Natural England Commissioned Report NECR032

Investigating the impacts of windfarm development on peatlands in England: Part 2 Appendices and References

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Introduction

Natural England commission a range of reports from external contractors to provide evidence and advice to assist us in delivering our duties. The views in this report are those of the authors and do not necessarily represent those of Natural England.

Background

Blanket Bog is a Biodiversity Action Plan (BAP) habitat. The peat it forms represents the largest terrestrial carbon store in the UK. Blanket Bog development is dependent on a number of very specific conditions including sufficient rainfall, suitable temperature, topography and landuse.

Areas of upland blanket bog without any nature conservation or landscape designation are often targeted by wind farm developers. They are high, exposed, windy places often sparsely populated and relatively unprotected by statutory regulations.

The development of wind farms on peat raises a number of issues, some of which are not easy to resolve.

Natural England commissioned this work to:

- Understand and collate evidence of the impact of wind farm developments on Blanket Peatland in England bogs.
- Develop a set of assessment criteria against which a development proposal can be tested to determine the scale of impact and enable an appropriate response to the Environmental Impact Assessment.

Part 2 of the report contains the appendices and references. The final report (Part 1) contains details of the work and the main findings.

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Further information
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APPENDICES

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Appendix A: - Project Information and Analysis

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A.1 LITERATURE REVIEW

A.1.1 Review of Windfarm and Blanket Peat Literature

The following provides a detailed review of the literature regarding wind farms and blanket peat. A synthesis of the literature review is provided in the main text with regard to how the literature describes the impact of wind farms on blanket peatland and the areas of uncertainty.

A.1.1.1 General Upland literature

There is a wide variety of general texts with regard to upland peat areas, and key texts are outlined below.

Ref. Warburton J. and Evans M., 2007, Geomorphology of Upland Peat, RGS-IBG Book Series, ISBN-13: 978-1-4051-1507-0.
Summary: This book provides a report on recent work on the geomorphology of upland peatlands, and provides a review of the current understanding of erosion process and the long-term evolution of eroding upland systems. There is a focus on Pennine peatlands in northern England. The book covers definitions of peat; properties of peat, and peat classification systems. The hydrology of peat is discussed including sediment generation; fluvial processes and peat erosion (including wind erosion) are considered; and slope processes and mass movement described. The issues of landscape change are discussed.
Relevance: This book provides a very good introduction to upland peatlands, and so is a very good background reference to the impacts of wind farms on peatlands. Its overall summary of work on upland peatlands is useful, as are the properties of peat and the description of how these uplands function hydrologically. These general insights are useful for the hydrological conceptualisation of upland peatlands within windfarm EIAs. The description of the peatland erosional features is useful in assessing the current state of peatlands. In particular the description of the mechanisms of peat failure provides good background to the assessment of the potential for peat slide on sites. However, other texts describe peat stability assessment in more detail.
Ref. Bonn, A., Allott, T., Hubacek, K. and Stewart, J. (eds.), 2009. Drivers of Environmental Change in Uplands. Routledge Studies in Ecological Economics, Routledge, ISBN 978-0-415-44779-9.
Summary: This volume is a collection of 26 papers on drivers of change in upland environments. The 61 contributors include geographers, economists, ecologists, social scientists and others involved in upland policy and management. The papers are grouped under three headings: Part 1: Process and policy – the overarching drivers of change Part 2: Ecosystem services and drivers of change Part 3: Social change, land management and conservation: driving change Uplands are considered both as vital providers of ecosystem services and as complex environments facing man-made pressures and threats. The book aims to identify the main drivers and directions of change in uplands and to discuss the relationship between change and ecosystem services. Ecosystem services may be affected by changes in the upland environment, or they may themselves act as drivers of change. A further aim of the book is to provide "insights into how future management and conservation options might address the challenge of sustaining ecosystem services" (p.3).

Topics covered include air pollution, climate change, wildfires, hydrology, ecology, agriculture, forestry, game management, leisure, rural economics, history, conservation, moorland restoration, policy-making and the impact of social class on people's perception of upland environments.
Relevance: The papers most relevant to the impact of wind farms on peatlands are: **Chapter 2** ***Evans, M., 2009. Natural changes in upland landscapes*** This paper provides a useful discussion of peatland erosion, including landslides. **Chapter 5** ***Worrall, F. and Evans, M. G., 2009. The carbon budget of upland peat soils.*** This paper discusses the role of peat as a carbon store and considers the potential impact of climate change on the carbon budget of peat soils. The UK climate appears to be moving towards a warmer, drier scenario; this could change peatlands from net sinks of atmospheric carbon to net carbon sources, potentially accelerating climate change. The paper is relevant to the present study because the development of a wind farm on peat soil may reduce the carbon storage capacity of the peat, thereby partly offsetting the carbon emission savings of the wind farm. **Chapter 6** ***Holden, J., 2009. Upland hydrology.*** This paper provides a useful summary of peat hydrology, including a discussion of the acrotelm-catotelm model and the role of soil pipes. It considers the hydrological impacts of artificial drainage, burning, grazing, afforestation, construction and climate change, and also discusses gully erosion in peat soils. **Chapter 16** ***Hubacek, K., Dehnen-Schmutz, K., Qasim, M. and Termansen, M., 2009. Description of the upland economy: areas of outstanding beauty and marginal economic importance.*** This paper includes a brief discussion of the economic significance of the carbon sequestration potential of peat soils (p.302).
Ref: Hack, V., 2005. Moorland Restoration: a Best Practice Manual. Final Draft, Version 3, Moorland Restoration Best Practice Handbook, V2.
Summary: This draft document is a best practice manual for moorland restoration. It covers moorland ecology, hydrology and erosion, as well as the planning and implementation of restoration projects. Anthropogenic causes of moorland degradation are discussed, including burning, overgrazing, drainage, cultivation, afforestation, trampling and atmospheric pollution. There is a long reference list.
Relevance: The manual provides brief summaries of bog hydrology and erosion, and also a more detailed discussion of moorland restoration.
Moors for the Future Partnership, March 2008, A Compendium of UK Peat Restoration and Management Projects. SID 5 report to DEFRA.
Summary Report describing work to produce a peat resoration projects compendium. Project has produced electronic compendium, website, short note and improved knowledge transfer between peat management and restoration work. Compendium currently contains information about 145 restoration projects, a mix of upland and lowland and mostly located in areas with conservation status (e.g. SSSI). Budgets ranged from £2000 to £30M with mixed funding sources.

A questionnaire was sent out to projects and restoration methods include:

- Stabilisation
- Reprofiling to reduce further erosion of steep faces.
- Reseeding
- Planting with plugs of bog species
- Grip blocking
- Gully blocking
- Vegetation removal.
- Stock reduction/ exclosure
- Rewetting – generally by grip and gully blocking but also binding in some lowland sites.

Wider peat management was part of some projects including hydrological management, mowing, grazing, burning, scrub clearandce and visitor facilities.

The report notes that project evaluation in terms of perceived success generally reached 80 to 100% after 3 years. Site condition data shows more variation and reported success should be carefully evaluated.

The report has a number of useful appendices including Appendix 6 which is an analysis of the existing UK science base on peatland restoration. This includes good practice advice for a number of techniques

Relevance

Useful when considering suitable restoration techniques to apply at a site and the conditions under which they are most likely to be successful.

Ref. Artificial drainage of peatlands: hydrological and hydrochemical process and wetland restoration, J Holden, PJ Chapman and JC Labadz, Progress in Physical Geography 28, 1, 2004, pp 95-123.

Summary: Holden *et al.* provide a review of the impact of artificial drainage schemes on peatland and their hydrological and hydrochemical processes. The review goes on to assess the main forms of wetland restoration and the controls on their effectiveness.

Groundwater levels control the balance in peat bogs between accumulation and decomposition by controlling the aeration of peat and therefore the amount of aerobic respiration. The main aim of constructing artificial drainage on peatland is to lower the groundwater water table, but it can have other consequences on the hydrological and hydrochemistry of the area.

Drainage can increase the stormflow of rivers by increasing amount of run off and reducing the time runoff takes to enter the river. The magnitude of the impact is controlled by several factors including:

- Lowered water table can increase the storage capacity of the peat and thus lowering runoff rates.
- In low hydraulic conductivity peats, ditches may only drain an area up to 2m from them, so fail to reduce the water table across a wider area and not increase the storage capacity of the peats but instead provide conduits for rapid runoff.
- Drainage density.

These controls mean that the impact of drain schemes can range from being limited to causing large increasing in down stream flooding.

Soil properties can be changed by drainage schemes. The increase in storage capacity is often short term as increased degradation rates lead to subsidence, increased bulk density and decreased porosity. The degree of impact is controlled by the effectiveness of the ditches to lower the water table over an extended area. If drainage schemes do lower the groundwater table they can increase aerobic decomposition which can lead to the mineralization and leaching of nutrients. Increased aerobic decomposition can lead to peatland no longer being carbon sinks but carbon sources. Vegetation in peatlands is often highly susceptible to changes brought on by drainage. Large changes in vegetation type can result from small changes in groundwater levels and this is often exacerbated by increases in grazing resulting from the draining of the land. Peatland restoration occurs in two main forms; restoring the water table and the recolonization of important peat forming species. Restoring the water table is often achieved by blocking drains and sealing the boundaries of the mire. Often this can not lead to true restoration where subsidence has lead to a decrease in the storage capacity of the peat so it is unable to maintain high groundwater levels during dry periods like the summer months, as it would have done before. Recolonization can be difficult especially were the initially conditions were marginal for growth (e.g. rainfall levels were just high enough to allow *sphagnum* growth). Holden *et al*. suggest that in a number of cases 'benign neglect' was the best option for restoration as a large number of ditches will silt up if left unmaintained.
Relevance: The report list a number of ways artificial drainage could cause negative impacts. • Downstream flooding • Subsidence • Increased aerobic respiration leading to the peat bog becoming a carbon source • Changes in vegetation The extent of these possible impacts should be investigated within the EIA process. It also shows that restoring peatland may be impossible if these negetative impacts prove to be too great. Therefore promises of peatland restoration will not limit the need to control the initial impacts of a wind farm development.
Ref: Holden and Burt (2003) Hydraulic conductivity in upland blanket peat: measurement and variability. Hydrological Processes 17, 1227-1237.
Summary: Holden and Burt compare the calculations of hydraulic conductivity (K) on blanket bogs when using rigid and compressible soil theories. Piezometers were installed in blanket peat on Moor House National Nature Reserve and falling head slug tests were conducted. The results were used to derive the hydraulic conductivity using equations based on rigid and compressible soil theory. It was hypothesised that the calculation of hydraulic conductivity could be significantly affected by the highly compressible nature of peat and the change in effective stress on the peat matrix as a result of the sudden lowering of pore water pressure, by withdrawing the slug. Holden and Burt showed that the equations which used compressible soil theory gave estimates of hydraulic conductivity five times greater than those using rigid theory. The authors also stated that the blanket bogs appeared to be highly heterogeneous as a result of structures like natural pipes which produced preferential flow paths.
Relevance: The report gives background information on regarding the hydrogeological conceptualisation of peat and the applicability of standard approaches.
Ref: Yeloff D.E, Labadz J.C, Hunt C.O (2006) Causes of degradation and erosion of blanket mire in the Southern Pennines, UK.
Summary: The paper tries to identify reasons why the condition of March Haigh Blanket Bog in the South Pennines declined and the bog eroded. Peat samples from across March Haigh were taken, dated by Pb^{210} and analysed for pollen, magnetic susceptibility and charcoal, to produce a proxy record of vegetation types, pollution

levels and peat burning, respectively. The authors concluded that there had been three periods of significant change brought about through different processes. The earliest was the decline of *Sphagnum spp*. in the mid 19th century; the result of the area being a marginal habitat for the species, unable to cope with precipitation levels falling after the little ice age and increased pollution levels. *Calluna vulgaris* replace *Sphagnum spp*. until c.1918, when large scale fires destroyed large areas of vegetation and limited grazing pressures meant that it could not re-establish and was replaced with grasslands. After the Second World War grazing pressures slowly rose in the area, so when deep droughts were accompanied by large scale fire (c.1959), even the grass land was unable to re-establish. This lead to areas of bare peat remaining for extended periods, allowing desiccation cracks to form and erosion to increase.
Relevance: The example shows how a number of facts can result in the degradation and loss of an area of blanket bog, over a number of years. It also shows that marginal and degraded peatland habitats are more prone to significant and irreversible changes, as a result of developmental pressures, than healthier peatlands.
Ref: Rothwell A., Robinson S.G., Evans M.G., Yang J. And Allott T.E.H, (2005) Heavy Metal Release by Peat Erosion in the Peak District, Hydrological Processes, 19, 2973-2989
Summary: The report aimed to assess whether high lead concentrations in the peats of the Upper North Grain catchment, Peak District could pose a potential environmental hazard to aquatic and human receptors. Through atmospheric pollution, the lead concentrations in the upper layers of peat in the Upper North Grain catchment exceed Soil Guideline values for commercial land. Using magnetic ‘fingerprinting’ the report provides evidence that the dominant runoff pathway allowed lead from the upper peat to be ‘flushed’ into the streams during storm events. The report concludes that this mechanism could pose a potential environmental hazard, as one of the final sinks for the lead are the reservoirs in the area and the risk of this could increase if the peat become prone to greater degradation.
Relevance: It may be necessary in areas prone to historic and current heavy metal atmospheric pollution to assess for the risk of lead mobilisation and its potential impacts as a result of a wind farm development.
Ref: Hobbs N. B. 1986, Mire Morphology and the properties and behaviour of some British and foreign peats, Quaternary Journal of Engineering Geology and Hydrogeology, v.19, p7-80.
Summary: Hobbs discusses the morphology succession, flora and the geotechnical properties of mires. Peat has properties particular to it: a very high water content; high cation exchange capacity; and has extraordinary consolidation behaviour, which makes it difficult to predict behaviour using traditional engineering techniques. There are various properties which can be measured to indicate the state and condition of peat. These include the water content, bulk density (wet), degree of saturation, specific gravity, organic content, pH, liquid limit, plastic limit, linear shrinkage and the degree of decomposition. There are engineering properties which can also be used to describe peat: the permeability, compression index, coefficient of secondary compression, tensile strength and compressive strength. Peat is an extremely compressible material but the rate of compression is controlled by the way water is held in the peat. It is held in three ways: intercellular water, interparticle and bound water. This means that water held in peat does not drain in an ordinary way, and so does peat not compress in an ordinary manner. Hobbs goes on to assess the effectiveness of traditional methods of deriving a material’s properties when applied to peat. He concludes that due to its compression behaviour it is harder to predict the performance of fill on mires, and engineers working on them should develop an understanding of their morphology.
Relevance: Engineers planning wind farms on peat bogs should take into account the added uncertainties that building on peat entails. This means that there are uncertainties in the impact that wind farm development may have, which should be investigated within different stages of the development process.
Ref. Holden J., Shotbolt L., Bonn A., Burt T.P., Chapman P.J., Dougill A.J., Fraser E.D.G., Hubacek K.,, Irvine B., Kirkby M.J., Reed M.S., Prell C., Stagl S., Stringer L.C., Turner A., Worrall F. Environmental Change in Moorland Landscapes. Earth Science Reviews (2007a), doi:10.1016/j.earscirev.2007.01.003

Summary: This paper reviews how moorlands may respond to changes in environmental management based on current understanding of moorland science and using UK uplands as a case study.
Relevance: The paper provides a summary of competing pressures on the uplands and their current condition, which provides useful background information for the review of the impact of wind farms in blanket peat. The paper identified drivers for change and their likely consequences including erosion, vegetation change (in response to change in land management, atmospheric chemistry) and the potential for upland peat to become a source of carbon. The paper summarises the current responses to change in the uplands. This is useful context for other developments in the uplands. The paper includes a summary and review of recent work on the carbon cycle in the uplands. The paper recommends further research to improve understanding of how changes to the uplands may affect environmental processes and the links between them. The paper provides a useful context in which the review of wind farm impacts can be set.
Ref. Holden J. Chapman P, Evans M., Hubacek K, Kay P and Warburton J, 2007b. Vulnerability of Organic Soils in England and Wales. Report to Defra. Project SPO532, CCW FC 73-03-275
Summary: Desk based review of literature and practitioner techniques to produce a baseline report on the state of organic soil. The report describes classification and basic characteristics of organic soils and identifies types and causes of degradation. It reviews erosion processes and drainage, landslides, subsidence and wastage, mining, footpath erosion and recreation, climate change (considers impacts of scenarios e.g. increase in summer droughts), atmospheric deposition, livestock and arable farming, burning and socio economic change. The report outlines the functions of organic soils – hydrology, agriculture, biodiversity and geodiversity reservoirs, archaeological preservation and tourism, leisure and recreation. The state of organic soils in England and Wales is summarised and the report concludes that many are severely degraded. The report estimate the loss of organic soils including a discussion of peat harvesting, land drainage losses (including chemical changes), burning, livestock grazing (incl liming), afforestation, atmospheric pollution. The report includes the views of some stakeholders but does not provide a comprehensive survey. The report reviews the carbon cycle and stores, the financial cost of erosion and finally offers guidance on soil protection.
Relevance: 80% of organic soils in the uplands in the UK. The Habitats Directive refers to active bog. This can affect windfram development on blanket peat. The report identifies threats as: • water and wind erosion; • landslides; • chemical and physical degradation of soils (including changes in atmospheric deposition); • climate change. Degradation processes can include overgrazing, forestry, land drainage agricultural activities and over exploitation by processes such as peat extraction (these are summarised in table 3). Increase in mineralisation of soils (e.g. by lowering the water table by drainage) can generate losses of C, P, N and S. The report considers carbon stores and balances and the potential for carbon sequestration in peatlands. The report considers atmospheric pollution and the balance between alternative sources of power. The assessment of economic benefits of conserving organic soils may also be relevant to assessing the impact of windfarm developments on blanket peat.
Ref. Lindsay R. A., Charman D. J., Everingham F., O'Rielly R.M., Palmer M.A., Rowell

T.A. and Stroud D.A., 1988. The Flow Country, The Peatlands of Caithness and Sutherland. Ed Artcliffe D.A., and Oswald P.H., Report to Nature Conservancy Council, Peterborough, 174pp. ISBN 0 86139 457 7.
Summary: This book reports on an NCC investigation into the Flow Country which is the largest expanse of blanket bog in Britain. The aim of the survey was to identify a suitable nature conservation approach. The book is divided into 3 parts. Part 1 covers peatland formation and development, characteristics of peat soils, classification and the links between climate and world blanket bog distribution. Part 2 focusses on Caithness and Sutherland describing the peatlands (including distribution and area, notable mire features, vegetation and site types) and human impacts including: • Drainage (with details about response of peat) • Peat cutting • Burning (response of peat includes nutrient cycling, hydrological impacts and vegetation change) • Grazing and manuring • Erosion (including peat slides) • Acid deposition • Forestry Part 3 summarises freshwater habitats, part 4 describes birds and part 5 takes an overview of different conservation interests.
Relevance: General peat development, mire classification and human impacts are relevant to blanket peat elsewhere in the country.
Ref: Stroud DA, Reed T.M., Pienkowski M.W. and Lindsay R.A.,1987. Birds, Bogs and Forestry. The Peatlands of Caithness and Sutherland.Nature Conservancy Council ISBN 0 86139 377 5.
Summary: Report to Nature Conservancy Council. It describes blanket bog distribution and area including threats to peatlands in the British Isles. It contains results of peatland bird surveys, and describes and discussed the impact of forestry on peatlands including hydrology and biodiversity. It considers the international implications of threats to peatlands.
Relevance: General material relevant to blanket peat elsewhere.
Ref. Forestry Commission, Edinburgh, 2003, Forests and Water Guidelines, ISBN 0 85538 615 0.
Summary: These guidelines provide details for the design and management of forests in order to protect and enhance the water environment. The guidelines provide details of catchment water pathways, freshwater environments and the effects that forestry have on these. Site planning and forestry operations regarding best practice for the water environment are outlined. The following effects of forests on the water environment are described: • Siltation and turbidity – good forestry can result in reduction of soil disturbance and erosion compared to other uses such as arable cropping. • Poor management of forests can result in significant sediment release. • Nutrient release following felling.
Relevance: Wind farms over peat are often developed in areas which are also forested and require limited forestry felling in order to construct access tracks and wind farm infrastructure. These guidelines provide standard best practice regarding managing forestry for the protection of the water environment.

RSPB, 2002. Restoration of Peatland through Deforestation, Clach Geala, Sutherland. Non Technical Summary of Focused EIA produced by NDR Environmental Services (http://www.lifepeatlandsproject.com)
Summary: Assesses impact of proposal to fell trees and dam drains to raise water levels in peat and encourage peatland vegetation to reestablish. Assesses impacts on hydrology and water quality, landscape and ecology. Identified impacts as long or short term, positive or negative and whether significant.
Relevance: Example of EIA on peat system. Approach to assessing significance of impacts relevant to wind farms on peat.

A.1.1.2 Literature Relating to Wind Farm Development

There is a more limited amount of literature directly relating to wind farm developments and peat.

Ref: Windfarm impacts on blanket peat habitats in Scotland Dargie, T. (2004). In: F. Maxwell (ed.) *Renewable energy – is it ecologically friendly? Proceedings of the 19th Conference of the Institute of Ecology and Environmental Management*, pp. 43-51. London 18 May 2004. IEEM, Winchester.
Summary: This report highlights the important of blanket bog as an ecological resource, discusses the impact of wind farms on them, the accuracy of predictions of damage produced in the EIA process and discusses a range of mitigation measures which have been implemented. Blanket peat develops on relatively smooth ground in very windy environments therefore is often an ideal site for wind farm development. Blanket peat is important as it is ecologically rich, can be an important carbon sink and an archive of past environments, however it can be degraded through natural erosion, drainage, excessive grazing, burning and acid deposition. Wind farms can impact blanket bogs in several ways, including: in the construction of roads, construction areas, turbines, crane hardstanding, borrow pits and drains. The impact of roads can be limited through the choice of route (minimising the crossing of water courses and avoiding deep and wet peat) and by the construction techniques (using floated roads). Roads crossing a blanket bog site can still interfere with drainage: cut and fill works can cause additional seepage from the newly exposed faces and floated roads can compact the ground beneath, reducing the hydraulic conductivity of the peat. The report lists a number of sites where mitigation measures have been implemented. These measures include the blocking of drains and reductions in grazing pressures to aid the restoration of the habitat and off-setting impacts by the creation of new areas of blanket bog (usually through deforestation of adjacent land). Dargie raises the issue that is often impossible to assess the accuracy of the EIA predictions on the extent of damage to blanket bogs as the plans that they are based on are often wildly different from those finally given planning permission or constructed.
Relevance: Highlights impact mitigation measures that potentially could be employed in wind farm construction. It also shows that the accuracy of any EIA predictions is partially controlled by the similarity of the plans that they were based on to the development that was built.
Lindsey R.A., and Freeman, J. (2008), “Lewis Wind Farm E.I.S: A Critical Review
Summary: Lindsay and Freeman aimed to review the Environmental Impact Statement (EIS) by Lewis Wind Power (LWP) for a proposed wind farm development on the Isle of Lewis. The report provides a detailed explanation of where Lindsay and Freeman perceive the EIS produced by LWP is missing important information, misleads, underestimates, employs unsuitable methods and is based on fundamental misunderstanding by the author. The report is split into a number of chapters under which individual themes are discussed. The majority of the criticisms have been responded to by Dargie (2007).

'Micro-siting' is used by LWP to describe the fact that in the construction of the site, the position of the structures may vary from the plans, to account for unforeseen ground conditions or to minimise environmental impact. This variation means that the development may be quite different from that which was planned, so the footprint of the development may increase, as roads are forced to be more sinuous. As the development was flexible in its design, Lindsay and Freeman felt that the extent of the area studied by the EIS should have been more than just narrow corridors along the planned structure locations.

Several issues on assessing the impacts of the roads and power lines were raised. Limited assessment of the impact of the two chosen methods of road construction was made. Rock filling roads could cause peatslides but the EIS did not acknowledge this risk. Floated roads require drainage and repair, due to subsidence but the impacts of neither was assessed. According to Lindsay and Freeman; the construction of power lines requires temporary access roads but the damage to the peat through cutting and filling to build these was not assessed by the EIS.

The EIS conducted a survey to describe and classify the peatland system. Lindsay and Freeman criticised the method employed as it was of the EIS author's own creation and did not follow established peer reviewed methods. Lindsay and Freeman state as a result the information from the survey is of a poor quality and utility and does not draw proper attention the extensive areas of Ladder Fen (a habitat of high value which would pose engineering difficulties as it is very wet). The EIS states that the main vegetation is of poor quality and dry, however independent surveys disagree and state that the quality of the vegetation is higher; Lindsay and Freeman find it hard to account for the differences but do state that part of the site is within a SAC and RAMSAR area, identified for its vegetation interest.

Lindsay and Freeman have criticises the methods and conclusions drawn on erosion within the development area. The EIS states that the blanket mire is undergoing atypical natural erosion (which Lindsay and Freeman state that there is no literature cited or evidence gathered to support) but the structures should cause limited erosional impact. The EIS states that the impact of the drains is limited in catolelm layer but fails to emphasise that the drains will impact the acrotelm layer up to 50 m away; a large difference from the EIS statement, which states that the peat will only be affected in an area up to 2 m from any structure.

According to Lindsay and Freeman, many aspects of the impact on water quality by the proposed wind farm are inadequately assessed. Due to the site's hydrology it is deemed unsuitable for settlement lagoons either for turbine foundation dewatering or for the road network runoff. It is stated in the EIS that fine sediments will therefore be removed by flocculants but Lindsay and Freeman question the practicalities of applying them over such a wide area at any time and the ecological and water quality impact of doing so. The site also includes Loch Mor an Starr, a source of drinking water for the local community. The possibility of pollution, sedimentation and peatslides into it are not accounted for within the EIS.

The report concludes that due to the peatland function, diversity and nature, and the potential impacts of the proposed development that the site is wholly unsuitable for a wind farm.

Relevance: The review shows that there may be significant differences in opinions on the degree of impact a wind farm proposal may have on peatlands. It shows that to properly assess the impact within the EIA process the following points should be adhered to:

- Impacts should be assessed in light of likely changes to the initial design.
- An adequate peatslide risk assessment should be conducted.
- Widely recognised methods should be employed where possible.
- All potentially major impacts should be assessed, like the potential effects on water quality.

The report also highlights the need for good procedure to be put in place to identify the likely impacts and thus suitability of a site at an early stage in the planning process.

Ref: Dargie (2007), Predicting the impact of wind farm developments upon blanket bog habitat: approach and professional standards in the case of the controversial proposed Lewis Wind Farm, available at http://www.imcg.net/imcgnl/pdf/nl0704.pdf.
Summary; Dargie provides a firm rebuttal to the criticisms levelled at the Lewis Wind Farm Environmental Statement by Lindsay and the RSPB (2007). He suggests that the individual criticisms derive from a misunderstanding of the information contained in the original ES, difference of opinion rather that wilful misleading and not allowing for the fact that the proposed development is on a very large scale, over a wide area, so proportionally the impacts will be small.
Relevance; The scale of the development should always be kept in mind when judging the relative size and significance of impacts. However, there are approaches which emphasize the integrated 'whole system' nature of peat bogs.
Ref: Fraga M.L., Romero-Pedreira D., Souto M., Castro D., Sahuquillo E, 2008. Assessing the impact of wind farms on the plant diversity of blanket bogs in the Xistral Mountains (NW Spain). **Mires and Peat, Volume 4 (2008/9), Article 06, http://www.mires-and-peat.net/, ISSN 1819-754X © 2008 International Mire Conservation Group and International Peat Society 3**
Summary: This paper reports on a study in the Xistral Mountains in NW Spain assessing the impact of windfarms on diversity of blanket bog vegetation. The study was carried out in an area where wind farm development had been happening during the previous 9 years. The study looked at vegetation in areas within 50m of turbines (locations described as 'impacted') and more than 50m from turbines (and where there is no evidence of human impact, described as 'not impacted'). The study assessed the vegetation diversity within each surveyed area and between the impacted and non-impacted areas. The paper notes that ombrotrophic mires are stable systems and wind farms can rapidly change this. Potential impacts are identified as: • Landscape devaluation • Destruction of plant cover • Change in hydrology • Change in nutrients (e.g. N and others) • Habitat fragmentation by roads • Peat slides • Invasive plants • Genetic pollution if reseeding with commercial varieties of plants • Increase in grazing and traffic pollution due to improved access. The study found that areas affected by wind farm development show a lower biodiversity. Although the study found that the variation in species composition is affected by the sampled area in addition to wind farm development. There was no available pre-impact vegetation data. The loss of biodiversity is linked to the sensitivity of species to groundwater levels and hydrochemical conditions. The study identified roads and restoration activities as the source of most negative impacts on vegetation as these activities allow colonisation of blanket bog by pioneer and alien species from disturbed habitats. The main conclusions and recommendations were: • Lower vegetation diversity was found in areas influenced by wind farm development. • Blanket Bog communities are being replaced by grassland and heath communities and a new wet meadow community had been introduced to the study site. (This represents less common habitats being replaced by more common ones). • Threatened and rare species should be monitored to assess the scale of habitat and

plant diversity losses.

- Restoration activities must be compatible with the original vegetation to avoid loss of native communities, spread of invasive species and hydridisation with commercial varieties.

Relevance: Direct investigation of wind farm impact on blanket bog vegetation. The study was based in Spain but the conclusions about replacement of rarer communities, monitoring of species and potential impacts of restoration activities are relevant elsewhere.

Ref: Scottish Natural Heritage (2005) Constructing tracks in the Scottish Uplands

Summary: The report gives guidance on how to construct tracks in upland areas and minimise impact to natural heritage.

The guidance tackles the key issues of routeing, landscape and visual impact, biodiversity impact, geodiversity impact, engineering requirements, reinstatement and restoration. When planning tracks it gives the general advice to minimise the impact to natural heritage:

- Identify – identify through desk studies, site surveys and other sources the potential impacts that a road could pose.
- Avoidance – ask whether the road is strictly necessary.
- Mitigation – the guidance gives an number of areas where the impacts of a track on various aspects of natural heritage can be mitigated, like re-routeing to avoid more sensitive areas, using numerous smaller borrow pits rather than one large one and putting in place effective drainage measures.
- Compensation – look to find ways to compensate for the impact of the route like the creation of areas of peat bog.
- Enhancement – for example, investigate where the planned road could improve recreational access to an area and whether such a side effect would be welcome.

In addition to this general guidance the report compares the advantages and disadvantages of various construction techniques. For example it state that floating roads may be an appropriate technique when constructing a road to cross blanket bogs but there are subsidence and drainage issues associated with them.

In relation to wind farms construction tracks, the guidance makes clear that they are built to a higher specification than most upland roads due to the load size they carry. This means that the carry capacity is high, the cornering radii large, the width can be around 6-7 m and they will have low maximum gradients. This means that the potential impact of them can be far greater than other upland tracks.

Relevance: The guidance deals specifically with tracks across blanket peats and tracks built for wind farms. It provides practical guidance on which methods of construction may be suitable and a framework in which the impacts of the tracks on the natural heritage can be mitigated.

A.1.1.3 Literature Relating to Peat Instability

There is literature relating to both general landslides and also peat instabilities, some in connection with wind farms.

Ref: Warburton J., Holden J., Mills A.J., 2004, Hydrological controls of surficial mass movements in peat, Earth Science Reviews, 67, 139-156.

Summary: The paper outlines the current state of knowledge on the mechanisms for peat mass movements.

Peat mass movements can be split into two main types: bog burst, the result of swelling and liquefaction of peat; and peatslides, slab like shear failures. There are common characteristics to most peat mass movement sites:

- The peat layer overlying a low permeability base.
- Convex slopes or slopes with a break of slope at the head.
- Proximity to local natural or artificial drainage features such as seepage points, flushes, pipes, streams or ditches.
- Connectivity between surface drainage and the peat / low permeability base interface.
- The most likely slopes to fail are those on upper hill slopes.

These features, along with intense rainfall periods can produce mass movements through five different mechanisms:

- Shear failure by loading: where an intense rainfall event can suddenly increase the weight and thus loading of the peat on a slope.
- Buoyancy effect: where routeing of water to the base of the peats through pipes generates artesian pressure; and as the pore water pressure increases, the cohesion of the peat decreases.
- Liquefaction: where routeing of water to the peat base, and/or a bottleneck in the subsurface drainage pattern cause the water content of the peat to increase, forcing the peat above its liquid limit.
- Surface rupture: where the peat at the base swells to a greater extent than peat above it.
- Marginal rupture: where basal peat at the margins is undercut by streams or human peat cutting.

The major control which sets off these mass movement mechanisms is an increase in moisture content at the peat/substrate interface.
Artificial drainage can increase the likelihood of mass movements for several reasons. Firstly, artificial drainage can increase piping and so increase water movement to and along the peat / impervious base interface. Secondly, drainage may also increase overburden pressures. Thirdly, drains break the support that the up slope peat receives from downslope.

Relevance: The paper shows that there are a number of peat mass movement mechanisms but they are not fully understood. This means that as a result of these knowledge gaps and the unusual engineering properties of peat, conservative assumptions should be adopted in mass movement risk assessments. In particular, wind farm drainage systems can adversely affect the stability of peat.

Ref. Geological Survey of Ireland, 2006. Landslides in Ireland. Report from the Irish Landslides Working Group, Ed Creighton R..

Summary: The report was commissioned in response to landslides in 2003 as little was known about landslide risk in Ireland even though landslides (mainly peat) have been recorded (earliest on record was in 1488). The report discusses landslide classification including peat flows and also considers landslide materials and triggers. The study produced a database of landslides in Ireland. Many of these involve peat flows including blanket peat, or slides on the edges of raised bogs. The report reviews bog burst events at Pollatomish and Derrybrien in 2003.

The report considers the strength of material and role of water in landslides and includes section on the geotechnics of landslides in organic soils including a discussion about whether conventional soil mechanics are applicable to peat. It summarises ongoing research on Irish landslides, which includes case studies reviewing mechanisms for peat movement and

laboratory research into the shear strength of peat. The report identifies research priorities: including the study of stable and unstable peat slopes to develop methods for reliably determining their stability under extreme conditions. This includes: • Behaviour of peat at low effective stresses; • Methods of measuring properties of peat relevant to slides; • Observations of critical areas.
Relevance: This report is an investigation into landslides in Ireland, but the more general points and background information is relevant elsewhere. Many of the landslides on record in Ireland have involved peat and the background including a review of mechanisms and geotechnical methods and their relevance to peat is relevant to a review of windfarm impacts. The recommendation for additional research highlights uncertainties in the understanding of peat and hillslope strength. This report provides a good summary of peat stability from a geotechnical perspective and is important background for windfarm development on blanket peat.
Ref. Scottish Executive, December 2006. Peat Landslide Hazards and Risk Assessments. Best Practice Guide for Proposed Electricity Generation Developments.
Summary: Guidance developed to provide best practice information on methods for identifying, managing and mitigating peat slide hazards and their associated risks. Developments on peat are required to assess stability. Peat reports are to be assessed by ECU (Energy Consents Unit) to ensure that risk has been treated adequately by the developers. The report recommends a design team and provides a checklist for peat hazards. Reviews peat landslide mechanisms including triggers and indictors of instability. The report recommends desk study, site visit, ground investigation techniques, stability (including assessment of the Factor of Safety) and hazard ranking, and proposed measures.
Relevance: Guidance for peat assessments for Scotland. Relevant to windfarm developments in England.
Ref. MacCulloch F., January 2006. Guidelines for the Risk Management of Peat Slips on the Construction of Low Volume/ Low Cost Roads Over Peat. Forestry Commision, Scotland.
Summary: Scottish windfarm developers are required to assess risk of peat slide during development (this is response to Derrybrien peat slide in 2003 during windfarm construction). Road construction within peatlands is a challenge due to the variable nature of peat. Windfarm developers use forestry techniques and experience to build roads. The challenge is dealing with high traffic volume during construction then very traffic low during operation. The guidance describes mass peat movement and mechanisms and identifies future climate scenarios for Scotland in 2080s (UKCIP) and their likely impact. The guidance outlines peat formation and classification including Von Post, hydrological processes including pipe formation and collapse, shear strength issues, density and a summary of the effect of forest planting. Discusses construction methods for roads and associated risks including factor of safety recommendations for excavations (used if peat < 2m) or floating roads (peat > 2m). The guidelines include a table with probabilities of risk factors. There is risk associated with construction of roads on peat, some failure is to be expected in uncertain situations and processes must be in place to minimise the impact of any failure.
Relevance: Very clear summary of key processes and mechanisms in peat and associated engineering issues. The guidance is very clear and practical and should be followed when constructing access roads for wind farms.
Ref. Lindsay R. and Bragg O., 2005. Wind farms and blanket peat a report on the Derrybrien bog slide. 2nd Ed. University of East London.
Summary: Report on a bog burst at Derrybrien, Co Galway in 2003 during development of a 71 turbine windfarm on blanket peat which had been forested.

Provides a general review of factors potentially contributing to peat instability. This includes a review of peat formation and a discussion of its structure and strength. The relevance of peat stability triggers at the site is discussed and the scope of the EIA identified. This includes assessing the current site conditions, a review of mechanisms of bog bursts and slides, assessing the construction process and other impacts of the site and the interactions between different impacts. The report considers the planning process applied in this case and reviews of the existing environmental statement. Events during the bog burst are described including an assessment of likely trigger factors. Geotechnical reports produced after the event are reviewed.

Relevance: The report provides a very good and detailed review of the factors leading to peat instability. The review of the planning process and the environmental impact assessment is useful. Although the Derrybrien windfarm was developed under Irish legislation and guidance the general points in the report are very relevant to development of windfarms on blanket peat in other locations. In particular the report identifies key issues:

1. Full EIS was not required for all of the site. EIS should consider current condition and history of the site against likely trigger factors. This includes local evidence of historic instability. Cumulative impacts are important and the boundary for the EIS may be larger than the immediate site boundary if the impacts of any site instability may be seen downstream.
2. The windfarm was submitted as 3 smaller schemes and not reviewed at planning as a single scheme.
3. Evidence of instabilities on site during construction.
4. Geotechnical techniques were applied after the bog burst but did not predict all locations for instability. This suggests techniques for mineral soils assessments are not always appropriate in peat.

In this case triggers include forestry (cracking of peat due to drainage and drying out), topography and hydrology, and construction activities (loading, drainage and possibly pumping).

A.1.1.4 Literature Relating to Carbon Processes

There is literature relating to carbon budgets on peatlands and also regarding wind farm carbon payback periods.

Ref: Holden (2005). Peatland hydrology and carbon release: why small scale processes matter. Philosophical Transactions of the Royal Society 363, 2891-2913

Summary: Holden challenges the standard two layered model of peat and suggests that a large proportion of water moves through the lower layer (catotelm) in macropores and natural pipes. These can increase in number as a result of drainage which has important implications on carbon release and peatland restoration.

The standard model of peat splits it into two layers. Firstly, the upper active acrotelm with its high hydraulic conductivity and fluctuating water table and secondly, the lower, more inert catotelm which is permanently saturated. If this model holds true, the main control on the pathways water takes through the peat system is the groundwater level in the acrotelm, with higher levels leading to greater Hortonian flow. In Holden's updated model, greater emphasis is given to the role of water movements with macropores and pipes. Water movement through pipes allows greater transport of water, sediments and nutrients through the catolem layer. Drainage of peatland can increase the density of pipes, leading to increased DOC (Dissolved organic carbon) leaching and greater POC (Particulate organic carbon) removal which are then available to be converted to CO_2 to enter the atmosphere. Restoration processes may not be able to reverse the creation of these pipes and therefore if the restoration may increase the water movement through these pipes and so the net carbon flux out of the post restoration peatlands may be higher than the peatlands prior to the initial drainage.

Holden lists a number of issues affecting peatland restoration projects: • The high cost of ditch blocking and identifying the best method. • Uncertainties in the response of peat and vegetation due to the permanent structural and chemical changes which resulted from drainage. • Uncertainties on the impact of blocking ditches on river flow and water quality.
Relevance: Full restoration of peat lands, after a drainage scheme has been removed, may be impossible as changes hydrological structures, like pipes which form as a result of draining, may be difficult to reverse. These pipes may continue to keep the rate of carbon loss above pre-drainage levels and ensure that the original vegetation can not re-establish itself. As a result, the paper makes clear that the impacts of restoration are uncertain.
Ref: Grieves I. and Gilvear G. (2008), Effects of wind farm construction on concentrations and fluxes of Dissolved Organic Carbon and suspended sediment from peat catchments at Braes of Dorne, Central Scotland, Mires and Peat (4) 1-11
Summary: The DOC and suspended sediment concentrations were measured in 6 streams on a wind farm site immediately after its construction. The concentrations were compared to three control streams. This showed that the wind farm streams had significantly higher concentration than the controls; suggesting that the development was responsible for more carbon and sediment entering the rivers.
Relevance: The study showed that wind farm develops could cause significant changes to the sediment load of a stream, by degrading the peat they are constructed on.
Ref: Wallage Z.E., Holden J., and McDonald A.T., 2006, Drain blocking: an effective treatment for reducing dissolved organic carbon loss and water discoloration in a drained peatland, Science of the Total Environment 367, 811-821
Summary: The paper investigates the impact of drain blocking on DOC and colour dynamics in blanket peat soils The report showed that within a small catchment (Oughtershaw Beck), the areas of drain block peat had significantly lower DOC concentrations than drained peat. This show that drain blocking can prove valuable, as it reduces the cost for potable treatment works, as a result of habitat and carbon storage potential improvements, reducing colourisation. Block-drain peat however was not restored to its original condition as the drained water was darker and had a lower DOC concentration than the intact peat. The lower DOC content was explained by the flushing of DOC out of the peat when it had been drained, lowering its concentration. The darker colour suggested that DOC production and transportation processes had been modified. When the groundwater table was lowered, oxidation of deep peat reduced the concentration of phenolic compounds which inhibit degradation, by phenol oxidase metabolising enzymes. When groundwater levels are restored, the concentrations of phenolic compounds remain low and so microbial activity is less inhibited and therefore the rate of degradation in the deep peat is higher than would be in an intact peat. The authors also suggest that changes in DOC transportation, as a result of modified hydrological routing, could also be an influence on the differences between water in intact and drain-blockage peat.
Relevance: The report shows that even if a drain blocking restoration programme is instigated, the hydrology and bio-chemistry could be impossible to fully restore back to pre-drainage peat conditions.
Ref: Worral F., Armstron A., Holden J. (2007) Short-term impact of peat drain-blocking on water colour, dissolved organic carbon concentration, and water table depth, Journal of Hydrology, 337, 315-325
Summary: A study on the effect of a number of drain blocking techniques on peatland on the water colour and DOC concentration. To make potable, water treatment works in peatland catchments often have to chemically low DOC concentrations and remove colour from the water. The paper studies whether peatland drain blocking techniques were effective in reducing the colour of the water and whether any variation could be found between them. The study showed that in the first year after drain blocking, drain water increase it DOC concentration and darkened. The authors postulated

that this was the result of drains lowering the water table allowing the creation of DOC in a form that was easily liberated once the groundwater levels rose. They believe such effects would be short term and after a couple of years, water colour would lighten and DOC concentrations would reduce, in line with the finding of other studies. The report found that there was little variance between the drain blocking techniques in restoring the groundwater table so they recommended that the most economic techniques should be employed.
Relevance: In peatland restoration, the more expensive techniques for drain blocking are not necessarily the most effective.
Ref: Berry P.M. and Butt N. (2002), CHIRP – Climate Change Impacts of Raised Peatbogs, A case study of Thorne, Crowle, Goole and Hatfield Moors. No. 457 English Nature Research reports.
Summary: The report aims to predict the impact of climate change on the hydrology, species and habitat quality of two peatland SSSIs near the Humber. Climate change will affect climatically marginal peatland areas the greatest. The two sites studied are marginal; and with climate change they will see a reduction in their water table and changes to species diversity, but this can be mitigated against through 'expensive' projects. Lowered water tables may also increase the outflux of carbon from the peatland areas.
Relevance: Restoration plans for peatlands should take into account the affects of climate change, especially if they are planned for several decades in the future after the decommissioning of a site.
Ref: Nayak D.R., Miller D., Nolan A., Smith, P. and Smith J. (2006), Calculating Carbon Savings From Wind Farms on Scottish Peat Lands – A New Approach, Report for the Scottish Government.
Summary: The report provides a method to determine potential carbon (C) losses and savings associated with wind farm developments on peat land, taking into account peat removal, drainage habitat improvement and site restoration. This replaces SNH 2003 guidance (Technical Guidance Note: Windfarms and Carbon Savings) which has more simple calculations. On wind farm developments, C is lost and saved through a number of mechanisms. Developments reduce bog plants' ability to fix C from the atmosphere through the degradation of their habitat; but this is a minor component compared to the losses resulting from damaging the peat, and so allowing the release of C stored within it. Wind farms damage the storage capacity of peat in a number of ways. Firstly, through excavation and the building of structures on site. Secondly, by increasing drainage on site, groundwater levels are lowered creating aerobic conditions in the peat, increasing oxidation and so allowing more CO_2 to be released. Lastly, leaching of particulate and dissolved organic carbon from peat is increased as it is drained; this freed C is then able to enter the atmosphere. C can be lost in other ways; with deforestation often occuring during the development of wind farms. This results in a loss of biomass, though whether it results in an increase in Carbon entering the atmosphere is controlled by the end use of the wood. Developments can also result in carbon storage by peatland restoration: improving the peat's ability to capture and store C. If restoration occurs at the end of a wind farm's lifespan, it can mean that there are no further losses of C from peatland degradation at the site. The report recommends the use of site specific equations developed by Nayak *et al*. to calculate the C saving from wind farms and states that they produce similar results to the ECOSSE model. To implement the equations requires the following information; • Number of turbines, foundation and hard standing dimensions, turbine capacity and assumptions about efficiency; • Drainage of turbine bases; • Forestry felling areas; • Borrow pits in peat areas; • Road type and drainage; • Cable lengths (if not alongside roads); • Proposed restoration following construction and following decommissioning; • Air temperature; • Peat depth;

- Water level;
- The extent of water table lowering around drainage features;
- Soil pH.

If site specific information is not available, such as details of the depth of peat on site, less accurate estimations can be obtained by using IPCC generic values within simplified equations.

The Nayak et al. method uses an excel spreadsheet which contains fifteen worksheets into which site specific parameters on the construction, peat type, drainage, energy production and others can be entered. The parameters are of such a nature that they should be obtainable from the site developers, site visits and literature figures. Once the parameters are entered, the spreadsheet produces an estimate of the C saving from the wind farm.

Relevance: The report provides a method that is well suited to the purposes required for this project regarding estimations of the C that could be lost by proposed windfarms on blanket bogs.

Ref: Hall M.J. (2006) Peat - Carbon Dioxide Payback and Windfarms, Renewable Energy Foundation

Summary: The author lays out a method for calculating the duration required to pay back the carbon dioxide produced by wind farms. The carbon storage properties of peat are discussed and how, through oxidation it may be released.

The report states that wind farms emit CO_2 in four separate ways. Firstly, by the fabrication and construction of the wind farm. Secondly, through plant loss, which could have continued carbon fixation. Thirdly, through peat degradation leading to oxidation of the carbon within it. Fourthly, through the provision of fossil-fired power stations running inefficiently in back up mode for when wind is not blowing. The last three are often not calculated in Environmental Impact Assessment.

Hall gives a method for assessing the carbon released through peat degradation. He states that there are three main scenarios for assessing the extent of the impact.

- Low scenario – soil is destroyed in an area extending 10 m from any structure. This applies to lowland sites typically devoid of peat.

- Medium scenario – peat is damaged in an area extending 50 m from any structure.

- High scenario - peat is damaged in an area extending 100 m from any structure. This is the scenario that should be chosen for active blanket bogs.

Once the peat is damaged, Hall suggests that all the C will be released to the atmosphere over time. The method does not allow for a proportion of peat to remain undamaged within the areas affected under the different scenarios. The technique also does not taken into consideration the effect of lowering the groundwater table in increasing the oxidation rates in the peat material, or the possibility that C release may be halted by peat restoration works. Hall also offers no validation for the estimates that his technique produces and it appears to be critically flawed in its assumption that all the C is released from the peat surrounding the structures under his three scenarios.

Relevance: The report does provide an alternative method to calculate the carbon dioxide payback time of wind farms. It appears however not to be peer reviewed or endorsed by regulators.

Ref: Scottish Executive Environment and Rural Affairs Department (2007), ECOSSE – Estimating Carbon Organic Soil Sequestration and Emissions, Scottish Executive and Welsh Assembly Government.

Summary: The model developed estimates the carbon store in organic soils in Scotland and Wales and predicts the effects of climate change and land use changes on greenhouse gas emissions.

The model provides an assessment for the whole of Scotland and Wales' organic soils, the carbon stored in them and predicts the magnitude of the following;

- Climate change impacts on greenhouse gas emissions.
- Land-use changes and the release of dissolved organic carbon.
- Carbon loss from accelerated erosion.
- Effectiveness of mitigation measures on the release of carbon and nitrogen from agricultural organic soils

Relevance: The scale and complexity of the model is too great to be usefully applied to this project and would need adaption to be applied to wind farms. The chosen method (Nayak et al.) has been shown to provide similar estimation to the ECOSSE model.

Ref: Worral F., Reed M., Warburton J. and Burt T. (2003) Carbon budget for a British upland peat catchment, The Science of the Total Environment

Summary: The paper lays out the construction of a carbon budget for an upland peat area. In inputs to a peatland carbon budget are:

- Carbon dioxide and methane sequestrated from the atmosphere.
- DOC (Dissolved organic carbon) and C (inorganic carbon) from rainwater.
- Inorganic C from weathered rocks.

And the outputs of the budget are:

- Carbon dioxide and methane release to the atmosphere through decomposition.
- Fluvial outputs of DOC, POC (Particulate organic carbon), DIC (Dissolved inorganic carbon) and dissolved carbon dioxide.

In Worral's method the individual inputs and outputs are quantified over a year by sampling, laboratory analysis and through equations based on measurable parameters such as temperature. Uncertainties in the model of the budget are assessed by Monte Carlo simulations.

It is important to note that not all carbon released from peatland enters the atmosphere; some will enter other stores.

Relevance: Worral's model does provide a carbon budget for a peatland system. It would be difficult to implement his method on this project (or most wind farm developments) as it requires a large data set collected over a long period.

A.1.1.5 Existing Guidance Regarding Wind Farms

There is some guidance relating to wind farms and more general EIA assessment which is summarised here, if not included in the earlier sections (e.g. peat stability references are all listed under the peat stability section above).

Ref: English Heritage (2005): Wind Energy and the Historic Environment.

Summary: The guidance lays out how wind farms can affect the historic environment and where and how in the planning process these impacts should be scoped and assessed to avoid and mitigated against them.

The ability of wind farms to impact upon the historic environment should inform Local Development Frameworks when identifying broad locations than developments could be allowed. Historic sites are not wide spread so it should be relatively simple to avoid these at both a strategic and specific planning level.

Wind farms can affect the historic environment in two ways: direct physical impact and indirect impacts (i.e. in detracting from the historic character of an area).

Relevance: The guidance suggest that because of the limited distribution of historic sites, they can be avoided in the construction of a wind farm. This avoidance can take the form of not building on the site, or adjusting the layout of a site to stop direct physical impact on features of interest.

Ref: English Nature, RSPB, WWF-UK, BWEA, (March 2001) Wind Farm Development and Nature Conservation: A guidance document for nature conservation organisations and developers when consulting over wind farm proposals in England.

Summary: The guidance sets out an informal checklist for nature conservation organisations, developers and local authorities. The guidance states the kind of impacts that wind farms are likely to have on the natural environment. It also gives clear guidelines relevant to developments on peatland:

- Where wind farms are proposed, their development should not cause adverse effects on the integrity of statutory international sites (this includes indirect effects from outside the site).
- Where wind farms are proposed, their development should not adversely affect the conservation objectives and/or reasons for identification and notification or designation of sites of national wildlife importance (this includes indirect effects from outside the site).
- Where a proposed wind farm development is likely to have a significant adverse (not trivial or inconsequential) effect on a site of regional or local nature conservation importance, it should only be permitted if it can be clearly demonstrated that there are reasons for the proposal which outweigh the need to safeguard the nature conservation value of the site. In all cases where development is permitted which would damage the nature conservation value of a site or feature, such damage will be kept to minimum and, where appropriate, conditions and/or planning obligations may be used to provide compensatory measures.
- Where wind farms are proposed, their development should not cause significant disturbance to, or deterioration or destruction of, key habitats of species listed in Annex IV of the Habitats Directive.
- Consideration must be given to the potential impact of onshore wind farm developments on hydrological processes which may have a significant adverse (not trivial or inconsequential) effect on the conservation of wildlife and/or geological/geomorphological features.
- In respect to EIAs, early consultation between wind farm developers and key national nature conservation organisations from the outset of the site selection process may enable avoidance of, or mitigation measures to be identified for sensitive locations.

In Annex 1 of the guidance a checklist on how temporal, spatial and cumulative effects of a proposed wind farm may have a range of impacts on conservation interest, both directly and indirectly.

Relevance: The report gives wider guidance on the development and siting of wind farms and how to limit their effects on the natural environment.

Ref: Department of Environment, Heritage and Local Government (Ireland) (2007), Windfarm Planning Guidelines.

Summary: The report gives comprehensive guidance on all aspects of planning in relation to windfarms. Firstly, by providing a step by step guidance to analyse the suitable of areas for wind farm development by planning authorities. Secondly, by stating the role of EIAs in the planning applications and listing the potential impacts wind farms have. The report also provides an annex particularly concerned with the impacts of wind farms on peatland areas and gives the following best practice on how a wind farm should be developed:

- Where peat in greater than 50 cm thick, a thorough ground investigation (including hydrogeological, geotechnical, instability risks, habitat loss) should be carried out.
- Avoid construction on wet areas, flushes and easily erodible areas.
- Avoid the construction of drains but if constructed, ensure silt traps are used and

there are only diffuse discharges of water. • Avoid blocking existing drains. • Assess the impact of blasting, if it is to be used in the construction. • Operate machinery from the road as it is being constructed. • Minimise the road width but ensure it is compatible with sound engineering practice. • Where practical, culverts should be used to maintain existing surface drainage channels. • Protect the peatland surface from spoil with shuttering boards or geogrids / geotextiles. • Ensure that the water courses and drains that dewatering activities discharge to have the capacity to deal with the volumes encountered. • During construction, place vegetated peatlands scraghs on shuttering boards or geogrids / geotextiles and replace them vegetated side up and firm down with the back of an excavator bucket. • Use specialized low-ground pressure tracked machinery on bog mats when operating on peatland surfaces.
Relevance: The best practice guidance can be adapted for English peatland areas.
Ref: Irish Wind Energy Association, (2008) Best Practice Guidelines for the Irish Wind Energy Industry.
Summary: The report lays out best practical guidelines for the planning and construction of wind farms in Ireland. Within feasibly studies the following issues should be covered; planning, environmental aspects, archaeology, visual impact, wind resources and proximity to existing developments, as well as consultations with external parties to identify potential future issues. The report also states that there are particular issues related to developments on peat that should be tackled within the EIA process. These include; • Slope stability. • Dewatering effects. • Sediment, erosion and nutrient control. • Impact of tracks and drains on hydrology and ecology. • Re-vegetation measures. The various aspects of the design should be examined in light of these factors.
Relevance: This guidance shows that there are addition issues that should be tackled when developing on peatland areas due to peat's unique properties and value.
Ref: Town and Country Planning (Environmental Impact Assessment) (England and Wales) Regulations 1999 (SI No. 293). The Regulations implement EC Directive 85/337/EEC ("On the assessment of the effects of certain public and private projects on the environment") as amended by Directive No. 97/11/EC.
Summary: Wind farms are projects listed under Schedule 2 of the regulations. This means that either an EIA screening decision must be made by local authorities on a wind farm project involving the installation of more than two turbines or if any of the turbines have a hub height of over 15 m, or an EIA undertaken without screening.
Relevance: Whether the site will be built on peatland should inform a local authority's screening decision as peatlands are prone to being adversely impacted by such developments.

Ref: Department for Communities and Local Government Circular 02/99: "Environmental Impact Assessment".

Summary: The circular gives guidance on how to implement the Town and Country Planning (Environmental Impact Assessment) (England and Wales) Regulations 1999 (SI No. 293)

Relevance: The guidance states that a wind farm of above 5 turbines or above 5 MW is more likely to require an EIA.

Department of Communities and local Government (2000). Environmental Impact Assessment: guide to procedures. ISBN 072 772960 8

Summary: Outlines EIA process and when it is required. Identifies that the process helps the developer to take environmental considerations into account and mitigate for impacts including looking at alternatives. Helps planners in their decision making.

Document refers to other guidance for assessing significance of impacts but comments that there are no clear rules as 'significance' depends on the context. Recommends early consultation with other organisations.

Appendices include useful lists including:

- EU directive
- Schedule 1 and 2 developments
- Regulations for content of an EIA
- Checklist for producing and EIA
- List of statutory consultees
- List of UK statutory instruments relevant to EIA

Relevance: Useful overview of EIA process relevant to wind farm developments. Good practice identified includes consultation.

Ref: PPS (Planning Policy Statement) 1 – Delivering Sustainable Development (2005);

Summary: The statement lays out the government's sustainability principles of:

- social progress which recognises the needs of everyone;
- effective protection of the environment;
- the prudent use of natural resources; and,
- the maintenance of high and stable levels of economic growth and employment.

The statement develops an overall strategy to ensure that the planning system is in line with these through:

- making suitable land available for development in line with economic, social and environmental objectives to improve people's quality of life;
- contributing to sustainable economic development;
- protecting and enhancing the natural and historic environment, the quality and character of the countryside, and existing communities;
- ensuring high quality development through good and inclusive design, and the efficient use of resources;
- ensuring that development supports existing communities and contributes to the creation of safe, sustainable, liveable and mixed communities with good access to jobs and key services for all members of the community.

Relevance: The guidance on the development of wind farms on blanket peatland will be in line with the government's sustainable principles.

Ref: Department of the Environment, Transport and the Regions (DETR) Circular 03/99: "Planning Requirement in Respect of the Use of Non-Mains Sewerage Incorporating Septic Tanks in New Development".

Summary: The circular provides guidance to ensure that developments producing 'domestic'

waste which discharges to non-main sewerage (e.g. septic tanks) do not create environmental, amenity or public health problems. Within Annex A of the circular, the factors to be considered by planning authorities, in relation to this, are laid out.
Relevance: Any wind farm development planned with non-mains sewerage of 'domestic' waste will under go assessment by the planning authorities, as laid out in the circular.
Ref: PPS 7 – Sustainable Development in Rural Areas (2004).
Summary: The government has set several objectives: • To raise the quality of life and the environment in rural areas. • Promote a more sustainable pattern of development. • Promote the development of the English regions by improving their economic performance. • Promote a sustainable, diverse and adaptable agricultural sector. The statement highlights the key principle that development proposals should be based on sustainable principles. This should inform regional spatial strategies and local development plans to promote sustainable patterns of development.
Relevance: Strategic and specific wind farm development plans should abide by sustainable principles.
Ref: PPS 9 – Biodiversity and Geological Conservation (2004).
Summary: The government has set several objectives: • to promote sustainable development; • to conserve, enhance and restore the diversity of England's wildlife and geology; • to contribute to rural renewal and urban renaissance. The statement develops key principles including: 'planning policies and planning decisions should maintain, enhance, restore or add to biodiversity and geological conservation interest'. These principles should inform regional spatial strategies and local development plans to promote sustainable patterns of development.
Relevance: Strategic and specific wind farm development plans should abide by sustainable principles to protect biodiversity and geological conservation interest.
Ref: Planning Policy Guidance 14: Development on unstable land (1990, Annex 1: Landslides and Planning (1996), Annex 2: subsidence and planning (2002)).
Summary: The PPG gives advice for developers, local authorities and other interested parties on the best practice for developing on unstable ground. Annex 1 contains guidance for about landslides for developers and appendix includes a landslide risk assessment.
Relevance: Peat is a compressible material, therefore prone to instabilities especially in light of drainage schemes which can cause subsidence. PPG 14 should therefore be followed in the development on wind farms.
Ref: Planning Policy Statement 22: Renewable Energy (2004).
Summary: The government sets outs its objective in relation to renewable energy and its key principles which state that the development of renewable energy projects should be encourage within a planning framework which identifies suitable locations for them.
Relevance: The development of wind farms on peatlands should be done in such a way as to not contradict the government's objectives.
Ref: Planning Policy Statement 22: Renewable Energy – a Companion Guide (2004).

Summary: The companion guide gives practical guidance on how PPS22 can be implemented. It also gives detailed guidance on wind farms, describing the nature of these types of development and likely planning issues. It gives detailed descriptions to a number of planning issues, general, noise, landscape and visual impact, listed buildings and conservation areas, safety, proximity to roads, railways and public right of ways, ecology and ornithology and interference to electromagnetic transmission, amongst others. In relation to wind farms the guide also discusses EIAs and possible planning conditions.
Relevance: The specific guidance on wind farms should be implemented for the planning, development and construction of any wind farm.
Ref: Planning Policy Statement 23: Planning and Pollution Control.
Summary: The government sets outs its objective in relation to planning and pollution control and states that strategic and site specific planning should be used to mitigate against the risk posed by pollution and contamination. The guidance has been writtern in line with the sustainability and precautionary principles.
Relevance: This guidance should be followed to mitigate against pollution risk and control the risk posed by contamination on sites that wind farms are developed on.
Ref: Planning Policy Statement 25: Development and Flood Risk.
Summary: The statement requires that inline with government objectives and principles, any development in an area with a 1 % annual flood probability or is greater than 1 ha in size requires a flood risk assessment to assess the risk to the site and the wider catchment.
Relevance: Developers on peatland will have to show that proposed drainage scheme will not have an adverse impact on the flood risk for the rest of the catchment. This means that sustainable drainage schemes should be developed to deal with site specific needs.
REF: Scottish Planning Policy 6 (SPP6): Renewable Energy, March 2007.
Summary: Provides similar guidance to PPS22 on the forming of development plans and spatial plans in relation to renewable energy. It also contains an annex to with guidance to local authorities on wind farms and the planning process.
Relevance: The specific guidance on wind farms should be noted by planning authorities within England.
Ref: Scottish Executive Planning Advice Note 45 (PAN 45) (revised 2002): Renewable Energy Technologies.
Summary: PAN 45 provides a companion guide to National Policy Planning Guideline 6 (superseded by SPP6). This includes more information on wind farms.
Relevance: The note provides guidance useful to planning authorities in relation to wind farms.
Ref: Scottish Natural Heritage, Guidance on Cumulative Effects of Wind Farms, Version 2.
Summary: The guidance is designed to help Scottish National Heritage Staff when responding to consultation on proposed wind farms. It state that cumulative effects should be judged at both a site specific and strategic planning level. The guidance is mainly concerned with the cumulative visual impacts of wind farms.
Relevance: Cumulative effects on peatlands should be assessed at strategic and site specific planning level.
Dransfield J.M. (2004) Leaching of admixtures from concrete, Concrete vol. 38 p52-54
Summary: Dransfield lays out a procedure for assessing the leaching of admixtures from concrete.
Relevance: Admixtures can be harmful to human and ecological health so wind farm

proposals should prove that the concrete mixture that they intend to use will not pose a significant risk to receptors.

Ref: Environment Agency (2002), A Guide to Monitoring Water levels and flows at Wetlands Sites.

Summary: Hydrology and water quantity are the major factors driving wetland ecology therefore this report offers guidance on setting up a water level monitoring system and using the data in an effective way.

Relevance: If a water level monitoring system is required to assess the effect of a wind farm development on the hydrology and ecology of a blanket bog, the report offers particular guidance to the planning and regulation involved and how to produce an effective system which creates useable data.

Ref: CIRIA (2005) Environmental Good Practice on site.

Summary: The report offer guidance to site managers, site engineers, site foreman, project managers and others in similar positions, on how to implement good environmental practices on sites. This includes: obligations that site work may be conducted under, whether these are from legislation or from contract conditions; general site management issues of good site practice and frameworks for managing environmental impacts; and lastly construction processes and identifying particular environmental impacts that are related.

Relevance: In order to minimise environmental impacts at the construction stage this guidance should be implemented during site works.

Ref: CIRIA (2004). Interim Code of Practice for Sustainable Urban Drainage Techniques, National SUDS Working Group.

Summary: The report provides basic guidance on the benefits of Sustainable Drainage Systems (SUDS) and for practitioners, on the implementation of such schemes. It states that local authorities have an important role through the planning processes, in ensuring that SUDS are adopted into new developments.

Relevance: Planning authorities should require that SUDS are required as part of the planning conditions for wind farms, in line with this guidance. It must be noted that certain SUDS techniques, such as methods which discharge surface water to the ground, may cause stability problems in peat areas.

Ref: CIRIA (2006), Control of water pollution from linear construction projects. Technical guidance (C648).

Summary: The guidance is designed for a wide readership including clients, construction project management and regulators. It is concerned with pollution control from linear construction projects such as roads, cables and watercourses.

The guidance is split into three sections. Firstly, a section on the characteristic of linear projects and understanding water pollution that could result. Secondly, measures that can be taken at the initial stages of planning and design to minimise water pollution. Thirdly, at the construction stage; the implementation of management measure and controls to prevent pollution from key construction activities.

Relevance: Wind farm developments consist of a number of linear construction projects (roads, cabling and drainage) and the risk of pollution could be limited by the implementation of the framework that this guidance presents.

Ref: CIRIA (2001) Control of water pollution from construction sites. Guidance for consultants and contractors (C532).

Summary: This report gives easily accessible guidance to consultants and contractors on construction sites, on how to control water pollution. It provides additional detail to the guidance laid out in CIRIA (2005) 'Environmental good practice on site'.

Relevance: Blanket peatland can be highly susceptible to water pollution so the implementation of this, or similar guidance, when developing a wind farm on blanket bog

should be required.
Ref: Environment Agency, Pollution Prevention Guideline Series.
Summary: The series of PPGs are designed to give practical advice to parties to avoid pollution, minimize waste and comply with the requirements of the law. There are a number of publications in the series including: • PPG 1 – General Guide to the Prevention of Pollution (2001 due for review); • PPG 2 – Above Ground Oil Storage Tanks (2004); • PPG 4 – Treatment and Disposal of Sewage Where No Foul Sewer is Available (2006) • PPG 5 – Works In, Near or Liable to Affect Watercourses (2008); • PPG 6 – Working at Construction and Demolition Sites (2001); • PPG 7 – Refuelling Facilities (2004); • PPG 13 – Vehicle Washing and Cleaning (2007); • PPG 18 – Managing Fire Water and Major Spillages (2000); • PPG 21 – Pollution Incident Response Planning (2004); • PPG 22 – Dealing with Spillages on Highways (2002).
Relevance: The PPG series sets out the requirements of the law, that wind farm developments must comply with in relation to pollution and waste. The series also gives practical advice that should be adhered to, through out the development process.
Ref: Cumbria Wind Energy Supplementary Planning Document: Consultation Draft 2006, Allerdale Borough Council, Carlisle City Council, Copeland Borough Council, Cumbria County Council, Eden District Council South Lakeland District Council, Lake District National Park Authority.
Summary: The document provides guidance on wind farm proposals for local authorities and developers. It is mainly concerned with landscape issues, accessing particular landscape's capacity to take wind farm developments based on their character and value. The document also gives guidance on communicating with the local community and assessing cumulative effects. On the subject of peat soils, it gives the guidance that areas of peat should be avoided for wind farm development, as they are easily eroded and, if disturbed, can release CO_2 to the atmosphere.
Relevance: There is relatively limited information regarding peat, hydrology and biodiversity impacts as the document majors on landscape issues. However, it is an interesting example of supplementary planning guidance regarding wind farms for local authorities.
Ref: Landscape Sensitivity to Wind Energy Developments in Lancashire, 25-02-2005, Lovejoy for Lancashire County Council, Blackpool and Blackburn with Darwen Borough Councils.
Summary: The document provides a landscape sensitivity assessment for Lancashire; assess landscapes capacities for wind farm development. The document deliberately excludes ecology, hydrology and soil resources criteria but states that these merit careful consideration when assessing individual proposals.
Relevance: The document only focuses on landscape concerns, but is interesting in that it is specific guidance for wind farms.
Ref: National Assembly for Wales, Planning Policy Wales (2002) and echnical Advice Note 8: Planning for Renewable Energy (2005).
Summary: Planning Policy Wales aims to set the context for sustainable land use planning in Wales. It includes a section on sustainable energy, including wind farms. It encourages development of wind farms subject to obligations to protect nature conservation interests and the historic environment and to minimise impact on local communities. TAN 8 gives more detailed planning advice. Large scale wind farms (> 25MW) are to be

concentrated in strategic areas (identified in the document and avoiding national parts, AONB etc). Smaller developments will be considered in urban/ brownfield settings.

Relevance: Provides guidance useful to local authorities considering wind energy developments.

Ref: The Electricity Works (EIA), Scotland Regulations (2000). The Stationary Office. ISBN 0 11 05460.6

Summary: Regulations for wind farm developers in Scotland: Annex 4 contains a short outline of the information required in the EIA. This includes:

- A description of the development, its construction and operation. A description of residues and emissions (water, air and soil pollution, noise, vibration, light, heat, radiation, etc).
- A description of the aspects of the environment likely to be significantly affected by the development, including, in particular: population; fauna; flora; soil; water; air; climatic factors; material assets; including the architectural and archaeological heritage; landscape and the inter-relationship between the above factors.
- A description of the likely significant effects of the development on the environment, which should cover the direct effects and any indirect, secondary, cumulative, short, medium and long-term, permanent and temporary, positive and negative effects of the development, resulting from the existence and use of the development or the emission of pollutants
- A description of the measures envisaged to prevent, reduce and where possible offset any significant adverse effects on the environment.

Relevance: Provides guidance relevant to wind farm developments outside Scotland.

Ref: Blanket Bogs Habitat Action Plan (http://www.ukbap.org.uk/UKPlans.aspx?ID=21). Originally published as: UK Biodiversity Group Tranche 2 Action Plans - Volume VI: Terrestrial and freshwater species and habitats (October 1999, Tranche 2, Vol VI, p205)

Summary: The report provides a description of Blanket Bog Habitat, current condition and factors affecting habitat. The targets are to:

- Maintain the current extent and overall distribution of blanket mire currently in favourable condition.
- Improve the condition of those areas of blanket mire which are degraded but readily restored, so that the total area in, or approaching, favourable condition by 2005 is 340,000 ha (ie around 30% of the total extent of restorable blanket mire).
- Introduce management regimes to improve to, and subsequently maintain in, favourable condition a further 280,000 ha of degraded blanket mire by 2010.
- Introduce management regimes to improve the condition of a further 225,000 ha of degraded blanket mire by 2015, resulting in a total of 845,000 ha (ie around 75% of the total extent of restorable blanket mire) in, or approaching, favourable condition.

Identifies actions and lead agencies.

Relevance: Summary of blanket peat habitat in the UK and targets relevant for delivery of UK BAP.

Ref: British Wind Energy Association – Best Practice Guidelines for Wind Energy Development (1994)

Summary: Guidance document for wind farm developers covering phases of development including. Initial stage, feasibility, detailed design, construction, operation and decommisionning. Outlines contents for detailed assessment of the site and its impacts including:

• Policy framework • Site selection • Site designation • Visual and landscape impacts • Noise • Ecological impact • Archaeology • Hydrology • Safety (includes interference with communications, aircraft and traffic management) • Economic impact • Impact on the global environment • Tourism • Decommissioning and mitigation measures.
Relevance: Guidance for wind farm developers on the potential impacts of the development.
Ref: Scottish Power – Windfarm Sustainable Development Policy. Undated brochure
Summary: Short summary of Scottish Power's sustainable development aims for Wind Farms. It contains sustainability aims for each stage of wind farm development, (site selection, consultation, assessment, construction, operation, decommissioning) also for biodiversity conservation and socio economic benefits. It contains more detailed objectives for each aim which are mainly associated with their impact on biodiversity interests in particular developing biodiversity action plans for wind farm sites and implementing habitat management plans at more sensitive sites.
Relevance: Sustainability aims and objectives are relevant to other wind farm developers.
Ref: An Introductory Guide to Valuing Ecosystem Services. DEFRA 2007
Summary: Introduction to valuing ecosystem services taking a systematic approach to assessment of impacts. Defra response to the UN Millenium Assessment of Ecosystem Services (2000). Ecosystem services are services provided by natural environment that benefit people. Services include: • Food • Fibre • Fuel • Cultural services (recreation and appreciation of nature) • Regulation of climate • Purification of air and water • Flood protection • Soil formation • Nutrient cycling. Focus on valuing ecosystem services in a policy appraisal context. Report sets out the case for valuing ecosystem services. Discusses policy Appraisal and the environment. Identiofies key steps to value an ecosystem service, considers use of economic valuation services.

Includes a case study of United Utilities/ RSPB SCAMP project which has demonstrated improvement in water colour and quality and lowered treatment costs. This found that the benefit of restoring the peat was £1.2M to £2.6M in terms of reduction in water treatment costs.
Relevance: Methods could be used to estimate the cost of loss or degradation of peatlands due to wind farm development.
Ref: Securing a Healthy Natural Environment: An action plan for embedding an ecosystems approach. DEFRA, 2007
Summary: Companion document to DEFRA, 2007 (above). Outlines the approach that DEFRA will take to incorporate ecosystem services into their policy making. Priority area 3 is case studies that demonstrate the benefits of taking an ecosystems approach and within this action A4c is to use peat conservation as a case study this is due to report at the end of 2009. Report describes ecosystems approach and actions required to bt=ring the ecosystems approach into mainstream decision making. The document considers the concept of living within environmental limits and used peat as an aexample area where human activities have compromised an ecosystem. Peatlands are used as an example of an ecosystem that is a carbon sink in the discussion of climate change and ecosystems. Defra has a research programme which is aiming to synthesis research relevant to an ecosystem approach and identify gaps in evidence, cross cutting issues and a set of case studies showing a practical approach.
Relevance: Summarises ecosystems approach, summarises direction of research and highlights ongoing research which should assist in estimating the value of peatland degradation by wind farms.
Community Windpower Ltd, 2005. Aikengall Windfarm EIS, Non Technical Summary Produced by RSK Environmental
Summary: Example EIA for a windfarm close to a SSSI. Concludes that working closely with Scottish Wildlife Trust enabled them to demonstrate no impact on the nearby SSSI.
Relevance: Example of windfarm EIA where there are nature conservation concerns. Approach of working closely with wildlife trust could be relevant for windfarm developments on peat.
Davidstow Windfarm, Cornwall EIS (http://www.davidstowcommunitywindfarm.co.uk). Planning application submitted 2008.
Summary: Example EIA for a windfarm on a site with some peat adjacent to Bodmin Moor SSSI (designated for peatland features of interest including quaking bogs and transition mires). The hydrology section identifies hydrological constraints and areas to be avoided as well as mitigation measures. Impacts are discussed for construction, operation and decommissioning. Classify resource (e.g. nature conservation) as International, National, Regional and Local and use a matrix to report on overall significance of impacts.
Relevance: Example of approach to EIA and presentation of overall impacts.
Royal Town Planning Institute, 2001. Planning Policy Statement, Environmental Impact Assessment. ISBN 1-902311-28-0.
Summary: Advice and information about EIA best practice particularly aimed at town planners. Resports that EIA can increase sustainability of development by: • Considering environmental alternatives • Examining alternatives (statutory part of an EIA) • Highlightling environmental effects • Proposing mitigation and monitoring. Outlines EIA process and key stages from a planning process. These are:

• Screening –identify whether EIA needed (if schedule 1 then always, if schedule 2 then depends on development) • Scoping – identify environmental opportunities and constraints, consider construction/ operation and decommissioning/ restoration stages, direct and indirect impacts, short or long term impact, inter relationship between impacts. • Consider alternatives – outline alternatives and give a clear justification for choices, this is described as best practice for an EIA • Describe site and proposal – outlines requirements • Forecast Effects – determine likely changes, recommends agreeing methods with developer, local planning authority and consultees, methods should be appropriate and robust. • Determine significance of impacts • Identify mitigation and environmental enhancements – identifies the key to success as early consultation • EIS should be accessible and include non technical summary • Review of EIS carried out by local planning authority and statutory consultees. The document discusses the value of consultation and the evaluation of information for decision making.
Relevance: General EIA guidance applicable to wind farm developments. Summarises the process and requirements. Stresses the benefit of consultation to a successful EIA process.
Department of Communities and Local Government (2006). Evidence Review of Scoping in Environmental Impact Assessment. HMSO
Summary: Report on a project to consider whether scoping activities improve the EIA process. Project was a literature review of EIA examples and a survey of local authorities which have dealt with EIA recently. Study assessed whether existing EIA guidance was used (often expert judgement). Planning officers thought consultation improved the process and identified scoping as the most important stage in the EIA process and particaulrly useful in odentifying cumulative impacts. Study found that consultees in the scoping stage had an important influence on the content of the EIA. Issues for the scoping stage include a lack of time to carry out the work (both developers and consultees). Key benefits of scoping stage identified as: • Time and resource savings • Identification of key impacts • Contact with relevant stakeholders Report includes case studies including example of effective consultation, example of inefficient practice during the scoping stage. Scottish Power are used as an example of a company that demonstrate good practice in producing EIAs. Appendices summarise international practice and the results of the questionnaires and seminars held during the project.
Relevance: Identifies key benefits of scoping stage of EIA. Recommends consultation between developer and others, identifies that time pressures may be a problem at the scoping stage. Case studies provide good practice examples of approach to scoping an EIA. These are relevant to both Natural England and wind farm developers during the scoping stage of a project.
SEPA Position Statement to support the implementation of the Water Environment (Controlled Activities) (Scotland) Regulations 2005: Culverting of Water courses

V1.2 SEPA, Dec 2006 **(http://www.sepa.org.uk/water/water_regulation/guidance/engineering.aspx)**
Summary SEPA position statement on road crossings, particularly culverts. SEPA seek to promote retention of Habitat, presume against unjustified open or closed culverting., seek to improve existing culverts, seek mitigation where culverts are justified. Document summarises key impacts of culverts on: ecology, pollution, morphology and erosion, flooding, restoration, landscape and amenity, human health and safety. The document contains some interim good practice advice including the conditions in which culverts might be justified. The document includes a list of measures which may mitigate against the impact of culverts.
Relevance Useful summary of impacts of culverts, relevant when assessing the impact of a site design. Mitigation measures include culvert location and erosion management which should be incorporated into design of track layout and road crossing types and locations.
SEPA, April 2008. Engineering in the Water Environment Good Practice Guide: Construction of River Crossings, 1st Edition. **(http://www.sepa.org.uk/water/water_regulation/guidance/engineering.aspx)**
Summary: Detailed good practice guidance for road crossings. Includes a summary of the impact of road crossings including erosion and flooding. Discusses the requirement to demonstrate that there is a need for the work and the choice of appropriate alternative crossing types. These are summarised (e.g. types of bridges, culverts, bottomless culverts, fords) and the guidance includes a flow chart to assist in choosing a suitable road crossing. The guidance also includes considerations for good practice design.
Relevance: Guidance is relevant to developers choosing the type and location of river crossings to use for a windfarm development. The guidance is also relevant to Natural England (and other authorities) assessing whether the developer has properly considered the potential impacts of road crossings.

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A.2 CASE STUDIES

A.2.1 Introduction to Case Studies

A number of case studies have been undertaken. This appendix provides further details of the three main case studies at Scout Moor, Coal Clough and Wharrels Hill Wind Farms.

A.2.2 Case Study 1 - Scout Moor

A.2.2.1 Introduction

Scout Moor Wind farm consists of 26 turbines over 545 ha and is located 15 km north of Manchester. The planning applicant was Scout Moor Wind Farm Limited, a joint Venture Company between United Utilities Green Energy Ltd and Peel Investments (North) Ltd. The farm was constructed between 2007 and 2008, after planning permission was granted in May 2005 subject to conditions. This followed an inquiry held by the Planning Inspectorate which approved the project.

The site lies on a plateau with a large wind resource, on land outside landscape, ecological or archaeological national designations. The site is dominated by moorland grassland and blanket bog.

A.2.2.2 Identifying impacts and mitigation measures at the EIA stage

The finding of the Scout Moor Wind Farm Ltd's EIA process was presented in an ES (Scout Moor Wind Farm Ltd 2003) and a Supplementary ES (Scout Moor Wind Farm Ltd 2004). Over these two documents several assessments were made:

- Landscape and Visual,
- Ecological,
- Noise,
- Cultural Heritage,
- Electromagnetic Inference and Safety,
- Human Environment and Land Use,
- Mining,
- Hydrology and Hydrogeology.

The assessments and mitigation measures which are pertinent to this report are discussed below.

A.2.2.3 Hydrological and Hydrogeological

Under the initial ES, hydrological issues were dealt under the ecological assessment. It stated that some erosion and degradation would occur as the result of the construction of the wind farm but the majority of these impacts would be of a low magnitude and of minor significance.

Within the Supplementary ES, hydrology and hydrogeology issues were tackled in a separate assessment. Within Appendix H3 and H4, the potential impact assessed and proposed mitigation measures are laid out. The impacts cover several areas including: pollution from fuels, plant, etc.; increasing sediment loads in streams from construction and decommissioning; drainage ditches and water levels in peat; and discharging extracted water during construction. For all these impacts, mitigation measures were suggested which, according to the Supplementary ES, if implemented would limit the impact significance to an acceptable level. A discussion on the Construction Method Statement implementation of mitigation measures is found in section A.2.3.1.

The hydrological and hydrogeological assessment appeared to cover several areas well but failed to understand that the unique properties of peat as a soil type, might lead to several potentially significant impacts. Apparent weakness in the assessment identified in this review included:

- Not assessing the blanket bog as its own hydrogeological unit. This meant that it was not assessed in the hydrogeological assessment. As a result the impact of increased drainage, road and turbine construction and other activities on the integrity of the blanket bog as a whole hydrogeological unit was not discussed.
- A lack of focus on the issue that, when disturbed, peat losses much of its strength and therefore is prone to greater erosion.
- Confusing the fact of that much of the blanket bog was in a degraded state, with the potential magnitude of the impacts of the development on it. As a result, especially in the ES, the differences between magnitude, sensitivity and significance become confused.
- Much of the site is within catchments used for water supply but the impact on water quality of these resources was not discussed.
- A lack of conceptualisation of the hydrological and hydrogeological regime.

As a result, the important of mitigation measures and the reasoning for mitigation measures were not made clear. This resulted in mitigation measures not being adopted in the Construction Method Statement and those that did being of limited effectiveness (see section A.2.3.1 and A.2.3.3).

A.2.2.4 Ecological Assessment

Rightly, with the ES and Supplementary ES, there was overlap between the ecological and hydrological and hydrogeological assessments. The site lies within two local ecologically designated areas, Scout Moor Biological Heritage Site and Knowl Moor Site of Biological Importance. A phase one habitat survey identified two main habitats; grasslands (unimproved, semi improved and marshy) and mire (blanket bog, wet modified bog, dry modified bog, acid flushes, basin mires and valley mires). The ES noted that the habitats were supported by the underlying hydrological regime. The Supplementary ES stated that none of the blanket bog was in a favourable condition. The implication of this was that as the quality of the habitat already degraded, its sensitivity to impacts and the magnitude of those impacts was also significantly reduced. This is not always the case with blanket bogs and the reasoning behind assuming this for this site was not made clear.

It was stated in the Supplementary ES that the effectiveness of any habitat management measures would be limited by the common land status of much of the site. This would reduce the applicant's ability to construct works to restore habitat, like drain blocking or fence erection. The majority of mitigation measures on site would have to focus on avoidance of disruption.

Within the mitigation measures, no thought was given to the segregation of soil stockpiles on the basis of soil type and depth. Re-establishing plant communities on soils deposited during construction is made more effective if the correct type of soil is place there. The mixing of top and subsoil, peat and mineral soils in stockpiles, potentially means a soil unsuitable for the natural communities can be placed back. The mixing of peat with mineral soils can also increase the mineral content of the groundwater and changing ombrotrophic communities down the hydraulic gradient to a more fen-type one.

A.2.2.5 Cultural Heritage Assessment

The cultural heritage assessment in the ES and Supplementary ES dealt with the impacts on the sites archaeology. The site was found to have two main periods of historic activity: prehistoric; and post-medieval industrial activity. Especially in relation to prehistoric activity, the ES stated that it would be hard to avoid all archaeological features through planning alone, as the existence and location of many would not be known until construction activities revealed them. Archaeological mitigation measure therefore consisted of trial pits of turbine sites, micro-siting, a watching brief and the use of floating roads which were stated to have a lower impact than other road construction methods.

In the Supplementary ES, it is stated that the degraded state of the bog limits the chances of finding paleoenvironmental material. The further conclusion that the potential for increased degradation as the result the proposed wind farm project would lower those chances again was not made.

A.2.3 Planning Conditions for a Wind Farm on Peatland: Case Study

Planning permission granted in May 2005 by the Planning Inspectorate included twenty conditions (Department of Trade and Industry 2005). These were informed by the inquiry process which was conducted on the application (Planning Inspectorate 2005). Within that inquiry, landscape, public access and ecological issues amongst others were discussed. The head of the inquiry concluded that with mitigation measures, he was not persuaded that any significant harm to moorland ecology would ensue. In summary, the planning conditions were (Scout Moor Wind Farm Ltd., 2006):

- The development would be constructed and operated in accordance with the planning application, as amended by supplementary environmental information provided by the applicant.
- Development would commence no later than five years from the date of the consent.
- Permission would expire no later than 25 years from the date that electricity was first exported from the development to the grid.
- Any turbine not operational for 12 consecutive months would be dismantled and removed from the site, and the site would be restored in accordance with an agreed scheme.
- The turbines would be sited within 40m of the grid co-ordinates given in the ES.
- The turbine blades would all rotate in the same direction.
- No development would take place until the following details had been submitted to, and approved by, the local planning authorities (there were two authorities involved):
    - Size, design and external appearance of the turbines
    - Size, design and external appearance of the substation building
- Construction of the turbine masts or substation would not take place until the access roads had been constructed in accordance with plans previously submitted to, and approved by, the planning authorities.
- All cabling on site would be located underground and installed in accordance with an agreed scheme.
- The access tracks would remain unfenced.
- Access for members of the public, commoners and grazing stock would be allowed during the lifetime of the permission.
- No development would take place until a CMS had been submitted to, and approved by, the planning authorities.
- No development would take place until a badger survey had been carried out and, if necessary, the CMS modified to allow for the presence of badgers.
- Construction activity would be restricted to a period outside the bird nesting season (1st March to 31st July) unless the CMS provided alternative safeguards to protect nesting birds.
- No development would take place until a Pollution Incident Response Plan had been submitted to, and approved by, the planning authorities. This plan would need to be implemented.

- No development would take place until a scheme of archaeological investigation had been submitted to, and approved by, the planning authorities. This plan would need to be implemented.
- Construction work would not be carried out on site before 0800 hours on weekdays or Saturdays, nor after 1800 hours on weekdays or 1300 hours on Saturdays. No work would be carried out at any time on Sundays, Bank Holidays or Public Holidays.
- No electricity would be generated until a scheme providing for the remediation of any interference to domestic television reception had been submitted to, and approved by, the planning authorities. The scheme would have to be implemented, and the company would have to meet the costs of any remediation.
- Noise from the turbines would be limited to specified levels. Levels would be calculated using the methods in ETSU-R-97.
- Noise during construction would be limited to a specified level.

There were clauses allowing for the possibility of variation from the conditions if agreed in writing with the planning authority or if directed by the Secretary of State.

A.2.3.1 Review of Construction Method Statement

Under Planning Condition No.11 a Construction Method Statement had to be written and approved by the local planning authorities before construction started. Important mitigation measures should have been translated into this document from the ES and Supplementary ES; however there were several which were not, which increased the likelihood of significant impacts occurring. Several mitigation measures which did not make it to the Construction Methods Statement include:

- Turves to be placed over peat stockpiles to reduce sediment run-off.
- The use of geotextiles to reduce sediment run-off.
- On the impacts of drains:
- Installing peat dams and wooden slats in road side drains.
- Cut-off drains would not flow directly into gullies and streams but be returned to the ground through gulley pots or similar.
- In cable trenches peat dams would be constructed in cable trenches to avoid them acting as ‘French drains’.

Other mitigation measures in the statement could potentially be harmful. This includes measures to reseed areas of deposited soil and bare ground. The statement makes no illusion to different seed types being place in different habitats, as a result areas of moorland or blanket bog may be seeded with species which would not grow there or change the communities where they do grow. Another potentially harmful mitigation measure, is the depositing of soils into stockpiles which were not separate on the basis of soil type or depth, leading to a mixing soil type which would harm and change the established communities.

A.2.3.2 Site Visit

Scout Moor wind farm was visited on 18th March 2009, with the permission of Peel Ltd. A site walk over and peat augering was conducted to review the hydrological, hydrogeological and ecological impacts of the wind farm on the blanket bog.

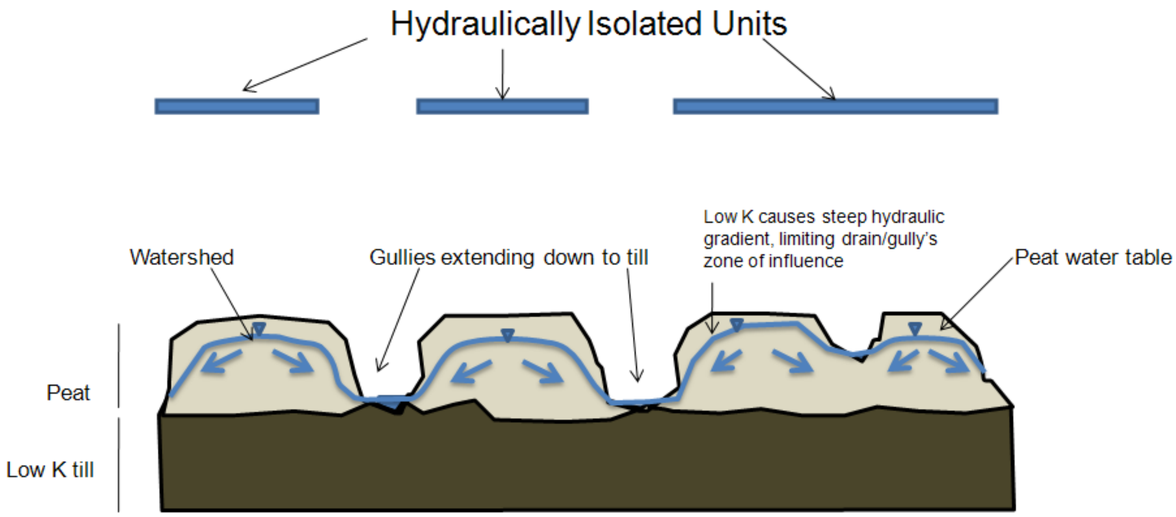
A.2.3.2.1 Condition of the Blanket Bog

The blanket bog habitat is moderately extensive at this windfarm site and is present in the southern and eastern ends of the site. It is interspersed mostly with acid grassland, except at the southern end of the site around turbine 1 where there is wet heath vegetation dominated by purple moor-grass (Molinia caerulea).

The blanket bog appeared to be in a degraded state over the whole site, due to overgrazing; historic peat cutting (Photograph A1); and to a lesser extent, the development of the wind farm. There is evidence of peat cutting as well as some large old ditches (e.g. Man Road Ditch) and grips. Virtually, the entire blanket bog habitat is affected by gullying, but it is particularly prevalent around Cowpe Moss and Hail Storm Hill.

No acrotelm was observed on site, whether in cuttings or in gouge auger samples, and the peat in the catotelm at this site is highly humified. The degree of degradation (between H4 and H7 on the Von Post scale (von Post and Granlund 1926)) has reduced the hydraulic conductivity of the peat bog. Over much of the site, gullies dissect the blanket bog at regular intervals, down to the till beneath (Photograph A2). These gullies pre-date the wind farm development and act as hydraulic boundaries, isolating area of blanket bog from each other (Figure A1). This means that the bog no longer act as one hydrogeological unit.

Figure A -1 Conceptual model of the Scout Moor blanket bog (K = hydraulic conductivity)



The dominant plant across the blanket bog habitat is harestail cotton-grass (Eriophorum vaginatum) and the vegetation type can confidently placed in the species-poor sub-community of the harestail cotton-grass raised and blanket bog community (M20a) of the NVC. There are small patches of common cotton-grass bog pool vegetation (M3) in the damper hollows where common cotton-grass (E. angustifolium) dominates the vegetation. Acid grassland has replaced blanket bog vegetation where the peat has eroded down to the mineral material in the drier areas and it is dominated by mat-grass (Nardus stricta) and therefore allocated to the species-poor sub-community of the mat-grass grassland (U5a). The wetter flushed areas are usually dominated by soft rush (Juncus effusus) and can be ascribed to the soft-rush sub-community of the star sedge – bogmoss mire community (M6c). The virtual absence of dwarf-shrubs across the site, other than a few scraps of bilberry and crowberry, is a reflection of the long history of heavy grazing. Also there is hardly any bogmoss present across the blanket bog vegetation. This is due to the trampling effect of the sheep and also to the drying effects of the gullying and drainage of the blanket bog habitat, resulting in the complete absence of any acrotelm at this site.

A.2.3.3 Impacts of the Development

A.2.3.3.1 Road side drains and culverts

On the whole, individual drains were not long and the drainage network was not extensive. The impact of drains was limited by two factors: the hydraulic conductivity of the peat was observed to be low due to the degree of degradation, so the zone of influence of drains on the peat water table was correspondingly low (approximately 5 m); and the pre-development gullying would only allow the impact of new drains to occur within hydraulically isolated units of bog. These observations are in contrary to observations of other blanket bogs (Lindsay and Freeman 2008) where the impact on peat water levels of drainage ditches has be observed to be higher. The nature of the Scout Moor blanket bog shows that it is hard to generalise about the zone of influence of drainage ditches on blanket bog. Site specific conceptualisation, taking in account the degree of degradation, acrotelm presence, hydraulic conductivity and gullies, is required to assess the likely zone of influence of drainage ditches.

The several individual drains were noted to have negative impacts. At least one drain extends over several hundred metres; this could lead to increase surface run-off and resultant increases in erosion. Additionally; many of the end of the ditches and culverts were left un-engineered, to discharge straight to the surface of the bog (Photographs A3, A4 and A5), as per the Construction Method Statement. This method appears to have two main negative impacts: causing erosion and potentially gulleying at the discharge point; and increasing mineral input, thus changing the habitat from ombrotrophic blanket bog to a fen (Photograph A6).

Where culverts discharge on the downslope side of the tracks, there was enhanced water supply. This was most significant where the culverts received large quantities of waters, i.e. the catchment is effectively large. Where the area to which the discharge was gently sloping and the effective ponding of the water, it enhanced the development of either more luxuriant cotton-grass growth, if there is little or no mineral input, or where there is significant quantities of mineral enriched water it changed the existing blanket bog/acid grassland vegetation to a type of poor-fen habitat. This was particularly obvious at turbine 26 (SD 8251, 1929) and here the surface vegetation became floating and emitted gases from the underlying substratum. The zone of influence from this culvert extends for approximately 50m downslope and over a width of about 30m. It is anticipated that these areas will move either towards a soft-rush dominated vegetation type (M6c) or where it is particularly wet to one dominated by short sedges (M6a or M6b).

A.2.3.3.2 Floated Roads and Pooling

In some locations pools were noted on the upslope side of floated roads (Photograph A7). This suggests that the roads had reduced hydraulic conductivity of the peat beneath it, damming water. This had created areas of increased habitat value where the pools had formed. The small areas of open water were dominated by common cotton-grass, effectively creating bog pools of the M3 type vegetation of the NVC, for example at SD 8408,1869. These pools were particularly prevalent on the northern side of the track between turbines 21 and 25. It was observed that this damming had not caused notable drying on the downslope side, which would have had a negative effect upon the blanket bog's integrity. This could be for a number of reasons:

- It is too soon to see these effects on this site.
- The blanket bog habitat is already relatively dry.
- Lateral movement of water across the surface of the blanket bog is not particularly important where individual sections of intact blanket bog peat and vegetation are relatively small or narrow.
- The observations were carried in late winter and the effects may be more obvious in late summer.

A.2.3.3.3 Turbine Foundations

The construction of deep turbine foundations, which are 15 m in diameter, required in thick peat a far larger excavation. This was due to the low strength of disturbed peat, causing slumping around the excavation (R Dibley pers. comm.), creating areas of disturbance up to 40 m wide. Slumping of peat in excavations meant that the disturbed area was far larger than if excavation occurred in a more cohesive material. At Turbine 26, in order to protect the disturbed material surrounding the foundations from erosion from surface water a large French drain and culvert system was constructed to divert water. This increase the development foot print around the turbine significantly. At the discharge point for this system the water and mineral input into the system changing the blanket bog at that location to a fen-type habitat (Photograph A6).

A.2.3.3.4 Export Cable Route

The top section of the export cable route was inspected. This unlike the other electricity cables on site does not follow a road. It was installed in mineral soils using a mole plough. The technique appeared to limit possible impacts as little disturbance was visible on the surface.

A.2.3.3.5 Increased Public Assess

The creation of access tracks has made accessing Scout Moor easier. During the site visit, walkers, farmers, mountain bikers and the police were all observed using the tracks. Tracks of motor cross bikes and a burnt out car were also observed (Photograph A8). These increases, especially in motor cross bikes, has compacted the peat, created runoff pathways and generated significant areas of bare ground. The bike tracks typically take a parallel line to the existing track or cut corners at junctions and bends in the track. In these areas it has enhanced the spread of the non-native moss Campylopus introflexus.

A.2.3.3.6 Landscaping surrounding roads

Over a large proportion of the site's roads, soils from excavations were deposited along the side and landscaped (Photographs A8 and A9). This was an example of bad practice which increased the ecology, hydrology and visual impact of the development. There are several reasons for this:

- Spreading soil next to the roads increased the area of disturbance from potential 5 m (the width of the road) to an average of 20 m; dramatically increasing the visual impact of the roads.
- The soil deposited often was not similar to the soil it was place on (Photograph A10). For example mineral soils and rock material was contained within soils place down on areas of blanket bog. Blanket bog plants would find colonising much of this soil difficult due to the soil type but also the lack of a seed bank within the surrounding moor.
- It appears that in some cases the soil has been placed on top of vegetation which was intact and so killed off the established vegetation unnecessarily.
- The bare peat along the margins of the tracks and around the turbines have been seeded with a grass-seed mix which appears to be a mixture of brown bent (Agrostis vinealis) and sheep's fescue (Festuca ovina). This has largely failed, leaving large areas of bare disturbed fragile peat exposed and prone to erosion. This could be due to sheep grazing, erosion of seedlings from the peat on the steeper batters, erosion of seeds and soil chemical properties, especially low pH. Some of the grasses have established where there is some mineral component in the peat in certain locations, but the lack of fencing around the re-seeded areas is a significant factor in the lack of establishment of the grasses.

A.2.3.4 Overall Impacts

Working on blanket peat poses technical problems as once disturbed the peat losses its strength. At Scout Moor, this has led to the zones of direct disturbance being greater than would be found on equivalent mineral soil sites. The areas for foundation excavation are large and easily eroded peat material has been placed by the sides of roads. Despite this, the impacts of the wind farm has being relatively small. The degraded state of the bog, pre development, reduced the sensitivity of the blanket bog to further degradation. The blanket bog consists of low permeability, hydraulically isolated units and this reduces the zones of influence of drainage, roads and other development features. This means that the hydrogeological, hydrological and ecological impacts appear to be constrained to within a small distance of the development footprint.

A.2.3.5 Carbon Assessment

A.2.3.5.1 Carbon Assessment of Case Studies

Scout Moor is constructed on blanket bogs. An assessment using Nayak et al. (2008) carbon losses and gain calculator was conducted for this site. The calculator determines potential carbon (C) losses and savings associated with wind farm developments on peat land, taking into account peat removal, drainage habitat improvement and site restoration. The calculator requires the following information:

- Number of turbines, foundation and hard standing dimensions, turbine capacity and assumptions about efficiency;
- Drainage of turbine bases;

- Forestry felling areas;
- Borrow pits in peat areas;
- Road type and drainage;
- Cable lengths (if not alongside roads);
- Proposed restoration following construction and following decommissioning;
- Air temperature;
- Peat depth;
- Water level;
- The extent of water table lowering around drainage features;
- Soil pH.

The input sheets of the calculator for both the sites are present later in appendix A.2. Using these inputs the calculator quantifies the carbon losses and gains of a wind farm development. There are a number of mechanisms which require quantification:

- The reduction in the bog plants' ability to fix C from the atmosphere due to the degradation of their habitat.
- Wind farms damage to the storage capacity of the peat:
  - Through excavation and the building of structures on site.
  - By increasing drainage on site, groundwater levels are lowered creating aerobic conditions in the peat, increasing oxidation and so allowing more CO_2 to be released.
  - By increased leaching of particulate and dissolved organic carbon from peat as it is drained; this freed C is then able to enter the atmosphere.
- Other carbon losses and gains:
  - Deforestation often occurs during the development of wind farms.
  - Developments can also result in carbon storage by peatland restoration: improving the peat's ability to capture and store C. If restoration occurs at the end of a wind farm's lifespan, it can mean that there are no further losses of C from peatland degradation at the site.
- The amount of carbon saved by avoiding the use of fossil fuel power stations.
- The carbon required to construct and build the wind farm.

By quantify the changes in carbon fluxes of all these mechanisms, the calculator calculates: the amount of carbon saved by avoiding using fossil fuel power stations; losses of carbon from the wind farm; and the amount of carbon gained through site and blanket bog improvements. This is used to calculate the 'payback' time of the wind farm development before the carbon losses due to its construction and the damage to the peat is off-set.

The payback time has been calculated at between 8 and 17 months with a net emission of carbon dioxide of 114490 tonnes. 43% of the emissions are estimated to have resulted from disturbing and damaging the blanket bog. The main contributor to the 43% is 'losses from soil organic matter': this is the result of the excavation areas being large due to slumping.

The assumptions and records of where the information for inputting to the carbon calculator (Nayak et al. 2008) was obtained is recorded within the input data sheet (see below).

This carbon assessment has not taken into account Scout Moor Wind Farm Ltd Habitat Enhancement Plan which will provide £400,000 for re-wetting blanket bog and improving other upland habitats (www.scoutmoorwindfarm.co.uk). Such schemes have the potential to off set a large proportion of the carbon losses of the site.

A.2.4 Carbon Assessment – Scout Moor

Full Carbon Calculator for Wind Farms on Peatlands - Version 1

This spreadsheet calculates payback time for windfarm sited on peatlands using methods given in Nayak et al, 2008 (final report)

INSTRUCTIONS

A There are 15 worksheets :

Input data

Payback time

1. Windfarm CO_2 emission saving
2. CO_2 loss due to turbine life
3. CO_2 loss due to backup
4. Loss of CO_2 Fixing Pot.
5. Loss of soil CO_2
   - 5a. Volume of peat removed
   - 5b. CO_2 loss from removed peat
   - 5c. Volume of peat drained
   - 5d. CO_2 loss from drained peat
   - 5e. Emission rates
6. CO_2 loss by DOC & POC loss
7. CO_2 loss - felling forestry
8. CO_2 gain - site improvement

B Enter information into the pink-shaded cells in the worksheet "Input data"

C View payback time shown in the yellow-shaded cells in the worksheet "Payback time"

D Intermediate stages in the calculations are shown in numbered worksheets 1 to 8

E Notes on calculations are given in pale green text boxes.

Assumptions are shown in pale blue text boxes.

19/06/2008

Note: The input parameters include some variables that can be specified by default values, but others that must be site specific. Variables that can be taken from defaults are marked with purple tags on left hand side.

Input data	Enter your values here	Record comments or assumptions here	Uncertainties Min	Uncertainties Max
Wind farm characteristics				
Dimensions				
No. of turbines	26			
Life time of wind farm (years)	25			
Performance				
Turbine capacity (MW)	2.5		20	30
Capacity factor (percentage efficiency)	34	Peel pers. Comm.	27	34
Backup				
Extra capacity required for backup (%)	5			
Additional emissions due to reduced thermal efficiency of the reserve generation (%)	10			
Carbon dioxide emissions from turbine life - (eg. manufacture, construction, decommissioning)	2 Calculate wrt installed capacity			
Total CO_2 emission from turbine life (tCO_2 wind farm^{-1}) *(if known use direct input of emissions from turbine life)*				
Characteristics of peatland before wind farm development				
Type of peatland	1 Acid bog			
Average air temperature at site (^oC)	7	Met Office Choropleth Map		
Average depth of peat at site (m)	1.26	Estimate from data in Supplementary ES		
C Content of dry peat (% by weight)	55	From MLURI (1991)		
Average extent of drainage around drainage features at site (m)	5	Field observations		
Average water table depth at site (m)	0.30	Estimate from field observations		

Note: Capacity factor. The average capacity factor between 1998 and 2004 for Scotland was 30% (DTI, 2006, Energy Trends, March 2006). We recommend that a site-specific capacity factor site should be used (as measured during planning stage). However, if this is unknown, the best (34%) and worst case capacity factors for Scotland (27%) should be used to determine the likely range of the results.

Note: Extra capaticity required for backup. If 20% of national electricity is generated by wind energy, the extra capacity required for backup is 5% of the rated capacity of the wind plant (Dale et al 2004, Energy Policy, 32, 1949-56). We suggest this should be 5% of the actual output. If it is assumed that less than 20% of national electricity is generated by wind energy, a lower percentage should be entered (0%).

Note: Extra emissions due to reduced thermal efficiency of the reserve power generation ≈ 10% (Dale et al 2004, Energy Policy, 32, 1949-56)

Note: Emissions from turbine life. Note, if total emissions for the windfarm are unknown, emissions will be calculated according to turbine capacity. The normal range of CO_2 emissions is 394 to 8147 t CO_2 MW (White & Kulcinski, 2000. Fusion Eng. Des. 48, 473-48; White, 2007, Natural Resources Research. 15, 271 - 281.)

Note: A fen is a type of wetland fed by surface and/or groundwater. A bog is fed primarily by rainwater and often inhabited by sphagnum moss, making it acidic.

Dry soil bulk density (g cm^{-3})	0.10			
Average soil pH	4.9	May be higher due to degraded state		
Characteristics of bog plants				
Time required for regeneration of bog plants after restoration (years)	7.5	A Headley estimate		
Carbon accumulation due to C fixation by bog plants in undrained peats (tC ha^{-1} yr^{-1})	0.25		0.12	0.31
Forestry Plantation Characteristics				
Area of forestry plantation to be felled (ha)	0	Area deforested in the Bronze Age		
Average rate of carbon sequesteration in timber (tC ha^{-1} yr^{-1})	3.60			
Counterfactual emission factors				
Coal-fired plant emission factor (t CO_2 MWh^{-1})	0.86			
Grid-mix emission factor (t CO_2 MWh^{-1})	0.43			
Fossil fuel- mix emission factor (t CO_2 MWh^{-1})	0.607			
Borrow pits				
Number of borrow pits	0	Scout Moor Quarry Used		
Average length of pits (m)	0			
Average width of pits (m)	0			
Average depth of peat removed from pit (m)	0.00			
Wind turbine foundations				
Average length of turbine foundations (m)	35	Area of foundation works large due to peat collapses		
Average width of turbine foundations(m)	35			
Average depth of peat removed from turbine foundations(m)	1.2			
Hard-standing area associated with each turbine				
Average length of hard-standing (m)	35	Field measurements		
Average width of hard-standing (m)	20			
Average depth of peat removed from hard-standing (m)	1.2			

Note: Time required for regeneration of previous habitat. It is suggested that loss of fixation should be assumed to be over lifetime of windfarm only.
This time could longer if plants do not regenerate. The requirements for after-use planning include the provision of suitable refugia for peat forming vegetation, the removal of structures, or an assessment of the impact of leaving them in situ. Methods used to reinstatement the site will affect to likely time for regeneration of the previous habitat.
This time could also be shorter if plants regenerate during lifetime of windfarm. If so, enter number of years estimated for regeneration.

Note: Carbon fixation by bog plants. Apparent C accumulation rate in peatland is 0.12 to 0.31 tC ha^{-1} yr^{-1} (Turunen et al., 2001, Global Biogeochemical Cycles, 15, 285-296; Botch et al., 1995, Global Biogeochemical Cycles, 9, 37-46). The SNH guidance uses a value of 0.25 tC ha^{-1} yr^{-1}.

Note: Area of forestry plantation to be felled. If the forestry was planned to be removed, with no further rotations planted, before the wind farm development, the area to be felled should be entered as zero.

Note: Plantation carbon sequestration. This is dependent on the yield class of the forestry. The SNH technical guidance assumed yield class of 16 m^3 ha^{-1} y^{-1}, compared to the value of 14 m^3 ha^{-1} y^{-1} provided by the Forestry Commission. Carbon sequestered for yield class 16 m^3 ha^{-1} y^{-1} = 3.6 tC ha^{-1} yr^{-1} (Cannell, 1999, Forestry, 72, 238-247)

Note: Coal-Fired Plant and Grid Mix Emission Factors. Coal-fired plant EF = 0.86 t CO_2 MWh^{-1}. Grid-Mix EF = 0.43 t CO_2 MWh^{-1}. Source = DEFRA, 2002. Guidelines for the measurement and reporting of emissions by Direct Participants in UK Emissions Trading Scheme (DEFRA,Oct 2002)

Note: Fossil Fuel Mix Emission Factor. The 5 year average emission factor calculated using estimated CO2 emissions for 2002 and 2003 from the National Atmospheric Emission Inventory (Baggott et al, 2007, http://www.naei.org.uk/reports.php. Report AEAT/ENV/R/2429 13/04/2007) and for 2004 to 2006 (Digest of UK Energy Statistics ,2007, http://www.berr.gov.uk/energy/statistics/source/electricity/page18527.html) is 0.607 tCO_2 MWh^{-1}

Access tracks				
Total length of access track (m)	12800	From ES		
Existing track length (m)	0			
<u>Length of access track that is floating road (m)</u>	7200	Road length on peat over 0.6m (Supplementary ES)		
Floating road width (m)	6.5			
Floating road depth (m)	0.6			
Length of floating road that is drained (m)	2190	30% - Estimate from field observations		
Average depth of drains associated with floating roads (m)	0.3			
<u>Length of access track that is excavated road (m)</u>	5600	Road length on peat under 0.6m (Supplementary ES)		
Excavated road width (m)	5			
Excavated road depth (m)	0.4			
<u>Length of access track that is rock filled road (m)</u>	0			
Rock-filled road width (m)	0			
Rock-filled road depth (m)	0			
Length of rock-filled road that is drained (m)	0			
Average depth of drains associated with rock-filled roads (m)	0			
Cable Trenches				
Length of any cable trench that does not follow access tracks and is lined with a permeable medium (eg. sand) (m)	1600			
Depth of cable trench (m)	2.0			
Peat Landslide Hazard				
Weblink: Peat Landslide Hazard and Risk Assessments: Best Practice Guide for Proposed Electricity Generation Developments	0			
Improvement of C sequestration at site by blocking drains, restoration of habitat etc				
<u>Improvement of degraded bog</u>				
Area of degraded bog to be improved (ha)	0			
Water table depth in degraded bog before improvement (m)	2.00			
Water table depth in degraded bog after improvement (m)	0.00			

Note: <u>Total length of access track</u>. If areas of access track overlap with hardstanding area, exclude these from the total length of access track to avoid double counting of land area lost.

Note: <u>Rock filled roads.</u> Rock filled roads are assumed to be roads where no peat has been removed and rock has been placed on the surface and allowed to settle.

Note: <u>Peat Landslide Hazard</u>. It is assumed that measures have been taken to may limit damage (Scottish Executive, 2006, Peat Landslide Hazard and Risk Assessments. Best Practice Guide for Proposed Electricity Generation Developments. Scottish Executive, Edinburgh. pp. 34-35) so that C losses due to peat landslide can be assumed to be negligible. Link: http://www.scotland.gov.uk/Publications/2006/12/21162303/1

Time required for hydrology and habitat of bog to return to its previous state on improvement (years)	10			
<u>Improvement of felled plantation land</u>				
Area of felled plantation to be improved (ha)	0			
Water table depth in felled area before improvement (m)	2.00			
Water table depth in felled area after improvement (m)	0.00			
Time required for hydrology and habitat of felled plantation to return to its previous state on improvement (years)	10			
<u>Restoration of peat removed from borrow pits</u>				
Area of borrow pits to be restored (ha)	0			
Water table depth in borrow pit after restoration (m)	0.00			
Time required for hydrology and habitat of borrow pit to return to its previous state on restoration (years)	10			
<u>Removal of drainage from foundations and hardstanding</u>				
Water table depth around foundations and hardstanding after restoration (m)	0.3			
Time to completion of backfilling, removal of any surface drains, and full restoration of the hydrology (years)	25			
Restoration of site after decomissioning				
Will the hydrology of the site be restored on decommissioning?	1 No	Difficulties presented by common land		
Will the habitat of the site be restored on decommissioning?	1 No	Difficulties presented by common land		

Note: <u>Restoration of site</u>. If the water table at the site is returned to its original level or higher on decomissioning, and habitat at the site is restored, it is assumed that C losses continue only over the lifetime of the windfarm. Otherwise, C losses from drained peat are assumed to be 100%

Choice of methodology for calculating emission factors	2	Site specific

Note: <u>Choice of methodology for calculating emission factors</u>. The IPPC default methodology is the internationally accepted standard (IPCC, 1997, Revised 1996 IPCC guidelines for national greenhouse gas inventories, Vol 3, table 5-13). However, it is stated in IPCC (1997) that these are rough estimates, and "these rates and production periods can be used if countries do not have more appropriate estimates". Therefore, we have developed more site specific estimates for use here based on work from the SEERAD funded ECOSSE project (Smith et al, 2007. ECOSSE: Estimating Carbon in Organic Soils - Sequestration and Emissions. Final Report. SEERAD Report. ISBN 978 0 7559 1498 2. 166pp.)

Note: The carbon payback time of the wind farm is calculated by comparing the loss of C from the site due to windfarm development with the carbon-savings achieved by the windfarm while displacing electricity generated from coal-fired capacity or Grid-mix.

1. Wind farm CO_2 emission saving

	Carbon dioxide saving ($tCO_2\ yr^{-1}$)
…coal-fired electricity generation	166493
…grid-mix of electricity generation	83246
…fossil fuel-mix of electricity generation	117513

Total CO_2 losses due to wind farm

	Carbon dioxide losses (t $CO_{2\ eq.}$)			Payback time (months)		
	…coal-fired electricity generation	…grid-mix of electricity generation	…fossil fuel-mix of electricity generation	…coal-fired electricity generation	…grid-mix of electricity generation	…fossil fuel-mix of electricity generation
2. Losses due to turbine life (eg. manufacture, construction, decomissioning)	22178	22178	22178	1.6	3.2	2.3
3. Losses due to backup	43203	43203	43203	3.1	6.2	4.4
4. Losses due to reduced carbon fixing potential	870	870	870	0.1	0.1	0.1
5. Losses from soil organic matter	40927	40927	40927	2.9	5.9	4.2
6. Losses due to DOC & POC leaching	7311	7311	7311	0.5	1.1	0.7
7. Losses due to felling forestry	0	0	0	0.0	0.0	0.0
Total losses of carbon dioxide	114490	114490	114490	8.3	16.5	11.7

Total CO_2 gains due to improvement of site

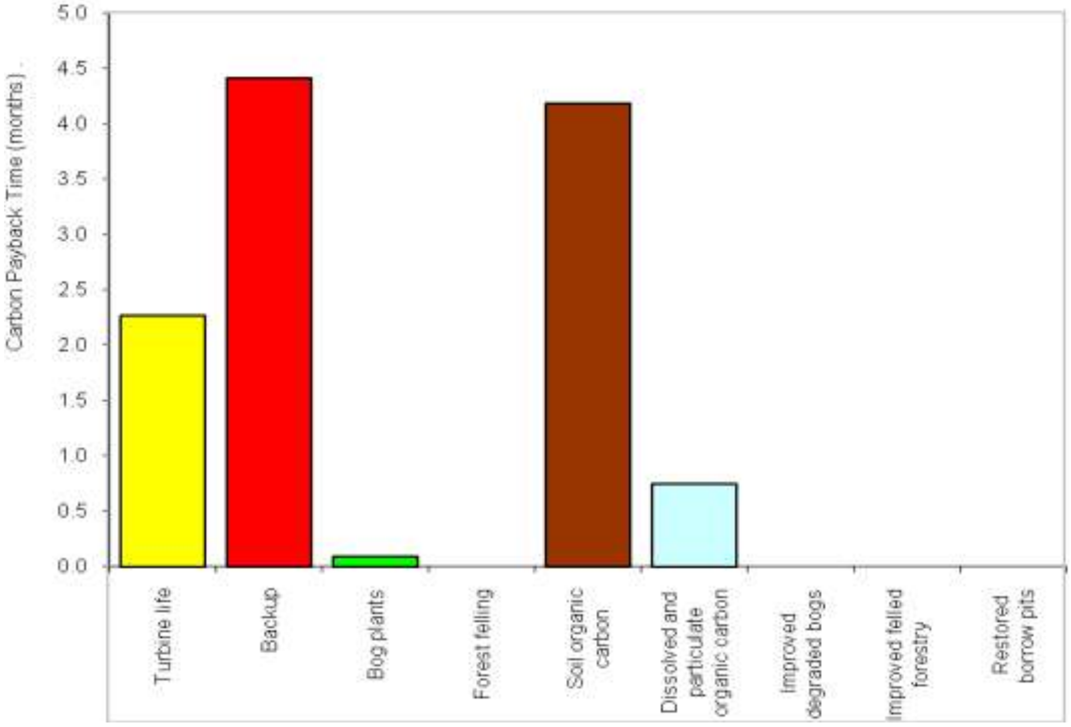
	Carbon dioxide gains ($tCO_{2\ eq.}$)	Reduction in payback time (months)		
		…coal-fired electricity generation	…grid-mix of electricity generation	…fossil fuel-mix of electricity generation
8. Gains due to improvement of degraded bogs	0	0.0	0.0	0.0
8. Gains due to improvement of felled forestry	0	0.0	0.0	0.0
8. Gains due to restoration of peat from borrow pits	0	0.0	0.0	0.0
8. Gains due to removal of drainage from foundations & hardstanding	0	0.0	0.0	0.0
Total gains	0	0.0	0.0	0.0

Net emissions of carbon dioxide ($t\ CO_{2\ eq.}$)	114490

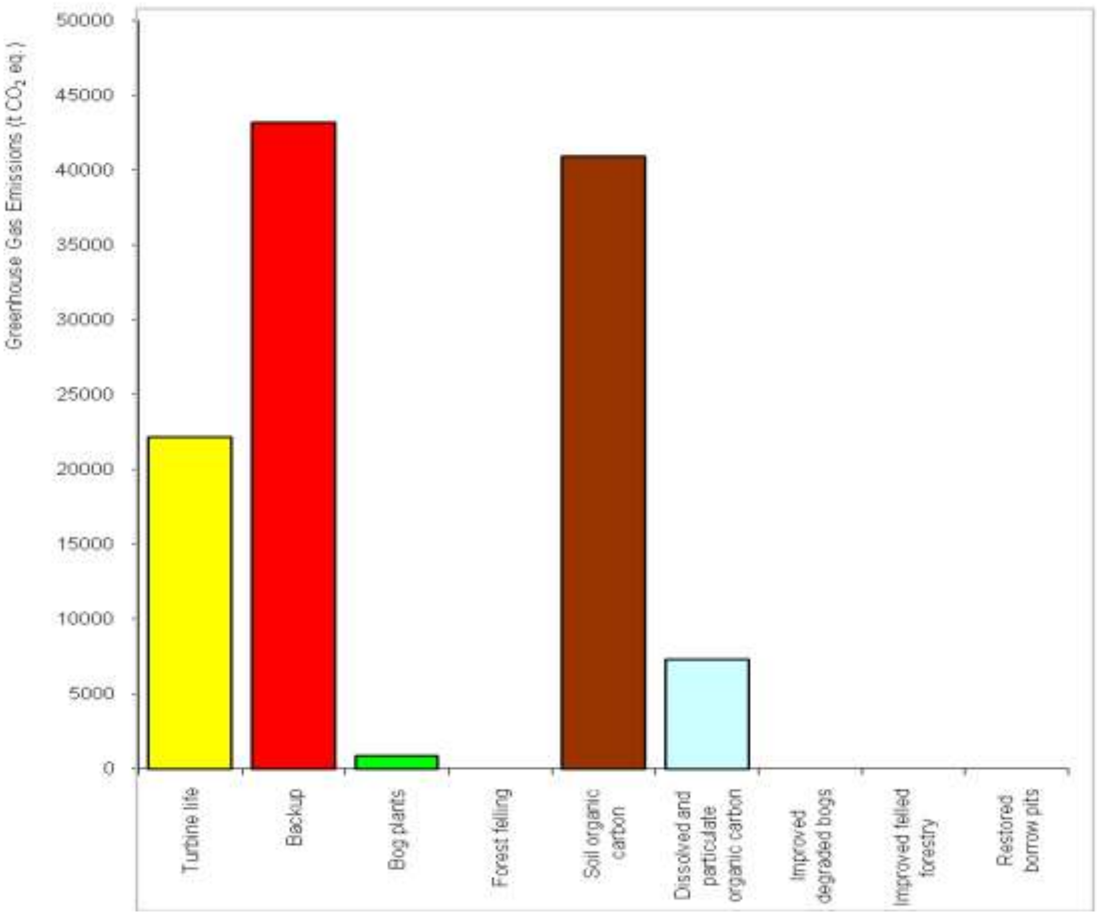
Payback time

	Total payback time of windfarm (yr)	**Total payback time of windfarm (months)**
Coal-fired	**0.7**	**8**
Grid-mix	**1.4**	**17**
Fossil fuel-mix	**1.0**	**12**

Carbon Payback Time using Fossil Fuel Mix as the Counterfactural



Greenhouse Gas Emissions associated with Wind Farm Development



Note: The total emission savings are given by estimating the total possible electrical output of the windfarm multiplied by the emission factor for the counterfactual case (coal-fire generation and electricity from grid)

Power Generation Characteristics	
No. of turbines	26
Turbine capacity (MW)	2.5
Power of wind farm (MW)	65
Capacity factor (percentage efficiency)	34
Annual energy output from wind farm (MWh yr^{-1})	193596

Counterfactual emission factors	
Coal-fired plant emission factor (t CO_2 MWh^{-1})	0.86
Grid-mix emission factor (t CO_2 MWh^{-1})	0.43
Fossil fuel- mix emission factor (t CO2 MWh^{-1})	0.607

Wind farm CO_2 emission saving over…	**Carbon Dioxide Saving (tCO_2 yr^{-1})**
…coal-fired electricity generation	**166493**
…grid-mix of electricity generation	**83246**
…fossil fuel - mix of electricity generation	**117513**

Note: The carbon payback time of the wind farm due to turbine life (eg. manufacture, construction, decomissioning) is calculated by comparing the emissions due to turbine life with carbon-savings achieved by the windfwrm while displacing electricity generated from coal-fired capacity or grid-mix.

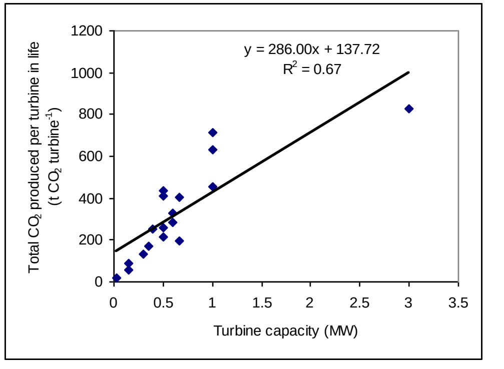
Method used to estimate CO_2 emissions from turbine life (eg. manufacture, construction, decommissioning)?	Calculate wrt installed capacity

Direct input of emissions due to turbine life (t CO_2 wind farm^{-1})	0

Calculation of emissions due to turbine life from energy output	
CO_2 emissions due to turbine life (tCO_2 turbine^{-1})	853
No. of turbines	26
Total calculated CO_2 emission of the wind farm due to turbine life (t CO_2 wind farm^{-1})	22178

Selected value for emissions due to turbine life (t CO_2 wind farm^{-1})	22178

Wind farm CO_2 emission saving over…	**Carbon Dioxide Saving (tCO_2 yr^{-1})**
…coal-fired electricity generation	166493
…grid-mix of electricity generation	83246
…fossil fuel - mix of electricity generation	117513



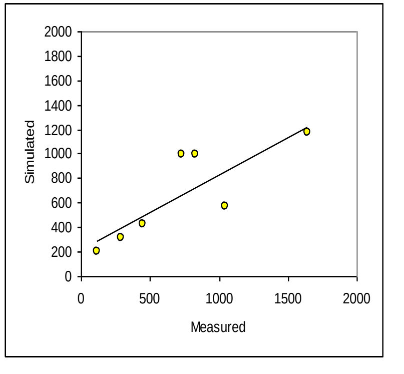
Derivation of equation from 18 European sites

Defensible figures for the specific wind farm should be used wherever possible, but if these are unavailable, carbon dioxide emissions due to the turbine life, L_{life} (t), can be estimated from the turbine capacity, c_{turb} (MW), using the following equation. This equation was derived using data from 18 European sites with a highly significant fit (P>0.95).

$$L_{life} = 138 + (286 \times c_{turb}).$$

Evaluation against independent data indicates that using this equation instead of site specific measurements will introduce an average error in estimated carbon dioxide emissions of 39%. However, the uncertainty in estimated carbon payback time introduced by this error is small and decreases with turbine capacity: uncertainty is less than 6 months for a turbine capacity under 0.5 MW; less than 1.5 months for a turbine capacity between 0.5 and 1 MW, and approximately 1 month for a turbine capacity over 1 MW. Note that inclusion of a life cycle figure for wind farms would ideally require that equivalent life cycle costs for conventional power sources are included in the carbon emission savings figure. However, in the absence of comparative figures for coal and gas generating plants, it should be noted that this is an over-estimate of the life cycle costs of a wind farm. A comprehensive life cycle assessment of a modern UK wind farm would provide more robust figures.

Evaluation of equation against independent data



Additional CO_2 payback time of wind farm due to turbine life (eg. manufacture, contruction, decomissioning)	**Additional payback time (yr)**	**Additional payback time (months)**
Coal-fired electricity generation	**0.13**	**1.6**
Grid-mix of electricity generation	0.27	3.2
Fossil fuel - mix of electricity generation	**0.19**	**2.3**

Uncertainty due to estimated CO2 emissions due to turbine life	39%	0.9

Note: CO2 loss due to back up is calculated from the extra capacity required for backup of the wind farm given in the input data.

Reserve capacity required for backup	
No. of turbines	26
Turbine capacity (MW)	2.5
Power of wind farm (MW h^{-1})	65
Rated capacity (MW yr-1)	569400
Extra capacity required for backup (%)	5
Additional emissions due to reduced thermal efficiency of the reserve generation (%)	10
Reserve capacity (MWh yr^{-1})	2847

Carbon dioxide emissions due to backup power generation	
Coal-fired plant emission factor (t CO_2 MWh^{-1})	0.86
Grid-mix emission factor (t CO_2 MWh^{-1})	0.43
Fossil fuel- mix emission factor (t CO_2 MWh^{-1})	0.607
Life time of wind farm (years)	25
Annual emissions due to backup from…	
…coal-fired electricity generation	2448.42
…grid-mix of electricity generation	1224.21
…fossil fuel - mix of electricity generation	1728.129
Total emissions due to backup from…	
…coal-fired electricity generation	61211
…grid-mix of electricity generation	30605
…fossil fuel - mix of electricity generation	43203

Assumption: Backup assumed to be by fossil-fuel-mix of electricity generation. Note that hydroelectricity may also be used for backup, so this assumption may make the value for backup generation too high. These assumptions should be revisited as technology develops.

Wind farm CO_2 emission saving over…	Carbon Dioxide Saving (tCO_2 yr^{-1})
…coal-fired electricity generation	166493
…grid-mix of electricity generation	83246
…fossil fuel - mix of electricity generation	117513

Additional CO_2 payback time of wind farm due to backup	Additional payback time (yr)	Additional payback time (months)
Coal-fired electricity generation	**0.26**	**3.1**
Grid-mix of electricity generation	0.52	6.2
Fossil fuel-mix of electricity generation	**0.37**	**4.4**

Note: Annual C fixation by the site is calculated by multiplying area of the wind farm by the annual C accumulation due to bog plant fixation

Area where carbon accumulation by bog plants is lost	
Total area of land lost due to wind farm construction (m^2)	124850
Total area affected by drainage due to wind farm construction (m^{-2})	167235
Total area where fixation by plants is lost (m^2)	292085

Assumptions:
1. Bog plants are 100% lost from the area where peat is removed for construction.
2. Bog plants are 100% lost from the area where peat is drained.
3. The recovery of carbon accumulation by plants on restoration of land is as given in inputs

Total loss of carbon accumulation	
Carbon accumulation in undrained peats (tC ha^{-1} yr^{-1})	0.25
Life time of wind farm (years)	25
Time required for regeneration of bog plants after restoration (years)	8
Carbon accumulation up to time of restoration (tCO_2 eq. ha^{-1})	30

Total loss of carbon accumulation by bog plants	
Total area where fixation by plants is lost (ha)	29
Carbon accumulation over lifetime of wind farm (tCO_2 eq. ha^{-1})	30
Total loss of carbon fixation by plants at the site (t CO_2)	**870**

Windfarm CO_2 emission saving over…	Carbon Dioxide Saving (tCO_2 yr^{-1})
…coal-fired electricity generation	166493
…grid-mix of electricity generation	83246
…fossil fuel - mix of electricity generation	117513

Additional CO_2 payback time of windfarm due to loss of CO_2 fixation	**Additional payback time (years)**	**Additional payback time (months)**
Coal-fired electricity generation	**0.005**	**0.1**
Grid-mix of electricity generation	0.010	0.1
Fossil fuel - mix of electricity generation	**0.007**	**0.1**

Note: Loss of C stored in peatland is estimated from % site lost by peat removal (sheet 5a), CO_2 loss from removed peat (sheet 5b), % site affected by drainage (sheet 5c), and the CO2 loss from drained peat (sheet 5d).

CO_2 loss due to wind farm construction	
CO_2 loss from removed peat (t CO_2 equiv)	20338
CO_2 loss from drained peat (t CO_2 equiv)	20589
Total CO_2 loss from peat (removed+ drained) (t CO_2 equiv)	**40927**

Note: % site lost by peat removal is estimated from peat removed in borrow pits, turbine foundations, hard-standing and access tracks. If peat is removed for any other reason, this must be added in to the volume of peat removed, area of land lost and % site lost at the bottom of this worksheet.

Peat removed from borrow pits	
Number of borrow pits	0
Average length of pits (m)	0
Average width of pits (m)	0
Average depth of peat removed from pit (m)	0
Area of land lost in borrow pits (m^2)	0
Volume of peat removed from borrow pits (m^3)	0
Peat removed from turbine foundations	
No. of turbines	26
Average length of turbine foundations (m)	35
Average width of turbine foundations(m)	35
Average depth of peat removed from turbine foundations(m)	1.23
Area of land lost in foundations (m^2)	31850
Volume of peat removed from foundation area (m^3)	39175.5
Peat removed from hard-standing	
No. of turbines	26
Average length of hard-standing (m)	35
Average width of hard-standing (m)	20
Average depth of peat removed from hard-standing (m)	1.23
Area of land lost in hard-standing (m^2)	18200
Volume of peat removed from hardstandingarea (m^3)	22386
Peat removed from access tracks	
Floating roads	
Length of access track that is floating road (m)	7200
Floating road width (m)	6.5
Floating road depth (m)	0.6
Area of land lost in floating roads (m^2)	46800
Volume of peat removed for floating roads	28080
Excavated roads	
Length of access track that is excavated road (m)	5600
Excavated road width (m)	5
Excavated road depth (m)	0.4
Area of land lost in excavated roads (m^2)	28000
Volume of peat removed for excavated roads	11200
Rock-filled roads	
Length of access track that is rock filled road (m)	0
Rock-filled road width (m)	0
Rock-filled road depth (m)	0
Area of land lost in excavated roads (m^2)	0
Volume of peat removed for rock-filled roads	0
Total area of land lost in access tracks (m^2)	74800
Total volume of peat removed due to access tracks (m^3)	39280
Total volume of peat removed (m^3) due to wind farm construction	**100841.5**
Total area of land lost due to wind farm construction (m^2)	**124850**

Note: If peat is treated in such a way that it is permanently restored, so that less than 100% of the C is lost to the atmosphere, a lower percentage can be entered in cell C10

CO_2 loss from removed peat	
C Content of dry peat (% by weight)	55
Dry soil bulk density (g cm^{-3})	0.10
% C contained in removed peat that is lost as CO_2	100
Total volume of peat removed (m^3) due to wind farm construction	100841.5
CO_2 loss from removed peat (t CO_2)	20338

Assumption: If peat is not restored, 100% of the carbon contained in the removed peat is lost as CO_2

CO_2 loss from undrained peat left in situ	
Total area of land lost due to wind farm construction (ha)	12
CO_2 loss from undrained peat left in situ (t CO_2 ha^{-1})	246
CO_2 loss from undrained peat left in situ (t CO_2)	3077

CO_2 loss attributable to peat removal only	
CO_2 loss from removed peat (t CO_2)	20338
CO_2 loss from undrained peat left in situ (t CO_2)	3077
CO_2 loss attributable to peat removal only (t CO_2)	**17261**

Wind farm CO_2 emission saving over…	Carbon Dioxide Saving (tCO_2 yr^{-1})
…coal-fired electricity generation	166493
…grid-mix of electricity generation	83246
…fossil fuel - mix of electricity generation	117513

Additional CO_2 payback time of wind farm due to removal of peat during construction	**Additional payback time (years)**	**Additional payback time (months)**
Coal-fired electricity generation	**0.12**	**1.5**
Grid-mix of electricity generation	0.24	2.9
Fossil fuel - mix of electricity generation	**0.17**	**2.1**

Note: Extent of site affected by drainage is calculated assuming an average extent of drainage around each drainage feature as given in the input data.

Extent of drainage around each metre of drainage ditch	
Average extent of drainage around drainage features at site (m)	5

Peat affected by drainage around borrow pits	
Number of borrow pits	0
Average length of pits (m)	0
Average width of pits (m)	0
Average depth of peat removed from pit (m)	0.0
Area affected by drainage per borrow pit	100
Total area affected by drainage around borrowpits (m^2)	0
Total volume affected by drainage around borrowpits (m^3)	0

Note: Borrow pit area itself not counted in drained area because C losses have already been accounted for in removed peat

Assumption: Depth peat affected due of drainage is equal to the depth of peat removed

Peat affected by drainage around turbine foundation and hardstanding	
No. of turbines	26
Average length of turbine foundations (m)	35
Average width of turbine foundations(m)	35
Average depth of peat removed from turbine foundations(m)	1
Average length of hard-standing (m)	35
Average width of hard-standing (m)	20
Average depth of peat removed from hard-standing (m)	1.2
Total length of foundation and hardstaning area (m)	70
Total width of foundation and hardstanding area (m)	55
Area affected by drainage of foundation and hardstanding area (m^2)	1350
Total area affected by drainage of foundation and hardstanding area (m^2)	35100
Total volume affected by drainage of foundation and hardstanding area (m^3)	43173

Note: Hardstanding and turbine foundations. These are counted together to avoid double counting of edges. If hardstanding is sited away from turbine foundations, additional drainage should be included.
Hardstanding and turbine foundation area itself not counted in drained area because C losses have already been accounted for in removed peat

Peat affected by drainage of access tracks	
Floating roads	
Length of floating road that is drained (m)	2190
Floating road width (m)	6.5
Average depth of drains associated with floating roads (m)	0.30
Area affected by drainage of floating roads (m^2)	36135
Volume affected by drainage of floating roads (m^3)	10841
Excavated Road	
Length of access track that is excavated road (m)	5600
Excavated road width (m)	5
Excavated road depth (m)	0.4
Area affected by drainage of excavated roads (m^2)	56000
Volume affected by drainage of excavated roads (m^3)	22400
Rock-filled roads	
Length of rock-filled road that is drained (m)	0
Rock-filled road width (m)	0
Average depth of drains associated with rock-filled roads (m)	0.0
Area affected by drainage of rock-filled roads (m^2)	0
Volume affected by drainage of rock-filled roads (m^2)	0
Total area affected by drainage of access track (m^2)	92135
Total volume affected by drainage of access track (m^3)	33241

Assumption: Peat under floating road is also drained when drains are installed

Assumption: Depth peat affected due of drainage is equal to the depth of peat removed

Note: Road area itself not counted in drained because C losses have already been accounted for in removed peat

Assumption: Depth peat affected due of drainage is equal to the depth of peat removed

Assumption: Peat under rock-filled road is compacted and looses water, but remains anaerobic. Therefore, the area of the rock-filled road iteself is not included in the drained area.

Assumption: Depth peat affected due of drainage is equal to the depth of peat removed

Peat affected by drainage of cable trenches	
Length of any cable trench that does not follow access tracks and is lined with a permeable medium (eg. sand) (m)	1600
Depth of cable trench (m)	2.0
Total area affected by drainage of cable trenches (m^2)	40000
Total volume affected by drainage of cable trenches (m^3)	80000.00

Total area affected by drainage due to wind farm (m^2)	**167235**
Total volume affected by drainage due to wind farm (m^3)	**156414**

Note: Note, CO_2 losses are calculated using two approaches: IPCC default methodology and more site specific equations derived for this project. The IPCC methodology is included because it is the established approach, although it contains no site detail. The new equations have been derived directly from experimental data for acid bogs and fens (see Nayak et al, 2008 - Final report).

Drained Land	
Total area affected by drainage due to wind farm construction (ha)	17
Will the hydrology of the site be restored on decommissioning?	No
Will the habitat of the site be restored on decommissioning?	No

Calculations of C Loss from Drained Land if Site is NOT Restored after Decommissioning

Total volume affected by drainage due to wind farm (m^3)	156414
C Content of dry peat (% by weight)	55
Dry soil bulk density (g cm^{-3})	0.10
Total GHG emissions from Drained Land (t CO_2 equiv.)	31546
Total GHG Emissions from Undrained Land (t CO_2 equiv.)	10957

Assumption: Losses of GHG from drained and undrained land have the same proportion throughout the emission period.

Calculations of C loss from Drained Land if Site IS Restored after Decommissioning

1. Losses if Land is Drained

Flooded period (days $year^{-1}$)	0
Life time of wind farm (years)	25
Time required for regeneration of bog plants after restoration (years)	7.5
Methane Emissions from Drained Land	
Annual rate of methane emission (t CH_4-C ha^{-1} yr^{-1})	-0.81
Conversion factor: CH_4-C to CO_2 equivalents	30.67
CH_4 emissions from drained land (t CO_2 equiv.)	0
Carbon Dioxide Emissions from Drained Land	
Annual rate of carbon dioxide emission (t CO_2 ha^{-1} yr^{-1})	21.8
CO_2 emissions from drained land (t CO_2)	11865
Total GHG emissions from Drained Land (t CO_2 equiv.)	11865

Assumption: The drained soil is not flooded at any time of the year.

Note:Conversion = (23 x 16/12) = 30.67 CO_2 equiv. $(CH_4\text{-C})^{-1}$

2. Losses if Land is Undrained

Flooded period (days $year^{-1}$)	178
Life time of wind farm (years)	25
Time required for regeneration of bog plants after restoration (years)	7.5
Methane Emissions from Undrained Land	
Annual rate of methane emission (t CH_4-C ha^{-1} yr^{-1})	0.14
Conversion factor: CH_4-C to CO_2 equivalents	30.67
CH_4 emissions from undrained land (t CO_2 equiv.)	1162
Carbon Dioxide Emissions from Undrained Land	
Annual rate of carbon dioxide emission (t CO_2 ha^{-1} yr^{-1})	10.6
CO_2 emissions from undrained land (t CO_2)	2959
Total GHG Emissions from Undrained Land (t CO_2 equiv.)	4121

Note:Conversion = (23 x 16/12) = 30.67 CO_2 equiv. $(CH_4\text{-C})^{-1}$

3. CO_2 Losses due to Drainage

Total GHG emissions from Drained Land (t CO_2 equiv.)	31546
Total GHG Emissions from Undrained Land (t CO_2 equiv.)	10957
Total CO_2 losses due to Drainage (t CO_2 equiv.)	**20589**

Wind farm CO_2 emission saving over…	Carbon Dioxide Saving (tCO_2 yr^{-1})
…coal-fired electricity generation	166493
…grid-mix of electricity generation	83246
…fossil fuel - mix of electricity generation	117513

Additional CO_2 payback time of wind farm due to drainage of peat	**Additional payback time (years)**	**Additional payback time (months)**
Coal-fired electricity generation	**0.12**	**1.5**
Grid-mix of electricity generation	0.25	3.0
Fossil fuel - mix of electricity generation	**0.18**	**2.1**

Note: Note, CO_2 losses are calculated using two approaches: IPCC default methodology and more site specific equations derived for this project. The IPCC methodology is included because it is the established approach, although it contains no site detail. The new equations have been thoroughly tested against experimental data (see Nayak et al, 2008 - Final report).

Selected Methodology = Site specific

Calculations following IPCC default methodology

Type of peatland	Acid Bog

Emission characteristics of acid bogs (IPCC, 1997)

Flooded period (days $year^{-1}$)	178
Annual rate of methane emission (t CH_4-C ha^{-1} yr^{-1})	0.04015
Annual rate of carbon dioxide emission (t CO_2 ha^{-1} yr^{-1})	35.2

Emission characteristics of fens (IPCC, 1997)

Flooded period (days $year^{-1}$)	169
Annual rate of methane emission (t CH_4-C ha^{-1} yr^{-1})	0.219
Annual rate of carbon dioxide emission (t CO_2 ha^{-1} yr^{-1})	35.2

Selected emission characteristics (IPCC, 1997)

Flooded period (days $year^{-1}$)	178
Annual rate of methane emission (t CH_4-C ha^{-1} yr^{-1})	0.04015
Annual rate of carbon dioxide emission (t CO_2 ha^{-1} yr^{-1})	35.2

Assumption: The period of flooding is taken to be 178 days yr^{-1} for acid bogs and 169 days yr^{-1} based on the monthly mean temperature and the lengths of inundation (IPCC, 1997, Revised 1996 IPCC guidelines for national greenhouse gas inventories, Vol 3, table 5-13)

Assumption: The CH_4 emission rate provided for acid bogs is 11 (1-38) mg CH_4-C m^{-2} day^{-1} x 365 days; and for fens is 60 (21-162) mg CH_4-C m^{-2} day^{-1} x 365 days (Aselmann & Crutzen ,1989. J.Atm.Chem. 8, 307-358)

Assumption: CO_2 emissions on drainage of organic soils for upland crops (e.g., grain, vegetables) are 3.667x9.6 (7.9-11.3) t CO_2 ha^{-1} yr^{-1} in temperate climates (Armentano and Menges, 1986. J. Ecol. 74, 755-774).

Calculations following ECOSSE based methodology

Drained Land

Total area affected by drainage due to wind farm construction (ha)	17
Total volume affected by drainage due to wind farm construction (m^3)	156414

Soil Characteristics that Determine Emission Rates

Average annual air temperature at the site (^oC)	7
Average depth of peat at site (m)	1.26
Average soil pH	4.9
Average water table depth at site (cm)	0.3
Average water table depth of drained land (m)	0.935291655

Annual Emission Rates following ECOSSE based methodology

Rate of carbon dioxide emission in drained soil (t CO_2 ha^{-1} yr^{-1})	21.83
Rate of carbon dioxide emission in undrained soil (t CO_2 ha^{-1} yr^{-1})	10.63
Rate of methane emission in drained soil ((t CH_4-C) ha^{-1} yr^{-1})	-0.81
Rate of methane emission in undrained soil ((t CH_4-C) ha^{-1} yr^{-1})	0.14

Selected Emission Rates

Rate of carbon dioxide emission in drained soil (t CO_2 ha^{-1} yr^{-1})	21.83
Rate of carbon dioxide emission in undrained soil (t CO_2 ha^{-1} yr^{-1})	10.63
Rate of methane emission in drained soil ((t CH_4-C) ha^{-1} yr^{-1})	-0.81
Rate of methane emission in undrained soil ((t CH_4-C) ha^{-1} yr^{-1})	0.14

Note: Equation derived by regression analysis against experimental data from 50 experiments. 41 cases were used and 9 included missing data values. The equation derived was
R_{CO2} = (3.667/1000) x (547 + (71.7 T) + (322 D) + (4810 W))
where R_{CO2} is the annual rate of CO_2 emissions (t CO_2 $(ha)^{-1}$ yr^{-1}), T = average annual air temperature (^oC), D is the peat depth (m), and W is the water table depth (m).
The equation has a R^2 value of 53.8%, P < 0.0001. By statistical convention, if P<0.001 this relationship can be considered to be highly significant.

Note: Equation derived by regression analysis against experimental data from 66 experiments. 40 cases were used and 26 included missing data values. The equation derived was
R_{CH4} = (3.667/1000) x (58.4 + (3.11 T) + (16.7 pH) - (410 W))
where R_{CH4} is the annual rate of CH_4 emissions (t CO_2 $(ha)^{-1}$ yr^{-1}), T = average annual air temperature (^oC), pH is the soil pH and$W$ is the water table depth (m).
The equation has a R^2 value of 52.7%, P <0.0001. By statistical convention, if P<0.001 this relationship can be considered to be highly significant.

Note: Note, CO_2 losses from DOC are calculated using a simple approach derived from estimates of the total C loss leached as DOC and the percentage of leached DOC lost as CO2

Total C loss	
Gross CO_2 loss from removed peat (t CO_2)	20338
Gross CO_2 loss from drained land (t CO_2)	8907
Gross CH_4 loss from drained land (t CO_2 equiv.)	0
Gross CO_2 loss from improved land (t CO_2)	0
Gross CH_4 loss from flooded land (t CO_2 equiv.)	0
Conversion factor: CH_4-C to CO_2 equivalents	30.6667
% total soil C losses, lost as DOC	10
% DOC loss emitted as CO_2 over the long term	100
% total soil C losses, lost as POC	15
% POC loss emitted as CO_2 over the long term	100
Total gaseous loss of C (t C)	7990
Total C loss as DOC (t C)	799
Total C loss as POC (t C)	1199

Assumption: The export from temperate and boreal peatlands ranges between 10 and 500 kg DOC ha^{-1} yr^{-1} (Dillon, P.J. and Molot, L.A. (1997) Water Resources Research 33, 2591–2600), which typically represents around 10% of the total C release.

Assumption: In the long term, 100% of leached DOC is assumed to be lost as CO_2

Assumption: The export from temperate and boreal peatlands ranges between 12 and 15% of the total gaseous C loss (Worrall, F., Reed, M., Warburton, J., Burt, T., 2003. Carbon budget for a British upland peat catchment. The Science of the Total Environment, 312, 133–146.) Tables 1 and 2.

Assumption: In the long term, 100% of leached DOC is assumed to be lost as CO_2

Total CO_2 loss due to DOC leaching (t CO_2)	**2924**
Total CO_2 loss due to POC leaching (t CO_2)	**4387**
Total CO_2 loss due to DOC & POC leaching (t CO_2)	**7311**

Wind farm CO_2 emission saving over…	Carbon Dioxide Saving (tCO_2 yr^{-1})
…coal-fired electricity generation	166493
…grid-mix of electricity generation	83246
…fossil fuel - mix of electricity generation	117513

Additional CO_2 payback time of wind farm due to DOC and POC leaching	**Additional payback time (years)**	**Additional payback time (months)**
Coal-fired electricity generation	**0.04**	**0.5**
Grid-mix of electricity generation	0.09	1.1
Fossil fuel - mix of electricity generation	**0.06**	**0.7**

Note: Emissions due to forestry felling are calculated from the reduced carbon sequestered per crop rotation. If the forestry was due to be removed before the planned development, this C loss is not attributable to the wind farm and so the area of forestry to be felled should be entered as zero.

Emissions due to forestry felling	
Area of forestry plantation to be felled (ha)	0
Carbon sequestered (tC ha^{-1} yr^{-1})	3.6
Life time of wind farm (years)	25
Carbon sequestered over the lifetime of the wind farm (t C ha^{-1})	90
Total carbon loss due to felling of forestry (t CO_2)	0

Wind farm CO_2 emission saving over…	Carbon dioxide saving (tCO_2 yr^{-1})
…coal-fired electricity generation	166493
…grid-mix of electricity generation	83246
…fossil fuel - mix of electricity generation	117513

Additional CO_2 payback time of wind farm due to felling of forestry	**Additional payback time (yr)**	**Additional payback time (months)**
Coal-fired electricity generation	**0.00**	**0.0**
Grid-mix of electricity generation	**0.00**	**0.0**
Fossil fuel - mix of electricity generation	**0.00**	**0.0**

Note: Note, CO_2 losses are calculated using two approaches: IPCC default methodology and more site specific equations derived for this project. The IPCC methodology is included because it is the established approach, although it contains no site detail. The new equations have been thoroughly tested against experimental data (see Nayak et al, 2008 - Final report).

Choice of methodology for calculating emission factors	Site specific

Reduction in GHG emissions due to improvement of site

Improvement of…	Degraded Bog	Felled Forestry	Borrow Pits	Foundations & Hardstanding
1. Description of site				
Life time of wind farm (years)	25	25	25	25
Area to be improved (ha)	0	0	0	4
Average air temperature at site (^oC)	7	7	7	7
Average soil pH	4.9	4.9	4.9	4.9
Average depth of peat at site (m)	1.26	1.26	1.26	1.26
Water table depth before improvement (m)	2.00	2.00	0.00	1.23
Water table depth after improvement (m)	0.00	0.00	0.00	0.30
2. Losses with improvement				
Flooded period (days $year^{-1}$)	178	178	178	178
Time required for hydrology and habitat to return to its previous state on restoration (years)	10	10	10	25
Improved period (years)	15	15	15	0
Methane emissions from improved land				
Site specific annual rate of methane emission (t CO_2 ha^{-1} yr^{-1})	18.22	18.22	18.22	4.39
IPCC annual rate of methane emission (t CO_2 ha^{-1} yr^{-1})	1.23	1.23	1.23	1.23
Selected annual rate of methane emission (t CO_2 ha^{-1} yr^{-1})	18.22	18.22	18.22	4.39
CH_4 emissions from improved land (t CO_2 equiv.)	0	0	0	0
Carbon dioxide emissions from improved land				
Site specific annual rate of carbon dioxide emission (t CO_2 ha^{-1} yr^{-1})	5.3	5.3	5.3	10.6
IPCC annual rate of carbon dioxide emission (t CO_2 ha^{-1} yr^{-1})	35.2	35.2	35.2	35.2
Selected annual rate of carbon dioxide emission (t CO_2 ha^{-1} yr^{-1})	5.3	5.3	5.3	10.6
CO_2 emissions from improved land (t CO_2)	0	0	0	0
Total GHG emissions from improved land (t CO_2 equiv.)	**0**	**0**	**0**	**0**

3. Losses without improvement				
Flooded period (days $year^{-1}$)	0	0	0	0
Time required for hydrology and habitat to return to its previous state on restoration (years)	10	10	10	25
Improved period (years)	15	15	15	0
Methane emissions from unimproved land				
Site specific annual rate of methane emission (t CO_2 ha^{-1} yr^{-1})	-74.00	-74.00	18.22	-38.49
IPCC annual rate of methane emission (t CO_2 ha^{-1} yr^{-1})	1.23	1.23	1.23	1.23
Selected annual rate of methane emission (t CO_2 ha^{-1} yr^{-1})	-74.00	-74.00	18.22	-38.49
CH_4 emissions from unimproved land (t CO_2 equiv.)	0	0	0	0
Carbon dioxide emissions from unimproved land				
Site specific annual rate of carbon dioxide emission (t CO_2 ha^{-1} yr^{-1})	40.6	40.6	5.3	27.0
IPCC annual rate of carbon dioxide emission (t CO_2 ha^{-1} yr^{-1})	35.2	35.2	35.2	35.2
Selected annual rate of carbon dioxide emission (t CO_2 ha^{-1} yr^{-1})	40.6	40.6	5.3	27.0
CO_2 emissions from unimproved land (t CO_2)	0	0	0	0
Total GHG emissions from unimproved land (t CO_2 equiv.)	**0**	**0**	**0**	**0**
4. Reduction in GHG emissions due to improvement of site				
Total GHG emissions from improved land (t CO_2 equiv.)	0	0	0	0
Total GHG emissions from unimproved land (t CO_2 equiv.)	0	0	0	0
Reduction in GHG emissions due to improvement (t CO_2 equiv.)	**0**	**0**	**0**	**0**

Reduction in CO_2 payback time of wind farm due improvement of site

Wind farm CO_2 emission saving over…	Carbon Dioxide Saving (tCO_2 yr^{-1})
…coal-fired electricity generation	166493
…grid-mix of electricity generation	83246
…fossil fuel - mix of electricity generation	117513

Reduction in CO_2 payback time of wind farm due improvement of	Degraded Bog	Felled Forestry	Borrow Pits	Foundations & Hardstanding	Total
	Reduction in payback time (years)				
Coal-fired electricity generation	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**
Grid-mix of electricity generation	0.00	0.00	0.00	0.00	0.00
Fossil fuel - mix of electricity generation	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**
	Reduction in payback time (months)				
Coal-fired electricity generation	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**
Grid-mix of electricity generation	0.00	0.00	0.00	0.00	0.00
Fossil fuel - mix of electricity generation	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**

A.2.5 Case Study 2 – Coal Clough

Coal Clough is a 24 turbine wind farm two kilometres north of Cornholme, Lancashire. It was constructed in the early nineties and each turbine is relatively small with a capacity of approximately 0.4 MW. The site contains several areas of blanket bog and presents a good example of how a wind farm development footprint can be constructed in such a way as to avoid blanket bog habitat areas. No review of the environmental statement or planning conditions was conducted on this site.

A.2.5.1 Site Visit

Coal Clough wind farm was visited on 8 April 2009, with the permission of Scottish Power. A site walk over and peat augering were conducted to review the hydrological, hydrogeological and ecological impacts of the wind farm.

A.2.5.2 Baseline Conditions

The site consists of several different habitats including: semi-improved pasture, rough pasture, and blanket bog. The soils outside the areas of blanket bog are either natural mineral soils (often gleyed) or restored soils associated with old quarry workings.

The pastures on the mineral soils are dominated by soft rush (*Juncus effusus*) (Photograph A11) and to a lesser extent coarse grasses, especially tufted hair-grass (*Deschampsia cespitosa*) and Yorkshire fog (*Holcus lanatus*). Some forbs, e.g. meadow buttercup (*Ranunculus acris*), creeping buttercup (*R. repens*), lesser spearwort (*R. flammula*) and daisy (*Bellis perennis*) are locally frequent, but the abundance of the common moss *Calliergonella cuspidata* indicates that the rush pastures are very wet for most of the year.

The blanket bog is limited to three depressions in the central and western parts of the site (Photograph A12-14) and these have not been extensively drained for farming. The peat has accumulated over clay in the hollows between the ridges. The blanket bog is dominated largely by harestail cotton-grass (*Eriophorum vaginatum*), common cotton-grass (*E. angustifolium*) and purple moor-grass (*Molinia caerulea*). The bog is still moderately wet with an acrotelm in places, where there is some ponding of water, as evidenced by an inability to sample the upper layers of peat with a gouge auger. The bogmoss *Sphagnum fallax* is locally abundant and the presence of other species of bogmoss (*S. subnitens, S. cuspidata, S. papillosum*) indicates the presence of locally 'active' peat growth. The lack of ericaceous dwarf-shrubs (e.g. heather, crowberry, cross-leaved heath and bilberry) suggests that a long history of grazing has eliminated these plants. Trampling by cattle and sheep will also limit the development of a significant cover of bogmoss.

Four watercourses cross the site. These occur either where blanket bog habitat starts to become more fen-like or within valleys which are entirely fen dominated. There are two drains on the two largest areas of blanket bog (Photograph A15); however the high levels of humification of the peat, with associated low permeability, mean that the impact of drainage on the ground water table of the peat is relatively limited.
There is evidence of extensive historic quarry working in the southern and central parts of the wind farm and much of the area is covered with vegetated spoil material.

A.2.5.3 Actual impacts

Although areas of blanket bog constitute approximately a fifth of the site, none of the development was built upon it. This may reflect construction expediency and/or the maximization of wind resources (blanket bog occupies depression on site), or other factors.

The development footprint only covers areas of pasture and the old quarry works (Photograph A16 and A17). The wind farm has had no discernible impact on the vegetation within these areas other than the direct loss to tracks, turbine bases, hard standing and piles of waste soil generated from the cutting of drainage channels and the construction of the batters and coverings over the turbine bases.

There are minimal impacts from the wind farm development on the areas of blanket bog habitat due to the location of the tracks and turbines on ridges away from the bog. There may have been a very small area of blanket bog where a track across a hollow was built up as a ridge. The soils and rocks used to build up the base of turbine 13 have resulted in the localised spread of soft rush onto part of the blanket bog below this turbine through the in-wash of soil, minerals in surface run-off and seeds from the area around the turbine base (Photograph A18). The significance of this impact may be limited because soft rushes have already been spread to other areas of the blanket bog by livestock.

None of the site tracks have drainage ditches along their course. Surface run-off from the tracks is not concentrated at particular discharge points so there is less potential for gulleying and significant nutrient enrichment of the blanket bog.

A.2.5.4 Carbon Assessment

Within the site boundary there are significant areas of peat; however, these were avoided during the construction so the development footprint only covered areas of mineral soils. As the areas of peat have been avoided, the potential for the development to affect the carbon stores on site is negligible, therefore a carbon assessment using Nakak et al. (2008) calculator has not been conducted.

A.2.6 Case Study 3 – Wharrels Hill

Wharrels Hill is an 8 turbine wind farm near the village of Bothel, Cumbria. It is sited on improved grassland and is contained within the case studies appendices to contrast its impacts against those wind farms built on blanket bog.

The site was granted planning permission in 2002 by the planning inspectorate on appeal, after the initial application was rejected by Allerdale Borough Council on the grounds of landscape and visual impact.

A.2.6.1 Identifying impacts and mitigation measures at the EIA stage

National Wind Power submitted an Environmental Statement with their planning application in 2000. But before this stage, preliminary site selection desk study work attempted to take into account landscape, ecological and noise, to minimize the sensitivity of the site chosen. The scoping exercise consisted of consultation with key stakeholders such as Allerdale Borough Council, Cumbria County Council, English Nature, the RSBP and the Cumbria Wildlife Trust. They also held a 3 day public exhibition in Bothel Village Hall. The outcome of this was that the initial plan for 10 turbines was reduced and the need for the following assessments was scoped:

- Landscape and Visual Assessment;
- Noise Assessment;
- Ecological and Hydrological Assessment;
- Archaeology;
- Electromagnetic interference;
- Shadow Flicker.

The assessments and mitigation measures which are pertinent to this report are discussed below.

A.2.6.2 Ecological and Hydrological Assessment

The initial site selection criteria were designed to find a site with minimal ecological value. The field work for the environmental statement confirmed that the site was mainly improved pasture with little bird life, plant species or plant communities of conservation value. The environmental statement identified sections of hawthorn dominated hedgerow as being of greatest importance and these were to be avoided in the site lay out.
Two streams, two farm ponds, three wells and a spring were identified in the hydrological assessment as being present on site. The access tracks would avoid all of these, so the impact of the scheme as outlined in the EIA, on hydrological features would be negligible.

A.2.6.3 Archaeological Assessment

A desk study and site walk over identified several archaeological features. The importance of these was assessed to be low but it was noted that this did not reduce their sensitivity. Adjusting the siting of the turbines could mitigate against damage by avoiding entirely the archaeological features. It should be noted here that such methods may not be as effective on blanket bog, as drainage schemes have the potential to lower groundwater levels over a large area, removing the preserving anoxic conditions within the peat. This means that the detrimental impact on archaeological features from a wind farm on blanket bog can be over a larger area than the direct development foot print.

A.2.6.4 Landscape and Visual Assessment

For Wharrels Hill, this was the largest and most important assessment; reflecting the proximity of the Lake District National Park to the site. The assessment concluded that the impact was significant but acceptable.

A.2.6.5 Planning Processes

The application was initially refused by Allerdale Borough Council. Within the decision process, the Lake District National Parks Authority, Cumbria County Council and others lodged objections on the grounds of landscape impact. Notably, the Environment Agency and English Nature lodged no objections and no parties lodged objection on the grounds of ecological or hydrological impacts. The decision was reversed by the Planning Inspectorate on appeal.

A.2.6.6 Review of planning conditions applied

The Planning Inspectorate's conditions deal mainly in three areas: ensuring the necessary infrastructure was in place before the turbines were constructed; ensuring details of material usage and construction particulars were approved by the local planning authority; and limiting visual impact through mitigating measures. In addition to these areas, the programme of archaeological works had to be agreed before the start of construction. There were no conditions relating to hydrology or ecology, reflecting the limited concerns Wharrels Hill posed in these regards.

A.2.6.7 Site Visit

Scout Moor wind farm was visited on 6 April 2009, with the permission of Windprospect Ltd. A site walkover and augering was conducted to review the archaeological, hydrological, hydrogeological and ecological impacts of the wind farm.

A.2.6.7.1 Baseline Conditions

The area of the development only occupies half of the area within the application boundary. Both the application boundary area and the site area were far smaller than that of the area assessment the ecological and hydrology chapter of the ES.

The site occupies an area of improved pasture dominated by cocksfoot (*Dactylis glomerata*), false oat-grass (*Arrhenatherum elatius*), meadow foxtail (*Alopecurus pratensis*) and ryegrass (*Lolium perenne*) with very limited potential ecological value. There are isolated mature wind-clipped hawthorn (*Crataegus monogyna*) bushes along the lines of highly fragmented field boundaries.The site is undelaid by the Carboniferous limestone series (BGS 2001), and several outcrop of limestone are present on site. An old abandon kiln is sited in the northern half of the site at least 40 m from any parts of the wind farm infrastructure. No streams occur within the area of the development, though two occur within the ES assessment area. There are two wells which are likely to penetrate the limestone aquifer beneath. A dew pond is located 150 m west of T1, the most northerly turbine (Photograph A19). The soil on site appears to be a well-drained sandy loam with low organic content (Photograph A20).

A.2.6.7.2 Impact of the Development

The road layout on site bares little resemblance to the one laid out in the ES and the access route into the site is completely different. Whether this has increased the landscape impacts of the site is difficult to judge but the development footprint of the built layout is less than the originally proposed. The zone of impact surrounding the roads is negligible; improved pasture borders all the roads (Photographs A21 and A22). No drainage ditches follow the roads or surround the turbines and it appear that run-off is controlled through infiltration which should be sufficient given the apparently well drained nature of the site and underlying permeable and limestone geology. The turbine foundation bases are covered by grass mixture similar to that of the surrounding pastures and there are no extensive areas of bare soil.

The development has had negligible impact on the sites hydrology. All turbines are located over 400 m from the nearest stream. In the south east of the site, a site track passes within 4 m of a well (Photograph A23), and there would be the potential for the road runoff to impact the water quality in the well.

The only likely ecological impact from this wind farm is potential bird strikes.

The old kiln is located at least 40 m from any part of the development footprint. Any impacts of the wind farm on it would be negligible.

Overall the impacts on the ecology, archaeology and hydrology were minimal. The sensitive of the site and its surrounding are low therefore the magnitude of impacts are accordingly low.

A.2.6.8 Assessment of carbon balance of the site

During the site walk over no peat soils were found on the site therefore no assessment of carbon flux using Nayak et al. (2008) method was conducted.

Scout Moor Photographs

A1	***GR:*** *384162 418706* *Photo Direction: E* ***Comments:*** Evidence of historic peat cutting, typical of much of Scout Moor.	
A2	***GR:*** *384153 418678* *Photo Direction: E* ***Comments:*** Typical gully cutting the blanket bog which extends down to the till beneath.	

A3	***GR:*** 384741 416938 *Photo Direction:* N ***Comments:*** Discharge of drain directly to ground.	
A4	***GR:*** 384741 416938 *Photo Direction: E* ***Comments:*** Discharge of drain directly to ground, erosion potential.	

A5	***GR:*** 384662 418335 *Photo Direction: N* ***Comments:*** A drain discharging to the surface has caused gullying at the discharge point near Turbine 19.	
A6	***GR:*** 382572 419304 *Photo Direction: N* ***Comments:*** Sediment from this ditch has caused the blanket bog below to start to change to a fen habitat. This has lead to increased gas emissions, ground quaking and peat buoyancy.	

A7	***GR:*** 384094 418686 *Photo Direction: E* ***Comments:*** Pooling on the upslope of a floated road.	
A8	***GR:*** 383626 418099 *Photo Direction: NE* ***Comments:*** Motor cross bike tracks on blanket bog in the foreground. Peat spreading can also be observed along the side of the tracks.	
A9	***GR:*** 384031 417300 *Photo Direction:* E ***Comments:*** Peat deposited on the road side. The seeding has not taken and so large areas of fragile bare peat are left exposed.	

A10	***GR:*** 383205 418924 *Photo Direction: NW* ***Comments:*** Mineral Soil and Rock Material deposited at the side of a road on top of an area of blanket bog.	

Coal Clough Photographs

A11	***GR:*** 389612 428584 *Photo Direction:* N ***Comments:*** Pastures dominated by soft rushes in the mineral soil areas. Note the zone of influence of the track is limited.	
A12	***GR:*** 389555 428548 *Photo Direction:* W ***Comments:*** Small area of blanket bog on the west of the site.	

A13	***GR:*** 389689 428534 *Photo Direction:* W ***Comments:*** Largest area of the blanket bog in the centre west of the site	
A14	***GR:*** 389661 428394 *Photo Direction:* E ***Comments:*** An area of blanket bog lies within the depression in the centre of the site. It has some soft rushes covering parts.	

A15	***GR:*** 389612 428584 *Photo Direction:* S ***Comments:*** Pre-development drainage ditch on the centre west blanket bog. The influence on the groundwater table is limited, indicated by the bog pools 20 m to the west.	
A16	***GR:*** 389555 428548 *Photo Direction:* W ***Comments:*** A turbine constructed on a ridge 30 m from the edge of the blanket bog.	

A17	***GR:*** 389555 428088 *Photo Direction:* N ***Comments:*** Turbines located off the blanket bog on ridges.	
A18	***GR:*** 389893 428292 *Photo Direction:* W ***Comments:*** Drainage ditch from T13 discharging to an area of blanket bog resulting in the localised spread of soft rushes.	

Wharrels Hill Photographs

A19	***GR:*** 317471 537889 *Photo Direction:* N ***Comments:*** Dew pond within the application boundary.	
A20	***GR:*** 317367 537596 *Photo Direction: N.A.* ***Comments:*** An example of the thin sandy loam that covers the whole area of development.	

A21	***GR:*** 317596 537708 *Photo Direction: W* ***Comments:*** The roads have had minimal impact and due to the permeability of the soil and geology no ditches are required.	
A22	***GR:*** 317650 537703 *Photo Direction: E* ***Comments:*** Turbine bases have grassed over.	

A23	***GR:*** 317340 537745 *Photo Direction: N* ***Comments:*** A well near a road for the use of sheep.	

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Appendix B: - Guidance on Wind Farm Assessment Regarding Blanket Peatland

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B.1 GUIDANCE FOR NATURAL ENGLAND ON WIND FARM ASSESSMENT

B.1.1 Introduction

The following sections outline guidance for Natural England staff with regard to commenting on wind farm proposals. However, for a more general discussion of assessment of wind farm proposals, and information concerning particular impacts, reference should be made to the main report text. The table from the end of the conclusions is repeated below for ease of access.

B.1.2 Development Assessment Criteria

The following table has been produced to summarise the Environmental Assessment Criteria that should be used to assess any wind farm development on blanket bog. There are four categories of site sensitivity for each criterion.

- Green – This factor is not an obstacle requiring mitigation (low sensitivity, low likelihood of significant impact).
- Amber – Convincing mitigation measures and good site practices required to minimise impact.
- Red – Considerable requirement for mitigation measures and good site practices likely to minimise impact, however, some negative impacts are likely to remain.
- Black – Impacts are likely to be significant even with the implementation of mitigation measures and good site practices.

The following table should steer development towards less sensitive sites, and less sensitive areas within particular sites. It should be noted that cumulative sensitivities and impacts should be considered although a number of the factors listed are interrelated.

Table B - 1 Proposed Wind Farm Development Site Sensitivity

Environmental Assessment Criteria	Site Sensitivity			
Ecological Designations	None	Local	National	International
Within the HAP restoration target				
Degree of existing peat degradation	Highly degraded	Degraded	Non-pristine	Intact
Degree of pre-development drainage	High density, effective drainage, dissecting the peat	Some drainage but not dissecting the whole peat thickness	Limited historical drainage	No drainage
Depth of Peat (intersected by infrastructure)	0 – 0.3 m	0.3 m – 0.5 m	0.5 – 2 m	2+ m [1]
Peat stability risk: slip or bog burst	Low	Medium[2]	High[3]	Almost Certain[4]
Ecological Sensitivity	Moorland Grassland	Degraded blanket bog	Mixed degraded and intact bog	Intact Sphagnum Moss blanket bog
Archaeological feature of Interest	None	Low importance	High Importance	International Importance
Amount of	None or limited	Some overlap	High proportion	

Environmental Assessment Criteria	Site Sensitivity			
development footprint on blanket bog.				
Is future restorability of the bog compromised?	No	Probably ok – needs careful site design	Uncertain – concerns should be addressed in EIA	Yes – restoration will be more difficult /impossible following development

1. There are generally increasing difficulties in working with deep peat. However, depths of peat in the English uplands (usually only up to a couple of meters) are much lower than found elsewhere in the UK and Ireland.
2. Peat Stability Assessment needs considering at EIA stage, but this shows limited risk factors. Full peat stability assessment required as part of planning condition.
3. Full Peat Stability Assessment likely to be required at EIA stage (or if not undertaken as a planning requirement). A number of risk factors are present.
4. Peat Stability Assessment indicates high likelihood of slip or burst and there is existing evidence of slippage on site.

B.1.3 Examples of Issues to be Considered at an initial site selection stage

Natural England may or may not have the opportunity to comment on proposals at the site selection or pre-scoping stage. However, if the opportunity arises, i.e. if developers make initial contact with Natural England the following points could provide guidance.

The following aspects of the development should be considered in the selection of the site (in order of preference):

- Avoidance of designated sites.
- Can all areas of blanket peat be avoided, given that it is a BAP priority habitat?
- Can all areas of deep peat be avoided (>0.5 m)?
- Can all areas of intact blanket peat be avoided?

Can some aspect of blanket bog restoration be included within the proposals? This could include measures to reduce erosion and degradation (e.g. drainage blocking) and measures to encourage re-vegetation (e.g. reduction of grazing pressures).

B.1.4 Example of Issues to be Considered at a Scoping Stage

The site selection points should be reiterated in terms of the general requirement to avoid blanket peat, which is a BAP priority habitat, within the site design. There is often the potential within a site to avoid the areas of blanket bog, or areas of most intact blanket bog.

The following aspects of the development should also be highlighted at the scoping stage for consideration by the developer:

- The integrity of the blanket peat body.
- The requirement for a peat stability assessment.
- The requirement for mitigation of peat impacts.
    - In areas with more than 0.5m of peat the peat tracks must be constructed in such a way as not to impact the flow of water through and over the peat.
    - A detailed Environmental Management Plan (EMP) which should include proposals for restoration of the site, habitat gains and restoration methods. This should be developed and agreed in consultation with Natural England and the local council in advance of any construction on site.

The scoping phase is important as there is more opportunity to influence the assessments which are undertaken and the final details of the development at this stage, than after the EIA has been finalised (see section **Error! Reference source not found.**).

B.1.5 Checklist of Assessment of Blanket Peat – for use by Natural England

The following provides a checklist of the aspects which should be presented in a wind farm planning application in blanket peatland areas.

Table B - 2 Checklist for Wind Farms

Assessment Aspect	Yes	No
Has a scoping exercise been undertaken?		
Have widely recognised methods and standards been used, and accepted guidance followed?		
Is there a clear baseline description of the site? This should include: • Topographic description, including surface water catchments, surface water courses and runoff description • Soils and geological description, including enough peat depths to adequately characterise the blanket bog on site (i.e. values at turbine locations, and trackways and areas up/down gradient). • Groundwater description, including likely groundwater fluxes, e.g. areas of groundwater discharge, and likely links between blanket bog and underlying sediment/rock strata. • Clear ecological baseline assessment including adequate vegetation survey and classification to identify any blanket bog habitat and condition. • A clear conceptual model of the site synthesising the above information into an overall understanding of the blanket bog in its hydrogeological and hydrological setting. This should include maps and figures.		
Has the blanket bog been identified as a concern and attempts made with site selection and micro-siting to avoid areas of particular concern (e.g. avoid blanket peat completely, avoid deep peat, avoid intact peat)?		
Are the existing geological/geomorphological processes e.g. slope processes and any peat erosion outlined?		
Is the area of direct blanket bog habitat loss (e.g. on site infrastructure, cable route) clearly outlined?		
Have there been attempts to reduce the amount of blanket bog habitat lost e.g. through moving turbines or trackways to non-blanket bog areas?		
Are the potential habitat damages clearly identified?		
Are the potential impacts of the development clearly identified and listed? These include: • Lowering of water levels and degrading blanket bog (e.g. through drainage and dewatering) • Change in hydrological processes and runoff, e.g. from tracks, hard standings leading to development of drier area and wetter areas (with potential erosion and instability) • Peat slide – slope stability risks • Sediment release, erosion and nutrient control • Water quality impacts and pollution risk		

Assessment Aspect	Yes	No
• Removal of vegetation. However, re-vegetation measures been presented?		
Are cumulative impacts considered, and impacts outside of the site boundary?		
Have mitigation measures been specified in detail?		
Are the residual impacts specified and realistic?		
Is there unacceptable impact on blanket bog habitat?		
Has the potential for biodiversity gains and habitat restoration been considered?		

Further details of the scope of assessments, and possible mitigation measures required are given in the main part of the report in Chapter 4. Chapter 3 provides details of case studies and Chapter 2 a background review of literature. A detailed summary of literature is provided in Appendix A.

B.1.6 Mitigation Measures

The following table provides a list of mitigation measures that may be proposed for a wind farm on blanket peat. The main impacts of wind farms on peat are given and their consequences. The consequences are categorised as reversible /irreversible and the scale of the consequences will vary according to the nature of the site. Potential mitigation measures are given in the final column. Mitigation measures are categorised as:

- **Site design**: Measures which can be incorporated into site design. The impact of these is long term, throughout the lifetime of the site and such measures generally aim to reduce the impact of the infrastructure on peat processes.
- **Construction**: These measures would be shorter term designed to reduce the impact of the construction activities.
- **Construction/ operation**: These measures would be in place for both the construction and operational stage of the wind farm. These measures generally mitigate against impacts (such as on-going drainage, traffic and vehicle management) which are seen throughout the lifetime of the site.
- **Operation**: These are longer term mitigation measures associated with longer term maintenance and operational impacts.

The list is not exhaustive and alternative actions may be appropriate on some sites.

Table B - 3 Mitigation of Impacts

Impact of Wind Farm on Peat	Consequence	Mitigation Measure
Drainage	Lowering water table Water table can be returned to original levels (i.e. *reversible)* – but associated changes to vegetation and peat structure *may not be reversible.*	Site Design • Appropriate design of tracks, drainage ditches and drainage systems following good practice guidance. • Avoid impediments to surface or groundwater flow. • Minimise depth of ditches. Construction • Manage drainage during construction of cut slopes and tracks. Mimic the natural drainage pattern as far as possible. • Pumping during construction of turbine bases to

Impact of Wind Farm on Peat	Consequence	Mitigation Measure
		soakaways or settlement ponds in suitable areas (avoid adding water to areas of peat > 0.5m depth).
	Loss of peat mass through oxidation or desiccation and wind erosion. (*Irreversible)*	Construction/ Operation • Avoid lowering water table. Limit drainage to small areas where it is absolutely necessary. • Avoid exposure of peat surface.
Change in runoff pattern	Change in flow in or downstream of site. (Increase in peak flow may lead to flooding. Decrease in low flows may affect downstream biodiversity.) Change in flow pattern is *reversible.* Associated changes (e.g. to biodiversity) may take a very long time to recover.	Site Design • Minimise the length of drains to avoid intercepting large volumes of water, concentrating flows or diverting water into adjacent catchments. • Camber tracks to avoid ponding and maximise runoff. • Tracks constructed from coarse erosion-resistant aggregate which will reduce runoff. • Interceptor drains on steeper tracks. • Track drainage designed to intercept large volumes of water should be porous to minimise direct discharge to watercourses. • Frequent surface water discharge points via level spreaders. Construction • Backfill cable trenches and minimise the amount of time they are open. Use clay bunds in backfilled trenches to prevent any flow of water along their length. Operation • Check crossings for blockages especially during and after heavy rainfall. • Maintain track surfaces.
	Erosion Erosion is *irreversible*. May be possible to stabilise remaining peat.	Site Design • Cross drains to prevent excessive build up of water in roadside ditches. Avoid concentrating flow peaks. • Channel runoff from hard standing areas to avoid erosion. • Low gradients in drainage ditches to avoid erosive flow velocities. Check dams / erosion protection in ditches with slope greater than 5%. Operation • Check crossings for blockages especially during and after heavy rainfall.

Impact of Wind Farm on Peat	Consequence	Mitigation Measure
		• Maintain track surfaces
	Water Quality impacts Change in water quality is *reversible* but associated impacts on vegetation and fish/ invertebrates may take a long time to recover.	Site Design • Use settlement ponds and silt traps and treat runoff in line with best practice. • Monitor water quality in key watercourses to ensure sediment load does not exceed suitable limits.
Changes to sediment supply	Increased sediment in downstream watercourses Increased sediment supply is *reversible* but associated impacts on vegetation and fish/ invertebrates may take a long time to recover.	Site Design • Manage track drainage to reduce sedimentation. • Construct water crossings to reduce flow at either end and use edge constraints to reduce splatter from vehicle wheels. • Use buffer zones, silt traps and settlement ponds to avoid sediment reaching watercourses. • Produce sediment and erosion control plan. Ensure that all contractors on the site understand and comply with the plan. Construction • Minimise the total exposed ground at any time by careful phasing of construction activities. • Minimise soil stockpiles. • Re-vegetate exposed areas as soon as possible. • Revise the sediment control plan if new sources of sediment are identified during construction. Site Lifetime • Maintain tracks to avoid rutting.
Pollution Incident	Pollution of watercourses on or downstream of site. Pollution is *reversible* but impacts on site and downstream biodiversity may take a long time to recover.	Site Design • Store equipment, materials and chemicals in site compound away from watercourses. Chemical, fuel and oil stores sited on impervious bases within a secured bund. Best practice guidelines to be followed. Construction • Intercept clean water upstream of construction ditches and pipe to a suitable location for dispersal. • Locate construction activities away from watercourses. • Construct toilet facilities using good practice

Impact of Wind Farm on Peat	Consequence	Mitigation Measure
		guidelines. • Avoid concrete batching on site. Construction/ Operation • Wheel washing activities in designated areas with runoff to soakaways. • Manage runoff from hard standing. • Use drip trays under standing machinery. • Refuel vehicles in designated areas away from drainage and watercourses. Provide spill kits. • No maintenance of vehicles (other than emergency maintenance) to be carried out on site.
Tree Felling	Sediment and nutrient release (*Irreversible*) Erosion of exposed surfaces (*Irreversible*)	Construction • Follow best practice tree felling guidelines. • Minimise exposed ground and soil stockpiles. • Re-vegetate exposed areas as soon as possible. Construction/ Operation • Monitor ground conditions around felled areas to identify any stability issues especially on slopes.
Peat Stability	Peat Slide (*Irreversible*) Local slumping (*Irreversible*)	Site Design • Avoid areas of potential instability Construction • Monitor groundwater levels and rainfall during construction. Avoid activities which may result in instability during very wet times. • Careful design of dewatering, tracks and drainage and support during excavations. • Control placement of material on the peat. Temporary storage of excavated material should be on less sensitive (i.e. flatter, firmer areas of shallow peat). • Construction of catchwall fences or ditches in areas at potentially higher risk of slippage. Construction/ Operation • Avoid uncontrolled discharge of water over peat surface. • Manage peat loading. This may include limitation of vehicle loadings under certain conditions (e.g. very wet) and the use of low pressure vehicles on the peat. • Avoid soakaways, SUDs or drainage into areas of deep and/ or potentially unstable peat. Use

Impact of Wind Farm on Peat	Consequence	Mitigation Measure
		surface level spreader. • Minimise vibration from construction activities or traffic. Operation • Maintenance of natural and engineered drainage.

B.1.7 Planning Conditions and Obligations

A short summary of planning conditions potentially relevant to wind farms is given in Appendix B.3, including the roles of planning conditions and section 106 planning obligations. More work and cost is generally involved in developing s106 planning obligations and so these are often not used unless specifically required. In the case of wind farms, where a fund of money is available for local improvements (community benefits) or local environmental improvements (e.g. local habitat restoration) this might be managed via a s106 agreement.

There may be benefit in recommending planning conditions regarding the following:

- Monitoring of impacts and restoration measures;
- The requirement for a peat stability assessment if this is not undertaken at the EIA stage;
- Use of habitat restoration funds (which may require a s106 agreement).

It is important that the design methods and mitigation measures proposed in the EIA are taken forward to the construction phase via the construction method statement. It is also important that detailed plans for the environmental management of the site are developed and approved prior to the commencement of construction on site (see Appendix B.3). Use of contractors on site who have experience of working in peat environments can be of benefit in the implementation of works to minimise impacts on peat.

B.1.8 Opportunities to influence the Planning Process

Natural England may seek to influence local planning policies so they explicitly take account of the sensitivities of blanket bogs, or more indirectly via the Biodiversity Action Plan (BAP) targets.

There are opportunities for councils to influence and steer the wider planning agenda in their area – by guidelines and areas of wind farm search, e.g. via local development frameworks (LDFs) or regional spatial strategies (RSSs). Natural England can have input to this process via consultation.

B.2 GOOD PRACTICE RECOMMENDATIONS FOR DEVELOPERS

B.2.1 Outline Good Practice Recommendations

It is important that developers follow good practice in the selection of sites and preparation of EIAs in order to successfully obtain planning consent for wind farm sites. The adequate description of, and assessment of impacts on, blanket bog habitats, and demonstration of appropriate mitigation measures is key to obtaining planning approval.

B.2.2 Avoidance of Blanket Bog Where Possible

Consideration should be given to other potential non-blanket bog sites as part of the site screening process, in order to demonstrate that other non-blanket bog sites were not available. Where suitable non-blanket bog sites are available in an area, without the habitat interest of blanket bog (or similar protected habitats) these areas are to be preferred.

Some areas of blanket peat are designated as national or international biodiversity sites (for example SSSI or SAC) and guidance from English Nature *et al* (2001) advises that development on these sites should not cause adverse impact to either the integrity of the site or its designated features. It is important to note that the onus is on the developer to show unequivocally that such damage will not occur. Developers should be aware that this is a formidable hurdle and will attract the most intense scrutiny. Developers should also be aware that designated site boundaries have frequently been drawn up in ignorance of the extent of the hydrological relationships between areas of bog. An event such as a wind farm proposal would trigger a detailed study and the new understanding of the hydrology would in many cases justify an extension of the designated site boundary.

If a wind farm is proposed on sites with local and regional designation (e.g. local nature reserve or SINCs – Sites of Importance for Nature Conservation – at a County Level) **and** it is likely to have a significant adverse impact then it should only be permitted if it can be demonstrated that there are reasons for the proposal which out weight the nature conservation value of the site.

It should be noted that the effects of a wind farm can be direct: for example if the proposed wind farm is inside a designated area. The effects of the wind farm can also be indirect for example when the wind farm is located on the boundary of a designated area or when the impact of the wind farm is seen at some distance from the development (e.g. changes to the water quality or sediment transport regimes downstream).

Wind farm developments should not take place on designated sites. If there are over-riding matters of public importance (in the view of the developer) that there should be a wind farm development, then a clear assessment of the benefits of the wind farm compared with the loss of biodiversity sites should be carried out.

If a blanket bog site is taken to planning, there should be a clear assessment of how the site would contribute to the HAP restoration programme with, and without, the proposed development. The potential gains and losses of the development can then be assessed.

Selection of a deep peat blanket bog site for a wind farm will result in a longer carbon payback period than the selection of a non-peat site, due to the peat losses incurred during the construction and operation of the site.

B.2.2.1 Consultation

The timing of such informal consultations is at the developer's discretion; but it will generally be advantageous to undertake consultation as soon as the developer is in a position to provide sufficient information about the proposal to form a basis for discussion. The developer can ask that any information provided at this preliminary stage should be treated in confidence by the planning authority and any other consultees.

If the developer is seeking a formal screening opinion from the planning authority on the need for environmental impact assessment, the information about the project which accompanies that request will be made public by the authority.

Early consultation with statutory authorities is of benefit in highlighting concerns and in allowing sufficient time, early enough in the process, to allow concerns to be addressed. Early consultation enables the developer to avoid unnecessary cost and delay by:

- Steering the location of the development away from sites which are unlikely to obtain planning permission;
- Highlighting what particular aspects should be required within the EIA, including specific studies (such as peat slide assessment, private water supplies risk assessments, specific ecological studies);
- Enabling the site layout to avoid particularly sensitive areas;
- Avoiding sites where more mitigation measures may be required;
- Avoiding sites which may have particular engineering problems e.g. unstable peat.

B.2.2.2 Habitat Management and Impacts on Blanket Bog

It is important that the sensitivities of blanket bog are considered in the EIA to an adequate level (see Chapter 4 and 2 of the main report and Appendix B.1.5). In particular, the consideration of the blanket bog as a hydrological and ecological unit, and presentation of a conceptual model of the blanket bog are important. Any changes to the water level (i.e. lowering the water level) in peat, or changes to the diffuse nature of flow (e.g. through focussed drainage measures) are likely to negatively impact the blanket bog. Where there is a significant thickness of blanket peat (>0.5 m depth) a peat stability assessment should be carried out.

B.2.3 Mitigation Measures

Detailed mitigation measures (see Chapter 4 and Appendix B1) should be specified in the EIA and carried forward into the construction management strategy CMS for implementation on site.

B.2.4 Restoration of Blanket Bog

The development should not impact on the potential of degraded blanket bog sites to be restored in the future. The design and location of tracks is particularly significant regarding their potential for impacting blanket peat integrity as they cross the peat body. For degraded blanket bog sites there is the potential for blanket bog restoration measures to be included within the development proposals.

The feasibility of the proposed restoration measures regarding the actual wind farm site and also any additional peatland restoration gains should be clearly assessed. A number of landowners may require convincing of the benefits of restoration of peatland (such as farmers) and buy-in from landowners regarding any peatland restoration proposed must be obtained. [For instance, in the Win Ash Wind Farm Public Inquiry there were objections by local people regarding the proposed peatland restoration that the developers were proposing – pers com. NE].

B.2.5 Long-term Monitoring

Following the development of the wind farm, long term monitoring of the impacts may be required, in order to identify the impact on the blanket bog and the success of the restoration and mitigation measures.

B.3 EXAMPLES OF PLANNING CONDITIONS FOR LOCAL AUTHORITIES

B.3.1 Good Practice Recommendations for Assessing Wind Farm Planning Applications on Blanket Peatland in England

This section provides some background to the planning situation regarding wind farms, and the types of planning conditions which are typically used. It is not an exhaustive review of all wind farm planning conditions, but reference has been made both to existing reviews of wind farm planning conditions and to specific conditions at particular sites in developing these general points.

B.3.1.1 Introduction

There are a number of aspects of blanket bog habitat, overlying blanket peat, which it is important to consider at the EIA stage of a development and in any subsequent planning conditions. Blanket bog is a biodiversity action plan (BAP) priority habitat, and as such has an associated Habitat Action Plan (see section **Error! Reference source not found.** of the main report, and subsequent sections for more details). Blanket bog vegetation is dependent upon the following:

- A high water table, ideally within 30 cm of the ground surface all year.
- Rainfall derived water, which is very low in minerals and nutrients.

Aspects of the development which may impact on water levels (particularly lowering water levels) or water quality (increasing dissolved content) can have very significant impacts on blanket bogs.

Blanket bogs have a delicate structure of a surface layer of vegetation and underlying peat material (comprised of dead vegetation). It is very easy to break the surface vegetation layer and leave the weaker more decomposed underlying deeper peat to erode. Once erosion of a peat body has been initiated, e.g. through channelling of surface water over the peat surface, it will tend to continue unless restoration measures are implemented. Hence the specification of: mitigation measures to protect the peat; and restoration measures to restore the blanket bog vegetation are very important.

The likely environmental impacts of a wind farm development must be considered at the planning stage. This section contains:

- a discussion of planning conditions imposed on wind farm developments;
- a discussion of the need to monitor adherence to planning conditions.

B.3.2 Planning Conditions

Section 70(1) of the Town and Country Planning Act 1990 allows a planning authority to grant permission for a development "unconditionally or subject to such conditions as they think fit". Planning conditions are "requirements attached to a planning permission to limit, control or direct the manner in which a development is carried out" (Planning Portal Glossary at **www.planningportal.gov.uk**). Guidance on the use of planning conditions is provided in DoE Circular 11/95 (DoE, 1995). Conditions must be necessary, relevant to planning, relevant to the development, enforceable, precise and reasonable (DoE, 1995).

Planning authorities often impose planning conditions on wind farm developments. For example, one condition may be that the developer produce a Construction Method Statement (CMS) for approval by the authority before any development takes place. Planning conditions can be very site-specific.

TNEI (2007) analysed the planning conditions attached to 100 wind energy planning consents in the UK and, in consultation with BERR (the Department for Business, Enterprise and Regulatory Reform), produced a generic set of planning conditions. These conditions fall into the following categories:

- example conditions, derived from the TNEI report; and
- from a review of planning conditions for wind farm developments on peatland sites.

B.3.2.1 Planning Obligations

Government Planning Circular 05/05 provides revised guidance to local authorities in England on the use of planning obligations under section 106 of the Town and Country Planning Act 1990 as substituted by the Planning and Compensation Act 1991. Sections 46 and 47 of the Planning and Compulsory Purchase Act 2004 give the Secretary of State the power to make regulations to replace s106, but the Secretary of State has not yet taken these powers, and so the Circular does not concern these sections.

Planning obligations are legal agreements between a planning authority and a developer, or undertakings offered unilaterally by a developer, that ensure that certain extra works related to a development are undertaken.

They may cover one or more of the following:

- restricting the use of the land or the way in which a development is to be carried out;
- requiring specific operations or activities to be carried out;
- requiring the land to be used in a specific way;
- requiring a sum or sums of money to be paid to the LPA for specified purposes.

With respect to wind farm development proposals Planning Obligations tend to be mostly applied where they relate to the last bullet point above.

Planning obligations may be used for a wide range of purposes. However, Government policy gives a clear set of rules which planning obligations must adhere to. They must:

- be necessary; this is generally taken to mean that without the planning obligation there would be sufficient reason to refuse planning permission for the development;
- be relevant to planning and to the development and/or use of the land to which they relate;
- relate directly to the proposed development ;
- be fairly and reasonably related in scale and kind to the proposed development;
- be reasonable in all other respects.

Use of s106 Agreements and Wind Farms

The following section provides four examples of where s106 agreements are commonly used:

- Television Reception – where it is identified that proposals may affect TV reception then to mitigate that impact local authorities may require the signing of an agreement where the applicant makes provision of £X to meet the cost of investigating and rectifying any reported problems of TV reception within a specified radius of the site.
- Traffic Routing – some councils have used s106s in requiring the submission of traffic routing schemes, including reference to HGVs visiting the site, traffic signage, traffic diversions, periods of time during which HGVs can enter and leave the site and off site preparatory highway survey and works within the adopted highway. It is noted, however, that most LPAs (Local Planning Authorities) use a planning condition to control these matters.
- Restoration Bond – s106 have been used to cater for instances if a difficulty arises in the applicant not being able to restore the site as agreed.
- Community Benefit Fund – some applicants have advanced the establishment of a community benefit fund eg. £1,000 per MW pa. Some LPAs have accepted such a proposal and controlled it through the use of s106 agreements.

It is rare that Planning Obligations are used in the determination of wind farm applications. The key use is linked to when monetary transactions are implicated.

Planning conditions are in all ways the easier option to apply; planning obligations require detailed documentation showing title, including all lenders etc.

Planning obligations can be lifted by agreement or on application to the Local Planning Authority after 5 years or a later date specified in the obligation. Planning Obligations are therefore much more binding on an applicant than planning conditions; it should be noted, however, that a planning condition can only be appealed within 6 months of decision.

B.3.2.2 Example Planning Conditions

General Conditions

- A condition clarifying the period of permission.
- Specification of the time by which construction is to commence.

Aeronautical Conditions

- A condition requiring that the Ministry of Defence (MOD) or Civil Aviation Authority (CAA) be informed of the date of commissioning or the date of erection of the first turbine.

Archaeological Conditions

- A requirement that no development will occur before an approved programme of archaeological investigation has taken place.
- A requirement that reasonable access be given to a nominated archaeologist.

Construction and Access

- A condition requiring that a Construction Method Statement (CMS) be submitted to, and approved by, the local planning authority (possibly in consultation with the Environment Agency/Natural England), prior to commencement of the works.
- A condition requiring that an Environmental Management Plan (EMP) be submitted to, and approved by, the local planning authority prior to commencement of the works.
- A requirement that the development be carried out in compliance with the approved CMS and EMP (unless otherwise approved in writing by the local planning authority).
- A requirement that land affected by the construction activities be reinstated within a certain time period according to a scheme approved by the local planning authority, and that a restoration method statement and detailed restoration monitoring plan be prepared and submitted for approval by the local planning authority in consultation with Natural England. This would need to allow for monitoring of vegetation establishment, assessment of further restoration requirements, and provision for long term ecological and environmental monitoring as part of the wind farm maintenance.
- A condition limiting the hours of work (so as to minimise disturbance to local residents).
- A condition limiting the proximity of turbines or other infrastructure to water courses, e.g. a minimum distance of 50m.
- A condition specifying that any changes in the position of new tracks/turbines be permitted so long as they are within an agreed distance threshold (e.g. 50m) and are accepted by an environmental specialist (approved by the planning authority). Variation beyond the agreed distance threshold would require written approval from the planning authority. The purpose of this condition is to ensure that micro-siting takes account of environmental considerations.
- Where not undertaken as part of the EIA, a full private water supply assessment should be undertaken if such supplies are present in the area; this should include both registered and un-registered water supplies.

Where a development has been subject to EIA, mitigation measures identified in the ES (and approved by the local planning authority) should be included in the CMS and/or EMP.

Decommissioning

- A requirement that decommissioning be carried out in accordance with a scheme approved by the local planning authority. A detailed restoration and aftercare programme should be supplied.
- A condition specifying a time by which decommissioning works are to be completed.

Ecology and ornithology

- A condition preventing a certain activity from occurring at a certain time of the year (e.g. the breeding season for a particular bird species).
- A requirement that a survey be carried out to confirm that certain bird species are not nesting within a certain distance of the turbine locations.
- Seed mixes used on site for vegetation reinstatement should be approved prior to use (see Section B.3.3 for discussion of specific conditions).
- A condition stating that appropriate environmental and/or ecological/peat specialists (approved by the planning authority) must be available on site to provide advice regarding peat, peat stability, environmental protection measures and ecological works (such as micro-siting to avoid particular areas of high ecological value) (see following section B.3.3 for specific conditions).
- A requirement for post-construction monitoring, e.g. of habitats and water levels.

Electrical connection

- A requirement that electrical cabling be placed underground as per the approved plan.
- A requirement that excavated ground be reinstated to its former condition within a certain time period.

Electromagnetic production and interference

- A requirement for a qualified engineer to undertake a baseline television reception survey prior to the development.
- A requirement for the developer to cover the cost of rectifying any interference shown to be due to the development.

Landscape and visual impact

- A condition requiring the developer to submit a landscape and visual impact mitigation scheme for approval by the local planning authority.
- A condition requiring that the approved landscape and visual impact mitigation scheme be implemented.

Noise

- A requirement that the developer measure and assess the level of noise emissions from the wind turbines following the procedures described in the ETSU publication “The Assessment and Rating of Noise from Wind Farms” (ETSU, 1997).
- *Note that ETSU-R-97 is the current definitive guidance on assessing noise from wind farms.*

Shadow flicker

- A requirement that operation of the turbines take place in accordance with a shadow flicker mitigation protocol approved by the local planning authority.

The generic conditions produced by TNEI (2007) are intended as a guide only. Each application for a wind farm development must be assessed on its own merits and conditions devised or adapted accordingly. Detailed examples of planning conditions are available from the Perth and Kinross Website (see reference list), and in the Scout Moor case study (Section A.2.2). However, for a peat site where there are significant concerns regarding the peat environment, further conditions to safeguard the peat environment could be considered.

B.3.3 Particular Conditions Relevant to Peat

When constructing wind farms in peat uplands it is very important to minimise the impact to the peat environment. It is more effective to prevent impacts than to remediate them after they have occurred. The following observations are made regarding planning conditions and upland peat environments:

1. Where there are significant quantities of peat on site which will be excavated at the turbine bases, and possibly disrupted by drainage and tracks, a **peat management plan** should be developed. Where there may be significant amounts of other soil materials generated on site this could be broadened into an overall **sediment management plan**. The inappropriate disposal of peat and sediment on a blanket bog site can have negative impacts on the peat ecosystem. The peat management plan should include details of peat/soil stripping and storage on the site and also proposed peat use and replacement operations, and should be incorporated into the CMS.

2. It is very important that all the mitigation measures identified in the EIA be carried forward into the CMS and implemented on site. In some instances mitigation measures proposed in the EIA have not been included in the CMS and not implemented on site. The CMS should include the following (pertaining to the peat aspects of the site):

    a. A track construction plan.

    b. Proposed phasing of the operations, including a construction timetable which takes account of the times of year when high rainfall is likely (as this has impacts on peat stability and sediment mobilisation).

    c. An Environmental Management and Pollution Prevention Plan (comprising arrangements to protect groundwater, private water supplies, surface water, mitigation against silt-laden run-off from temporary and permanent access tracks, spoil storage and other engineering operations, construction noise, dust, oil pollution, arrangements for concrete batching, including provision for an Incident Response Plan to deal with any pollution incidents).

    d. Measures to avoid any significant adverse impacts on fish (this also includes sediment runoff and peat slides).

    e. Details of any tree felling (which generates sediment and can result in increased nutrient loadings downstream on peat sites).

    f. Restoration following completion of construction activities. This should include a requirement that on-site seed banks within surface peat and peat turves are used for restoring vegetation in preference to external seed sources. If external seed is used, it must be appropriate to the habitat environment and approved prior to use.

    g. Details of the construction of the access tracks, drainage and turbines.

    h. Details of excavations and other earthworks.

    i. Arrangements for storing materials, including storage of oils and management of other potential pollutants.

    j. Details of vehicle access and movements which could lead to peat erosion and sedimentation in the water environment.

    k. Full details of drainage proposals for the site, including drainage of tracks, foul drainage from buildings, discharge from wheel cleaning and drainage of storage and compound areas. This should include measures to prevent sediment generation, pollution and erosion.

    l. Mechanisms for managing sub-contractors and all other parties on site, particularly with regard to pollution, peat stability and emergency procedures. An appropriately qualified environmental scientist should be present during construction to provide specialist advice.

    m. Measures for dealing with all waste streams that arise in the operational phase.

    n. Provision of welfare facilities on site during construction and disposal of sewage effluent.

    o. Mitigation and reinstatement proposals, including a peat (or sediment) management plan.

p. Emergency procedures for peat instability risks, and other environmental sensitivities e.g. otter or water vole encounters.

q. Notification procedures for any serious health and safety, environmental or planning incidents.

3. Regarding peatland impacts, it is important that the ES is specific in terms of how impacts of the wind farm (particularly the construction of roads and turbine bases, and drainage, but also cableways) are to be mitigated. These specific mitigation measures can then be included in the CMS and implemented on site.

4. If there is provision in the planning permission for micro-siting of wind turbines (within an agreed distance limit, e.g. 40m) then the final location of tracks and turbines should be provided to the planning authority a number of months (e.g. 3) prior to construction starting.

5. Some standard practices may not be appropriate in a peat environment, or care may be needed in their implementation. These include:

   a. Traditional site drainage measures – these generally involve lowering groundwater levels, which may not matter on insensitive sites. However, on peat sites, lowering water levels will cause long term drying out and oxidation of the peat and carbon loss. The ES, CMS and planning conditions should provide that the groundwater levels on site are not lowered by the development over any significant area. This could include provision of water level monitoring points (e.g. piezometers or boreholes in the peat to monitor groundwater levels, or gauge boards to record water levels in surface water bodies - SLR 2007).

   b. The construction of roads over peat and the potential for this to dissect the peat body should be considered. The type of road construction and its impact on the peat should be considered within the ES and CMS in detail.

   c. Use of Sustainable Urban Drainage Systems (SUDS) is often cited as mitigating the impact of a development on rainfall runoff and drainage from a site. However, not all SUDS measures are appropriate in a peat environment: in particular, drainage to ground is generally not appropriate as it may cause peat buoyancy, liquefaction or instability. The ES and CMS should state in detail if any SUDS methods are proposed and indicate that they are suitable for a peat environment.

   d. Re-seeding of restored ground around tracks and turbines, and seeding of soil stockpiles – in a peat environment it is preferable to re-use peat turves from the site, rather than to import grass seed from outside the site which does not form part of the on-site habitat. If seeding is undertaken then it should be with seed which is representative of the existing on-site vegetation and approved by the planning authority in consultation with Natural England.

6. Where peat is present in significant depths on site, a Peat Stability Assessment and Mitigation Statement should be submitted to the planning authority (in consultation with Natural England and the Environment Agency) prior to any development. Within this, best practice and any mitigation measures (including micro-siting arrangements) to reduce the impact of the development on the peatland habitat should be specified. These should address drying of the site and erosion of drainage channels, and the method of discharge of drainage water to prevent erosion or failure of peat. Proposals for safe temporary storage of peat should be provided, and details of re-use and disposal of peat specified. These should include avoiding loading the peat surface with stored peat, and limiting any loading of the peat by other materials. Any unloading of peat, e.g. in excavations, should be minimised and monitored, with support provided for excavations to prevent collapse of peat. Monitoring and mitigation arrangements to avoid a peat slide event should be detailed and a rapid response strategy for any peat slide event should be included. These could include:

   a. Provision of the services of a suitably qualified peat expert (as specified in the Scottish Executive Peat Landslide Hazards and Risk Assessments report 2006).

   b. Formalised reporting of ground conditions, site workings, monitoring results and construction progress relating to stability.

   c. Use of a geotechnical risk register, submitted regularly to the planning authority.

d. Regular inspection of the site by approved peat experts, with the production of a ground stability report based upon a walkover site inspection.

e. Installation of additional ground condition monitoring instrumentation in the event that indications of peat instability are observed on site.

f. A contingency plan to respond to poor ground conditions.

7. Any condition relating to hours of work on site could include a transport management plan covering the passage of vehicles over the peat and also the loading of the peat (rapid loading of peat by numerous vehicles over a short period of time can result in peat failure).

8. There is the potential for conflict between some aspects of site management and peat management. For instance, on open moorland which forms common land there is a desire to maintain open access for people and animals. In some cases this has been specified as a planning condition. However, grazing of peatland by animals makes it very hard for disturbed areas to be re-vegetated. There should perhaps be a requirement that fencing of disturbed areas be undertaken for a limited amount of time (possibly not all the areas fenced at the same time) to allow re-growth of vegetation.

9. A requirement for further details to be provided prior to commencement of a development (e.g. details of drainage design and sediment management) can be specified as a planning condition. It is important to manage peat, subsoil sediment and rock separately. The upper peat horizons provide most of the seed bank for vegetation regeneration. Mixing of peat with other materials, or runoff from other materials, will change the properties of the peat, including the level of nutrients/minerals, and may result in a change of vegetation.

B.3.4 Monitoring Adherence to Planning Conditions

If the planning system is to be effective, then planning conditions must be enforced. If a planning condition is not adhered to then the local planning authority can issue a Breach of Condition Notice (Bell and McGillivray, 2006). Failure to comply with such a notice can lead to a fine; continuation of the non-compliance constitutes a further offence (Bell and McGillivray, 2006).

Planning Obligations are often more easy to enforce than planning conditions because a greater amount of time has been spent on the precision of their wording; other than this there is no real difference on the difficulty of enforcement of one control tool over the other.

All Town & Country Planners know the requirements of Circular 11/95 and the 6 tests for their use: necessity, relevance to the development, relevance to planning, enforceability and precision and reasonableness. Precision of wording is often the downfall of a condition at appeal.

B.3.4.1 Long Term Monitoring Agreements

Planning conditions or planning obligations are often used to establish long term management plans affecting a development site. These tend to relate to landscaping or ecological management plans and run for a period defined by the type of development.

In some cases, such as Crystal Rig Wind Farm[1] and Cefn Croes Wind Farm (SLR 2007), planning conditions have provided for photographs of the site to be taken before development (e.g. of cable trenches, vegetation, ditch blocking) and then post development to demonstrate the level of impact and the effectiveness of restoration. Such monitoring of the impacts and restoration provides a means for the developer to demonstrate the condition of the site. Similarly monitoring of water levels and reporting of this can be undertaken to demonstrate the impact on water levels in the blanket bog near to the wind farm infrastructure. Blanket bog vegetation is dependant upon high groundwater levels and so impacts on water levels will impact the bog habitat.

[1] **http://www.planning.eastlothian.gov.uk/WAM/doc/Other-149972.pdf;jsessionid=E45173501B147D139553F6F3899B7AB1?extension=.pdf&wmTransparency=0&id=149972&wmLocation=0&location=VOLUME1&contentType=application%2Fpdf&wmName=&pageCount=9**

Breach of Condition Notice: Case Study

On 4th July 2008, Ribble Valley Borough Council served a Breach of Condition Notice on the operator of Wiswell Wind Turbine because a planning condition requiring that a timer device be fitted to the turbine had not been adhered to (Ribble Valley Borough Council, 2008). The condition was:

"Within one month of the date of this planning permission, precise details of a timer device which will ensure that the wind turbine does not operate at times of the day/year when it might cause a nuisance of flicker to the adjoining residential property, shall be submitted to and approved in writing by the Local Planning Authority. Within a further one month of the Council's written approval, the device shall be fitted and shall be operative at all times when the turbine is in use. If, two months from the date of this permission, the device has not been fitted, the turbine shall not be used." (Ribble Valley Borough Council, 2008).

The turbine was found to be operating without the timer device, details of which had not been submitted to the Council for approval. Local residents complained, and a Council officer witnessed the turbine in operation. The Breach of Condition Notice required the use of the turbine to cease within 30 days (the minimum notice possible), but the operator was strongly advised to cease use of the turbine immediately (Ribble Valley Borough Council, 2008).

B.3.5 References

DoE (Department of the Environment), 1995. Use of conditions in planning permission. Circular 11/95.

ETSU, 1997. The Assessment and Rating of Noise from Wind Farms. ETSU-R-97

Perth and Kinross Council Website – model planning conditions: **http://www.pkc.gov.uk/NR/rdonlyres/B5E9703A-440F-475D-87F3-9DEF87AB8840/0/Model_Conditions.pdf**

Planning Portal Glossary – definition of "condition" (planning condition) **http://www.planningportal.gov.uk/england/government/en/1115310687878.html**

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