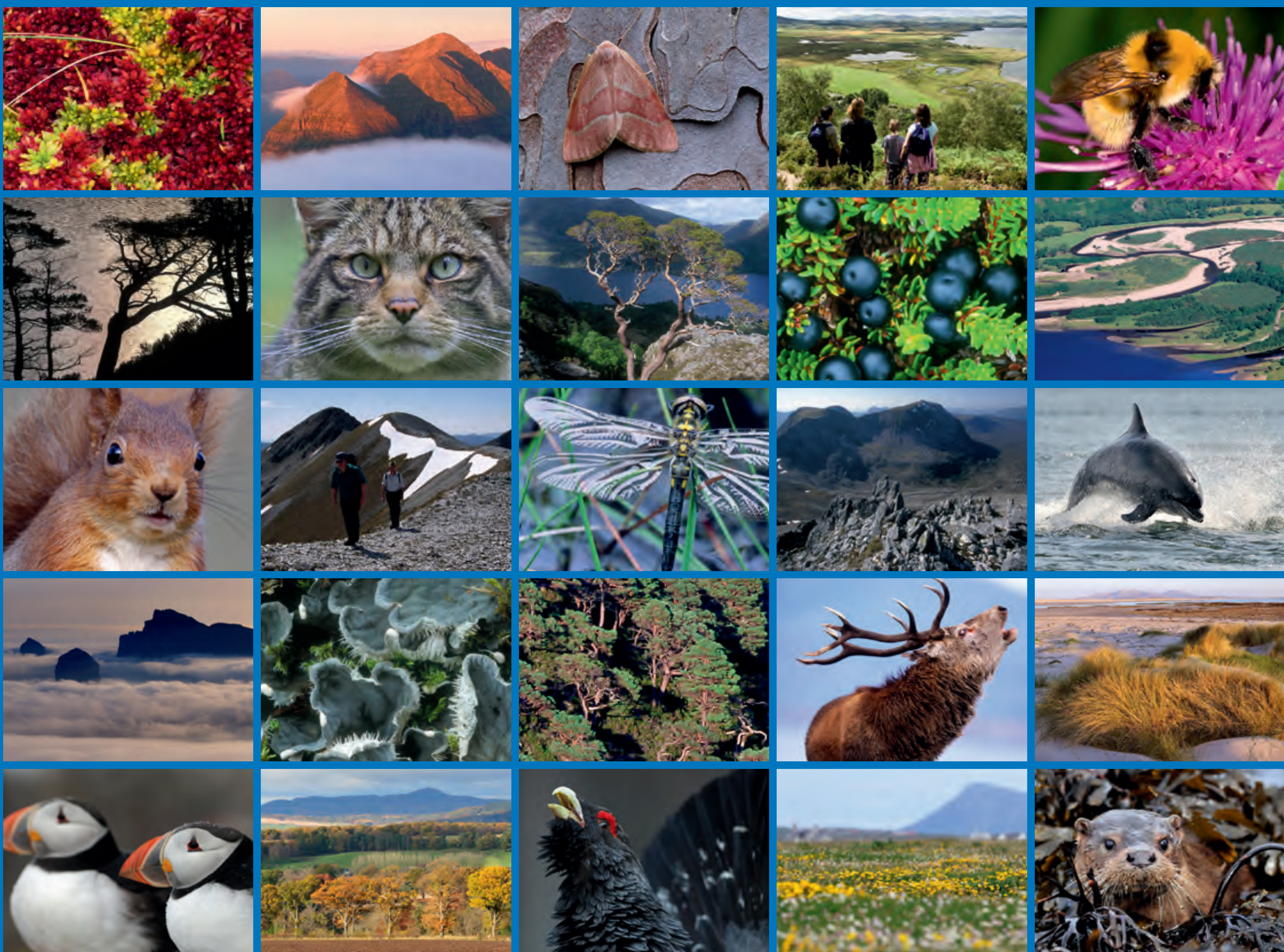
Scottish Natural Heritage
Commissioned Report No. 591

Research and guidance on restoration and decommissioning of onshore wind farms



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COMMISSIONED REPORT

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Research and guidance on restoration and decommissioning of onshore wind farms

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COMMISSIONED REPORT

Summary

Research and guidance on restoration and decommissioning of onshore wind farms

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Background

In 2010 Scottish Natural Heritage (SNH) published guidance on Good practice during wind farm construction (GPDWC). The GPDWC guidance is aimed at: wind farm developers, construction companies and contractors working on wind farm sites; consultants and advisors supporting the wind farm industry; planning officers working on wind farm applications; statutory consultees such as SNH, Scottish Environment Protection Agency (SEPA) and others with an interest in wind farm construction, and those responsible for the regulation of wind farms under relevant environmental protection and pollution prevention legislation and environmental / ecological clerks of works.

SNH intends to add to GPDWC with a chapter on Restoration and Decommissioning Plans (RDPs) for onshore wind farms. SLR Consulting Ltd (SLR) was commissioned by SNH to undertake background research to further develop our understanding of the environmental impacts and considerations for restoration and decommissioning to support this new guidance.

Main findings

- There is a willingness and enthusiasm amongst stakeholders to consider the issues of restoration and decommissioning in more depth than has been historically the case.
- There is recognition that by doing so the process of designing and constructing wind farms could be improved.
- It is acknowledged that earlier consideration and regular review of RDPs would be beneficial to the environment.
- There are existing processes where restoration and decommissioning plans could be effectively integrated (Habitat Management Plans, Health and Safety Plans, Construction Method Statement, Construction and Environmental Management Plan).
- There is interest in a step-by-step guide that would provide framework for site by site consideration whilst promoting consistency of approach.
- The planning and/or environmental statement needs to contain sufficient information regarding the likely options for decommissioning and their associated impacts so that this becomes an integral part of the process.
- Technological advances and changes in preferred approaches during the lifetime of a wind farm could mean it would be best practice not to limit options too far in advance of actual decommissioning but to maintain informed flexibility until close to the end-of-life of the wind farm.

- Future planning, beyond the first round of decommissioning and re-powering, and learning from previous experiences to influence good practice is essential.
- A thorough understanding of a site's natural heritage characteristics (its setting and relationship with surrounding area) and how these respond to change is critical to assess how the impacts of elements of the decommissioning strategy (e.g. construction works, habitat restoration, ground stability etc.) might affect the site. Only with this understanding can the decommissioning strategy be determined and appropriate mitigation measures identified.
- RDPs recommendations for infrastructure removal should reflect techniques and approaches that will result in the least disturbance to the environment, subject to the wider aims of the decommissioning strategy.
- From a landscape and visual perspective any demolition and reinstatement should achieve the greatest improvements with the least disturbance and impacts on landscape fabric, character or visual amenity of neighbouring receptors through careful control of the works.
- It is important to understand a site's soils and their influence on habitats so that re-established communities are likely to sustain themselves in the long term. The mass balance of soil movement, risk of contamination and avoidance of generating waste soil is critical to sustaining the site appropriately in the long term.
- HMPs need to be proportionate to the site, its ecological interest and the development's impacts, and expectations of their extent and content, even at the repowering stage, need to be reasonable.
- The RDP should not presume that all positive habitat management works will cease following decommissioning of the wind farm.

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1. INTRODUCTION

1.1 Purpose of the research

SLR Consulting Ltd (SLR) was commissioned by Scottish Natural Heritage (SNH) to provide research and guidance on the restoration and decommissioning of onshore wind farms. The key research areas were as follows:

- the potential impacts on the natural heritage of infrastructure being left in situ or removed;
- the criteria that determine when infrastructure will/should be removed, or otherwise;
- options and requirements for infrastructure removal techniques;
- options for reuse of any existing infrastructure with and without removal; and
- case study examples of current restoration practices and decommissioning proposals

1.2 Scope and methodology of the study

This research was commissioned to further the understanding of decommissioning and long-term restoration options for onshore wind farms. The aim was to provide a step-by-step approach to considering the best environmental options for long-term restoration and the post-operational stage of a wind farm development. Although such issues have been raised and discussed previously within the key stakeholder group, this study provided an opportunity for further structured research to progress this.

Based on the findings of the study, SNH will provide guidance for onshore wind farms later in 2013 including:

- Local Planning Authority approved developments (less than 50MW)
- Scottish Government Section 36 consents (greater than 50MW)

The key areas of focus for the study were ecological impacts, hydrological impacts, landscape impacts and the engineering limitations that require to be considered in the restoration and decommissioning of onshore wind farms. Broader issues such as health and safety, waste and land management issues are beyond the scope of this research. It is recognised that wind farms have been constructed on a variety of sites each with its own unique characteristics in terms of soil types, habitats and land uses. The research and guidance aims to make more explicit the issues to consider and the options for restoration and decommissioning rather than setting out a prescriptive approach for all onshore wind farm sites.

This report is the result of the study team:

- Undertaking a literature review;
- Investigating domestic and international examples of decommissioning;
- Investigating of decommissioning plans from other industries; and
- Engaging with industry stakeholders (see workshop summary in Annex 1).

It presents the research findings and provides the principles for the development of a Restoration and Decommissioning Plan (RDP) template to assist SNH produce good practice guidance. Areas of enquiry beyond the scope of this research have been identified for future study. The report is structured as follows:

- Chapter 2 - Restoration and Decommissioning Plans for onshore wind farms
- Chapter 3 - Decommissioning – the construction perspective
- Chapter 4 - Natural heritage – consideration of restoration and decommissioning impacts, mitigation and monitoring

- Chapter 5 - Options for end-of-life infrastructure
- Chapter 6 - Conclusions and Recommendations

1.3 Glossary of Terms

Acrotelm - The acrotelm is one of two distinct layers in undisturbed peat bogs. It overlies the catotelm. The boundary between the two layers is defined by the transition from peat containing living plants (acrotelm) to peat containing dead plant material (catotelm). This typically coincides with the lowest level of the water table. Fluctuations in water table in a peat bog occur within the acrotelm, and hence conditions may vary from aerobic to anaerobic with time.

Anthropogenically - Caused or influenced by humans.

Appropriate Assessment - Formal assessment of impacts as required by the Habitats Regulations.

Biodiversity - The number and variety of organisms found within a specified geographic region.

Construction Environmental Management Plan (CEMP) - A structured approach to identifying and managing environmental risks from construction.

Construction Method Statement (CMS) - Detailed statement of methods and mitigation relevant to the construction stage.

Decommissioning - De-energising and removing wind farm infrastructure.

Decommissioning bond or security - Fund in place to cover the costs of restoration and decommissioning.

Environmental Enhancement - A concept that goes beyond mitigation of negative impacts and towards additional positive impacts that benefit the local environment.

Geotechnical - Of or related to the soil and bedrock, especially aspects of foundations and earthworks.

Geotextiles - Permeable fabrics which, when used in association with soil, have the ability to separate, filter, reinforce, protect, or drain.

Habitat Management Plan (HMP) - A structured approach to identifying the objectives, methods and monitoring of habitat management measures.

Landscape and Visual Impact Assessment (LVIA) - A structured assessment of the impacts on landscape fabric and visual effects (see Guidelines for Landscape and Visual Impact Assessment).

Nacelle - A nacelle is a cover housing that houses all of the generating components in a wind turbine, including the generator, gearbox, drive train, and brake assembly.

Pyrolysis - Decomposition brought about by high temperatures.

Repowering - Removal of turbines and replacement with new ones.

Reinstatement - Reinstatement works are those undertaken during construction and aim to address any damage inflicted on the landscape as part of the construction works. Reinstatement is undertaken in parallel to, or as soon as possible following, the construction works in each area, such as the re-dressing of road and track verges and turbine bases (and other areas that may be disturbed as a result of the construction process). Where redressing proves unsuccessful re-seeding and hydro-seeding may be part of reinstatement measures. Reinstatement is primarily undertaken using in-situ and very local materials (turfs and top soils).

Restoration - Restoration works are long term measures aimed at restoring (and in some instances improving) the ecological status of the site with regard to the species and/or habitat management. Re-seeding and hydro-seeding may be part of the restoration works where reinstatement is found to be unsuccessful with regard to establishing plant growth. Restoration is undertaken using site-won, or imported, materials (seed mixes, turfs and top soils).

Vane Testing - An in-situ geotechnical testing methods used to estimate the undrained shear strength of fully saturated clays without disturbance.

Vegetation restorability - The ease by which a target vegetation community can be re-established, that is, in terms of required time periods and external influences, such as provision of propagules and/or intervention/management.

Vibro-stone column - A ground improvement technique to improve the load bearing capacity and reduce the settlement of the soil.

Wind Farm - A collection of wind turbines, generally with a 20 to 25 year planning permission.

Zone of Visual Influence - The area from which a development or other structure is theoretically visible.

2. RESTORATION AND DECOMMISSIONING PLANS FOR ONSHORE WIND FARMS

2.1 Introduction

This chapter presents the context for the research by exploring the principles and key drivers for RDPs. It sets the scene by describing:

- The overarching principles from a natural heritage perspective;
- What is meant by Best Practicable Environmental Option (BPEO);
- Examples of current RDP practice;
- Planning and policy drivers; and
- Decommissioning bonds and leases.

The final section summarises the main drivers for providing guidance for RDPs.

2.2 Overarching Principles

The overarching principles provide a framework within which guidance and good practice can be developed:

- Good restoration is the overarching principle with decommissioning an activity within this;
- RDPs may provide the opportunity to encourage improved restoration at decommissioning stage (especially if this was insufficient at construction stage) than was originally envisaged and should result in sites being left in better condition than the original baseline;
- To prove the ‘reversibility’ of wind farms where all visible traces and all significant environmental impacts are removed (including below ground infrastructure in some cases);
- To devise pragmatic solutions based on the existence of the wind farm;
- To gather evidence through the decommissioning process upon which to base future recommendations, such as standardisation of engineering design elements;
- To be assessed in terms of carbon balance (especially the level of peat disturbance, soil movement, distance to recycling, on site vehicle movements); and
- To inform the decision whether to repower or decommission.

As more experience is gained in planning for restoration and decommissioning onshore wind farms these principles may be developed and refined. However, they are a useful starting point for RDPs and can inform the aims and objectives of a BPEO.

2.3 Best Practicable Environmental Option

The aim of this research is to support the development of guidance that enables the user to reach a BPEO using a similar process adapted to the purposes of a RDP. It is therefore useful to look at the principles of BPEO as outlined below.

2.3.1 Definitions of BPEO

There are a range of definitions for BPEO which each have a slightly different emphasis, for example:

- BPEO has been defined by the Royal Commission on Environmental Pollution (1988) as

> *"the outcome of a systematic consultative and decision making procedure which emphasises the protection and conservation of the environment across land, air and water. The BPEO procedure establishes for a given set of objectives, the option that provides the most benefits or the least*

damage to the environment, as a whole, at acceptable cost, in the long term as well as in the short term".

- The Institute of Environmental Management and Assessment (2013) define BPEO assessment as a method for identifying the option that provides the "most environmental benefit" or "least environmental damage". It assesses the "performance" of different options in a range of criteria such as environmental impact, safety risk, technical feasibility and cost. It uses a combination of qualitative and quantitative assessments of the performance in each criterion, and a weighting of the relative influence or importance of the criteria, to derive an overall score or ranking of the options.

There are two key elements of relevance to RDP; firstly the balance of environmental benefit and damage and secondly the decision making processing and level of consultation.

2.3.2 Objectives

In terms of developing a RDP template the objectives for the BPEO process are of relevance and include:

- Establishing overall environmental impacts of several possible options;
- Comparing relative environmental "performance" of those options, absolutely and with respect to the Developer's goals;
- Highlighting key reasons for differing environmental performance; and
- Providing auditable basis for selection of "good" option.

2.3.3 Outline of BPEO Procedure

Likewise the typical procedure for BPEO provides some steps to consider for the RDP template. These are as follows:

- Define the objectives;
- Generate candidate options;
- Evaluate the options;
- Summarise and present the evaluation;
- Select the BPEO;
- Review the BPEO; and
- Implement and monitor.

The BPEO concept is discussed further in Chapter 6 Conclusions and Recommendations.

2.4 Requirement for Restoration and Decommissioning Plans (RDP)

To date, there has been limited experience in the decommissioning of onshore wind farms due to their expected 25 year life span, the majority having been constructed in the last 5-10 years (see Figure 1). However, there is a growing focus on this as some wind farms begin to reach this threshold and it is recognised that earlier consideration of restoration and decommissioning of sites is required.

The research study reviewed a number of existing RDPs and decommissioning sections for wind farms (onshore and offshore) within Environmental Statements (ES). Case study examples are provided in Annex 2. In the table overleaf we illustrate some of the key findings from a review of decommissioning statements within Environmental Statements (ESs).

Table 1: Decommissioning Statements within ESs and Key Findings of relevance to RDPs.

Finding	Relevance to RDP Guidance
Brevity	Some decommissioning statements are too brief to provide specific enough information.
Vagueness	General and vague statements made. For example, 'all major equipment and structures would be removed from site' and 'all land would be re-instated in accordance with best practice at the time'. It is not clear what is included within the term 'major' or what is likely to be viewed as best practice.
Lack of environmental or ecological appraisal of the preferred methods.	No transparent assessment of preferred methods. For example, criteria for defining appropriate reseeding or turfing techniques needs to be explicit. Source and quantity of materials should be defined.
Description of decommissioning process	A reverse engineering approach is presented but not assessed in terms of BPEO.
Variable detail and lack of evidence for proposed options	Evidence informed guidance is required on issues such as leaving concrete bases in situ, waste implications of other infrastructure left on site, natural heritage implications of removal or retention of infrastructure.

In general, it was found that restoration and decommissioning is not being given adequate or consistent coverage in ESs; there is a need for more detailed description of preferred options and the environmental impacts associated with these; and that quantification and source of restoration materials is insufficient. Onshore wind farms are often described as being relatively easy to decommission and having no legacy of pollution. However, if the restorability of the site is questionable the appropriateness of the original development may also be questioned.

Internationally, Erin Gill, Windpower Monthly, (28 March 2012) writes that there are concerns that

> *'the wind energy industry is right to portray itself as a "clean" and genuinely green energy sector. However, with this image comes the responsibility of making sure that the sector does not rest on its environmentally sound laurels...With the first generation of modern wind farms having been built in Germany, Denmark and California in the late 1980s, these three locations will be at the forefront of dealing with waste and recycling issues as old wind farms are dismantled or, in most cases, repowered...To date, attention in the US has focused on the costs of eventual site restoration and ensuring that financial liability for these costs is properly assigned prior to wind-farm commissioning.'*

More recently, in Scotland, Alistair Munro writes in the Scotsman (23.10.12), that evidence is being sought by stakeholders for clarity on the restoration and decommissioning process before planning consent is given. The wind energy industry is also showing early indications of repowering of sites commencing.

2.5 Repowering

Repowering generally involves the dismantling of existing turbines and replacing them with more efficient turbines which may be larger and fewer. Restoration and decommissioning is the focus of the research described in this report, but consideration of repowering is relevant as many of the same engineering, hydrological, ecological, and landscape issues will arise and a similar step-by-step process may help ensure that these are addressed systematically.

It is also possible that many wind farm sites in Scotland will be repowered rather than completely decommissioned.

Requirements, drivers and the scale of activity for repowering are of interest in the context of the continued sustainable development of renewable energy. In countries like Germany, Denmark, or the Netherlands, wind power is already so widespread that few onshore sites are left on which new units can be built. In these countries, it is more efficient for investors to replace smaller and mid-sized turbines on highly productive sites with newer and larger turbines, rather than just building the new turbines on less productive sites. (European Copper Institute, Walter Hulshorst, 2008).

In Germany, the wind industry has suggested that repowering could reach a rate of 1GW a year, given that just under half of the country's approximately 22,000 turbines are more than ten years old. Another driver behind increased repowering in Germany is its newly revised Renewable Energy Act, which offers an improved financial incentive for repowered wind farms. In 2011, 170 old turbines with a combined generating capacity of 123MW were taken down in the country and replaced with 95 larger turbines with a combined capacity of 238MW (Windpower Monthly, 28 March 2012).

Denmark was the first country to actively support wind repowering, in part because wind turbine installation began in the early 1980s, so a large number of aging, small (< 75 kW) wind turbines exist throughout the country. Denmark recognized that these smaller, aging turbines were an obstacle to new project development, and that removing and replacing those turbines would require an overt and explicit incentive. Denmark's repowering program has led to the replacement of two-thirds of the oldest turbines in the country.

At present there is no proactive repowering policy in Scotland but it may be a possibility with the continued drive to meet renewable energy targets. For the purpose of this study repowering in terms of its potential impact on site is considered alongside decommissioning.

2.6 Onshore Wind Farms in Scotland

Onshore wind farms were first consented in Scotland in the mid-1990s. Since then there has been considerable development at different scales, especially since 2006.

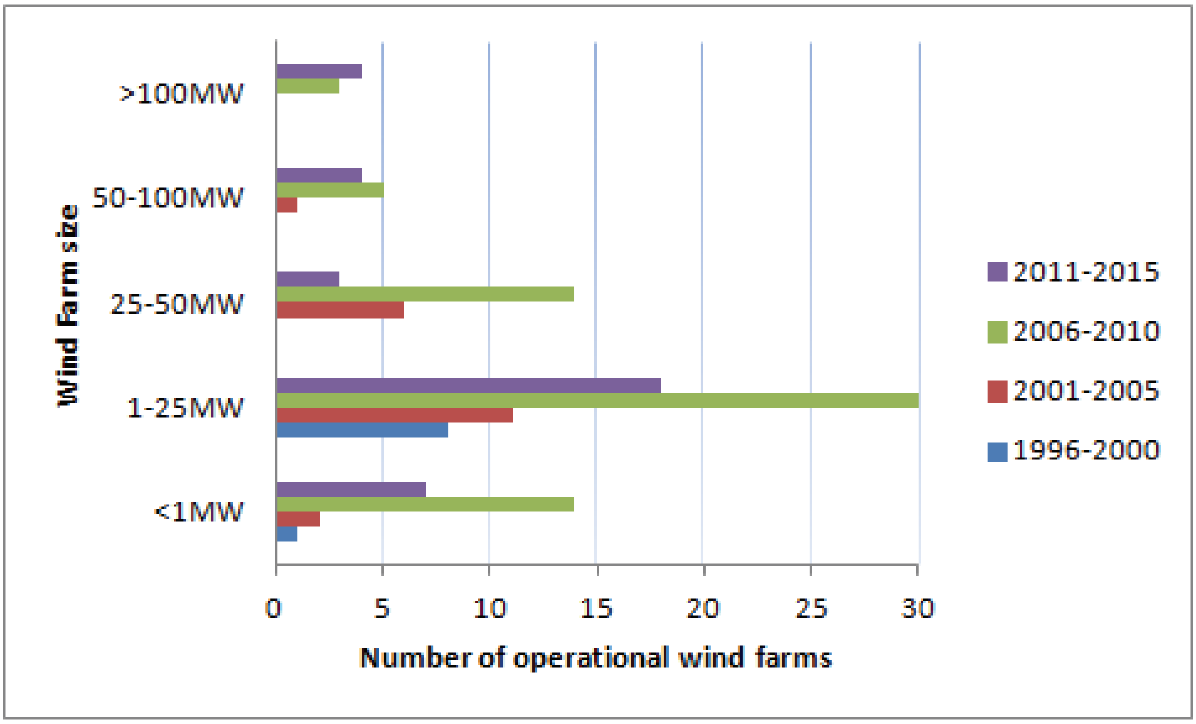

Figure 1: Indication of size and age of current wind farms in Scotland. Adapted from (Department of Energy and Climate Change, 2013).

CASE STUDY 1 – Windy Standard (Dumfries & Galloway)

Windy Standard is an example of one of Scotland's earliest wind farms becoming fully operational in November 1996. The wind farm is located on agricultural land in the hills above Carsphairn Forest, 9km north of Carsphairn, Dumfries & Galloway. The first phase consisted of 36 wind turbines each of 600 kilowatts (kW) maximum output, manufactured by Nordtank A/S of Denmark. The wind farm has a combined maximum power of 21.6 megawatts (MW). A second phase was consented in 2007.

Figure 2: Windy Standard Wind Farm (Courtesy RWE npower).

The Planning Conditions (Dumfries and Galloway Regional Council consent under Town and Country Planning (Scotland) Act 1972 and Town and Country Planning (General Development Procedure) (Scotland) Order 1992) stated that:

> *'The permission shall be for a period of 25 years from the date of approval. Within 6 months of the expiry of that period, unless further planning application is submitted and approved, all wind turbines, ancillary equipment and building shall be dismantled and removed from the site and the land restored to its former condition, or such other means of restoration as may be agreed, to the satisfaction of the Regional Council as Planning Authority.'*

The reason given for this condition was to enable the Planning Authority to retain control over the long term use of the land and to ensure satisfactory reinstatement.

Correspondence regarding the application by National Wind Power (9th October 1995) made the following statement in terms of decommissioning:

'We agree that a restoration plan is necessary on decommissioning. This will be drawn up in association with the landowner and the relevant planning authority at the time of decommissioning, and in the light of monitoring of track reinstatement during the life of the wind farm. The escrow accounts for decommissioning (£60,000 plus interest accrued for each operating company, giving a total of £120,000) cannot be released to the wind farm operating companies until restoration is complete. In the unlikely event that the wind farm has insufficient funds to complete restoration (the scrap value of the turbines will exceed the restoration costs) the landowner is entitled to draw upon these funds to complete restoration'.

2.7 Planning Permission

RDPs are increasingly required prior to planning consent for wind farm developments. This section provides an outline of planning process, the current requirements and how these relate to RDPs.

In Scotland, some applications to build and operate power generating stations and to install overhead power lines are made to the Scottish Ministers. Applications are considered by Scottish Ministers where they are:

- for electricity generating stations in excess of 50 megawatts (MW)
- for overhead power lines and associated infrastructure, as well as large gas and oil pipelines

Such applications cover new developments as well as modifications and extensions to existing developments. Applications below these thresholds are made to the relevant Local Planning Authority.

2.7.1 The Planning Process

Certain wind farm developments require the proposals to be subject to an Environmental Impact Assessment (EIA) either due to their size or if they are likely to have a significant effect on the environment, by virtue of factors such as its size, nature or location. The requirement for EIA comes from European Directive 2011/92/EU. In Scotland, the EIA Directive has been brought into Scottish law through a number of Scottish Statutory Instruments relevant to individual consenting regimes.

The findings of the EIA are presented in an Environmental Statement (ES), which accompanies the planning application. Statutory Consultees (Regulator) including SNH, SEPA and Historic Scotland, have a duty to provide relevant environmental information held by them to further the EIA process, particularly providing it to applicants and proposers preparing an environmental statement, unless the information is held in confidence (SNH, 2009).

The Town and Country Planning (Environmental Impact Assessment) (Scotland) Regulations 2011, Schedule 4 lists the information for inclusion an ES. Of particular interest to restoration and decommissioning are:

- 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:
    - (a) the existence of the development;
    - (b) the use of natural resources;

- (c) the emission of pollutants, the creation of nuisances and the elimination of waste, and the description by the applicant or appellant of the forecasting methods used to assess the effects on the environment.

- A description of the measures envisaged to prevent, reduce and where possible offset any significant adverse effects on the environment.

As such there are no specific requirements in the regulations concerning the restoration and decommissioning of wind farm sites. However, the interpretation of the regulations is a matter for the Planning Authority and the fact that a particular type of development is not specifically identified in one of the Schedules does not necessarily mean that it falls outside their scope (Paragraph 33 of Circular 3/2011 Guidance on The Town and Country Planning (Environmental Impact Assessment) (Scotland) Regulations 2011). For example, demolition works may constitute a 'project' for the purposes of the EIA Directive, and the schedules of the regulations refer to sectoral categories of projects, without describing the precise nature of the works, which may include restoration and decommissioning.

2.7.2 Carbon Impacts

The development of onshore wind farms contributes to renewable energy targets and the transition to a low carbon economy. However, the construction, operation and decommissioning of onshore wind farms has its own carbon impact, which is increased when the site is on peat land. The potential carbon impacts of the RDP are part of this assessment; however, in order to assess this, the RDP will need to include an appropriate level of detail in terms of the mass balance of materials to be removed, left in situ or brought on to the site plus the potential for carbon release from disturbed peat.

In determining whether an application to build and operate a wind farm should be consented, the assessment of potential carbon losses and savings is a material consideration for Scottish Ministers and planning authorities. Although Ministers do not consider that it is appropriate to set a "bar" for what is an acceptable or unacceptable payback period they do expect Developers to follow best practice for minimising carbon emissions and disturbance of peat, and provide a carbon payback calculation to assess proposals (Scottish Government, 2011).

2.7.3 Planning conditions

Restoration and decommissioning of wind farms is currently usually required through the use of a condition or series of conditions, attached to the planning permission but in some circumstances a legal agreement, known as a Section 75 Agreement, between the Developer/Operator, Landowner and Planning Authority can be used to secure these objectives.

2.7.4 The Role of Environmental and Ecological Clerks of Work (ECoW)

Due to the ecological sensitivity of some onshore wind farms sites, the planning conditions for an approved site may require the employment of an ECoW during the construction and operation of the wind farm. There are also examples of this during decommissioning and repowering of sites such as, Spurness Wind Farm, Orkney (SSE Renewables).

The Association of Environmental and Ecological Clerks of Works (AEECoW) has been developed to raise professional standards amongst those providing Env/ECoW services whilst promoting Env/ECoWs as valuable members of site development teams. AEECoW defines Env/ECoWs as an environmental or construction professional with direct responsibility for monitoring compliance with environmental legislation, policy or mitigation. Env/ECoWs may be engaged during the construction or operation phase of any given development where environmental compliance requires to be audited or monitored.

Env/ECoWs will normally be professionally qualified environmental or construction professionals such as environmental consultants, surveyors or contract managers.

The role of the EnvCoW or ECoW can include some or all of the following activities:

- Regular surveying to monitor environmental/ecological sensitivities at the site. These may be sensitive receptors such as a protected watercourse or static sensitivities such as badger setts or more transient features such as nesting birds;
- Monitoring construction activities in close proximity to sensitive environmental receptors to ensure impacts are minimised, i.e. preventing pollution run-off to rivers;
- Auditing of site management plans/method statements to ensure project compliance;
- Providing advice to contractors on the delivery of agreed mitigation measures;
- Liaising with stakeholders such as statutory regulators, planning officials and members of the public; and
- Preparation of compliance reports for clients and stakeholders and advisory reports for site managers/staff.
- A Hydrological Clerk of Works (HCoW) has a similar role to cover hydrological issues on site.

2.7.5 Habitat Management Plans

Many, but not all, wind farm sites have an associated Habitat Management Plan (HMP). These usually contain long-term prescriptions for the management of habitats to encourage species of biodiversity interest, as well as desired habitat composition and structure, for the duration of the life of the wind farm. They are often a means by which residual impacts of the original development can be compensated. HMPs are separate, but often closely related, to construction phase restoration plans; they may be similarly interlinked with decommissioning restoration proposals. They also relate to the management of carbon emissions from the site.

There is usually no obligation on a Developer to continue to fund the HMP beyond the lifetime of the planning consent and expiry of Landowner agreement, and many of these plans involve off-site habitat restoration or enhancement which is likely to be unaffected by decommissioning proposals. However, repowering proposals will, through the appropriate EIA process, present an opportunity to continue, alter or extend the HMP.

2.7.6 Current restoration and decommissioning guidance

The duration of planning consent for onshore wind farms is normally 25 years although there may be variations to include, for example, an additional 3 years for the construction phase. At the end of the consented life of the developments (or earlier) there are two options:

- Re-powering and Restoration
- Restoration and Decommissioning

Guidance available from Scottish Government (2012) states that:

> *"In many cases, wind turbines can be decommissioned and sites cleared and restored easily and rapidly. Turbine bases tend to be left 'in situ' to avoid damage taking place through removal. Planning authorities should ensure via conditions and/or legal agreement that site restoration takes place either on the expiry of the consent or in the event of the project ceasing to operate for a specified period. Prior to the expiry of consents, proposals may come forward to extend the life of the project by re-equipping or replacing the original turbines with new ones. While there are*

obvious advantages in utilising established sites, such cases will have to be determined on merit and in the light of current policy considerations".

2.8 Landowner's Perspective and Restoration and Decommissioning Bonds

The importance of decommissioning security is of concern to the Landowner and is often more closely considered in the ground lease and other contractual arrangements with the Developer than the consenting process and EIA. It is in the Landowner's interests that the lease contains provisions requiring the lessee to remove the wind farm and to restore the land to its original condition otherwise the land could be returned to the Landowner with a non-operating energy facility and all related structures left on it. Such a situation could limit the use of the land and also result in removal costs and expenses, unless reimbursement of the same has been addressed at the outset of the lease. This could result in landscape and visual issues and detract from the value of the land.

Including a decommissioning provision in the ground lease ensures that the Developer will ultimately be responsible for the decommissioning of the wind farm. This would include the associated environmental factors to be considered such as, noise, dust, public safety, water quality, waste and hazardous materials, impact on habitats, wildlife and livestock.

Decommissioning bonds and security have been developed for wind farms in Scotland but knowledge of this is rather fragmented due to commercial sensitivities and an organic approach of bespoke arrangements between Developer, land owner, the Planning Authority and their legal advisors, Biricik and Haroun (2010) explain how the experience of public Landowners in the United States (US) has led to the development of regulations concerning the removal and restoration requirements of energy projects which include:

- Removal of all foundations, pads and underground electrical wires to a depth of four feet below ground surface;
- Removal of all hazardous materials from the property and disposition of hazardous material in accordance with federal and state law;
- Restoration of the site to its original condition prior to location of the generating facility, subject to reasonable wear and tear;
- Restoration of site vegetation;
- Removal of all structures (including transmission equipment and fencing) and debris to a depth of four feet, restoration of the soil, and restoration of vegetation within six months of the end of project life or facility abandonment; and
- Removal of all access roads (unless the Landowner desires to keep the access roads) and implementation of a post-decommissioning storm run-off plan.

In the case of such regulations in the US these are considered at the time of developing the ground lease such that they can be the responsibility of the lessee rather than fall to the Landowner. In the UK, the Developer's obligations under the lease tend to be based on the contents of the ES and therefore, in terms of restoration and decommissioning, will be reliant on the level of detail provided within this.

The cost of the decommissioning (in the US) can be provided for by agreeing security before commencing construction on the site. This can take several different forms:

- A letter of credit from a financial institution that is creditworthy or that is otherwise subject to the Landowner's approval, and the form of the letter of credit should similarly require Landowner approval;
- A guaranty, with similar considerations to the letter. For example, the Landowner will want to analyse the credit-worthiness of the entity providing the guaranty and perhaps set forth

minimum requirements in the lease agreement as to who may act as a guarantor and what form the guaranty should take.
- A cash account, held by the Landowner, to which the Developer makes periodic contributions until the fund reaches a denominated amount which equals the parties' reasonable estimate (or the estimate of a neutral third-party consultant) of the costs required to decommission the project.

The decommissioning security is also referred to as a Reinstatement or Decommissioning Bond. For example, for Brown Muir Wind Farm (near Elgin) the Developer Vento Luden (2012) states that a provision will be agreed with the Local Authority and contained within the Section 75 agreement. This sum of money will be held in a bond available for use by either the Landowner or the Planning Authority and will cover the full decommissioning costs of the wind farm and reinstatement of the land. The bond is required to provide security in the event that the Developer defaults on their obligation to decommission and restore the wind farm. If the Developer fulfils their obligations this is at their own cost, the bond cannot be drawn on by the Developer.

In SSE Renewables British experience, where a Planning Authority has required a Section 75 Agreement the Decommissioning Bond (i.e. security) is also put in place prior to commencing construction. Typical values are of the order of £15K per MW installed to cover the cost of breaking out foundations to c.1m below ground level, some track reinstatement and removal of cables and substations. The dismantling of the turbines is assumed to be paid for by the monies recovered from onward sale or scrap value of the components.

2.9 Summary – Requirement for Decommissioning Plans

This chapter has provided an outline of the main drivers for RDPs for use both in decommissioning and repowering of wind farm sites. The requirement for RDPs is often not fully specified but is dependent on the interpretation of the regulations and policies of the Planning Authority. It can also be influenced by the policies and aspirations of the Statutory Consultees (Regulators), such as SNH and SEPA, and by other relevant stakeholders such as the Landowner and Developer.

The main drivers for RDPs come, therefore, from a variety of perspectives including the Planning Authority, Regulator, Developer and Landowner. These drivers are summarised below.

- To gain planning consent through provision of information within the ES;
- As a condition of planning and to comply with planning regulations;
- To establish appropriate decommissioning bonds/security;
- To protect the Landowner and Planning Authority;
- To demonstrate what 'reversible' means;
- To maintain a low carbon approach to sustainable energy;
- To optimise habitat enhancement;
- To develop good practice;
- To develop understanding in terms of carbon, costs, waste implications, reuse and recycling markets.

3. DECOMMISSIONING – THE CONSTRUCTION PERSPECTIVE

3.1 Introduction

The decommissioning of a wind farm will ultimately require removal of infrastructure and further construction related activities to re-instate the site. The removal of elements of the wind farm will be a relatively short-term activity, but the legacy of what is left and what is done to restore the site can have a much longer term impact on the site.

The construction issues associated with decommissioning of a wind farm will be driven by a number of factors, which include:

- After use of the site;
- An assessment of the environmental impact of activities and longer term stabilisation requirements of the site; and
- Costs associated with decommissioning and after care/management.

This chapter focuses on setting out the construction related activities of decommissioning and what mitigation measures can be undertaken to minimise the environmental impact. The potential options for reuse and recycling of infrastructure removed from wind farm sites are discussed in Chapter 5.

3.2 Key Construction Elements

In order to address the construction related activities associated with the restoration and decommissioning of a wind farm, it is important to understand the original design related issues, residual hazards associated with the development and the materials that have been used to construct the wind farm.

Wind farms will typically comprise of the following construction elements:

- Junction between public highway and site access tracks;
- Site access tracks (usually unbound crushed rock), which may include floating roads and/or cut tracks;
- Hardstandings such as compound areas, crane pads, laydown/waiting areas (usually unbound crushed rock);
- Wind turbines founded on ground bearing reinforced concrete bases or piled reinforced concrete bases, including transformers located on concrete plinths;
- Sub-station and control building consisting of concrete pad, switchgear, hardstandings and a brick/stone/timber/steel portal frame structure;
- Cable trenches; and
- Miscellaneous works such as surface water management systems, culverts, bridges, borrow pits, earthworks (cuttings or embankments) etc.

The Construction (Design and Management) Regulations (CDM) 2007 will have been applied to most wind farm construction projects. These regulations set out to reduce the number of health and safety related accidents associated with the construction, maintenance/operation and decommissioning of structures (structures being defined within the regulations and applicable here to wind farm developments). The emphasis tends to be placed on addressing health and safety issues associated with the construction, and then maintenance and operation of sites, with less focus on decommissioning although CDM requires decommissioning to be considered as part of the design. This is particularly the case with wind farms, as there is limited experience of decommissioning of such sites from which to draw good practice.

Whilst the CDM Regulations address health and safety issues associated with a development, the environmental issues associated with developments including wind farms are generally addressed through the planning process and to some extent any habitat or conservation management plan. The construction related activities at wind farm sites are also addressed through the development of Construction Method Statements (CMS), and Construction Environmental Management Plans (CEMP). These are then implemented by adoption of good practice by contractors and are typically monitored during the construction phase by an ECoW. However, ECoWs are not 100% utilised across projects. Some Developers will only use them where formally required to under planning while others would employ an ECoW as standard good practice.

It would be expected that plans and technical details for the site which would inform the decommissioning process would be available from sources such as planning and EIA documents, the Health and Safety File, Operations and Maintenance Manual, and various other site wide information. These documents would be used in order to provide suitable information regarding the structures, their locations and their materials, and it should be possible to ascertain any residual hazards from this information.

Where information is not available, or there is a risk that conditions have changed, site surveys and investigations should be undertaken to allow a detailed assessment of material types, quantities, risk of contamination and the impact on ground/surface water from the decommissioning works.

For the purpose of considering the impact of the decommissioning process, it should be assumed that the site is to be returned to at least its original condition, or as close to this original condition as possible or appropriate, and that infrastructure has to be removed from site.

This may not always be the case, and it is possible that desired outcomes, including stability of the site, can be achieved with minimal post-decommissioning works. The original condition of the site may not be the desired outcome, as the site setting may have changed since the wind farm was developed or enhancement might be desired. Environmental enhancement is a concept that goes beyond mitigation of negative impacts and towards positive impacts that benefit the local environment (University of Strathclyde 2012).

3.2.1 Process Overview

Good practice in relation to wind farm design and construction, and health and safety, develops over time, and may have changed during the wind farm's operational life. Historically planned procedures for decommissioning may in fact differ from what is required at the point of delivery, and therefore the process may require further detailed attention nearer the time of the decommissioning. Similarly, there is no guarantee that measures now deemed to be good practice were employed during construction, and this may leave a legacy of issues that need further consideration and investment at the decommissioning stage. Reviewing the RDP on a regular basis throughout the operational life of the wind farm could help to pre-empt issues that may arise at the decommissioning stage.

Therefore, the process of decommissioning from a practical construction perspective has to provide a flexible framework for a range of situations that may exist.

A logical sequence for planning and executing the decommissioning with regards to the construction activities is suggested as follows:

- De-energising of the site. This would involve initially high voltage (HV) disconnection or isolation in the event of re-energising of the site or partial decommissioning, followed by low voltage (LV) disconnection of affected turbines.
- Handover of site responsibility to a Principal Contractor (CDM responsibility) and management of Operator access and site set up.
- Decommissioning of structures. This is most likely to be a reverse of the installation procedure. This is likely to involve:

a) Stripping out of turbine internals and removal of transformer;
   i. Controlled dismantling of turbines (blades, nacelle, tower);
   ii. Removal of turbine base and backfilling void;
   iii. Removal of cables (whole or partial) and making good trenches (throughout);
   iv. Removal of crane pads (whole or partial) and backfilling/landscaping;
   v. Removal of Sub-station and associated buildings;
   vi. Removal of access tracks (whole or partial) and associated water crossings, passing areas etc. Working from end point towards exit point;
   vii. Reinstating watercourses and /or removing watercourse crossings;
   viii. Final landscaping (seeding) and making good remaining borrow pits etc; and
   ix. Make good public road junction, if required.

b) Providing 'as-built' documentation including residual risks to Landowner and Planning Authority.

c) Monitoring and maintaining the site to achieve end-use requirement.

The photographs below show the decommissioning of the nacelle and towers at Spurness Wind farm in July 2012.

Figure 3: Lowering of wind turbine nacelle at Spurness Wind farm, Orkney. Courtesy SSE Renewables.

Figure 4: Cutting tower base at Spurness Wind farm, Orkney. Courtesy SSE Renewables.

3.2.2 Key Elements of Decommissioning

A summary of the key decommissioning elements and method of removal is presented in the table below.

Table 1: Key decommissioning elements and method of removal.

Key Element	Components	Constituents	Methodology / Options
Turbines	i. Blades	Resin / fibre glass	Crane on existing/original crane pad to dismantle.
	ii. Blade hub and nose cone	Cast iron / resin / fibre glass	
	iii. Nacelle / Gear Box	Iron / steel / copper / resin / silica	
	iv. Tower	Steel (sections)	
Turbine Base	i. Backfill above and around base.	Suitable engineering fill / crushed rock	Excavator and dump trucks. Either remove or use as backfill (at same or other location on site)
	ii. Concrete Bases	Concrete / steel reinforcement	Hydraulic breaker or explosive charges can be used to aid. Need steel burning equipment to cut through re-bar. Remove to recycling area. Then remove off site or reuse if possible.
	iii. Concrete Piles	Concrete / steel reinforcement and	Extract and then break up and remove for recycling/disposal. Cap ends if partially removed. If

		casing	piles are withdrawn backfill will be needed with suitable material.
Transformer	i. Transformer	Electrical components	Remove on low-loader.
	ii. Concrete Base	Concrete / steel reinforcement	Break and remove with hydraulic breaker
Crane Pad	i. Hardstanding	Crushed rock / geogrid reinforcement. Weathered and possibly vegetated	Excavate with bucket and load onto dumper for onward use. Alternatively retain, regrade as required and cover with growing medium.
	ii. Soils	In-situ soils retained	Excavate with bucket and load onto dumper for onward use. Excavator and bulldozer if spreading in-situ.
Tracks	i. Forestry Spec Roads (granular fill) (also floating roads)	Crushed rock / possibly geotextile separators / geogrids on weaker ground	Excavate using excavator and dumpers. Work from end point back to access point. Reinstate as required.
	ii. Bituminous/ Asphaltic Roads	Bitmac/tarmac/bitumen / Type 1	Excavator to break out or plane out if volume permits. Remove material off site with tippers/dump trucks. Can remove down to Type 1 if risk assessment allows. Reinstate with suitable soils.
Buildings	i. Control Building / Staff Building	Timber / brick / prefabricated panels / glass / steel / concrete Buried and O/H Services.	Internal contents removed manually and taken off site. Excavator to demolish buildings if not modular. Concrete slab removed. Ground reinstated.
Substation	iv. Switchgear / Cabling	Switchgear / Cabling Other miscellaneous – fencing / lighting etc	Isolation of electrical power. Controlled removal using cranes and specialist contractors.
	ii. Hardstanding	Compacted granular material / concrete plinths	Removed using excavators and dumpers/tippers
Cables	i. Cables	Copper / Aluminium / Fibre optic / plastic and rubber sheaths	Remove using excavator to pull out of trench or duct. Load onto tippers and remove from site.

4. NATURAL HERITAGE – CONSIDERATION OF RESTORATION AND DECOMMISSIONING IMPACTS, MITIGATION AND MONITORING

4.1 Introduction

This chapter considers the key natural heritage issues in terms of hydrology, ecology, and landscape of wind farm infrastructure being left in situ or removed.

4.2 Potential Impacts on Hydrology and Decommisioning Options

Construction work associated with decommissioning wind farms and their associated infrastructure (e.g. tracks, sub stations, borrow pits control buildings etc.) has the potential to impair the quality and quantity of the ground and surface water environment and habitats (e.g. peat, mires and flushes) and fisheries that depend on water. In addition, there is the potential, without appropriate controls, that the quality of water shed from the site may change and/or flood risk may be increased as a result of inappropriate decommissioning. The effects on water quality and quantity therefore need to be considered.

Similarly, works undertaken to restore or create ecological habitat, if undertaken inappropriately can also have an adverse impact on ground or surface water as a consequence of altering rainfall runoff relationships or changing the proportion of rainfall that is available to infiltrate into the ground and recharge groundwater.

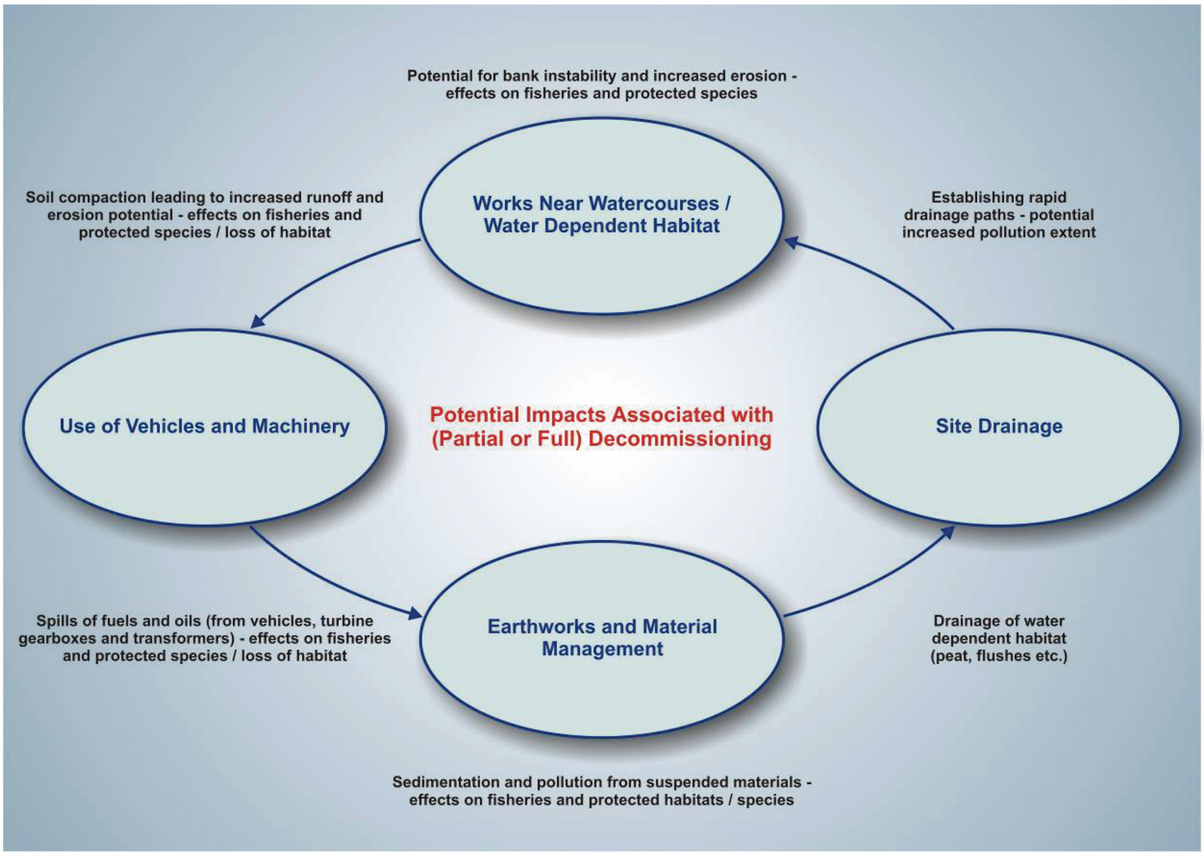

Figure 5: shows a summary of potential impacts that might arise as a result of wind farm decommissioning and how they might affect the ground and surface water environment.

A thorough understanding of a site's hydrology and its response to rainfall, its hydrological and hydrogeological setting, as well as habitats on site and downstream of the site that might be water dependent, is critical to assess how the decommissioning strategy (e.g.

construction works, habitat restoration, ground stability etc.) might affect ground and surface water. Only with this understanding can the decommissioning strategy be determined and appropriate mitigation measures identified.

Impacts associated with decommissioning should have been addressed in the ES, or planning statement for applications below the EIA threshold, which would have been prepared in support of the original planning application and consenting process. It is also possible that decommissioning will have been considered in the wind farm CEMP. However, it is noted that these documents often focus on potential construction and operational impacts rather than on potential decommissioning impacts. A more detailed RDP would be beneficial to understand the impacts and options more fully.

Potential impacts associated with wind farm decommissioning are similar to construction impacts, and issues to be assessed might include:

- the treatment of turbine foundations (e.g. remove, break-up, leave in situ) and the potential long term effects on ground and surface water movement and runoff;
- the treatment of access tracks, watercourse crossings, crane pads and lay-down areas (e.g. will their size be reduced, will they be removed) and the effects on water runoff, water quality, aquatic communities and water dependant habitat;
- reinstatement / management of cut-off and trackside drains; and
- decommissioning of the cable trench(es), electrical substation(s) and grid connection(s)

The hydrological assessment should make reference to related disciplines (particularly peat stability, landscape and ecology) as works that affect the water environment may also effect or benefit these subject areas.

The use of machinery, disturbance of soils and potential alteration of drainage regimes can have a range of (positive or negative) impacts on water quality, water resources and storm water runoff. Table 2 shows a summary of possible generic hydrological effects of wind farm decommissioning if they are not appropriately mitigated and provides a guide to issues that need to be considered when developing a decommissioning plan. The list of issues is not exhaustive, and depending on the hydrological site setting, more or fewer issues may need to be considered.

Table 2: Possible generic effects on hydrology associated with wind farm decommissioning.

Possible Generic Effects on Hydrology Associated with Wind Farm Decommissioning		
Activity	Potential Consequences	Potential Effects (Direct and Indirect)
Peat excavation & soil stripping	Change to the run off rates and paths.	Detrimental effects / significant changes to habitats, species & designated sites.
Excavation works for turbine removal and borrow pit restoration	Contamination hazard	Detrimental effects / significant changes to habitats, species & designated sites
Excavation for removal of cables and grid connection	Change and deterioration in surface & groundwater quality	Detrimental effects on private and public water supplies
Accidental chemical spillages (from machinery and wind farm infrastructure)	Sediment release from areas of soils movement	Detrimental effects on fisheries and water quality
Use of non-sewage mains connected facilities	Ground instability that could lead to sediment release	Increased flood risk
Use and removal of culverts for river crossings	Impediment of or creation of preferential groundwater flow paths	Reduction in low river flows
Use and removal of tracks, storage compounds and laydown areas	Reduction in water levels in peat and soils	
	Alteration to watercourses	

4.2.1 Criteria to be Considered when evaluating Hydrological Options

4.2.1.1 Legislation and Good Practice Guidance

The decommissioning of a wind farm should be undertaken using available technical guidance, relevant Pollution Prevention Guidelines (PPG) and other codes of good practice in order to limit the potential for impacts on the ground and surface water environment. Much of the guidance has been written to comply with the requirements of National and European legislation which includes:

- Habitats Directive (2007)
- The Conservation (Natural Habitats) Regulations 1994;
- Scottish Government (2012) Habitats Regulations Appraisal - Development Plan: Advice sheets;
- Scottish Government (2010) Scottish Planning Policy;
- Water Environment (Controlled Activities) Regulations, 2011;
- Flood Risk Management (Scotland) Act 2009;
- EC Water Framework Directive (2000/60/EC), 2000; and
- Water Environment and Water Services (Scotland) Act 2003.

This legislation provides the criteria against which proposals for wind farm restoration and decommissioning can be assessed.

Little guidance has been written specifically on the decommissioning of wind turbines and their associated infrastructure, however, there are documents that are relevant to this activity. The following guidance documents describe ways of minimising potential impacts associated with development of wind farms (and thus potential effects associated with construction activity required to decommission a site), or of ancillary features, such as roads:

- Good Practice during Wind Farm Construction (Ver1), A Joint Publication by Scottish Renewables, Scottish Natural Heritage, Scottish Environment Protection Agency and Forestry Commission Scotland, October 2010;
- Floating Roads on Peat – Scottish Natural Heritage and Forestry Commission, August 2010;
- Land Use Planning System – SEPA Guidance Note 4 Version 6 (Planning Guidance on Wind Farm Developments), Scottish Environment Protection Agency, 12th March 2012;
- Developments on Peatland: Guidance on the Assessment of Peat Volumes, Reuse of Excavated Peat and the Minimisation of Waste (Version 1), Scottish Renewables and Scottish Environment Protection Agency, January 2012;
- Forests and Water – UK Forestry Standard Guidelines. Forest Commission, 2011;
- Engineering in the Water Environment Good Practice Guide - Construction of River Crossings, First Edition, Scottish Environment Protection Agency, April 2008;
- Control of Water Pollution from Construction Sites – Guide to Good Practice, CIRIA, 2002;
- Environmental Good Practice on Site C650, CIRIA, 2005;
- Control of Water Pollution from Linear Construction Projects C649, CIRIA, 2006;
- The SuDS Manual C697, CIRIA, 2007.

In addition, many planning authorities, and the National Park authorities, have policies that have been written specifically to safeguard the water environment, water dependent habitat and water users. Prior to decommissioning a wind farm, proposed works should be assessed for potential adherence to these policies.

Most of the guidance documents promote the use of sustainable drainage systems (SUDS). These are passive drainage measures that seek to safeguard water resources by replicating the rate and quality of runoff to pre-development conditions and the principles are directly relevant to managing water on wind farm sites.

4.2.1.2 Existing Site Specific Reference Material

Many of the potential decommissioning impacts on the water environment are similar to the potential impacts associated with construction of a wind farm. Therefore the ES and/or planning statement and accompanying impact assessments prepared at the time of the original planning application should provide a useful initial screening of sensitive habitats and water features near to site and that might need to be considered as part of any decommissioning plan. Legislation, and standards, as well as the local environmental baseline, may have changed since the original impact assessments were completed, and any decommissioning proposals should be assessed against these new criteria and circumstances.

If a CEMP was prepared prior to construction, and maintained during development and operation of the wind farm, this is likely to provide a useful site specific reference regarding any difficulties encountered during construction (and therefore might be expected during decommissioning) and for assessing potential impacts and mitigation measures that may be required to safeguard the water environment.

When designing the RDP reference should be made to other construction management plans (e.g. drainage management plan, peat management plan, pollution management plan etc.).

4.2.1.3 Site Specific Considerations

Recommendations for infrastructure removal should reflect techniques and approaches that would result in the least disturbance to the water environment, subject to the wider aims of the decommissioning strategy.

Any mitigation measures proposed should reflect the hydrological site setting and be site specific. They might, for example, consider the potential decommissioning options shown in Table 3.

Table 3: Matrix to Assess Possible Impacts on the Water Environment and Potential Mitigation.

Element of Wind Farm Infrastructure	**Potential Existing Hydrological Impact and Considerations**	**Potential Decommissioning Options**	**Other Potential Considerations**
Turbine Foundation Removal	• Have existing foundations under drained soils resulted in drying of adjacent habitat? • Do the foundations need to be removed? • Would it be an option to remove part of the foundations? • If all or parts of the foundations are to be left in situ will they pose a long term	• Do nothing – leave all or part of the foundation in –situ • If there is potential for a positive impact associated with turbine foundation removal, assess impacts associated with mobilising plant, undertaking works to the foundations and assess these impacts against those of	• Consider potential for works to effect ecology and ground stability (and other subject areas) that might indirectly effect the ground and surface water environment • Adhere to CAR and General Binding Rules (SEPA 2011) • Develop and agree construction method

	threat to ground or surface water quality? • Would altering the foundation lead to ground instability, ecological impacts or other indirect impacts? • Could works affect water supplies?	leaving the foundations in situ e.g. would the existing water environment be impaired and/or would new water pathways be created which might realise new hydrological impacts or increased under drainage • Identify mitigation measures as required to safeguard water yield and quality	statement prior to works commencing • Wide consequences of considering turbine foundation removal – noise, dust, CDM, waste issues.
Watercourse Crossing / Culverted Watercourse	Are crossings in line with Controlled Activities Regulations (CAR) For example; • Does crossing impede storm water flows and increase flood / erosion risk? • Does crossing impede fish or mammal movement? • Is crossing required following restoration?	• Do nothing – leave culvert in situ • Remove culvert if not required • If culvert required and it impedes flow or fish / mammal movement replace with bottomless arch culvert or single span deck • Identify mitigation measures as required to safeguard water yield and quality	• Works to be undertaken in accordance with CAR (either General Binding Rule or with authorisation from SEPA) • Liaise with fisheries bodies and SNH • Develop and agree CMS prior to works commencing
Track Removal	• Does the track need to be removed? • Has the track significantly altered baseline hydrological conditions? • Would it be an option to remove part of the track (e.g. reduce its width)? • What effect would altering the track have on related disciplines (e.g. ecology and ground stability etc.)? • Could works affect water supplies?	• Do nothing – leave track in situ • If there is potential for a positive impact assess impacts associated with mobilising plant, undertaking works and assess these impacts against those of leaving the track in situ e.g. would the existing water environment be impaired and/or would new water pathways be created which might realise new hydrological impacts or increased under drainage • Identify mitigation measures as required to safeguard water yield and quality	• Consider potential for works to effect ecology and ground stability (and other subject areas) that might indirectly effect the ground and surface water environment • Adhere to CAR and General Binding Rules • Develop and agree CMS prior to works commencing
Drain Blocking	• What effect are current drains having on habitats and hydrology?	• Do nothing – leave drains as they are • If there is potential for a positive impact,	• Consider potential for works to effect ecology and ground stability (and other

	• Are drains required to maintain ground stability? • Do all the drains need to be blocked or would it be appropriate only to block some drains? • Do the drains need long term maintenance? • Could works affect water supplies?	assess impacts associated with mobilising plant, undertaking works and assess these impacts against those of leaving the drains in situ e.g. would the existing water environment be impaired and/or would new water pathways be created which might realise new hydrological impacts or increased under drainage • Identify mitigation measures as required to safeguard water yield and quality	subject areas) that might indirectly effect the ground and surface water environment • Adhere to CAR and General Binding Rules • Develop and agree CMS prior to works commencing
Cable Removal	• Have the cable routes effected baseline hydrology and/or resulted in drying of habitat? • If the cables are left in situ would there be a long term risk to the water environment? • Could works affect water supplies?	• Do nothing – leave the cables as they are • If there is potential for a positive impact associated assess impacts associated with mobilising plant, undertaking works and assess these impacts against those of leaving the cables in situ e.g. would the existing water environment be impaired and/or would new water pathways be created which might realise new hydrological impacts or increased under drainage • Identify mitigation measures as required to safeguard water yield and quality	• Consider potential for works to effect ecology and ground stability (and other subject areas) that might indirectly effect the ground and surface water environment • Adhere to CAR and General Binding Rules • Develop and agree CMS prior to works commencing

Where works are undertaken that could affect the water environment, mitigation measures will need to be agreed locally with Regulators (e.g. SEPA) and third parties with an interest in the water environment (e.g. Scottish Water, Fishery Boards and Trusts).

Mitigation measures agreed should be incorporated in the RDP. Any specific method statements should form part of the documentation issued to contractors tendering to undertake decommissioning works.

4.2.2 Decommissioning, Monitoring and Management - Hydrology

As is common during wind farm construction, it is anticipated that a programme of water monitoring would be undertaken prior to, during and following decommissioning works. The scope of the monitoring should be dependent on the site setting and, in particular, on the sensitivity of the water environment, the extent of water dependent habitat and local water use.

Notwithstanding this, it is anticipated that the following monitoring routine may be required:

- daily visual monitoring of watercourses during decommissioning works;
- quality monitoring of key watercourses prior to, during and following decommissioning;
- quality monitoring of private or public water supplies that could potentially be effected by the decommissioning works;
- habitat monitoring to assess saturation in water dependent habitats; and
- in certain cases it may be appropriate to carry out invertebrate monitoring in watercourses to assess for long term change in water resources.

In addition, and in common with wind farm construction works, an ECoW may be employed during the decommissioning works to provide onsite and day to day advice with respect to water management and habitat protection.

If a potential ground stability risk has been identified as part of the decommissioning assessment, it may also be appropriate to maintain a geotechnical risk register and to carry out monitoring to assess for potential ground movement, that without mitigation and monitoring, could realise an indirect impact on ground or surface water.

Provision should be made for agreeing the scope of any monitoring with SEPA, SNH and, if appropriate, fishery bodies. A plan should also be made for reporting the monitoring data and, where appropriate, for agreeing actions should a detrimental impact on water flow or quality be detected.

4.2.3 Other Post-Operational Phase Hydrological Conditions

The original planning application, associated impact assessments and/or a CEMP/CMS, should provide valuable sources of information on the potential effects of decommissioning on the water environment. However, the site's setting may have changed since the original site assessments were completed and the wind farm constructed. Changes that might have occurred could include:

- Legislation. It is likely that legislation applicable at the time the wind farm was consented and constructed will have been superseded such that the impacts associated with decommissioning works should be assessed against current standards which may include Water Framework Directive objectives;

- Climate change. Over the consenting and operational life of a site it is possible that the local climate will have changed which may affect the seasonality and intensity of rainfall and thus alter the site response to rainfall runoff;

- Designations. It is possible that, in the intervening period between consenting and decommissioning, new habitat designations could have been published;

- Habitats. There is potential that the habitats on site may have changed while the wind farm has been operational (naturally or in response to a habitat management plan); and

- Water Use. During the operation of a wind farm, the use of water near to site may have changed, for example, fisheries interest may have extended and/or there may be a new water abstraction close to the site.

Much of the information required to assess potential changes that might have occurred during operation of a wind farm is likely to have been collected as part of routine site inspections, habitat surveys, ongoing site monitoring and through engagement with local Landowners and stakeholders. However, if this is not the case, further survey work will be required to confirm existing hydrological and hydrogeological conditions.

The case study below provides an example of how hydrological measures have been used to restore habitat

In recent years there has been an increase in artificial blocking of drains in peatland habitat. In the UK, drain blocking has been undertaken to restore peat habitat that may have been previously drained for forestry, land management or peat cutting purposes. In many cases, the drain blocking has been undertaken or is planned as part of a HMP, associated with wind farm developments. It can also help improve the carbon balance of the site by improving peat development and therefore carbon sequestration.

Ploughing, prior to planting associated with forestry, destroys the upper acrotelm layer of the peat and creates furrows which act as drains. The effects of ploughing, and any additional drainage introduced prior to planting, can result in a general compaction and drying of the peat with increased moisture deficits and mineralisation of the peat. During this period surface water runoff rates are typically 'flashy', a response that is accentuated by the disruption of the vegetation by ploughing, and the resultant decline in evaporation, as well as the release of previously stored water via increased drainage. Significant erosion and sediment losses can also occur at this time. Similar hydrological effects occur when drains are established in peat for land management or peat cutting purposes.

As a consequence, and to reverse these potential impacts, recent interest in drain blocking has resulted in research papers (SNH 2006 and 2008) and Armstrong et.al. (2009) and test sites where drain blocking has been undertaken. Evidence is now emerging with respect to the most appropriate drain blocking techniques in differing site settings.

Experience shows that the materials used to construct drain dams are predominantly heather bales, peat turves, plastic piling, wood, stones and combinations of these materials. Peat turves, plastic piles and wooden dams aim to create a watertight seal whereas bales and stone aim to decrease flows, trap sediment and hence result in drain filling. To be effective, the type of drain blocking approach used should reflect:

- the slope of the drain
- drain orientation relative to slope and catchment
- upslope catchment area
- the amount of water the drain currently carries
- potential to intercept peat pipes

Figure 6: Sheet piling damming a ditch at Flanders Moss ©Lorne Gill/SNH

Armstrong *et. al.* (2009) provide a useful framework for determining the most appropriate dam type specific to site conditions.

The location and construction of the dams is commonly specified by the site ECoW prior to the dams being constructed, and the following principles are commonly adopted:

- prior to constructing the dam the drain should be locally re-profiled so that the dam can be easily constructed and the ability to achieve a water tight seal is increased;
- only peat from within the drain or excess peat from elsewhere on site should be used to create peat dams;
- the height of the dam should be raised slightly above the height of the drain to prevent over spilling of the dam;
- turves should be placed on top of a peat dam to prevent peat being exposed and eroding
- where possible the water held back by a dam should reach the foot of the next dam upstream in the drain; and
- any clay beneath the peat should not be disturbed or breached by the dam construction works.

In addition, care is required to ensure that the proposed method of working does not locally compact peat deposits or increase the potential for suspended solids to be discharged from the area of working. The proposed works should not increase potential peat instability; it may be necessary for the drain blocking measures to be agreed with a geotechnical specialist.

4.3 Potential Impacts on Ecology of Decommissioning Options

Decommissioning options may affect ecological receptors, including habitats, species and protected sites. These effects may be positive or negative, and will vary depending on the decommissioning option that is selected, as summarised in the table below. A number of these issues will be similar to those encountered during the construction and/or operation of a wind farm. In practice, decommissioning solutions, and hence ecological impacts, are likely to sit in between the two extremes identified in the table.

Table 4: Summary of Potential Impacts on Ecological Receptors.

Nature of Effect	Decommissioning Option	
	Retention of Infrastructure In Situ	**Removal of Infrastructure**
Positive	Retention of access that may facilitate habitat/land management, and recreational activity. Reduced disturbance of species. Reduced re-disturbance of vegetation.	Restoration to pre-development ecological condition (or "better").
Negative	Long-term alteration of hydrological flows within water-dependent habitats (sub-surface and surface) compared to pre-development. Use of materials that are not native to the site.	Poorly executed restoration may result in poorer habitat conditions than pre-decommissioning. Likely short term significant disturbance of surface and sub-surface ecosystems within the immediate vicinity of the infrastructure, including floral and faunal communities, and microbiology. Likely short term disturbance of fauna (by noise, light or vibration) within the relevant zone of influence around the work areas. Removal of access tracks may affect logistics of habitat management works on the site. Use of material from outwith the site for backfilling any voids.
Effects with uncertain outcome direction (could be +ve or -ve)	Cumulative impacts of infrastructure left in situ.	At least short-term and possibly longer-term disruption of hydrological flows within water-dependent habitats, both in the immediate vicinity and within a wider zone of influence. This may result in the restoration of original patterns of surface and sub-surface hydrology. Cumulative impacts of removal of infrastructure.

Technological advances and changes in preferred approaches during the lifetime of a wind farm could mean that the potential negative impacts of either of these options may be reduced and positive effects may increase. Because of this, it would be best practice not to limit options too far in advance of actual decommissioning.

4.3.1 Criteria to be considered when evaluating ecologically optimal options

4.3.1.1 Filling the void – backfill, soil conservation and management

The complete removal of wind turbine infrastructure is likely to require some type of rock-based backfill to the voids, as it is highly unlikely that sufficient quantities of substrate will be available (see Chapter 3). However, if a wind farm site is being repowered, the excavations for new turbine bases may provide new sources of onsite material for backfilling voids associated with the old bases.

The majority of the decommissioning plans reviewed have proposed decommissioning options that involve the removal of turbine infrastructure to a depth of approximately 1 m below ground level and then surface restoration of topsoil. The ecological feasibility of this approach needs to be considered carefully, as for larger sites this also could involve a requirement for a significant volume of soil or peat (and also rock backfill). Although material may have been side-cast elsewhere on the site as part of the original construction methods, it may not now be available (or suitable) in sufficient quantities. Ecologically, use of restoration techniques that involve large quantities of off-site rock or soil backfill may have similar ecological consequences to the scenario of leaving the majority of the infrastructure in situ, especially if the chemical composition of that backfill is significantly different to that found in undisturbed areas of the site.

Some of the most significant direct and indirect impacts on soil properties occur as a result of activities associated with construction, and these are also relevant to the decommissioning phase, such as:

- covering soil with impermeable materials can effectively seal it, and result in significant detrimental impacts on its physical, chemical and biological properties, including drainage characteristics;
- contaminating soil as a result of accidental spillage or the use of chemicals;
- over-compacting soil through the use of heavy machinery or the storage of construction materials;
- reducing soil quality, for example by mixing topsoil with subsoil, or with construction waste or contaminated materials (contamination may require treatment before reuse, or disposal at landfill may even be required);
- indirect effects in water quality such as increase in dissolved organic carbon and suspended solids;
- indirect effects such as reduction of carbon storage capacity of soil and associated carbon emissions from drying soils.

Although planning approval is a pre-requisite for all development proposals, and consideration of the impact on soil is an integral part of the environmental assessment process, there is no specific direct planning control on the sustainable use and management of soil resources on construction sites or a requirement for the monitoring of soil protection and sustainable reuse (DEFRA, 2009). However, it is important to understand a site's soils and their influence on habitats so that re-established communities are likely to sustain themselves in the long term (Bradley *et. al.*, 2006).

A thorough assessment of the available soil and soil-forming resources on site with which to form the restoration layers should be carried out before any decommissioning and restoration design work. This should include assessment of the quality and composition of soils that may be available for restoration purposes, and how previous disturbance may have affected their properties and/or distribution. Although information regarding soil storage and management since wind farm construction should be a key component of this assessment, up to date investigations of quality, quantity and distribution may be required.

Semi-natural habitat restoration often requires low nutrient substrates, whereas amenity and agricultural restoration need at least a thin layer of topsoil. For woodland planting, a minimum depth of 1.0 m of suitable materials is likely to be needed (Forest Research, 2008).

Repeated handling of soils and peats can affect their structure, and in many situations it would be undesirable to import such material unless it could be sourced locally. Imported soils should match the nutrient and chemical status of the receptor site, and must be clear of propagules of invasive and undesirable species. The volumes required increase substantially if cranepads are also to be restored in this manner, and if woodland replanting is proposed. The use of imported peat or soils is highly likely to result in a need for re-sowing, unless the material contains a viable seedbank of appropriate species (of local provenance). Even materials that were side-cast during the original construction process will not contain a sufficiently viable seedbank to regenerate the whole restoration area, and re-seeding techniques will inevitably be needed.

In the absence of sufficient topsoil or peat, and appropriate propagules, the potential use of other soil-forming material can be explored. It is important that soils, or soil substitutes, are evaluated in the context of the site's target ecosystem. To this end, if imported material is used, soil analyses should be undertaken to establish requirements and suitability. This will vary within a site.

Low inputs of organic compost have been trialled at china clay restoration sites on Bodmin Moor in the south west of England (Putwain, pers. comm. 2012), and at a larger scale, water filter sludge, which has a high organic component but is low in nutrients, has also been shown to be successful. In the English Peak District, where the long-term degradation of upland peatlands resulted in large areas of mineral substrates being exposed, extensive restoration has been undertaken using geotextiles overlain with an appropriate organic layer and seeds. Similarly, at colliery sites in South Wales, at elevations of up to 500 m AOD, geotextiles were placed on colliery spoil and, over time, a thin soil layer has developed, and with it an interesting bryophyte/lichen heathland (also Putwain, pers. comm. 2012). This type of approach is likely to be costly at larger scales, but should be an option open for consideration on wind farm sites.

4.3.2 Vegetation Restorability

The primary objective of habitat restoration is to minimise the degradation of the ecological resource and to promote the re-establishment of a functional ecosystem in the long-term.

Habitat restoration techniques need to consider the ease with which different habitats can be "restored", and the likely success of this restoration. As a general principle, habitat resilience (the ease with which habitats can return to a pre-disturbance state) is a continuum whereby highly artificial and anthropogenically modified ecosystems (such as arable landscapes and improved grasslands) are more resilient than previously undisturbed or more complex (and often species-rich) environments such as semi-natural grasslands and ancient woodlands. Habitats prevalent in warmer, drier environments tend also to be more resilient than those in cooler, wetter areas. Success is driven by the maintenance of soil structure and function (see above), and availability of propagules (see below). It is also thought that habitat resilience is not necessarily a linear function of the magnitude of disturbance, and that there may be thresholds beyond which restoration is much less predictable or easy (Hirst *et. al.*, 2005). This is likely to be particularly true for repeatedly disturbed environments, and is likely to be relevant to decommissioning plans where the likelihood of previously disturbed habitats is extremely high.

Decommissioning options which involve significant disturbance of habitats, such as the complete removal of infrastructure, are likely to require a much longer recovery period in environments which are much less resilient to disturbance, such as peatlands in the cooler north and west of the UK, or species-rich grasslands. Many wind farm sites do contain peatlands, as these tend to form in the exposed locations that are attractive for wind farm development.

In contrast, wholesale removal of infrastructure is likely to be more straightforward in arable and improved grassland settings. The potential challenge of the peatland site does not necessarily mean that bases should be left in situ as in some conditions bases may start to surface over time due to the movement of the peat bog. This should be considered when assessing options for removal.

It is important that the restoration potential of the site is considered at the original design phase. Natural England (2010) suggests that, if there are doubts over the feasibility of site restoration at development proposal stage, then this should raise questions as to the appropriateness of the location for wind development.

Figure 7: Tracks on Forestry Commission land are often left to regenerate naturally. Their edges become softened, and the colonising vegetation is native to the site. Photograph © Forestry Commission Scotland.

To date, no systematic review of available evidence for the optimum approach to habitat restoration has been undertaken, and to do so is beyond the scope of this research study. The purpose of this research is not to provide detailed information on the restoration of vegetation communities, as this is highly site specific and is covered elsewhere in the literature.

However, as a general principle, the main sources of propagules for restoration are:

- from seed;
- use of plug plants;
- translocated turves and/or bryophyte carpets; and
- use of other vegetative material, such as heather brash.

Each of these methods has associated benefits or drawbacks, either ecologically, financially or logistically, depending on the scale and location of a site, its environmental characteristics, and the desired outcome.

4.3.3 Peatlands

Much guidance exists with regard to peatland restoration (see Peatlands and Upland Biodiversity Delivery Group, 2010; O'Brien *et. al.*, 2007; Schumann & Joosten, 2006; Quinty & Rochfort, 2003). However, there remains a need to quantify the processes involved in the degradation and recovery of peatlands, and the responses of flora and fauna to such processes. Such lack of knowledge has meant early attempts to restore peatlands have been based on assumptions and experience rather than on hard data.

Lunt *et. al.*, 2010, in their review of peatland restoration, found that the main factor limiting our knowledge of the success of peatland restoration is the absence of long-term monitoring data. Post restoration monitoring shows that recovery of water levels is possible in a relatively short time frame (2-5 years). Restoration of target mire vegetation in response to management may take several decades to achieve, with agriculturally improved and heather-dominated peatlands presenting the greatest challenges.

Restoring appropriate *Sphagnum* species and cotton-grasses is vital to restoring peat forming processes and securing UK peatlands as both secure long-term stores of carbon and also future carbon sinks. Many restoration projects show short-term negative impacts on surface water quality and methane generation but, where data exist, positive responses in the medium- to long-term are seen. There needs to be a greater commitment to data sharing and formal experimentation within restoration sites in order to further this knowledge.

The SNH guidance "Good Practice During Wind farm Construction" (Scottish Renewables *et. al.* 2010) contains a final section on habitat restoration. As stated in this guidance,

> *"The aim of peatland restoration should be to restore the original function (e.g. habitat, carbon store and sequestration) of the peatland, in consultation with a specialist. This is often an approximation of the original condition with the primary aim to avoid the loss of soil carbon and to create the conditions for peat accumulation, for example via recolonisation of Sphagnum mosses. Consideration should be given to the need to modify current land management practices, such as grazing, to achieve restoration.*
>
> *On operational wind farm sites in Scotland the periods of restoration have been too short to show successful restoration to a fully functional peatland. Restoration of a peatland can take from 5 to 30 years depending on the initial condition and primarily the effectiveness of raising the water table to or near to the surface. Long-term monitoring is essential to develop cost-effective techniques and methods that work to ensure successful restoration."*

Translocation of peat and subsequent re-establishment of a functional peatland ecosystem is less well studied/understood. Techniques in peat handling and re-use are discussed in recent guidance (Scottish Renewables and SEPA, 2012) which contains an example of translocated peat and peat turfs being used to restore a borrow pit, with reasonable success within a six year time frame.

The Peak District Moorland Management Project (Phillips *et. al.* 1981, Tallis *et. al.* 1983, Anderson *et. al.* 1997, O'Brien, *et. al.*, 2007) has provided a long term study of several large- and small-scale restoration projects within the Peak District National Park. Anderson *et. al.* (1997) emphasise the need for site characteristics to be assessed and evaluated prior to the revegetation of peatlands. They concluded that areas of deep peat, particularly at high altitude (>550 m AOD) on steeply sloping ground (soil covered hillsides or gully sides), and areas of extensive downwash of sediments and unstable peat soils, were particularly difficult to restore. Many of the trials met with limited success under these conditions.

Furthermore, despite the extensive study of the ecology of *Sphagna*, there is still comparatively little knowledge of the life history strategies of these species, particularly concerning their dispersal and establishment potential which is seen by many as being paramount to the success of peatland restoration in the context of creating an "active bog" (O'Brien *et. al.*, 2007).

Restored vegetation does not necessarily revert to the pre-damaged state and new vegetation can migrate in different directions. On shallow peats (and/or mixed with clays and silts) with a constant flow of ground water, rushes can invade and prevent other species colonizing (Marrs *et. al.* 2004). However they seem not to persist on peatlands that have a high, stable, water table (Lunt, *et. al.*, 2010).

It is possible with time (20-50 years as seen in cutover bogs) for all but highly modified peat bodies to recover to an active peat forming state once the degrading influence/(s) have been removed. However, many restoration projects show no change or short term negative impacts on ecosystem services such as surface water quality and methane generation in the medium- to long-term (Lunt *et. al.*, 2010).

4.3.4 Grasslands

Experimental approaches to grassland restoration have primarily focussed on the restoration of species-rich swards on ex-arable or improved grassland areas (e.g. Walker *et. al.*, 2004). Much of the output from this work is transferable to post-decommissioning restoration of grassland areas, in that there are three main approaches to grassland restoration.

"Turf translocation", i.e. translocating whole turfs (usually 0.5 x 0.5 m or 1 x 1 m size) is a relatively intensive technique, which creates patches of target grassland communities within the restoration area, from which wider colonisation is possible. For reasons of cost and practicality this can usually only be done over small areas but it does form source populations for subsequent spread.

More moderate forms of intervention, such as harrowing or slot-seeding of propagules over large areas, can be used to establish a limited number of desirable, generalist species that are known to perform well in restoration. This method is low cost and rapid but the trajectory of the restoration is less predictable. Hydro-seeding is recommended for large and inaccessible sites, and can be a cost-effective solution in these situations. This technique can be used on both natural and artificial substrates, and can be adapted to include adhesives, fertilisers and microbial bacteria to help germination and aid moisture retention.

Phased restoration methods could be used to complement the above approaches, but are more applicable to lowland neutral grasslands than upland acid grassland habitats. Productivity and competition are reduced over 3-5 years using *Rhinanthus* or fertilizers to accelerate phosphorus off-take. After this time, harrowing and seeding should allow a wide range of more specialist species to establish. However, further research is required to determine the long-term effectiveness of these approaches (see Pywell *et. al.*, 2007).

The 'Nature after Minerals' website contains a number of information sheets regarding the restoration of different grassland types following mineral extraction works which may be relevant to some wind farm settings.

4.3.5 Heathlands

Heathland restoration is well described in the literature, and research in this area has been on-going for a long time (see, for example, British Gas, 1988). It is known that former land use has a significant role to play in successful re-establishment of lowland heath (Walker *et. al.*, 2004), and these authors describe how research on former arable sites and improved grassland areas has shown that antecedent management can cause significant changes to the seed bank and soil properties, which in turn can influence the direction and success of restoration.

In contrast, former plantation seed banks and soils have been shown to be similar to that in heathland control plots, and in these areas rapid regeneration of *Calluna* heath has taken place (*ibid*.). Heathland restoration generally requires particularly careful consideration of the nutrient and pH status of the substrate, deliberate introduction of *Calluna* propagules (often from heather brash), and regular monitoring and maintenance to prevent sward domination by tall grasses.

The Nature after Minerals website also has extensive advice regarding the recreation of heathlands which may be of relevance to some wind farm sites.

4.3.6 Woodlands

If afforestation is identified as a post-operational restoration option for a wind farm site, substrate restoration depths need to be sufficient to sustain tree planting (see Chapter 3), and tree species will need to be selected on the basis of their tolerance for the restored environment and nutrient requirements, as well as their ecological and landscape appropriateness. Woodland areas can have a significant influence on adjacent habitats, and this should also be taken into consideration.

It is important that the way in which restored areas will be monitored and managed, at least in the short to medium-term, should have been pre-determined and agreed. The success of ecological restoration is highly dependent on subsequent manipulations to keep it “on track”, and this aspect is often overlooked. There is little point in planning for and executing, good ecological restoration if it is not followed through with adequate monitoring and management.

4.3.7 Post-decommissioning, monitoring and management

Interventions may (or may not) be needed in order to increase the likelihood of achieving the desired habitat and ensuring its stability. This may take the form of vegetation monitoring for the first couple of years post-restoration, and the provision of management advice based on the monitoring outputs. The type, extent and frequency of the monitoring should be dependent on the size and complexity of the area that has been restored, and the resilience of the habitats involved.

Following disturbance, long-established habitats such as ancient woodland and unimproved grassland, or fragile, slow growing habitats such as montane heath may never recover their former character within a human timescale. Management techniques for such systems are less well understood than those for agricultural land or plantation forests, and outcomes from disturbance (including management practices) are less certain due to the greater number of variables and complexities involved. However, monitoring their progress and intervening where necessary can improve the chances of success.

4.3.8 Other post-operational phase ecological considerations

4.3.8.1 Habitat Management Plan

As mentioned in Chapter 2, there is usually no obligation on a Developer to continue to fund the HMP beyond the lifetime of the planning consent, and many of these plans involve off-site habitat restoration or enhancement which is likely to be unaffected by decommissioning proposals. However, repowering proposals may present an opportunity to continue, alter or extend the HMP. This may be in response to the residual impact outcomes of the repowering Ecological Impact Assessment (EcIA), but it can also be seen as a source of planning gain (Scottish Borders Council has a formal approach of biodiversity offsetting in the context of renewable energy developments). Nevertheless, HMPs need to be proportionate to the site, its ecological interest and the development's potential impacts, and expectations of their extent and content, even at the repowering stage, need to be reasonable and proportionate.

Decommissioning options should also take into consideration any habitat management operations within the zones affected by decommissioning works. There will have been little advantage in c. 25 years of positive habitat management if it is subsequently significantly disturbed by "restoration" activities. Work areas may need to be tightly defined and contained, and where habitat restoration is proposed, this should aim to tie in with any relevant objectives within the HMP. Although the Developer is unlikely to continue funding the HMP works, the land needs to be left in such a condition that the Landowner would be able to continue with similar HMP prescriptions, perhaps via a relevant agri-environment scheme. There should not be a presumption that all positive habitat management works will cease, post decommissioning although in practice there would be no control over that.

It is also possible that there may be a residual obligation to continue habitat management works, if the original HMP was implemented to compensate for ecological impacts of the development in order to establish acceptable residual effects of the proposals. If monitoring outputs from the HMP process indicate that the desired outcomes of the HMP have not been realised, then there may be a requirement to continue or alter habitat management works so as to meet the terms of the original planning conditions.

4.3.8.2 Protected Areas

Over a 25 year period, it is possible that new protected areas will have been designated in the vicinity of a wind turbine development, or pre-existing areas altered in terms of their extent, or their notified features. It would be good practice to screen decommissioning proposals for their potential to affect protected areas (e.g. via disturbance of species, or hydrologically linked habitats), and where this involves Natura 2000 sites an Appropriate Assessment may be required in accordance with the requirements of the Habitats Regulations.

Proposals for repowering should be subject to Habitats Regulations screening as part of planning application process (see Chapter 2).

4.3.9 Restoration Case Studies

The case studies presented here illustrate the process by which restoration has been achieved as well as the works undertaken. Although the sites involved are not wind farm sites, they are extensive and are considered good analogues for future restoration of wind farm sites.

CASE STUDY 2 - Bramford Landfill Site

The Bramford Landfill site is in Suffolk, approximately 10 km north-west of Ipswich. It is a worked-out clay pit which has been developed as a licensed waste management facility. In 1998, planning permission was granted to extend the site, subject to a number of conditions relating to the restoration and after-care of the site's substrates and habitats, including chalk grassland.

In order to discharge these conditions, which applied to on-going restoration throughout the life of the operation, an Outline Restoration and Aftercare Report was produced, which detailed how the nature of the soils and the techniques for restoration would be reviewed through the life of the site. An outline of a 5-year aftercare programme was also provided, along with details of monitoring.

As this is an on-going process, a detailed Annual Restoration Plan is produced which provides a record of all site monitoring (including ecological monitoring), and recommendations and priorities for the forthcoming year. The report reviews the progress made since the preceding year's report, and makes recommendations for adjustments to be made to the restoration programme, techniques or aftercare in the following year. The site is inspected annually by the Local Authority, and this visit is used to confirm the accuracy of the monitoring reports and to review and agree the Annual Restoration and Aftercare Plan for the following year. The detailed aftercare plan can then be used to formulate specifications for specialist contractors.

This is a useful case study as it illustrates how a systematic and transparent process for the planning and reviewing of site restoration progress can contribute significantly to the success rates of the process. It demonstrates the benefits of sustained and positive communication lines, and practical working relations between Developers, Landowners and Planning Authorities (or regulators). The experience at Bramford Landfill Site has also increased the confidence of the regulating agencies and the general public that these sites can be successfully restored to a high standard, and in a timely fashion.

Figure 8: Bramford Landfill Site - restoration in progress. The foreground of the photo shows an area of recently established restoration substrate specifically designed to provide suitable ground conditions for the establishment of calcareous grassland. The surface water ditch at the centre of the image was lined with a permeable geotextile and then soiled and seeded for stability. In the background on the left hand side of the image a calcareous sward and deciduous woodland stand are already maturing and diversifying floristically. Photograph © SLR Consulting Ltd.

Figure 9: Bramford Landfill Site – restored grassland. This image illustrates progress in the establishment of the calcareous grassland two years after original restoration works. The grassland evidences a growing diverse sward structure, but with areas of open ground retained into which native species continue to colonise. Areas such as this received annual inoculations with green hay from suitable donor sites in the vicinity of the site.
Photograph © SLR Consulting Ltd.

CASE STUDY 3 -The Point of Ayre

The Point of Ayre sites are a series of aggregate extraction areas that have subsequently been used for landfilling. The sites were subject to Geological Conservation Review (GCR) which underpins their geological site of special scientific interest (SSSI) status. Permission for filling came with a requirement to design and oversee the restoration and subsequent aftercare, management and ecological monitoring works. The restored landfills lie within an area of ‘Gallic Heath’ a landscape/habitat of international importance in terms of rarity of this habitat type. Through considered establishment techniques and a responsive approach to management intervention the aim is to regenerate this habitat type on the former landfills.

The project has been carried out in a series of phases to enable the progressive restoration of the landfill areas. The nature of the operations means that works are restricted to particular seasonal opportunities. Broadly, landscape works were carried out twice a year from 2004 – 2007, aftercare and maintenance visits have been carried out four times per year since, with ecological monitoring being carried out twice a year, also ongoing.

The Point of Ayre is almost unique in terms of its microclimate and ground conditions. These factors have shaped a habitat of international importance in terms of its rarity which presented a challenge on many levels. It was recognised that if the scheme was to succeed it would have to be sensitive to the context yet robust enough to endure the harsh site conditions.

An iterative approach to management and monitoring techniques has also been applied, in response to ecological opportunities arising throughout the restoration process. While the long term aim is still to re-create Gallic Heath, many successional habitats develop in the interim periods that are interesting and valuable in their own right. A sensitive approach to management that is led by ecological monitoring has enabled 'guided development' of plant communities rather their being forced in a particular direction. All works have had a strong technical grounding and followed a rigorous consultation process with all interested parties being involved. The site has now become more diverse and self-sustaining.

Figure 10: Point of Ayre phased restoration plan. Background aerial photography supplied courtesy of the Isle of Man government, annotation by SLR Consulting Ltd Photograph © SLR Consulting Ltd.

Point of Ayre Restoration History

PHASE 1
Ballacallow
This area was restored in autumn 2001; after some initial issues with nutrient loading the enriched soils were stripped from this area and the surface was subsequently treated the same as 'Phase 2' i.e. seeded with a nurse crop and brash material added. As with the

'Phase 2' areas further brash material was broadcast and rolled into the surface during autumn 2006.

PHASE 2

Ballacallow

This area was restored via the same methods as described for Wright's Pit East 'Phase 2 i.e. with sands and gravels, seeded and then brash material collected from the adjacent heathland incorporated with the surface, this took place in autumn 2004. This area has then subsequently received low levels of fertiliser in order to maintain the nurse crop and additional brash material during autumn 2006.

Wright’s Pit East (Northern Area)

Restoration materials (i.e. sands and gravels) were placed on this area and seeded with a nurse crop. As with Phase 3 brash material collected from the adjacent heathland was then incorporated with the surface in autumn 2004. This area has then subsequently received low levels of fertiliser in order to maintain the nurse crop and additional brash material during autumn 2006.

PHASE 3

Wright’s Pit North (East) and Wright’s Pit East (Southern Area)

In the most part this area was restored using soils stripped from the nearby field which were subsequently applied to a depth of 50-100mm; some soils which cover the northern part of Wright's Pit East and restored area of Wright's Pit North were taken from a stock pile on Island Aggregates land and applied via the same method. The areas were first seeded, and then brash material collected from the adjacent heathland was incorporated with the surface. These operations took place in autumn 2006 with some outstanding seeding work being undertaken in late summer 2007.

Figure 11: Point of Ayre, View across previously restored landfill. Early successional Gallic Heath comprised of a diverse sward with emerging heather and western gorse plants and is evident in the foreground of the view. Photograph © SLR Consulting Ltd.

4.3.10 Good Practice Guidance for the Ecological Aspects of Decommissioning Wind Turbines

Good practice should start with the original planning application. The application and any accompanying ES needs to contain sufficient information regarding the likely options for decommissioning and their associated impacts so that this becomes an integral part of the process. These documents usually form the basis for most ecologically-related planning conditions. Therefore the information they contain needs to be comprehensive and clear.

At the planning application stage, it is good practice to:

- state clearly the preferred engineering approach for decommissioning and identify the likely implications for the site's flora and fauna, including description of the likely future need for updated surveys and possible licence applications;
- identify the likely source of materials needed for restoration (substrate and vegetative propagules) - "wait and see" is not sufficient;
- identify other ecological constraints or methodological considerations, such as habitat management areas, and how these will be protected during the decommissioning phase.

At some point during a wind farm's lifetime, it may be necessary to produce a formal RDP informed by the experience of construction, and operational phase ecological monitoring.

Such a RDP should incorporate the following from an ecological perspective:

- confirmation of the quantity and source of restoration materials;
- outline of the timescales for pre-decommissioning protected species checks and habitat mapping;
- production of a Ecological Protection Plan, covering all pertinent habitat and species issues (including terrestrial and aquatic environments). This should then be incorporated into the construction method statements;
- screening for engagement with the Habitats Regulations; preparation of protected species licences, if relevant;
- transfer of all relevant HMP documentation to the Landowner to encourage continuity, possibly under an appropriate agri-environment scheme. Good practice would also be to provide a measure of consultancy time to advise the Landowner as to what agri-environment options might be open to him/her in order to continue HMP works;
- provision of restoration monitoring plan and details of data publication and dissemination.

Repowering and refurbishment options will be subject to new planning applications, which will need to be supported by appropriate and recent ecological surveys and environmental assessment.

4.4 Restoration and decommissioning of Wind Farms – Landscape and Visual Considerations

The restoration and decommissioning of wind farms will have short term and long term effects on the landscape character and visual amenity in the zone of visual influence and views of the site.

4.4.1 Potential impacts on Landscape Fabric, Landscape Character and Visual Amenity of decommissioning options

4.4.1.1 Infrastructure left in situ

The effects of retaining wind farm infrastructure such as access tracks and crane pads within the site, and any off-site highway improvements will continue some of the operational impacts on the character and visual amenity of the landscape. Such effects are likely to be adverse in nature and related to the loss or alteration of key characteristic landscape or visual elements.

4.4.1.2 Infrastructure removed

The removal of infrastructure can provide for beneficial impacts through the return of the site to a condition similar to that prior to the development. The removal of elements which have resulted in impacts on the landscape fabric, character and visual amenity of the site and adjoining landscape are likely to be beneficial. However, demolition and removal of infrastructure can, in itself, result in a number of adverse impacts, including:

- damage to substrates and habitats and vegetation established over the life of the operational wind farm and which constitute characteristic elements of the current landscape context;
- the establishment of temporary excavations and anomalous temporary material storage mounds that are inconsistent with, or detract from the current landscape or injurious to the fabric and/or character of the landscape.

Notwithstanding the possible long-term effects of disturbance to some of the more sensitive/fragile habitats and vegetation, impacts arising from removal of the infrastructure are generally anticipated to be of relatively short duration. However, this assumes that reinstatement is of a sufficiently high standard to ensure that reinstated land can blend in with adjoining, undisturbed ground.

4.4.2 Repowering

In the event of the site being repowered, the decision as to whether to remove existing infrastructure can be even more complicated as in some circumstances the retention of infrastructure and overlaying of new infrastructure could lead to significant long term or even permanent combined impacts on the landscape of the site and the amenity of neighbouring receptors. Wherever possible, preference should be given to the adaption and re-use of existing infrastructure. Where this is not possible the new infrastructure should be designed to:

- limit the amount of new infrastructure required;
- minimise the size and extent of new infrastructure;
- be consistent with (or improve upon) the original pattern and character of existing site infrastructure; and
- follow good practice in respect to its landscape fit and relationship with the pattern, scale and form of existing landscape elements.

If significant landscape and visual effects are still anticipated as a result of the combined effect of existing and proposed infrastructure the removal (or partial removal) of existing infrastructure is advisable.

4.4.3 Criteria to be considered when evaluating Landscape and Visual options

The principal consideration for decommissioning is a comparison of effects arising from either removal or retention of wind farm elements and infrastructure. Key considerations in this regard include:

- Whether the retention of infrastructure or wind farm elements would result in the persistence or extension of significant adverse impacts (direct or indirect) on landscape character and visual amenity (including cumulative impacts) with particular relevance to wild land and/or the more remote landscapes where man-made elements are unusual;
- Whether landscape and visual impacts associated with retained infrastructure/wind farm elements can be mitigated using measures that are consistent with the character of the broader landscape in the vicinity e.g. amendment of access tracks to be consistent in character and appearance to existing farm tracks elsewhere in the vicinity, or establishment of new forestry planting or woodland in a wooded landscape to mask infrastructure;
- Whether retention or partial retention of wind farm infrastructure is consistent with, or provides benefit in respect of, broader landscape management or land-use priorities;
- The short-, medium- and long-term benefits or dis-benefits accrued by removal of infrastructure in terms of landscape character and visual amenity, including off-site infrastructure;
- The duration, geographical extent and significance of landscape and visual impacts (including cumulative impacts) likely to arise from removal of wind farm infrastructure/elements; and
- The likelihood of successful and sustainable reinstatement of infrastructure locations to a condition/character consistent with the adjoining undisturbed landscape.

The balance of benefits and dis-benefits associated with either the removal or retention of wind farm elements and infrastructure will vary on a site by site basis. Any judgements made will require clear and rigorous justification in terms of an optimum solution for protection of the landscape and visual amenity of both the development site and adjoining landscape.

In respect of repowering, the key consideration is whether significant landscape and visual effects are still anticipated as a result of the combined effect of existing and proposed infrastructure

4.4.4 Recommendations for infrastructure removal techniques

From a landscape and visual perspective any decommissioning and restoration work should achieve the greatest improvements with the least disturbance and impacts on landscape fabric, character or visual amenity of neighbouring receptors through careful control of the works, including:

- the restriction of working widths;
- protection of adjoining areas from vehicle incursion and stockpiling;
- weather/seasonal timing to avoid damage of substrates;
- control of working hours to minimise night time intrusion in the countryside;
- dust suppression measures to avoid damage to vegetation and creation of visible dust plumes;
- avoidance or careful design and siting of stockpiles/storage mounds; and
- rapid and progressive re-soiling and restoration of the site with an appropriate substrate.

4.4.5 Good Practice Guidance for Landscape and Visual Aspects

Good practice in decommissioning is best considered as part of the original design of the site. This includes sensitive design to achieve good landscape and visual fit for wind farm elements; minimisation of impacts on landscape fabric, loss of characteristic landscape elements and visual amenity. Design innovations in foundation design, and the potential use of temporary access tracks, laydown areas and crane pads which utilise geotextiles to increase strength) generated during this early stage may also provide for mitigation of decommissioning impacts and may make removal of infrastructure cheaper and easier.

At the project planning stage, it is good practice to:

- undertake an analysis and comparison of design layouts in the form of a risk assessment in respect of both temporary and permanent landscape and visual impacts;
- undertake an analysis and comparison of construction methods, with an emphasis upon innovative solutions, with regard to establishing potential landscape benefits and adverse implications of any given approach;
- identify the likely quantity and source of materials needed for restoration (including substrate and vegetative propagules) based on preferred design and construction method options and any alternatives that may provide a contingency;
- identify the other constraints or methodological considerations, such as site areas or landscape elements that are to be protected during the decommissioning phase; and
- plan for a phased restoration of the site to minimise the extent of landscape disturbance apparent at any given time and to ensure the rapid assimilation of the site into the adjoining countryside.

A RDP should be based on any outline in the planning statement and/or ES, and should be informed by the experience of construction and considerations such as cumulative Landscape and Visual Impact Assessment (LVIA) of turbine removal i.e. how does the removal of the scheme under consideration affect the views of other still active schemes or in the case of repowering the combination of schemes. From a landscape perspective the RDP should incorporate the following steps:

- confirmation of the quantity and source of restoration materials;
- production of an updated site survey logging site levels, landcover and land-use, and any key landscape elements or features that require protection during decommissioning works and specification of the means of protection (e.g. exclusion fencing based on British Standards);
- preparation of a detailed site layout plan for decommissioning identifying haul routes and any storage areas;
- preparation of detailed restoration designs for areas affected by demolition and removal of wind farm elements and temporary demolition elements such as stockpiles, including provision of restoration levels, seeding and planting plans and specification of substrates, ground preparations, cultivations and planting/seeding;
- provision of both outline and detailed restoration and aftercare plans; and
- site inspections with relevant parties including Planning Authority officers, Statutory Consultees and Landowners during decommissioning, restoration and aftercare (as appropriate) in order to ensure ongoing communication and to provide for a responsive approach to the decommissioning of the site and its restoration.

Repowering and refurbishment options will be subject to new planning applications, which will need to be supported by relevant landscape and visual assessment. These new applications should also consider decommissioning in the manner described above.

4.5 Summary - Addressing RDP natural heritage issues at different planning and development stages

In the table below a summary of the key natural heritage issues for consideration in restoration and decommissioning has been drawn together.

Table 4: Summary of Natural Heritage Issues.

Development stage	Natural Heritage Issue		
	Hydrology	**Landscape**	**Ecology**
EIA	Identify likely effects on the water environment (altered hydrological pathways, water quality and quantity) arising from excavation works, spillages, removal of sewage facilities, alteration of culverts and removal of infrastructure	Evaluate potential permanent horizontal landscape impacts as well as temporary vertical elements Evaluate potential landscape impacts of proposed restoration materials and methodologies, including restoration phasing and site assimilation into wider landscape	Identify likely habitat and species impacts Identify likely preferred restoration techniques, and their ecological impacts Identify likely quantity and sources of restoration materials, and their ecological impacts Consideration preferred habitat/ecology outcome post RDP.
Pre-decommissioning site status (for example, 3 years prior to RDP)	Re-evaluate site's drainage infrastructure (condition, specification and location) Re-evaluate local water use Ground stability	Revised assessment of landscape features requiring protection Cumulative assessment of LVIA effects of turbine removal	Re-evaluate site species and habitat interest/value and use this to inform restoration approaches and locations Re-evaluate site hydrological characteristics (groundwater and surface water)
External considerations	Consultee input Changes in legislation, standards and policy priorities since EIA Landowner preferences Climate change influences	Consultee input Changes in legislation, standards and policy priorities since EIA Landowner preferences Climate change influences	Consultee input Changes in legislation, standards and policy priorities since EIA. Landowner preferences Climate change influences
Primary site considerations	Use techniques that minimise effects on the water environment (quality, location and quantity of flow)	Assessment of landscape effect of proposed restoration techniques – fine scale detail	Practicalities and comparative success rates of habitat restoration (vegetation and soils) – fine scale detail

	Requirement for relevant consents Reinstatement of drainage infrastructure where necessary.	Assessment of potential for phasing of works to minimise landscape effects	Requirement for protected species licences Requirement for Appropriate Assessment.
Long-term management	Monitoring and maintenance of drainage infrastructure (and agreement of responsibility for the above). Hydrological Clerk of Works	Detailed restoration and after-care programmes	Employ ECoW to monitor and manage ecological aspects of decommissioning process. Facilitate continuation of existing HMPs Monitoring of restoration and remedial action Dissemination of monitoring results.

5. OPTIONS FOR END-OFLIFE INFRASTRUCTURE

5.1 Introduction

This chapter considers the materials and potential resources to be removed during the decommissioning process and the options for their reuse or recycling. This will have a bearing on the level to which the site is cleared of all materials after consideration of their value and the carbon impact of materials being transferred to either a reuse or reprocessing market. The options for reuse and recycling of wind farm components is beginning to be the focus of related stakeholder groups as illustrated by the Danish stakeholder initiative described below.

Danish stakeholder initiative - recycling of end-of-life blades

The issue of hard-to-recycle turbine blades is quietly rising up the agenda in Denmark, where a working group has been set up bringing together several important players including LM Wind Power, Siemens and Vestas, to share knowledge about recycling options. Co-ordinated by the Danish Wind Energy Association, the working group is partly driven by the fact that a new national waste strategy for Denmark is in progress, with the wind industry expected to account for its specific waste streams.

"*Blades have been an issue for a number of years and there have been a series of isolated research projects*," explains working group co-ordinator Anya Pedersen, an adviser at the Danish Wind Energy Association. Small-scale pilot projects have been undertaken in various European countries, but there has been little sharing of knowledge and results.

Questioned by Windpower Monthly (March 2012) on the issue, turbine manufacturer Vestas says in a statement that the responsibility for disposing of end-of-life blades rests with the wind-farm owner or operator. With the producer responsibility principle now a driving force behind waste policy in Europe, it is notable that several manufacturers have chosen to sit on the Danish working group investigating blade-related waste issues.

5.2 Waste Hierarchy

Scotland Government's Zero Waste Plan (2010) sets out the vision for a zero waste society. This vision describes a Scotland where all waste is seen as a resource; waste is minimised; valuable resources are not disposed of in landfills, and most waste is sorted, leaving only limited amounts to be treated.

Application of the waste hierarchy, set out in the EU Waste Framework Directive, is central to the delivery of this vision. Figure 12 illustrates what is meant by the waste hierarchy with the least desirable outcome at the bottom of the hierarchy.

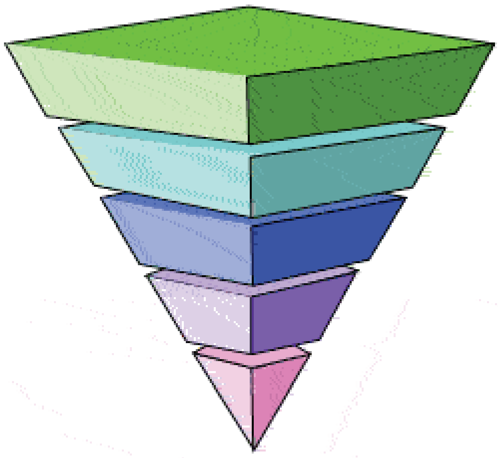

Figure 12: Waste Hierarchy. Scottish Government (2010)

To achieve this vision the Zero Waste Plan sets out new measures, some of which are of relevance here, including:

- 70% recycling and recovery by weight of non-hazardous construction and demolition waste excluding naturally occurring material. This will include backfilling operations using waste to substitute other materials;
- A Site Waste Management Plan (SWMP) as part of planning applications for all development types.

5.3 Decommissioning Process and Materials Arising

This section describes the infrastructure to be decommissioned, the potential environmental impact and options for the materials arising.

In general, the turbine would be completely dismantled at ground level and removed from site for onward disposal, recycling or re-use off site. This will primarily involve a crane and then public road transporters to remove the turbine from site. The type of vehicles used may depend on whether the components from the turbine are to be removed for onward use as a turbine component, or can be broken down and removed by more conventional vehicles.

Should the components be removed for future re-use, then a transport assessment may be required, as it is possible that the original assessment may have not accounted for vehicle movements in the opposite direction, or the roads (and associated infrastructure) may have changed since the original study.

The decommissioning of the turbine structure should have minimal environmental impact, and costs would be driven by craneage and haulage charges.

Installed wind turbines consist of four distinct sections the rotor, the nacelle, the tower and the foundation. The size of each section varies dependent on the turbine type and site conditions.

5.3.1 The Rotor

The rotor is the front section that consists of the blades, the blade hub and the nose cone.

- Turbines traditionally have three blades although a number of manufacturers produce two bladed machines. The blades are made of carbon or glass fibre reinforced composites. These consist of a carbon or glass fibre that is reinforced with a resin.
- The blade hub holds the blades in place and is made of cast iron.

– The nose cone is made of similar components to the blades themselves.

5.3.2 The Nacelle

The structure of a nacelle consists of a bed frame (iron) and a nacelle cover made of composite material. Inside the nacelle are the main components of the turbine responsible for converting the mechanical rotational energy of the rotor into electrical power. The main components are the main shaft, the gearbox, the generator and (in some cases) the transformer. The main components are made up of a mixture of steel, iron, copper and silica.

5.3.3 The Tower

The tower is made up of a number of sections for transportation purposes and is usually steel (a minority are concrete).

5.3.4 The Foundation

The size of the foundation will vary dependent on the size of the turbine, the type of land and the wind speed at the site. The foundations will generally consist of concrete and steel.

Table 5 shows the typical make up of an installed wind turbine adapted from Martinez et.al. (2009).

Table 5: Components of a typical 2MW wind turbine.

Component	Sub-component	Weight (tonnes)	Materials
Rotor	Three blades	19.5	11.7 resin 7.8 fibre glass
	Blade hub	14	14 cast iron
	Nose cone	0.3	0.12 fibre glass 0.18 resin
Nacelle	Bed frame	10.5	10.5 steel
	Main shaft	6.1	6.1 steel
	Transformer	5	0.15 silica 1.5 copper 3.3 steel
	Generator	6.5	0.2 silica 2 copper 4.3 steel
	Gear box	16	8 iron 8 steel
	Nacelle cover	2	0.8 fibre glass 1.2 resin
Tower	Three sections	143	143 steel
Foundation	Footing	725	700 concrete 25 iron
	Ferrule	15	15 steel

5.3.5 Turbine Foundations

Turbine bases are typically reinforced concrete gravity structures or reinforced concrete bases supported on piles.

The design of the former will be based primarily on the size of the turbine, although other factors are taken into consideration. Over the last 10 years, the sizes of turbine bases have been increasing as a direct result of larger turbines being used in wind farms. This trend is likely to continue for the foreseeable future. A typical 2-3MW turbine foundation is c.16m^2 x 18m^2, and c.350 – 450m^3 and c.45-70 tonnes of steel rebar. In addition, gravity bases are founded on an engineered platform of crushed rock and blinding concrete, and surrounded by compacted engineering fill to ground surface level (less approximately 0.3m). This fill could be in situ material or imported, and will typically be a specifically selected subsoil material of the appropriate density.

The construction of a base could be completed within two weeks, with the steel reinforcement installation accounting for much of this. The removal of the base will involve breaking out the reinforced concrete. The concrete will require to be broken down into sections of a manageable size, using steel cutting equipment, hydraulic breakers, excavators, and dump trucks to remove them from the site. Using standard plant, working within the confined space of a turbine foundation, the breaking up and removal of a reinforced concrete base could be completed within a week, and sooner if only the top layer of 1 metre is removed. Additional time would also be associated with further processing to separate steel and concrete, although this may take place off site.

If reinforced concrete is processed on site to remove steel (for recycling) and create a granular/rubble material of concrete, it may be used for further construction if required (such as tracks, hardstandings etc) if it is appropriate to the site. It is also possible that processed or unprocessed reinforced concrete will be removed from site and recycled / re-used off site. The remote locations of many wind farm sites will mean that haulage to recycling or re-use locations is likely to be over relatively long distances.

Depending on the site, the type and quantity of concrete (e.g. reinforced or mass concrete) and the need for any further development/repowering or remediation at the site, then the use of recycled concrete on site can be considered.

Reinforced concrete can under normal circumstances remain in situ as a relatively inert material. Concrete is inherently durable, unless attacked by aggressive agents, such as soils containing sulphates and/or of low pH (i.e. less than 7). The risk of rebar corrosion is usually low in buried concrete because of the low risk of carbonation and the lack of oxygen (The Concrete Society pers comm. 2013). The site specific risk can be assessed as part of the decommissioning plan, as the base is likely to have been in situ for upwards of 15-20 years. Therefore, consideration should be given to retaining the base in situ. This could depend on the final landform to be achieved, and partial removal of the structure may be required, such as the tower base up-stand. Partial removal of the base (typically to 1m below finished ground level) which exposes reinforcement may lead to this reinforcement having to be protected/capped.

Where ground conditions pose a chemical risk (such as acidic/alkaline conditions), it is likely that the concrete will have been designed to be resistant to that particular condition, such as sulphate resistant concrete, and again this can be taken into account when assessing the longer term stability of the concrete material.

The complete removal of a concrete base without backfilling would leave a sizeable void that could become an unwanted water feature, or even a hazard, if not backfilled with suitable material. Consideration of the localised influence of the groundwater table associated with such filling may be required. For example, if it is planned to revert to original conditions at the site, then soils similar to the original in situ material may be required. Alternatively, a suitable general fill material to suit the hydrogeological conditions could be considered, ensuring this does not compromise stability, create unnecessary erosion or unwanted pathways for surface and sub-surface water. It is important that consideration of these issues is undertaken at the design stage of the wind farm.

Turbine bases that are supported on concrete piles will be difficult to remove as the piles may rely on skin friction in their design to provide the bearing capacity required for the base which should be very difficult to overcome. Depending on size, materials, in situ conditions, depth etc it may be possible to extract piles, especially shallower end bearing piles. Where piles consist of concrete within a steel case these should be removed as a single unit. Ideally these should be extracted as the steel lining could oxidise and stain/contaminate surrounding ground and watercourses. For driven reinforced concrete piles, there is a risk that these can break and snap during extraction, and therefore contingency measures may be required to further excavate snapped piles, or to cap exposed reinforcement. Again, leaving such piles in situ should not create a significant environmental hazard, but the depth of cover between concrete and reinforcement in the piles may be less than in the gravity bases, and therefore may be more prone to oxidising and subsequent staining/contamination.

Piles are generally installed by a rig which is supported on a designed piling mat constructed from compacted granular material. It is most likely that this mat will have been removed once the piles have been installed in order to facilitate the construction of the rest of the turbine foundation. In the event that shallow piles can be extracted, these can then be cut if required and then loaded onto a Heavy Goods Vehicle (HGV) for onward processing/storage.

In summary, there is a relatively low environmental risk associated with reinforced concrete that is left in situ (The Concrete Society pers comm. 2013), and the noise, ground disturbance and cost (excavation/breaking/processing/transporting), along with associated carbon emissions, may create a larger environmental impact than leaving such concrete in situ. Figure 13 provides suggested measures that can be taken for the decommissioning of turbine bases. It should be noted, however, that some ground conditions can be dynamic, such as upland peatland environments. Therefore the decision to retain a buried structure should take into account the longer term stability of the landform in order to avoid buried structures becoming exposed in the future.

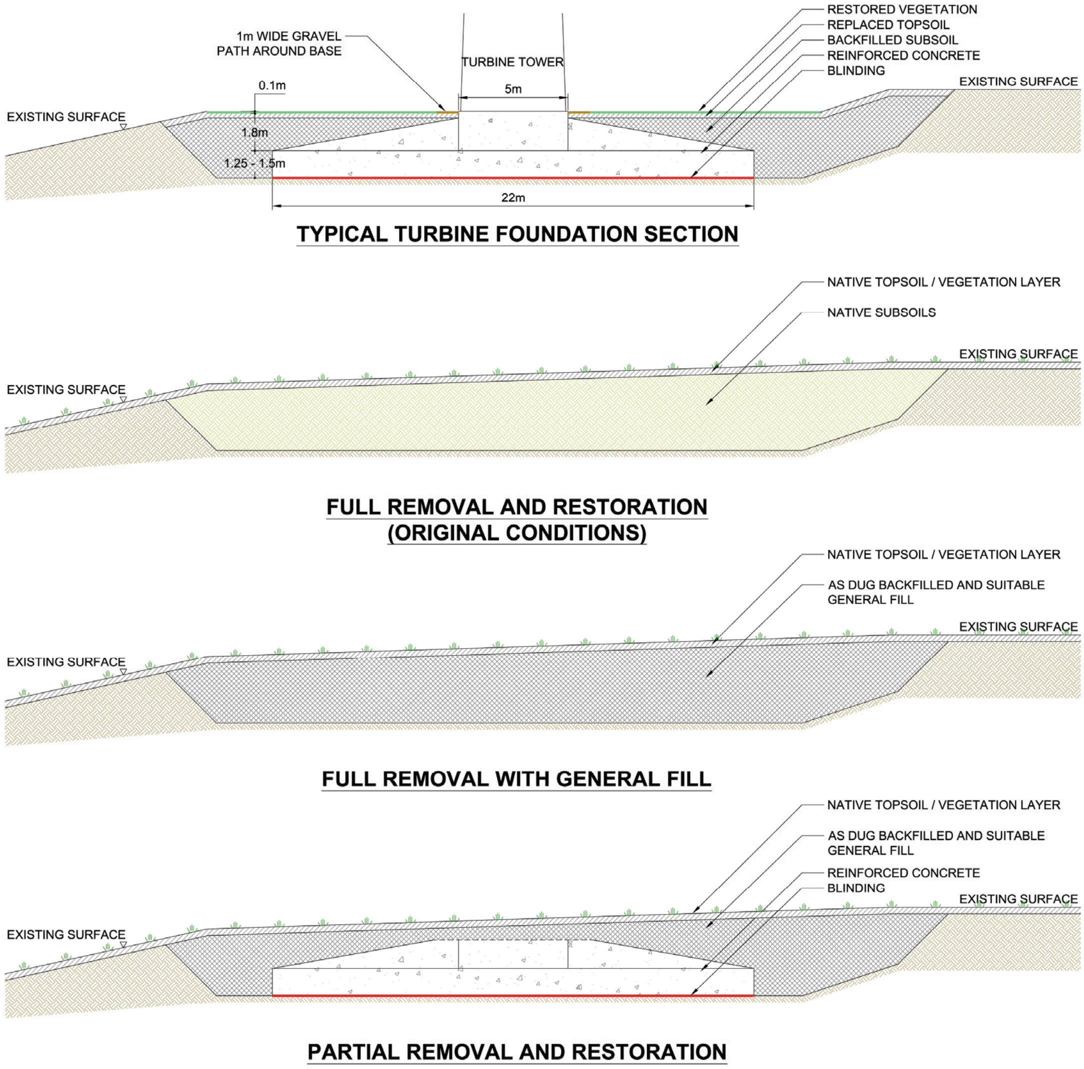

Figure 13. Possible measures for the decommissioning of turbine bases.

Key design considerations at design/construction stage include additional protection measures to prevent corrosion (cement mixes, steel protection), and drainage to permit wind farm requirements and future proofing for the longer-term.

5.3.6 Crane Pads

Crane pads are generally specific for the size and type of turbine to be installed, but will typically involve a compacted granular hardstanding founded on competent in situ material. Typically they will measure 50mx30m (for 2-3MW turbines), which again will increase in size as turbines increase in size, and will usually be 0.3-0.5m of crushed rock, laid on some form of geotextile. There may also be circumstances where the crane pad has undergone additional engineering support where the ground conditions were originally poor. This could include structural upfill, vibro-stone columns, piling, ground stabilisation measures, ground reinforcement etc.

The construction of these hardstandings will have generally involved stripping back any vegetation, then removing soft and unsuitable soils until a firm formation is obtained. Any stripped vegetation is likely to have been used in landscaping the original construction, been mixed with soils, or has since died back if stockpiled. Soils/peat may have been used in the original works or stockpiled in bunds adjacent to the hardstandings to be used for restoration. In some cases, crane hardstandings may have been left in situ and the surface reinstated immediately after the construction phase was complete, but stripped back again for each and every maintenance event where a crane was required. Over time, any stockpiled material may have re-vegetated, weathered, oxidised and become inhabited by wildlife. Consideration should have been given to the long term stability and likely condition of the material at the initial design/construction stage, but will certainly need to be monitored during the operational stage and then re-assessed at the decommissioning stage.

The reinstatement of the crane hardstandings would generally involve the removal of the compacted granular material using an excavator and dump trucks. This could be from the whole area or part of it as required. The area would then be backfilled with a more suitable material (e.g. original in situ material) if required, then dressed off with the topsoil/vegetation layer material. Re-seeding may be required to accelerate the restoration process. For areas where peat is present, reinstatement needs to take into consideration how the peat is managed prior to placement, and how quickly this is likely to re-vegetate naturally, or with the assistance of turves or localised seed mixes. Excavated material is likely to be suitable for a number of engineering uses either on site, as required, or at an off-site location.

If the material is to be removed, this can amount to a significant quantity, and therefore this is likely to be a time consuming and expensive operation with associated environmental impact such as traffic movements, carbon emissions and noise and waste legislation implications.

The most significant issue associated with the reinstatement of the crane pads is likely to be the availability of suitable topsoil (or equivalent) material and prevention of soil contamination. Careful consideration of the stockpiling and acquisition of suitable material should be given at the design and construction stage. A large volume of material may be required to be imported, or removed, in order to allow the re-made ground to suit local levels bringing with it the risk of soil contamination. The storage of materials on site and the disposal of materials off site would need to be undertaken in accordance with SEPA regarding the Waste (Scotland) Regulations 2012 (or any amendment thereof).

5.3.7 Transformers/Package Substations

Transformers tend to be located adjacent to the wind turbine they service. These are likely to be removed from the site as part of any decommissioning, or removed and upgraded with a new one where the intention is to repower the site. This would involve lifting equipment, such as a crane or lifting arm, and a transporter.

Transformers are typically founded on a reinforced concrete raft slab or structural upfill, as part of, or adjacent to, the crane hardstanding. Typically, this would be no greater than 5m x 5m and 0.3m thick. Any concrete slab could be broken up by hydraulic breakers and the material removed from site for onward recycling and reuse, or processed on site and used as backfill or engineering fill if the conditions permit.

Transformers and some other components within wind turbines can contain oils and other lubricants. Contamination from these during the operational phase is likely to be limited to localised spills which could be cleaned by standard spill-kits or by removing the contaminated material etc. During decommissioning, it is recommended that all fuel, oils and lubricants are drained from the components under a controlled method and then recycled or disposed of appropriately. Similarly, consideration may need to be given to the secure transit of such components. Any storage on site for processing, bulking or onward collection should be sited to mitigate any risk of contamination of local water courses and groundwater. Measures such as use of a low permeable liner may be required in any storage locations.

5.3.8 Site Access Tracks, Laydowns and Passing Places

Site access tracks can comprise of a number of materials. They are typically comprised of crushed rock, but could in some locations be concrete or bound asphalt.

The running surface will typically be 5-6m wide, but can be founded on a variety of different formations. Some tracks may be floating roads, which will comprise of layers of geogrid and a thicker layer of crushed rock (0.5-1.0m). These are generally used where the underlying strata is a deep (typically greater than 1-1.5m thick), soft and usually wet natural material, such as peat. Some tracks may also be constructed on a large embankment, which can result in a significant quantity of engineering fill material. Consideration should also be given to brownfield sites, where tracks could be prone to contamination from surrounding materials.

The total volume of material associated with the tracks could be significant given the length of tracks used in many remote wind farm developments. If the after use of the site can make use of some or all of these tracks this could justify a reduction in the number that might need to be removed. Conversely, if the development is in an area of wild land, it may be desirably to remove the tracks altogether.

In most cases, and certainly for granular based tracks (but also concrete and asphalt) these materials are mostly inert and stable over the long-term, so will not pose a contamination risk if left in situ.

Compacted granular tracks can be removed using excavators and dump trucks. Again, like other crushed rock products, these could be used elsewhere on site if required, such as new tracks, backfilling borrow pits, filling in turbine base excavations etc., or transferred to road tippers for onward re-use at another location. Geotextiles/geogrids etc. can be selectively removed for recycling or disposal.

One of the key issues associated with removal of tracks is the reinstatement of the ground. In many cases there will have been a large volume of original material cut in order to form the road/track, and the footprint of tracks with large earthworks (cuttings or embankments) could be 20m plus in width. During the construction stage, topsoil and the vegetation layer, and any suitable sub-soils, may have been used to dress embankments and possibly stockpiled at the side of the track for future restoration purposes. In some cases, however, this may not have been done, or the material may now not be available.

Therefore, once a track has been removed, it may require a large volume of material (natural in situ) to reinstate the profile of the ground, followed by placement of a suitable topsoil material and seeding as required. In reality, this may be very difficult, or impossible to achieve without disturbing other areas of the site.

The risks associated with leaving tracks in situ are relatively low. If the tracks are not required to be re-used, then localised grading of the road to suit the ground profile followed by reinstatement of topsoil/vegetation layer would be a low risk activity. Consideration and sensitive management of the movement of groundwater and surface water would be important. Similarly, the underlying track, once covered, may drain water from the overlying topsoil and vegetation, and therefore reinstatement may not achieve the desired outcome. This can be managed and engineered to mitigate these risks.

One of the key considerations in restoring tracks to their original condition will be the availability of suitable material to backfill and reshape the site. If the original material that was moved during the construction phase is not available, this could lead to the winning of material from elsewhere on site which itself could create an additional environmental impact. Alternatively, importing fill material from off site will be expensive and may not provide the desired restoration product that meets the same criteria as in situ material. It will also increase road traffic, thus increasing road safety risks, reducing local amenity, and increasing carbon emissions.

There may be a requirement for new tracks or tracks to be upgraded as part of an extension or re-powering of a site. In such cases, it may be possible to recycle track material or processed concrete. Consideration should also be given to the placement of newly excavated topsoil and subsoil material from these new tracks to areas that are required to be restored.

Consideration is therefore required at the original design and construction stage to minimise the cut and fill to create tracks, and also to efficiently manage and protect the condition of stripped topsoil/subsoil resources for their future use in the reinstatement of the site. The Quarry Regulations (1999) may provide useful guidance here although they only apply to quarries.

Figure 14 provides some examples of restoration options for tracks. Edge protection bund to be installed as required for safety and screening as identified in the site design.

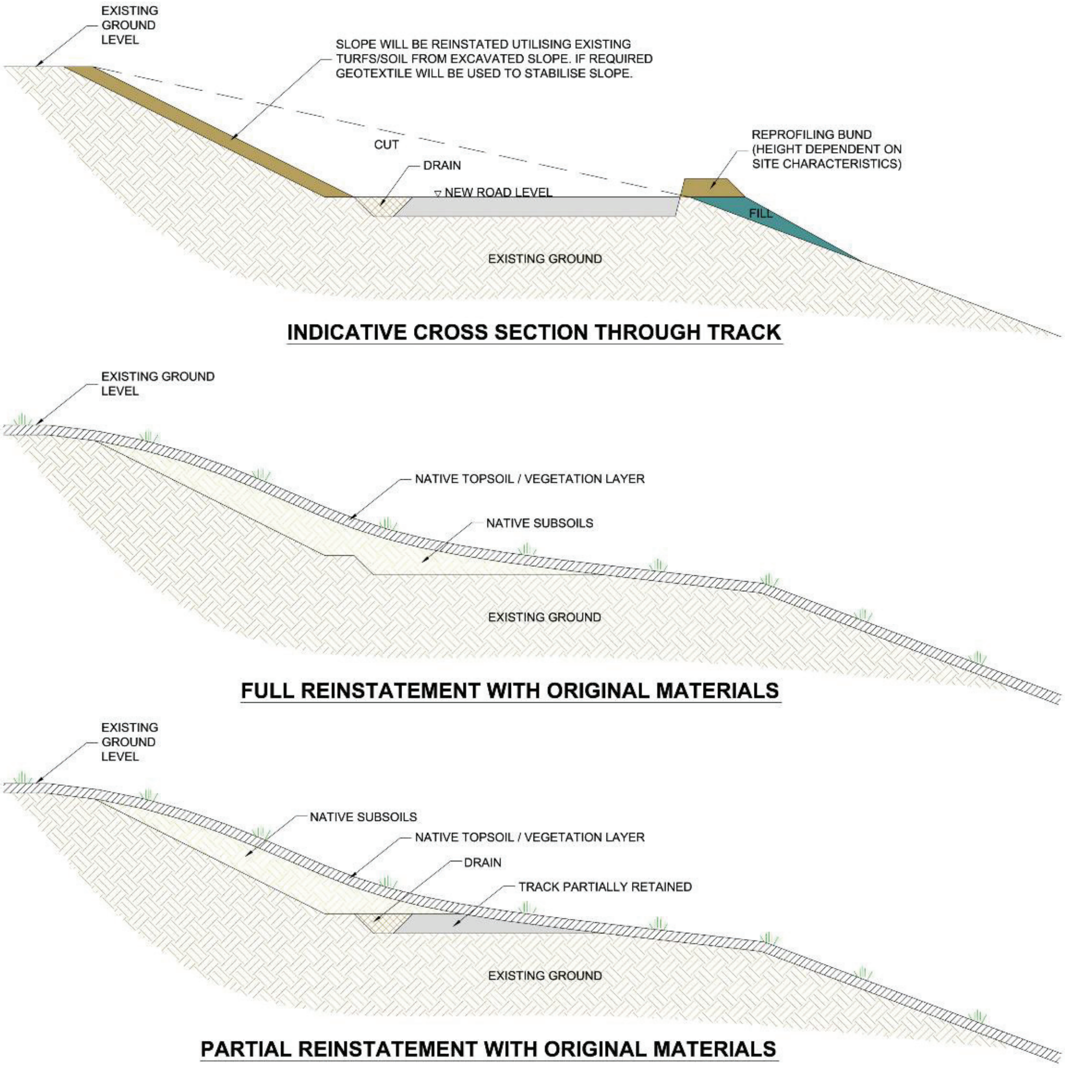

Figure 14. Restoration options for wind farm tracks.

Key recommendations for the design, construction and decommissioning of tracks are as follows:

(a) Consideration should be given to the management of restoration soils at the original design and management stage. Further guidance is needed to inform options and procedures;
(b) Future proofing the design of tracks/embankments etc. for leaving in situ and future use options;
(c) If retained for future use, then tracks/ embankments can be adjusted to suit with partial restoration as required;
(d) If not required for any future use, remove any excess or unwanted vegetation, contamination or other unsuitable materials, and consider localised regrading using existing materials to suit adjacent ground profile. Then place an appropriate topsoil/peat/vegetation layer (at a suitable depth) and seed as appropriate;
(e) If not required and need to remove the track, then a detailed method statement detailing excavation and removal practices, including details of how and where suitable restoration materials will be obtained and how these will restore the site to the required specification.

5.3.9 Sub-Station and Control Building

The sub-station and control building are generally co-located, and in some cases the control building will serve as a standalone structure specifically to serve the sub-station, or it may also be a control room for operational and maintenance staff.

Typically, the sub-station will consist of:

(a) Levelled area on suitable formation (typically natural in situ material);
(b) Granular hardstanding (typically 80m x 80m, and 0.3-0.5m thick);
(c) Reinforced concrete plinths/slabs;
(d) Buried cables / trenches;
(e) Switchgear;
(f) Fencing, such as palisade or chain link; and
(g) Other items, such as kerbing, lighting, parking (hardstanding) etc.

The control buildings and site offices etc. are typically founded on a reinforced concrete base and of traditional timber and brick construction, or pre-fabricated panels on a steel portal frame. Control buildings will be serviced and likely to have LV power, possibly HV connections, telecommunications, water supply, and foul sewer connection or serviced cesspit.

It is likely that, unless there is any future use of these, all elements of the sub-station and buildings would be removed from site. Again, careful consideration at design stage could provide structures that could be converted to other uses post-decommissioning, such as an interpretation point or resting place for walkers. The sub-station hardstanding may be retained in place and covered with restoration soils, but in general all activities associated with the decommissioning of these elements are low risk activities from an environmental perspective. Standard methods and procedures should be adopted to remove these buildings and restore the site as required. However, this activity could be subject to the same constraints as other hardstandings and roads/tracks, in that restoration soils may be difficult to procure if there has been no management of the original materials/soils from these locations.

5.3.10 Cable Trenches

The electricity generated from wind turbines is transmitted to the national grid via a network of cables to the sub-station then onwards to the grid connection. In general, cables tend to be buried between turbines and the sub-station, and will generally be grouped into bundles (runs) which only spur off locally to the individual turbines.

Cables can be removed and taken off site as part of the restoration and decommissioning process. This will help to mitigate the risk of uncontrolled access to the cables through theft. In most cases, cables are buried in shallow trenches that run adjacent to the wind farm access tracks, but inevitably there will be routes which divert off the tracks.

Trenches can be 1-4m wide and 1m deep, depending on soil type, with bundles of cables buried at 0.8-0.9m depth. The backfill will tend to be un-compacted materials. Over time, vegetation may hide and obscure the visible evidence of these trenches, but they should be clearly marked with cable markers for visual reference.

It is likely that cables will be removed upon decommissioning, as even re-energising the site could require upgraded/different cabling.

Once the cable route has been identified and marked out, extraction may involve an excavator pulling/digging the cable and then loading onto a dump truck for onward bulking and removal off site for recycling. There is a risk that cables will snap, and this could be a time consuming activity with close supervision needed to ensure all the cable is extracted. Given that the cables are in trenches that were previously excavated, access for their removal should in most cases be achievable. In general, it is recommended that cables are removed and the trenches reinstated with the existing material, with vegetation preserved and replaced on completion.

Should any cable be left in situ, then providing it is undisturbed, it should remain relatively inert due to the rubber/plasticised coating.

5.3.11 Road Junction Works

Wind farms may have had a bespoke junction with a public road installed as part of the construction phase, which may also have been left as the access for operational staff.

These will tend to be bell-mouth junctions composed of bituminous or asphalt material (to meet the Local Authority highway specification), and will extend into the new development a minimum of 10-15m. They may continue as a bound carriageway or change to a granular track. In some cases, services diversions or protection works may have been undertaken where they cross the junction.

If the track and junction are to be fully reinstated, this should be standard operation undertaken by a suitably qualified highways contractor in which all bituminous/asphalt compounds should be removed for recycling and the public carriageway verge reinstated to its original condition. It is unlikely that any further work would be needed to services that were previously protected, but if this is the case then a suitably qualified contractor would seek the permissions and undertake these works with minimum environmental impact.

It may be possible that any such junctions and possibly tracks have since become shared access routes for other developments, dwellings, or for other local access, and as such, care needs to be taken that rights of way and public access etc are not compromised by any re-instatement works.

5.3.12 Miscellaneous

There are a number of other smaller and stand alone structures that may be constructed as part of a wind farm development.

Examples include:

(a) Permanent meteorological masts
(b) Bridges and other water crossings;
(c) Car parks; and
(d) Display panels and fences.

Most of these structures will generally be simply removed, or upgraded as part of any decommissioning and after use of the site, which will be undertaken using standard engineering procedures. However, consideration may be required prior to any decommissioning of routes and facilities with regards to access rights, shared access and potential impact for any other developments and users in and around the site.

5.3.13 Summary

The table below provides a summary of the options to be considered for reuse and recycling in wind farm decommissioning.

Table 6: Key decommissioning elements, recycling options, relative costs and recommendations.

Key Element	Constituents	Recycling Options	Relative cost of activity	Recommendations
Turbines	i. Blades Resin / Fibre Glass	Yes Off-site uses	Low-Medium	Remove off site. Potential to re-use.
	ii. Blade Hub and nose cone Cast Iron / Resin / Fibre Glass	Yes Off-site uses	Low-Medium	Remove off site. Potential to re-use.
	iii. Nacelle / Gear Box Iron / Steel / Copper / Resin / Silica	Yes Off-site uses	Low-Medium	Remove off site. Potential to re-use.
	iv. Tower Steel (sections)	Yes Off-site uses	Low-Medium	Remove off site. Potential to re-use.
Turbine Base	i. Backfill above and around base. Suitable engineering fill / crushed rock	Yes On-site uses e.g. backfill into void. Also can be used off-site	Low	If base needs trimmed or removed, use as backfill back into excavation. Use locally as fill. Export off site if viable.
	ii. Concrete Bases Concrete / steel reinforcement	Yes Limited options for on site uses. Options greater for off site uses.	High	Consider options to retain in situ. May need to trim top off base and then cap. All concrete and steel removed (as whole or partial demolition) to be taken off site. Processing could be done on site in a centralised location for onward disposal, or re-use if required.
	iii. Concrete Piles	Limited options other than breaking up and	Medium	Cut back to a suitable depth and cap.

	Concrete / steel reinforcement and casing	processing concrete/steel		Any that are withdrawn will need backfilled with suitable material.
Transformer	i. Transformer	Limited options Most likely removed off site for disposal or use by others.	Low	Remove from site.
	ii. Concrete Base	Limited options other than breaking up and processing concrete/steel	Low-Medium	Break up and remove from site.
Crane Pad	i. Hardstanding Crushed rock / geogrid reinforcement Weathered and possibly vegetated	Yes On-site uses e.g. backfill into void. Also can be used off-site	Low-Medium	Retain, regrade, and then cover. Vital that original soils are managed to be re-used for restoration.
	ii. Soils In situ soils retained	Yes High potential if suitable for restoration. Low if unsuitable.	Low (if on site). Very High (if imported)	Have to use if possible, alternatively, use in less sensitive areas of site (e.g. as a subsoil)
Tracks	i. Forestry Spec Roads (granular fill) (also floating roads) Crushed rock / possibly geotextile separators / geogrids on weaker ground	Yes On-site uses e.g. backfill into void. Also can be used off-site Volumes could be significant and will be difficult to re-use all on site.	High (against leaving in situ and monitoring) if tracks to be removed. Significant volumes of material and high costs for reinstatement.	If suitable, can leave in situ. This may involve trimming (cut and fill) to suit profiles. If other risks are identified such as visual, hydrology etc, then tracks may be required to be removed. If to be fully reinstated make use of original topsoil and seed layer for reinstatement
	ii. Bituminous/ Asphaltic Roads	Yes Processed road planings	Low-Medium costs.	More likely limited to road junctions with public highway.

	Bitmac/tarmac/bitumin/ type 1	can be used for tracks etc. More likely for off site, but can be used on site.		Recommend removing if on site and no requirement for road. Remove down to type 1, remove from site for recycling and use by others.
Buildings	i. Control Building / Staff Building Timber / brick / prefabricated panels / glass / steel / concrete Buried and O/H Services.	Medium. Materials can be segregated and re-used off site.	Low Cost	Demolish and remove materials off site if no future use intended. Remove concrete slab and reinstate ground, including removal of buried services.
Substation	i. Switchgear / Cabling Timber / brick / prefabricated panels / glass / steel / concrete Buried and O/H Services. (other miscellaneous – fencing / lighting etc)	None on site. Products may be used off site. Materials can be segregated and reused off site	Medium costs associated with craneage and specialist contractors.	Remove from site.
	ii. Hardstanding Compacted granular material / concrete plinths	Yes Can be used for regrading works / drainage. Can be used off site by others.	Low costs	Remove if possible, or regrade and cover with reinstatement soils.
Cables	i. Cables Copper /aluminium/ Fibre optic / plastic and rubber sheaths	Yes. Copper and other metals can be recycled off site.	Low-Medium costs May be slow and access to some locations difficult.	Remove as much cabling as possible and reinstate trenches by covering with suitable soils.

5.4 Reuse of Turbines

The successful implementation of wind energy in Europe has led to a developing market for second hand wind turbines. Repowering of wind farms after 5 to 15 years of operation releases a large number of turbines into the market. For developing countries, this is an opportunity to gain experience in working with renewable energy sources, to establish their own wind energy industries and to profit from technology transfer with low capital expenditure.

For many developing countries, projects with new wind turbines have proven unaffordable and cheaper used turbines provide an option. Used turbines have also been attractive for community led schemes in Scotland and the UK. Several benefits of this are highlighted in European Copper Institute (2008) Hulshorst's report including:

- lower capital expenditure saves the investor's capital resources and reduces the efforts involved in collecting borrowed capital;
- shorter project duration reduces the investor's financial risk, especially valuable in politically and economically unstable conditions;
- turbines from 150 to 600 kW can be transported and erected without major problems;
- maintenance work on used turbines can be conducted easily, compared with the latest technology turbines that require both a sophisticated infrastructure and specialists to carry out routine work. Using used turbines means that it is not necessary to make high demands on qualified personnel;
- a substantial overhaul and adaptation to regional requirements can take place while the used turbine is being dismantled.

Several companies in Europe are now specialising in selling or offering advice regarding used wind turbines.

CASE STUDY 4 - Isle of Gigha

The small community of the Isle of Gigha, off the west coast of Scotland, bought three second hand Vestas machines in 2004; it became one of the first buyers to tap Europe's market for used wind turbines. However, the cabling, substation, transformer, switchgear etc used was brand new, The Isle of Gigha Heritage Trust (2013).

The 675-kilowatt wind farm produces enough power to meet. al.most all of Gigha's annual electricity needs; has significantly cut the island's carbon footprint, and generates an annual c.£93,500 profit for Gigha Renewable Energy, the locally owned company that operates the turbines.

The success of Gigha's reconditioned turbines, known locally as the Dancing Ladies, highlights a fast-growing new market created by the global boom in wind-generated power as reported by Mark Scott (2008).

Figure 15: The Dancing Ladies, Isle of Gigha. Photograph © Audrey Dickie courtesy of The Isle of Gigha Heritage Trust.

5.4.1 Reuse of Turbine Blades

The market for second hand turbines is growing due to increased demand from Eastern European countries as well as the waiting list for new turbines. The almost two-year waiting period for new turbines was forcing some buyers into the second hand market to meet the European Union's CO_2 reduction targets. Moreover, used turbines cost 40% less than new turbines, and their typically smaller size makes it easier to get local approval for their installation.

While second hand turbines have been sold in Europe for almost 15 years, the small number now reaching the market is expected to grow rapidly. Many utilities are exploring the possibility of upgrading their existing wind farms over the course of the next five years, replacing the existing turbines with larger, more modern turbines with greater generation capacity. That means more than 5,000 second hand turbines are expected to go on the market, in Europe, by 2013.

Windbrokers, a turbine dealer based in the Dutch city of Maarsbergen, has already sold hundreds of second hand turbines to companies such as GlaxoSmithKline and Nissan Motor, which installed them to generate electricity for their plants across Europe. Utility companies in emerging markets are also buying. Huge demand from Eastern Europe, Asia, and Latin America saw revenues associated with the sale of second hand turbines soar from $3.1 million in 2004 to an estimated $108.6 million this year.

The emergence of this secondary market is of benefit to utilities looking to dismantle outdated wind farms. Although wind turbines can usually operate for 20 years, many utilities retire them after 10 years and install more-efficient equipment.

Reconditioned turbines are generally not covered by manufacturers' warranties, and repair costs on aging equipment can mount quickly. Those expenses, along with investment needed to connect turbines to the electrical grid, puts them out of reach for some customers. However Windbrokers anticipated that demand for used turbines will continue to outstrip supply. The company, founded by Vermeulen in 2002, is now starting to sell new turbines, as well as offering services such as guarantees on reconditioned equipment.

Other more innovative reuse options, such as use of redundant turbines as play equipment, have emerged as illustrated below. However, there will be a limit to how much decommissioned material can be used in this way.

Figure 16. Wind turbine playground, Netherlands.

Playground design: 2012architecten
Recycled: windmill wings
Construction: 2008
Location: Netherlands
Photos: Allard van der Hoek, Jos de Krieger/2012Architecten

5.5 Recycling Wind Turbine Blades

Wind turbine blades typically consist of reinforcement fibres, such as glass fibres or carbon fibres; a plastic polymer, such as polyester or epoxy; sandwich core materials such as polyvinyl chloride (PVC), PET or balsa wood; and bonded joints, coating (polyurethane), and lightning conductors.

Professor Henning Albers from the Institut für Umwelt und Biotechnik, Hochschule Bremen, estimates that for each 1 kilowatt (kW) installed, 10 kg of rotor blade material is needed. For a 7.5 megawatt (MW) offshore turbine that would translate into 75 tonnes of blade material. In a presentation at Composites Europe in September 2008, Albers predicted that by 2034, around 225,000 tonnes of rotor blade material are due to be recycled per year worldwide, as reported in Renewable Energy Focus (January 2009).

At present there are very limited commercial recycling operations for main stream composite materials, due to technological and economic constraints. Essentially, it is difficult to liberate homogeneous particles from the composite material. Because of this challenge, most of the recycling activities for composite materials are limited to the down cycling (the process of converting waste materials or useless products into new materials or products of lesser quality and reduced functionality) such as energy or fuel recovery with little materials recovery such as reinforcement fibres. Relatively recent environmental legislation like the EU-directive for end-of-life vehicles and the directive for waste electric and electronic equipment causes increasing demand for recycling techniques that realise true material recycling. Extensive R&D activities have been conducted, and various technologies, yet to be commercialised, have been developed in three categories: mechanical recycling, thermal recycling, and chemical recycling.

- Mechanical recycling involves shredding and grinding followed by screening to separate fibre-rich and resin-rich fractions for re-use. The method is very energy-intensive and the recyclates have relatively low quality.

- Thermal processing uses high temperature (between 300 and 1000 ◦C) to decompose the resin and separate the reinforcement fibres and fillers. Clean fibres or inorganic fillers are re-generated, and thermal energy can be produced through pyrolysis, gasification or combustion. However, the quality of the recovered fibres or filler materials degrades to a varying extent during thermal processing.

- Chemical recycling aims at chemical depolymerisation or removal of the matrix and liberation of fibres for further recycling by using organic or inorganic solvent. Lack of flexibility and generation of waste chemicals with environmental concerns mean there is no active development at the moment. However, a cleaner process based on near- and super critical fluid (in particular water) technology has gained more attention in the research world and has shown an interesting potential.

Lack of markets, high recycling cost, and lower quality of the recyclates versus virgin materials are major commercialisation barriers, and will hinder further use. Environmental legislation will help to promote recycling, but long-term technological developments are needed. Groundbreaking innovations are necessary in the following three areas:

(1) Materials development for new and easily recyclable composite materials.
(2) Materials recycling for more efficient and intensified separation and purification technologies
(3) Production techniques that can at least partially use the recycled fibres instead of only new fibres.

It is hoped that future innovative research and development, and new breakthrough separation and recycling technologies for the composite materials recycling will be available along with more easily recyclable composite Yang *et. al.* (2011).

5.5.1 Reprocessing blades for use in cement production

The world's only industrial-scale reprocessing of end-of-life wind turbine blades is currently undertaken by Zagons Logistik at its factory in Malbeck, northern Germany.

The company's service begins with the use of a mobile saw that can be used in the field to cut large blades into shorter sections of 10-12 metres - which can then be transported in a conventional truck rather than a wider vehicle requiring police escort.

At the reprocessing facility, a stationery cable saw is used to reduce blade sections further, to about one metre in length. These sections then enter a crusher that reduces material size to about 30-50 centimetres.

The next stage sees the material being fed into a cross-flow shredder, which rotates 800 times per minute, reducing the chunks of waste blades further. A hammer mill then takes their size down to a maximum of 5 centimetres, after which they are mixed with other, wet waste materials. The addition of wet substances ensures that glass fibres from the crushed turbine blades are captured and bind to the rest of the mixed waste. The resulting end product is a compound that cement producer Holcim can use both as a substitute fuel, reducing coal-ash, and as a raw material, displacing some of its need for virgin washed sand.

Zagons Logistik is keen to secure larger volumes of waste turbine blades since its plant is running only at about one third of its full capacity. The company currently reprocesses about 400-500 tonnes of waste turbine blades each month. (Windpower Monthly March 2012)

5.6 Cost and Benefit of Restoration and Decommissioning

There are a limited number of studies and examples of the costs and benefits of restoration and decommissioning. This will improve as activity in this area increases. This section has drawn on a number of decommissioning plans for proposed and existing wind farms in the UK and USA and research undertaken by the University of Strathclyde (2012) which developed a decommissioning case study for Whitelee wind farm.

The table below provides a summary of findings. The cost estimates do not necessarily indicate what would be the best practicable environmental option, for example they may include infrastructure which may be left in situ.

Table 7: Decommissioning and Restoration Costs

Wind Farm	What does it cover?	Cost Estimate	Revenue Estimate
Whitelee Wind Farm	Removal/restoration of turbines, top level of foundations, tracks, cables, substation, associated buildings plus enhancement of visitor centre for future use.	£23,000/turbine £4,651/turbine for blade recycling £7,938/turbine foundation £3,761/turbine for tracks £10,027/turbine cable removal £60,000/substation, associated buildings, enhancement of visitor centre.	£78,690/turbine (steel, copper, cast iron resale) Positive balance estimated at between £3million and £8.1 million.
Carraig Gheal Wind Farm	All turbines and assoc electrical components, turbines split on site, bases to depth of 1.0m, buried cables left in situ, cut back and backfilled where above ground. Tracks left.	£300 tonnes/turbine estimate Overall cost estimated between £27,438 and £548,778/turbine (including scrap value and inflation)	£200/tonne scrap value
Gwynt y Môr Offshore Wind Farm Ltd	Removal of installations Waste management Surveys Monitoring, maintenance and management where installation is not entirely removed.	£400,000/turbine Decommissioning fund estimated at £106 million to be placed in escrow account (10th/yr)	Not estimated
New Grange Wind Farm, New York State	Removal of towers, bases (48 inch depth), removal collection system, seeding	Gross cost - $88,955/turbine	$35,000

	and re-vegetation.	Net cost - $53,955/turbine	
Stony Creek Wind Farm, Wyoming County	Removal of blades, hub, nacelle, tower, foundation and backfill/ restoration	Net cost $17,494/turbine	Approx $10,000/turbine
Little Raith, Fife	Removal of turbines, foundations (1m), anemometry mast, access tracks, control building, crane hard standings, soil and seed for affected areas.	Net cost £15,000/turbine.	Not provided separately

5.6.1 Consideration of costs within the RDP

The literature review identified a range of issues that should be considered including:

- Techniques – for example, crane lifts reduce damage to components and helps retain their value in the reuse/recycling market.
- Regulations – for example the Waste Electric and Electronic Equipment Directive (WEEE) requires that 75% by weight of WEEE material is recycled.
- Weight of materials – accurate figures may not be available post-construction
- Recycling of blades - is likely to be significantly advanced over the next decade due to strong drivers from waste targets, regulations and interest in developing the market.
- Remote locations - may mean that costs could rise considerably to cover haulage.
- Employment – period of restoration and decommissioning could range from 3 months to several years depending on method and monitoring requirements
- Allowances, for example;
    - 5% allowance for possible future regulatory changes
    - Overheads, e.g. 15% of cost for office staff, plant items and compound set up charges
    - Inflation allowance compounded over a 25 year period
    - Professional fees e.g.7% of the construction costs
    - VAT
    - isolations to National grid
    - any special insurances bonds and contract conditions
    - archaeological investigation costs
    - presence of any endangered species
    - adverse site conditions

A number of the examples reviewed used the following data sources to estimate costs and value of materials:
- Davis Langdon, Spon's External Works and Landscape Price Book 2013
- David Langdon, Spon's Civil Engineering and Highway Works Price Book 2013
- Scrap value is available from European Metal Recycling (EMR) and Letsrecycle.com

It can be seen from the table above that a relatively wide range of costs have been estimated across these examples. Understanding the cost/benefit balance is an important element of the RDP and provides a basis by which the process can be considered fully and appropriate decommissioning plans and bonds put in place.

6. CONCLUSIONS AND RECOMMENDATIONS

6.1 Introduction

This study set out to increase understanding in relation to restoration and decommissioning of onshore wind farms. The research has investigated the current practice and drivers for RDPs, the restoration and decommissioning process, the potential impacts of restoration and decommissioning impacts on the natural heritage, and the options for end-of-life infrastructure. The key areas of focus for the study were potential ecological, hydrological and landscape impacts and the engineering limitations that require consideration in the restoration and decommissioning of onshore wind farms. Broader issues such as health and safety, waste and land management are beyond the scope of this research.

This final chapter draws together the building blocks for establishing a good practice RDP template, presents the conclusions, areas of future research and recommendations.

6.2 What have we learnt from current practice?

In the course of this research a number of RDPs have been reviewed from the UK and overseas. Case examples of RDPs are provided in Annex II. In developing good practice for RDPs it is useful to consider the following:

- The drivers for RDPs
- The process of developing an RDP
- The implementation of a RDP

The research has shown that there are several drivers for developing good practice; however, they are relatively disparate forces. They include:

- Legislative drivers, such as planning consent and conditions. However, unlike offshore wind farms the guidance and leverage for RDPs is weaker and the results vary from minimal information (within the ES) to reasonable RDPs produced for the decommissioning and repowering of sites;
- Social and policy drivers, such as establishing appropriate leases and bonds, the ‘reversibility’ of wind farms, and the long term ‘social license to operate’ wind farms;
- Natural heritage, such as the opportunity to optimise habitat enhancement, protect soils, water, habitat and landscape; and
- Technology and innovation, for example, increasing understanding of the best environmental option for turbine bases, tracks and cabling, reuse and recycling options and improved site and technology design.

Drawing these drivers together can help inform good practice in RDP. The process of developing an RDP has underpinned this study in the interests of delivering good practice. Questions that arise with regard to the process include:

- What are the aims and objectives of the RDP? For example, is the site to be restored to its original land use purpose? Is environmental enhancement an option?
- How is the RDP developed and who is involved in its approval (Planning Authorities, Landowner, statutory consultees, wider stakeholders)?
- At what stage should the RDP be developed?
- Is a new EIA required? If so what is the baseline?

The examples of RDPs that have been reviewed demonstrated that a variety of approaches were taken to develop an appropriate process which may be site or sector specific. For example, Gwent y Mor offshore wind farm provided a RDP pre-consent in response to a notice under Section 105(2) of the Energy Act 2004 requiring a RDP prior to the start of construction. Other sites, such as the Spurness wind farm submitted a RDP to Orkney Council concurrent with an application to repower the site.

In terms of implementing RDPs for onshore wind farms, there is relatively little experience in the UK and it will therefore be very useful to capture lessons learned as this becomes a more frequent occurrence. Some key points from the literature review are as follows:

- The implementation of a RDP is a self-contained project and should be set up as such with appropriate contracts put in place;
- The site activities constitute a construction project and must comply with all relevant regulations (i.e. CDM, peat handling and storage, waste, health and safety, CAR)
- The overarching principles of restoration must be maintained throughout the implementation of the RDP, mitigation of impacts and monitoring and management of residual effects.

The main focus of this research is on the development of an appropriate process for onshore wind farm RDPs. Drawing on the main findings of the research the building blocks for establishing a good practice RDP template are presented in the next section.

6.3 Principles and Best Practice

6.3.1 Principles

As discussed in Chapter 2 BPEO provides a framework for a RDP, especially in considering the balance of environmental effects of removing or leaving infrastructure, method of removal and the process to underpin environmental decision making.

This along with the overarching principles provides a framework within which to develop RDPs.

- Restoration is the overarching principle with decommissioning an activity within this;
- RDPs should provide the opportunity to lever improved restoration at decommissioning stage (especially if this was insufficient at construction stage) and leave the site in better condition than the original baseline;
- To prove the ‘reversibility’ of wind farms where all visible traces and all significant environmental impacts are removed (including below ground infrastructure) if appropriate;
- To devise pragmatic solutions based on the existence of the wind farm;
- To gather evidence through the decommissioning process upon which to base future recommendations, such as standardisation of engineering design elements;
- To be assessed in terms of carbon balance especially level of peat disturbance, soil movement, distance to recycling, on site vehicle movements); and
- To help decide whether to repower or decommission.

6.3.2 Practice

Figure 17 presents an outline template for the RDP which can be adapted according to site specific conditions.

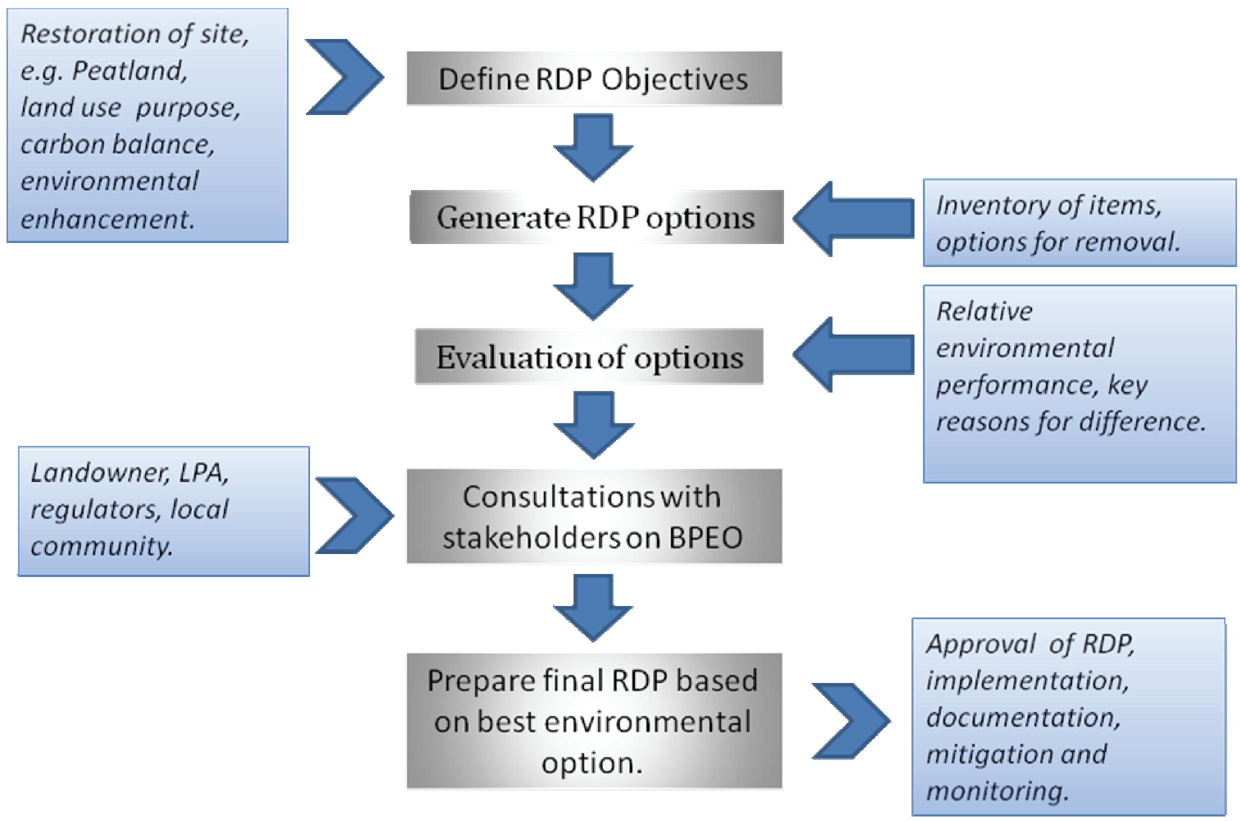

Figure 17. Framework for Restoration and Decommissioning Plan

The approach outlined in the table above will provide a systematic, transparent and flexible process for a RDP and importantly planning and reviewing the success of site restoration and aftercare. Experience from other industries suggests that sustained positive communication and practical working relations between Developers, Landowners and Planning Authorities/Regulators will help minimise potential problems and achieve better long-term results. In turn this will also build confidence within regulating agencies and public in the ability of sites to be successfully restored to a good standard and in a timely fashion.

6.4 Conclusions

The research study has found that:

- There is a willingness and enthusiasm amongst stakeholders to consider the issues of restoration and decommissioning in more depth than has been historically the case;
- There is recognition that by doing so the process of designing and constructing wind farms could be improved;
- It is acknowledged that earlier consideration and regular review of restoration and decommissioning plans would be beneficial to the environment;
- There are existing processes where restoration and decommissioning plans could be effectively integrated e.g. Habitat Management Plans, Health and Safety Plans, CDM;
- There is interest in a step-by-step guide that would provide a framework for site by site consideration whilst promoting consistency of approach.

In terms of developing effective best practice RDPs:

- The planning and/or environmental statement needs to contain sufficient information regarding the likely options for decommissioning and their associated impacts so that this becomes an integral part of the process;
- Reviewing the RDP on a regular basis throughout the operational life of the wind farm will help pre-empt issues that may arise at the decommissioning stage;
- Technological advances and changes in preferred approaches during the lifetime of a wind farm mean it would be best practice not to limit options too far in advance of actual decommissioning but to maintain informed flexibility until close to the end-of-life of the wind farm;
- Future planning, beyond first round of re-developing, and learning from previous experiences to influence good practice is essential.

In terms of infrastructure removal:

- A thorough understanding of a site's natural heritage characteristics (its setting and relationship with surrounding area) and how these respond to change is critical to assess how the impacts of elements of the decommissioning strategy (e.g. construction works, habitat restoration, ground stability etc.) might affect the site. Only with this understanding can the decommissioning strategy be determined and appropriate mitigation measures identified;
- Recommendations for infrastructure removal should reflect techniques and approaches that will result in the least disturbance to the environment, subject to the wider aims of the decommissioning strategy;
- From a landscape and visual perspective any demolition and reinstatement should achieve the greatest improvements with the least disturbance and impacts on landscape fabric, character or visual amenity of neighbouring receptors through careful control of the works;
- It is important to understand a site's soils and their influence on habitats so that re-established communities are likely to sustain themselves in the long term. The mass balance of soil movement, risk of contamination and avoidance of generating waste soil is critical to sustaining the site appropriately in the long term;
- HMPs need to be proportionate to the site, its ecological interest and the development's impacts, and expectations of their extent and content, even at the repowering stage, need to be reasonable.
- There should not be a presumption that all positive habitat management works will cease.

6.5 Recommendations

It is recognised that wind farms have been constructed on a variety of sites each with their own unique characteristics in terms of soil types, habitats and land uses. This research aims to make more explicit the issues to consider and the options for restoration and decommissioning rather than a prescriptive approach for all sites. The recommendations seek to balance the overarching aims in terms of reversibility and reinstatement with the need for a RDP to be a flexible framework for different sites and to result in pragmatic solutions. The key aspects for the RDP are therefore as follows:

- To provide a comprehensive framework such that the considerations for restoration and decommissioning can be properly scoped yet there is flexibility for site specific conditions;
- To continuously improve good practice as more experience is gained;
- To provide consistency in approach;
- To inform other agreements and processes such as the lease;
- To integrate with other processes such as HMP and decommissioning bond review.

6.6 Areas for further research

Further areas for research that would help inform the RDP and sustainable management of onshore wind farms identified during the study include:

- Removal techniques that minimise environmental impact, for example, cable installation and removal design such as via ducting;
- Options and costs for turbine base and track removal;
- Blade recycling (pyrolysis, shredding for insulation, separation and recycling of component materials) and potential markets to avoid landfill disposal;
- Risks to natural heritage of leaving infrastructure in situ, such as, cables and reinforced concrete bases;
- Short and long term effects of removal of infrastructure on soils and habitats (bases, tracks, cabling);
- Assessing long term effects of floating road construction on peat and peat hydrology; and
- Review of habitat restoration and creation techniques and their effects on hydrology and potential to generate desired habitats.

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ANNEX 1: DEVELOPING GOOD PRACTICE WORKSHOP REPORT

Onshore Wind Farm Restoration and Decommissioning:

Event summary

This is a summary of the Sharing Good Practice Event, held at Battleby Conference Centre, Perth on Tuesday 27th November 2012. The presentations are available online: http://www.snh.gov.uk/policy-and-guidance/sharing-good-practice/presentations/document/?category_code=SGP&topic_id=1587

Introduction

In September 2012 SNH commissioned SLR Consulting Ltd (SLR) to research the long-term Restoration and Decommissioning options for onshore wind farms. The aim of the research is to provide a step-by-step approach to considering best current environmental options for the post-operational stage of wind farm development. The results of this research will then be used by SNH to develop good practice guidance.

The purpose of the workshop was to focus on the likely process involved in a Restoration and Decommissioning Plan for onshore wind farms. The objective was to explore and discuss different stakeholder's perspectives as to the process by which sustainable Restoration and Decommissioning could be achieved. The workshop sought to:

- gather stakeholder views and experiences;
- discuss what good practice might look like; and
- identify criteria for designing Restoration and Decommissioning plans.

Key aspects of the event

The event was organised by SLR with support by SNH. It was a 'Developing Good Practice' event held upon the 'Sharing Good Practice' platform. This reflects the early stage of developing our understanding of best practice in this area.

SLR built on the stakeholder list from the previous Decommissioning of Wind Farms event in 2011 to generate a broader stakeholder list to invite. The event was not a training course but designed to help develop the approach to good practice in Restoration and Decommissioning through sharing ideas, experience and views on the process to achieve a sustainable outcome.

The event was attended by 49 participants including Local Authority planning and biodiversity officers, policy advisors, Developers, Regulators, solicitors, insurers, peatland experts, ecologists, wetland ecologists, project managers, quantity surveyors, heritage management, construction managers, landscape architects and upland managers.

The opening session was used to present the 'hopes and fears' of the key stakeholders – Scottish Natural Heritage (SNH), Scottish Environment Protection Agency (SEPA), Forestry Commission Scotland (FCS) and Scottish Renewables (SR) as the industry representatives. This was followed by a panel Q&A before participants joined syndicate groups for facilitated round table discussion. Syndicate groups focussed on the following topic areas:

- Principles for decommissioning, repowering and restoration
- Process options
- Critical issues and suggestions

A plenary session with panel discussion involving Scottish Government, SEPA, FCS, SNH and SR completed the morning session.
Two case studies were presented in the afternoon session:

- Case Study 1: Decommissioning of Spurness Wind Farm by James Milner Smith, SSE Renewables
- Case Study 2: Bramford Landfill Restoration by Bob Bainsfair, SLR Consulting Ltd

The main points arising from the presentations, panel discussions and syndicate groups are summarised in the section 'summary of issues of relevance to research' at the end of this report.

The issues are summarised in the table below:

Issues before the event	Issues following the event	Role
Further disturbance of ground and habitats.	Same	Regulator
Peat, turbine bases, tracks removal.	Complete removal of bases and tracks unlikely to be viable or acceptable.	Developer
Removal of foundations. Decommissioning bonds.	Vast majority were in agreement that bases should not be completely removed. There was no substantive debate on Decommissioning bonds.	Developer
Restoring for landuse and visual impacts while minimising ecological impacts.	Potential ecological impacts and project costs (which may not have been factored in from the start) were of higher priority than landscape.	Developer
Turbine bases	Additional issue of cabling.	Risk manager
Removal of infrastructure	Additional concerns of the impact on ecosystems of the removal or leaving in situ of infrastructure.	Local Authority biodiversity officer
Levels to which it would be acceptable and agreed to restore sites.	Same	Local Authority planning officer
Consistency in what is expected with different consents.	Some guidance would be good to harmonise the approach to this issue.	Ecologist
Concern about inability to follow through with restoration plans (particularly where peat is involved). Concern about potential gradual breakdown of concrete founds over time following covering over (rather than being broken up). Limited previous experience to go on (lack of decommissioned / repowered WF's)	Lack of experience in carrying out restoration works. Still concerns about peat degradation and intentions to restore failing. Less concerned about pollution from founds.	Local Authority planning officer
Standard Restoration and	Need to discuss with	Developer

Decommissioning text in EIA	stakeholders what use will be after de-commissioning and tailor input accordingly	
Whether the turbine bases / foundations were removed or not, and whether access roads are reinstated	Similar, but also where would peat etc be found to fill in any gaps if roads and turbine foundations were removed - and also what, if any, ongoing management of the property should take place after decommissioning, who should be responsible for that, and the effects that removal of certain infrastructure may have on the environment in the area.	Solicitor
Decommissioning actually happening and technical aspects of removing the kit	Ecological effects of removal and restoration.	Developer

The main learning points from the event organisation and content were:

Positives	Areas for improvement/suggestions
The voting on issues at the end of the day	More focus on certain issues for individual's interests
Good content and length with good speakers coming from different perspectives	More time or fewer presentations
Syndicate groups covered topics well and had good mix of representatives	Greater representation from local authorities
Good mix of content and lots of practical applications	Follow up within 12 months
Well organised, good/excellent catering, excellent venue	

Summary of issues of relevance to research

The main issues of relevance to the research are summarised in the table below:

Issue	Comment
Leases	Inconsistency for different sites causes concern for Developers. Rigidity of lease may mean aspects are irrelevant in 25 years time. Over prescriptive-ness causes cost issues for Developers. How specific can leases be in decommissioning – ie detail for track removal, is this feasible 25 years before the event? Potential for conflicting considerations at the end of the lease. Landowner and Developer work closely throughout the operational phase to keep an open forum. Lease should be structured around final land use post wind

	farm. Principles for decommissioning should be included in lease (e.g. Forestry Commission). Most agreements require tracks to be left. If lease ends then no longer tenant and have no rights to the site
Post decommissioning responsibility	Who is responsible and who bears the cost? Developers would appreciate guidance/clarification over their duties and obligations. Policing and managing the site is key. May need additional planning condition to monitor. No requirement from insurance industry to remove bases. Existing planning conditions will determine if the road can be left for the Landowner Insurance implications – risk of leaving infrastructure - Don't like using explosives - Long term – disclosure of facts – old turbine bases for land ownership Maintaining presence on site for two years post decommissioning / rest completion – can this be planning condition? Developer doesn't have right of access but Landowner can request redress if not happy with reinstatement.
Decommissioning bond	Applied differently to different sites – lack of consistency. Budgets for restoration may be too low especially for example to cover the cost of soil needed, land filling turbines. Review every 5 years to allow changes to be incorporated. Rolling assessment of liabilities. Managed via planning condition or Section 75 Agreement. Insurance top-ups for decommissioning phase. If addressing the R & D plan throughout the operational stage rather than currently three years before end – half way through or throughout – increased workload for planning authorities and statutory agencies – should the bond cover everything? Bonds – we think they are a decent representation of what might be done. We don't want to stagnate the industry

Degree of infrastructure removal	Influenced by five factors: - Environmental legislation - Money, who pays, costs - Lease issues (all agreements are different) - Landowner (who will live with the after effects) - How it was constructed originally, better consideration at the outset might reduce potentially burdensome obligation e.g. ducting cables. It is accepted / understood that all infrastructure cannot / will not be removed at decommissioning. Risk of theft if cables left in the ground. If the habitat management has been implemented efficiently there should not be a need to remove bases. Removing floating road would do more damage than good - Market for rock - Peat from where? - No free use organic material
Multi-generational sites/repowering	When a wind farm is first envisaged (Phase 1) it is rarely designed to be extended latterly. So any “Phase 2” is NOT normally considered. This is due to the uncertainty associated with Phase 1 itself (will it even be consented), and the uncertainty about potential political, legislative and commercial certainties for any potential extension as they’re normally another 5 years later (not back to back normally). Repowering may lead to multiple foundations due to original ones being unsuitable for reuse. Repowering of a WF that has been operational for 10 years will, inevitably, mean that WTG sizes have increased (<1MW to >2MW), so spacing will have increased, so cannot use original infrastructure footprint again – will need to change. However for sites being built “now” then chances of WTG’s getting substantially larger over next decade is reduced, so footprints can be more easily (not always) “recycled”.
Technical constraints, drivers.	Volume of material in bases – time and cost to remove, where would material come from to refill, too many to leave as empty or water filled features. Haulage costs for aggregate, would it be aggregate tax free? Design to reduce material need from outset Is capping of reinforcement required? Floating roads require long term maintenance but are also difficult to remove – liability question? Limited tests on turbines. Test and certify for another 5-10

	years, bases for 75 years? MOT system. Peat - impact of removing bases, storage limitations, slide risk. Potential for wind farms to promote peat growth.
Research and Innovation	Impacts of decommissioning (financial/community benefit, carbon, noise, visual, roads and hardstanding), potential use of infrastructure – e.g. tracks, bases, buildings. Chemical breakdown of concrete over time. Is there a role for innovation? Get turbine suppliers to accept reduced hard standings for construction, means less to decommission (good opportunity / idea). Is there opportunity for R&D on how peat behaves under a floated road? build section of floated road – say 100m long – and then decommissioning it after 2 years, or 3 or 5, whatever, and see what has happened to the peat (soil and vegetation) and how quickly (if at all) it recovers – hydrology, vegetation, thickness (does it expand again ?) Design changes – i.e. rock piles bases, rock anchor Cable removal - ecological issues requires specialist research
Habitat Management Plans	Restoration to complement HMP if on the same site. Continuation post lease is at the discretion of Landowner. Mechanisms required to enable habitat plans to become sustainable long term. Could include section on decommissioning. May indicate that original decommissioning principles are not relevant at the time of decommissioning due to habitat change.
Public attitudes/policy approaches	Uncertainty of public perception and whether the wind farm being no longer visible or the whole base removed would be preferable. Consider public access that has occurred during life time of wind farm. Should wind farms be built with an expectation of repowering. Impact of lack of subsidy in future. May be educational issue to decommission small sites.
Cross stakeholder working	In research into impacts of decommissioning. Pre/during construction to help set standards and approach when decommissioning.

	Role of Directorate for Planning and Environmental Appeals
Decommissioning Plans	Need to know future use of land. Principles of decommissioning included in original ES. Is a further EIA required for Decommissioning Plan? Is guidance for existing or future wind farms? What size of project should it cover? Consideration of phased decommissioning for larger wind farms. Landfill sites have 5 year after care plan, should this be the same for wind farms. Who should look after decommissioning records of a wind farm? Needs to be an iterative process as wind farm may change. Issue of "restoration design" vs. "decommissioning" – the latter is functional, and what is seemingly asked for, the former is more appropriate, and includes habitats, landscape, logistics and materials balance. So "restoration design" should be sought by planners and consultees, not "decommissioning plans" When should the "Decommissioning Statement" be asked for in planning conditions? 1 year before end? 3? 5? Perhaps it should be asked for at PRE-CONSTRUCTION to force consideration of Decommissioning before infrastructure is actually built? (pro-active approach rather than reactive) – whilst acknowledging that proposed methods may change over the operational life as good / best practice evolves. Should, perhaps, decommissioning be a MATERIAL consideration as planning (as part of EIA) – forcing Developer's to think "harder" – rather than just palm it off with "someone else can worry about that in 25 years time" ?!
Waste management/legislation	Most components reach end-of-life at 25 years. Glass fibre turbine blades difficult to recycle in sufficient volume. Require database of companies able to recycle turbines. Water Environment (Controlled Activities) Regulations 2011 Waste
Land type considerations	Habitats (vegetation); Soil types (Peat vs. other soils), Land Use (forestry vs. agriculture vs. Sporting vs. Rough grazing

	etc); Amenity (cultural heritage, recreational access). How do we define what "better" is in terms of land?
Cultural heritage	Cultural heritage issues need to be considered. Impact on settings? Impacts on monuments / houses? Might some wind farm structures become of industrial heritage value in the years to come? And thus become designated themselves?
Restoration	Land owners desires have to be considered, not just environmental. The water flows will have changed over the lifetime of the wind farm. Restoration of borrow pits (BP) – issue of "mass balance" (remove stone to build tracks, reinstate with site won soils, then need to excavate restored BP to put stone from removed tracks back in, and take soils back to site ? issues of mixing, and genesis of soils (will they go back where they came from ?) SEPA now precludes storing of peat in borrow pits, so it won't be available to use for restoration (this is a BIG issue), BP may have become a wetland or some such and actually may now have increased value and should not be re-dug up at decommissioning to put stone back in ... Landowner (LO) education – how do we stop LO's reverting land at end operational life? CAP, SRDP? Needs Governmental incentive and influence Opportunity – to plan for the future whilst repairing mistakes of the past (development permits blocking of peatland drains installed in 1950s, as well as creating something positive for future) – so need to avoid each generation repairing mistakes of previous – time to move forward and build for future.

ANNEX 2: RESTORATION AND DECOMMISSIONING CASE STUDIES

Examples of restoration and decommissioning plans are provided with the following case studies:

- Bramford Landfill Restoration
- Bu Wind Farm, Orkney
- Dalswinton Wind Farm, Dumfries and Galloway
- Galloper Wind Farm, Suffolk coast
- Gwynt y Môr offshore wind farm, North Wales
- Marble River Wind Farm, New York State
- Spurness Wind Farm, Orkney

Case study title	Bramford Landfill
Size, Location, date of commissioning	Progressive restoration of licensed landfill in Bramford, Suffolk, and aftercare/management of resultant habitats.  Source: SLR Consulting Limited
Reason for restoration and aftercare.	Restoration and aftercare is a requirement of the planning consent given in 1998 regarding an extension to the existing landfill site at Bramford.
Content of Decommissioning/Restoration Plan	Site is a licensed waste management facility comprising: • a landfill receiving putrescible waste and some selected contaminated soils; • a Materials Recycling Facility (MRF); • a gas utilisation plant (utilising landfill gas to generate electricity for use on the site and/or for feeding into the local grid); • gas flares; and • offices, weighbridges, access roads and general infrastructure. subject to a number of planning conditions related to: • specification of soils/restoration substrate; • a phased programme of restoration concurrent with landfilling; • details of demolition/removal of site infrastructure and buildings; • details of restoration techniques (in respect of calcareous grassland, damp grassland, scrub/woodland edge, deciduous woodland habitats); • details of measures to protect newly established habitats from rabbit and deer grazing; • details of aftercare and habitat management priorities to ensure that habitats are successfully established; and • details of habitat and restoration monitoring in respect of substrate stabilisation, ecological development of the site. The restoration and aftercare were set out in an outline scheme at the time of the planning application and then supplemented by details pursuant to planning conditions and then Detailed Annual Restoration and Aftercare Reports (DARARs) and site inspections with the Local Planning Authority. The DARARs included reviews of progress, including ecological monitoring reports and survey records.

Points of relevance to establishing step-by-step BPEO for DRP	The use of a systematic and transparent process for planning and reviewing the success of site restoration and aftercare in order to ensure the successful establishment of the restoration. The adoption of sustained good and positive communication and practical working relations between Developers, Landowners and Planning Authorities/Regulators. Growing confidence within regulating agencies and public in the ability of sites to be successfully restored to a good standard and in a timely fashion.
Assumptions	None
Degree of removal/techniques	With the exception of the site access, all site infrastructure and structures are to be removed and agricultural access instated.
Reinstatement techniques	In accordance with outline and detailed restoration and aftercare proposals and formal contract arrangements. Engagement of specialist landscape contractors. Monitoring of progress on an annual basis, including the use of ecological surveys and site inspections with Developer and Local Planning Authority. Reliance on a combination of a small proportion of imported soils and soil making materials recovered from the site, including chalk dug from the base of landfill cells. Use of locally grown plant stock and green hay propogules (including hay from rabbit exclusion enclosures established during previous restoration phases) instead of commercially available non-native materials). Use of sustainable green engineering for slope stabilisation and erosion control.
Conclusions and recommendations	The approach outlined represents a systematic, transparent and flexible process for planning and reviewing the success of site restoration and aftercare. It provides for cost effective responses to unforeseen constraints or difficulties, and for new innovations in restoration and aftercare. The adoption of sustained good and positive communication and practical working relations between Developers, Landowners and Planning Authorities/Regulators helps to head off potential problems and achieves better long-term results. The approach also helps to build confidence within regulating agencies and public in the ability of sites to be successfully restored to a good standard and in a timely fashion.

References	Bramford Landfill – Detailed Annual Restoration and Aftercare Reports (SLR) 1998 – 2007.
Case study title	Bu Wind Farm, Orkney
Size, location, date of commissioning	Three GE 900kW turbines at Bu, Orkney, consented in May 2001.  Courtesy of SSE Renewables
Reason for decommissioning - Planning condition, repowering.	Condition 6 of Planning Consent. Developer wishes to decommission and apply separately to repower. Existing turbine model no longer in production, difficult to obtain parts for repairs and maintenance. Can Foundations
Content of Decommissioning Plan	Project description Reason for decommissioning Site characteristics Description of items to be decommissioned and decommissioning methods Transport required Environmental considerations (waste management, ground disturbance, material excavation and reinstatement, imported materials, ecological protection, pollution prevention) COSHH Decommissioning schedule References/Guidance
Points of relevance to establishing step-by-step BPEO for DRP	Separate decommissioning and repowering plan/application Provides reasons for decommissioning Emphasis on applying waste hierarchy through reuse and recycling (turbine parts, stone) Mitigation measures Site Waste Management Plan (SWMP) Principal Contractor will be responsible for delivery of SWMP, reinstatement and documenting all volumes and types of excavated and

	used materials. ECoW on site throughout decommissioning and construction period. Consideration of surface water pollution and techniques to prevent.
Assumptions	Excavated concrete will be reused on site but not for new turbine bases.
Degree of removal/techniques	Removal of turbines Top 200mm of bases broken Transformers and their housing removed No Temporary Construction Compound but one will be constructed for repowering works. Some widening of public roads for abnormal load movements. Existing access track will be upgraded with stone from existing borrow pit. All plant and machinery will keep to existing infrastructure and will not track across adjacent grassland/habitats. Temporary cut off drains and silt traps used to prevent potential pollutants (fuel/oil, wet cement, raw concrete or silty water). Refuelling done in designated area over impermeable surface at least 50 metres from surface water/surface water drains. Bunding, Spill kits, drip trays and appropriate storage for materials used.
Reinstatement techniques	Foundations to be used in repowering application will be capped using stone. Foundations of no future use will be capped with topsoil and left to re-vegetate naturally from indigenous vegetation. Where transformers removed stone from existing borrow pit will be used or soil depending on their location relative to repowered wind farm infrastructure. Imported soil will be a last resort, if this is the case a Declaration of Analysis and WRAP Quality Protocol will apply. Topsoil and subsoil stored separately. Reinstatement done as soon as possible to avoid erosion and leaching/loss of nutrients.
References	SSE Renewables Decommissioning Method Statement October 2012

Case study title	Dalswinton Wind Farm
Size, Location, date of commissioning	30MW, Dumfries and Galloway, 2008.  Courtesy of Infinis
Planning condition in relation to decommissioning.	“prior to the commencement of any work on site a scheme for decommissioning and reinstatement of the site , including the removal of all turbines and ground reinstatement, shall be submitted for the approval of the council as Planning Authority. The scheme shall include an accurate scaled plan of the site and shall include a specification of all land reinstatement and any form of planting.” Dumfries and Galloway Council Planning and Environment Services Committee Report (05/01/2005, ref 03P/30610)
Content of Decommissioning Plan	• Habitat Management Plan (HMP) • Decommissioning of Access Tracks and Crane Hardstandings, Turbines Bases, Substation and Cable Trenches • Provision for Review of Decommissioning Options
Points of relevance to establishing step-by-step BPEO for DRP	• Alignment with HMP 5 yearly review. • The HMP is seen as a working document and therefore the Decommissioning and Reinstatement Scheme is likely to be included in later revisions of the HMP so that any changes to legislation, climate and habitat over the lifetime of the wind farm can be accounted for to ensure continuity of the nature conservation interest of the site. • Site assessment before decommissioning to determine whether rare or protected mammal or bird species have colonised the vicinity of the tracks, foundations and crane pads. • Decommissioning bond in Section 75 Agreement based on options assessment for decommissioning
Assumptions	No additional planting at decommissioning as preceding 25 years will allow sufficient time for semi-natural heathland vegetation and the riparian habitats to become well established. Also considered appropriate in landscape terms. Minimal removal was considered less environmentally damaging than seeking to remove foundations and cables entirely. For example, access tracks and hardstandings with minimal traffic flows over 25 years likely to support reasonable amounts of semi-natural vegetation.
Degree of removal	The bases of the turbines would be broken out below ground level and

	all cables cut at a depth of 1m below ground level and left in the ground. Roads would either be left for use by the Landowner or covered with topsoil. No stone would be removed from site.
Reinstatement techniques	Cover stone tracks and bases/pads with 100-150mm topsoil originally cast aside during construction. Use this as seed source of characteristic local species to quickly re-establish semi-natural vegetation.
References	Airtricity (2005) Dalswinton Wind Farm Decommissioning and Reinstatement Scheme

Case study title	Galloper Wind Farm
Size, Location, date of commissioning	Onshore substation works on the Suffolk coast, pre-construction Decommissioning Strategy  Courtesy of RWE npower renewables, SSE Renewables
Planning condition in relation to decommissioning.	Decommissioning strategy in line with Development Consent Order
Content of Decommissioning Plan	Statement capturing proposals, discussions and agreements
Points of relevance to establishing step-by-step BPEO for DRP	Consultations with local authorities and Landowner
Assumptions	Agreed that it would not be appropriate or logical to require GWFL to return the land to its original form (a landform was created to mitigate visual impact and noise). The landform and planting were part of an integral part of the landscaped vision providing a woodland core transitioning into heathland habitat – removal of the 20+ year old woodland was deemed unnecessary No topsoil replacement proposed as compound platforms will remain and are nutrient poor meeting the requirement that the vision seeks to create.
Degree of removal	All above ground structures will be removed and foundations broken out to a minimum depth of 1m below ground level All ducted and unducted onshore cables are assumed to be removed on decommissioning, although ducts would be left in-situ to minimise disruption to Landowners which would otherwise occur through their removal. This would be confirmed closer to decommissioning All above surface equipment and structures associated with transition bays would be removed from site and concrete foundations and subsurface chambers removed.

Reinstatement techniques	No sealing of end compounds but will be reprofiled back to original gradients on removal of all above ground equipment. The regular shapes of the landform would be sensibly broken away whilst maintaining safe gradients to create a less regular edge and additional irregular planting would be placed within the substation area.
References	RWE npower renewable, SSE Renewables (2011) Galloper Wind Farm Project Environmental Statement Annexe – Onshore Decommissioning Strategy

Case study title	Gwynt y Môr offshore wind farm
Size, Location, date of commissioning	160 wind turbines, 576MW, located 13-15km off North Wales coast and 18Km of Wirral Coast, within Liverpool Bay. Consent granted 2008. Construction 2013.  Courtesy of RWE npower
Reason for decommissioning - Planning condition, repowering.	DECC issue notice under Section 105(2) of the Energy Act 2004 stating requirement to prepare and obtain approval for a decommissioning programme prior to construction. Design life of turbines is 20-23 years, lease is 50 years.
Content of Decommissioning Plan	Background Information Description of items to be decommissioned Description of proposed decommissioning measures Environmental impact assessment Consultation with interested parties (Joint Nature Conservation Committee, Environment Agency, Countryside Council for Wales, Fisheries Organisations and Committees, Cadw, Maritime and Coastguard Agency, Trinity House Lighthouse Service, Chamber of Shipping, Royal Yachting Association and aggregates industry) Costs Financial security Schedule Seabed clearance Restoration of the site Post decommissioning monitoring, maintenance and management of the site Supporting studies Summary of EIA for offshore components Summary of consultation responses
Points of relevance to establishing step-by-step BPEO for DRP	Follows DECC Guidance - Decommissioning of Offshore Renewable Energy Installations under the Energy Act 2004. Standards by International Maritime Association specify reasons for not entirely removing infrastructure – not technically feasible (design should make it so, but weight and depth may be an issue for foundations), extreme cost, and unacceptable risk to personnel and / or the environment. CDM 2007 Regulations (H&S file will be passed to dismantling contractors during the process) Based on 8 stage process, including consultation and post-decommissioning monitoring. Informed by planning application EIA. Draft decommissioning strategy and programme to be finalised at least a year before decommissioning and include an environmental impact, available technology and legislative framework review.

	Agreed review periods and expectations on content with DECC – 5, 10 and 15 years following commencement of generation. Final review in year 19 Decommissioning strategy helps ascertain level of financial security to be offered. Decommissioning programme is made publically available (may require proof of this). Main considerations – BPEO; safety of surface and subsurface navigation; other users of the sea and health and safety considerations.
Assumptions	Project within Liverpool Bay Special Protection Area for non-breeding birds in inshore waters, an AA will be undertaken before finalising the decommissioning programme. Reuse and recycling of parts. The site will be restored as far as possible and desirable to the pre-construction condition.
Degree of removal/techniques	Offshore wind turbines – complete removal Piled foundations – cut off at or below seabed, removed to a depth not to become uncovered in future. Gravity based foundations– complete removal Suction cassions – complete removal Sub-sea cables (inter-array and export) – left in situ Anemometry masts – complete removal Transformer platforms – complete removal of topside Scout material – left in situ
Reinstatement techniques	Cut foundations below natural level of the seabed are made safe and adequately covered. Ensure that cable ends are sufficiently buried. Active restoration not proposed as this poses unnecessary and unacceptable risk to personnel. Natural resettlement is sufficient and less disruptive to marine life.
References	RWE npower renewables (2010) Decommissioning Strategy Gwynt y Môr offshore wind farm Ltd.

Case study title	Marble River Wind Farm, New York State
Size, Location, date of commissioning	109 turbines (210 MW) installed 2005 in New York State, by Marble River LLC a subsidiary of EDP Renewables.  Source: PPM Energy and Horizon Wind Energy
Reason for decommissioning - Planning condition, repowering.	In 2010 in co-ordination with local towns and Landowners EDP-R decided to reconfigure with large turbines reducing footprint from 109 turbines to 70 and gravel access roads from 42 miles to 22 miles. Aim to minimise permanent impact on sensitive wetland habitat (775 wetlands and 285 surface water bodies).
Content of Decommissioning Plan	Anticipated Life of Wind Turbines Estimated Cost of Decommissioning Ensuring Decommissioning and Site Restoration Funds Decommissioning Process Description Site Restoration Process Description Community Relations and Complaint Resolution Plan
Points of relevance to establishing step-by-step BPEO for DRP	Reconfiguration means reduction in area of Section 404 Wetland Permit. Construction during winter months and when site frozen has reduced wetland impacts. Materials selected so that after the thaw there would be no erosion. All decommissioning will adhere to requirements of appropriate governing authorities and permits. Process of removing structures involves evaluating and categorising all components and materials into categories of recondition (transported whole), reuse, salvage, recycling and disposal (dissembled for transport).
Assumptions	Minimise impact on wetland habitat. Efficiency and minimising of transport impacts. Environmental damage of complete removal may outweigh the benefits. Underground collection cables and conduits contain no materials known to be harmful to the environment. All cable and conduit at a depth greater than 36 inches will be left in place and abandoned.
Degree of removal/techniques	All above ground structures (turbines, transformers, overhead collection lines, wind farmed owned portions of the substation, maintenance buildings and access gates. All below ground structures to a depth of 36 inches (turbine foundations, collection system conduits, drainage structures, access

	road sub-base material). Removal of access roads if required by Landowner. Widening of roads where necessary for decommissioning cranes and machinery. Components and materials may be stored on site in pre-approved location until the bulk of similar components or materials are ready for transport. Access gates and ditch crossings will be removed at the end of the decommissioning process unless the Landowner requests they remain. Following decommissioning the sub-grade material and topsoil from all affected agricultural areas will be de-compacted and restored to a density and depth consistent with the surrounding fields or to a depth of 18 inches.
Reinstatement techniques	Creation and restoration of a self-sustaining, continuous system capable of replacing the original wetland functions. A two-acre wetland complex will be created and will consist of a combination of emergent, scrub-shrub, and forested wetlands to compensate for permanent impact associated with the construction of the project. Additionally, temporary impacts to about 2.4 acres of emergent, scrub-shrub, and forested wetlands will be restored to their pre-construction condition; as will approximately nine acres of temporary impacts to wetland buffers. Sub-grade material to fill excavations will be compacted to similar density to surrounding sub-grade material. Unexcavated areas will be de-compacted to similar compatible density. Restoration of topsoil, re-vegetation and re-seeding use set-aside topsoil where possible. Appropriate quality topsoil imported if necessary. Original surface contours established where possible. In all areas restoration shall include, as reasonably required, levelling, terracing, mulching, and other necessary steps to prevent soil erosion, to ensure establishment of suitable grasses and forbs, and to control noxious weeds and pests Two year monitoring and remediation period (New York State Department of Agriculture and Markets guidelines). Follow up restoration requirements may be identified during this period.
References	Marble River LLC (2008) Marble River Decommissioning and Reinstatement Plan

Case study title	Spurness Wind Farm
Size, Location, date of commissioning	Three Nordtank Energy Group Micon NM92/2750 turbines, 8 MW, sited on the extreme south west of Sanday, Scottish and Southern Energy (SSE) owned. Operational since 2005  Courtesy of SSE Renewables
Reason for decommissioning - Planning condition, repowering.	Parts for the turbines in use at Spurness are no longer available, and so the decision was made to remove the turbines. Due to the excellent wind resource on the island (achieving 45% capacity factors), replacing the old turbines, and extending the wind farm to 5 turbines (Vestas V80 2MW) was pursued as a viable option.
Content of Decommissioning Plan	Planning Application with Environmental Statement Update (2011) to Orkney Island Council by SSE to decommission and repower.
Points of relevance to establishing step-by-step BPEO for DRP	SNH consulted on locally important heritage interests on site. Potential impacts to birds and otters. No significant landscape or visual impacts identified in the Environmental Statement. Site visit during decommissioning and construction work by SEPA, SNH and SSE. The Environmental Clerk of Work (ECoW) was on site 1-2 days per week, average, but associated with more intense periods or more sensitive issues 3-4 days per week. The ECoW has maintained close contact with the project manager, and based on advised activities for upcoming weeks they have modified attendance accordingly. It has always been the ECoW's decision as to what is appropriate / necessary. SSE receives weekly and monthly reports from the ECoW, who is based with Aquatera, mainland Orkney. Old turbine components shipped to Latvia for reuse. It was suggested that perhaps the welfare building, currently under

	construction, has been over designed in terms of size and space requirements for long term use.
Assumptions	The soils on site are generally brown earth, with a mixed land use of grazing and arable farming. The Calf of Eday Special Protection Area lies 1Km to the north (bordering the west coast of Sanday). Its features are Cormorant, Fulmar, Great black backed gull, Kittiwake, Guillemot, and seabird assemblage. During the original construction period, SNH were informed of potential impacts on Arctic terns.
Degree of removal	The ‘cans’ (metal rings embedded in the concrete base to which the tower is attached) in the old bases were cut free, but the concrete foundations (bases) will remain in-situ. Crane hard standings, created for the original turbines and their subsequent removal, are being re-used for new turbine erection i.e. no additional land take One of the islands main roads (B9070) continues to act as the spine road. Cables will be cut back and re-used where appropriate.
Reinstatement techniques	Less than 1km of new track required for turbines 4 and 5. All other tracks upgraded. Road material was won from excavations for infrastructure, or from that permitted to be taken from the existing quarry by the Council Area to the south of turbine 1 cordoned off to protect Arctic terns that began nesting close to, and on the hardcore areas. Unfortunately, the communications about the cordon to the crane drivers broke down and 1 nest has been lost (2 chicks) during de-commissioning.
References	SSE Renewables Planning Application SNH site visit report July 2012

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