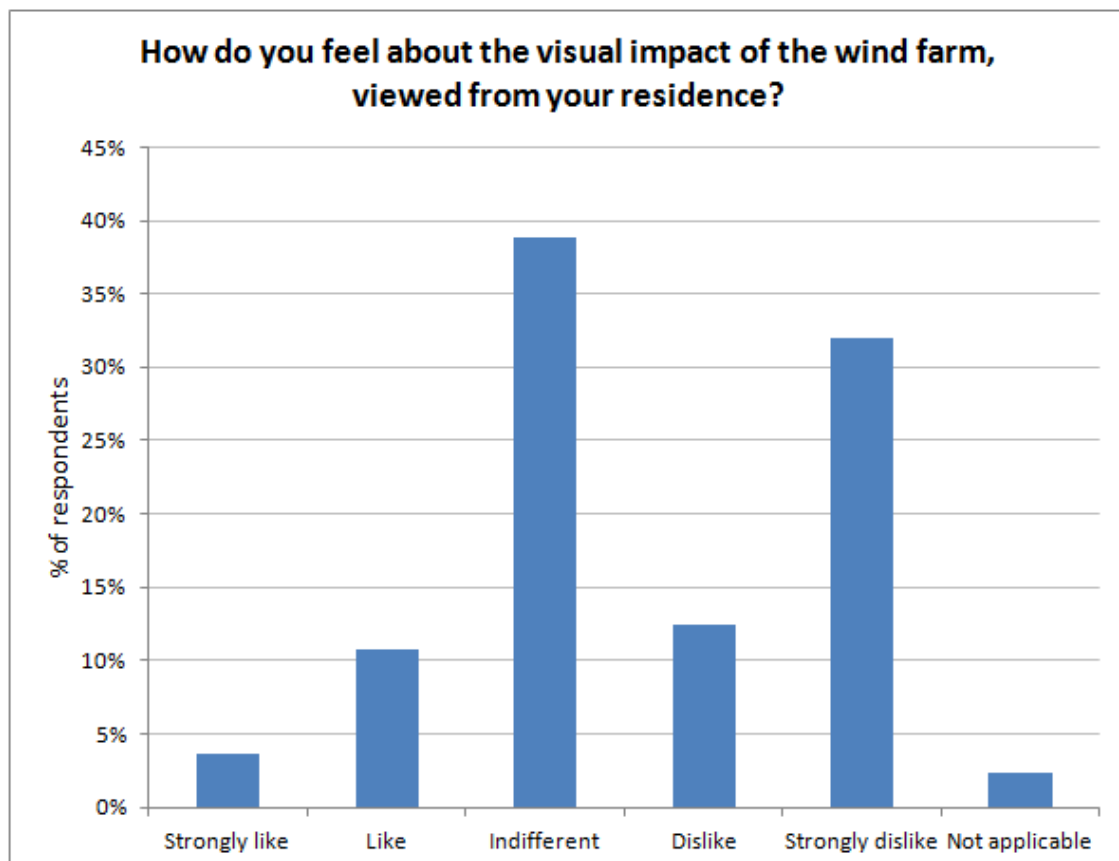
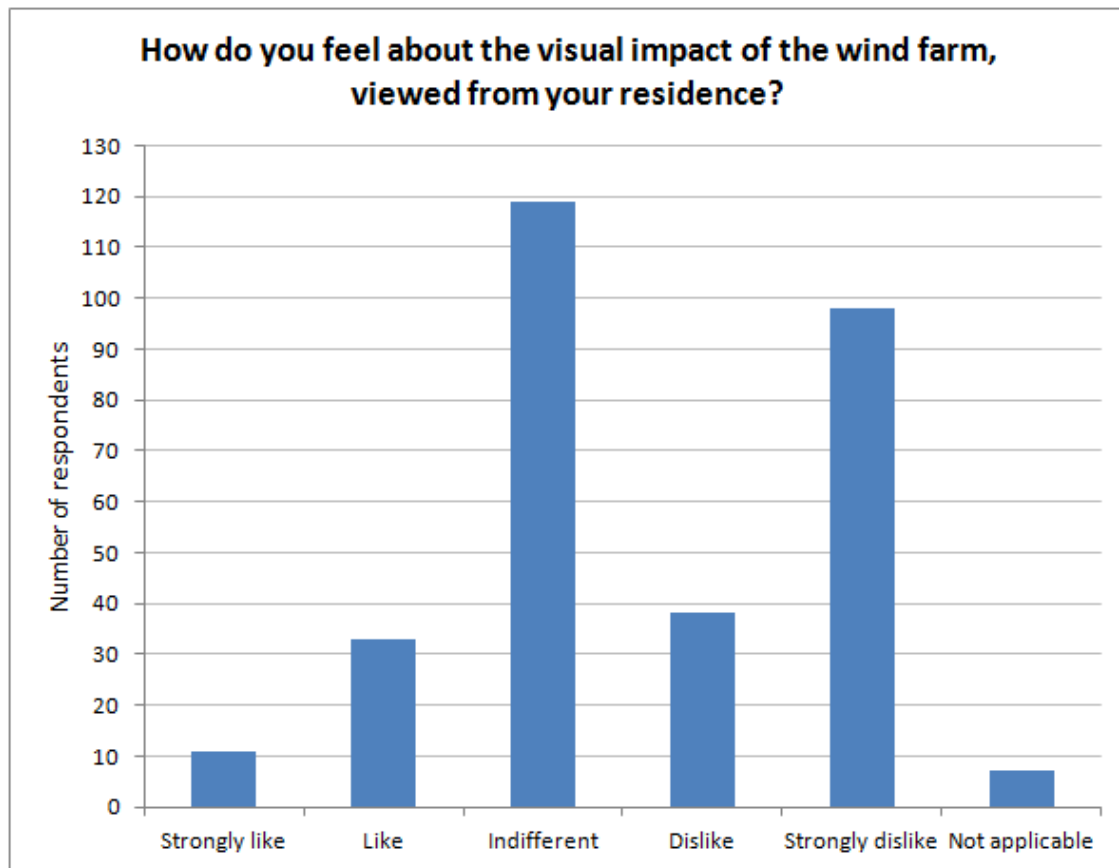
Question 12



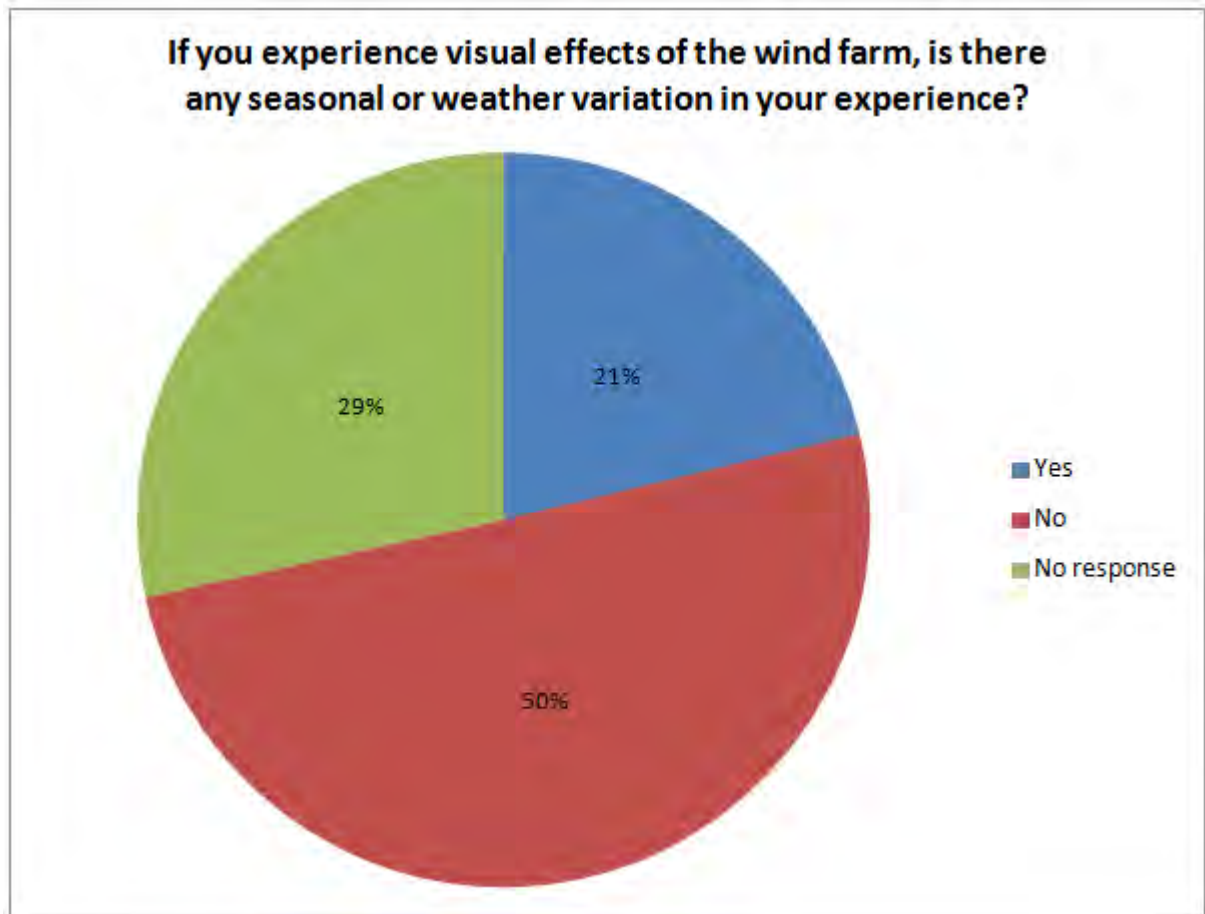
Question 13 - No response included



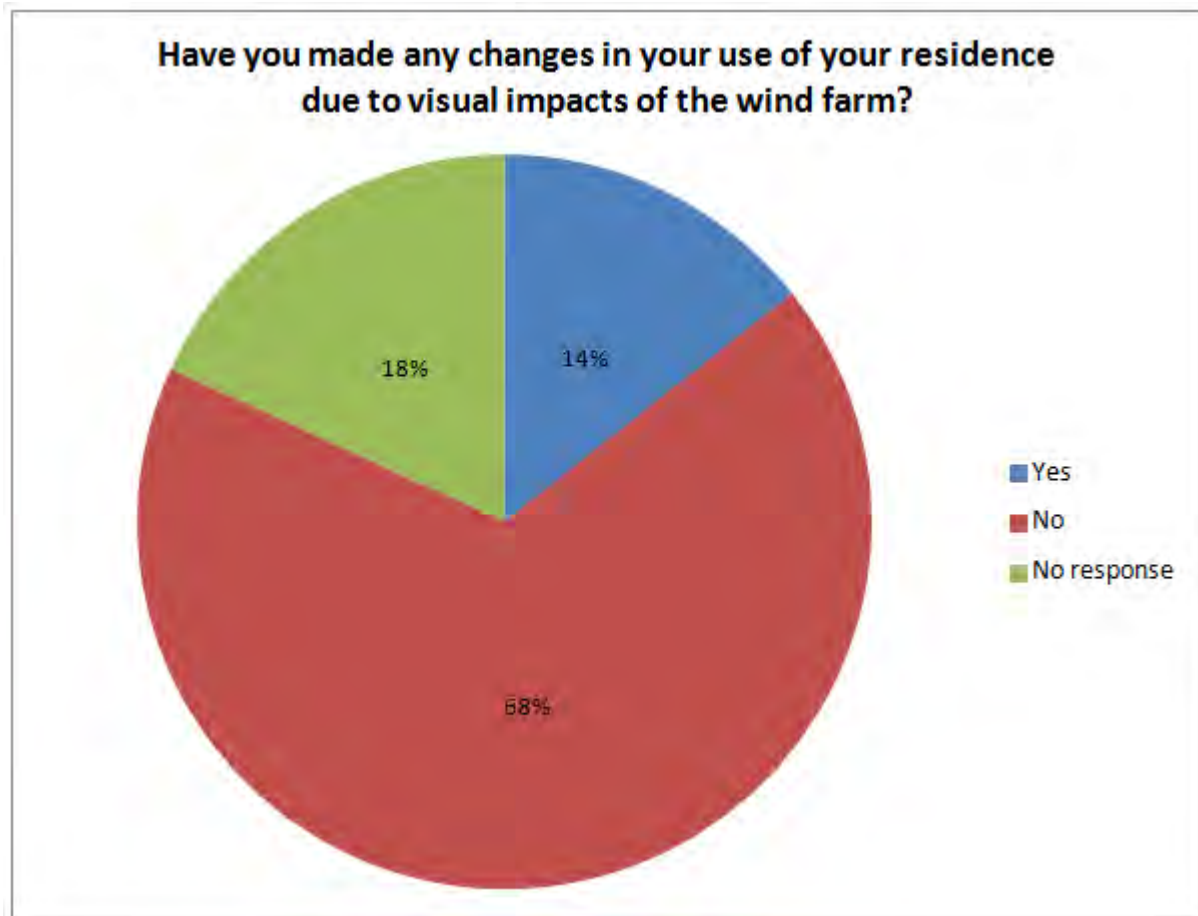
Question 13 - No response excluded



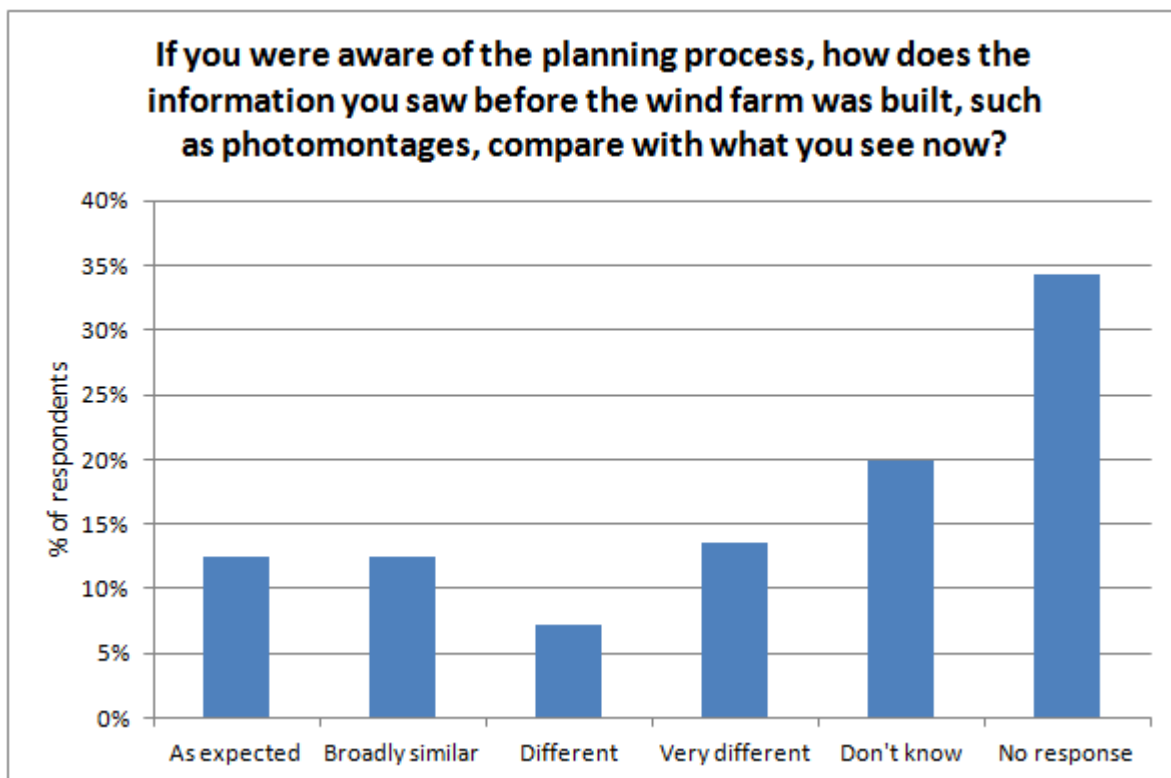
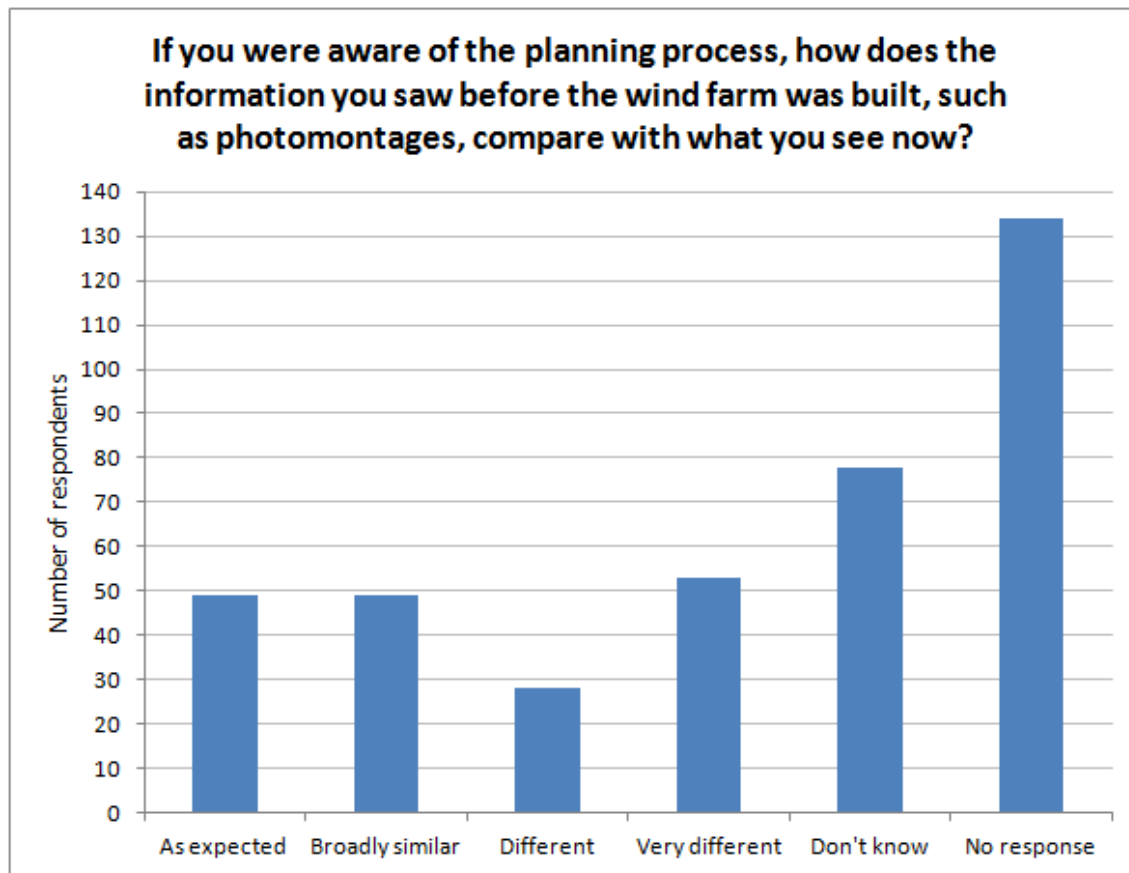
Question 14



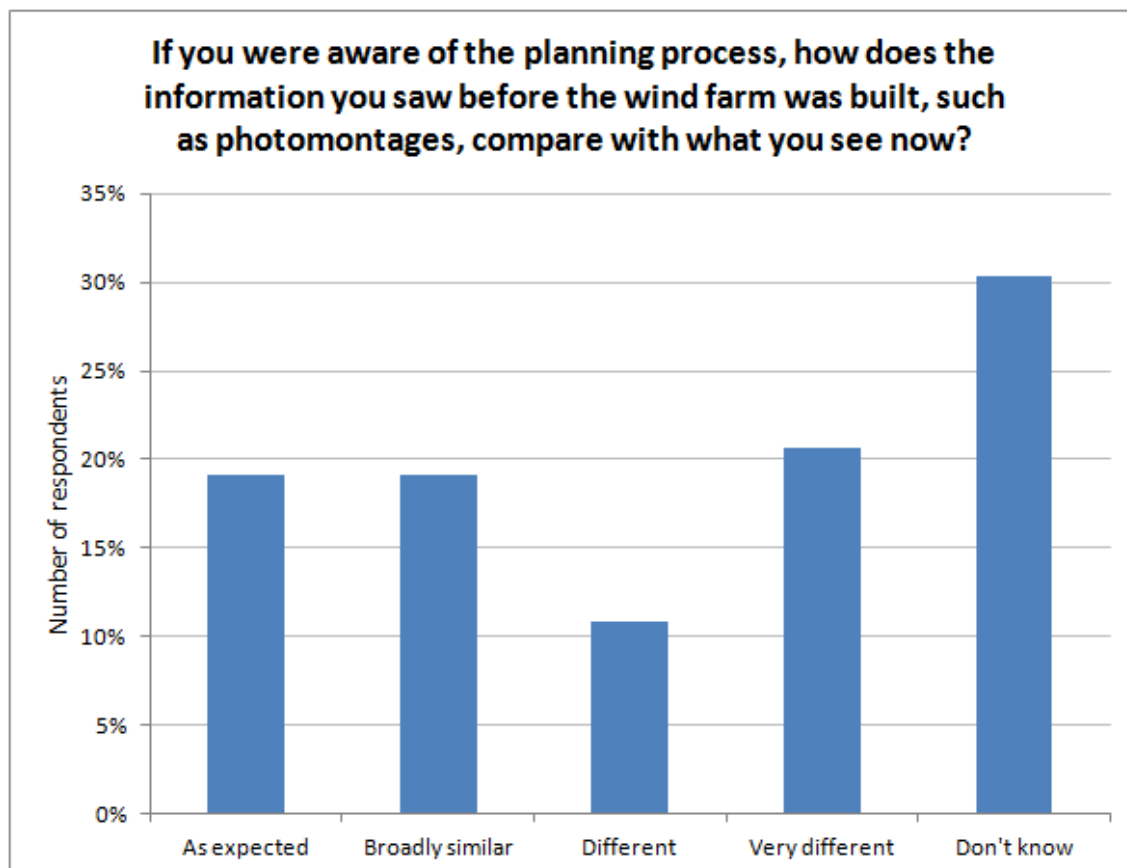
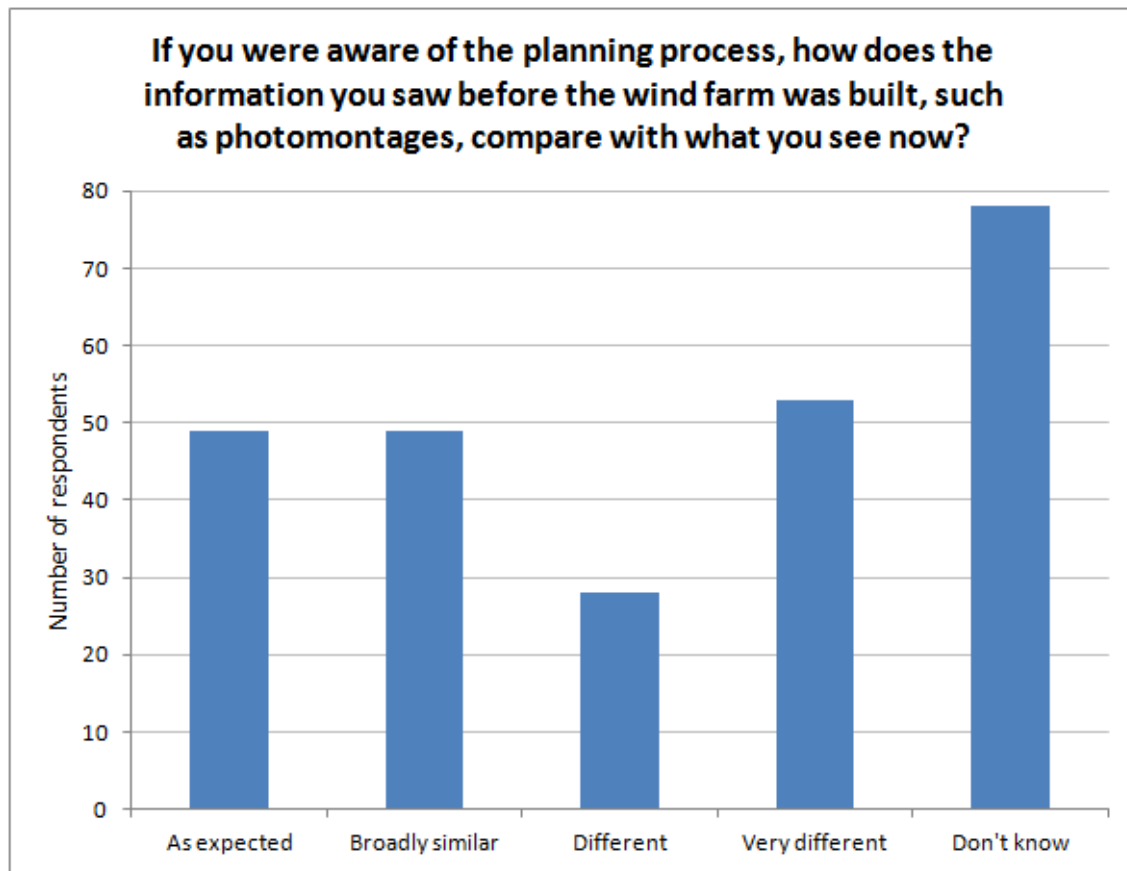
Question 15



Question 16 – No response included

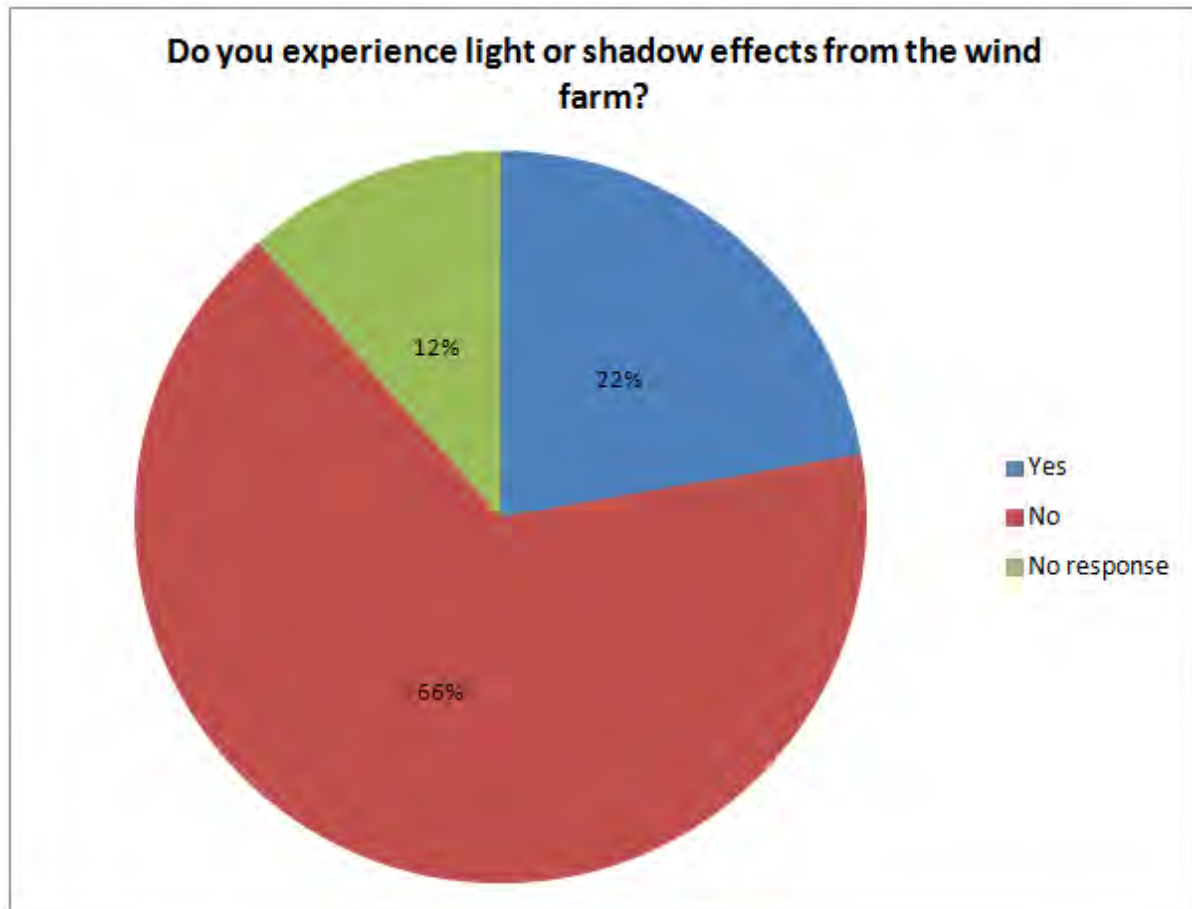


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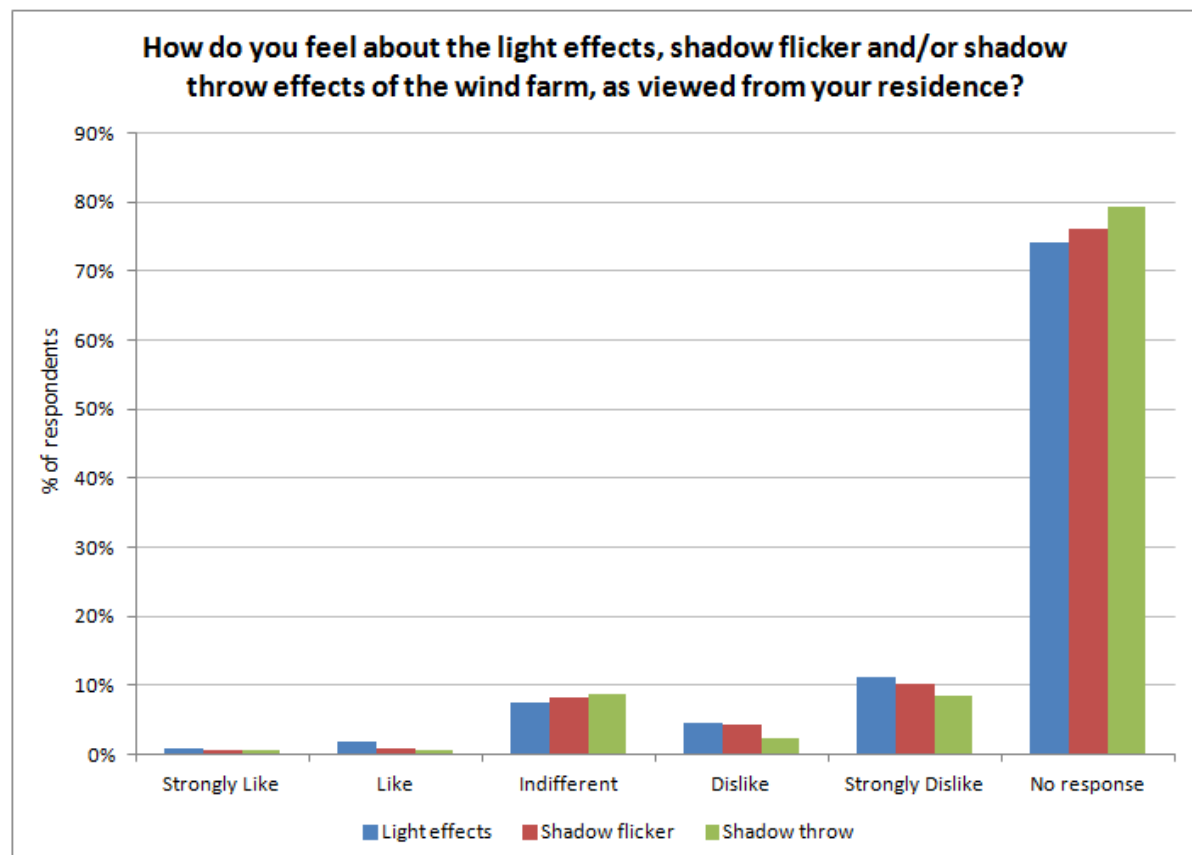
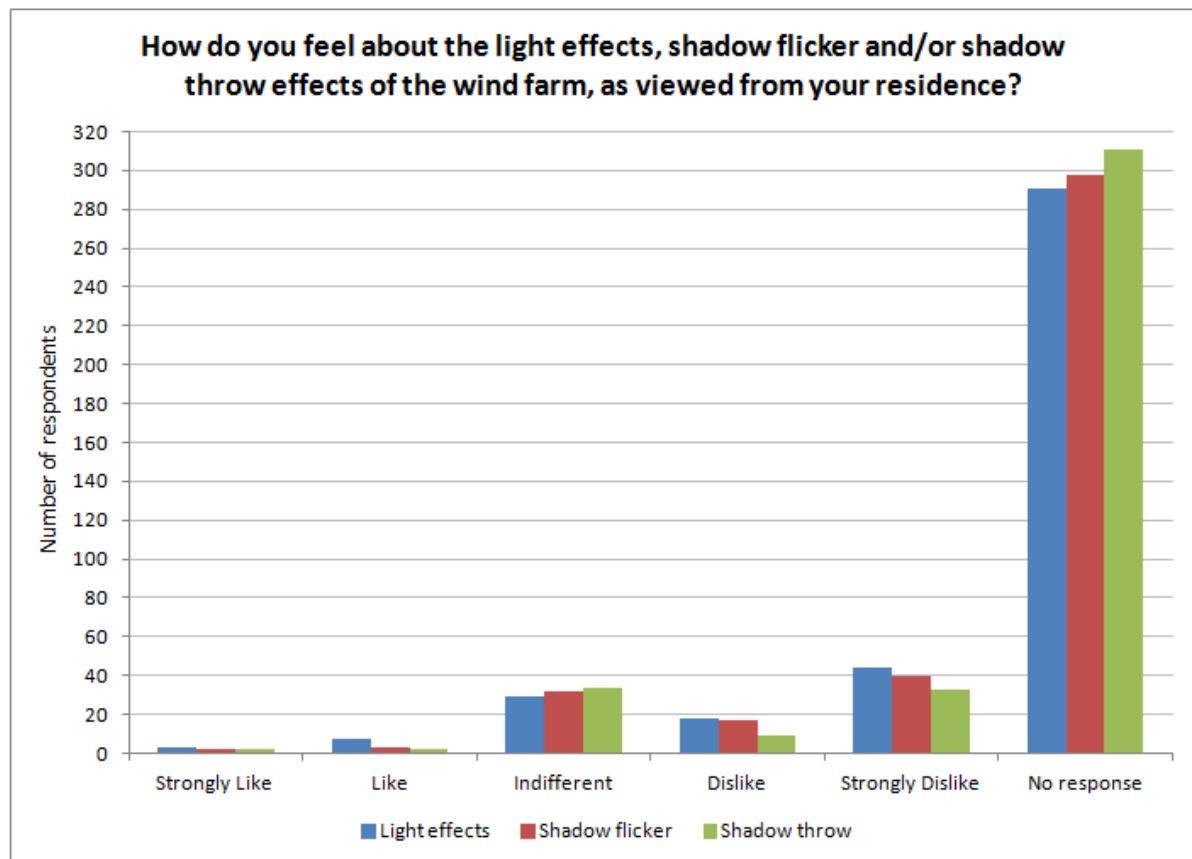


Light Effects

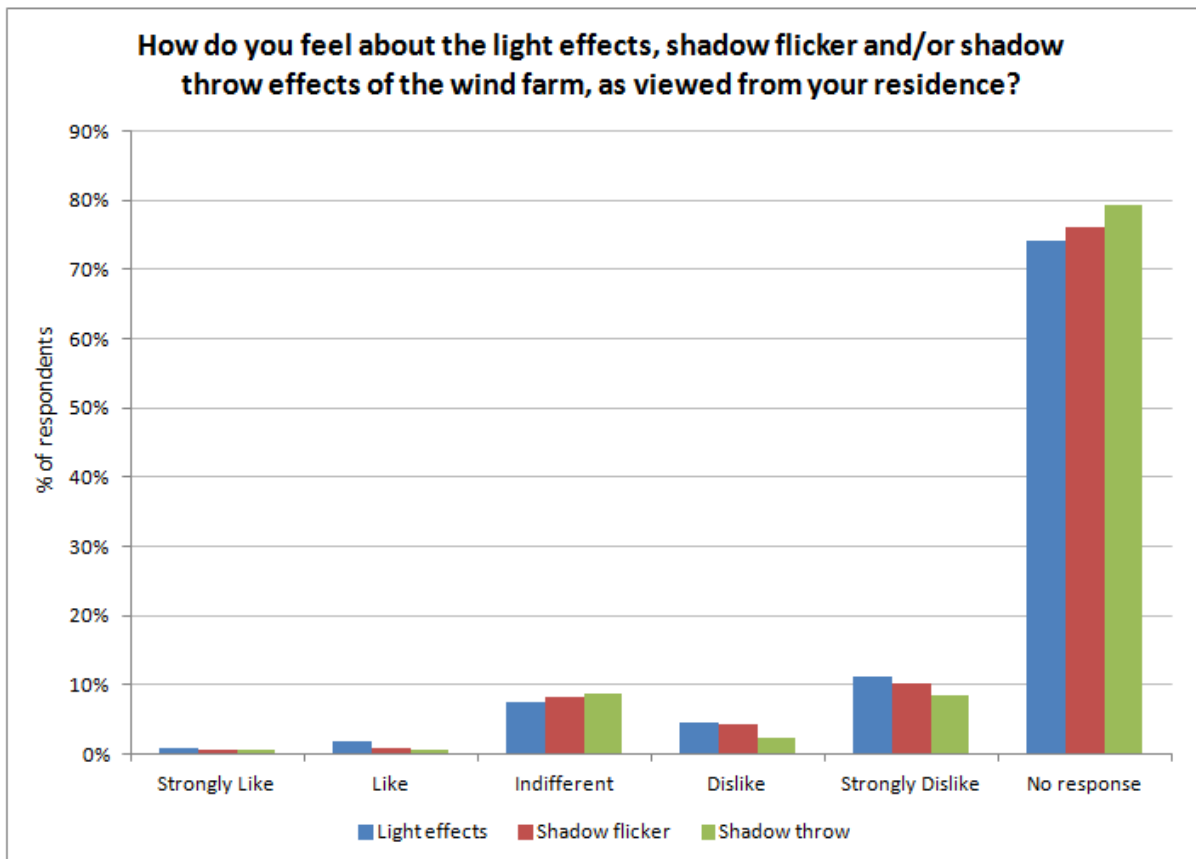
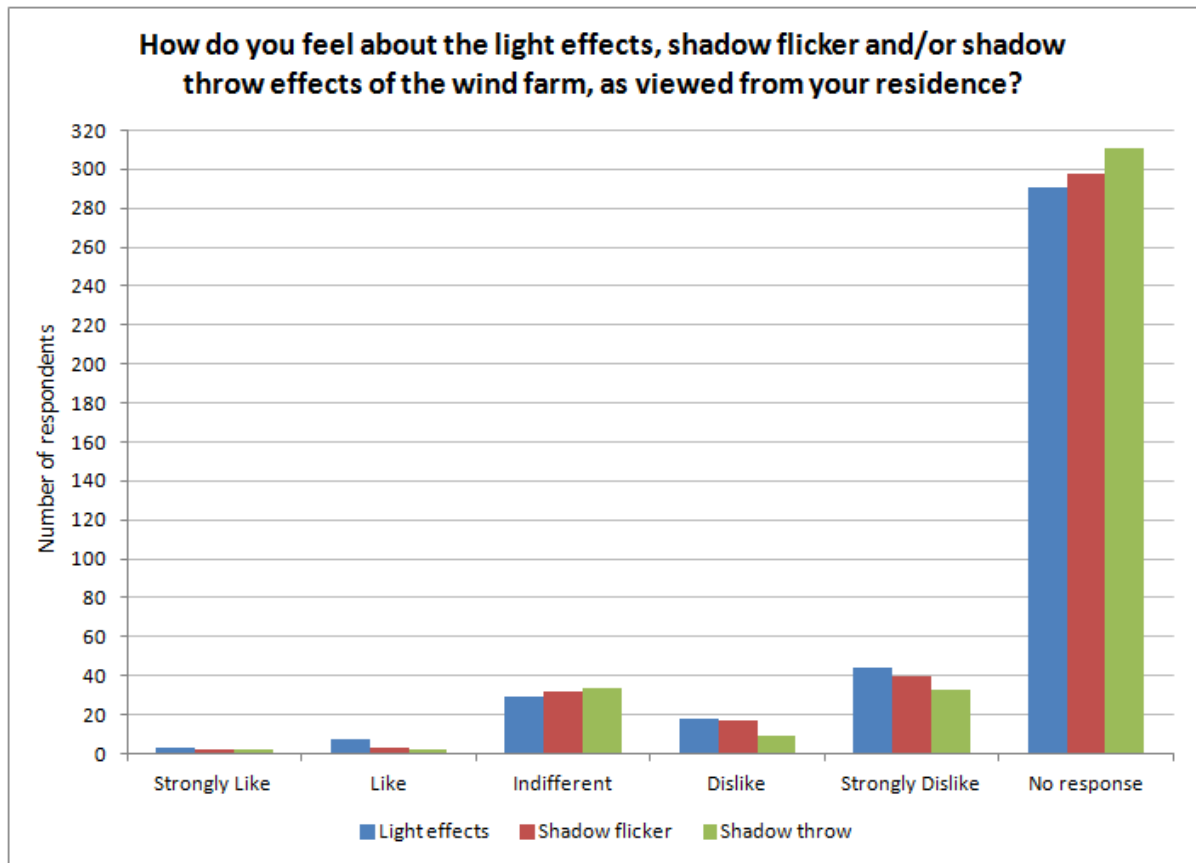
Question 18



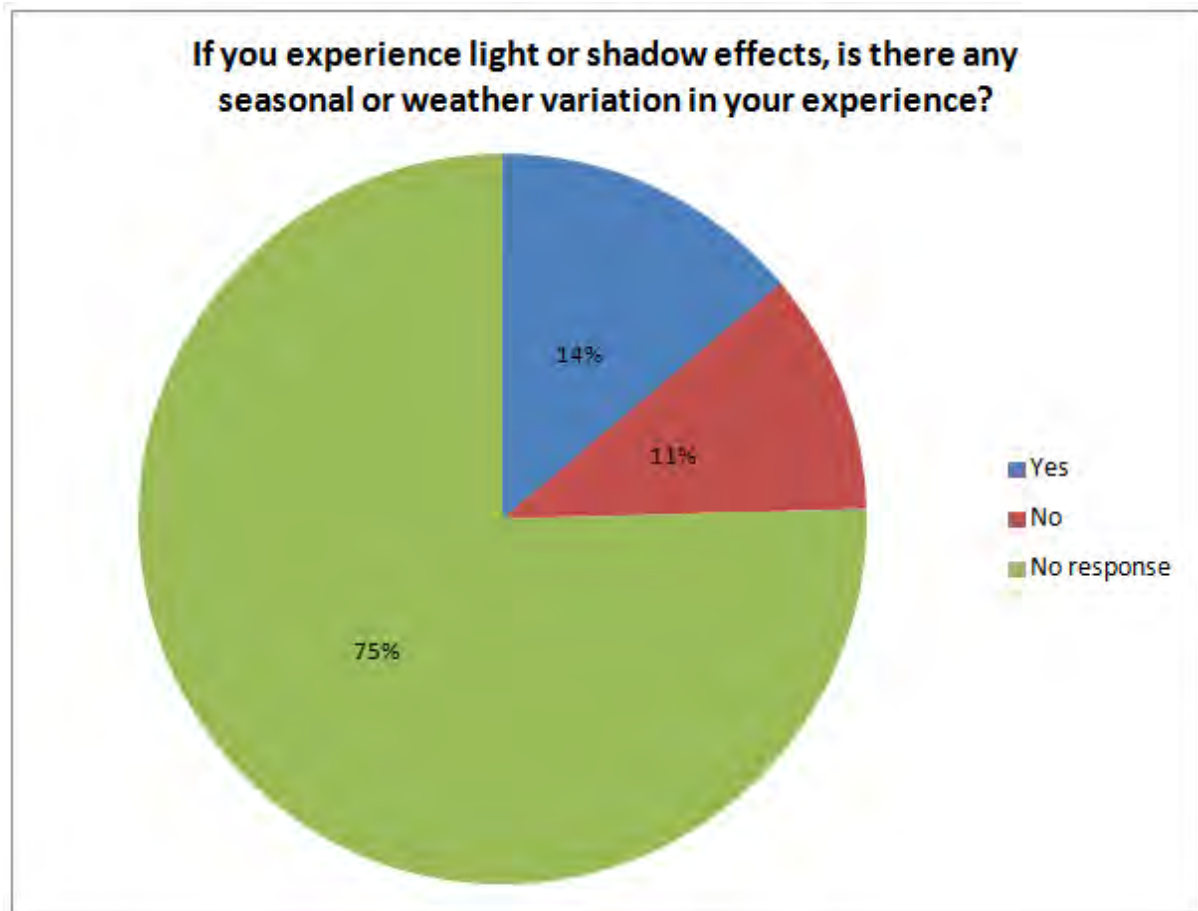
Question 20 – No response included



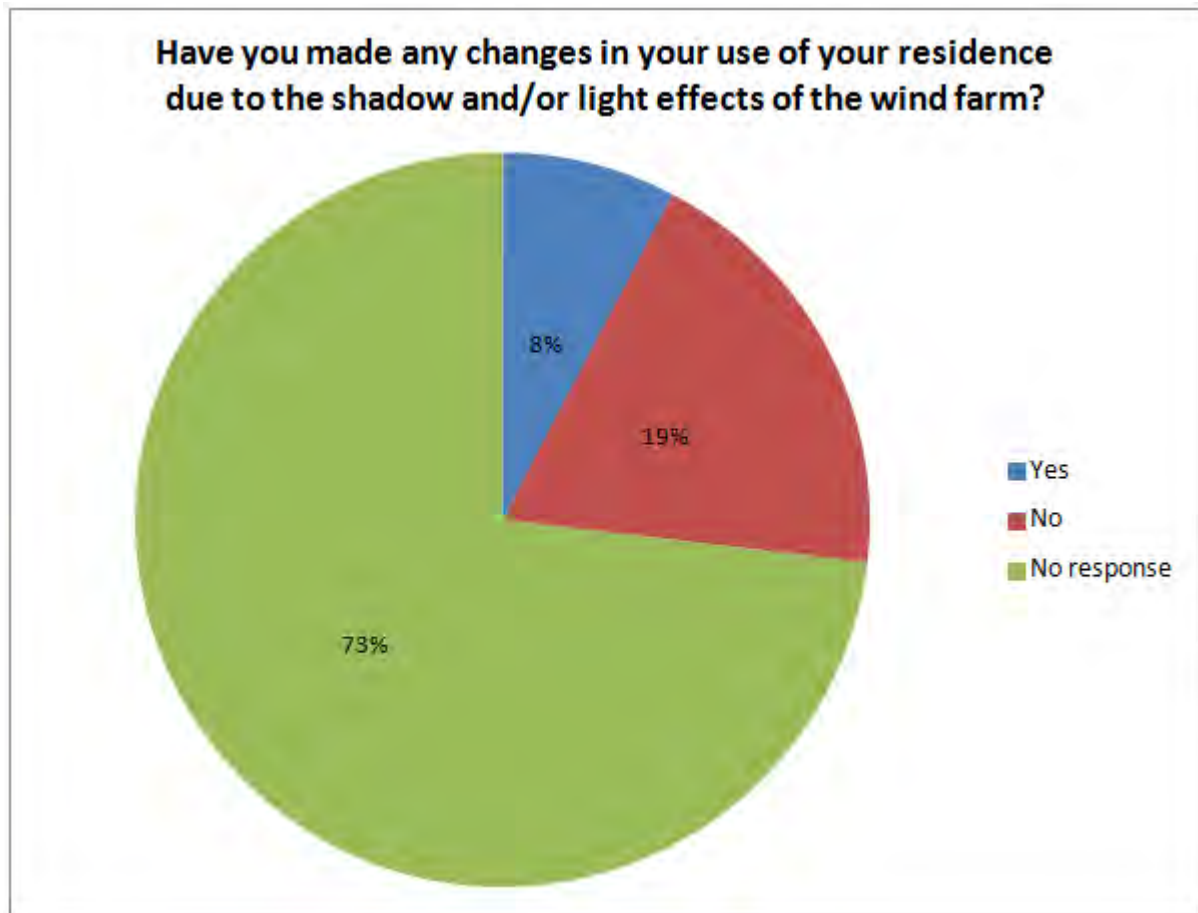
Question 20 – No response excluded



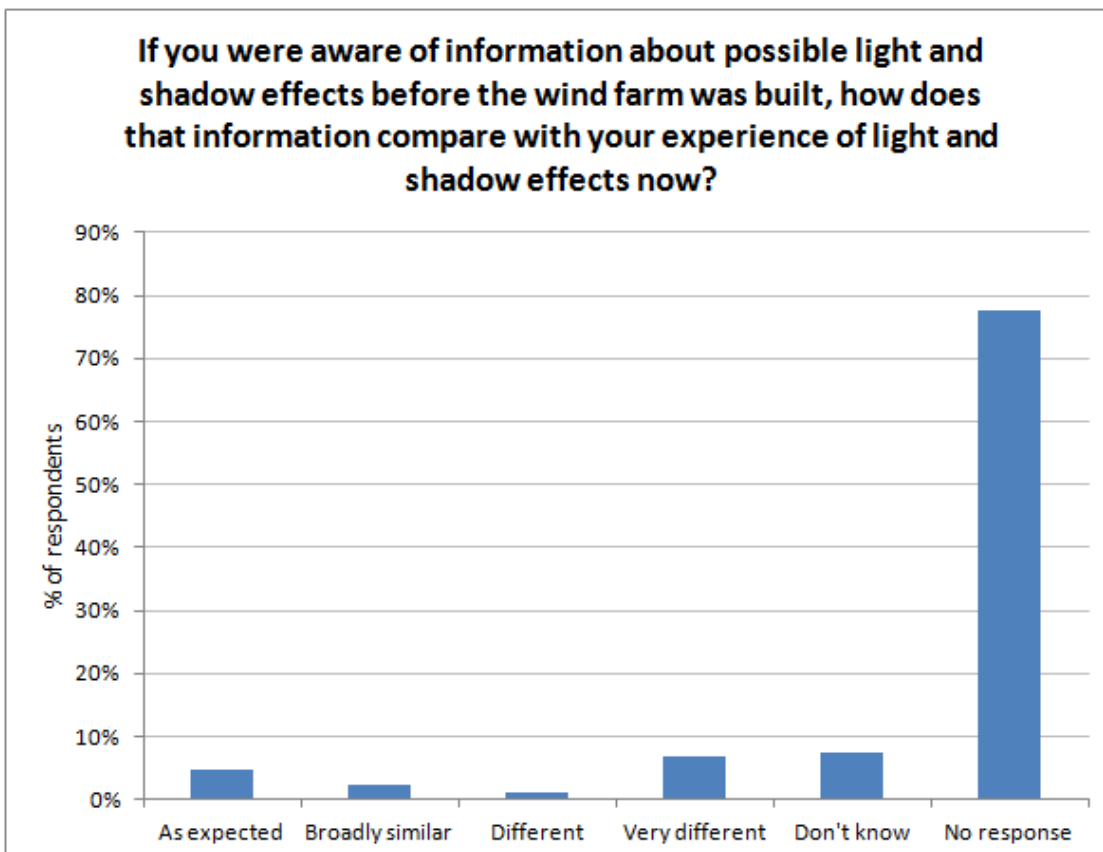
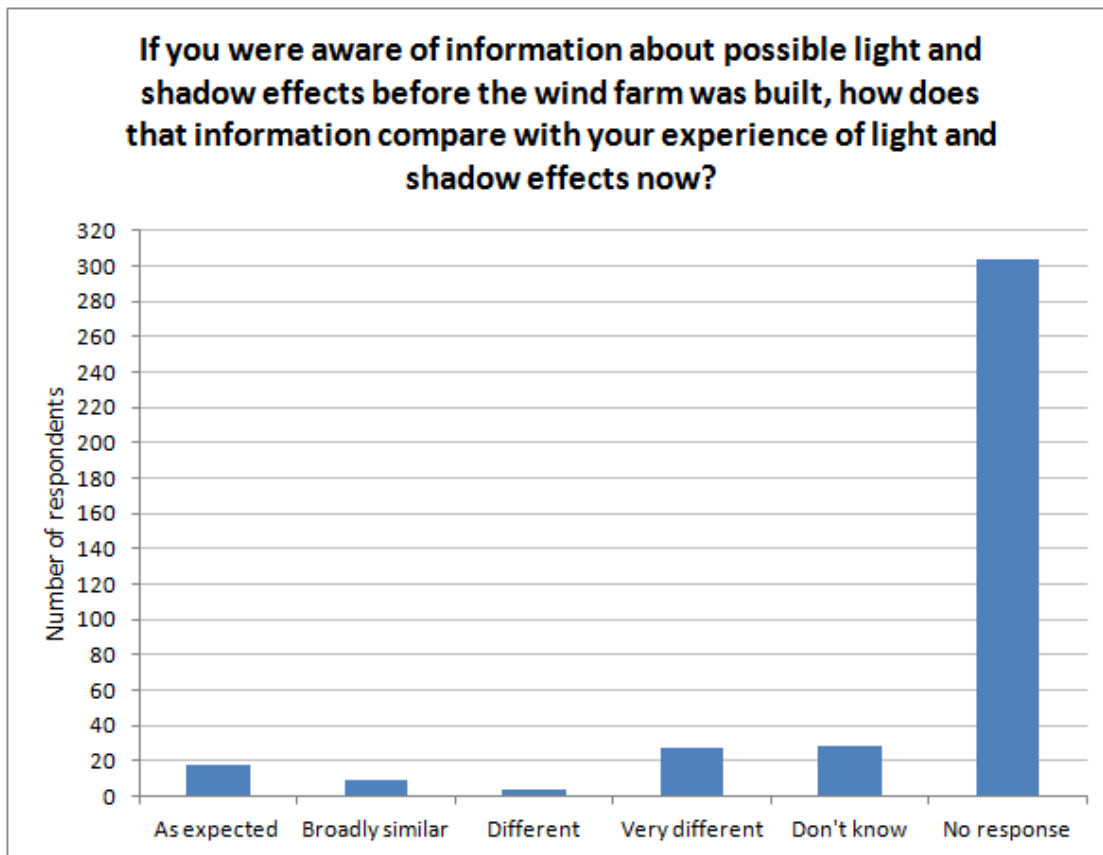
Question 21



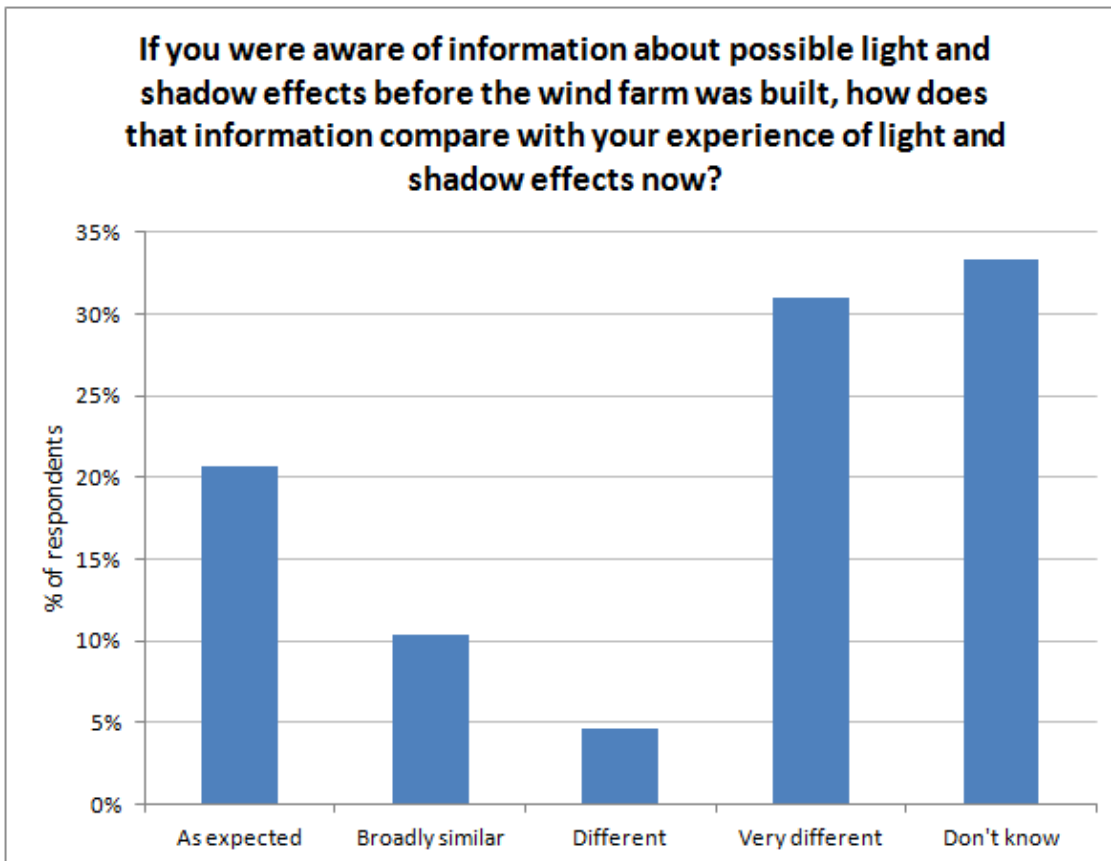
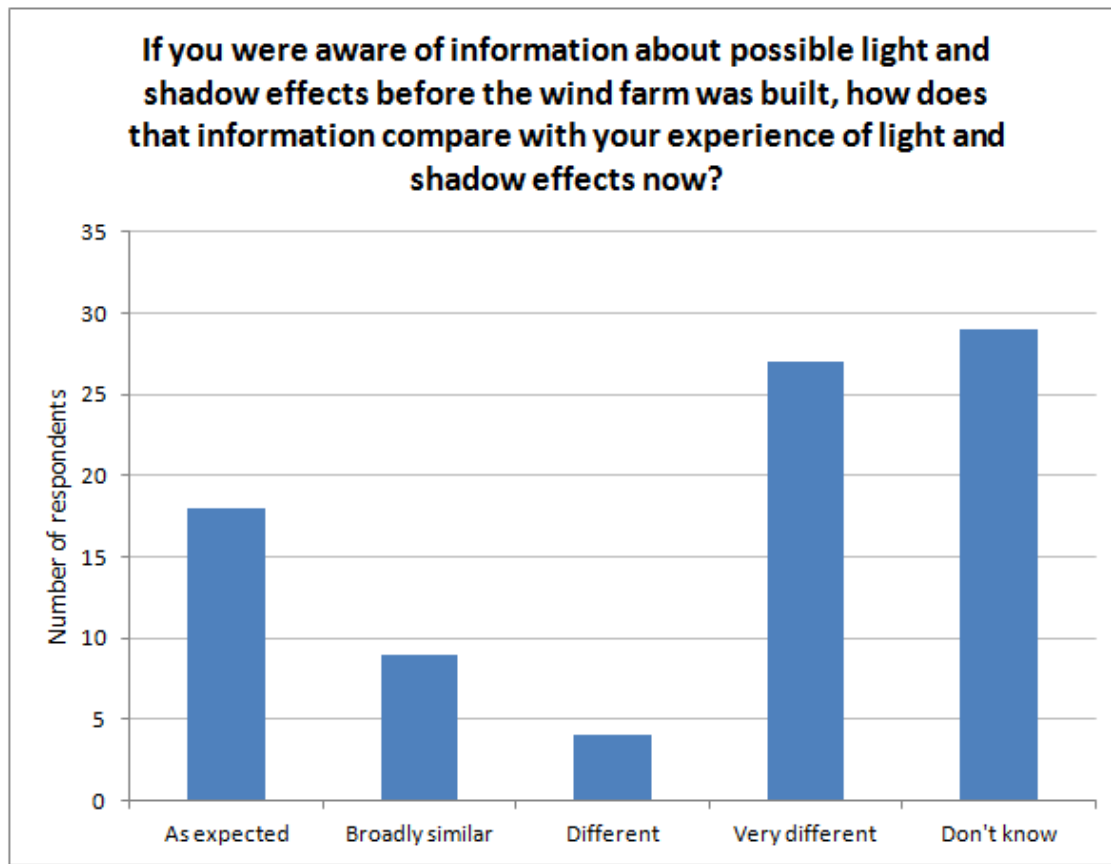
Question 22



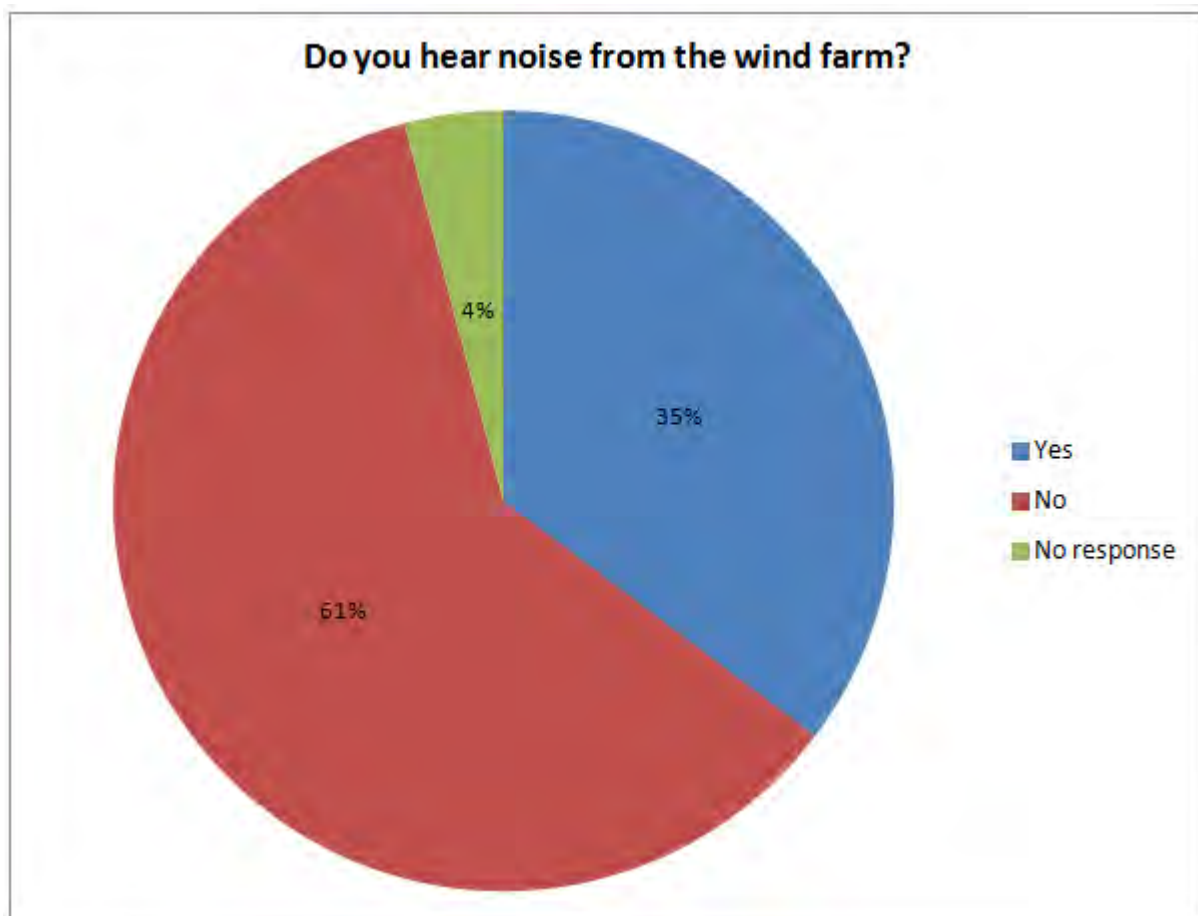
Question 23 – no response included



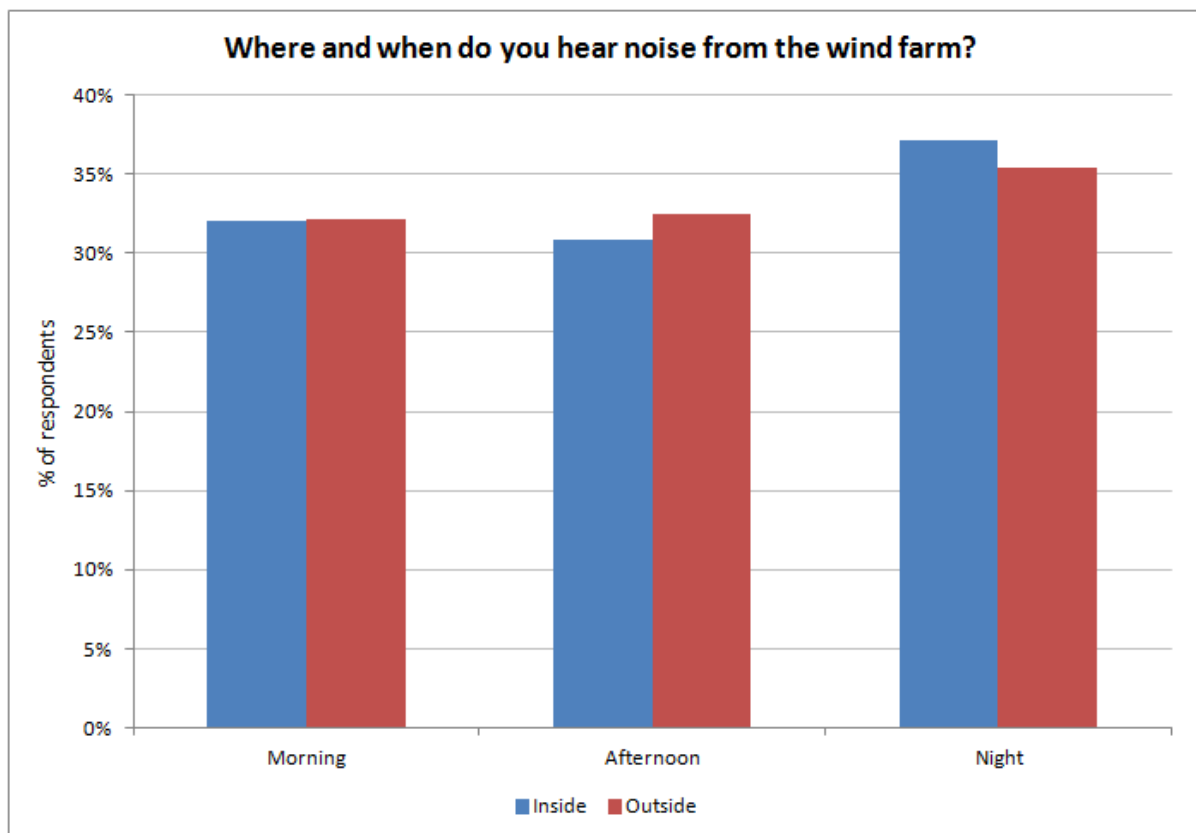
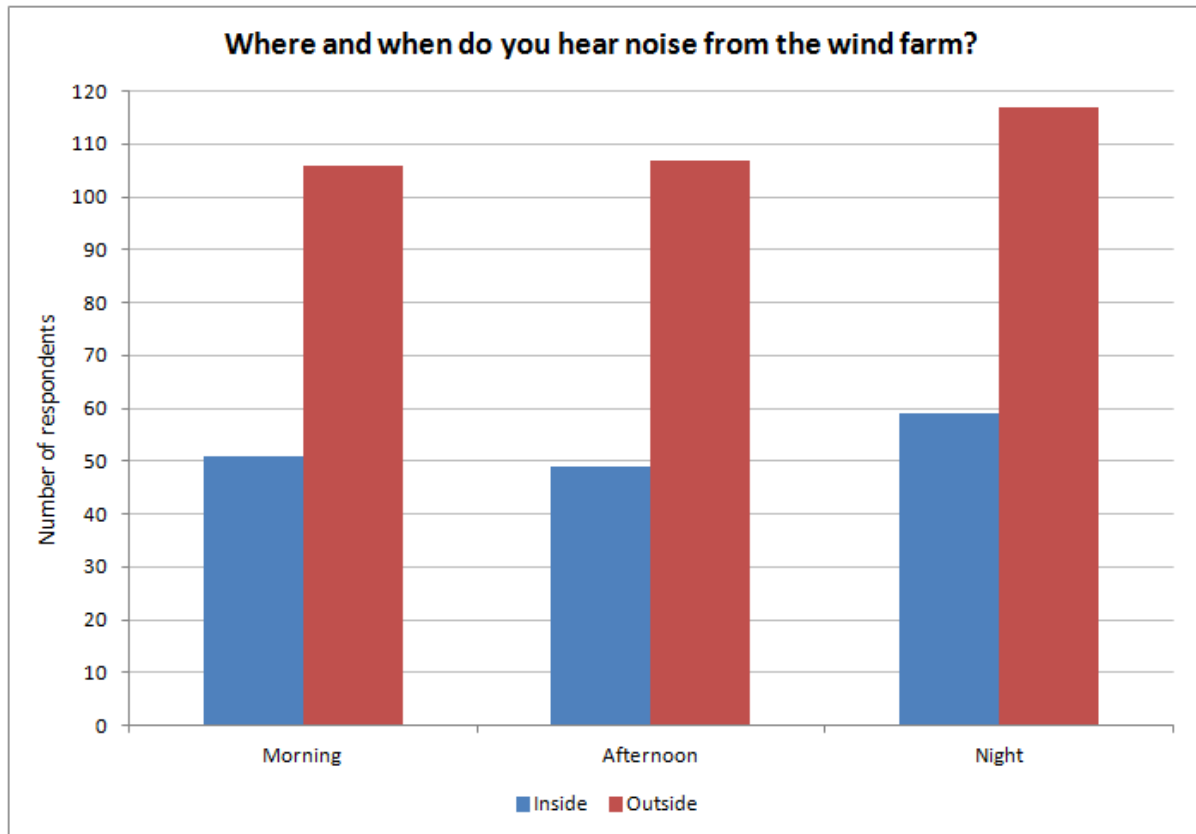
Question 23 – no response excluded



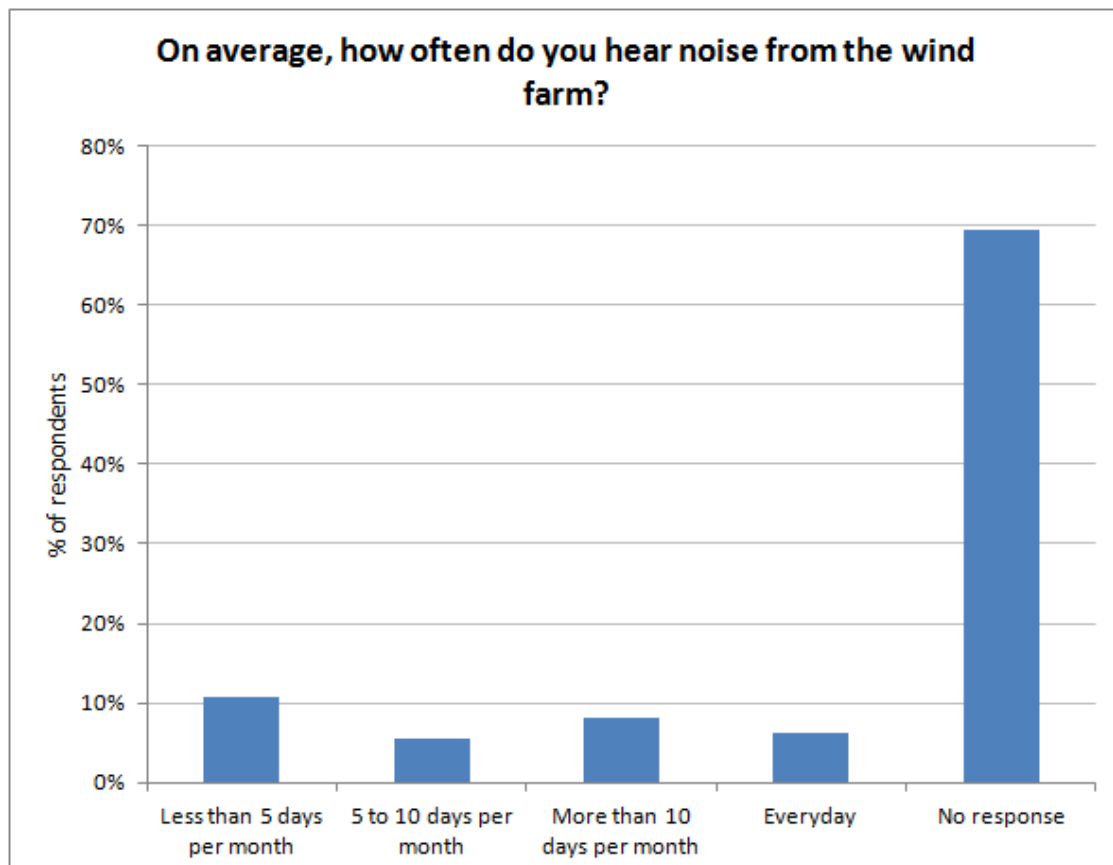
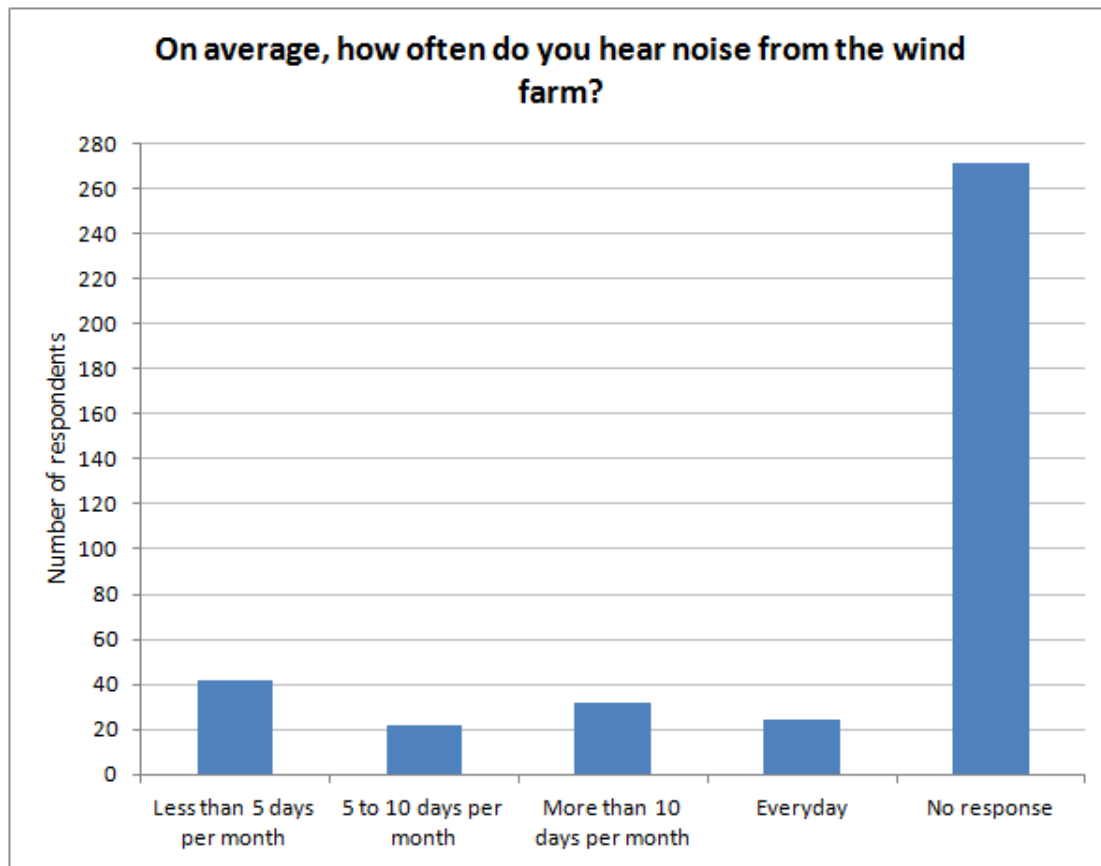
Noise perception Question 25



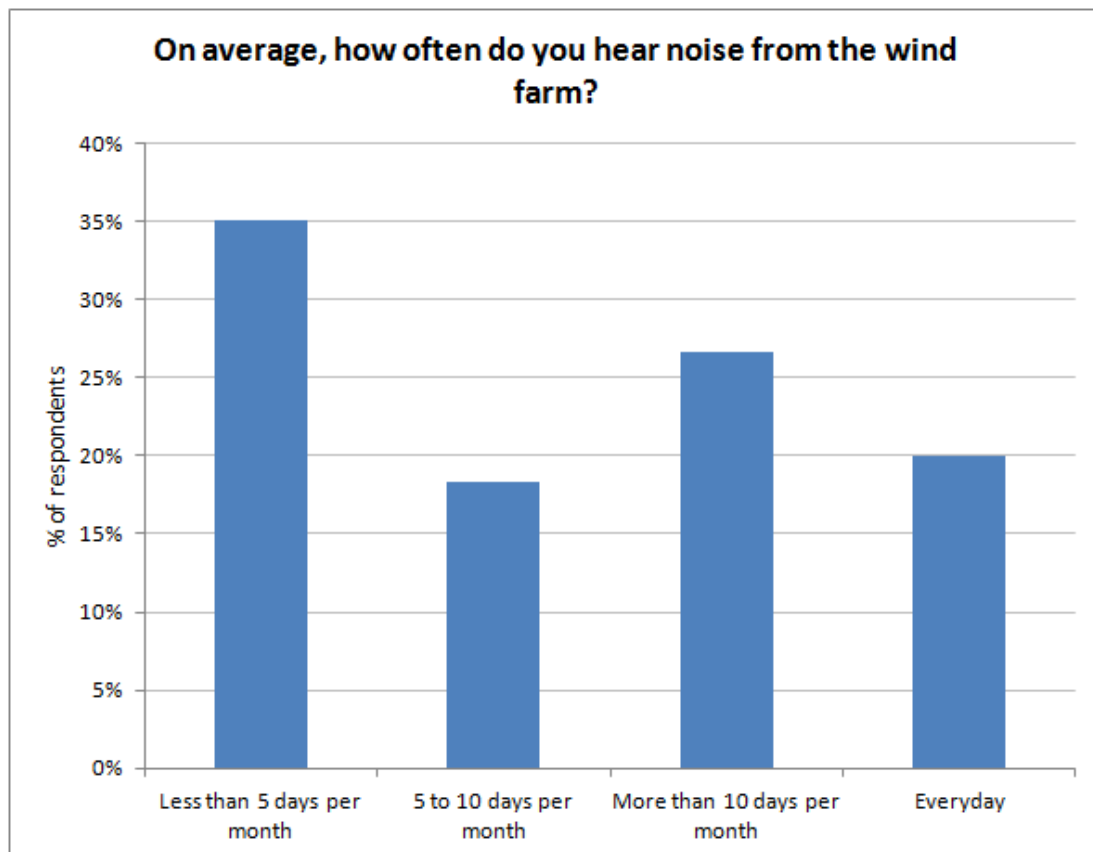
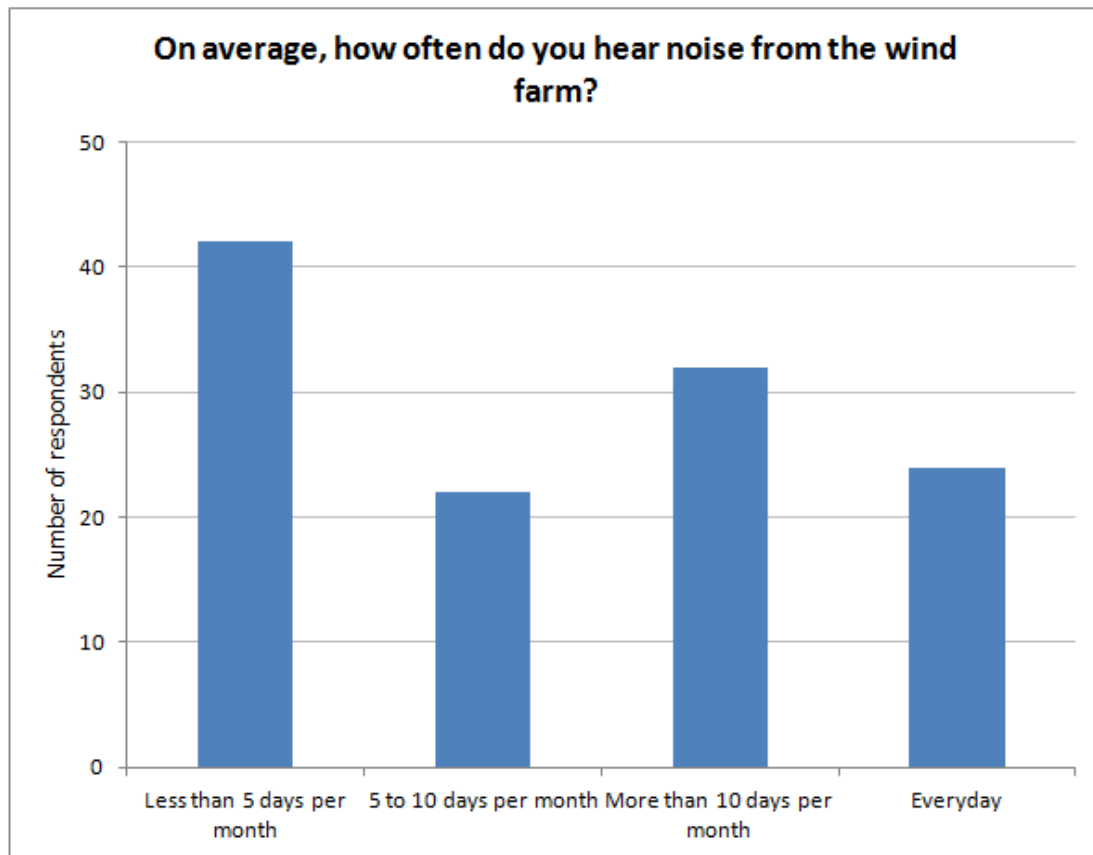
Question 26



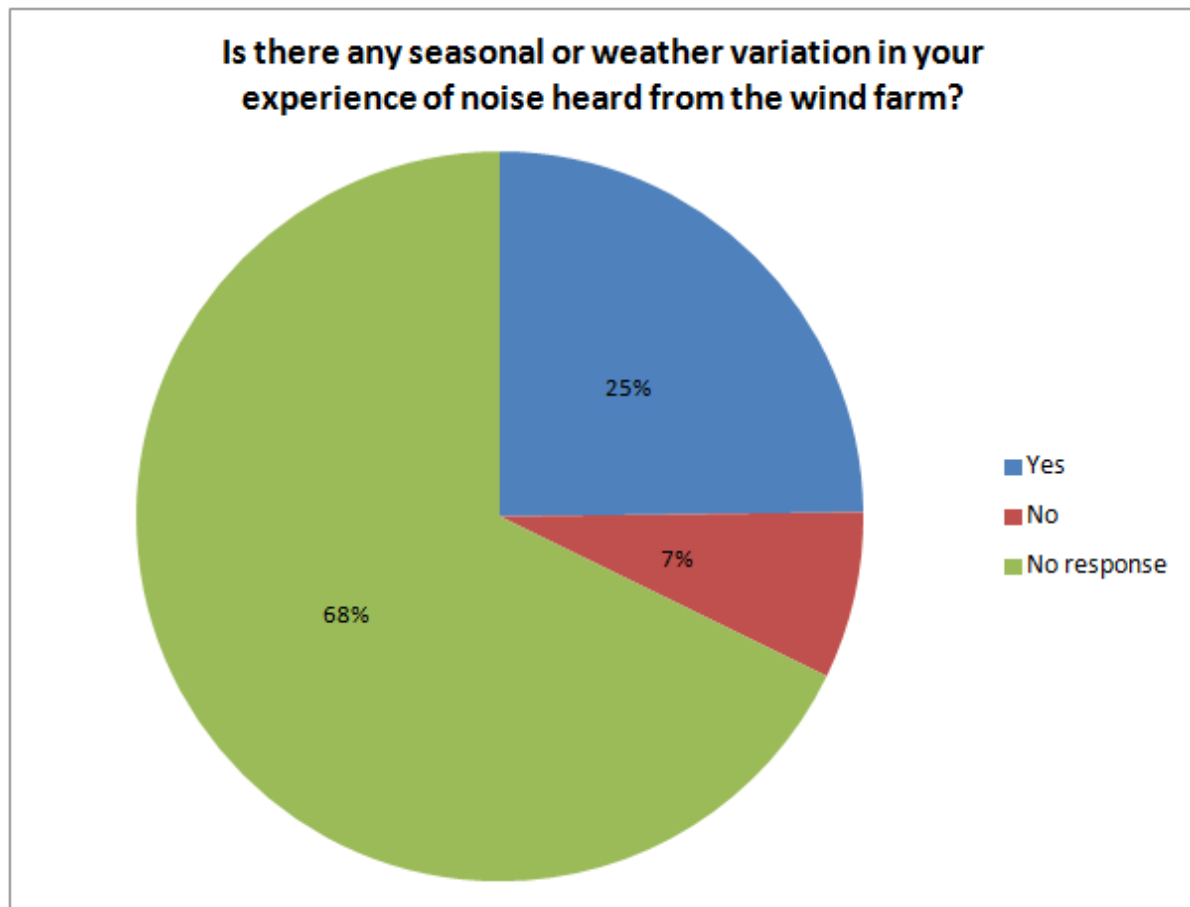
Question 27 – No response included



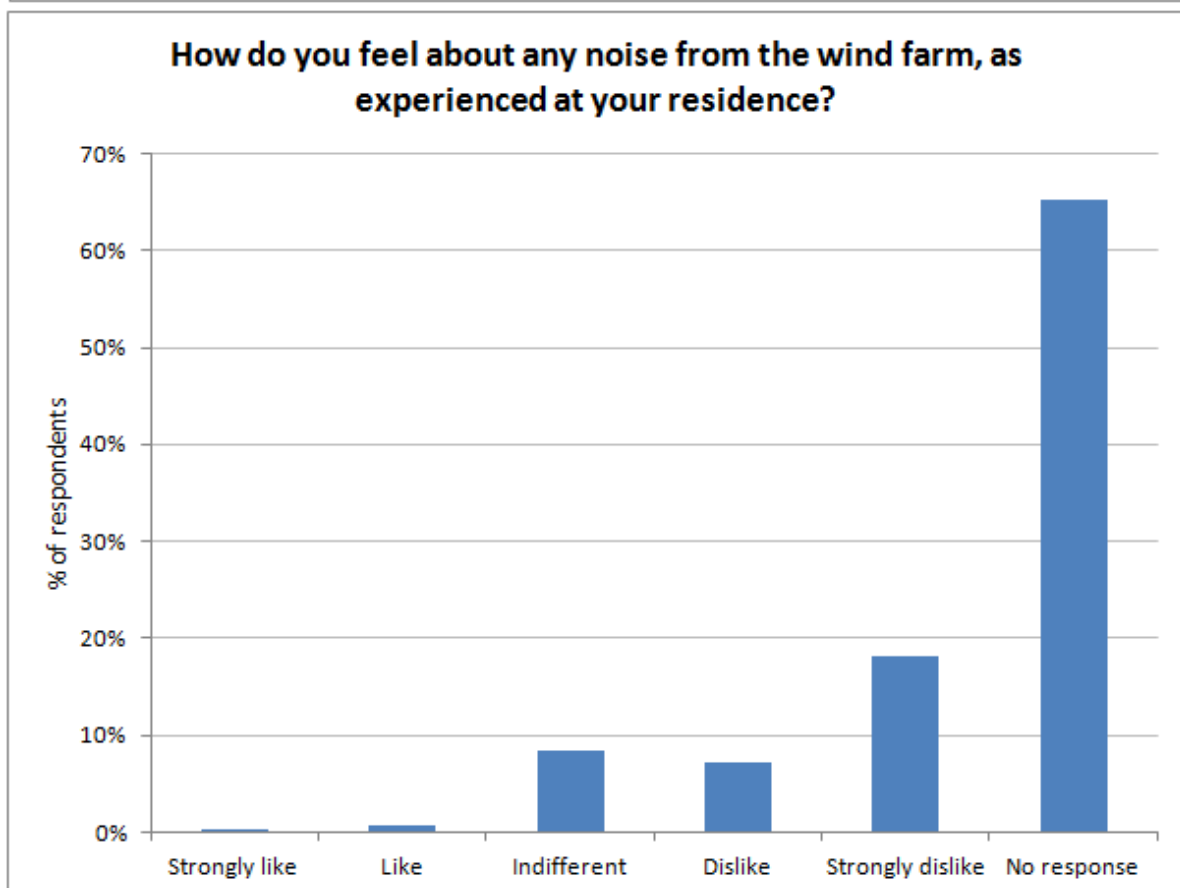
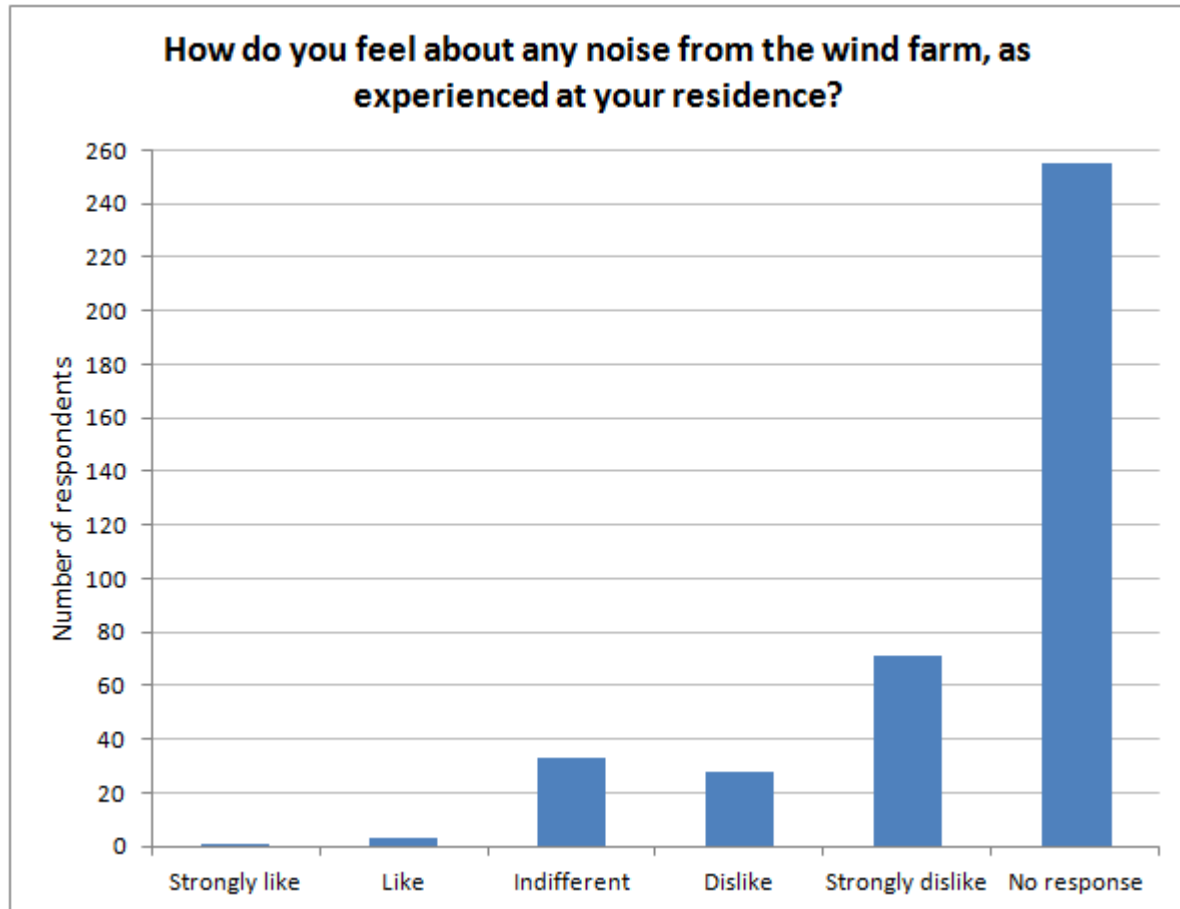
Question 27 – No response excluded



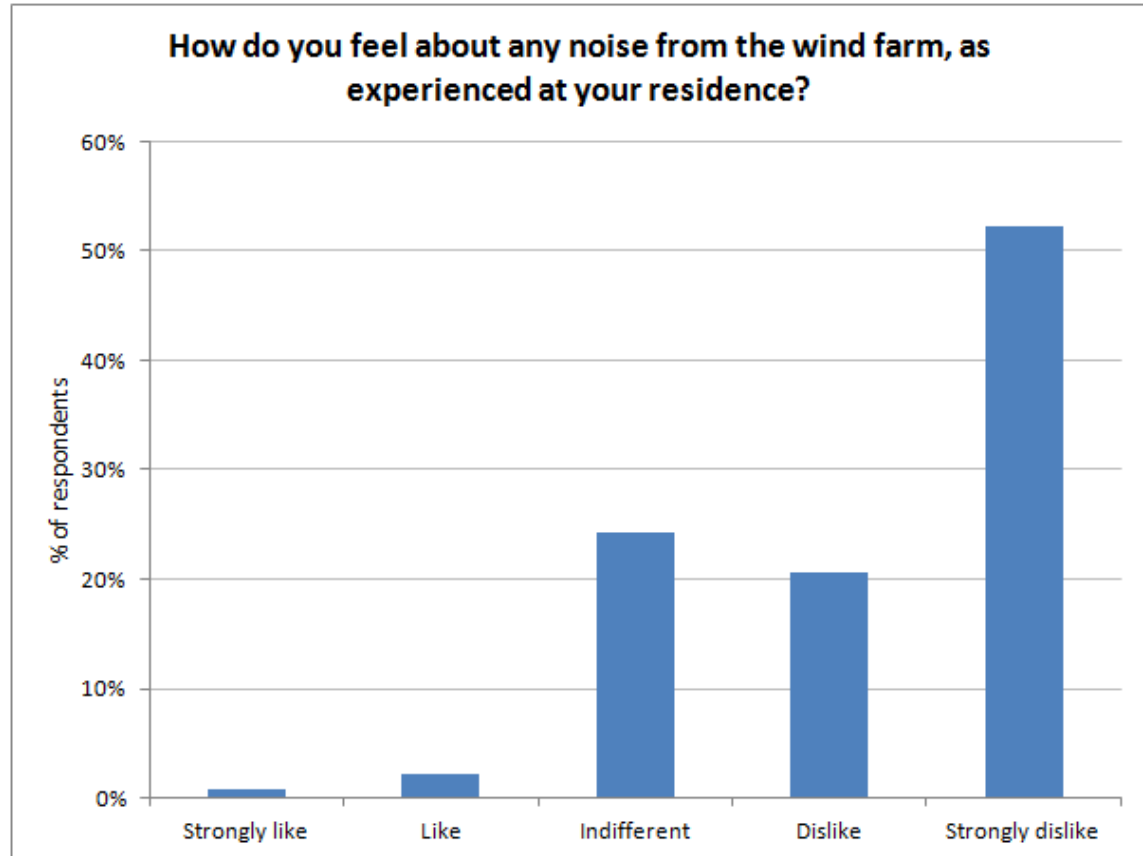
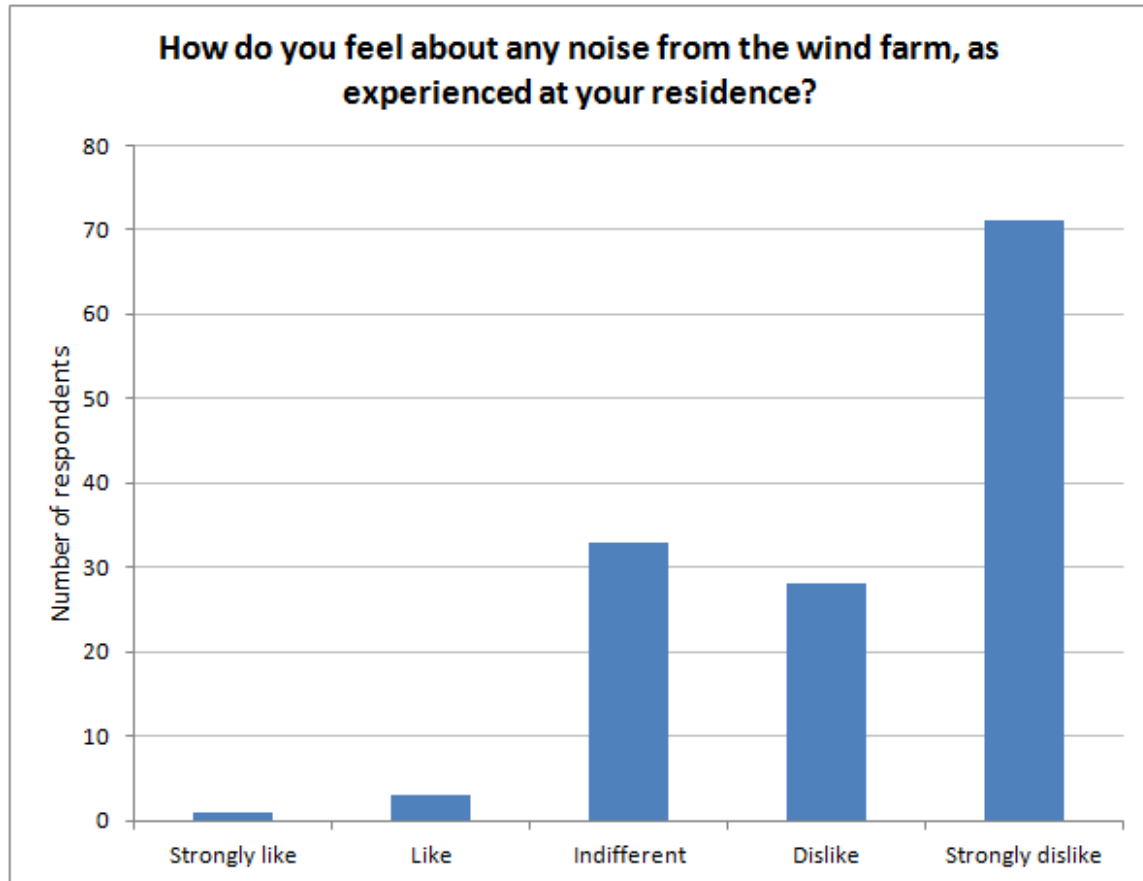
Question 29



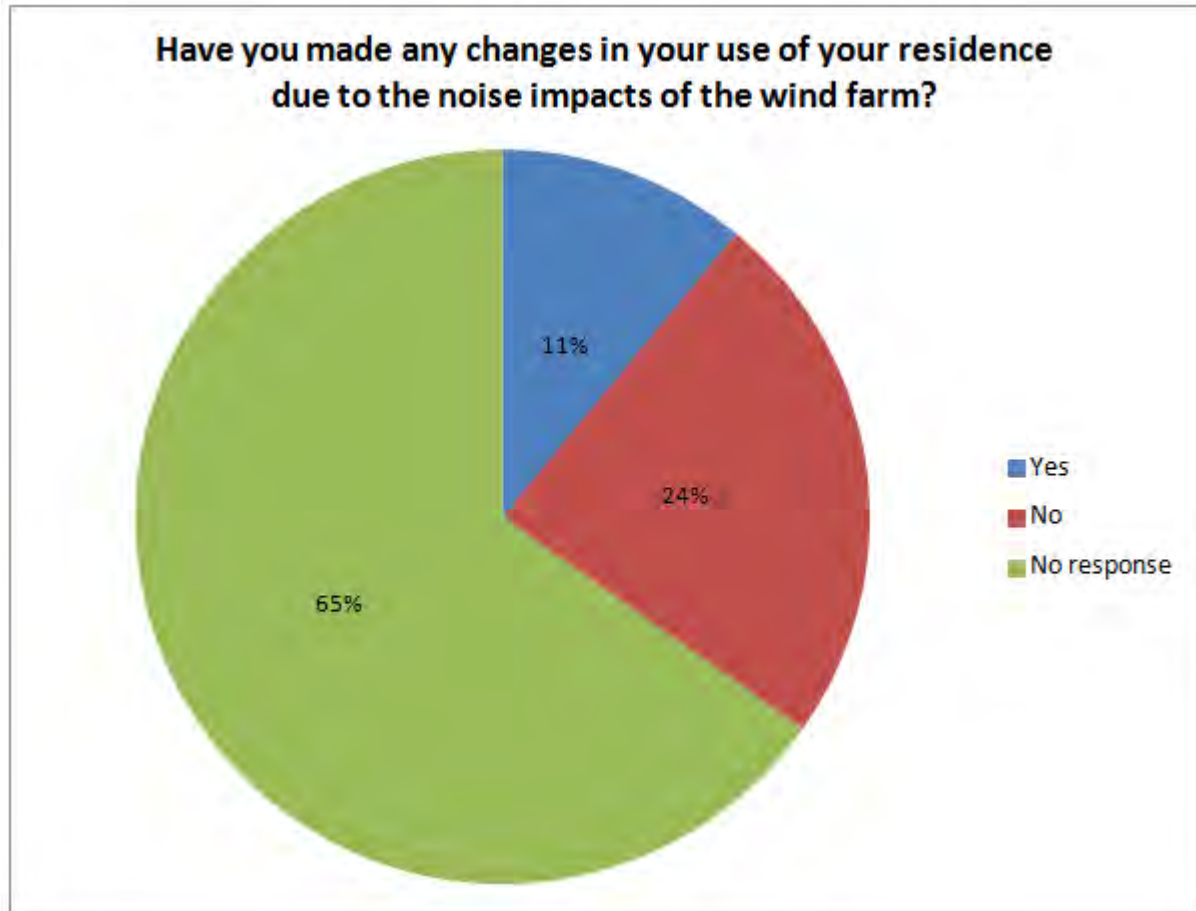
Question 30 – No response included



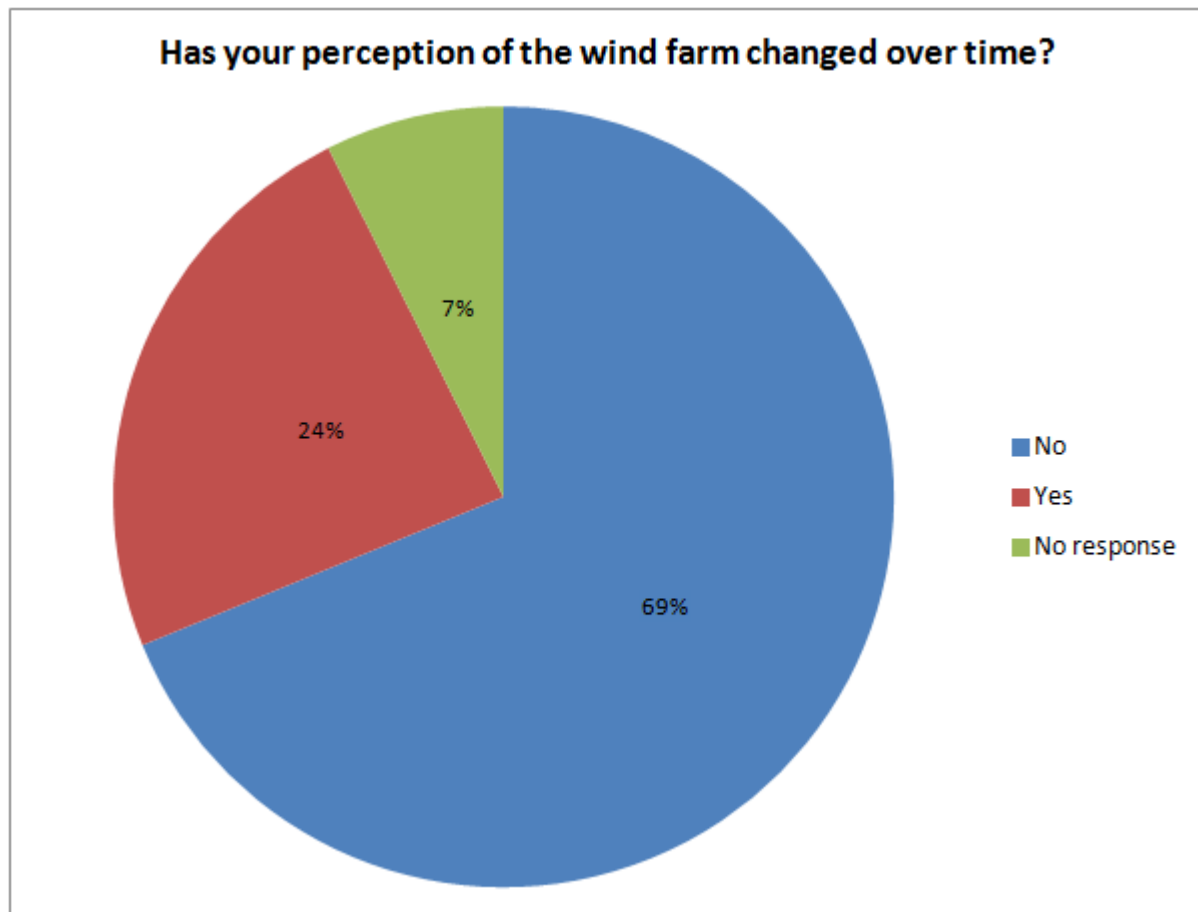
Question 30 – No response excluded



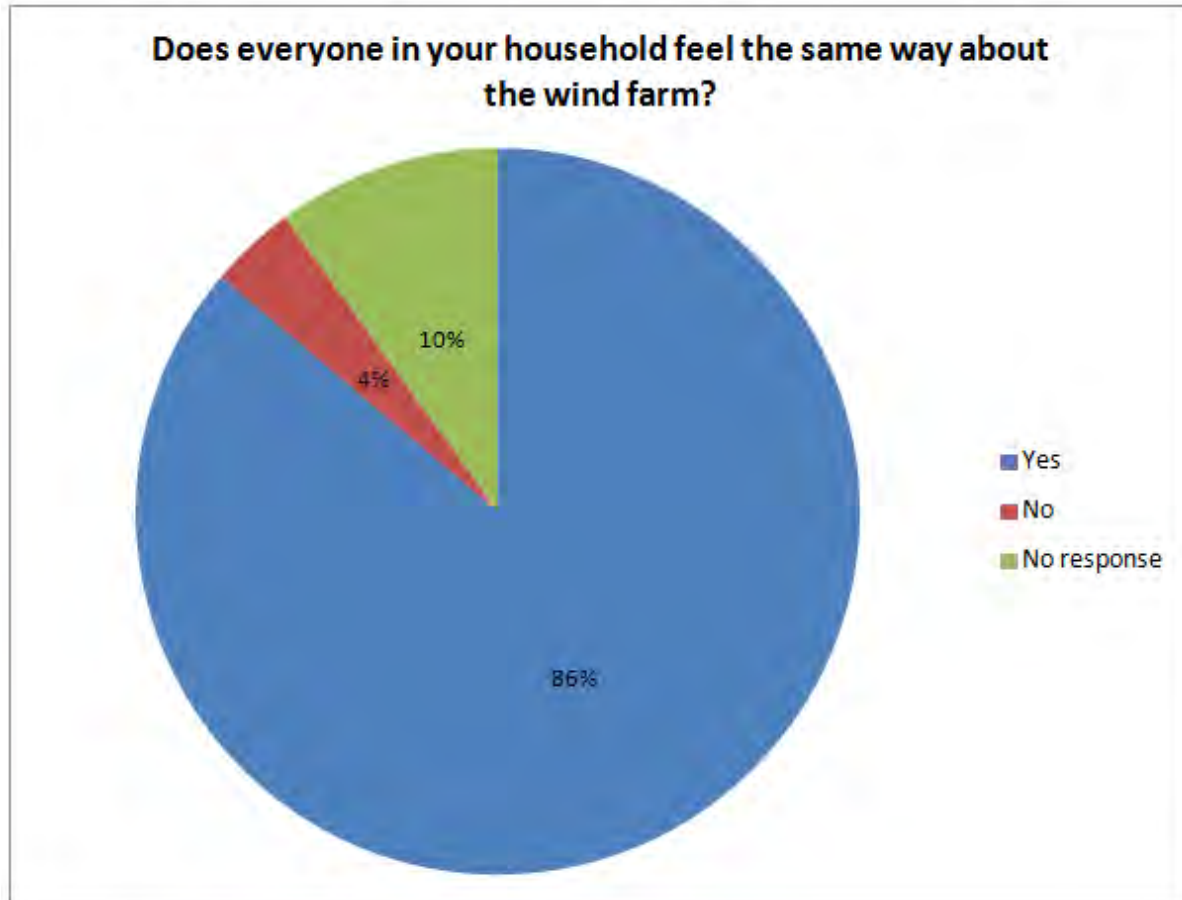
Question 31



Perception
Question 32



Question 33



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.

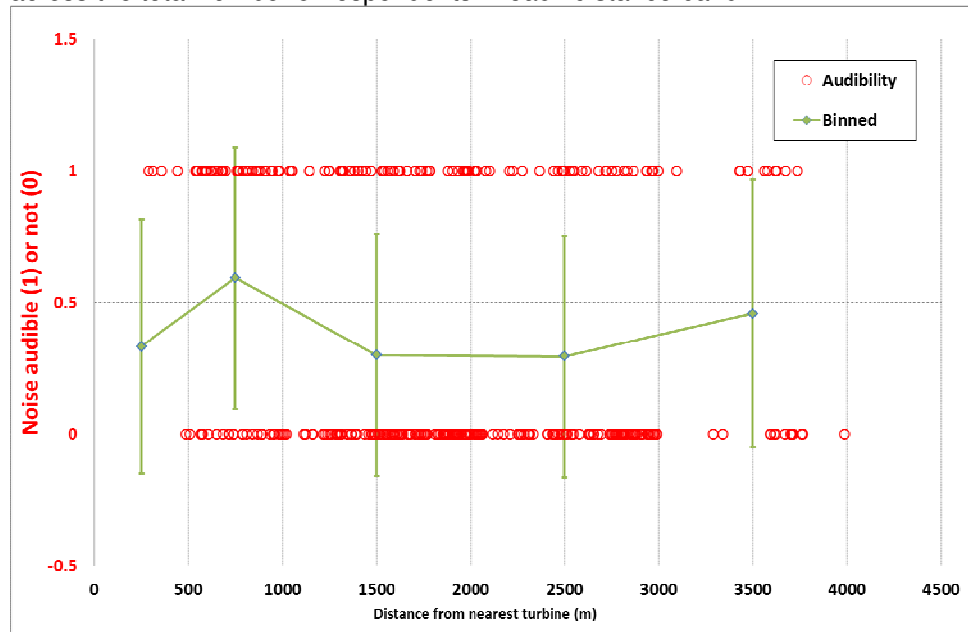


Figure C2 Residents' Survey reported opinion of the wind farm as a function of the respondent's distance to the nearest turbine. The green curve corresponds to the numerically averaged response (calculated from the five possible responses ranging from strongly dislike at -2 to strongly like at +2) across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

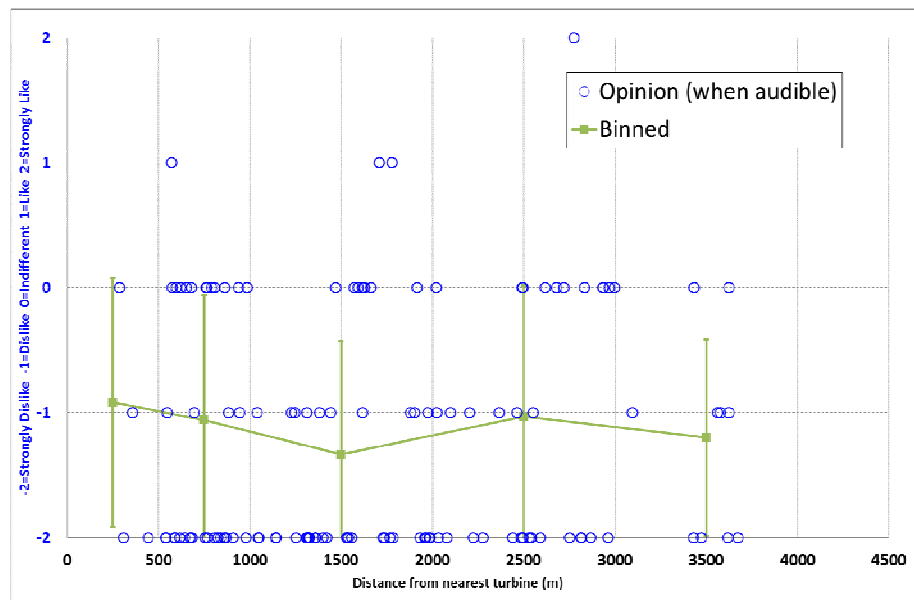


Figure C3 Residents' Survey reported audibility of the wind farm as a function of the calculated noise level. The green curve represents numerically averaged response (calculated from the two possible responses of inaudible at 0 or audible at 1) across the total number of respondents in noise level band,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

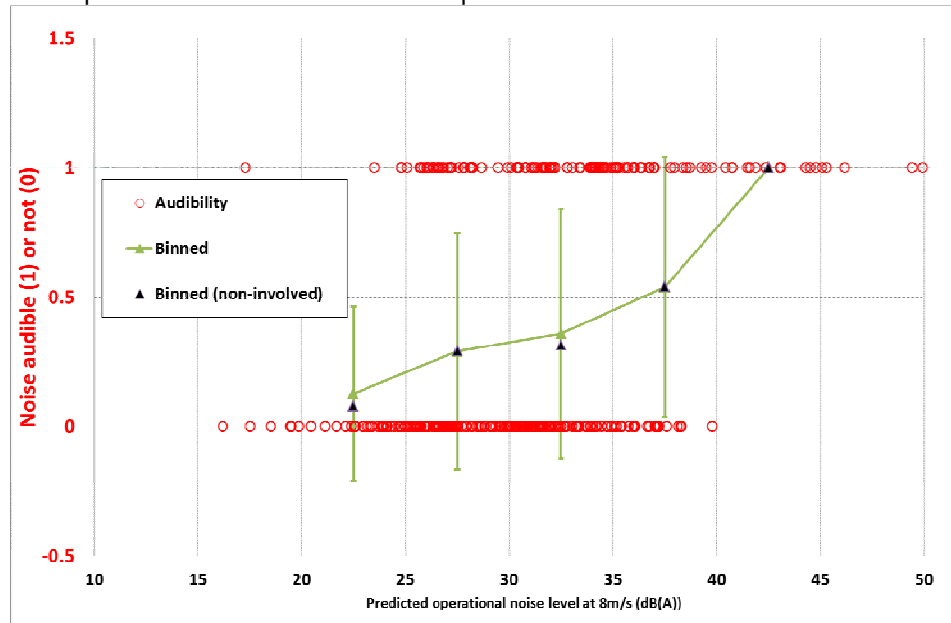
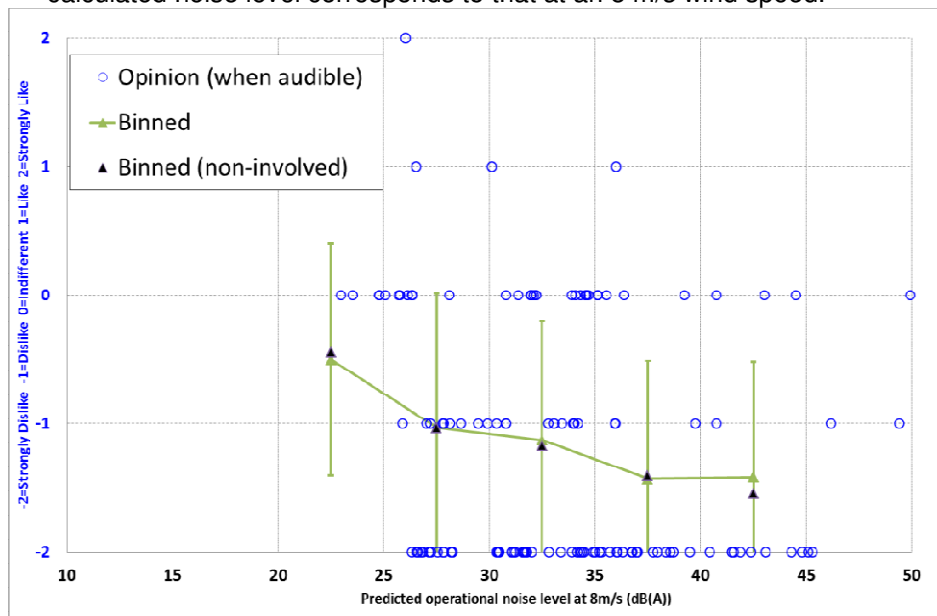


Figure C4 Residents' Survey reported opinion of the wind farm as a function of the calculated noise level. The green curve represents the numerically averaged response (calculated from the five possible responses ranging from strongly dislike at -2 to strongly like at +2) across the total number of respondents 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 landscape quality of condition, scenic quality, rarity, representativeness, conservation interests, recreation value, perceptual aspects and cultural associations.

The overall sensitivity of the landscape and visual resources are 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, states (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 of 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 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. However, the lack of a clear methodology for carrying out residential visual amenity surveys or identifying whether the so-called “Lavender test” has been exceeded or not, 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 its 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 <i>Profile data</i>). Often utilised as a basis for visibility modeling 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 discernable 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, tranquility 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 to 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.

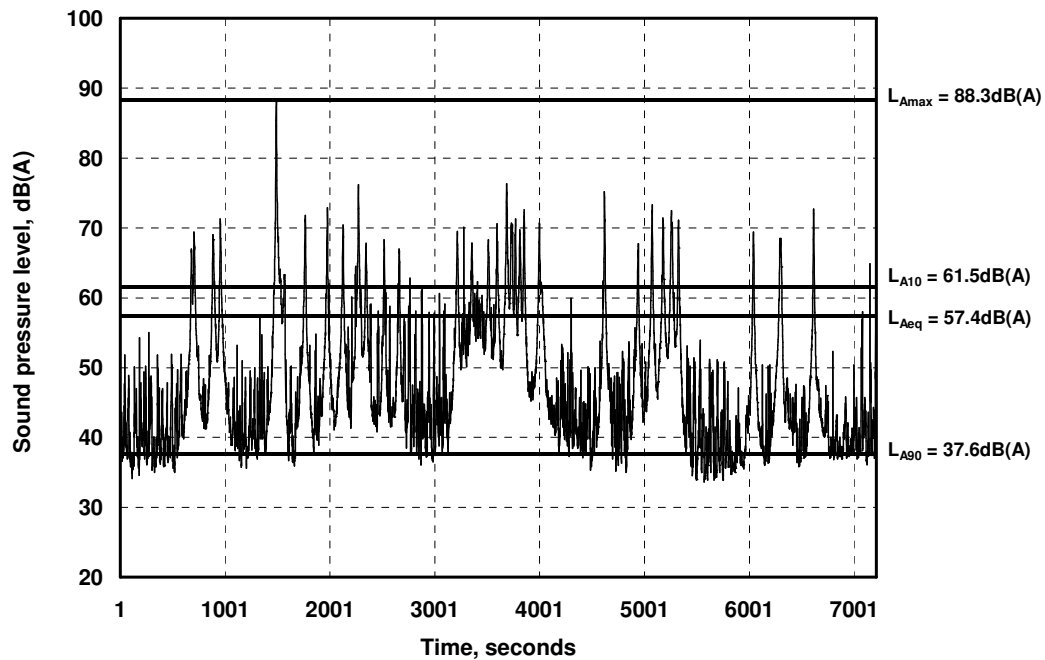


Figure F1 Sample time history of the sound pressure level measured close to a road

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 human subjective 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 derivation of a likely subjective response from a simple objective measure a complex problem. 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. Thus, any

objective measure of noise can, at best, be used to infer the average subjective response over a sample population.

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 $40 \text{ dB} + 40 \text{ dB} = 43 \text{ dB}$ and $50 \text{ dB} + 50 \text{ dB} = 53 \text{ dB}$. 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, $40 \text{ dB} + 50 \text{ dB} = 50 \text{ dB}$.

An increase in sound pressure level of 3 dB is commonly accepted as the smallest change of any subjective 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 subjective 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'.

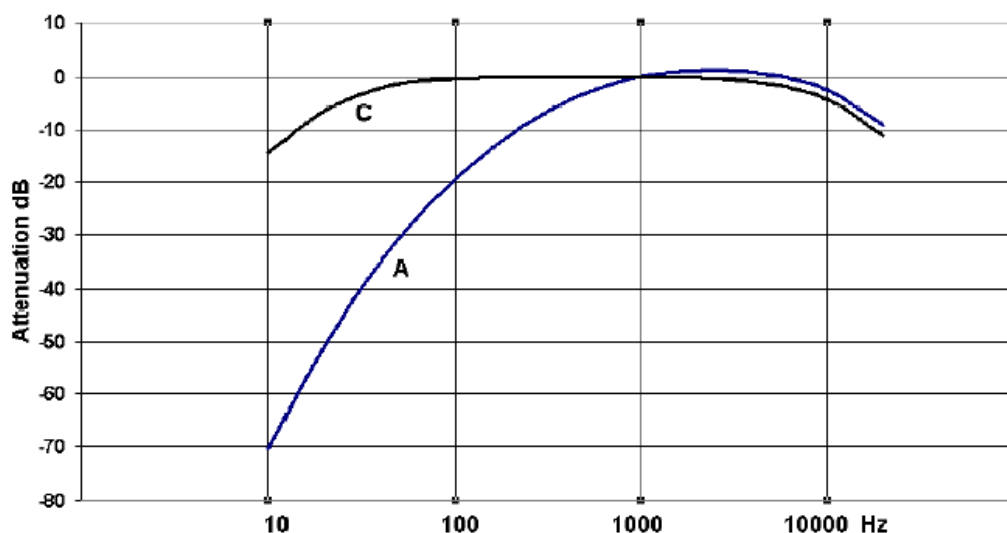


Figure F2 Comparison of the 'A' and 'C' weighting curves

When measuring sound with the aim of assessing subjective 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 subjective 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 subjective 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) sound at the same location. It is a useful 'general' noise index that has been found to correlate well with subjective 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 $L_{Aeq,1\text{ hour}}$ 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 $L_{Aeq,1\text{ hr}}$ 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 subjective 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 subjective 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.

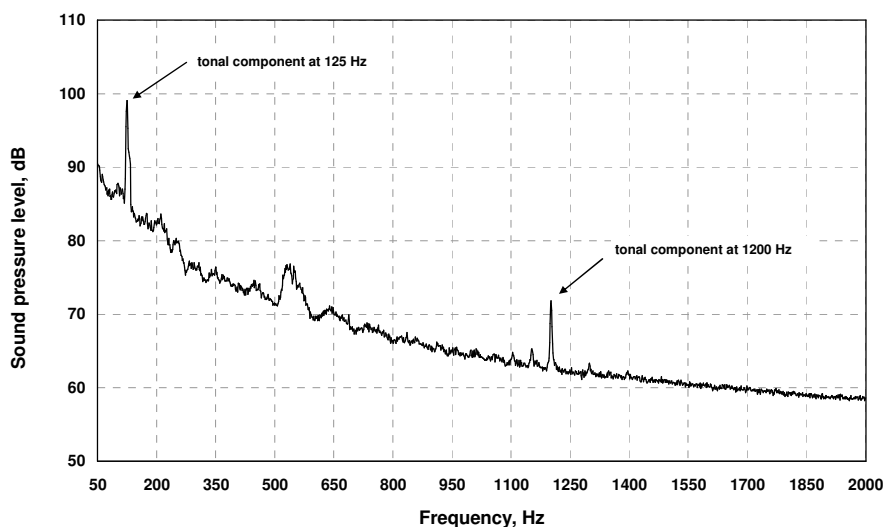


Figure F3 Sample narrow band analysis of an acoustic signal which contains tonal components at frequencies of 125 Hz and 1200 Hz.

GLOSSARY OF ACOUSTIC TERMINOLOGY

TERMINOLOGY	DESCRIPTION
<i>A-weighting</i>	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
<i>acoustic character</i>	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 subjective impact than the level of the sound alone might suggest
<i>acoustic screening</i>	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
<i>ambient noise</i>	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
<i>annoyance</i>	a feeling of displeasure in this case evoked by noise
<i>attenuation</i>	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.
<i>audible sound</i>	a sound that can be heard above all other ambient sounds
<i>audio frequency</i>	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
<i>background noise</i>	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)

TERMINOLOGY	DESCRIPTION
<i>dB</i>	abbreviation for 'decibel'
<i>dB(A)</i>	abbreviation for the decibel level of a sound that has been A-weighted
<i>decibel</i>	the unit normally employed to measure the magnitude of sound
<i>directivity</i>	the property of a sound source that causes more sound to be radiated in one direction than another
<i>equivalent continuous sound pressure level</i>	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 $L_{Aeq,T}$
<i>external noise level</i>	the noise level, in decibels, measured outside a building
<i>filter</i>	a device for separating components of an acoustic signal on the basis of their frequencies
<i>frequency</i>	the number of acoustic pressure fluctuations per second occurring about the atmospheric mean pressure (also known as the 'pitch' of a sound)
<i>frequency analysis</i>	the analysis of a sound into it's frequency components
<i>ground effects</i>	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
<i>hertz</i>	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
<i>impulsive sound</i>	a sound having all its energy concentrated in a very short time period
<i>instantaneous sound pressure</i>	at a given point in space and at a given instant in time, the difference between the instantaneous pressure and the mean atmospheric pressure
<i>internal noise level</i>	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
<i>level</i>	the general term used to describe a sound once it has been converted into decibels
<i>loudness</i>	the attribute of human auditory response in which sound may be ordered on a subjective scale that typically extends from barely audible to painfully loud
<i>masking</i>	the effect whereby an otherwise audible sound is made inaudible by the presence of other sounds
<i>noise</i>	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. Subjectively: sound that evokes a feeling of displeasure in the environment in which it is heard, and is therefore unwelcomed by the receiver
<i>noise emission</i>	the noise emitted by a source of sound
<i>noise immission</i>	the noise to which a receiver is exposed
<i>noise nuisance</i>	an unlawful interference with a person's use or enjoyment of land, or of some <i>right</i> over, or in connection with it
<i>octave band frequency analysis</i>	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)

APPENDIX F

TERMINOLOGY	DESCRIPTION
<i>percentile exceeded sound level</i>	the noise level exceeded for n% of the time over a given time period, T, denoted by $L_{An,T}$
<i>receiver</i>	a person or property exposed to the noise being considered
<i>residual noise</i>	the ambient noise that remains in the absence of the specific noise whose impact is being assessed
<i>sound</i>	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 subjectively: the sensation of hearing excited by the acoustic oscillations described above (see also 'noise')
<i>sound level meter</i>	an instrument for measuring sound pressure level
<i>sound pressure amplitude</i>	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)
<i>sound pressure level</i>	a measure of the sound pressure at a point, in decibels
<i>sound power level</i>	the total sound power radiated by a source, in decibels
<i>spectrum</i>	a description of the amplitude of a sound as a function of frequency
<i>third-octave band frequency analysis</i>	a frequency analysis using frequency bands one third of an octave wide
<i>threshold of hearing</i>	the lowest amplitude sound capable of evoking the sensation of hearing in the average healthy human ear (0.00002 Pa)
<i>tone</i>	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 Planning Advice Note 1/2011 (PAN 1/2011) 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 PAN 1/2011, 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 range⁴⁴.

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 group comprised a cross section of interested persons including, amongst others,

⁴⁴ 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.

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 (subjectively). 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 daytime⁴⁵ 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);
- 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

⁴⁵ 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.

demonstrated not to exceed the derived noise limits (see Figure G2), having also accounted for any applicable tonal penalties.

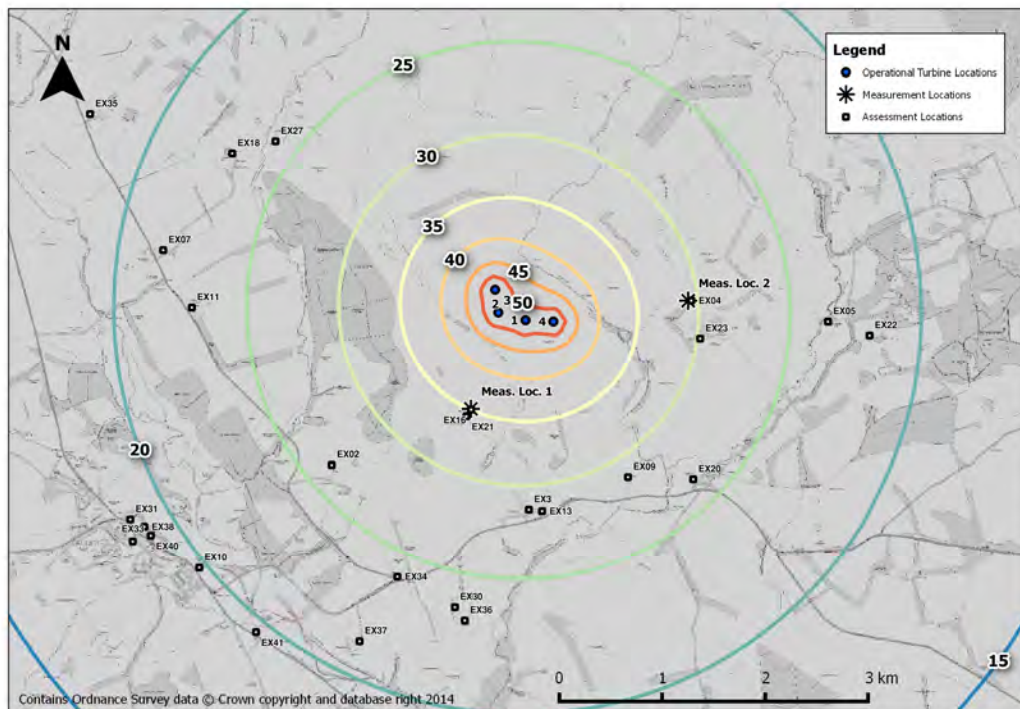


Figure G1 - Hypothetical wind farm layout illustrating the procedure of ETSU-R-97

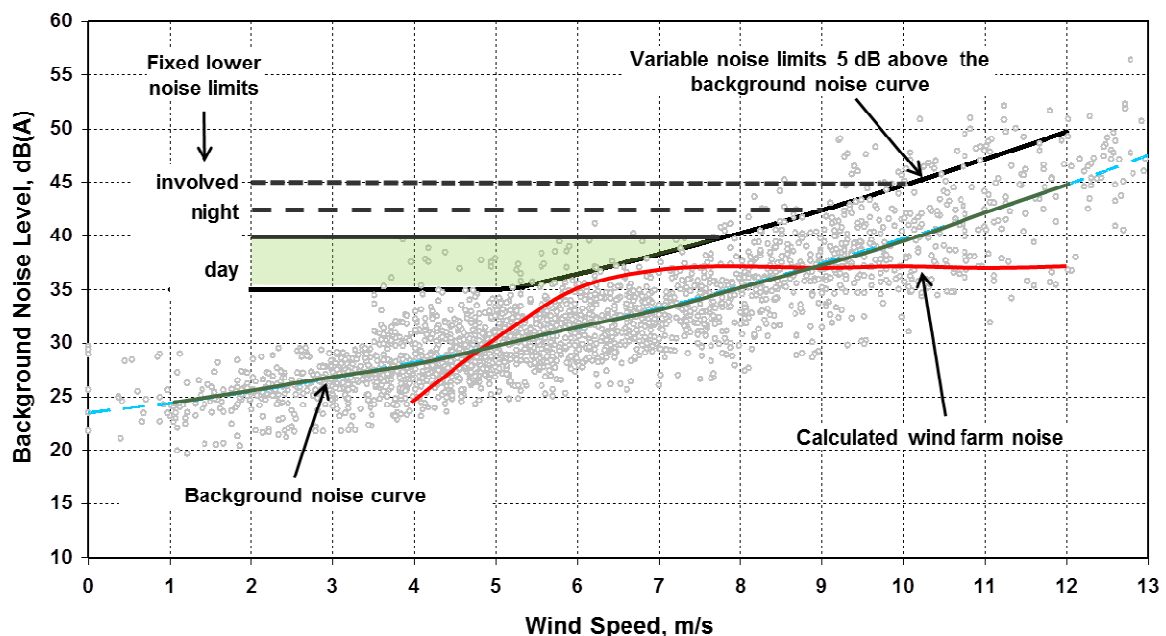


Figure G2 - Illustrative noise assessment under ETSU-R-97 at a residential location

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

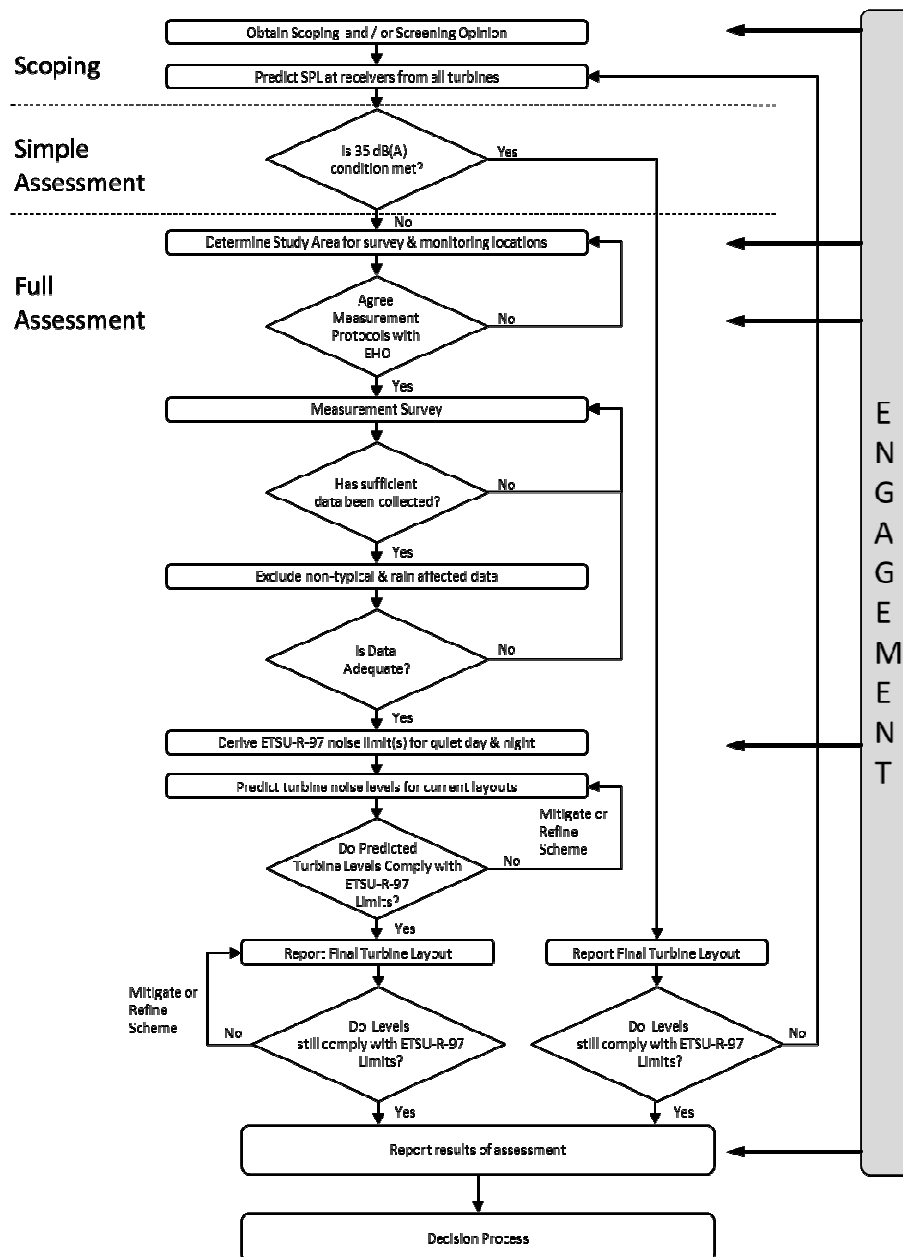
Formal conditions are often attached to wind farm planning consents, requiring that the noise limits derived in accordance with the ETSU-R-97/IOA GPG procedures should not be exceeded. These are called conditioned noise limits, and will normally apply to all potentially noise affected properties and 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 limits⁴⁶.

⁴⁶ 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.

Figure G3 - Flowchart illustrating the standard process for a wind farm noise impact assessment (taken from IOA GPG)



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 noise⁴⁷. 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 subjective 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 would have the consequence that compliance with the planning conditions would in practice be more difficult because of this penalty, which represents the subjective impact of the tone.

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

⁴⁷ 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 ‘whoomping’ 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. Efforts are presently underway, however, to develop a robust objective AM assessment methodology (see, for example, the IOA Working Group on AM⁴⁸). 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.

⁴⁸ 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.

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 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 conservative⁴⁹ 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.

⁴⁹ 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 cases⁵⁰ 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,

⁵⁰ 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 unknown⁵¹ 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.

⁵¹ 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).

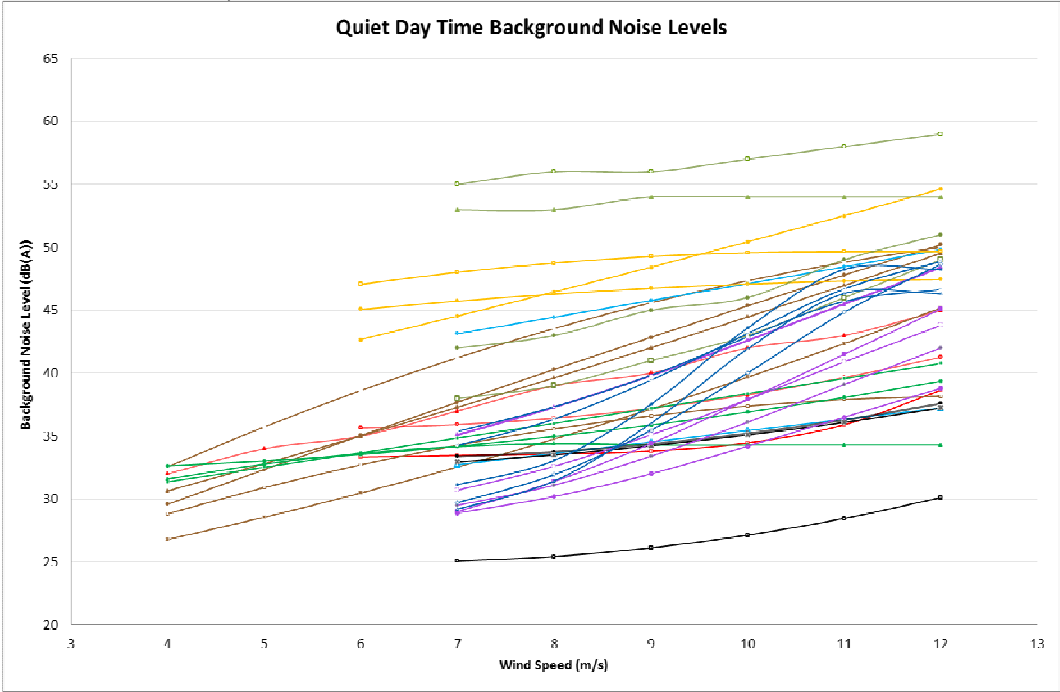
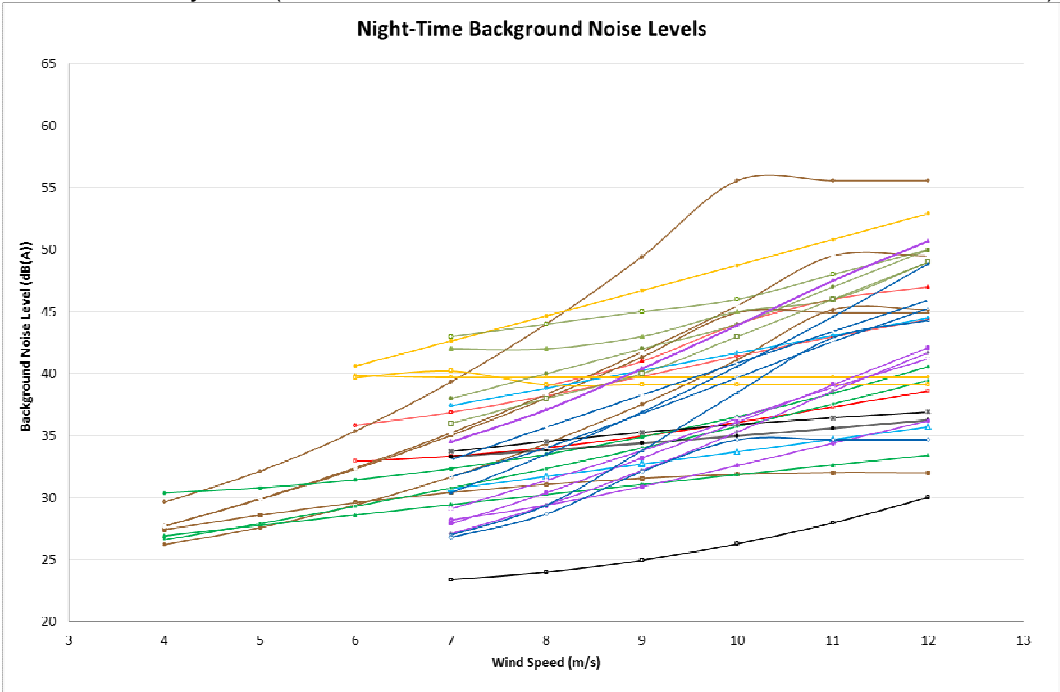


Figure J2 Graphical comparison of the reported baseline background noise levels (L_{A90} , dB) across the study sites as a function of wind speed for the ETSU-R-97 defined night time periods. The levels have been derived from the relevant summary information contained in the various noise impact assessment 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 speed⁵² of 8 m/s. Such noise contour plots were used to illustrate the calculated spatial distribution of the overall A-weighted L_{A90} noise levels⁵³ 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 receptor⁵⁴. 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' conditions⁵⁵ 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.

⁵² 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.

⁵³ 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.

⁵⁴ Downwind conditions.

⁵⁵ Wind blowing from the receiver towards the turbines.

The resultant noise contours therefore provided a conservative ('worst-case') but useful and 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 factor⁵⁶ ($G=0.5$) 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 document⁵⁷ 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

⁵⁶ 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.

⁵⁷ 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.

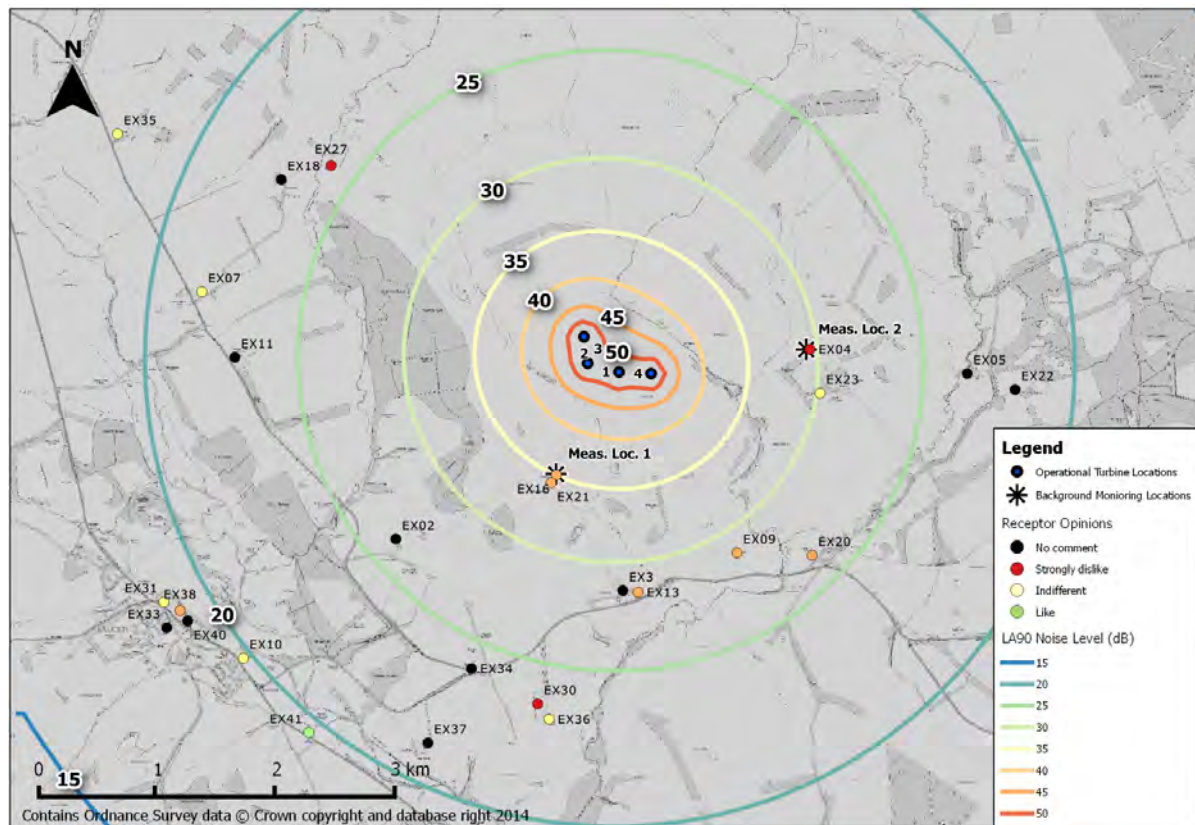


Figure K1 - Planning application layout - Predictions as per EIA/report [hypothetical example to illustrate the method used in this study]

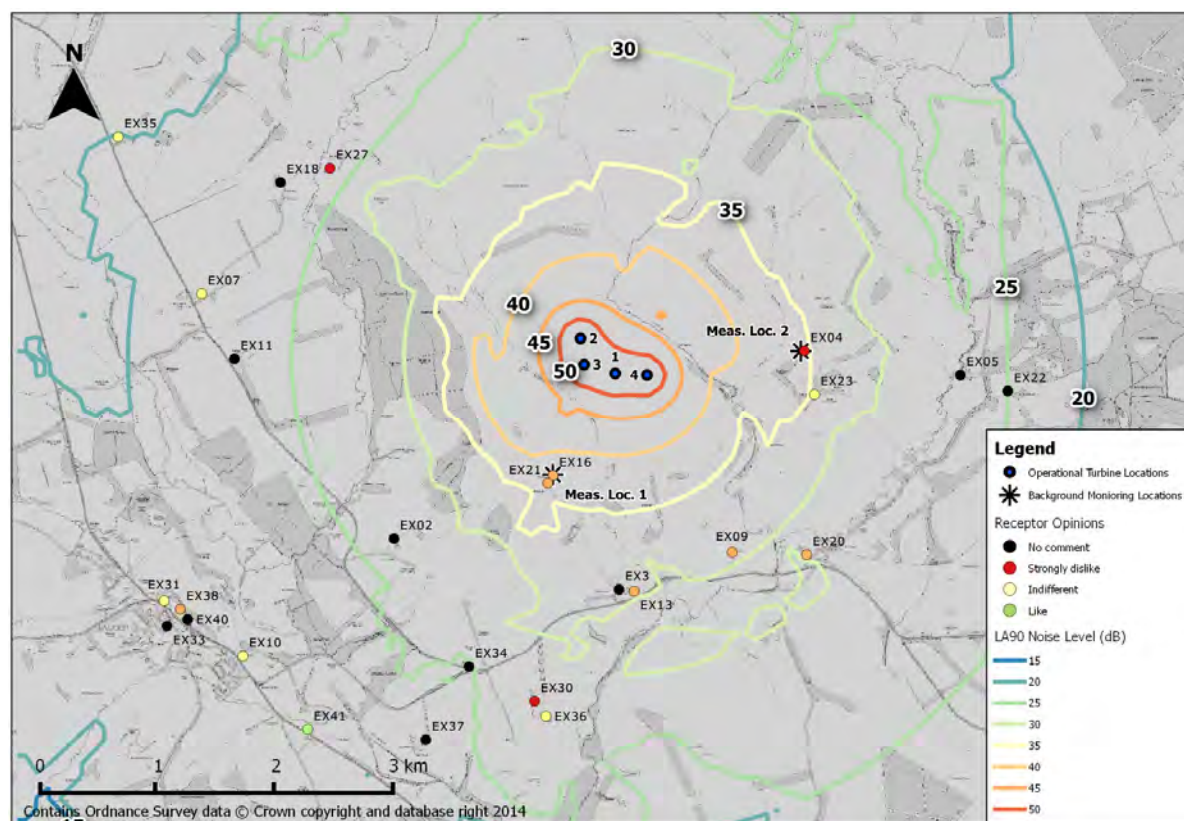


Figure K2 - Planning application layout - Predictions as per IOA GPG [hypothetical example to illustrate the method used in this study]

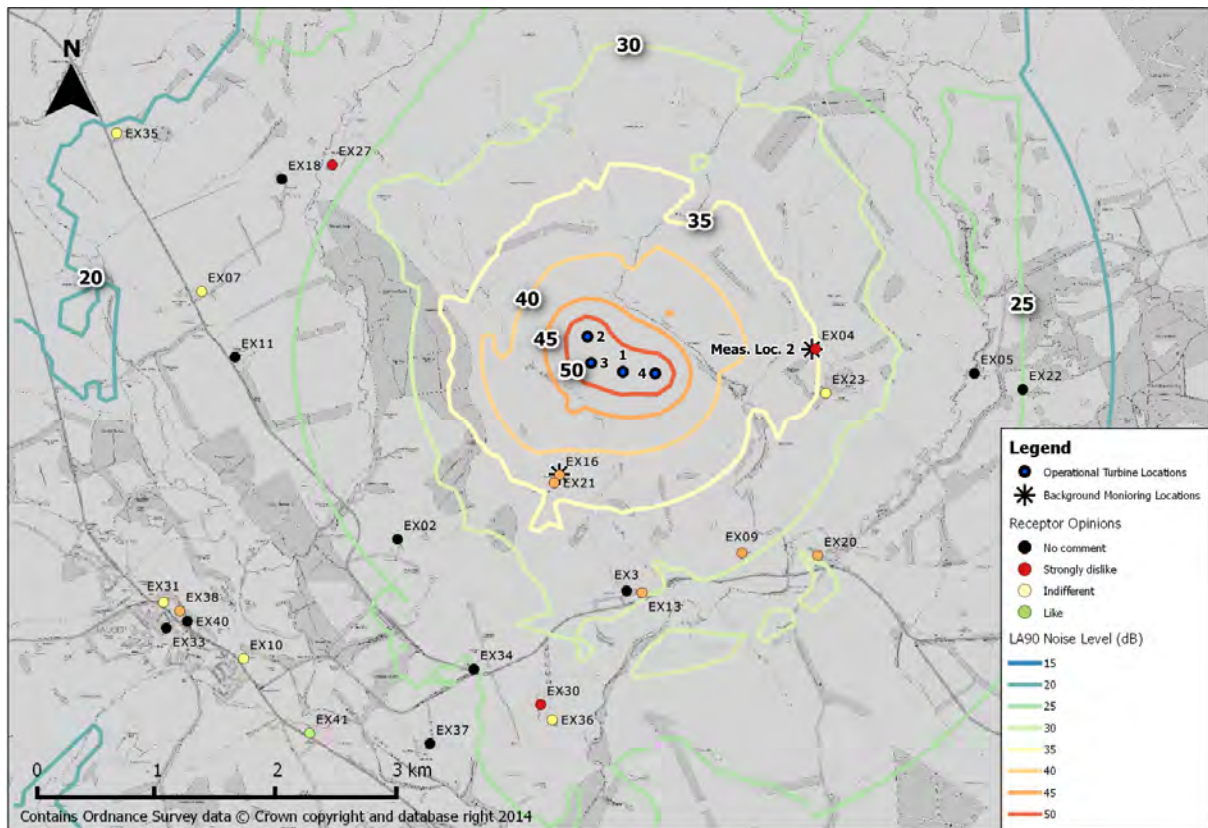


Figure K3 - Planning application layout - Predictions as per EIA/report [hypothetical example to illustrate the method used in this study]

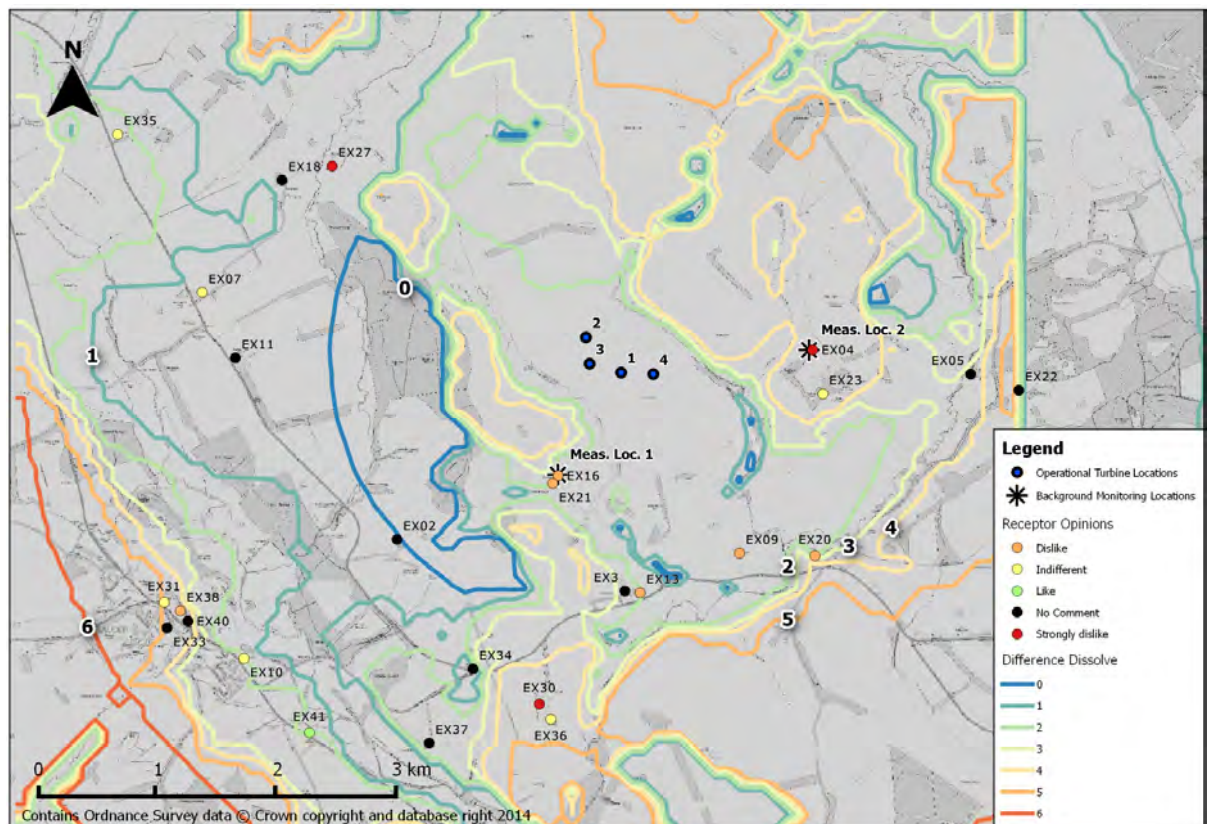


Figure K4 – Difference between the predictions of Figures N5.3 and N5.1. [hypothetical example to illustrate the method used in this study]

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global environmental solutions

AYLESBURY

7 Wornal Park, Menmarsh Road,
Worminghall, Aylesbury,
Buckinghamshire HP18 9PH
T: +44 (0)1844 337380

BELFAST

24 Ballynahinch Street, Hillsborough,
Co. Down, BT26 6AW Northern Ireland
T: +44 (0)28 9268 9036

BRADFORD-ON-AVON

Treenwood House, Rowden Lane,
Bradford-on-Avon, Wiltshire BA15 2AU
T: +44 (0)1225 309400

BRISTOL

Langford Lodge, 109 Pembroke Road,
Clifton, Bristol BS8 3EU
T: +44 (0)117 9064280

CAMBRIDGE

8 Stow Court, Stow-cum-Guy,
Cambridge CB25 9AS
T: +44 (0)1223 813805

CARDIFF

Fulmar House, Beignon Close, Ocean
Way, Cardiff CF24 5PB
T: +44 (0)29 20491010

CHELMSFORD

Unit 77, Waterhouse Business Centre,
2 Cromar Way, Chelmsford, Essex
CM1 2QE
T: +44 (0)1245 392170

DUBLIN

7 Dundrum Business Park, Windy
Arbour, Dundrum, Dublin 14 Ireland
T: +353 (0)1 2964667

EDINBURGH

No. 4 The Roundal, Roddinglaw
Business Park, Gogar, Edinburgh
EH12 9DB
T: +44 (0)131 3356830

EXETER

69 Polsloe Road, Exeter EX1 2NF
T: +44 (0)1392 490152

FARNBOROUGH

The Pavilion, 2 Sherborne Road, South
Farnborough, Hampshire GU14 6JT
T: +44 (0)1252 515682

GLASGOW

4 Woodside Place, Charing Cross,
Glasgow G3 7QF
T: +44 (0)141 3535037

HUDDERSFIELD

Westleigh House, Wakefield Road,
Denby Dale, Huddersfield HD8 8QJ
T: +44 (0)1484 860521

LEEDS

Suite 1, Jason House, Kerry Hill,
Horsforth, Leeds LS18 4JR
T: +44 (0)113 2580650

LONDON

83 Victoria Street,
London, SW1H 0HW
T: +44 (0)203 691 5810

MAIDSTONE

19 Hollingworth Court, Turkey Mill,
Maidstone, Kent ME14 5PP
T: +44 (0)1622 609242

NEWCASTLE UPON TYNE

Sailors Bethel, Horatio Street,
Newcastle-upon-Tyne NE1 2PE
T: +44 (0)191 2611966

NOTTINGHAM

Aspect House, Aspect Business Park,
Bennerley Road, Nottingham NG6 8WR
T: +44 (0)115 9647280

SHEFFIELD

STEP Business Centre, Wortley Road,
Deepcar, Sheffield S36 2UH
T: +44 (0)114 2903628

SHREWSBURY

Mytton Mill, Forton Heath, Montford
Bridge, Shrewsbury SY4 1HA
T: +44 (0)1743 850170

STAFFORD

8 Parker Court, Staffordshire Technology
Park, Beaconside, Stafford ST18 0WP
T: +44 (0)1785 241755

WARRINGTON

Suite 9 Beech House, Padgate Business
Park, Green Lane, Warrington WA1 4JN
T: +44 (0)1925 827218

WORCESTER

Suite 5, Brindley Court, Gresley Road,
Shire Business Park, Worcester
WR4 9FD
T: +44 (0)1905 751310



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