Institute for European Environmental Policy

PROVISION OF EVIDENCE OF THE CONSERVATION IMPACTS OF ENERGY PRODUCTION

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EXECUTIVE SUMMARY

This report provides a broad overview of 15 energy technologies identified by JNCC, including their life cycle carbon dioxide reduction potential and their other environmental impacts. It then focuses on eight key technologies that are likely to have the most significant impacts on the environment over the next 50 years (namely coal, oil, gas, nuclear, wind, tidal stream and range, biomass crops and biofuels). The report describes and whenever possible quantifies the likely impacts of the key UK energy technologies, in the light of current capacity and a selection of published future scenarios for the UK energy mix for 2020 and 2050.

The analysis primarily investigates the impacts of the key energy technologies on biodiversity (particularly regarding UK BAP Priority habitats and UK BAP priority birds). In addition, significant implications for geodiversity (ie the variety of rocks, minerals and landforms), landscape and access to nature are identified. The focus is on impacts to the UK environment, but insights on wider global environmental impacts are provided when relevant.

The review provides clear evidence that energy production can have significant detrimental impacts on the environment, particularly as a result of land take and habitat change (especially from open cast coal mining, tidal barrages, biomass and biofuels), disturbance (eg seismic surveys for oil and gas production, infrastructure construction such as new power plants and transmission systems, and wind farm operation), pollution (eg from oil spills, acid mine drainage from coal pits, biofuels and especially eutrophication impacts from nitrogen oxides from coal power stations), and the accidental killing of some species (eg by power lines, wind turbines and tidal barrages).

However, the actual impacts of future developments of each energy technology are likely to vary considerably as a result of three key factors:

- Their scale of use, as this directly affects their land requirements, and with increasing requirements there will be an increasing likelihood that sensitive habitats and sites will be considered for use.

- Their location and in particular the degree to which particularly sensitive sites are avoided (eg through planning and licensing decisions that reflect the findings of adequate SEAs and EIAs). By avoiding sensitive sites it should be possible to avoid many of the most potentially significant impacts identified in this review.

- The degree to which mitigation measures are identified and implemented, as some measures such as those that reduce emissions, noise, hydrological disruptions, disturbance and collisions have a major effect on potential impacts.

The conclusions that can be drawn from the analysis of energy scenarios are limited for a number of reasons, including their varying derivations, purposes and constraints. Many technologies are the subject of specific ongoing political and policy discussions, which could have profound effects on their use etc. New technologies,

such as carbon capture and storage (CCS), are still in a pilot phase, hence their future level of uptake and the extent to which they will be able to mitigate environmental impacts from energy production is still difficult to predict. There also appear to be some discrepancies between the projected use of some energy technologies in some scenarios and the published practical limits to their application. In addition, there is insufficient scientific information to reliably predict the impacts of the use of some technologies on some habitats and species, Furthermore, many impacts will be site-specific and therefore difficult to predict (and as a result the possible impacts of tidal barrages are not include in the scenario analysis).

Nevertheless, despite the limitations of this assessment, some broad indications of the likely scale of potential biodiversity impacts are evident from the analysis of the current situation and combined projections from the selected energy scenarios. Assuming that the most sensitive sites would be avoided and basic mitigation measures would be introduced, impacts on Priority Habitats and Priority Birds are likely to be relatively low under most scenarios, especially up to 2020.

By 2050 modest impacts could result from the energy mixes projected in the UK government's Energy White Paper carbon constrained scenario, which incorporates moderate increase in biomass crops and a high increase in biofuel use. Similarly moderate impacts may result from the Tyndall Centre's red scenario, which projects a moderate increase in the use of coal and biomass, and high increases in wind power and biofuels. The highest impacts are likely to result from the Tyndall Centre's purple scenario, which assumes high energy demands met by very high increases in the use of nuclear, wind power and biomass, and exceptionally high use of biofuels (and no use of coal). This scenario illustrates the importance of reducing total energy use. It also suggests that the principal projected impacts would arise from the very high increase in the domestic production of biofuels (resulting in further intensification of agriculture and loss of grasslands and other semi-natural habitats). However, it is highly unlikely that the projected increase in biofuel use under that scenario would be matched by a proportional increase in UK production. With high levels of biofuel use, most feedstocks would be imported, but this could result in even higher biodiversity losses elsewhere, potentially of global significance.

There could also be additional significant biodiversity impacts from the use of tidal barrages - a large-scale scheme such as proposed for the Severn estuary being necessary to meet the renewable requirements under the Tyndall Centre's purple scenario. Such schemes have not been incorporated in this study's scenario analysis as their impacts are likely to be highly site specific. It is also difficult to reconcile the inclusion of a large scheme on the Severn estuary with this study's assumption that all environmental legislation will be adhered to, because the scheme would almost certainly contravene the EU Birds and Habitats Directives.

This study has been carried out in a short-time scale and has therefore not been able to include a thorough review or analysis of evidence or address all environmental issues comprehensively. It is therefore suggested that a follow up study should be undertaken to explore the key results in more detail and fill the most significant gaps. However, it should be noted that further assessments will also be constrained by numerous significant knowledge gaps. These will need to be further investigated by primary research, and some suggested priority issues include:

- Impacts of tidal barrages on marine ecosystems, including effects on planktonic and benthic food-webs and communities, productivity and impacts on fish and birds.

- Collision risks and possible population level impacts of underwater turbines.

- Impacts of underwater noise (eg from oil rig works, demolition, wind turbines and tidal turbines) on cetaceans and other potentially sensitive species.

- Further research into collisions rates from wind turbines (and overhead power lines) particularly offshore, and their impacts on populations; and potential mitigation measures.

- Probable growing locations and management practices for bioenergy crops (including novel crops).

It is also clear that more comprehensive and detailed monitoring needs to be undertaken of the impacts of energy developments, during their construction, operational and decommissioning phases. Such monitoring should assess the effectiveness of project level mitigation measures as well as the overall cumulative effects of energy policies on landscapes, geodiversity resources, habitats and species populations.

ACRONYMS

AGR .... Advanced Gas-Cooled Reactor
AMD .... Acid Mine Drainage
aSi .... Amorphous Silicium
BAP..................... Biodiversity Action Plan
bbl/d .... Barrel per Day
Bcf/d.................... Billion Cubic Feet per Day
BE .... British Energy
BERR .... Department for Business, Enterprise & Regulatory Reform
BOE..................... Barrel of Oil Equivalent
CATS .... Central Area Transmission System
CCGT .... Combined Cycle Gas Turbine
CCS .... Carbon Capture and Storage
CdTe.................... Cadmium Telluride
CH_4...................... Methane
CHP .... Combined Heat and Power
CIS .... Copper Indium Di-Selenide
CO .... Carbon Oxide
CO_2...................... Carbon Dioxide
CO_2 -e .... Carbon Dioxide Equivalent
DEFRA .... Department of Environment, Food and Rural Affairs
DERV.................. Diesel Engined Road Vehicle
DOE .... US Department of Energy
DTI...................... Department of Trade and Industry (now BERR)
EIA...................... Environmental Impact Assessment
EU .... European Union
GHG.................... Greenhouse Gases
GSHP .... Ground Source Heat Pumps
GW...................... Gigawatt (1Watt x 10^9)
MWh .... GigaWatt Hour(s) (1 MWh x 10^3)
Ha........................ Hectare
Hg........................ Mercury
IA .... Impact assessment
IGCC .... Integrated Gasification Combined-Cycle
IPCC.................... Intergovernmental Panel on Climate Change
kV........................ kilovolt (1Volt x 10^3)
kW....................... Kilowatt (1Watt x 10^3)
LIMPET .... Land Installed Marine Powered Energy Transformer
LNG .... Liquefied Natural Gas
Mmcf/d .... Million Cubic Feet per Day
Mst .... Million Short Tons
Mt........................ Megatonnes (1 tonne x 10^6)
Mtoe .... Megatonnes of Oil Equivalent
MW .... Megawatt (1Watt x 10^6)
MWh .... MegaWatt Hour(s)
NEGTAP............. National Expert Group on Transboundary Air Pollution
NGCC .... Natural Gas Combined-Cycle
NH_3 .... Ammonia

NO_X .... Nitrogen Oxides
OGJ .... Oil and Gas Journal
R&D .... Research & Development
SEAL .... Shearwater-Elgin Line
SNH .... Scottish Natural Heritage
SO_2 .... Sulphur Dioxide
SOx .... Sulphur Oxides
SRC .... Short Rotation Coppice
SSSI .... Site of Special Scientific Interest
PM .... Particulate Matter
PV .... Photovoltaic
PWR .... Pressurised Water Reactor
RCEP .... Royal Commission on Environmental Pollution
RES .... Renewable Energy Sources
RFA .... Renewable Fuels Agency
ROCs .... Renewable Obligation Certificates
RSPB .... Royal Society for the Protection of Birds
RTFO .... Renewable Transport Fuel Obligation
SAC .... Special Areas for Conservation
SDC .... Sustainable Development Commission
SEA .... Strategic Environmental Assessment
SPA .... Special Protection Areas
SRC .... Short Rotation Coppice
Tcf .... Trillion Cubic Feet
TEC .... Transmission Entry Capacity
TOE .... Tonne of Oil Equivalent
TRU .... Transuranic
TWh .... TeraWatt Hour(s) (1 MWh x 10^6)
UNFCCC .... United Nations Framework Convention on Climate Change
US .... United States
US EIA .... United States Energy Information Administration
UK .... United Kingdom
UKCS .... United Kingdom Continental Shelf
V .... Volt
VOC .... Volatile Organic Compounds

1 INTRODUCTION

1.1 Background

The International and European Context
There is a growing consensus worldwide that in order to keep the level of greenhouse gas (GHG) in the atmosphere within safe limits, developed countries must expect to collectively reduce their emissions by 20-30% by 2020, implying reductions in developed countries of 60-80 % by 2050. After years of intense negotiation, political attention is now focused on the multilateral negotiations on a post-2012 global climate change regime launched in December 2007 by the Bali Action Plan of the United Nations Framework Convention on Climate Change (UNFCCC).

The EU has been a key promoter of climate action and has long been at the forefront of international negotiations. In order to take the lead and set the example for other States, in January 2007 the European Commission put forward a series of ambitious targets for the EU - to reduce GHG emissions by 20 per cent by 2020 (or 30 per cent if other industrialised countries join a post-Kyoto agreement); increase the share of renewable energy in the overall primary energy supply to 20 per cent by 2020; including an increase in the share of renewable energy in transport fuels to 10 per cent by 2020 (with some sustainability safeguards). These targets were endorsed by EU leaders in March 2007 and a package of climate and energy legislative proposals was put forward by the European Commission on 23 January 2008. Currently the European Parliament and EU Council are considering the adoption of this package of legislation. In order to achieve the 20 per cent renewable target, different percentages of Renewable Energy Sources (RES) share increase have been set for the 27 EU Member States, on the basis of their RES levels in 2005 and of their per capita gross domestic product (GDP). Under the Commission's proposal (EC 2008), as it stands, the UK would need to increase its energy use from RES to 15 per cent by 2020, against its 2005 base of 1.3 per cent.

1.1.1 UK Climate and Energy Policy

For domestic political and economic reasons, the UK went from being relatively sceptical about reducing its emissions in the early 1990s to being a strong supporter of climate action. It was well placed to take on tough targets under the EU's first burden sharing agreement, having greatly reduced coal firing in a 'dash for gas' from the mid-1980s onwards.

More recently, however, the drastic cuts in the domestic coal industry have been accompanied by an unexpectedly sharp decline in national oil and gas reserves, most notably from the North Sea. As natural fossil resource availability declined and was only marginally replaced by indigenous renewable resources (such as wind), the UK became increasingly dependent on imported fuels, and is now a net energy importer. This has significantly increased the UK's concerns over energy security, and also over the current high price of oil and gas.

On 13 March 2007 the UK Government published a draft Climate Change Bill which puts in place a commitment to reduce carbon dioxide emissions through domestic and international action by at least 60 per cent by 2050 and 26-32 per cent by 2020, against a 1990 baseline, setting out a framework for moving the UK to a low carbon economy. An independent Committee on Climate Change will be set up (and already exists in shadow form) which *inter alia* will advise on future carbon reduction pathways, and on the need to extend the indicative 2050 target from a 60 per cent to an 80 per cent reduction.

In addition, on 10 January 2008 the UK published a draft Energy Bill which contains the legislative provisions required to implement the UK energy policy and strengthen the legislative and market framework. Among other things, the Bill aims to strengthen the Renewables Obligation to drive greater and more rapid deployment of renewables in the UK, and would enable private sector investment in gas supply projects to help maintain reliable supplies of gas. It also proposes the development of a clear framework to ensure that the operators of new nuclear power stations accumulate sufficient funds to meet their decommissioning and waste management costs. The Bill also intends to create a regulatory framework for Carbon Capture and Storage (CCS) projects, which would apply to the pilot project funded by the UK Government to demonstrate the full chain of CCS technology on a commercial scale coal fired power plant.

It is expected that both the Climate Change Bill and the Energy Bill will get Royal Assent by autumn 2008.

1.1.2 Specific National Low-Carbon Energy Technology Policies

The UK has implemented several specific climate-related policies in recent years, some of which are intended to stimulate demand for renewable energy. In particular two existing obligations required companies supplying electricity and separately transport fuels to make use of a proportion of renewable energy: the Renewable Obligation Certificates (ROCs) – which focused on delivering renewable electricity - and the renewable transport fuel obligation (RTFO) - which required that, by 2010, 5 per cent of all road vehicle fuel supplied to UK consumers should be from sustainable renewable sources – ie primarily biofuels.

In spite of its unparalleled ***wind power*** resources, the UK's current deployment of onshore wind is small by comparison with some continental countries. About 2,000 turbines are currently operational, with an overall capacity slightly above 2,500 MW. Many more applications are in the pipeline, with 700 turbines under construction, 1,800 having consent and a further 3,200 planned – with an overall potential capacity of about 16,700 MW[1]. Nevertheless UK deployment has been hampered by insufficiently strong financial incentives, and strong opposition to wind farms at or near sensitive sites. Currently increasing attention is being paid to offshore wind, which has greater potential and possibly lesser environmental impacts. As from 2000 the Crown Estate, which is the owner of the UK seabed and part of the foreshore area, has granted leases for the construction of 8 GW of offshore wind farms within 12 nautical miles of the coast, which are now currently under development. Recently a new leasing round has been launched for the delivery of a further 25 GW of new offshore wind farm sites by 2020 – leading to an overall potential of 33 GW of wind energy coming from offshore wind resources[2].

Other low carbon technologies are under consideration. In particular the government has signalled renewed interest in ***tidal barrages*** and a new generation of ***nuclear plant***. Plans are also afoot for a demonstration project on carbon capture and storage; but meanwhile plans for a new unabated coal fired plant at Kingsnorth have attracted controversy and direct action protests.

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[1] *BWEA UK WED http://www.bwea.com/ukwed/*

[2] *The Crown Estate – Offshore Wind Energy. http://www.thecrownestate.co.uk/offshore_wind_energy*

Realising the significant obstacles that are presented by any new low-carbon technology on the scale that will be needed, there is also growing interest in energy efficiency. The UK Renewable Energy Consultation Document (BERR 2008c) states that energy saving is meant to be the starting point of the Renewable Energy Strategy, and recalls a number of measures already in place to reduce energy use (e.g - beside the EU ETS - the Climate Change Levy, Climate Change Agreements and the new Carbon Emission Reduction Targets). New energy use reduction measures to be introduced, include the Carbon Reduction Commitment and a Suppliers Obligation to reduce energy demand through energy services markets, as well as targets for carbon emission from new homes, buildings and cars. A separate consultation on new and enhanced energy efficiency policies is expected in the near future. Nevertheless, while energy measures in general terms have far lower environmental impacts than supply side technologies, there are substantial difficulties in engineering change on the scale that is needed, especially in the problematic domestic and transport sectors that are not covered by the ETS.

1.1.3 Impacts of energy technologies on the environment and environmental objectives

Although there is increasing recognition that actions need to be taken to combat climate change there are also concerns that some low carbon energy production initiatives may seriously damage the environment (whilst in some cases achieving insignificant climate benefits). There have, for example, been widespread and well publicised concerns over the impacts of wind farms on landscape character and birds, such as raised over the proposed Lewis wind farm. Proposed schemes for tidal barrages have also been the subject on longstanding debate and studies. Although some large schemes such as in the Severn estuary may provide significant amounts of energy with low carbon emissions, residual biodiversity impacts would probably be substantial and contravene EU wildlife Directives.

In contrast some energy technologies such as nuclear power may provide electricity with relatively few predictable environmental impacts, but in this case there is obvious public concern regarding wider nuclear safety issues. There is some suggestion that some biomass crops may provide some environmental benefits, but this depends very much on the amount that is grown and its location. If grown at large scales, biomass and biofuel crops could lead to the loss of some remaining areas of ecologically important habitats. On the other hand measures that aim to reduce domestic impacts from biofuels and biomass could result in importation of large quantities of biofuel feedstock, leading to impacts on habitats of much greater biodiversity importance.

The development of energy policies that avoid significant environmental impacts is therefore complex and subject to considerable uncertainties. This study therefore aims to shed light on this issue by reviewing the evidence for environmental impacts and identifying some of the most likely environmental challenges that may arise from future energy policies in the UK.

1.2 Objectives and scope of the study

This study has been carried out under contract for the UK Joint Nature Conservation Committee (JNCC). The study aims to provide JNCC with information on the environmental impacts of various energy production technologies which exist and/or are foreseen in the UK, in light of current and expected capacity and existing scenario analysis. The work intends to provide useful background to help JNCC develop position statements, responses to consultations and other work at EU and international level on energy technologies and their impacts on nature conservation.

Specifically the study specification states that JNCC requires information on:

- "*The potential positive and negative contribution each technology will have on the drivers of biodiversity loss as identified in the Millennium Ecosystem Assessment (i.e. Habitat loss, Pollution, Overexploitation, Invasives, Climate change);*
- *The types of energy mixes in the UK that will have the least environmental impacts over several time scales (e.g at 2020, 2040 and 2050). For example if most energy is supplied by nuclear power what would the environmental impact be when compared to using other forms of energy production?*
- *the CO_2 reduction potential for each technology taking into account full life-cycle of energy production and transmission;*
- *the impact associated with the life-span of each technology and how long it will take for new and emerging technologies to contribute to the UK's energy demands".*

The study focuses on impacts on the UK environment, but also provides insights on wider global environmental impacts. The identified impacts are especially meant to highlight biodiversity issues (ie effect on species and habitats), but the most prominent implications on geodiversity (ie the variety of rocks, minerals and landforms), landscape and access to nature are also identified.

It is important to note that this study was carried out in a very short-time scale (ie approximately three-weeks) to provide information for a JNCC meeting. This study has not therefore been able to compile a comprehensive evidence-base or provide in-depth analysis of all the significant issues. Instead it has focussed on identifying biodiversity impacts of 8 key technologies that are currently of greatest significance or are likely to be over the next 50 years according to a range of proposed energy scenarios.

The study has reviewed a number of proposed energy scenarios, but does not develop its own energy scenarios. This is because a more extensive study would be required to detangle and compare all the relevant existing scenarios, which usually refer to different year, units, assumptions and energy categories. This study though aims to provide a useful overview of the energy technologies that are most prominent in the UK political agenda, providing an understanding of how they work, their potential and their impacts on nature conservation, their possible development as assessed in authoritative energy mix scenarios, and the environmental implications that their future deployment can have in the UK environment and worldwide.

It is expected that further work by JNCC will build on the results of this initial study to verify its key conclusions, provide further quantification of impacts and fill gaps in knowledge where possible.

1.3 Structure of the report

The report is structured as follows.

- *Chapter 2* provides an overview of the methodologies used to gather relevant information, select appropriate energy scenarios and analyse impacts on biodiversity.
- *Chapter 3* presents an overview of the 15 energy technologies identified in the study specification, and includes background information on the way these work, their potential in the UK and summaries of their key environmental impacts (including physical, biodiversity, geodiversity, landscape, and access).
- *Chapter 4* examines proposed UK energy scenarios for the UK for 2020 and 2050 and selects four as a basis for the selection of key technologies covered in Chapter 5 and the detailed analysis of impacts of each scenario on biodiversity in the UK.
- *Chapter 5* includes a more detailed description of each of the 8 selected key energy technologies. It includes an assessment of their physical effects and a semi-quantitative analysis of potential impacts on biodiversity in 2020 and 2050 according to their contributions under each of the four energy scenarios.
- *Chapter 6* presents an assessment of the likely combined impacts of all energy technologies on biodiversity according to each of the four selected energy scenarios.
- *Chapter 7* provides conclusions and recommendations based on this study's analysis.

2 METHODS

2.1 Information sources and search methods etc

This study has been principally carried out by a review of readily available literature on energy technologies, their environmental impacts and scenarios on future UK energy mixes. A full list of references is provided in Chapter 7. Given that the study aimed to provide a broad overview of key impacts and be concise, the choice of the relevant literature that was examined needed to focus on the most important publications. It was not therefore meant to be comprehensive, although it intended to cover the most important issues and reliable and up-to-date sources.

Key sources of information that were examined included:

- Official documents from UK government departments and statutory agencies (eg the 2007 UK White Paper on Energy, the Renewable Strategy consultation background papers and recent BERR statistics on the existing UK energy mix).
- Official reports from the EU Commission and European Environment Agency.
- UK and EU contracted research projects and review studies, in particular an ADAS/Ecoscape review of *Potential impacts of future energy policy on UK biodiversity* for DEFRA (Hossell et al. 2006).
- Energy technology sector websites (see list in Chapter 8).
- Specialist energy research institutions (eg the UK Energy Research centre).
- Research reports by non-governmental environmental research and conservation organisations.
- Published research.

Relevant research was identified by searching key journals and recent important review papers known to the study team, from which further citations of potential relevance were identified and examined. This targeted search was supplemented with an electronic search of on-line databases using a range of appropriate search terms.

Due to the limited time available for the study, it was not possible to investigate sources of information from Environmental Impact Assessments (EIAs) of energy developments, or post-project monitoring reports, although such sources may contain useful information.

The literature review was complemented by selected consultations with some organisations that are known to be conducting research into the impacts of new energy technologies on biodiversity.

2.2 Review and selection of energy scenarios

This study has selected four energy scenarios as a basis for an analysis of the potential impacts of future energy mixes on biodiversity. These are based on the following three studies of future energy use in the UK under emissions constraints:

- The modelling done for the 2007 Energy White Paper.
- A set of scenarios developed by the Tyndall Centre.

- Scenarios developed by Poyry Consulting for WWF and Greenpeace.

The first provides insights into the modelling that has informed government policy and as such is important to review. The second is useful because it expands on a wide range of scenarios with much broader differences among them, allowing more discussion of the contrasting impacts of various energy mixes. And the third is useful because it alone breaks down the renewable energy sources in more detail.

As the scenarios use different energy units, figures are made comparable by converting all of them into megatonnes of oil equivalent (Mtoe). BERR 2007 data (BERR 2008a) are also used to provide a basis for comparing modelled changes from the White Paper and Tyndall centre to current levels.

2.3 Comparison of the impacts of selected energy scenarios on biodiversity

This study has attempted to provide indicative quantitative estimates of the likely impacts of total energy production (*ie* electricity, heat and transport fuels) by the 8 key technologies on biodiversity according to their projected use in each of the four selected energy scenarios. These estimates are provided for 2020 and 2050. Estimates of the individual impacts of each of the key technologies is provided for each technology individually (and presented in relevant sections of Chapter 5) and in combination to illustrate the overall impact of energy production in the UK under each scenario (presented in Chapter 6).

The impacts on biodiversity have been estimated using the following selected habitats and species:

- UK Biodiversity Action Plan (UKBAP) Priority Habitats.
- UK BAP Priority Species of bird.

These have been chosen as they represent the key national biodiversity objectives in the UK and have been identified using standard criteria. The updated lists of Priority Habitats and Priority Species produced in 2007 have been used in this analysis[3].

The analysis of Priority Species has been restricted to birds because enough evidence has been compiled in this study to be able to provide a relatively robust estimate of likely impacts of each technology on all UK BAP Priority bird species. Although evidence exists for some other species, the addition of these could bias the assessment as they are typically fewer in number and tend to be associated with a narrower range of habitats. Ideally the analysis of birds should have been based on all bird species, as this would provide a less-biased assessment. In addition, it would take into account the possibility that some currently non-Priority bird species could decline substantially under some energy scenarios (and thereby become Priority species). However, a full analysis of all bird species was not possible within time-frame of this study.

This selective approach is justified as birds are generally regarded as good environmental indicators. Moreover, they are a Headline Indicator of sustainability in the UK (DEFRA 2007a). However, birds are not representative of all groups and can be more adaptable and resilient to environmental change than some other taxa. Thus care should be taken in the

[3] *www.ukbap.org.uk*

interpretation of the bird impact assessments with respect to their extrapolation to other taxa groups.

The potential impacts of the key energy technologies on Priority Habitats and Priority Species was assessed by carrying out a simple quantitative vulnerability assessment. For each habitat type and species, vulnerability was estimated by multiplying estimates of the following three factors:

- Sensitivity.
- Resilience / adaptive capacity.
- Exposure.

<u>Sensitivity</u> estimates the maximum extent of loss/degradation of a habitat or decline in a species population where they are exposed to the energy technology. For most habitats the sensitivity estimate relates to the direct loss of the habitat as a result of the development footprint and thus equates to 100 per cent (*ie* 100 per cent loss). For some habitats sensitivity relates to habitat degradation, eg as a result of pollution. Sensitivity for many birds species relates to the likely change in population size, eg the estimated reduction in a population resulting from collision mortality at a wind farm. **Sensitivity impacts are based on likely <u>residual impacts</u> assuming basic mitigation measures are implemented effectively**. Complete avoidance of protected habitats and features is not assumed.

<u>Adaptation</u> acts as a weighting score for the sensitivity estimate. For habitats it estimates the capacity for each habitat to recover or be restored or recreated. E.g. a adaptation value of 10 per cent indicates that it is expected that only 10 per cent of the sensitivity impact will last in the long-term as a result of habitat recovery or compensation. For Priority Bird species, the variable relates to the threat status of the species, such that declining and rare species are considered to have a low resilience to added impacts and are given an additional weighting (see Appendix 3 for details).

<u>Exposure</u> estimates the proportion of the habitat or the species habitat that may be potentially impacted under current conditions and the selected energy scenarios.

In practice, most estimates of these factors follow a very simplistic log-scale, ranging from 0.01 per cent to 100 per cent, to represent estimated orders of magnitude of impact.

In some cases there is a possible range of impacts on a habitat or species with differing sensitivity and exposure combinations (eg widespread but low level pollution impacts estimated as 0.1% sensitivity and 1% exposure, and habitat loss over a very small footprint estimated as 100% sensitivity and 0.001% exposure). In such cases the sensitivity and exposure combination with the highest overall impact (ie sensitivity x exposure) is used in the calculation.

The impacts are assessed firstly in relation to current estimates of sensitivity, adaptive capacity and exposure. The exposure estimates are then adjusted according to the projected increase or decrease in the magnitude of each according to each energy scenario. It should be noted however, that this simple multiplication assumes a linear relationship between the sensitivity and exposure, which is almost certainly an oversimplification. In some cases sensitivity may increase disproportionately as exposure increases because increasingly fragile or important habitats may be impacted.

3 CHARACTERISTICS OF ENERGY TECHNOLOGIES AND TRANSMISSION

This chapter provides an overview of 15 energy technologies which are relevant for the UK, requested in the study specification, namely: oil, gas, coal, nuclear, hydrogen, hydro, wind (onshore and offshore), solar, wave, tidal, biomass, biofuel, waste, combined heat and power (CHP)/district heating and microgeneration. On the basis of existing literature and evidence, the key features of each have been summarised, providing insights on their technological characteristics, energy demand and supply in the UK, future potential and significant environmental impacts. At the end of the chapter a table briefly summarises the key physical, biodiversity, geodiversity, landscape and access impacts within and (when relevant and where information is available) outside the UK.

On the basis of this preliminary analysis 8 ‘key’ technologies (oil, gas, coal, nuclear, wind, tidal range, biomass and biofuels) have been selected and explored in more detail in Chapter 5.

3.1 Overview: UK energy

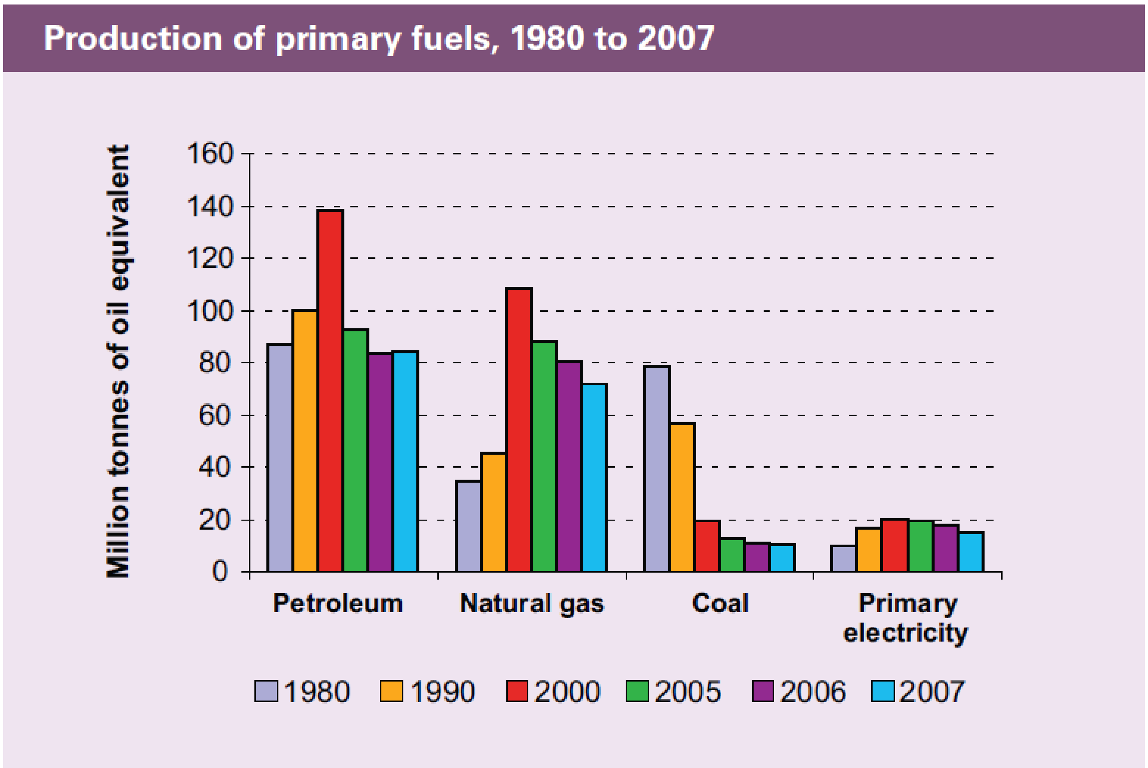
An overview of the UK’s energy production, consumption, electricity generation, capacity and greenhouse gas emissions is provided below, when applicable for each of the energy technologies referenced in this report. These terms are employed in the following manner:

- *Energy production* (or *supply*) refers to the amount of electricity and energy resources produced in the UK.
- *Energy consumption* (or *demand*) refers to the amount of electricity and energy resources consumed in the UK.
- *Electricity generation* refers to the amount of electricity generated by energy sources in the UK.
- *Capacity*, or more specifically installed or generator nameplate capacity, refers to the maximum rated output of a generator under specific conditions designated by the manufacturer. Capacity is used primarily in describing renewable energy technologies.
- *Greenhouse gas emissions* (GHGs) are gases such as carbon dioxide, water vapour, nitrous oxide, methane, hydrofluorocarbons, perfluorocarbons and sulphur hexafluoride that contribute to global climate change. The report will mainly focus on carbon dioxide (CO_2).

Overall Energy Production: In 2007, 185.9 million tonnes of oil equivalent (TOE) energy were produced in the UK. Renewables and waste accounted for 4 million TOE. Total production of primary fuels (mainly oil, coal, gas and primary electricity) fell by 5.6 per cent between 2006 and 2007. Petroleum makes up 45 per cent of the production of primary fuels, natural gas 39 per cent, coal 6 per cent and primary electricity (nuclear and natural flow hydro) 8 per cent (BERR 2008a). See Figure 3.1.

Figure 3.1 Production of primary fuels, 1980 to 2007

Between 1980 and 2000, production of primary fuels increased rapidly. Overall energy production was at record levels in 1999, yet natural gas hit record production levels 2000.

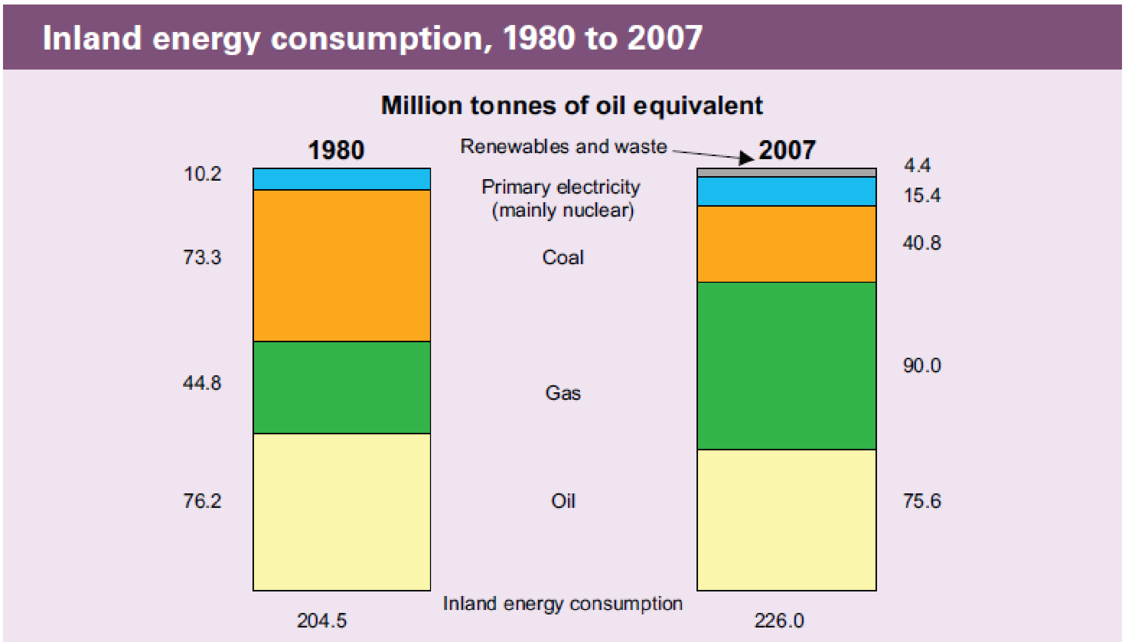


Source: BERR 2008a

Overall Energy Consumption: In 2007, the total inland primary energy consumption in the UK was 226.0 million TOE, 2.7 per cent lower than in 2006. Consumption by each sector has changed significantly since 1980. While consumption in the industrial sector has fallen dramatically since 1980, the transport sector has seen a major increase yet levels remained the same between 2006 and 2007 (BERR 2008a). See Figure 3.2.

Figure 3.2 Inland energy consumption, 1980 to 2007

Between 1980 and 2007, oil consumption remained steady, whereas gas consumption doubled. Coal consumption saw a dramatic decline. By 2007, 4.4 million TOE renewables and waste were consumed in the UK.



Million tonnes of oil equivalent

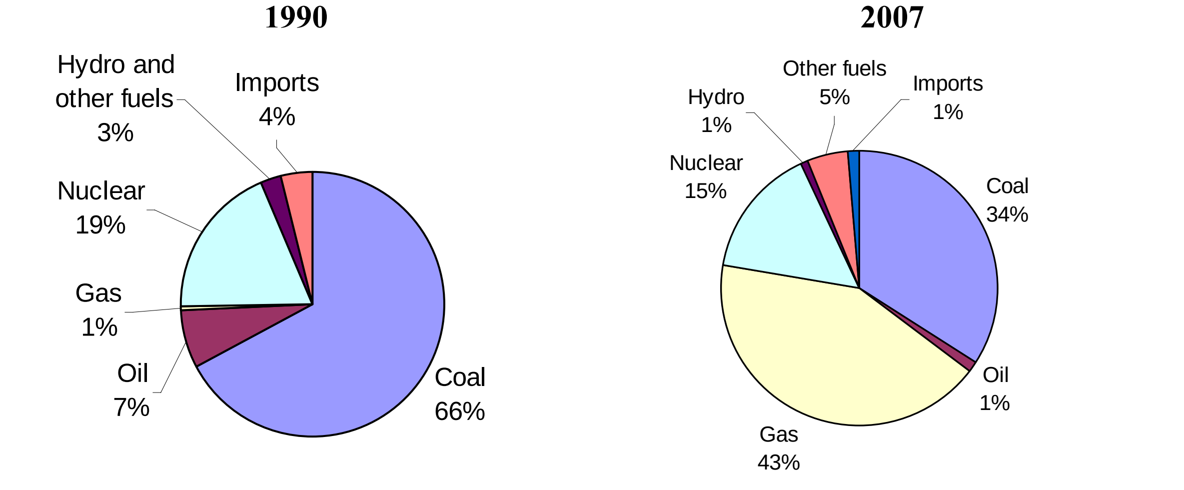
	1980	1990	2000	2005	2006	2007
Conversion losses	62.1	66.4	53.8	54.2	55.4	53.2
Distribution losses and energy industry use			20.7	20.2	18.9	17.8
Final consumption						
Industry	48.3	38.7	35.4	33.6	32.8	31.7
Domestic sector	39.8	40.8	46.9	47.2	45.7	44.0
Transport	35.5	48.6	55.5	59.1	59.8	59.8
Services[1]	18.7	19.2	21.5	20.2	19.7	19.3
Total final energy consumption	**142.4**	**147.3**	**159.2**	**160.2**	**157.9**	**154.9**
Total inland primary energy Consumption[2]	**204.5**	**213.6**	**233.7**	**234.7**	**232.3**	**226.0**
Temperature corrected Total	206.2	221.6	239.8	239.3	236.1	231.0

1. Includes agriculture
2. Excludes non-energy use

Source: BERR 2008a

Overall Electricity Generation: In 2007 a total of 378.5 TWh of electricity was supplied in the UK. Gas was the primary fuel for electricity generation on an output basis (161.1 TWh), followed by coal (129.4 TWh) nuclear (57.2 TWh) other fuels (17.7 TWh) and imports (5.2 TWh.) (BERR 2008a). Oil accounted for only 1 per cent of electricity production. The main renewable source used was hydro (1 per cent). The contribution of coal to electricity production dropped substantially compared to the levels in the 80s, and was increasingly substituted by gas in the past decade. See Figure 3.3.

Figure 3.3 Electricity supplied by fuel type, 1980 to 2007



Fuel	Electricity supplied (ThW)					
	1980	1990	2000	2005	2006	2007
Coal	190	208	114.7	128.6	142.2	129.4
Oil	33.9	21.1	5.9	4.5	4.5	4.1
Gas	1.6	1.6	145	149.2	138.1	161.1
Nuclear	32.3	58.7	78.3	75.2	69.2	57.2
Hydro	7.3	7.9	4.2	3.8	3.4	3.8
Other fuels			9.2	15.5	17.2	17.7
Net imports		11.9	14.2	8.3	7.5	5.2
Total electricity available for supply	265.1	309.4	371.5	385	382.2	378.5

Source: Based on BERR 2008a

Overall Greenhouse Gas Emissions: According to the policy goals set out in the 2007 Energy White Paper, the UK aims to cut its CO2 emissions by some 60 per cent by about 2050, with real progress by 2020.

It has been estimated that in 2004 the UK was responsible for 2 per cent of the world's carbon dioxide emissions and 13 per cent of the emissions from the then 25 EU Member States (DTI 2006). To meet its commitment under the Protocol, the UK has agreed a legally binding target to reduce its greenhouse gas emissions to 12.5 per cent below the 1990 base year level (ie 779.9 million tonnes CO2-e) over the period 2008-2012. This implies that UK's GHG emission must be below 682.4 million tonnes CO2-e on average per year over the first five year commitment period of the Protocol – ie 3,412 million tonnes carbon dioxide equivalent over the full five year period[4].

The UK is on track to deliver its Kyoto target, on the basis of existing policies and measures (DEFRA 2006). Overall GHG emissions fell by 17 per cent between 1990 and 2007 in the UK (see Table 3.1 below). Between 2006 and 2007, GHGs decreased by 1.8 per cent (BERR 2008a).

[4] *DEFRA, Statistical release* http://www.defra.gov.uk/news/2008/080131a.htm

Table 3.1 Low carbon – GHG and carbon dioxide emissions, 1990 to 2007

	1990	1995	2000	2005	2006	2007 (p)
Carbon dioxide	592.4	549.8	548.6	555.2	554.5	543.7
Methane	103.5	90.2	68.4	49.6	49.6	
Nitrous oxide	63.8	53	43.6	39.8	38.3	
HCF	11.4	15.5	9.1	9.2	9.2	
PCF	1.4	0.5	0.5	0.3	0.3	
SF6	1	1.2	1.8	1.1	0.9	
Basket of GHGs	770.8	709	671.4	655.5	652.3	639.4
Δ base year (779.9 tonnes CO2e)		*-9.1%*	*-13.9%*	*-16.0%*	*-16.4%*	*-18.0%*

Source: Based on BERR 2008a

The energy sector is the largest source of GHG – e.g in 2005 it emitted about 560 million tonnes of CO_2e contributing to almost 80 per cent of UK's GHG emissions (National Audit Office 2008). Estimates based on energy production and consumption in 2007 indicate that carbon emissions are decreasing, as they were 1.9 per cent lower than the previous year, and 8.2 per cent lower than in 1990 (BERR 2008a).

A breakdown of carbon dioxide emission by energy source from 1990 to 2005 is provided in Table 3.2 below. Solid fossil fuels, oil, gas and electricity production contributed approximately one fourth each. As for electricity, Table 3.3 depicts the tonnes of carbon per GWh supplied by various types of fuel for power stations.

Table 3.2 Sources of carbon dioxide emissions in the UK

	Million tonnes of carbon				
By fuel	**1990**	**1995**	**2000**	**2005 (p)**	**Δ between 1990 and 2005 (%)**
Coal and other solid fuels	68.6	49	38.1	41.7	-39
Petroleum	57.1	54.2	50.4	52.1	-9
Natural gas	30	40.8	55.9	55.5	85
Others	9.6	10.1	8.8	8.2	-15
Emissions power stations	55.6	44.6	42.4	46.8	-16

Source: Based on DTI 2006a

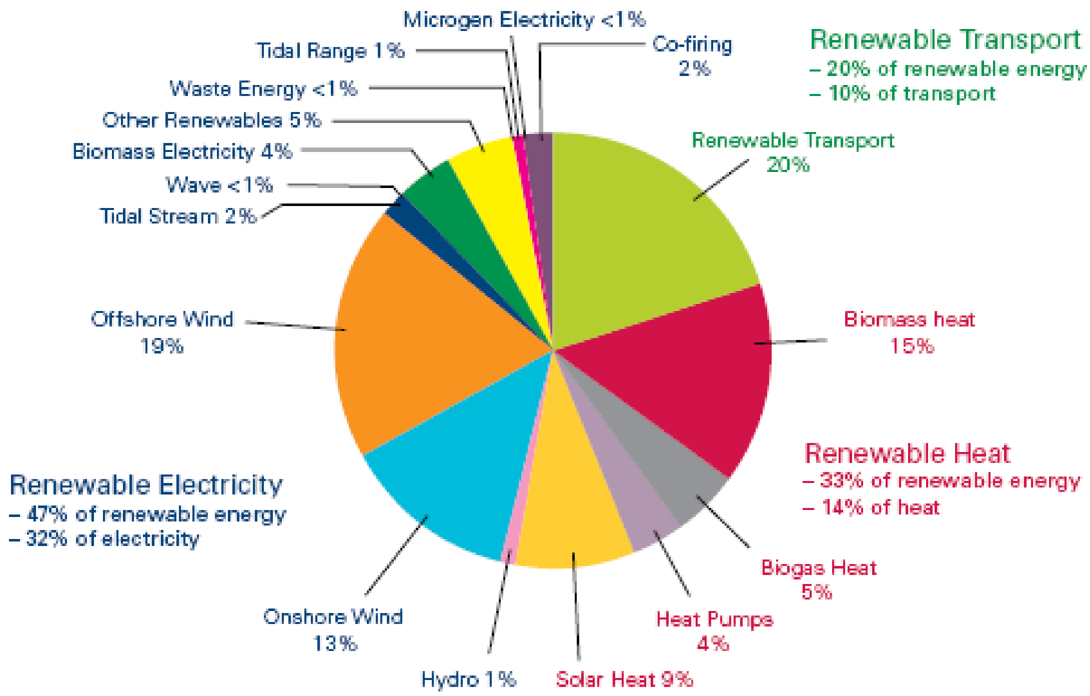
Table 3.3 Estimated carbon dioxide emissions from electricity generation 2005-2007

	Emissions (tonnes of CO2 per GWh electricity supplied)		
Fuel	**2005**	**2006**	**2007**
Coal	932	928	939
Oil	675	606	658
Gas	408	415	405
All fossil fuels	651	674	643
All fuels (including nuclear and renewables)	483	506	501

Source: Based on BERR 2008b

The renewables target: The European Commission has proposed that the UK's should increase the share of renewables in its energy mix from around 1.5 per cent in 2006 to 15 per cent by 2020. The figure below shows a potential split of total renewable energy in 2020 between three sectors: 20 per cent coming from renewable transport sources; 33 per cent from heat; and the remaining 47 per cent from electricity, as proposed in the UK Renewable Energy Strategy Consultation paper (BERR 2008c).

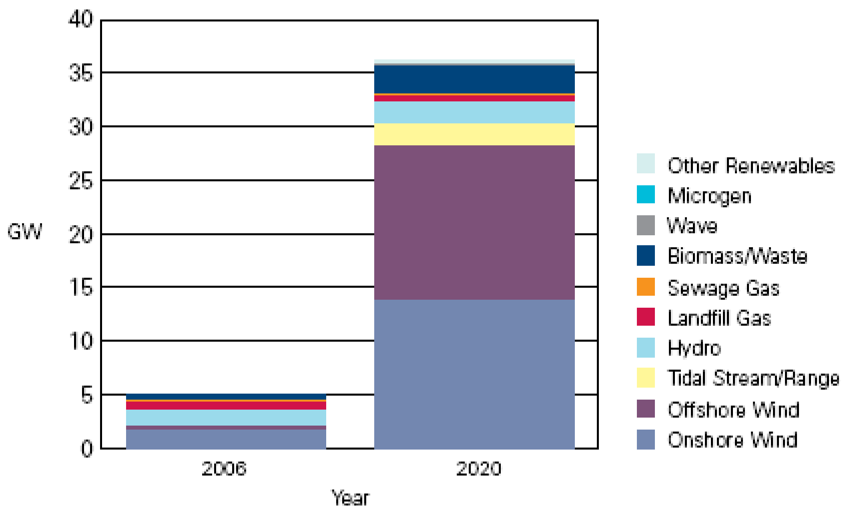
Figure 3.4 Illustrative renewable technology breakdown to reach 2020 target



Source: Redpoint et al (2008), NERA (2008), Department for Transport estimates (as from BERR 2008c)

To achieve this target the UK is considering, among other objectives, to encourage up to 30-35 per cent of electricity to come from renewable sources by 2020. The UK Renewable Energy Strategy Consultation paper proposes the following contribution by different Renewable Energy Sources (RES) – see figure below:

Figure 3.5 Renewable electricity generation capacity – comparison between 2006 and projected 2020



Source: BERR 2008c – based on BERR 2007c

3.2 Coal

3.2.1 Technology description

Coal is a fossil fuel resource primarily used for the generation of electricity by power plant, and elsewhere as a solid fuel to produce electricity and heat through combustion in a range of plant types, including heat-only boilers and combined heat and power (CHP) plant. It is the fossil fuel with the highest carbon intensity, with carbon content varying between 50 and 98 per cent. Other coal components include hydrogen (3-13 per cent), oxygen, and small amounts of nitrogen and sulphur, beside other minor elements. In addition, coal contains different proportions of water and inorganic matter which result in residue (ash) when burnt (Kavalov et al. 2007).

According to the amount of carbon contained, coal can be classified as: lignite (the youngest coal); sub bituminous; bituminous; or anthracite (very hard coal at the latest stage of development and with a high heating value). These large variations in coal composition determine the type of coal available for different applications.

Coal occurs in seams or beds and, depending on the geology of deposits, it can be mined underground and in surface or ‘opencast’ mines. Large opencast mines can cover an area of many square kilometres and use very large pieces of equipment, including: draglines, which remove the overburden; power shovels; large trucks, which transport overburden and coal; bucket wheel excavators; and conveyors (World Coal Institute 2005). This may result in some important environmental problems which will be further discussed in the following section.

Potential in the UK: In the UK, there were about 220.4 million tonnes[5] of estimated recoverable coal reserves in 2003, and the UK was the 5th largest coal producer in the European Union. In 2006, 67.4 million tonnes of coal were consumed in the UK. The amount of coal consumption has fallen by 66.2 million tonnes since 1980. In 2006 coal was approximately 19 per cent of total energy consumption (ie 49.9 over 232.1 million TOE) (BERR 2007).

Coal production has declined steadily and significantly over the past several decades. In 2005, the overall production accounted for 20 million tonnes, with 9.6 million tonnes from deep-mined production and opencast accounting for 10.4 million tonnes. Deep-mined production was 24 per cent lower than in 2004 and 39 per cent lower compared to 2003 figures. This is mainly due to the closure of mines such as the Selby Complex, Betws and Ellington, also as a consequence of low cost coal imports. In addition, opencast output was down 13 per cent in 2005 compared to 2004, having declined steadily since1997. By 2006, coal production was 9 per cent lower than 2005 levels, as deep mined production fell by 1.5 per cent, and opencast production fell by 17.5 per cent.[6] On the other hand, coal imports in 2005 accounted for a record of 44 million tonnes, mainly from Russia,

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[5] 243 million short tons (mts) – where 1 short ton is about 907 kg

[6] Energy Information Administration, Official Energy Statistics from the U.S. Government, United Kingdom, http://www.eia.doe.gov/cabs/United_Kingdom/Coal.html

Australia, Colombia, South Africa and Indonesia[7]. However, there are new open cast coal mines planned for Wales and the Midlands.[8]

Most UK coal is used for power generation, and eighteen coal-fired power stations are currently operating in the country. In 2006 53 million tonnes of coal were used to fuel power stations, while the remaining 12.9 million tonnes were consumed by domestic users, industry, services, and other energy industries (BERR 2007). The use of coal for electricity generation has decreased sharply in the past 2 decades, as it has increasingly been substituted by gas. In 2007 34 per cent of electricity was generated from coal, ie providing about 130 TWh, which is much less than 1990 levels when coal was contributing to 67 per cent of electricity production (BERR 2008a) – see also Figure 3.3 above. Demand for coal for energy generation has been rising recently as coal has become more competitive in price compared to gas. There are 18 coal-fired power stations in the U.K., with capacities ranging from 360 MW to 3,870 MW. There are at least ten proposals for new coal-fired power stations. Energy companies for instance are proposing the Kingsnorth Power Station, a 1600 megawatt supercritical coal plant (running boilers at higher temperatures and pressures than 'standard' coal plants - leading to higher efficiencies) with a commissioning date of 2012, and two further supercritical coal plants (with a capacity of 1600 and 2400 megawatts respectively), both to be commissioned by 2014.[9]

3.2.2 Overview of potential environmental impacts

In 2007, coal-fired power plants in the UK emitted 939 tonnes of carbon dioxide per GWh of electricity supplied. If the entire life-cycle of a plant is considered, emissions could amount up to 990 g CO2-e/kWh of electricity generated (Odeh et al 2008). Considering that, on average, electricity generation releases 461.2 tonnes of carbon per GWh, coal is the by far the most carbon-intensive emitter of carbon dioxide (BERR 2008b).

Beside CO_2, emissions of other pollutants such as Mercury (Hg), Nitrogen Oxides (NO_x) and Sulphur Oxides (principally SO_2) are the main environmental problems associated with the use of coal. SO_2 emissions in particular pose the most significant challenge as they cause acid rain. The substitution of coal with other fuels (especially gas and nuclear) in power generation has contributed the main part of the gradual decline of SO_2 emissions in the UK, although some abatement has also been applied. Emissions from coal fired power plants decreased from 2.7 Mt SO_2 in 1990 to 0.41 Mt in 2006 (ie 61 per cent of the overall 2006 SO_2 emissions).[10] NO_x emissions from coal also decreased significantly in the past decades, from 0.78 Mt in 1990 to 0.36 Mt in 2006 – representing about 22 per cent of overall NO_x emissions. Furthermore, coal mines led to the emission of 0.2 Mt of methane in 2006[11].

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7 BERR, http://www.berr.gov.uk/energy/sources/coal/industry/page13125.html

8 World Development Movement, Stop Kingsnorth Power Station, http://www.wdm.org.uk/kingsnorth/ukcoal.htm

9 James Richens, King Coal Promises to Clean Up, ENDS Report 396, January 2008, pp 26-29.

10 DEFRA, e-Digest Statistics about: Air Quality Emissions of Sulphur dioxide: 1970-2006 http://www.defra.gov.uk/environment/statistics/airqual/download/xls/aqtb08.xls

11 DEFRA, e-Digest Statistics about: Climate Change - UK Emissions of Carbon Dioxide, Methane and Nitrous Oxide by National Communication Source Category http://www.defra.gov.uk/environment/statistics/globatmos/gagccukem.htm

Mines are also a major cause of pollution, especially in South and West Wales, and Northern England. Coal mining – particularly surface mining – requires large areas of land to be temporarily disturbed. This raises a number of environmental challenges, including soil erosion, dust, noise and water pollution, and impacts on local biodiversity.

Coal excavation may reveal previously unseen geological strata and other geodiversity features of interest that could be worthy of conservation. However, it also causes topographic and landscape transformations, and could result in the destruction and permanent loss of some of the UK's most valuable geological exposures with a negative effect on geodiversity. Post-mining areas pose the greatest concern. Furthermore, extended or new mineral operations can have negative implications for visual amenity and landscape character, especially during strip mining and open cast mining, although this may be partly reduced through restoration plans. Landscape impacts can also result from quarry traffic.

A summary of the main physical effects of energy production from coal is provided in Table 3.1 and a more detailed discussion and analysis of the impacts on biodiversity is provided in Section 5.1.

3.3 Gas

3.3.1 Technology description

Natural gas is a mix of light hydrocarbons, primarily methane (CH_4) formed by decayed organic material. It can be mixed with oil at pressures found in the reservoirs (*associated gas*) or found alone in the reservoirs (*non associated gas*). Gas is usually obtained from conventional natural gas deposits by drilling a well into the reservoir. However, resources of natural gas can also be found in areas where the gas is trapped within material that has very low permeability to natural gas. Under this circumstance, if there are no natural channels through which the gas can flow to the well, the shale or tight sand strata must be fractured either by explosives or by water injected, to make channels in order to stimulate the gas flow (Hinrichs 1996).

Natural gas has many uses, as it can be supplied by pipeline and burns readily: its main uses are space heating, water heating, as fuel for boilers (industrial and utility) and in transport. Natural gas is also used increasingly to generate electricity.

Liquefied Natural Gas (LNG): Liquefaction enables natural gas from supplier countries to reach major markets that require that energy which are usually located at long distances over which pipeline construction is impractical. While natural gas consists almost entirely of methane (CH_4), typically liquefied natural gas (LNG) is 85 to 95-plus per cent methane, along with a few per cent ethane, even less propane and butane, and trace amounts of nitrogen. However, the exact composition of natural gas (and the LNG formed from it) varies according to its source and processing history (DOE 2005)

The LNG 'value chain' includes the following stages: natural gas production, liquefaction capacity, transport shipping, storage, and regasification[12].

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[12] *DRAGONLNG, http://www.dragonlng.co.uk/thelngprocess.cfm*

Potential in the UK: The Oil & Gas Journal (OGJ)[13] estimates that the UK proven natural gas reserves accounted for 18.8 trillion cubic feet (Tcf) in 2006, a 10 per cent decline from the previous year. In 2004, the UK was a net importer of natural gas for the first time since 1996 (US EIA 2006) and the country was the sixth-largest producer of natural gas in the world in 2006 (US EIA 2007). Then in 2007 the UK saw production fall 9.9 per cent. It was the world's largest decline in volume for a second consecutive year.[14]

The percentage of total energy consumption sourced from natural gas in the UK has increased from 20 per cent in 1980 to 34 per cent in 2003 as a result of several measures put forward by the UK government to encourage the use of natural gas, including its substitution for coal and oil in industrial consumption and electricity production. It is also used widely for domestic heating.

As a fuel source, gas made up 43 per cent of the UK electricity supply in 2007 (BERR 2008a). In 2007 there were approximately 28 gas, gas/oil, gas/CHP or gas/oil/CHP fuelled power stations and 28 combined cycle gas turbine (CCGT) or CCGT/oil/gas plants in the UK (BERR 2007).

The Government expects there will be a significant rise in the import levels of gas, driven by the demand from the power sector for electricity generation. It is foreseen that in gas demand will increase at a rate of 2.3 per cent per year (National Grid 2007).

3.3.2 Overview of potential environmental impacts

In 2007, gas power plants emitted 405 tonnes of carbon dioxide per GWh electricity supplied. This was a decrease from 415 in 2006. (BERR 2008b)

A number of physical/environmental impacts are generated during extraction (land use for drilling and brine disposal), transportation (land use for pipelines and possible methane leakage), processing (some air emissions), conversion (land use and air emissions, including carbon monoxide, nitrogen oxides and GHGs, thermal discharges and landscape disturbance).

In 2006 gaseous fuels were estimated to have generated about 0.014 Mt of SO_2 (ie 2 per cent of overall UK SO_2 emissions)[15] and 0.29 Mt of NO_x (ie 18 per cent of NO_x emissions)[16].

Gas production can also lead to significant visual impacts from a variety of sources, in particular from pipelines, through the clearance of vegetation, earthworks associated with site preparation works, drilling activities and loss of landscape features, such as hedgerows. However, most pipeline effects will be temporary and with adequate mitigation only minor residual long-term landscape impacts should remain.

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[13] *Oil & Gas Journal, www.ogj.com*

[14] *Global LNG Info, 2007, http://www.globallnginfo.com/develop2007.htm*

[15] *DEFRA, e-Digest Statistics about: Air Quality Emissions of Sulphur dioxide: 1970-2006 http://www.defra.gov.uk/environment/statistics/airqual/download/xls/aqtb08.xls*

[16] *DEFRA, e-Digest Statistics about: Air Quality Emissions of Nitrogen oxide: 1970-2006 http://www.defra.gov.uk/environment/statistics/airqual/download/xls/aqtb06.xls*

A summary of the main physical effects and environmental impacts of energy production from gas is provided in Table 3.1 and a more detailed discussion and analysis of the impacts on biodiversity is provided in Chapter 5.2.

3.4 Oil

3.4.1 Technology description

Crude oil is a complex mixture of hydrocarbons and other organic compounds. The hydrocarbons in crude oil are mostly alkanes, cycloalkanes and various aromatic hydrocarbons while the other organic compounds contain nitrogen, oxygen and sulphur, and trace amounts of metals such as iron, nickel, copper and vanadium. However, the exact molecular composition varies widely from formation to formation (Hinrichs 1996).

Crude oil is usually found in association with natural gas in porous rock formations known as reservoirs. When oil is trapped in a reservoir formation, an oil field forms, from which the oil can be extracted by drilling and pumping. Seismic surveying is an important feature of locating oil and gas for potential exploration and it can be performed on land and sea.

The global processes of exploring and producing oil includes the following stages: extracting oil (through drilling), transporting it (often with oil tankers and pipelines, processing and refining the oil into more useful petroleum products, such as gasoline, diesel fuel, heating oil, kerosene, etc., and marketing these petroleum products. Petroleum is also the raw material for many chemical products, including pharmaceuticals, solvents, fertilizers, pesticides, and plastics.

Potential in the UK: Currently the UK produces roughly the same quantity of oil as it consumes, but the country exports more than 60 per cent of its production to other EU Member States and the US. In total, 35 per cent of crude oil refined in the UK comes from the UK's continental shelf (UKCS), 46 per cent from Norway, 8 per cent from Russia, and the remaining 2 per cent from the Middle East (BERR 2007).

According to Oil and Gas Journal (OGJ), the UK had 4.0 billion barrels of proven crude oil reserves in 2006, the most of any EU member country. The country recovered 2.8 million Barrels of Oil equivalents (BOE) per day in 2007[17].

For many years oil reserves remained fairly constant (due to new discoveries and improved recovery technologies), but currently reserves are going through a steady decline. In 2007, oil production in the UK was 44 per cent lower than the record level seen in 1999. Nine new fields began producing oil in 2007 including the very large Buzzard field. (BERR 2008a)

There are currently 9 refineries in the UK which transform crude oil into petrol, diesel, jet fuel and other products. These refineries produce 82 million tonnes of oil products per year. (BERR 2007)

Final consumption of oil products in 2007, excluding transformation purposes, amount to 72 million tonnes. There has been an increase in oil demand for air and road transport (78 per cent of demand in 2007 – BERR 2008b). However, electricity generators switched

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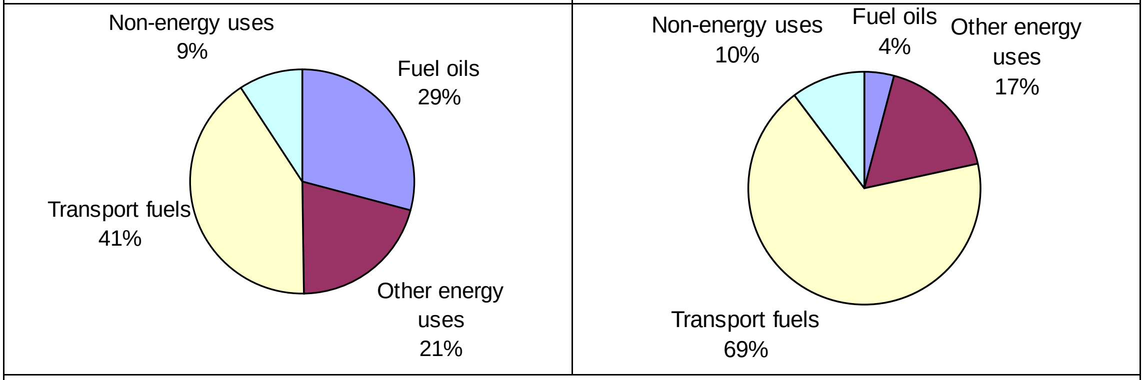
[17] *Alexander's Gas & Oil Connections, Report underscores maximizing recovery of UK's oil and gas,* *http://www.gasandoil.com/goc/frame_nte_news.htm*

increasingly to natural gas, which explains the decrease in the demand for fuel oil since 1980 (see demand and use trends Figure 3.9 below). (BERR 2007) Overall, on current trends, production decline is expected to average 5 per cent over the next five years[18].

Figure 3.9 Petroleum - Demand by product, 1980 to 2007



Million tonnes

Energy uses (1)	1980	1990	2000	2005	2006	2007
Motor spirit (petrol)	19.2	24.3	21.4	18.7	18.1	17.6
DERV fuel (2)	5.9	10.7	15.6	19.4	20.1	21
Aviation turbine fuel	4.7	6.6	10.8	12.5	12.6	12.6
Burning oil	2.1	2.1	3.8	3.9	4	3.6
Gas oil	11.6	8	6.8	6.8	6.3	5.9
Fuel oil	22.7	14	3.3	3.5	3.1	3.3
Other	4.3	4.9	5.3	5.5	5.6	4.8
Total energy uses	**70.5**	**70.6**	**67.1**	**70.3**	**70**	**68.9**
Of which:Transport fuels	31.9	43.5	49.5	52.8	53.5	53.6
Non-energy uses	**7**	**9.2**	**10.1**	**10.7**	**10**	**8**
Total deliveries	**77.5**	**79.8**	**77.2**	**81**	**80**	**76.9**

Notes: (1) Energy uses include uses for transformation (e.g electricity generation) and energy industry own use (e.g refinery fuels)

(2) DERV = diesel engined road vehicle

Source: Based on BERR 2008a

3.4.2 Overview of potential environmental impacts

Oil is a major contributor to carbon dioxide emissions. In 2007, oil power plants emitted 658 tonnes of carbon dioxide per GWh electricity supplied (BERR 2007). According to the latest verified figures, the transport sector, fuelled primarily by oil products, was responsible for 130 million tonnes of CO_2 in 2005. (National Audit Office 2008)

Offshore development projects can lead to air emissions, wastewater discharges, solid and liquid waste, noise generation and spills. Decommissioning offshore installations can imply leaving the structures totally or partially intact – which may cause physical interference with fisheries, but at the same time possibly enhancing fish habitats and creating refuges. Complete or partial removal of steel or concrete fixed platforms requires the use of explosive materials, leading to powerful, although short-term, impact on the marine environment and biota.

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18 *ibidem*

Oil refining typically leads to air emissions (including NO_x, VOCs, SO_x, PM and GHG), wastewater and hazardous waste. According to DEFRA, petroleum fuels lead to 0.18 Mt of SO_2 (about 26 per cent over total SO_2 emissions) in 2006 – which however represented a significant decrease compared to 1990 levels (about 0.78 Mt)[19]. They also led to the emission of 0.89 Mt NO_x in 2006 (ie 56 per cent of total NO_x emissions), which also decreased significantly from 1990 levels (1.8 Mt)[20].

Visual landscape impacts related to oil production and pipelines are similar to those due to natural gas (see above).

A summary of the main physical effects and environmental impacts of energy production from oil is provided in Table 3.1 and a more detailed discussion and analysis of the impacts on biodiversity is provided in Section Chapter 5.3.

3.5 Nuclear

3.5.1 Technology description

Nuclear power stations generate electricity from nuclear fuel, currently through the process of nuclear fission whereby heat released from the splitting of atoms is captured. A fission chain reaction is controlled in a thermal nuclear reactor. The fission process takes place in the reactor core which is contained within a pressure vessel and a biological shield. Inside the core is a moderator, typically made of graphite or water, which slows down the neutrons so that a chain reaction occurs. Control rods, made of material that absorbs neutrons, a placed inside the core, along with fuel rods, made up of fissile material (usually uranium). To start the reaction the control rods are removed, and then reinserted to shut it down. Coolant, such as water or gas, passes through the reactor and moves the heat generated to a boiler. From this point forward, the production of electricity at the nuclear power station is similar to any other power station.[21]

Usually nuclear power stations use enriched uranium as fuel. Uranium must be converted into uranium hexafluoride for advanced gas-cooled reactors (AGRs) or pressurised water reactors (PWRs), and then enriched to increase the proportion of the Uranium 235. The enriched fuel is then converted into either AGR or PWR ceramic fuel pellets which are then packed into stainless steel tubes for AGRs to form fuel pins, or zirconium alloy tubes for PWRs to form fuel rods. The pins and rods are then assembled into a fuel element.[22] This process though does not apply to the UK's two remaining Magnox stations, as they use un-enriched uranium.

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19 *DEFRA, e-Digest Statistics about: Air Quality Emissions of Sulphur dioxide: 1970-2006 http://www.defra.gov.uk/environment/statistics/airqual/download/xls/aqtb08.xls*

20 *DEFRA, e-Digest Statistics about: Air Quality Emissions of Nitrogen oxide: 1970-2006 http://www.defra.gov.uk/environment/statistics/airqual/download/xls/aqtb06.xls*

21 *BERR, Nuclear Reactors, http://www.berr.gov.uk/energy/sources/nuclear/technology/reactors/page17918.html (last visited 29 July 29, 2008).*

22 *BERR, The Nuclear Fuel Cycle, http://www.berr.gov.uk/energy/sources/nuclear/technology/fuel-cycle/page17921.html (last visited 29 July 2008)*

Potential in the UK: The UK does not have uranium reserves and must import the fuel. Currently, Canada produces the largest share at 23 per cent of world supply from mines, followed by Australia at 21 per cent and Kazakhstan at 16 percent.[23]

There are currently 19 operating reactors at 10 power stations[24] which generated 15 per cent of the UK's electricity in 2007, ie 57.2 TWh.(BERR 2008a). Further information on currently operating nuclear power stations and their locations can be found in Chapter 5.4.

3.5.2 Overview of potential environmental impacts

Although nuclear power does emit CO_2 when the entire fuel chain is considered, nuclear can contribute to GHG emission reductions. The UK Government states that, in the absence of nuclear generation, emissions of carbon dioxide in 1999 would have been 12-24 million tonnes higher and nuclear generation currently reduces national carbon emissions by between 7 and 14 per cent.[25]

However, there are significant environmental impacts arising from this technology, ranging from long-term waste disposal to the handling and disposal of toxic chemical wastes associated with the nuclear fuel cycle.

Uranium mining outside the EU leads to physical impacts similar to those of other metalliferous mining – in terms of land take and landscape deterioration - but the radioactive content of waste materials (eg spoils and tailings) is a significant difference.

The land area required by nuclear power plants is comparable to that for coal- and gas-fired stations and around the same as that required by on-shore wind power. It is estimated that the total land-take for a 1000MW nuclear power plant is between 100 and 400ha. Furthermore, most plants are surrounded by an exclusion zone of anything between 500m and 1,500m, although this land is not necessarily unproductive.

Water used in the plant as a coolant is indeed significant. It is estimated older plants need about 40-60m^3 per second of water.

The issue of waste is of major importance. The spent fuel from nuclear reactors contains radioactive material that presents environmental risks that persist for tens of thousands of years. At present no country has yet successfully implemented a system for disposing of this waste.

Fuel processing and reprocessing of waste fuel can also lead to the release of radioactive material into the wider environment, where it is highly persistent. Serious accidents are extremely rare, but can lead to catastrophic levels of radioactive contamination over wide areas and very long periods of time. Movement of livestock is still restricted in areas of North Wales as a result of radioactive contamination from the Chernobyl accident.

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23 *World Nuclear Association, World Uranium Minding, http://www.world-nuclear.org/info/inf23.html (last visited 5 August 2008).*

24 *BERR, Nuclear Power Generation and Development, http://www.berr.gov.uk/energy/sources/nuclear/technology/generation/page17922.html (29 July 29, 2008).*

25 *BERR, Nuclear Power Generation and Development, http://www.berr.gov.uk/energy/sources/nuclear/technology/generation/page17922.html (29 July 29, 2008).*

The principal landscape and access impacts from nuclear power will result from the presence of nuclear plants and associated facilities, and these may be substantial. Nuclear power station buildings and cooling towers can be up to 60 metres high, and many are placed in remote costal areas of high scenic value. Coastal nuclear facilities can also be significant barriers to coastal access, interrupting coastal footpaths and requiring long detours to circumvent.

A summary of the main physical effects and environmental impacts of nuclear energy production is provided in Table 3.1. A more detailed discussion and analysis of the impacts on biodiversity is provided in Section Chapter 5.4.

3.6 Hydrogen

3.6.1 Technology description

Hydrogen is an energy carrier, like electricity, that requires a source of primary energy, such as fossil fuels, nuclear energy, or renewable resources, to generate it. Once generated, it can be converted to electricity or heat using modified internal combustion engines, gas turbines or fuel cells. Fuel cells convert hydrogen, or a hydrogen-rich gas stream, into electricity or heat through an electrochemical process which releases water or steam emissions. Fuel cells could play an important role in stationary power generation, combined heat and power, distributed generation, portable power, and transport, possibly replacing the internal combustion engine. Both hydrogen and fuels cells are in the demonstration phase and must overcome significant techno-economic barriers in order to become cost-competitive with conventional energy sources and technologies. According to the UK Government, niche fuel cell applications such as portable and remote power are expected to be commercialised first, followed by stationary power/CHP, and finally transport.[26] It is not economical to burn hydrogen in boilers or internal combustion engines owing to the high cost and low efficiency of conversion.

Potential in the UK: Because hydrogen is still maturing, it does not account for a significant portion of the UK's energy portfolio, and it is currently supported mainly through demonstrations and R&D support programmes. The Government "recognises that a number of hydrogen energy chains will, by 2030, potentially offer the UK cost-competitive CO_2 savings, and that action needs to be taken now to develop these options"[27] . Nevertheless, according to a strategic framework for hydrogen energy in the UK, the general view is that until 2030, hydrogen will serve a niche market only. Hence, although in the long-term it may be a means for energy storage or transport fuel, some believe that its application in the UK may not materialize (Eoin Lees Energy 2004). As a result of this ambiguity, it is not possible to predict what share of the energy sector hydrogen will take up in the future – but it can be assumed that the role it will play on the UK energy production in the short/medium-term will be very limited.

3.6.2 Overview of potential environmental impacts

Hydrogen could have various different environmental impacts depending on the size and scope of its application.

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[26] *BERR, Hydrogen and Fuel Cells, http://www.berr.gov.uk/energy/sources/sustainable/hydrogen-fuel-cells/page25586.html*

[27] *BERR, Hydrogen and Fuel Cells http://www.berr.gov.uk/energy/sources/sustainable/hydrogen-fuel-cells/hydrogen/page26734.html.*

Depending on how the technology is employed, hydrogen could have significant infrastructure impacts. Infrastructure includes hydrogen production facilities (including the associated power generation facilities), pipelines, trucks, storage facilities, compressors and dispensers involved in the process of delivering fuel. (U.S. Dept. of Energy 2008). Major dedicated infrastructure development would be needed mainly to transport hydrogen fuel to the point of end-use.

There are no representative statistics about the GHGs emissions arising from hydrogen or fuel cells in the UK. Because hydrogen can be made from many different types of fuel and through different process, the emission level will depend heavily on the source of primary energy and process chosen. For instance, if hydrogen is synthesized from non-renewable resources (coal, oil and natural gas), it could increase the demand for fossil fuels that contribute to climate change, and may well be more carbon-intensive on a life-cycle basis than the fuel from which it is made. Indirectly, this may incentivise the construction of new power plants in the UK. Conversely, if hydrogen is obtained through renewable sources it could contribute to GHG emission reductions.

Because of its very small molecular size, hydrogen is particularly difficult to contain. There is a danger of releasing hydrogen into the atmosphere (e.g due to leakages in pipelines) which could disrupt the distribution of methane and ozone in the atmosphere, thereby exacerbating climate change (European Commission 2006). Escaped hydrogen could also be absorbed in the soil, although its environmental consequences are uncertain.

3.7 Hydro-electric power

3.7.1 Technology description

Water-power is primarily used to generate electricity, essentially in two ways. First, it can be made by installations in the natural flow of a river, where turbines are placed in flowing water which drives turbines, which in turn drive generators converting the mechanical energy into electrical energy. Second, it can be created by man-made installations where water flows from a high reservoir through a tunnel and away from the reservoir's dam. These are termed run-of-river and high-head installations respectively. These types of energy systems can be stand-alone or connected to the grid. [28]

Potential in the UK: In 2007, about 450 Mtoe of primary electricity was produced by hydro power in the UK, ie about 1 per cent of total electricity (see Figure 3.3 above). The majority of hydroelectric power is produced in the Scottish Highlands. The production of electricity from hydro power has slightly declined in the past decade. Hydro used to be the second largest renewable energy source used in the UK (after biomass), but in 2007 for the first time wind accounted for more than hydro (7.6 per cent) in primary input terms. In terms of RES electricity, hydro remains one of the main contributors, together with wind and biomass. With a capacity of 1,369 MW, in 2006 large scale hydro contributed 30 per cent of RES electricity from renewables.

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[28] *Department for Business Enterprise & Regulatory Reform, Questions about Hydroelectric Energy, http://www.berr.gov.uk/energy/sources/renewables/news-events/press-materials/background/hydroelectric/page24353.html*

According to BERR, there are very few additional sites for hydro power in the UK that are commercially attractive and environmentally acceptable.[29] Only one large 100-megawatt hydroelectric project, the Glendoe Hydro Scheme, has been approved recently and construction has begun. A few other small-scale hydroelectric schemes are being planned or developed, for example, a 3.5-megawatt development at Kingairloch in Lochaber and a 2.2-megawatt scheme at Braevallich in Argyll. Also, some old watermills are being upgraded to contribute to the electricity supply.[30] Given site constraints, it seems unlikely that hydro power will increase substantially in the short/medium term, beside some micro and small-scale schemes. For instance, energy scenarios developed by the UK Business Council for Sustainable Energy (2008) to meet the UK 15 per cent renewable target in 2020 (ie hypothetically 145 TWh) foresees that the hydro contribution to the overall RES energy mix would be 4 per cent, ie about 500 Mtoe (similar to the current level of production).

3.7.2 Overview of potential environmental impacts

Hydroelectric projects can require significant infrastructure work. For example a dam project, similar to the Glendoe scheme mentioned above, requires the construction of a dam that can be hundreds of meters long; a large water storage and catchment area; aqueducts and pipes feeding water into the reservoirs; tunnel from the dam to power stations and water discharge area; and power lines from power station to national grid. (Scottish Wild Land Group 2005; Glendoe Hydro Scheme 2008). Dams can create a physical barrier that disrupts the movement of species leading to changes in upstream and downstream species composition and even species loss (World Commission on Dams 2000).

Some hydroelectric projects require large areas of land to be submerged. If built in populated areas, people and communities may be displaced by dams. Even in the case that a dam is sited in a more remote area, public access to natural areas may be limited.

Similar to wind, solar and wave power, hydroelectric power systems produce no carbon dioxide emissions at their point of use, but they do have life-cycle emissions. In particular, hydroelectric power stations contribute to climate change at the decommissioning stage in which GHGs stored in sediments is released (Pacca 2007).

Hydroelectric projects may also contribute to GHG emissions at other times. Natural ecosystems such as lakes, rivers, forests and peat land emit GHG naturally. After impoundment of a reservoir, flooded vegetation itself undergoes decomposition, which leads to the production of both carbon dioxide and methane. During the early years following impoundment, a large part of GHG emissions from the reservoir is from decomposition of organic material. Then, within a ten-year period there is a gradual decrease in emissions, and levels return to those comparable with natural lakes. No estimate was found on methane emissions from hydroelectric installations in the UK; but owing to the age of most installations and the limited prospects for further development, it appears likely that these are small.

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[29] *BERR, Questions about Hydroelectric Energy, http://www.berr.gov.uk/energy/sources/renewables/news-events/press-materials/background/hydroelectric/page24353.html*

[30] *BERR, Questions about Hydroelectric Energy, http://www.berr.gov.uk/energy/sources/renewables/news-events/press-materials/background/hydroelectric/page24353.html.*

3.8 Wind

3.8.1 Technology description

Wind turbines harness the energy contained in moving air. Turbines can be situated either onshore or offshore and can be up to 7.5MW in capacity. There is also micro-wind technology, ie based on <100kW turbines, that can be mounted to roofs as well as attached to tall masts (BERR 2008b).

Potential in the UK: The UK has the largest potential wind energy resource in Europe.[31] In 2007, UK onshore and offshore wind generated 453.5 thousand TOE. The use of wind energy has increased sharply in recent years. In 2003 for instance wind resources only generated 110 thousand TOE.[32] Wind is now the main contributor to RES electricity, covering 39 per cent of production in 2006 (33 per cent onshore and 6 per cent offshore).

Currently (as of September 2008) there are a total of 176 operational (169 onshore and 7 offshore) wind farms in the UK. Together the wind farms have a capacity of 2,547 MW. Another 40 farms (33 onshore and 7 offshore) are under construction and will contribute approximate 1,673 MW to the overall capacity. Consent has been given for another 140 farms (131 onshore and 9 offshore) contributing 6,850 MW. There are another 234 projects (230 onshore and 4 offshore) that are in the planning process which could add 8,127 MW of capacity.[33] Overall, the capacity of existing, under construction, consented and planned turbines is about 19.2 GW.

Although this contribution is still relatively small, the estimated potential of onshore and offshore turbines makes wind a promising source of RES electricity for the future.

BERR (2008c) foresees that offshore and onshore wind will be key to meet future objectives for RES electricity. It is expected that by 2020 deployment of offshore turbines may be closer to 14 GW, ie around 3,000 extra offshore turbines of 5 MW. About 14 GW of onshore wind would be also needed – equating to around 4,000 new 3 MW onshore turbines in addition to the approximately 2,000 turbines already installed.

Energy scenarios estimated by Pöyry (2008) predict that, in order to meet the RES target, the total renewable capacity in 2020 should be between 32 to 52 GW, of which 22-31 GW would be from from offshore and onshore wind.

3.8.2 Overview of potential environmental impacts

Wind energy produces no carbon dioxide emissions at their point of use, but they do have life-cycle emissions. The manufacturing of wind turbines requires electricity, often generated from coal, making it the largest contributor to climate change in the life-cycle. If lower-carbon electricity is used during the manufacturing process than there is less climate change impact. The recycling of steel and iron from wind turbines may reduce these potential impacts further by offsetting the need to produce more materials, and ultimately reducing energy consumption. (Nalukowe *et al* 2006)

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[31] *BERR, Wind, http://www.berr.gov.uk/energy/sources/renewables/explained/wind/page16085.html*

[32] *BERR,, Renewable sources used to generate electricity and heat and for transport fuels, http://stats.berr.gov.uk/energystats/dukes7_6.xls*

[33] British Wind Energy Association, Statistics, http://www.bwea.com/statistics/

Danish turbine manufacturer Vestas conducted a life cycle assessment of their wind turbines and found that a V80 – 2MW onshore turbine farm can generate about 6.8 g CO_2/kWh, while a V80 – 2.0MW offshore turbine farm leads to 7.62 g CO_2/kWh (most of which comes from the manufacturing process) (Elsam 2004).

A brief summary of the main impacts on biodiversity, geodiversity, landscape and access is provided in Table 3.1. Geodiversity impacts are likely to be highly site-specific and should therefore be avoidable if proposed schemes are subject to a comprehensive EIA that adequately considers potential impacts on geological features.

Most wind farms are unlikely to have significant access impacts. Such issues should be identified during an EIA and adequately addressed through appropriate mitigation measures as a requirement of planning permission. Stanton (1996) observes that some wind farms may fence off the public from their vicinity, which can cause frustration amongst those who wish to accesss the area and see the turbines closely. The ability to view a wind farm at close range has been considered a possible factor that increases their appreciation amongst the public. In some circumstance wind farms may increase access through the creation of access roads, though few are likely to allow unrestricted public access. Where such additional access is provided then there may be unintended secondary impacts on biodiversity (see above).

The principal impacts from wind power generation will be on the aesthetic values of landscapes and seascapes, and biodiversity. Visual impacts on land and seascapes can be very significant and cover large areas as the total height of turbines usually range between 60 and 120m. The problem is also exacerbated by the fact that areas with the best wind resources tend to be coastal and upland areas, many of which are of high aesthetic value. Although some people view wind turbines as aesthetically pleasing many see them as undesirable intrusions in the landscape. Consequently, there is significant public concern over landscape impacts from wind turbines and many proposed schemes have been withdrawn or refused permission on these grounds.

However, potential landscape impacts will vary considerably according to their location, and many sensitive and highly valued landscapes are likely to be avoided. Mitigation measures may also significantly reduce potential visual impacts. According to the SDC (2005), the visual impacts of wind installations are highly dependent on the area from where it is seen (extent of visibility) and how it appears within these views (nature of visibility). For example, for onshore wind, a development which is grouped into a tightly clustered array is usually visually more acceptable in an open, undeveloped land. In agricultural landscapes instead rows of turbines may be visually acceptable where formal field boundaries are used as an existing feature. It is generally considered that lesser number and larger turbines have a lower visual impact that greater numbers of smaller turbines

Offshore developments tend to have a higher number and taller turbines, but their visual impact is generally less given their distance from the coastline. The farther offshore they are, the smaller their aesthetic impact. In some cases though offshore wind developments can have high impacts as coastal landscapes are often of particularly high aesthetic value.

The decommissioning of wind turbines is a relatively straightforward process and in most cases the land can be returned to a ‘normal’ state, with access roads and other impacts generally reversible over time (except on peatlands – see Section 5.5 below).

A summary of the main physical effects and environmental impacts of wind energy is provided in Table 3.1 and a more detailed discussion and analysis of the impacts on biodiversity is provided in Section Chapter 5.5.

3.9 Solar (PV and solar water heating)

3.9.1 Technology description

Solar energy technologies capture and harness the sun's energy. There are three primary solar technologies: passive solar design, solar water heating and solar photovoltaics (PV).[34] This section will focus on solar water heating and PV.

Solar water collectors absorb energy from the sun and transfer it to heat water. According the National Energy Foundation, solar water heating systems are the most popular form of solar energy used in the UK.[35] Two types of systems exist: flat-plate collectors and evacuated tubes.

- Flat plate collectors, in their simplest form, are made of sheet metal painted black which absorbs the sun's energy, and water is moved through the panel in pipes attached to the metal sheet so it can absorb the heat from the metal. Because of the climate in the UK, non-toxic anti-freeze is added to the pipes. This type of system is generally placed on a roof.
- Evacuated tube solar water systems consist of a series of glass heat tubes grouped together and highly insulated due to a vacuum inside the glass.[36]

PV panels transform solar radiation directly into electricity. They can be installed on buildings to generate power for export to the national grid. If a system is grid-connected, when more electricity is being generated than being used the excess is sold back to the electricity supplier. When less is being generated, electricity is bought from the supplier. This allows for the national grid to act as a battery bank allowing for power to be exported and imported between a building and the grid.[37] PV systems can also be off-grid, providing power in remote areas where grid connection is expensive. However since the sun though only shines for a portion of time and intermittently, off-grid PV systems need to have a battery to store energy and/or some other form of backup.[38]

Potential in the UK: Solar Water Heating - Solar heating has steadily increased since 2003. According to BERR, 44.9 thousand TOE of active solar heating energy was produced in 2007. There is a small but established market for solar water heating systems.

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34 *BERR, Solar Energy – How it Works, http://www.berr.gov.uk/energy/sources/renewables/explained/solar/page16366.html (last visited 30 July 30, 2008).*

35 *Ibid.*

36 *Ibid.*

37 *Centre for Alternative Technology, Grid-Connect Domestic Renewable Energy Systems, http://www.cat.org.uk/information/catinfo.tmpl?command=search&db=catinfo.db&eqSKUdatarq=InfoSheet_GridConnected*

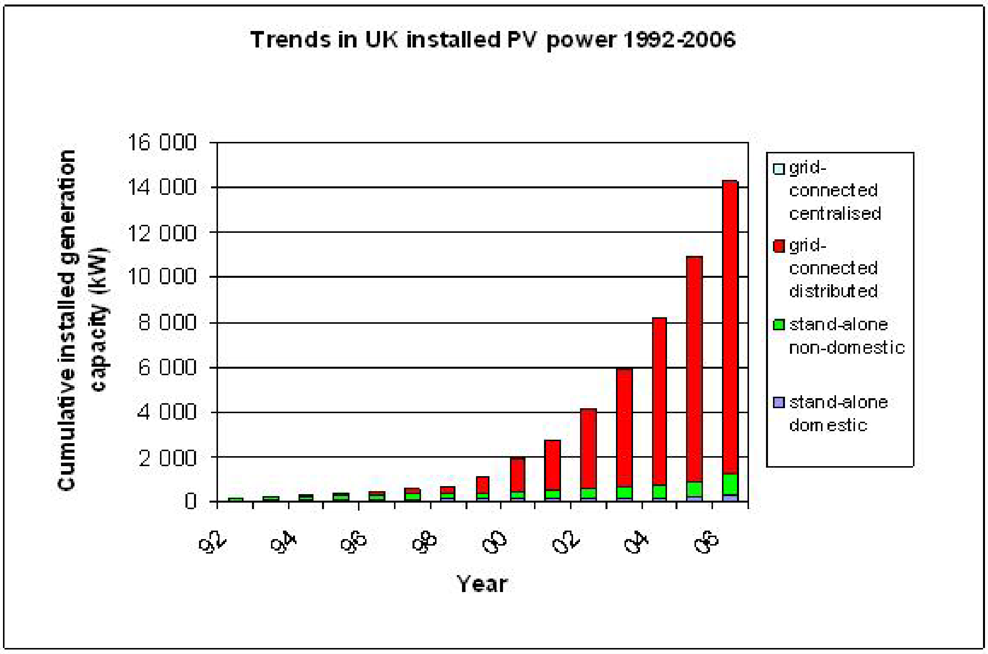
38 *National Energy Foundation, Solar Energy, http://www.nef.org.uk/renewableenergy/solar.htm*

It is estimated that around 10,000 systems are installed in the UK every year and approximately 100,000 are already in place.[39]

Photovoltaic - PV produces much less power than solar in the UK. In 2007, only 0.9 thousand TOE of PV electricity were produced in the UK. However the installed capacity of PV has more than doubled since 2003. BERR estimates that there were 14.3 MW of solar PV installed in UK by the end of 2007. (BERR 2008b)

Figure 3.6 Trends in UK installed PV Power 1992-2006

Since 1999 there as been major increase in grid-connected distributed PV in the UK.



Source: Davidson, 2008.

Both types of technologies are sun dependent, so it makes most economic sense to locate these systems in areas of high solar radiation. Below is a map of the UK depicting the total average solar radiation falling on one square metre surface inclined at 30 degrees to the horizontal, measured in kilowatt-hours, showing that the most irradiated area is the southern part of the country.

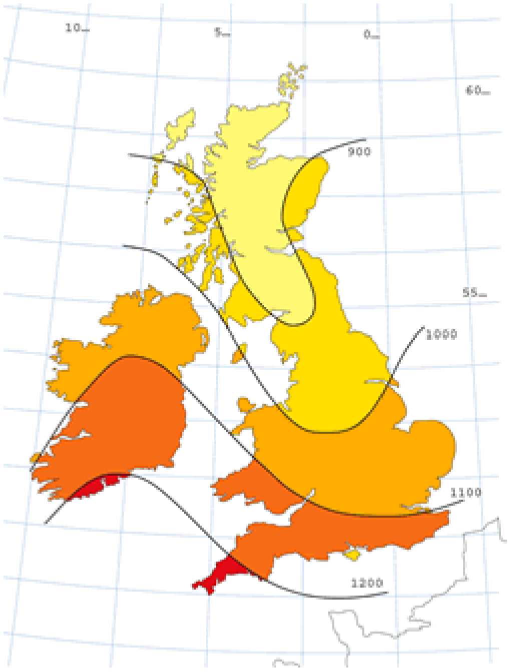
In spite of the perceived paucity of sunshine in the UK, solar could make a significant contribution. Heat output projections calculated by Enviros (2008) for the UK RES strategy consultation foresee, under different scenarios, that in 2020 solar water heating could provide from 41.6 to 90 TWh.

The contribution of PV instead is likely to be less significant in the short to medium term. PV for instance was not included in the expected renewable electricity mix suggested by the UK Business Council for Sustainable Energy (2008) to meet the UK RES target.

39 *BERR, Solar Energy – Current UK Use, http://www.berr.gov.uk/energy/sources/renewables/explained/solar/current-use/page16374.html*

Figure 3.7: UK solar irradiation (Annual Total kWh/m2)

The highest solar potential is in the southern part of the UK.



Source: The Solar Trade Association, Solar Energy – The UK's Large Solar Energy Resource, http://www.solar-trade.org.uk/solarenergy/ukresource.htm.

3.9.2 Overview of potential environmental impacts

This section looks mainly at the environmental impacts of PV as these are better known and more accurately explored in existing literature. (Union of Concerned Scientists 2008).

Utility-scale PV installations may cause soil erosion and compaction and may inhibit access to certain areas (Abbasi et al. 2000). However, most solar PV and solar hot water are integrated into homes or buildings, thus the systems do not cause further disruption of landscapes or inhibit public access (Union of Concerned Scientists 2008). In this sense they have much lower land-use implications than any other major RES technology.

PV panels are composed of, among other raw materials, arsenic and cadmium, which are highly toxic. Furthermore, panels are also composed primarily of silicon, which need to be mined, sourced from recycled components or from the reuse of parts (Fthenakis et. al. 2005). The PV manufacturing process is very energy-intensive and may increase demand for power from fossil fuel power plants. It also involves the use of potentially toxic substances such as semiconductor materials, amorphous silicium (aSi), copper indium di-selenide (CIS) and cadmium telluride (CdTe) (Nieuwlaar et al. 1997). Manufacturing takes place in and outside of the UK (especially in Japan). It can be assumed that most of the manufacturing impacts are perceived mainly outside Europe.

Similar to wind, wave and hydro, solar energy produces no carbon dioxide emissions at its point of use, but it does have life-cycle emissions. PV systems require energy to fabricate silicon and to manufacture PV equipment and batteries if needed. Similarly, solar hot water systems require energy inputs in the manufacturing of its parts. There are many complex lifecycle analyses available of solar and PV installations. To provide an order of magnitude, an LCA study revealed the CO_2 emission of solar PV in its whole life cycle is

100g/kWh (Banerjee et al, undated). This is less advantageous than large-scale wind, but still significantly better than the best fossil-fired electricity.

3.10 Wave

3.10.1 Technology description

Wave energy harnesses the movement and energy contained in the ocean converting it to electrical power. Waves, created by the wind interacting with the surface of the sea, have the potential to provide almost unlimited power for the UK. Energy can be extracted from waves with devices that can be placed on the shoreline or in deep waters. There are currently three types of technologies: oscillating water column, buoyant moored device and hinged contour device. One of the main problems with wave power is that the sea is a harsh environment, and these machines need to withstand a wide range of wave sizes, servere storms and problems with algae, barnacles and corrosion.[40]

Potential in the UK: There are two wave power devices installed in the UK, the LIMPET (Land Installed Marine Powered Energy Transformer) and the Pelamis sea snake. The LIMPET is a 500-kilowatt shoreline oscillating water column machine on the Scottish island of Islay, connected to the national grid.[41] The Pelamis sea snake is a 750-kilowatt hinged contour device and is the first deep-water grid-connected trial. Currently, it is installed at the European Marine Energy Centre in Scotland where it is being tested.[42]

Overall, the amount of energy currently produced from waves in the UK is as yet very limited, ie about 0.5 MW of electricity were produced in 2006 (BERR 2007).

The greatest wave energy potential in the UK is located on the west coast of the British Isles with the areas of highest potential density being off Cornwall, Pembrokeshire and the Outer Hebrides. (Project Management Support Services 2007). The Carbon Trust (2006) has estimated that, in the UK, the practical offshore wave energy resource is in the region of 50 TWh/year. Nevertheless, wave energy is not expected to play a big role in electricity production in the short/medium term. In the RES Strategy consultation BERR (2008c) states that, despite its potential, wave generation technology is still in its infancy, and unlikely to generate large quantities by 2020, although it is likely to remain an important element to meet longer-term climate change goals.

3.10.2 Overview of potential environmental impacts

Both offshore and onshore wave devices may negatively impact the environment.

Offshore devices need cables to be laid across ocean floor and beaches. During the installation phase, seabed habitat and species may be disturbed as cables are laid Associated onshore structures must also be built to oversee the operation of wave devices. (Project Management Support Services 2007). Fish, crustaceans and other marine species

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40 BERR, Wave Power – How it Works, http://www.berr.gov.uk/energy/sources/renewables/explained/wave-tidal/wave/page17058.html

41 BERR, Limpet http://www.wavegen.co.uk/what_we_offer_limpet.htm

42 BERR, Wave Power, http://www.berr.gov.uk/energy/sources/renewables/explained/wave-tidal/wave/current-use/page17048.html may be disturbed by the device's presence when operating. There are also concerns about the creation of electromagnetic fields (see Section 5.9).

Onshore or shoreline wave devices may also cause negative environmental impacts especially in terms of aesthetic and noise impacts from the machinery. Habitats and their associated species inshore of the devices may also be impacted through changes in wave energy, land take for the installation and habitat squeeze (Wildlife Trusts 2004).

Similar to wind and solar, wave power systems produce no carbon dioxide emissions at their point of use, but they do have life-cycle emissions. The manufacturing process requires electricity thus contributing to climate change. There does not appear to be extensive lifecycle assessments of wave power devices as yet. This is probably due to the fact the technology is mainly still at the demonstration phase.

Offshore wave devices could accidentally discharge oil and lubricants that could affect sediments and water quality. Furthermore, for both onshore and offshore wave devices, there appears to be some concern that the natural flow of sand and other beach sediment would be disturbed when they are in position.

3.11 Tidal

3.11.1 Technology description

Tidal energy harnesses the movement and energy contained in the ocean's tidal flows and converts it to electrical power. Specifically, the technology takes advantage of the natural ebb and flow of coastal tidal waters caused by the gravitational fields of the earth, sun and moon. As the coastal water level moves higher and lower twice daily filling and emptying natural basins along the shoreline, the currents can be used to turn mechanical devices which then produce electricity.[43]

There are two main types of tidal technologies being explored:

- Tidal range: used to covert tidal energy into electricity, is similar to that of hydroelectric power plants because gates and turbines are installed along a dam that forms a barrier across a tidal bay or estuary. When there is a substantial difference in the height of water on either side of the dam the gates open and the 'hydrostatic head' that is created causes water to flow through the turbines producing electricity. The tidal range resource can be harnessed though tidal barrages and tidal lagoons. Tidal barrages are already a proven system, while lagoons are a fairly recent yet unproven technology.
- Tidal stream technology is different because it harnesses the kinetic energy of tidal currents in a way similar to a submerged wind turbine. It is still currently at demonstration phase.

Potential in the UK: Currently, there are no tidal projects contributing to the UK's electricity supply because the technology is new and being tested.[44] According to a Government-commissioned report (SDC 2007), the UK has the potential to generate up to 10 per cent of its electricity from the tides tidal stream and tidal range – around 5 per cent

[43] *BERR, Tidal Power – How it Works, http://www.berr.gov.uk/energy/sources/renewables/explained/wave-tidal/wave/page17058.html*

[44] *BERR, Tidal Power – Current UK Use, http://www.berr.gov.uk/energy/sources/renewables/explained/wave-tidal/tidal/current-use/page17055.html* .

from each resource. The same report states that the best tidal stream sites are in the north of Scotland. North Wales, Northern Ireland, and the Channel Islands also have potential. Tidal range resources are located in particular in the largest estuaries off the coast of Britain, most notably the Severn estuary (which could possible supply up to 5 per cent[45] of the UK's electricity demand), the Mersey and the Humber. (SDC 2007)

3.11.2 Overview of potential environmental impacts

Several tidal projects are envisaged in the future, the main one being the installation of a tidal barrage in the Severn Estuary. Several options are being considered, from a relatively small system (Shoot scheme) with an embankment of 4.1 km, to a much larger system (Cardiff-Weston) covering 16.1 km. Other barrages are being investigated, e.g in the Loughor, Duddon, Whyre and Thames estuaries. A number of sites are also being taken into consideration for tidal stream – which being partly underwater may have a lower visual impact, and environmental effect similar to onshore infrastructures.

Since tidal power is not in operation, it does not currently affect the UK's greenhouse gas emissions target. As a renewable source, tidal energy has the potential to contribute to reducing GHG emissions.

Geodiversity impacts may arise from barrages because they can have major effects on sedimentary transport by reducing the tidal force on the seabed near the barrage, leading to significant reduction in sand transport (freezing usually mobile sand banks) and likely deposition of mud sediments. A barrage may result in deposition of up to 85 per cent of the mobile sediment load (in turn leading more light to access the water column creating viable photic zones). As some rocky intertidal areas will become subtidal, some geological features (e.g wave cut platforms) relying on erosion of their maintenance would be lost.

Tidal stream developments will generally have relatively low visual impacts because only a small part of their structures are above water and visible from land and or vessels. Once a structure is installed, effects will be more significant during maintenance as result of increased activity and mobile elements (e.g cross-arm) be raised above the water level. However, associated onshore infrastructures, in particular power cabling, may lead to additional aesthetic impacts. As a result, Scottish Natural Heritage suggested that development should be avoided in isolated or underdeveloped coastal areas (SNH 2004), which could significantly reduce its potential benefits.

According to a report commissioned by Natural England (Land Use Consultants 2007) a tidal barrage system such as the Cardiff-Weston scheme at the Severn Estuary could cause a significant effect on some aspects of the landscape and seascape character, national landscape designations, and views. Direct impacts to the landscape will be due to both the physical presence of a barrage, physical changes to water levels and coastal morphology and the upgrading and expansion of transmission lines required to accommodate tidal electricity. Furthermore, secondary impacts could arise from related infrastructures, such as possible road and/or rail links and possible new coastal development.

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45 BERR, Tidal Power- the Severn Estuary, http://www.berr.gov.uk/energy/sources/renewables/explained/wave-tidal/tidal/severnbarage/page41473.html

A summary of the main physical effects and environmental impacts of tidal is provided in Table 3.1 and a more detailed discussion and analysis of the impacts on biodiversity is provided in Section 5.6.

3.12 Biomass

3.12.1 Technology description

The term biomass is generally used to cover all vegetable matter grown or harvested for energy purposes, apart from biofuel crops. This can encompass a wide variety of materials including the following main categories:

- straw and other agricultural residues;
- forestry wastes and thinnings;
- wood or woodchips; and
- other waste products including municipal solid waste.

Dedicated energy crops such as short rotation coppice (SRC) and grasses such as *Miscanthus* are also promising sources of biomass. It is expected that some of these materials will be able to be used to produce biofuels in the future (as noted in the section below), but it is generally more efficient in both carbon and energy terms simply to burn them in a boiler to produce heat and/or electricity. Currently a large proportion of the biomass used in the UK is co-fired with conventional fuels in existing coal-fired power stations.

Potential in the UK: Energy from biomass constituted 81.8 per cent of all the UK's renewable energy in 2007 (BERR 2008) – far more than wind and other sources combined. The largest part of this was landfill gas, but co-firing and waste combustion were also significant. The potential contribution of biomass to produce heat and electricity is very large. For example, the Royal Commission on Environmental Pollution (2004) suggested that biomass could deliver up to 12 per cent of the UK's end use energy requirements, and deplored the limited extent to which it has thus far been utilised in the UK. A particular advantage of biomass over most other renewable energy technologies is that it is storable, and hence can be burnt when needed, and can even help to counteract the intermittency of other major renewable energy sources.

3.12.2 Overview of potential environmental impacts

Land take for crop growing is the major impact of biomass crops. Given the almost limitless potential for the use of biomass, potentially very large areas of land could be taken up. For example, the RCEP (2004) estimated that up to 6 million hectares of land in the UK might be dedicated to energy crops and other biomass sources. As McDonald *et al* (undated) argue, this will all be likely to be grown on areas currently in use in some form for agriculture or forestry, so it cannot be regarded as a 'new' land use. On the contrary, the potential environmental impacts of this use will depend upon what the new crop is substituted for.

Other phases of the biomass life cycle (e.g fuel production and transportation, generation of heat and electricity) are generally commensurate with those of the fossil fuels that they displace. There is, however, greater likelihood of biomass generating plant being sited in rural areas, where the transport of fuels to the plant may have significant local impact.

There are likely to be some greenhouse gas emissions incurred in the growing, transporting and preparing of biomass sources as fuels. However, such inputs are generally significantly lower than for biofuel crops. At the same time, energy crops such as SRC are much more efficient at accumulating usable energy content, and the conversion efficiencies of burning them are far higher. As a result, biomass fuels have very low life cycle carbon dioxide emissions (RCEP 2004).

Significant local landscape impacts may occur local as both crops are tall and dense and may therefore contrast sharply with other crops and habitats. The main concerns relate to the obscuring of landscape features (such as hedgerows), obstruction of views, and rapid scenic changes as a result of harvesting. Despite some environmental regulation of SRC plantations in the UK, a study of 13 plantations found that four had adverse effects on the visual quality of the landscape (Fawcett and Fawcett cited in Rowe et al 2007). However, with moderate scales of planting, potential impacts may be significantly reduced through with appropriate site selection and mitigation measures that blend plantations with dominant habitat features. Furthermore, in some landscapes such crops may serve to increase visual interest and obscure unsightly features.

There could be some potential access impacts as the plantations poses a dense and impenetrable mass to would-be walkers. These could be significant if new plantations are commonly placed on grasslands and other open land that currently allows public access under CROW Act provisions.

A summary of the main physical effects and environmental impacts of energy production from biomass is provided in Table 3.1 and a more detailed discussion and analysis of the impacts on biodiversity is provided in Section 5.7.

3.13 Biofuel

3.13.1 Technology description

The term ‘biofuels’ is applied to all liquid and gaseous fuels derived from organic materials. Most such fuels are liquid and used to power vehicles, although biogas can also be used in stationary plant, most notably for heating and drying on or near farms, or sometimes for electricity production. In the future it is expected that biofuels may be able to be manufactured from a wide variety of organic materials (as described above under Biomass), but current ‘first generation’ fuels are primarily bioethanol made from sugar cane or agricultural crops containing sugars or starch (principally sugar beet in Europe, and maize in the US); and biodiesel based on vegetable oils (principally rapeseed oil in Europe, but also soya and palm oil elsewhere). Liquid biofuels can be blended into conventional road fuel supplies, or in some cases used in high biofuel blends in dedicated engines.

Potential in the UK: At the time of writing, biofuels accounted for 2.14 per cent of UK road fuel, 86 per cent of this being biodiesel (Renewable Fuels Agency 2008a). This is likely to increase further, as the Renewable Transport Fuel Obligation sets a target of 5 per cent for 2010, while controversial Commission proposals suggest a 10 per cent target for 2020. Very substantial land areas would be required to make a significant contribution to UK road fuel demand, while the total agricultural land area of the UK would be insufficient to fuel all road vehicles on first generation biofuels alone.

Note however that, unlike most other renewable technologies, the market is not currently supplied primarily from domestic production, although this too is likely to increase. Hitherto supply has been dominated by imports, primarily of US soy for biodiesel and Brazilian sugarcane for bioethanol (RFA 2008a).

3.13.2 Overview of potential environmental impacts

The land use implications of growing crops in the UK for first generation biofuels are potentially very large, but it can be expected that all energy crops in the UK will be grown on land that is already in agricultural use or was previously set-aside. Thus in most cases the physical impacts will be little different from those of existing food crops, and in many cases the same crop can be grown for either food or fuel purposes. Establishment of a fuel production facility might however lead to some intensification of production of a given crop in the surrounding area owing to the need to minimise transport costs.

Globally, the land use implications of growing demand for biofuels can be very diverse and are currently attracting controversy. Concerns have been widely raised over the indirect impacts of this demand in terms of encouraging destruction of natural carbon sinks such as rainforests, and in pushing up the prices of staple foods. The recent Gallagher Review (RFA 2008b) confirms that these concerns are valid, but concludes that a sustainable global biofuels industry is attainable if the current growth in demand is slowed down.

The growth of fuel crops presents the main causes of physical impacts from biofuels. Other phases of the life cycle (e.g fuel production and transportation) are generally commensurate with those of the fossil fuels that they displace.

Biofuels offer CO_2 reduction benefits relative to mineral fuels because their carbon was absorbed from the atmosphere as the source plants grew, rather than being released from underground storage as with fossil fuels. However few if any biofuels are truly ‘carbon neutral’ in practice, because greenhouse gases are emitted during growing, transport and fuel production, and others are embodied in other inputs such as fertilisers.

A range of life cycle analyses of different biofuels have been undertaken. These were summarised *inter alia* in Smokers *et al* (2006), which concluded that those grown in Europe typically offer around a 50 per cent greenhouse gas reduction relative to their fossil fuel equivalents, although the benefits of ethanol imported from Brazil are typically much greater (around 80 per cent reduction or more). Note, however, that if use of crops for biofuels indirectly causes natural grassland or forest to be put to agricultural use for the first time, the carbon released can offset the benefits of using the fuel for many years ahead, with the payback period extending to decades or even centuries in some cases (RFA 2008b).

A summary of the main physical effects and environmental impacts of biofuel production and use is provided in Table 3.1 and a more detailed discussion and analysis of the impacts on biodiversity is provided in Section Chapter 5.8.

3.14 Waste

3.14.1 Technology description

Waste covers a broad range of substances from food to wood and even plastics and poultry litter, and can overlap in definition with biomass (discussed above). Waste, like coal or gas, can be used as fuel to generate electricity or heat. There are several different types of waste technologies including: anaerobic digestion, direct combustion (incineration), secondary recovered fuel (an output from mechanical and biological treatment processes), pyrolysis, gasification, and plasma arc heating. It is important to note that many of these technologies can use fuels other than wastes, e.g biomass (see section on biomass).

Potential in the UK: Assuming that landfill gas, sewage gas, domestic wood, industrial wood and other biofuels are not considered waste-to-energy technologies, purely "waste combustion" accounted for 10.1 per cent of the renewable energy resources in the UK during 2006. This equates to 520.5 thousand TOE (BERR 2008a) – of which 486.8 thousand TOE was used to generate electricity and 33.7 thousand TOE was used to generate heat (BERR, undated). If one were to include non-biodegradable wastes (not included under the international definition of renewables), the amount of electricity, heat, and transport fuels produced from wastes increases to 1391.7 thousand TOE (BERR, undated).

In 2006, there was 1453 MW of biofuels and waste generation capacity (BERR 2007). By 2007, 22 waste-to-energy plants were in operation, burning municipal solid waste, refuse derived fuel, and general industrial waste.

According to the *Waste Strategy for England 2007*, the Government wants to maximise energy recovered from unavoidable residual waste and promote greater energy recovery from food waste (via anaerobic digestion) and waste wood (via combustion) (DEFRA 2008). The Government did not set a specific target for the proportion of waste expected to go for energy recovery. However, there are targets for municipal waste recovery which includes, among other things, energy recovery. If these targets were met, it would mean an increase in energy recovery to about 25 per cent of municipal waste in 2020 compared to the current rate of recovery of 10 per cent. While the Government cannot require the adoption of one specific technology since local authorities have the authority to decide, it is encouraging the use of anaerobic digestion for food waste which is eligible for Renewable Obligations Certificates (DEFRA 2007).

3.14.2 Overview of potential environmental impacts

There are several concerns with waste-to-energy technologies. First, waste that could otherwise be reused or recycled may be used for energy production. Second, there are fears over health effects, especially linked to incinerators and dioxin emissions. Third, there is a concern that waste-to-energy facilities may emit more GHGs than foreseen. Hogg (2006) suggests that the typical UK incinerators, generating only electricity, are unlikely to be emitting a lower quantity of greenhouse gases per kWh than the average gas-fired power station in the UK. There are hence outstanding questions as to the carbon benefits of waste-to-energy technologies.

Waste energy is not carbon-free, although it may help reduce emissions by offsetting the amount of waste ending up in landfills and thus creating methane. The amount of greenhouse gas emissions emitted resulting from the combustion of waste depends on its composition (DEFRA 2007).

Incinerators emit sulphur dioxide, oxides of nitrogen, hydrochloric acid, carbon monoxide, volatile organic compounds, particulate matter, hydrogen fluoride, heavy metals and dioxins. Other environmental impacts associated with waste-to-energy are common to other types of centralised energy units.

3.15 Combined heat and power / district heating

3.15.1 Technology description

Combined heat and power (CHP), or co-generation, is an energy conversion process, whereby electricity and useful heat are produced simultaneously in one process and the heat can be used either for district heating or for industrial processes. Because plant can be optimised for both heat and electricity, CHP plant are significantly more efficient than electricity-only plant. The CHP process may use steam or gas turbines or combustion engines and the fuel sources can be biomass or fossil fuels, as well as renewable resources such as geothermal and solar energy.[46]

District heating (or cooling) systems, a related technology, distribute steam or hot water to multiple buildings. The heat can be provided by a variety of systems including CHP, geothermal, waste heat, and purpose-built heating plants.

Potential in the UK: Currently, 27,973 GWh of electricity generated in the UK use CHP technology and the majority of that electricity (21, 427 GWh) is generated by natural gas fired CHP plants.[47] Also in 2007, 53,050 GWh of heat was generated by CHP units.[48] The current capacity of CHP in the UK is 5.79 GW including both large and small facilities (BERR 2007). The UK currently makes very little use of CHP compared with many continental countries.

Recent estimates revealed that the UK could have a cost-effective potential for 13.8 GWe of CHP by 2010, although only 7.5 GWe are expected to be built.(BERR 2008e)

3.15.2 Overview of potential environmental impacts

Although CHP units can achieve overall efficiencies in excess of 70 per cent (Combined Heat & Power Association 2007), CHP units still share some of the same problems of conventional power plants.

CHP units have physical effects in the UK. According to the International Energy Agency, most CHP plants are larger than 10MW. (IEA 2002). This means that substantial land space is needed. Often units are attached to already existing industrial complexes, but as with any power plant, CHP impacts the immediate physical area. Impacts outside of the UK are related to the type of fuel used in the CHP plant – e.g in case coal that is mined and imported to the UK may serve as a source.

Furthermore, building new pipelines for district heating through buildings, cities and communities can cause negative environmental impacts, especially in terms of

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[46] *CHP Info, What is CHP, http://www.chp-info.org/.*

[47] *BERR,, Energy Statistics – CHP, http://www.berr.gov.uk/energy/statistics/source/chp/page18528.html*

[48] *BERR, Energy Statistics – CHP, http://stats.berr.gov.uk/energystats/dukes6_6.xls*

geodiversity. However, in the case of both CHP and district heating, it is the high level of efficiency that reduces the overall footprint of these projects.

The emission levels from CHP units are lower than conventional power plants because they use fuel more efficiently. Yet, there still are emissions. CHP units require about 65 per cent less energy input than conventional power plants, and these units also operate more efficiently (Intermountain CHP Center 2008).

District heating is also another technology that in itself does not emit greenhouse gases, but works to reduce them by meeting thermal loads that would otherwise be met with individual industrial boilers or electric power, thus improving energy efficiency. By reducing the need for on-site fossil fuel combustion in individual boilers or furnaces, district heating plays an important role in reducing emissions through efficiency.

3.16 Microgeneration

3.16.1 Technology description

Microgeneration, also called micropower, is not one distinct type of technology but rather refers to small-scale energy production for individual buildings or communities emitting zero or low amounts of carbon dioxide (DTI 2006b). Microgeneration takes many forms, including:

- Solar PV producing electricity.
- Solar thermal providing hot water and space heating.
- Ground source heat pumps harnessing the energy stored in the ground for heating.
- Micro-combined heat and power providing both heat and electricity.
- Micro-wind turbines providing electricity powered by either wind or naturally flowing water.
- Hydrogen powered fuel cells producing heat and electricity.[49]
- Biomass, typically using commercial energy crops in the form of fast growing tress such as willow or poplar for woodchips or waste wood products, producing heat in small boilers or domestic heating systems.[50]

Potential in the UK: There are approximately 100,000 microgeneration installations in the UK – which registered an increase from an estimated 82,000 at the end of 2004. Since April 2007, the number of microgenerators accredited under the Renewables Obligation increased from 410 units to 1,329 units by 31 March 2008 (BERR 2008f).

The Government has not set a target for microgeneration, but it does have a strategy. The objective of the microgeneration strategy is to "create conditions under which microgeneration becomes a realistic alternative or supplementary energy generation source for the householder, for the community and for small businesses." (DTI 2006b).

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49 Micropower, What is Micropower or Microgeneration?, http://www.micropower.co.uk/about/whatismicropower.html.

50 Micropower - Biomass heating http://www.micropower.co.uk/about/biomass.html.

3.16.2 Overview of potential environmental impacts

Since microgeneration encompasses many different types of technologies, it is difficult to pinpoint the environmental impacts these technologies will have in the UK. Physically, microgeneration requires the installation of small energy systems on homes, businesses and public buildings (DTI 2006b). Microgeneration also requires the installation of ancillary yet associated technologies, such as metering devices, and possibly the upgrading of the distribution grid (DTI 2006b).

As discussed with solar, there are life cycle costs associated with these technologies, for example the mining of raw materials and the manufacturing of the systems. For information about solar, please refer to Section 3.8.2. Micro-wind technology, like solar, requires energy inputs. One recent report found that "up to two thirds of micro-wind turbines installed on homes and offices could result in more carbon emissions than they save" because of the energy inputs needed to produce the technology (BusinessGreen 2007).

Some of the microgeneration technologies present unique environmental threats. For example, ground source heat pumps (GSHP) contain refrigerants which are highly toxic and flammable and have high global warming potential. However, new GSHP systems have improved, and if installed by a professional, leakage can be prevented. For information on the environmental impacts of biomass microgeneration, please see section 5.7.2.

Table 3.4 Summary of principal physical effects and impacts on biodiversity, geo-diversity, landscape and access.

Energy source/technology	Physical effects		Biodiversity impacts		Geodiversity	Landscape	Access	References
	UK	Out side UK	UK	Outside UK				
Coal	Largest source of GHG: 939 tonnes C/ GWh electricity Other significant emissions: Hg, NO_x, SO2. Pollution and land uptake due to mining (esp. South and west Wales and Northern England).	Mining and transport	Habitat loss (esp open-cast) pollution, hydrological disruption, and disturbance – see Chapter 5.	Global climate impacts due to GHG emissions. As UK, though some habitats may be of higher biodiversity importance	Potential loss of features of interest, esp in open cast mines	Substantial impacts due to mining (esp open-cast) and spoil heaps, power plants and transmission infrastructures	Loss of access in mining workings, though many may already have restricted access.	See text
Gas	GHG Emissions: 405 tonnes of CO_2/ GWh Land use for drilling brine disposal, pipelines, and conversion plants, possible methane leakage from pipelines, air emissions from processing and conversion (including CO, NOx and), and thermal discharges.	From drilling operations outside the UK. Contribution to global warming	Marine habitat damage from rigs and pipelines, terrestrial habitat loss from pipelines, and storage facilities. Pollution from drilling rigs. See Chapter 5 for details	As UK, though some habitats may be of higher biodiversity importance	Unlikely to be significant if sensitive sites are avoided	Impacts from power stations, storage and processing facilities etc, but localised and many likely to be in industrial landscapes or low aesthetic value. Most terrestrial pipelines buried and invisible, other than occasional pumping stations. Most rigs distant offshore.	Loss of access in works areas, but many likely to be already in industrial areas with limited access and low amenity value.	See text
Oil	GHG emissions: 658 tonnes CO_2/ GWh Air emissions, wastewater	From drilling operations outside the UK. Contribution to	Marine habitat damage from rigs and pipelines, terrestrial habitat loss from pipelines, and	As UK, though some habitats may be of higher biodiversity importance	Unlikely to be significant if sensitive sites are avoided	Impacts from refineries, power stations, and storage facilities etc, but localised and many	Loss of access in works areas, but many likely to be already in industrial areas	See text

Energy source/technology	Physical effects		Biodiversity impacts		Geodiversity	Landscape	Access	References
	UK	Out side UK	UK	Outside UK				
	discharges, solid and liquid waste management, noise generation and spills from offshore developments. Impacts from decommissioning if structure are left in place or if explosive used. Air emissions (SO_2 and NOx) , wastewater and hazardous waste results from oil refining.	global warming	storage facilities. Pollution from drilling rigs and oil spills. Contributor to acidification and airborne nitrogen deposition and eutrophication. See Chapter 5 for details			likely to be in industrial landscapes or low aesthetic value. Few terrestrial pipelines and these are buried and invisible, other than occasional pumping stations. Most rigs distant offshore.	with limited access and low amenity value.	
Nuclear	Contribute to GHG reduction (12-14 million tonnes CO2 in CO2 in 1999 ie 7-14% total emissions) Land uptake of 100-400ha for 1000MW power + exclusion zone around the plant of 500-1,500m. Substantial consumption of water for cooling (40-60m3/sec) Issues related to radioactive waste storage.	Mining activities Possible transboundary effects in case of accident (radioactivity)	Main impacts are habitat loss from the powers station and processing facilities. Some habitat degradation form thermal pollution.	Uranium mining.	Unlikely to be significant if sensitive sites are avoided	Significant visual impacts from power stations, many of which are located in coastal areas of high landscape value. Buildings and cooling towers can be 60 or more metres high.	Loss of access in works areas. New facilities may block access to the coast and coastal footpaths.	See text
Hydrogen (not including fuel	May increase demand for non-RES	Hydrogen leakage during synthesis may	Depending on the fuel used – see	Depending on the fuel used –	Hydrogen could be	New transport infrastructure could	New infrastructure	Tromp et al. (2003); European

Energy source/technology	Physical effects		Biodiversity impacts		Geodiversity	Landscape	Access	References
	UK	Out side UK	UK	Outside UK				
cells)	– (see related physical effects) Major infrastructure development to transport hydrogen fuels to the point of end-use (pipelines, trucks, storage facilities, etc)	increase global climate change.	impacts of RES and non-RES	see impacts of RES and non-RES	absorbed in the soil. Undersea and underground pipelines and storage tanks needed to transport and store hydrogen fuel.	harm landscapes.	could inhibit access to areas.	Commission (2006); Derwent et al. (2006); U.S. Dept. of Energy (2008).
Hydro-electric power	Large infrastructure works, wide land use: eg dams, water storage areas, aqueducts and pipes, tunnels, power stations, water discharge areas, power lines.	Increased methane emissions which contribute to climate change.	Significant disturbance and siltation during construction. Dams can disrupt the movement of species leading to changes in upstream and downstream species composition and species loss. Substantial downstream hydrological disruption.	None	Some projects require areas of land to be submerged which in turn changes natural geological formations.	Significantly changes landscapes, eg submerging valleys and landscapes of high aesthetic value. But impacts are variable and can be positive.	Displacement of communities and elimination of access to areas submerged or part of project.	Scottish Wild Land Group (2005); Glendoe Hydro Scheme; International Rivers Network (2008); World Commission on Dams (2000); Copestake (2006); Young (2004)
Wind	Land uptake: on average 0.18 ha/MW onshore Offshore are bigger (up to 5MW) and at 2-10 km from shore – some expected to be build further out to sea. Transmission: mainly related to	Beneficial effects due to reduced climate change. Some emissions/pollution.	Limited direct habitat loss, but disturbance impacts may result in larger scale effective habitat loss for some sensitive species. Mortality rates from collisions may be significant for some species in certain situations. Some habitat degradation	Unlikely to be significant from UK production	Potential impacts but depend on site location.	Obvious wide-ranging impacts on the landscape leading to considerable public concern. But most proposed developments avoid the most sensitive areas. Concerns over off-shore wind farms tend to be much	Some potential impacts if wind farms are located on or close to access routes, but these should be avoided or mitigated for.	See text

Energy source/technology	Physical effects		Biodiversity impacts		Geodiversity	Landscape	Access	References
	UK	Out side UK	UK	Outside UK				
	sub-sea cables for offshore GHG emissions are generated in the manufacturing phase, but offset during the life cycle. Emission reductions: 5.8 million tonnes CO_2 (1% UK emissions) – ie 2,300/MW		in some habitats, eg peat lands from soil disturbance and hydrological. See Chapter 5.			lower.		
Solar (PV and solar water)	Manufacturing process is very energy intensive and may increase demand for fossil fuel power plants. Manufacturing process involves the use of potentially toxic substances: semiconductor materials, a-Si, CIS and CdTe. Utility-scale solar installations require large land area.	Mining of arsenic, cadmium, and silicon outside EU. Manufacturing process is energy intensive and toxic – mainly taking place outside the EU (e.g Japan)	Relatively low or no impact	Mining of raw materials can lead to land conversion and loss of species habitats.	Mining resources of PV panels may disturb rock and land forms (espec outside the EU). Utility-scale PV installations may cause soil erosion and compaction.	Minor/no impact if integrated PV (BIPV) located on existing structures. Larger impacts in case of utility-scale solar installations.	Minor/no impact of BIPV. Utility-scale PV may inhibit access to certain areas.	Fthenakis et. al. 2005; Abbasi et al. 2000; Nieuwlaar et al. 1997; Union of Concerned Scientists 2008; European Commission 2008; European Renewable Energy Council et al. 2007.
Wave	Accidental discharge of oil and lubricants. Cables that attach to devices laid across ocean floor and beaches. Associated onshore	n/a	During installation of devices and cables seabed habitat and species may be disturbed. During operation marine life may be affected by changes	n/a	Natural flow of sand and other beach sediment could be disturbed by both onshore and offshore	Possible aesthetic and noise impact of onshore devices.	Onshore devices may disturb access to coastline.	Project Management Support Services et al. 2007; BBC 2000.

Energy source/technology	Physical effects		Biodiversity impacts		Geodiversity	Landscape	Access	References
	UK	Out side UK	UK	Outside UK				
	structures built to oversee operations.		in wave energy and disturbed by sounds. Possible electromagnetic effects of transmission cables.		devices.			
Tidal	Land uptake: Need to create barrages in estuaries in case of barrage tidal. (e.g Severn barrage could range from 4 to 16 km)	n/a	Potentially significant habitat loss and indirect habitat impacts; mortality of fish from barrages. Uncertain impacts from tidal flow schemes, but likely to be low. See Chapter 5.		Littoral features of interest may remain submerged, reducing their educational and scientific value etc.	Impacts from barrage structure and reduced tidal range and associated properties (eg tidal bore). Minimal impacts from tidal stream turbines as these are mostly underwater.	Reduced access to inter-tidal foreshore.	See text
Biomass	Significant land uptake – mainly farmland. Impacts of biomass production, transportation and heat/electricity generation similar to fossil fuels. Generating plants likely to be in rural areas – possible local impacts due to fuel transport. Low life-cycle CO2 emissions	Land uptake if production outside the UK	Impacts uncertain and will depend on habitats replaced. Most impacts likely to be beneficial if crops grown on arable farmland and in appropriate locations and scales. See Chapter 5	No direct impacts likely as most biomass will be grown in the UK. But large-scale production could displace harmful land uses (eg biofuels) to other countries	No significant impacts likely.	Potential landscape impacts if large-scale and inappropriate planting of biomass crops is undertaken, esp where this replaces grazed grasslands and other semi-natural habitats.	Reduce access to open land (under CROW Act) where grasslands are replaced with cultivated biomass crops.	See text
Biofuel	Land uptake, but no	Major concerns if	Impacts are similar	Most biofuels	No significant	No additional	Reduce access to	See text

Energy source/technology	Physical effects		Biodiversity impacts		Geodiversity	Landscape	Access	References
	UK	Out side UK	UK	Outside UK				
	change in crop type in existing arable farmland. Growth of fuels presents the main physical impacts from biofuels – e.g pollution from fertilisers, emission from transportation etc Contribution to GHG reduction: 50% less than fossil fuels	production outside the UK: e.g potential destruction of natural carbon sinks like forests. Potential negative effect on world food prices	or identical to those of arable crops (*ie* wheat and oil-seed-rape). But increased consumption may drive further increases in arable cropland in the UK, eg with losses of grassland. See Chapter 5.	likely to be produced outside the UK, thus resulting in direct or indirect impacts (via displacement) on other habitats, some of which may be of high biodiversity value.	impacts likely.	impacts to those of existing agriculture in arable areas. Possible loss of grasslands and associated livestock and replacement with biofuel crops in some areas.	open land (under CROW Act) where grasslands are replaced with cultivated biofuel crops.	
Waste	Possibility that waste that would otherwise be reused or recycled is used instead for energy recovery. GHG emissions related to transport of waste to the facility. Incinerators emit SO2, NO_x, CO, hydrochloric acid, VOC, PM hydrogen fluoride, heavy metals and dioxins. Land uptake due to construction of waste-to-energy facility.	N/a	Emissions and construction of facilities may harm local biodiversity.	n/a				DEFRA 2008; DEFRA 2007; Hogg 2006; Environment Agency 2008.
CHP / district	Depending on the	Impacts depending	Depending on the	Depending on	Laying of	Depending on the	Depending on the	Combined Heat

Energy source/technology	Physical effects		Biodiversity impacts		Geodiversity	Landscape	Access	References
	UK	Out side UK	UK	Outside UK				
heating	fuel used – see impacts of RES and non-RES Land uptake/disruption due to construction of district heating pipeline network.	on the fuel used (e.g mining, GHG emissions) – see impacts of RES and non-RES	fuel used – see impacts of RES and non-RES	the fuel used – see impacts of RES and non-RES	pipelines for district heating.	fuel used – see impacts of RES and non-RES	fuel used – see impacts of RES and non-RES	& Power Association 2007; Intermountain CHP Center 2008; IEA 2002; IEA 2008.
Microgeneration – (see solar, wind and biomass)	Mining of raw materials and manufacturing of the systems. GSHP contain refrigerants which are highly toxic and flammable.	Mining of raw materials and manufacturing of the systems. GHGs emissions from refrigerant leakage in GSHP.	None likely to be significant	None likely to be significant	GSHP require underground installation.	Minor additional impacts, as microgeneration facilities are usually installed on or near existing infrastructure.	Minor, as microgeneration facilities are usually installed on or near existing infrastructure.	DTI 2006; BusinessGreen 2007

4 REVIEW AND SELECTION OF ENERGY TECHNOLOGIES AND SCENARIOS

4.1 Future energy scenarios

The UK Energy White Paper sets out a baseline case (not driven by climate change policy) for 2020 and 2050, and compares it to a case constrained by climate policy, ie constrained to deliver the UK government's goal of 60 per cent reduction in carbon emissions by 2050. In addition it sets out several alternatives under the 2050 constrained case. These are summarised in the following figures, which detail the primary energy sources per scenario, then compare each energy type across scenarios; the same is done for electricity

Figure 4.1 White paper – primary energy

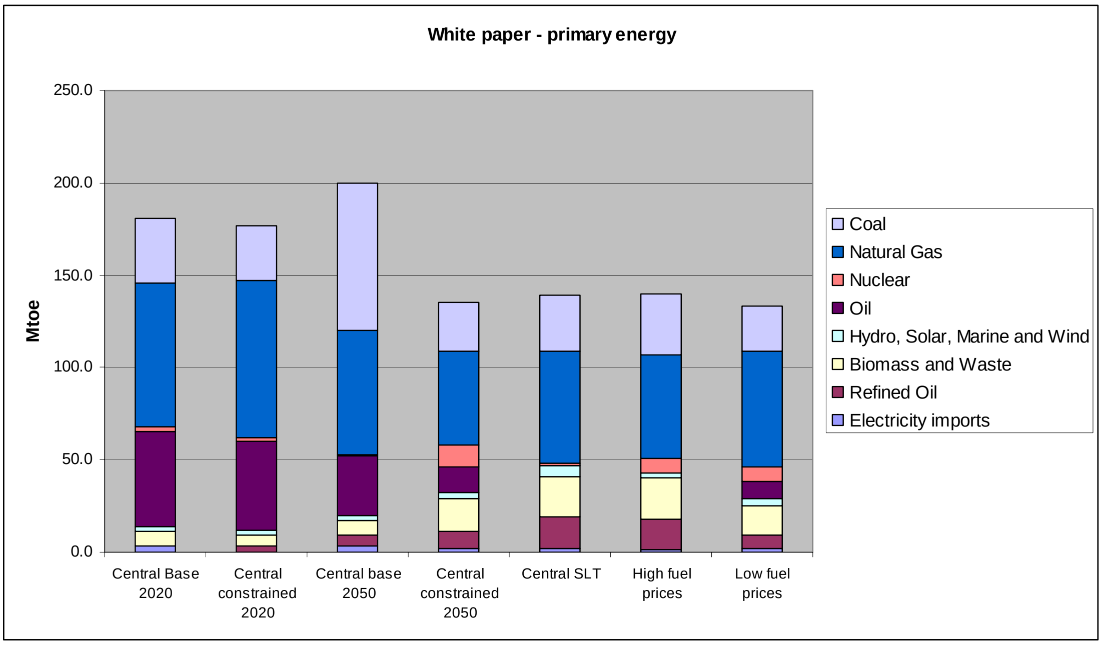


Figure 4.2 White paper – primary energy by type

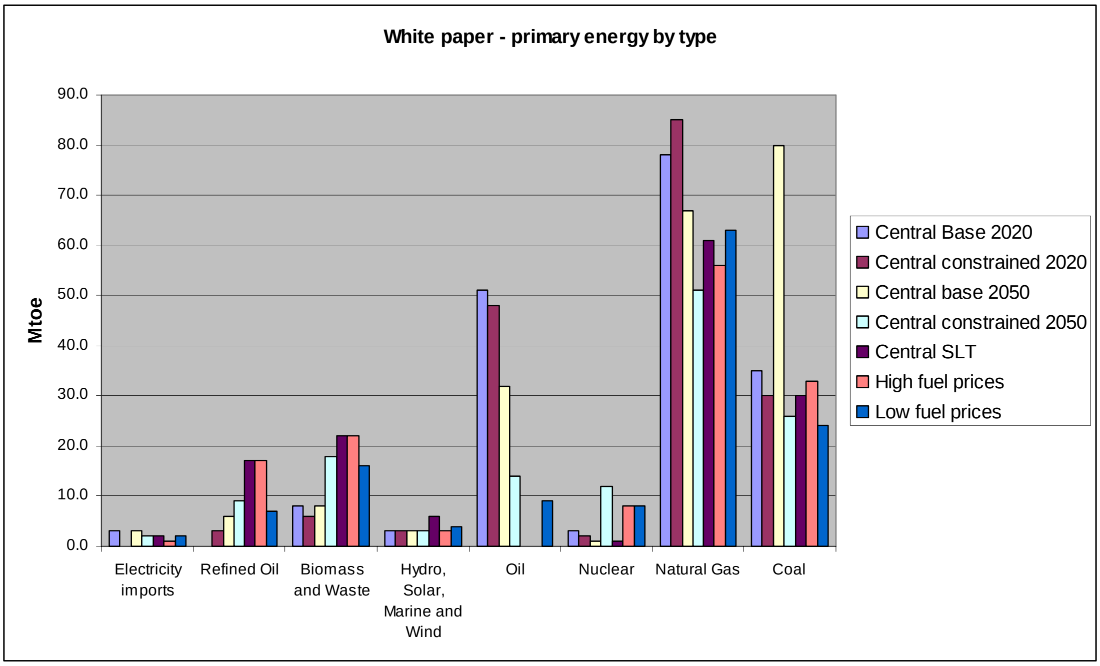


Figure 4.3 White paper – Electricity

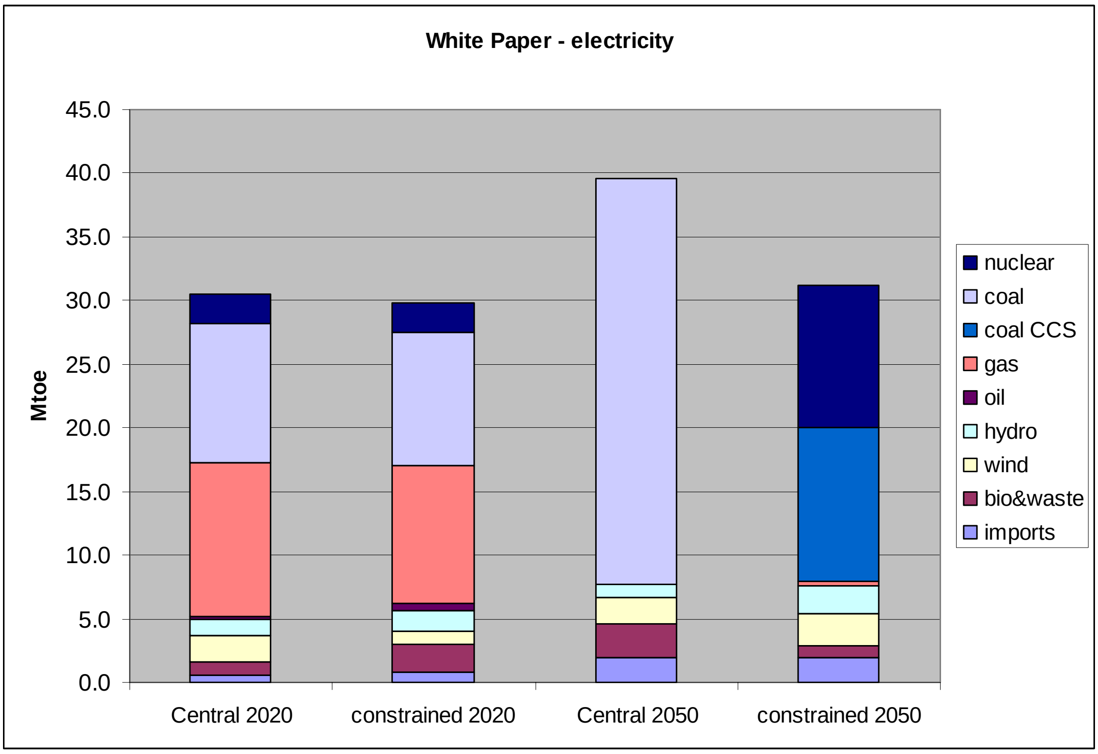
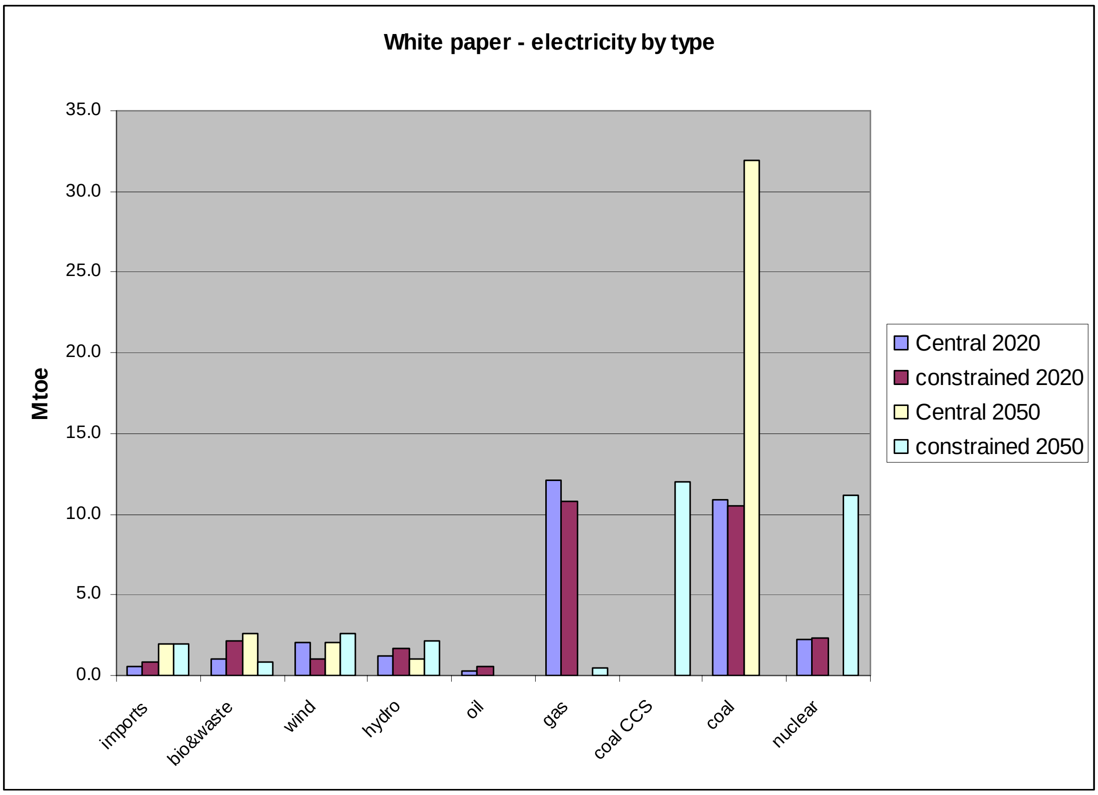


Figure 4.4 White paper – electricity by type



From the White Paper, we see that the central expectation is that, in the absence of climate policy to push for change, the primary energy mix would be dominated by coal, oil and gas through 2020 and even in 2050. Carbon constraints would not significantly alter the picture by 2020, but in 2050 there are major differences. These start with about a one-third reduction in energy demand, and a cut of anywhere from 50 to 100 per cent in oil use, though alternative scenarios show different combinations of primary energy.

In electricity, the central and constrained scenarios in 2050 show a major shift –gas has all but been squeezed out of the sector by then under both cases, and conventional coal disappears under the carbon constraint, with the two largest sources becoming nuclear and coal with CCS. Hydro, solar, marine and wind power play only a token role, with biomass and waste growing significantly. This government report may be taken as the 'conventional' view of future development, which explains the importance of the debate around nuclear and CCS at the moment.

The Tyndall Centre worked from the point of view of 2050 only, comparing scenarios that all reach the same goal – 60 per cent emissions reductions by 2050 compared to 2002 – but using different means. The scenarios are assigned colours simply to distinguish them; the important differences are spelled out in the Table 4.1, followed by the differences in primary energy and electricity by scenario and by energy source.

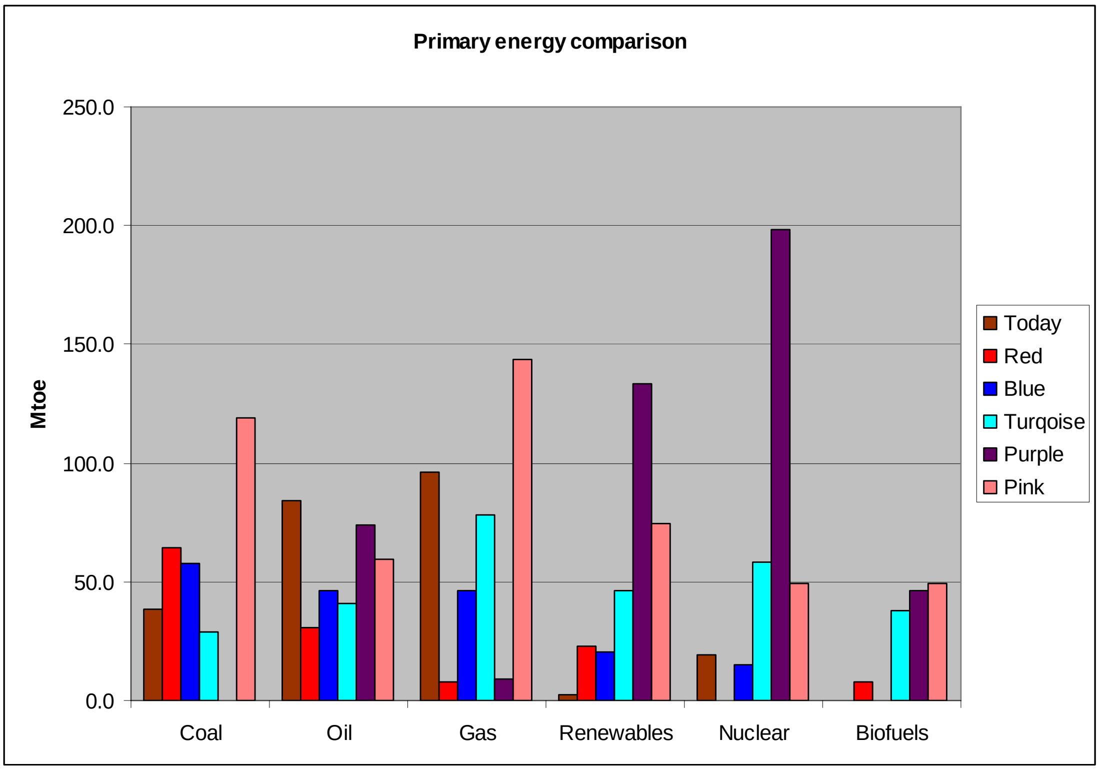
Table 4.1 Tyndall Centre scenarios

	Red	**Blue**	**Turquoise**	**Purple**	**Pink**
Growth in UK GDP (per year)	3.3%	1.6%	2.6%	3.9%	3.9%
Dominant economic sectors	- commercial	- commercial - public admin - non-intensive industry	- commercial - construction - public admin	- commercial - non-intensive industry	- commercial - non-intensive industry
Energy consumption (Mtoe)	90	130	200	330	330
Number of Households (million)	27.5	25	30	27.5	27.5
Energy use per household	large reduction	very large reduction	small reduction	similar to current	similar to current
Supply mix	- coal (w and wo CCS) - RES - hydrogen - biofuels	- coal (w CCS) - nuclear - CHP - biofuels	- gas (w and wo CCS) - biofuels - nuclear - hydrogen - RES	- nuclear - RES - hydrogen - biofuels	- nuclear - CCS (coal & gas) - RES - biofuels
Decarbonisation policies	innovation & technology driven	collectivist approaches to demand-side policy	similar to today with focus on supply	strongly market-focused government	strongly market-focused government
Transport	- low growth in aviation - reduction in car use - very large increase in public transport	- medium growth in aviation - low growth in car use - large increase in public transport	- large growth in aviation - no growth in car use - small increase in public transport	- very large growth in aviation - large growth in car use - large growth in public transport	- very large growth in aviation - large growth in car use - large growth in public transport
Tranport fuels	- oil - electricity - hydrogen	- oil - electricity - hydrogen	- oil - biofuels - electricity - hydrogen	- oil biofuels - electricity - hydrogen	- oil - biofuels - electricity
Hydrogen	- stationary and transport uses - production from gasification with CCS and RES - no pipelines	- transport uses - production from gasification with CCS, nuclear and RES - no pipelines	- all sectors including aviation - production from gasification with CCS, nuclear and RES - pipelines and H2 by wire	- stationary and transport uses - production from RES and nuclear - extensive pipeline system	no hydrogen

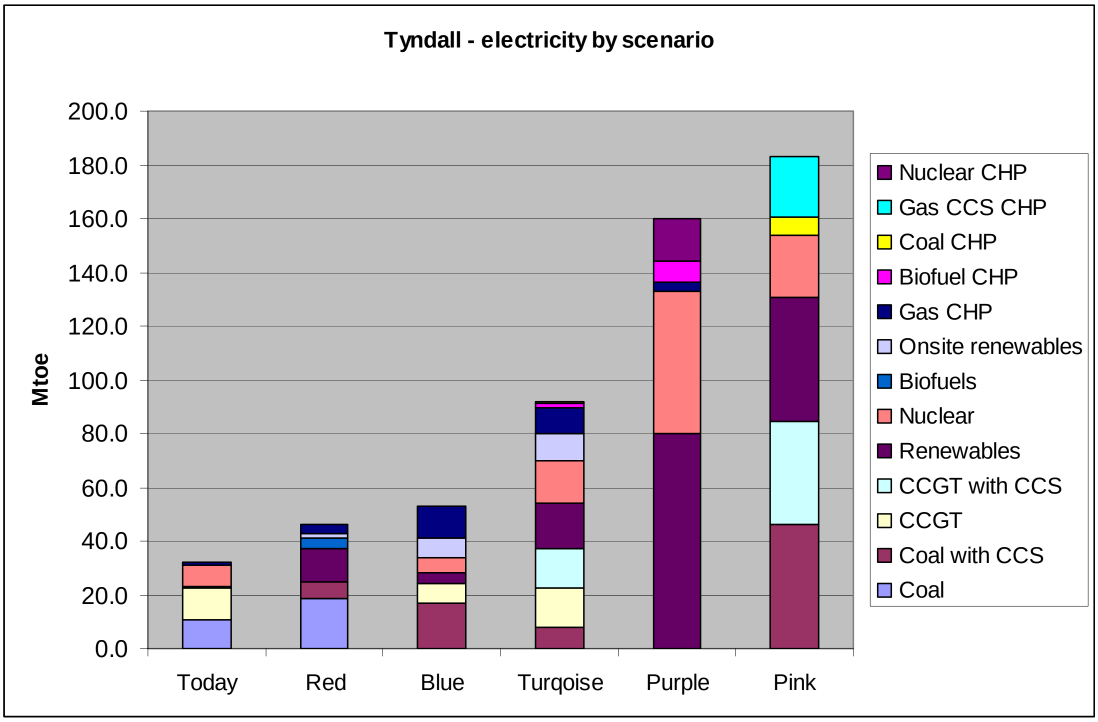
Source: Based on Tyndall Centre (2005)

Figure 4.5 (a-c) Assumptions behind the different scenarios in Tyndall Centre (2005).

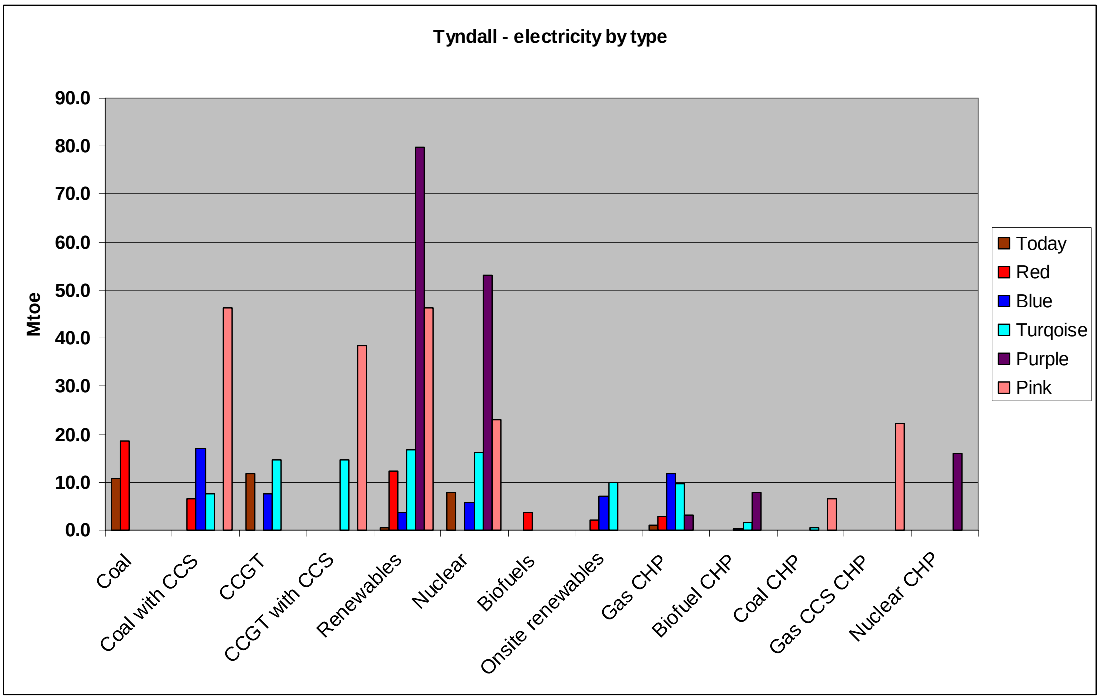
a) Primary energy comparison



b) Electricity by scenario



c) Electricity by type



The Tyndall scenarios are meant to show a great deal of variety, starting with energy demand, which differ between scenarios by a factor of over 3.5: a minimum of 134 Mtoe in the 'Red' scenario and a maximum of 495 Mtoe in the 'pink' scenario. Energy types are diverse, with, for example, large amounts of coal (largely with CCS) in the red scenario but no nuclear, but large nuclear builds in the turquoise, pink and especially the purple scenario. These differences result from a range of assumptions about not just the development of these energy sources, but of society as a whole.

The Poyry analysis for Greenpeace and WWF focuses on 2020 with some references to 2030. It creates six scenarios which rapidly increase renewable energy, and the report has the advantage of a more detailed examination of the different types of renewables.

Emissions reductions (in per cent below 1990) for each scenario are as in Table 4.2 below.

Table 4.2 Emission reductions

	2015	2020	2025	2030
Green Power	-19	-26	-27	-28
Shared load	-18	-23	-24	-25
Energy Rev	-24	-34	-38	-43
Energy Rev non-bio	-26	-37	-41	-46
Power down	-24	-34	-39	-44
Power down non-bio	-26	-37	-42	-47

Source: Based on Poyry (2008)

Expressed in GW of installed capacity, the breakdowns are shown in Figure 4.6 below. The renewables figures are in turn broken down into type in more detail in Figure 4.7.

Figure 4.6 Electricity in 2020 installed capacity

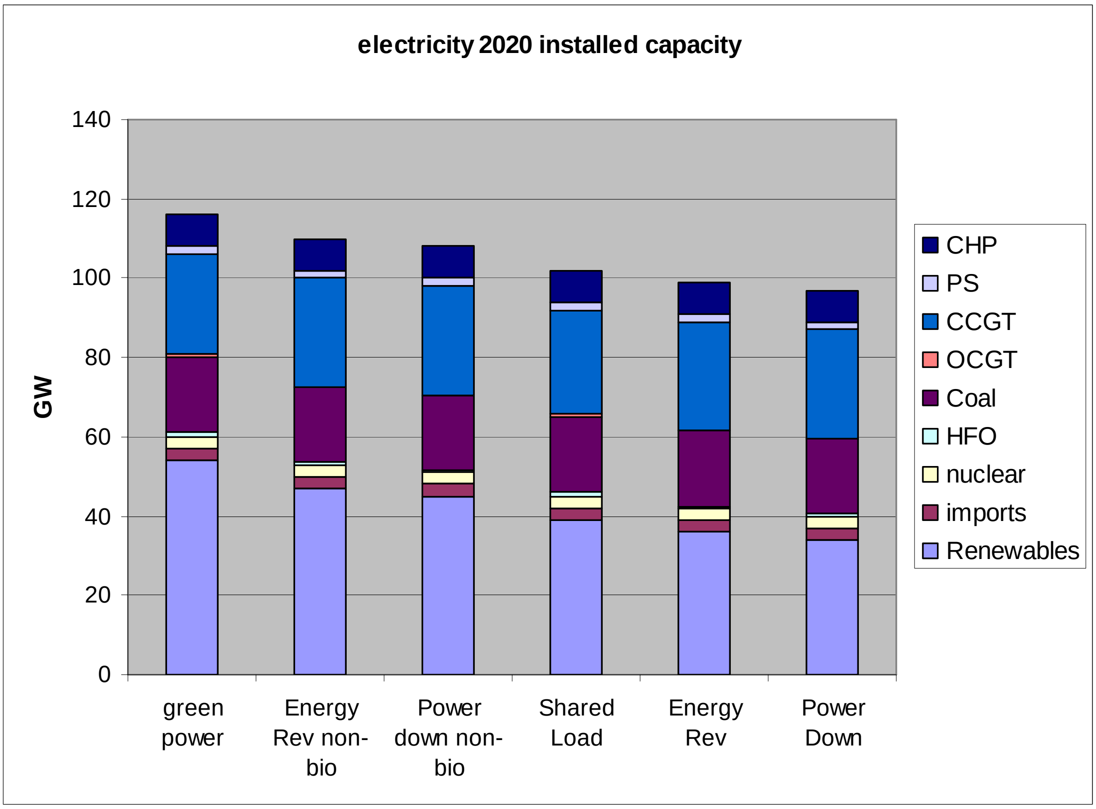
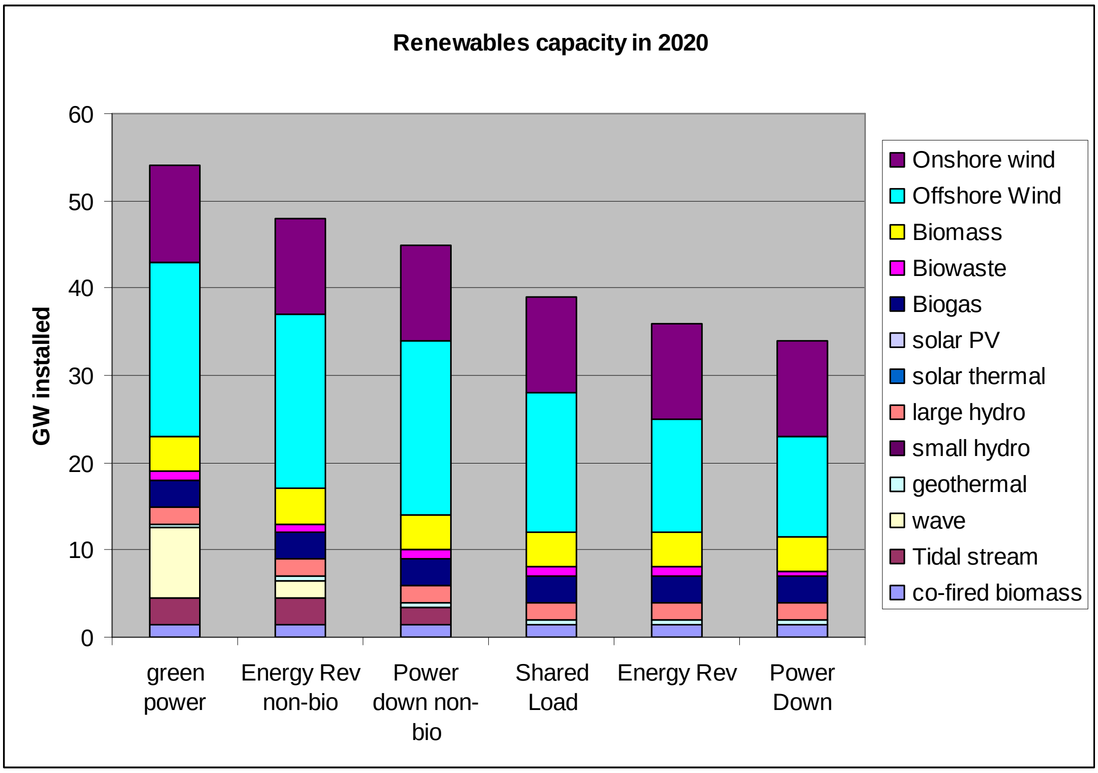


Figure 4.7 Renewables capacity in 2020



The Poyry analysis tries to push the envelope on renewable energy capacity in 2020, reaching levels of 35 to 45 per cent of electricity. This is done to explore the effect on the stability of the system and the required capacity to maintain needed reserves. Of particular interest here is the dynamic between increased energy requirements and the use of specific energy types – when more energy is required, as in the green power scenarios, wave and tidal energy begins to be exploited in greater amounts. Other than that, however, the primary difference is in the amount of offshore wind power use.

4.2 Scenarios for analysis

We have chosen four examples to represent a range of projections for 2020 and 2050, which will be used to compare the impacts of each individual technology on biodiversity (in chapter 5) and in combination (in chapter 6). These assessments are based on:

- A baseline of current emissions (Berr 2008b) for comparison with the future scenarios.
- The White paper baseline and reduction cases for 2020 and 2050.
- The 'Red' and 'Purple' Tyndall cases in 2050. These were chosen because they represent two important contrasts: the red case has low overall energy demand, while the purple is very high, and secondly the red case relies largely on conventional coal and renewables for energy supplies, while the purple shifts to biofuels, nuclear and CCS.

These reports do not always break energy uses down into the same categories. To create Table 4.4 below, we have taken the liberty of making the most sensible combinations – eg where one report notes the sector 'oil' and the other 'oil' and 'refined oil' separately, we combine the latter into one 'oil' sector.

While these combinations were straightforward to do for fossil and nuclear energy, renewable energy is reported in much more widely varying degree: in the case of the Tyndall scenarios, they are simply broken into 'renewable' primary energy, 'renewable' electricity, and biofuels, while there are several more categories in the White paper. We felt it important to at least break renewable energy into the types of particular interest from the point of view of this study. To do this, we model the more detailed breakdown on the study by the Royal Commission on Environmental Pollution (2000), which describes energy types in more detail, and which informed the Tyndall scenarios as a point of reference. We have specifically used 'scenario 1'. The breakdowns used in the Royal Commission report (as indicated in Table 4.3) were not used for their absolute amounts, but instead for the proportions of each type of energy of interest here. These proportions were then used to fill in the gaps in the White paper and Tyndall reports using *their* absolute numbers[51].

Table 4.3 Breakdown of renewable energy sources in 2005, scenario 1 (RCEP, 2000).

Energy source	Mtoe
Onshore wind	4.90
Offshore wind	8.59
Photo voltaic	7.53
Wave	2.82
Tidal stream	0.19
Tidal barrage	1.66
Old large hydro	0.59
New small hydro	0.23
Energy crops	3.49
Agricultural waste	1.81
MSW/lf gas	0.60

In addition the scenarios are reported in their original publications in different terms: eg the White Paper uses Mtoe for primary energy and Twh for electricity, while the Tyndall report is in Mtoe for both – here we convert Twh to Mtoe (by multiplying by 0.086) for consistency.

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[51] For example, the White paper reports 'wind energy', but not offshore and onshore. The RCEP report has a proportion of 1.75 : 1, offshore : onshore – that proportion, applied to the White paper's 2050 Central case of 2.07 Mtoe wind yields 1.31 offshore and 0.76 onshore.

Table 4.4: Energy scenarios used for the analysis of impacts on biodiversity (Mtoe)

Primary energy	Berr	Central 2020 (EWP)	Δ%	constrained 2020 (EWP)	Δ%	Central 2050 (EWP)	Δ%	constrained 2050 (EWP)	Δ%	Red (Tyn)	Δ%	Purple (Tyn)	Δ%
Imports		3.0	n/a	0.0	n/a	3.0	n/a	2.0	n/a		n/a		n/a
Coal	40.80	35.0	-14.2%	30.0	-26.5%	80.0	96.1%	26.0	-36.3%	64.3	57.6%	0.0	-100.0%
Oil	75.60	51.0	-32.5%	51.0	-32.5%	38.0	-49.7%	23.0	-69.6%	30.8	-59.2%	73.8	-2.4%
Gas	89.91	78.0	-13.2%	85.0	-5.5%	67.0	-25.5%	51.0	-43.3%	8.0	-91.1%	9.2	-89.7%
Offshore wind	0.29	1.31	355.1%	0.65	127.6%	1.31	355.1%	1.63	468.9%	4.89	1603.8%	25.86	8916.5%
Onshore wind	0.17	0.76	355.1%	0.38	127.6%	0.76	355.1%	0.95	468.9%	2.83	1596.8%	14.74	8742.9%
Biowaste/biogas/landffill gas	1.86	0.61	-67.2%	1.27	-31.6%	1.53	-17.8%	0.51	-72.6%	1.46	-21.5%	6.42	245.3%
Biomass	2.01	5.22	159.2%	3.08	52.8%	4.45	121.0%	8.75	334.4%	7.12	253.6%	49.39	2352.2%
Tidal barrage	0.00	0.00	n/a	0.00	n/a	0.00	n/a	0.00	n/a	1.89	n/a	4.99	n/a
Other renewable electricity	0.48	1.20	148.7%	1.63	237.5%	1.03	113.1%	2.15	344.0%	4.60	849.8%	32.29	6568.7%
Biofuels	0.36	7.22	1906.1%	5.08	1310.8%	6.45	1691.9%	15.75	4275.1%	7.12	1878.3%	95.49	26426.1%
Nuclear	4.92	3.0	-39.0%	2.0	-59.3%	1.0	-79.7%	12.0	143.9%	0.0	-100.0%	198.2	3929.7%
Totals	**216.40**	**186.3**	**-13.9%**	**180.1**	**-16.8%**	**204.5**	**-5.5%**	**143.7**	**-33.6%**	**133.1**	**-38.5%**	**510.4**	**135.9%**

Source: adapted from Tyndall (Tyn), and the Energy White Paper (EWP.).

The main drivers for choices among technology in these models are fuel costs and infrastructure costs, the latter of which is affected by both the financial situation (interest rates, etc) and the degree of maturity of the technology. Aside from CCS, therefore, fossil fuel implementation rates tend to be governed by estimates of fuel costs, plus the implied carbon price due to a carbon constraint (which is what tends to keep coal out of most future scenarios despite its abundance).

With renewable energy, the primary costs are infrastructure; the farther to the future we look, technological development will have a larger influence over cost than for conventional fossil fuel technologies.

It is perhaps interesting to note that the Tyndall ‘purple’ scenario yields a renewable electricity use rate about three times the ‘maximum’ economic potential cited in Barrett (2006). The reasons could be two-fold, bearing in mind that *technical* limits are much higher (often many times higher) than economic limits. Firstly, assumptions under the purple scenario may lead to cheaper technology, expanding its potential use. Secondly, production may be carried out uneconomically – arguably this is the case for much conventional energy historically in that more is being used than is economically efficient due to a lack of proper incorporation of external costs. Indeed, more photovoltaic energy is used in Europe than is economic due to subsidies, though there is a rationale of long-term benefit.

5 IMPACT ANALYSIS FOR SELECTED TECHNOLOGIES

This chapter focuses on 8 of the 15 technologies described in chapter 3, namely: coal, gas, oil, nuclear, wind, tidal, biomass and biofuel. More detailed information is provided on the characterisation of these key technologies in the UK, their current and expected future uptake, and their environmental impacts, including physical implications and biodiversity, geodiversity, landscape and access impacts.

The choice of the 8 key technologies was made on the basis of their degree of use and diffusion, their expected level of uptake in the next decades (taking into account the scenarios reviewed in Chapter 4) and their potential nature conservation impacts. In brief, the key technologies were selected for the following reasons.

- *Coal* and *gas* are currently the main fuels used for electricity production and are among the energy sources that most contribute to GHG emissions in the UK; they are expected to continue to play a significant role in the future – their relative weight depending on future energy demand and prices and the uptake of alternative energy sources – e.g RES and nuclear.

- *Oil* is responsible for a considerable amount of GHG emissions, affecting climate change. Although less relevant for electricity generation in the UK, oil is largely used for transport (almost 80 per cent of oil demand) and accounts for almost one third of energy consumption in the country. It is expected to continue playing a significant role in the future.

- *Nuclear energy* is the third main contributor to electricity production, after gas and coal. Since its combustion does not lead to GHG emissions, it can contribute to climate mitigation. Nevertheless, the process implies significant environmental risks, especially related to uranium mining and radioactive waste disposal. The future of nuclear energy in the UK is still uncertain, with some old plants getting closer to decommissioning and ongoing political discussions (e.g on the UK White Paper on Nuclear Power) on the possible development of new installations.

- *Wind* has recently overtaken hydro in its contribution to electricity production from RES, second only to biomass, and it is expected to have a great potential to contribute to the RES-e UK target and hence to climate mitigation. The number of turbines installed has been increasing exponentially in recent years and numerous wind farms are planned to be built in the relatively near future.

- *Tidal* has also been indicated as one of the renewable sources with a highest potential in the UK. A large tidal barrage project is being closely investigated in the Severn Estuary, and others are being explored elsewhere in the UK. Tidal has an interesting potential to help reduce GHG emission, but can lead to significant disturbance to the natural environment, similar to that caused by hydroelectric dams.

- *Biomass* and *biofuel*s represent the largest share of renewable energy sources used in the UK. Biomass currently accounts for about 1.5 per cent of electricity and 1 per cent of heat production in the UK, but its potential is far higher. The Renewable Energy Strategy suggests up to 30% of renewable energy could be supplied by biomass for electricity and heat alone. The contribution of biofuels, now providing 2.14 per cent of UK road fuel, is also expected to increase further, as the Renewable Transport Fuel Obligation sets a target of 5 per cent use by 2010, while controversial Commission proposals suggest a 10 per cent target for 2020. Very substantial land areas would be required develop these resources further, with significant environmental implications.

5.1 Coal

5.1.1 Characterisation of the technology in the UK

Coal production

Potential: In 2005, total UK coal production accounted for approximately 20 million tonnes, with 9.6 million tonnes from deep-mined production and opencast accounting for 10.4 million tonnes, while coal consumption was 68.15 million tons (US EIA 2006). This represented a decrease in deep-mined output of 24 per cent compared to 2004 figures, and 39 per cent lower than in 2003, mainly due to the closure of mines such as the Selby Complex, Betws and Ellington. In addition, opencast production was 13 per cent lower in 2005 compared to 2004, having declined steadily from a peak of around 16.7 million tonnes in 1997.

By 2006 production had fallen to 18.6 million tonnes and coal was imported mainly from Russia and South Africa. In 2007 total coal production further decreased to 17 million tons while imports addressed the shortfall, accounting for 43,4 million tons[52].

Some projections show UK coal production in 2020 at 13 million tonnes, with net imports at 35 million tonnes[53]. England, Wales and Scotland still have significant recoverable coal reserves. However, a number of factors affect the extent to which these reserves may be recovered, including the costs of recovery compared with the market value of the coal and potential environmental impacts (BERR 2007).

The coal produced in England and Scotland is almost entirely *bituminous coal* but producers in Wales describe their product as *anthracite*. In Northern Ireland there are large resources of lignite that have been evaluated for power generation but have not been explored.

Location: Past and current coal mining activities are quite widespread in the UK as the following map demonstrates.

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52 *BERR - Coal Industry in the UK http://www.berr.gov.uk/energy/sources/coal/industry/page13125.html*

53 A study commissioned by DTI in 2004 estimated the potential for UK coal production could be sustained within a band of 21-29 mt in 2010 and 15-21 mt in 2016 (MacDonald, 2004).

Figure 5.1Coal mining activities in the UK

Source.: *Coalfield mining overview, The Coal Authority*[54]

The Coal Authority issues licenses for exploration for and extraction of underground and opencast coal and the development of coal bed methane. At the end of 2005 there were 34 opencast sites in operation in the UK, of which 5 were in England, 21 in Scotland and 8 in Wales.

The following picture identifies opencast coal resources in February 2006. The red circles show the location of opencast coal sites; the pink shades identify former opencast working areas; and the grey shades show areas with coal at or near surface.

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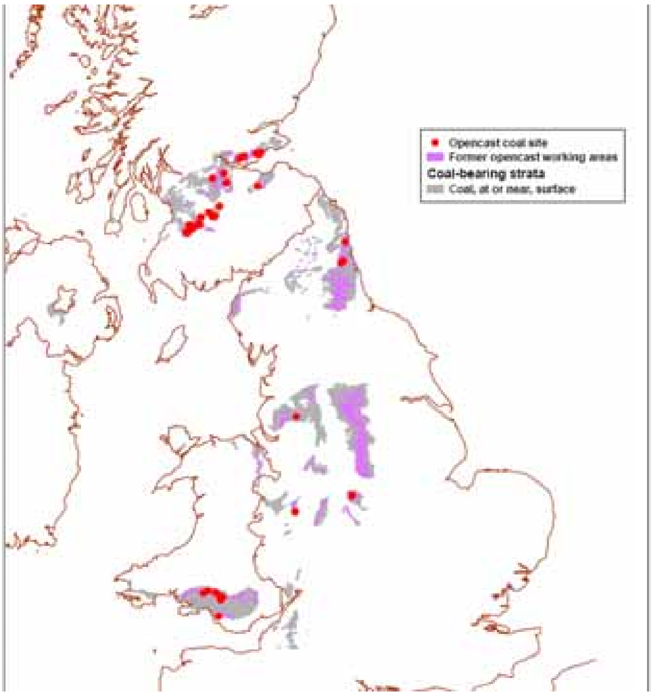
54 Coal Authority - Mining and Ground Stability Report Overview *http://www.coal.gov.uk/services/miningreports/mininggroundstabilityoverview/index.cfm*

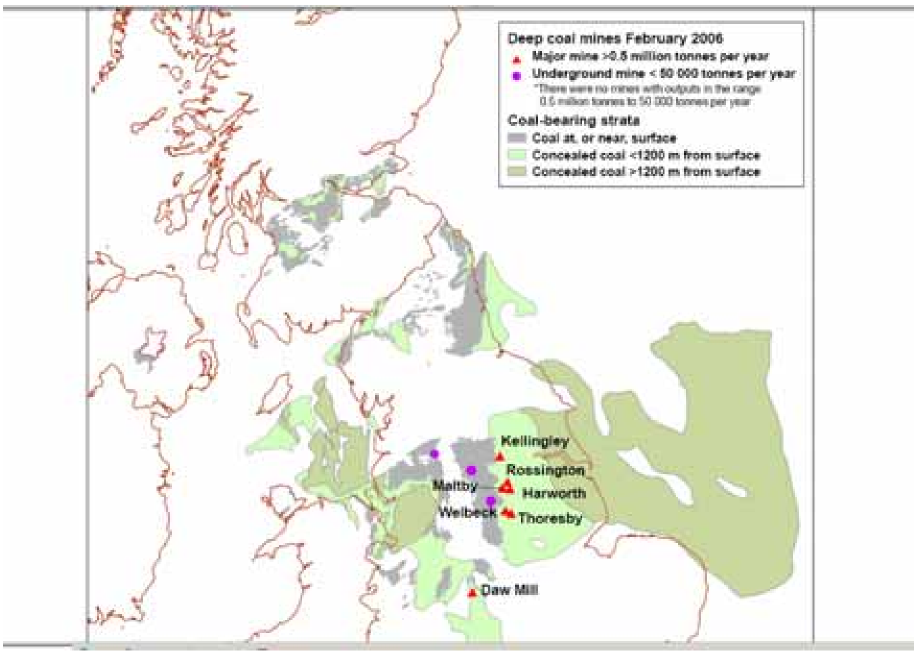
Figure 5.2 Map of opencast coal resources in the UK - 2006



Source.: *Location of opencast coal sites, Chapman et al. 2006*

The picture below shows the location of deep coal mines in February 2006. The red triangle identifies major mine producing more than 0.5 million tonnes per year, while the purple circle shows underground mines producing less than 50.000 tonnes per year.

Figure 5.3 Map of deep coal mines in the UK - 2006



Source.: *Location of deep mines, Chapman et al. 2006*

The opencast sites in production in the UK[55] as of 31 March 2008 are listed in Table 5.1 below.

Table 5.1 List of opencast sites in UK - 2008

Site Name	**Location**
Glenmuckloch	Dumfries and Galloway
Leigh Glenmuir Site	East Ayrshire
Skares Road	East Ayrshire
East Pit	Neath Port Talbot
Margam Opencast	Neath Port Talbot
Nant Helen	Powys
Selar	Neath Port Talbot
Dynant Fawr	Carmarthenshire
Nant-y-Mynydd	Neath Port Talbot
Delhi Site	Northumberland
Earlseat	Fife
Wilsontown	South Lanarkshire
Greenburn Project	East Ayrshire
Ffos-y-Fran Land Reclamation Scheme	Merthyr Tydfil
Chalmerston	East Ayrshire
Chapelhill	South Lanarkshire
Glentaggart	South Lanarkshire
Greenbank (St Ninians)	Fife
Thornton Wood (St Ninians)	Fife
House of Water	East Ayrshire
Powharnal	East Ayrshire
Shewington	Midlothian
Spireslack	East Ayrshire
Cutacre	Bolton
Long Moor	Leicestershire
Maiden's Hall Extension	Northumberland
Sharlston Colliery Reclamation	Wakefield
Steadsburn	Northumberland
Stobswood	Northumberland

Source: Opencast sites in production, The Coal Authority

In addition, there were six opencast mines under development[56]:

- Cwm Yr Onen Colliery Reclamation, in Carmarthenshire
- Temple Quarry, in Kirklees;
- Caughley Quarry, in Shropshire;
- Bwich Ffos, in Neath Port Talbot;

55 *ibidem*

56 *ibidem*

- Poniel, in South Lanarkshire; and
- Lodge House, in Derbyshire.

The major deep mines in production as of 31 March 2008 are listed in Table 5.2 below. In addition, according to the Coal Authority there were also two medium sized and eight small mines producing or developing[57]:

Table 5.2 List of deep coal mines in the UK - 2008

Site	Location
Maltby Colliery	Rotherham
Hatfield Colliery	Doncaster
Daw Mill Colliery	Warwickshire
Kellingley Colliery	North Yorkshire
Thoresby Colliery	Nottinghamshire
Welbeck Colliery	Nottinghamshire

Source: Major deep mines in production, The Coal Authority

Energy production from coal

Potential: No new coal-fired plant has been built in the UK since the 1970s, and much of the existing plants were able to operate for longer than their original intended life because of replacements and upgrades. However, operators have been submitting proposals for building new plants to replace those that are about to close. The new plants would have to meet more stringent environmental standards from the start and could also incorporate carbon dioxide capture and storage (CCS) technology in a later stage, as long as it is technically and economically feasible.

Location: The figure reported below identifies the coal power stations operating in the UK in January 2007 and their location. The figure shows that current capacity will be significantly reduced from 1 January 2008, as existing plants for which it is uneconomic to fit new abatement technology required by EU legislation[58] may operate until 2016, but may not operate for longer than 20,000 hours. It is estimated that 20 GW of existing coal-fired power station will comply with new EU emissions legislation (BERR 2007).

[57] *ibidem*

[58] *The EU Large Combustion Plant Directive restricts emissions of sulphur dioxide and nitrogen emissions from coal and oil plants.*

Figure 5.4 Existing UK coal power stations – opt-in and opt-out

Opt-out

Power station	**Owning company**	**Mwe**
Ironbridge	Eon	972
Kingsnorth	Eon	2000
Didcot	RWE NPower	1920
Tilbury	RWE NPower	1050
Cockenzie	Scottish Power	1200
Ferrybridge (2 units)	SSE	1000
Total Opt-out		**8142**

Opt-in

Power station	**Owning company**	**Mwe**	**Approach**
Kilroot	AES	520	ELV
Eggborough	British Energy	2000	NERP
Uskmouth	Carron Energy	393	ELV
Drax	Drax Power Limited	3960	NERP
Cottam	EdF Energy	1948	ELV
West Burton	EdF Energy	1924	ELV
Ratcliffe	Eon	2000	ELV
Rugeley	International Power	996	ELV
Aberthaw	RWE NPower	1386	ELV
Longannet	Scottish Power	2400	NERP
Ferrybridge (2 units)	SSE	1000	ELV
Fiddlers Ferry	SSE	2000	ELV
Total Opt-in		**20527**	

Location

Source: Based on IEA Clean Coal Centre, January 2007, http://www.berr.gov.uk/files/file39914.pdf

5.1.1 Environmental impacts

The environmental impacts arising from coal are well known and result from the following activities: coal mining; coal preparation; coal transportation; and finally coal combustion. Each stage of this process has specific effects, as described in the figure below.

We will focus here on mining and combustion, given the magnitude and specificity of their impacts.

Table 5.3 Coal environmental impacts – by operation

Operation	Potential environmental impact

Surface mining	• Land disturbance
	  o Acid mine drainage
	  o Silt production
	  o Solid waste
	  o Habitat disruption
	  o Aesthetic impacts
	• Health & safety

Underground mining	• Acid drainage • Land subsidence • Health & safety • Solid waste • Coal mine methane emissions
Processing	• Solid waste stockpiles • Wastewater • Health & safety
Transportation	• Land use • Accidents • Fuel utilisation

Conversion	• Land use
	• Air pollution
	  o Sulphur oxides
	  o Nitrogen oxides
	  o Particulates
	• Greenhouse gases
	  o Carbon dioxide
	• Solid waste
	• Thermal discharge
	• Aesthetics

Source: Based on Jain et al. (2002)

Carbon dioxide emissions and/or reduction potential: Carbon Dioxide is formed when fuels containing carbon are burnt, and is a significant greenhouse gas which contribute to climate change. In 2007, coal-fired power plants in the UK emitted 939 tonnes of carbon dioxide per GWh electricity supplied (BERR 2007). If the entire life-cycle of a plant is considered, emissions could amount up to 990 g CO2-e/kWh of electricity generated (Odeh et al 2008). On average, electricity generation releases 461.2 tonnes of carbon per GWh. This positions coal as the largest emitter of carbon dioxide per GWh electricity supplied. (BERR 2007)

A number of advanced combustion techniques already exist to reduce harmful emissions. They require less coal to run the steam turbines that generate electricity, producing fewer emissions and waste along the way. However, even the most advanced integrated gasification combined-cycle (IGCC) coal-firing power plants emit approximately twice as much CO_2 than similar natural gas combined-cycle (NGCC) plants. While new plant might in future be retrofitted with CCS equipment, for now they offer only limited GHG reductions relative to conventional plant.

Other pollutants/emissions: The use of coal in combustion - whether to generate electricity or heat, creates a number of environmental challenges. The primary environmental issues relating to the combustion of coal, beside CO_2, are (adapted from World Coal Institute 2005):

- *Particulate emissions*: such as ash from coal combustion. Particulates can impact local visibility and cause dust problems.
- *Trace elements*: Emissions from coal-fired power plant include mercury, selenium and arsenic which can be harmful to human health and the environment
- *NO_x*: Formed during the combustion process, they can contribute to smog, ground level ozone, acid rain and greenhouse gas emissions (see biodiversity section below). NO_x emissions from coal also decreased significantly in the past decades, from 0.78 Mt in 1990 to 0.36 Mt in 2006 – representing about 22 per cent of overall NO_x emissions.
- *SO_x*: Mainly sulphur dioxide, produced from the combustion of elemental sulphur present in many coals. Emissions can lead to acid rain and acidic aerosols (see biodiversity section below). The substitution of coal with other fuels (especially gas and nuclear) in power generation has contributed to the gradual decline of SO_2 emissions in the UK. Emissions from coal fired power plants decreased from 2.7 Mt SO_2 in 1990 to 0.41 Mt in 2006 (ie 61 per cent of the overall 2006 SO_2 emissions). Nevertheless, due to the presence of sulphur, nitrogen and inorganic matter, coal is at a disadvantage compared to natural gas, which contains virtually only carbon and hydrogen.
- *Waste from coal combustion*: Consists primarily of incombustible mineral matter that must be disposed of.

Other physical impacts – mining: Mines are a major cause of environmental degradation in parts of England and Wales, especially in South and West Wales, and Northern England. Coal mining – particularly surface mining – requires large areas of land to be temporarily disturbed. This raises a number of environmental challenges, including soil erosion, dust, noise and water pollution, and impacts on local biodiversity (see below).

As noted by UKRIGS Geoconservation Association (undated), the mineral industry has a long link with geodiversity. Exploration has increased our knowledge of geology while extraction has exposed many new and interesting features that would otherwise have remained hidden.

Further Coal extraction may affect geological sites or create new ones. The most significant impacts should be avoided or reduced through the planning system, which has a duty to ensure that geodiversity is maintained through careful planning, quarry operation and sympathetic restoration schemes (UKRIGS Geoconservation Association, undated). On the other hand, a new development may reveal previously unseen strata which have, thus, only been hypothesised and could be worthy of conservation for special features in the future (Ellis 2008).

There is potential for extended or new mineral operations to have negative implications for visual amenity and landscape character. The negative visual impacts are present mainly during strip mining and open cast mining, although this may be partly reduced through restoration plans. Landscape impacts can also result from quarry traffic.

The environmental impacts of mining can be classified in the following way (adapted from World Coal Institute, 2005 and Environmental Agency, 2007):

- *Land Disturbance:* covering impacts of mining on surface and ground water, soils, local land use, native vegetation and wildlife populations
- *Mine Subsidence:* related to underground coal mining, whereby the ground level lowers as a result of coal having been mined beneath.
- *Water Pollution:* acid mine drainage (AMD) is metal-rich water formed from the chemical reaction between water and rocks containing sulphur-bearing minerals. The runoff formed is usually acidic and frequently comes from areas where ore- or coal mining activities have exposed rocks containing pyrite, a sulphur-bearing mineral. AMD is formed when the pyrite reacts with air and water to form sulphuric acid and dissolved iron. This acid run-off dissolves heavy metals such as copper, lead and mercury into ground and surface water.
- *Dust & Noise Pollution:* mainly caused by trucks being driven on unsealed roads, coal crushing operations, drilling operations and wind blowing over areas disturbed by mining.

Biodiversity: The main UK biodiversity impacts from energy production from coal will be the result of habitat loss from mining operations (especially open cast), AMD impacts on aquatic systems (see above), acid deposition and nitrogen deposition (see Table 5.2 below). There may also be impacts from power stations, which are discussed with respect to nuclear power in Section 5.4 below.

Clearly surface mining will result in the total destruction of the vegetation and soils, leading to the effective loss of the habitat and its associated species. However, the impact of such losses on the overall status of UK habitats and species will be highly dependent on the scale of mining and especially its location. It has not been feasible within this study to map the location of possible future mines and from this to ascertain probable habitat impacts. However, it is likely that most new open cast mines would be located on farmland or rough grassland. Mines are unlikely to affect the uplands and it is assumed that mining would be avoided or carried out with deep mines in areas with particularly valuable habitats (eg ancient forests).

The impacts of mining on many habitats may be reduced in the long-term through habitat restoration (eg on spoil heaps) and creation measures, which have been well developed and tried and tested in the UK (Bradshaw & Chadwick 1980; Perrow & Davy 2008a, b; White & Gilbert 2003). Opencast sites and depressions created by subsidence may also be used to create various wetlands of high biodiversity conservation value. Furthermore, without restoration the unusual and harsh environmental conditions on mining spoil and coal ash (eg resulting from high pH, toxic metals and free-drainage) can lead to the creation of some unusual habitats that can develop high ecological values, especially for some rare plants and invertebrates (Bradshaw 1999; Gilbert 1991; Kendle & Forbes 1997; Sukopp & Hejny 1990; Tucker et al. 2005). However, the creation of large areas of such habitats would probably not be desirable.

As mentioned above, many watercourses in mining areas are affected by AMD. Once in the watercourse its ecology is affected both by the direct toxic effects of metals and by the smothering effect of the deposition of metal hydroxides on the river bed. This can have wide-ranging impacts on the aquatic community depending on the concentration of pollutants and the aquatic habitats affected.

In the past the burning of coal (for power, industry and residential heating) was a major contributor to acid deposition in the UK and continental Europe. Acid deposition can result in acidification impacts on soils, freshwater ecosystems and vegetation through direct toxicity, changes in nutrient availability and other chemical processes (Erisman & Draaijers 1995). Particularly widespread impacts have been observed in rivers in the UK. For example, in Wales alone some 12,000 km out of 20,000 km assessed were found to be affected by acidification with impacts on various primary producers, invertebrates, fish and birds (Rimes et al. 1994; Stevens et al. 1997).

Emissions of NO_x can also significantly impact ecosystems in various ways (Langan 1999; Lee & Caporn 1998). Nitrogen oxides and ozone, a secondary pollutant formed from oxides of nitrogen and volatile organic compounds, are directly toxic to plants. However, indirect effects through acidification and eutrophication (*ie* nutrient enrichment) are the most significant impacts. Nitrogen deposition is known to reduce terrestrial species richness in communities such as heathlands (Carroll et al. 1999; Heil & Diemont 1983) and acid grasslands (Stevens et al. 2004). From their study of species-rich grasslands in the UK, Stevens et al concluded that at a nitrogen deposition rate of 17 kg Nha^{-1} $year^{-1}$, which is typical for the UK and central Europe, there is a 23% species reduction compared with grasslands receiving the lowest levels of nitrogen deposition.

Hotspots of NOx deposition, and hence eutrophication, can occur close to areas with high emissions, such as roads. However, the residence time for oxidised forms of nitrogen in the atmosphere is relatively long-lived. Therefore NOx emissions tend to travel a long-distance before they are deposited, with a mean distance of about 1,000 km (NEGTAP 2001). Travel distances are also likely to be much greater for emissions from tall power station chimneys than from vehicles. Consequently, according to NEGTAP about 85% of NOx emissions are exported from the UK. Thus most eutrophication impacts from coal use in the UK will be outside the UK.

The substantial switch from coal to gas use in the UK (see above) and technological measures to reduce air pollution has greatly contributed to reduced atmospheric concentrations of sulphur dioxide and oxides of nitrogen in the UK over recent decades (NEGTAP 2001). As a result the acidity of rainfall more than halved over large areas of the UK between 1985 and 1999 and deposition of sulphur and oxidised nitrogen in the UK declined since their peak in emissions by 50 per cent for sulphur and 16 per cent for oxidised nitrogen.

Despite this, detailed monitoring, research and modelling indicates that air pollution from sulphur, nitrogen and ozone remains a widespread problem over much of the UK. Critical loads have been identified for pollutants (ie thresholds below which, according to current knowledge, there will be no harmful effects on an ecosystem) and pollutant deposition levels mapped in relation to these. These comparisons indicate that critical loads for acidification were exceeded in 71 per cent of UK ecosystems in 1999 (NEGTAP 2001).

NEGTAP also report that critical loads for eutrophication by nitrogen deposition (in 1995-97) were exceeded in c. 25 per cent of UK 1 km squares with sensitive grasslands and c. 55 per cent with heathland. Virtually all woodlands will be subject to pollution above critical loads as woodland is an efficient interceptor of airborne pollutants. The likely impacts are particularly great on Sites of Special Scientific Interest (SSSIs) as these tend to be sensitive habitats. Estimates for 1995-97 suggest that 72 per cent of terrestrial SSSI land was at risk of exceeding acidification limits, and about 92 per cent was at risk of exceeding the limits of nitrogen enrichment (English Nature 2003).

However, careful interpretation of critical load predictions is required. Exceedance of critical loads only indicates that there is a risk to the ecosystem, it does not indicate that impacts have occurred or will occur. Nevertheless, evidence from national vegetation and plant species mapping indicates that there has been a widespread detectable shift in vegetation types towards those of nutrient enriched conditions (Haines-Young et al. 2000; Preston et al. 2002). Furthermore, the UK has recently completed an analysis of critical loads on Habitats Directive Annex I habitats as part of its Article 17 Conservation status report. This revealed that 33 out of 51 assessed Annex I habitats are probably threatened by acid deposition and nutrient nitrogen deposition.

The UK's main policies and measures for achieving air quality improvements and EU obligations are set out in the Air Quality Strategy for England, Scotland, Wales and Northern Ireland[59]. The 2007 Strategy predicts that the UK will meet its targets under the EU National Emissions Ceilings Directive[60] with regards to three of the four pollutants responsible for biodiversity impacts namely SO_x, ammonia (NH_3) and non-methane volatile organic compounds. It is not expected to meet its obligations for NOx. Thus, a large increase in coal use in the UK could hamper efforts to meet EU emission obligations. However, the effect on habitats in the UK would be relatively limited because most NOx deposition is outside the UK, and transport emissions are now much more significant.

Table 5.4 Biodiversity impacts of energy production from coal

Selected technology	Coal
Direct mortality	Some losses from machinery, eg of ground-nesting birds in open cast mines and spoil areas.
Direct habitat loss	Extensive habitat areas can be lost for open-cast coal extraction and spoil heaps. Contributor to the requirement for port developments.
Disturbance	Substantial disturbance on operational mines.
Indirect habitat degradation	AMD and silt impacts on aquatic habitats. Hydrological disruption of surrounding habitats from drainage operations and possible subsidence. Combustion contributes to acidification from SO_2 emissions and deposition and eutrophication from NO_x.
Secondary impacts	Activities associated with port development.
Potential for mitigation	High. Future additional SO_2 and NO_x emissions assumed to be low due to new regulations and increasing use of clean-coal technology
Potential for ecological compensation	Variable, depending on habitat type involved, but farmland and rough grassland habitats can be compensated for. Some post-mining habitats are of high ecological value.
Impacts outside the UK	Airborne disposition of NO_x (mainly in NW Europe), leading to habitat eutrophication. Mining and transport impacts.

The vulnerability assessment carried out in this study indicates that most of the current impacts of coal are likely to be low with respect to Priority Habitats and Priority Species (Tables 5.5 and 5.6). This is primarily because the main impacts of energy production from coal result from habitat loss from open cast mining. Presently, such mines cover a

59 http://ec.europa.eu/environment/air/nationalprogr_dir200181.htm

60 *Directive 2001/81/EC of the European Parliament and of the Council of 23 October 2001 on national emission ceilings for certain atmospheric pollutants*

very small proportion of all Priority Habitats and the habitats of most Priority bird species. Thus although most Priority Habitats and bird habitats are destroyed (ie reflected as a sensitivity index of 100%) the overall exposure of Priority habitats and Priority Bird species to coal developments is very low. Although accurate figures are not available, it estimated that exposure levels will typically be well below 0.01% of each habitat. Furthermore, some bird habitats can be adequately restored or compensated for, and therefore the adaptive capacity of some species may reduce the immediate impacts of habitat loss.

Some habitats and species may be subject to wider indirect impacts, eg as a result of pollution from acid mine drainage, siltation, SO_2 and NO_x emissions. However, although such impacts will go beyond the mine footprints, exposure rates from water pollution are likely to be very low. Similarly, sensitivity and exposure levels to significant acidification and nitrogen deposition impacts are likely to be low now as a result of the technological developments, the recent decline in coal use and the tendency for most NO_x deposition to occur outside the UK (see above). Nevertheless, it is anticipated that some Priority Habitats, especially in the uplands will be subject to moderate impacts from nitrogen deposition. It is assumed that these habitat impacts would not lead to significant impacts on Priority bird species, but this is not certain.

Energy production from coal is unlikely to provide any significant benefits for Priority Habitats or Priority Species, either now or in the future. One Priority Habitat, “Open Mosaic Habitats on Previously Developed Land” may be created by new coal workings. However, it is equally likely that new workings will utilise remaining areas of industrial land and thus as much of this habitat may be destroyed as created. Therefore the overall impacts of coal mining on this habitat is considered to be neutral in terms of this broad assessment. Nevertheless, in some situations coal workings could be lead to opportunities for the creation of some valuable habitats if appropriately planned, carefully implemented and afforded long-term management.

Three of the energy scenarios considered in this study project reduced use of coal in future, with a complete abandonment of coal use by 2050 in the Tyndall Purple scenario. Thus the already low biodiversity impacts from coal would be expected to decline in accordance with these changes and be avoided altogether in the latter situation. However, it should be pointed out that the scenarios relate to coal use, and UK coal production may not track consumption levels as a result of other drivers, eg coal prices in the UK and elsewhere, energy security and other political considerations.

The other three scenarios project increases in coal use. However, even the largest projected increase of 96 per cent is relatively modest compared to some other technologies (eg biomass and wind) and is insufficient to make any substantial differences to the vulnerability indices across the Priority Habitats and Priority Species.

Table 5.5 The estimated vulnerability of UKBAP Priority habitats to energy production using coal under current conditions and the future energy scenarios for 2020 and 2050

Notes: Impacts are based on likely residual impacts assuming basic mitigation measures are implemented effectively. See Section 2.3 for details of the analytical methods and Section 4.2 for the derivation of the energy scenarios. See Appendix 2 for vulnerability assessments for each habitat type.

		UK Government White Paper scenarios				Tyndall scenarios	
	Baseline	Central	Constrained	Central	Constrained	Red	Purple
	2008	2020	2020	2050	2050	2050	2050
% change in scenarios		-14.2%	-26.5%	96.1%	36.3%	57.6%	-100.0%
Average score	0.152%	0.131%	0.112%	0.298%	0.207%	0.240%	0.000%
Detrimental Impacts							
Critical (100%)	0	0	0	0	0	0	0
High (>10-100%)	0	0	0	0	0	0	0
Moderate (1-10%)	9	0	0	9	9	9	0
Low (0.1-1.0%)	3	10	10	3	3	3	0
Very low (0.01-0.1%)	28	30	30	28	28	28	0
No impact	25	25	25	25	25	25	65
Beneficial impacts							
High (>-10%)	0	0	0	0	0	0	0
Moderate (-1 to -10%)	0	0	0	0	0	0	0
Low (-0.1 to -1.0%)	0	0	0	0	0	0	0
Very low (-0.01 to -0.1%)	0	0	0	0	0	0	0

Table 5.6 The estimated vulnerability of UKBAP Priority birds to energy production using coal under current conditions and the future energy scenarios for 2020 and 2050

Notes: Impacts are based on likely residual impacts assuming basic mitigation measures are implemented effectively. See Section 2.3 for details of the analytical methods and Section 4.2 for the derivation of the energy scenarios. See Appendix 3 for vulnerability assessments for each species.

		UK Government White Paper scenarios				Tyndall scenarios	
	Baseline	Central	Constrained	Central	Constrained	Red	Purple
	2008	2020	2020	2050	2050	2050	2050
% change in scenarios	-	-14.2%	-26.5%	96.1%	36.3%	57.6%	-100.0%
Average score	0.011%	0.010%	0.008%	0.022%	0.016%	0.018%	0.000%
Detrimental Impacts							
Critical (100%)	0	0	0	0	0	0	0
High (>10-100%)	0	0	0	0	0	0	0
Moderate (1-10%)	0	0	0	0	0	0	0
Low (0.1-1.0%)	2	1	1	2	2	2	0
Very low (0.01-0.1%)	33	34	34	33	33	33	0
No impact	24	24	24	24	24	24	59
Beneficial impacts							
High (>-10%)	0	0	0	0	0	0	0
Moderate (-1 to -10%)	0	0	0	0	0	0	0
Low (-0.1 to -1.0%)	0	0	0	0	0	0	0
Very low (-0.01 to -0.1%)	0	0	0	0	0	0	0

5.2 Gas

5.2.1 Characterisation of the technology in the UK

Potential: The OGJ[61] estimates that the UK proven natural gas reserves accounted for 18.8 trillion cubic feet (Tcf) in 2006, a 10 per cent decline from the previous year.

The percentage of total energy consumption sourced from natural gas in the UK has increased from 20 per cent in 1980 to 34 per cent in 2003 as a result of several measures put forward by the UK government to encourage the use of natural gas, including its substitution for coal and oil in industrial consumption and electricity production. It is also widely used for domestic heating. Natural gas consumption in the UK reached 3.4 Tcf in 2003 (about 78.4 Mtoe), while the country produced 3.6 Tcf (about 83 MToe) of natural gas in the same year[62]. In 2004, the UK was a net importer of natural gas for the first time since 1996 (US EIA 2006) and the country was the sixth-largest producer of natural gas in the world in 2006 (US EIA 2007). Then in 2007 the UK saw production fall 9.9 per cent. It was the world's largest decline in volume for a second consecutive year.[63]

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61 *Oil & Gas Journal, www.ogj.com*

62 Conversion factors based on http://www.worldenergy.org/publications/survey_of_energy_resources_2007/625.asp

63 *Global LNG Info, 2007, http://www.globallnginfo.com/develop2007.htm*

In 2007 there were approximately 28 gas, gas/oil, gas/CHP or gas/oil/CHP fuelled power stations and 28 combined cycle gas turbine (CCGT) or CCGT/oil/gas plants in the UK (BERR 2007).

Location: Most of the UK gas reserves are located in three distinct areas: 1) associated fields in the UKCS; 2) non-associated fields in the Southern Gas Basin, located adjacent to the Dutch sector of the North Sea; and 3) non-associated fields in the Irish Sea.

The largest concentration of natural gas production in the UK is the Shearwater-Elgin area of the Southern Gas Basin of the North Sea. The area contains five gas fields, Elgin (Total), Franklin (Total), Halley (Talisman), Scoter (Shell), and Shearwater (Shell), producing a combined 1.2 Tcf in 2005, according to IHS Energy (US EIA 2007). Although the United Kingdom was the largest producer in the North Sea in 2007, the region is seen as a mature one in regards to natural gas.

Pipelines: There are seven locations of offshore pipeline gas terminal facilities in the UK and three additional interconnector sites, as shown in Table 5.6 below.

Investments to increase import capacity in winter 2006/07 included the extension of the Interconnector pipeline between Bacton, England and Zeebrugge, Belgium, the construction of the Langeled pipeline from Norway and the BBL Interconnector from the Netherlands, all of which became operational in the latter part of 2006, as well as the Teeside Gas Port project providing additional LNG import capacity, which started operation in February 2007.

Liquefied Natural Gas (LNG): The UK accounted for a single LNG import terminal in 2006, the NGT's Grain LNG terminal on the Isle of Grain. The facility was built with a sendout capacity of 420 Bcf/d, which NGT plans to expand. Algeria's Sonatrach and BP are the principal importers using the terminal.

However, ExxonMobil and Qatar Petroleum have received regulatory approval for the construction of the South Hook LNG receiving terminal in Milton Haven, Wales. The terminal will receive its LNG from the Qatargas II liquefaction project in Ras Laffin, Qatar, which is also a joint project between the two companies. The South Hook LNG project scheduled for 2007, with an initial capacity of 1.0 billion cubic feet per day (Bcf/d) was delayed until 2008. Finally, BG has collaborated with Netherlands-based Petroplus and Malaysia-based Petronas to also build an LNG receiving terminal in Milton Haven, on the site of an existing natural gas storage facility owned by Petroplus. The project should start receiving cargos by the end of 2008 at an initial sendout capacity of 580 Million Cubic Feet per Day (Mmcf/d).

Table 5.7 Offshore pipeline gas terminal facilities in the UK

Terminal	Operator	Pipelines (from)	Details
St Fergus	Exxon Mobil Shell Total Chevron/Conoco Phillips	SAGE - Scottish Area Gas Evacuation (Beryl, Brae, Scott), Britannia, Atlantic & Cromarty FLAGS - Far North Liquids and Gas System (Brent Cormorant Tern etc) Fulmar (Fulmar Clyde Nelson) Goldeneye UK Frigg (Otter, Alwyn, Bruce & Dunbar), Vesterled (Norwegian Frigg & Heimdal), Miller Brittannia line	320km, 30-inch 450km, 36-inch 289km, 20-inch 110km, 20-inch 362km, 32-inch
Teesside	BP CATS Enron	CATS - Central Area Transmission System (Armada, Everest, Lomond, ETAP) CATS	400km, 36-inch
Dimlington/Easlington	BP	Village, West Sole, Amethyst Ormen Lange interconnector	1,200km (2007 completion)
Teddlethorpe	ConocoPhillips	Viking Transport System, LOGGS, CMS	
Bacton	Shell Gasunie Interconnector (UK) Ltd Tulow Oil Perenco	SEAL - Shearwater-Elgin Line (Leman, Brigantine etc) Balgzand (NL) interconnector Zeebrugge (BE) interconnector Hewett, Thames, LAPS	467km, 34-inch 235km (2006 completion) can flow in either direction
Point of Ayr	BHP Petroleum	Liverpool Bay	
Barrow	Hydrocarbon Resources Ltd / Centrica Hydrocarbon Resources Ltd / Burlington	Morecambe North & South Rivers	
Brigghouse Bay	BGE	Loughshinny (IRL) interconnector	
Beattock	BGE	Gormanston(IRL) interconnector	
South west Scotland	Phoenix Natural Gas	Northern Ireland interconnector	

Source.: Based on UK gas pipelines (ENTEC 2006) http://www.berr.gov.uk/files/file28601.pdf

5.2.2 *Environmental impacts*

Greenhouse Gas Emissions: Natural gas combustion produces less carbon dioxide than either coal or petroleum products. In 2007, gas power plants emitted 405 tonnes of carbon dioxide per GWh electricity supplied. This was a decrease from 415 in 2006. (BERR 2008b).

Carbon dioxide is likely to be released in gas terminals, as pressure relief, depressuring and vent systems will be routed to the flare. All terminals are actually likely to have flares for handling excess and unwanted gas and to cater for process upsets. In addition, carbon dioxide is emitted at fuel gas combustion.

Other emissions and physical impacts: Gas-fired electrical generating units produce little SO_2. In 2006 gaseous fuels were estimated to have generated about 0.014 Mt of SO_2 (ie 2 per cent of overall UK SO_2 emissions)[64] and 0.29 Mt of NO_x (ie 18 per cent of NO_x emissions)[65].

Table 5.8 below summarizes the environmental impacts arising from natural gas activities at each stage of the production process:

Table 5.8 Gas environmental impacts – by operation

Operation	Potential environmental impact
Extraction	• Land use (drilling) • Brine disposal
Transportation	• Land use (pipelines) • Leakage (methane emissions)
Processing	• Air pollution (minor)
Conversion	• Land use • Air pollution (relatively minor) o Carbon monoxide o Nitrogen oxides • Greenhouse gases o Carbon dioxide o Methane • Thermal discharge • Aesthetics

Source: Based on Jain et al. (2002).

Atmospheric emissions take place at all stages of gas and oil industry's activities. The main sources of these emissions include:

- constant or periodical burning of associated gas and excessive amounts of hydrocarbons during well testing and development as well as continuous flaring to eliminate gas from the storage tanks and pressure-controlling systems;

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64 *DEFRA, e-Digest Statistics about: Air Quality Emissions of Sulphur dioxide: 1970-2006* *http://www.defra.gov.uk/environment/statistics/airqual/download/xls/aqtb08.xls*

65 *DEFRA, e-Digest Statistics about: Air Quality Emissions of Nitrogen oxide: 1970-2006* *http://www.defra.gov.uk/environment/statistics/airqual/download/xls/aqtb06.xls*

- combustion of gaseous and liquid fuel in the energetic units (diesel-powered generators and pumps, gas turbines, internal combustion engines) on the platforms, ships, and onshore facilities; and
- evaporation or venting of hydrocarbons during different operations of their production, treatment, transportation, and storage.

Offshore drilling: Potential environmental issues associated with offshore gas and oil development projects include: air emissions, wastewater discharges, solid and liquid waste management, noise generation and spills. These are presented in more detail below:

- According to some estimates (Kingston 1991), up to 30 per cent of the hydrocarbons emitted into the atmosphere during well testing precipitate onto the sea surface and create distinctive and relatively unstable slicks around the offshore installations.
- The discharges of produced waters considerably dominate over other wastes. Produced waters include formation water, brine, injection water, and other technological waters. All of these waters are usually polluted by oil, natural low-molecular-weight hydrocarbons, inorganic salts, and technological chemicals, and are one of the main source of pollution of offshore oil (and gas) production. Depending on its quality, the produced water is either discharged into the sea or injected into the disposal well. Sometimes the oil-water mixtures are transported along the pipelines to onshore separation units.
- The volume of drilling wastes usually ranges from 1,000 to 5,000 m^3 for each well – that can range in number from dozens for one production platform to many hundreds for a large field.
- Large quantities of produced waters, drilling muds, and drilling cuttings, discussed above, as well as discharges of storage displacement and ballast waters are the source of regular and long-term impacts of the offshore industry on the marine environment. All kinds of drilling are associated with drilling wastes, including drilling muds (which include lubricants having a hydrocarbon base) and cuttings. The discharges of spent drilling muds and cuttings coated by these muds contain considerable amounts of relatively stable and toxic hydrocarbon compounds and a wide spectrum of many other substances. The produced sand coated by oil has a regular and long-term impact on the marine environment
- All stages and operations of offshore hydrocarbon production are accompanied by undesirable discharges of liquid, solid, and gaseous wastes.
- Natural gas infrastructure can affect geological sites or create new sites.

Decommissioning, abandonment and removal of the offshore installations (based on Stanislav Patin): In some cases, especially when structures are very large and/or in located in deep water, the offshore installations are partially or entirely left on the sea bottom, causing physical interference with fishing activities for many decades after the oil and gas operators leave the site.

In shallow waters instead complete or partial removal of steel or concrete fixed platforms is possible, but usually requires the use of explosive materials, leading to short-term - impacts on the marine environment and biota (see below).

Biodiversity: Impacts are most likely to arise from habitat loss as a result of the laying of terrestrial and marine gas pipelines (see Table 5.4), and although it has not been possible to quantify the area affected, the proportions of habitats affected are clearly extremely low. Moreover, with appropriate routing to avoid sensitive sites most impacts will be on habitats of relatively low ecological value that can be restored or compensated for. Thus such impacts are unlikely to have any significant effect on the overall status of habitats and species, unless pipelines are poorly sited and affect rare or localised biodiversity features.

There may also be some local impacts from power stations, which are discussed with respect to nuclear power in Section 5.4 below.

Drilling rigs may contribute to impacts on some marine habitats and species as a result of the disturbance of benthic habitats and pollution, but there is little evidence that these have any population level impacts.

Noise and explosions associated with oil and gas exploration, extraction and decommissioning may have more significant and widespread impacts on some marine species, especially cetaceans. Noise from gas and oil drilling and production rigs, is likely to cause significant disturbance to marine mammals (Boesch & Rabalais 1987). Furthermore, there is particular concern over the disturbance and possible injury or death of marine mammals as a result of underwater explosions for seismic surveys for oil and gas (eg McCauley *et al*. 2000). A number of studies have shown that cetaceans may avoid or leave an area because of noise (Richardson & Wursing 1995; Simmonds *et al*. 2003). Stress in marine mammals due to noise may also cause the disruption of normal activities, such as resting, feeding and social interactions (Fair & Becker 2000).

Evidence that noise can be a direct cause of injury or death of marine mammals is less clear. Nevertheless, it is known that noise can cause temporary or permanent reduction of the auditory senses (Fair & Becker 2000). Some studies also suggest that anthropogenic noise may increase the bycatch of cetaceans, collision with vessels and mass strandings, probably as a result of auditory damage or disruption of important acoustic signals (Perry 1999).

As a result of concerns over the possible effects of seismic surveys on cetaceans measures have been taken to reduce potential impacts. According to the UK BAP for baleen whales,[66] preliminary cetacean surveys and impact assessments are now required before licenses are awarded for oil and gas exploration. Guidelines to minimize the effects of acoustic disturbance from seismic surveys were also agreed with the oil and gas industry in 1995 and revised in April 1998. Application of the Guidelines is required in blocks awarded to operators under the 16th and 17th Offshore Licensing Rounds. However, member companies of the UK Offshore Operators Association (UKOOA) have indicated that they will comply with these Guidelines in all areas of the UK Continental Shelf and, in some cases, elsewhere. Under the guidelines visual and acoustic surveys of areas affected by seismic testing are required to determine if cetaceans are in the vicinity. Testing must also involve a slow and progressive build-up of sound to enable animals to move away from the source. It is therefore likely that the potentially most damaging impacts of seismic surveys on cetaceans are avoided through such measures. However, much more research on the effects of marine noise is required, especially regarding the impacts of lower level but common place noises on cetacean behavior etc.

There is good evidence that explosions for demolition and other purposes can kill substantial numbers of fish. It is difficult to estimate the possible mortality of marine organisms, especially fish, given the high heterogeneity of fish distribution. Nevertheless,

[66] *http://www.ukbap.org.uk/UKPlans.aspx?ID=753*

one study calculated that with a 2.5-ton (TNT equivalent) charge the mass of killed fish can amount to 20 tons during each explosion (Patin 1999). Much more hazardous for the fish stock are explosive impacts on fish larvae and juveniles. The threshold of lethal impacts for the younger organisms weighing up to several grams is tens of times lower than that for adult specimens (Yelverton *et al*. 1975; Side 1992).

The overall results of the vulnerability analysis are summarised in Tables 5.10 and 5.11 for Priority Habitats and Priority Birds, and indicate that with proper implementation of appropriate mitigation measures overall biodiversity impacts from energy production from gas are likely to be very low. Furthermore, all of the energy scenarios considered in this study project a reduction in gas use, and therefore further reductions in associated impacts are expected.

Table 5.9 Biodiversity impacts of energy production from gas

Selected technology	Gas
Direct mortality	Low level mortality from attraction to gas flares and collisions with rigs. Fish and cetaceans may be killed by underwater explosions for demolition and seismic surveys. Pollutants from drilling muds and water may be toxic to some species.
Direct habitat loss	Some marine and terrestrial habitat loss from distribution pipes, but normally insignificant, esp if terrestrial pipes are buried. Port developments.
Disturbance	Some disturbance related habitat loss during pipeline construction. Disturbance at sea from work on rigs, demolition and seismic surveys. Low level disturbance at refineries, storage and ports.
Indirect habitat degradation	Pollution impacts from rigs (drilling muds and water, and wastes) on marine ecosystems
Secondary impacts	Activities associated with port development.
Potential for mitigation	High. Most habitats can be restored following pipeline construction, most sensitive habitats can be avoided.
Potential for ecological compensation	Impractical for marine habitats. High for pipeline impacts on most terrestrial habitats (if fragile habitats and that require long-time scales for restoration are avoided).
Impacts outside the UK	Offshore impacts similar to UK, and greater terrestrial drilling impacts in some countries.

Table 5.10 The estimated vulnerability of UKBAP Priority Habitats to energy production by gas under current conditions and the future energy scenarios for 2020 and 2050

Notes: Impacts are based on likely residual impacts assuming basic mitigation measures are implemented effectively. See Section 2.3 for details of the analytical methods and Section 4.2 for the derivation of the energy scenarios. See Appendix 2 for vulnerability assessments for each habitat type.

		UK Government White Paper scenarios				Tyndall scenarios	
	Baseline	Central	Constrained	Central	Constrained	Red	Purple
	2008	2020	2020	2050	2050	2050	2050
% change in scenarios	-	-13.2%	-5.5%	-25.5%	-43.3%	-91.1%	-87.9%
Average score	0.006%	0.006%	0.007%	0.005%	0.004%	0.001%	0.001%
Detrimental Impacts							
Critical (100%)	0	0	0	0	0	0	0
High (>10-100%)	0	0	0	0	0	0	0
Moderate (1-10%)	0	0	0	0	0	0	0
Low (0.1-1.0%)	2	0	2	0	0	0	0
Very low (0.01-0.1%)	27	36	34	36	36	36	36
No impact	36	29	29	29	29	29	29
Beneficial impacts							
High (>-10%)	0	0	0	0	0	0	0
Moderate (-1 to -10%)	0	0	0	0	0	0	0
Low (-0.1 to -1.0%)	0	0	0	0	0	0	0
Very low (-0.01 to -0.1%)	0	0	0	0	0	0	0

Table 5.11 The estimated vulnerability of UKBAP Priority birds to energy production using gas under current conditions and the future energy scenarios for 2020 and 2050

Notes: Impacts are based on likely residual impacts assuming basic mitigation measures are implemented effectively. See Section 2.3 for details of the analytical methods and Section 4.2 for the derivation of the energy scenarios. See Appendix 2 for vulnerability assessments for each species.

		UK Government White Paper scenarios				Tyndall scenarios	
	Baseline	Central	Constrained	Central	Constrained	Red	Purple
	2008	2020	2020	2050	2050	2050	2050
% change in scenarios		-13.2%	-5.5%	-25.5%	-43.3%	-91.1%	-87.9%
Average score	0.003%	0.003%	0.003%	0.003%	0.002%	0.000%	0.000%
Detrimental Impacts							
Critical (100%)	0	0	0	0	0	0	0
High (>10-100%)	0	0	0	0	0	0	0
Moderate (1-10%)	0	0	0	0	0	0	0
Low (0.1-1.0%)	0	0	0	0	0	0	0
Very low (0.01-0.1%)	41	41	41	41	41	41	41
No impact	18	18	18	18	18	18	18
Beneficial impacts							
High (>-10%)	0	0	0	0	0	0	0
Moderate (-1 to -10%)	0	0	0	0	0	0	0
Low (-0.1 to -1.0%)	0	0	0	0	0	0	0
Very low (-0.01 to -0.1%)	0	0	0	0	0	0	0

5.3 Oil

5.3.1 Characterisation of the technology in the UK

Potential: According to the OGJ, the UK had 4.0 billion barrels of proven crude oil reserves in 2006, the most of any EU member country. The country recovered 2.8 million boe per day in 2007[67].

Most of the UK crude oil grades are generally attractive to foreign buyers, and the UK has been a net exporter of crude oil since 1981. However, the importance of oil to the UK economy has declined slightly over the past two decades, with oil's contribution to total energy consumption falling from 37 per cent in 1983 to 35 per cent in 2003 (Figure 5.5). Production is forecast to drop slightly in 2008 as several large projects reach full production. On current trends, production decline is expected to average 5 per cent over the next five years[68]. Reasons for this decline include i) the overall maturity of the country's oil fields; ii) the application of new crude oil extraction technologies that lead to

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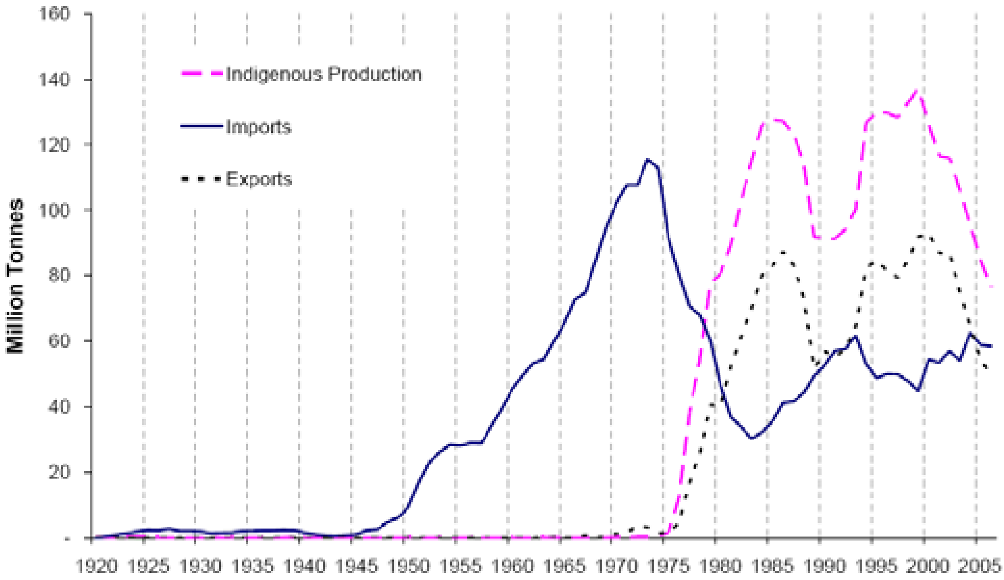
67 *Alexander's Gas & Oil Connections, Report underscores maximizing recovery of UK's oil and gas,* [*http://www.gasandoil.com/goc/frame_nte_news.htm*](http://www.gasandoil.com/goc/frame_nte_news.htm)

68 *ibidem*

fields being exhausted at a quicker rate; and iii) increasing costs as production shifts to more remote and inhospitable regions (US EIA 2006).

Figure 5.5 Crude oil production, imports and exports, 1920 - 2006



Source: BERR (2007b)

Location: The largest part of the country's oil reserves is in the UK Continental Shelf (UKCS), located in the North Sea off the eastern coast of the UK. There are also sizable reserves in the North Sea north of the Shetland Islands, with smaller amounts in the North Atlantic. Besides these offshore assets, the UK also has the Wytch Farm field, the largest onshore oil field in Europe.

Land coverage: There is an extensive network of submarine pipelines in the UK to carry oil extracted from North Sea platforms to coastal terminals in Scotland and northern England, as described in the table below:

Table 5.12 Oil pipelines in the UK

Operator	From	To	Details
BP	Forties fields	Cruden Bay Terminal, Scotland	177km, 36-inch
BP	Cruden Bay	Kinneil refinery Grangemouth	
BP	Ninian system	Sullom Voe terminal, Shetland Islands	177km 36-inch
Total	Bruce & Forties fields	Cruden Bay	240km, 24-inch
Total	Piper system	Flotta terminal, Orkney Islands	210km, 30-inch
Shell, Esso	Cormorant field	Sullom Voe	150km, 36-inch
Talisman Energy	Beatrice field	Nigg Bay terminal	60km, 16-inch

Source.: Based on UK oil pipelines (ENTEC 2006)

There are also numerous, small pipelines that connect each North Sea oil platform to these major backbones. In addition, the UK has developed a sophisticated network of underground pipelines to transport the petrol and diesel products from the refineries on the coast, to local distribution terminals.

The UK also has a few onshore crude oil pipelines:

- Wytch Farm – operated by BP in Dorset is the largest onshore oil field in Europe (65 million tonnes). Oil is piped from Wytch Farm to BP's Hamble terminal on the South Coast from where it can be exported or supplied to Esso's Fawley refinery.
- Singleton, West Sussex - situated across the valley from Goodwood Racecourse (several other prospects along strike on the South Downs).
- East Midlands oilfield, centred on Eakring, Nottinghamshire, and extending up to Eskdale, North Yorkshire and the Pickering / Kirkby Misperton structure under Ryedale.

The UK has a single international crude oil pipeline, the 220-mile, 34-inch Norpipe operated by ConocoPhillips. It connects Norwegian oil fields in the Ekofisk system to the oil terminal and refinery at Teesside and has a capacity of 900,000 bbl/d.

The UK accounted for 1.9 million bbl/d of refining capacity in 2006, according to OGJ. As indicated in Figure 5.6 below, the nine major UK refineries are located on coastal sites.

Figure 5.6 Map of major refineries in the UK

Source: Greenenergy, undated

5.3.2 Environmental impacts

Oil industry installations are major sources of solid, liquid and gaseous wastes to air, ground and water. They are sources of sulphur dioxides, carbon monoxide, nitrous oxides, volatile organic compounds and others. But the environmental impact is not limited to production sites. Impacts of oil transport are a long-standing concern. Impact and footprint of pipelines for oil (and gas) during installation as well as decommissioning: pipelines consume land, create visual impacts, can disrupt habitats and are potential sources of leakage. Impacts due to GHG emissions and other physical impacts generated by different life-cycle phases are presented below.

Greenhouse Gas Emissions: Oil is a major contributor to carbon dioxide emissions. In 2007, oil power plants emitted 658 tonnes of carbon dioxide per GWh electricity supplied. (BERR 2007) According to national sources, the transport sector, fuelled primarily by oil products, was responsible for 130 million tonnes of CO_2 in 2005. (National Audit Office 2008)

Other pollutants/Emissions:

Nitrogen oxides and sulphur dioxide emissions from petrol fuels have decreased substantially in the past two decades. According to DEFRA, in 2006 petroleum fuels lead to the emission of 0.18 Mt of SO_2 (about 26 per cent of total SO_2 emissions)[69] and of 0.89 Mt NO_x (ie 56 per cent of total NO_x emissions)[70]. Nevertheless, nitrogen oxide emissions are a significant contributor to eutrophication impacts from airborne nitrogen deposition and the eutrophication of habitats (see Section 5.1).

The most significant impacts for the UK are those related to offshore drilling (see Section 5.2) and oil refining, as these are the most relevant oil-related activities that takes place in the country.

Oil refining impacts are mainly related to air emissions, wastewater and waste. Typical air emissions are exhaust gases (mainly nitrogen oxide emissions), venting and flaring, fugitive emissions (eg from pipes, valves, seals, tanks and other infrastructure components) likely to lead to emissions of volatile organic compounds (VOC), sulphur oxides, particulate matter from point sources and GHGs. Wastewater impacts are related to industrial process wastewater and other wastewater streams and water consumption. Finally, oil refining leads to the production of spent catalysts and other hazardous wastes.

Oil production and transport can also lead to acute impacts as a result of major spillages from oil tankers.

Biodiversity: Potential impacts from oil production are mostly the result of similar activities to those described above for gas, including exploration, drilling and the construction of supply pipelines. However, impacts from terrestrial pipelines are likely to be very low due to the low number of pipelines (there being no equivalent to the terrestrial gas network).

Oil production may, however, have some more significant impacts on marine ecosystems and associated species. In particular, oil spills from tankers and pipelines can result in the

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69 DEFRA, e-Digest Statistics about: Air Quality Emissions of Sulphur dioxide: 1970-2006 http://www.defra.gov.uk/environment/statistics/airqual/download/xls/aqtb08.xls

70 DEFRA, e-Digest Statistics about: Air Quality Emissions of Nitrogen oxide: 1970-2006 http://www.defra.gov.uk/environment/statistics/airqual/download/xls/aqtb06.xls loss of large numbers of seabirds and disruption of marine ecosystems. For example, major incidents such as the spill from the Exxon Valdez, have had profound and long-lasting impacts on the Alaskan coastal ecosystem, with unexpected persistence of toxic subsurface oil and chronic exposures, even at sublethal levels, have continued impacts on wildlife (Peterson *et al*. 2003). These effects have caused delayed population reductions and cascades of indirect effects, which have postponed ecosystem recovery. Such major accidents are, however, very rare and unpredictable.

Although oil spills can result in the deaths of large numbers of birds, there appears to be little evidence that such occasional incidents typically have long-term population impacts. For example, Votier *et al* (2005) showed that although four major oil spills doubled adult mortality in Common Guillemots (*Uria aalgae*) there was no significant effect on the number of individuals counted at the breeding colony (Votier *et al*. 2005), primarily as a result of increased recruitment of immatures to the breeding population (Votier *et al*. 2008).
Improved safety and clean-up measures appear to be reducing the frequency and impacts of major oil incidents. Chronic levels of oil pollution also appear to be declining, at least in some areas (Camphuysen 1998).

Gas flares from drilling rigs have been known to attract and kill large numbers of migrant birds (Sage 1979; Wiese *et al*. 2001). However, the frequency and significance of these events is uncertain.

Table 5.13 Biodiversity impacts of oil

Selected technology	Oil
Direct mortality	As gas. Also impacts of oil spills on marine and coastal species.
Direct habitat loss	Some marine habitat loss from distribution pipes and port developments, relatively small terrestrial impacts from refineries and storage facilities.
Disturbance	As gas.
Indirect habitat degradation	As gas, but also significant impacts from oil spills (and dispersant) on marine and coastal ecosystems. NO_x emissions from vehicles contributes to airborne eutrophication impacts.
Secondary impacts	Activities associated with port development.
Potential for mitigation	High, as for gas for extraction and pipelines. Low for NO_x emissions and impacts.
Potential for ecological compensation	As for gas, except for large scale-eutrophication impacts, which cannot be easily compensated for.
Impacts outside the UK	As gas

The results of the vulnerability analysis as summarised in Tables 5.14 and 5.15 clearly indicates that overall impacts from oil use are very low with respect to Priority Habitats and Priority Birds. As with gas, predictable impacts are most likely to arise from relatively small-scale habitat losses as a result of the laying of pipelines (mostly affecting marine habitats in the case of oil) and the disturbance of benthic habitats and pollution associated with drilling rigs. The potential impacts of major oil spills are not taken into account as the impacts of such low probability events vary according to their specific circumstances and are thus very difficult to predict.

All of the energy scenarios considered in this study project a reduction in oil use. Oil production within UK waters is also decreasing and therefore it can be probably be reliably assumed that biodiversity impacts from oil production and use will continue to decline.

Table 5.14 The estimated vulnerability of UKBAP Priority Habitats to energy production from oil under current conditions and the future energy scenarios for 2020 and 2050

Notes: Impacts are based on likely residual impacts assuming basic mitigation measures are implemented effectively. See Section 2.3 for details of the analytical methods and Section 4.2 for the derivation of the energy scenarios. See Appendix 2 for vulnerability assessments for each habitat type.

		UK Government White Paper scenarios				Tyndall scenarios	
	Baseline	Central	Constrained	Central	Constrained	Red	Purple
	2008	2020	2020	2050	2050	2050	2050
% change in scenarios		-32.5%	-32.5%	-49.7%	-69.6%	-59.2%	-2.4%
Average score	0.007%	0.005%	0.005%	0.004%	0.002%	0.003%	0.007%
Detrimental Impacts							
Critical (100%)	0	0	0	0	0	0	0
High (>10-100%)	0	0	0	0	0	0	0
Moderate (1-10%)	0	0	0	0	0	0	0
Low (0.1-1.0%)	2	0	0	0	0	0	2
Very low (0.01-0.1%)	35	35	35	35	35	35	33
No impact	28	30	30	30	30	30	30
Beneficial impacts							
High (>-10%)	0	0	0	0	0	0	0
Moderate (-1 to -10%)	0	0	0	0	0	0	0
Low (-0.1 to -1.0%)	0	0	0	0	0	0	0
Very low (-0.01 to -0.1%)	0	0	0	0	0	0	0

Table 5.15 The estimated vulnerability of UKBAP Priority birds to energy production from oil under current conditions and the future energy scenarios for 2020 and 2050

Notes: Impacts are based on likely residual impacts assuming basic mitigation measures are implemented effectively. See Section 2.3 for details of the analytical methods and Section 4.2 for the derivation of the energy scenarios. See Appendix 3 for vulnerability assessments for each species.

		UK Government White Paper scenarios				Tyndall scenarios	
	Baseline	Central	Constrained	Central	Constrained	Red	Purple
	2008	2020	2020	2050	2050	2050	2050
% change in scenarios		-32.5%	-32.5%	-49.7%	-69.6%	-59.2%	-2.4%
Average score	0.007%	0.004%	0.004%	0.003%	0.002%	0.003%	0.006%
Detrimental Impacts							
Critical (100%)	0	0	0	0	0	0	0
High (>10-100%)	0	0	0	0	0	0	0
Moderate (1-10%)	0	0	0	0	0	0	0
Low (0.1-1.0%)	0	0	0	0	0	0	0
Very low (0.01-0.1%)	29	29	29	29	29	29	29
No impact	30	30	30	30	30	30	30
Beneficial impacts							
High (>-10%)	0	0	0	0	0	0	0
Moderate (-1 to -10%)	0	0	0	0	0	0	0
Low (-0.1 to -1.0%)	0	0	0	0	0	0	0
Very low (-0.01 to -0.1%)	0	0	0	0	0	0	0

5.4 Nuclear

5.4.1 Characterisation of the technology in the UK

Potential: The UK has 19 reactors generating one fifth of its electricity (totalling 11 GWe capacity) and all but one of these will be retired by 2023 (Table 5.16). In addition, about 3 per cent of UK electricity demand is met by imports of nuclear power from France, so overall nuclear total in UK consumption is about 22 per cent[71].

But as current reactors approach the end of operating life, a review of UK energy policy has taken place and new-generation plants are expected to be built in mid 2013. Several could be in operation by 2020.

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[71] *World Nuclear Association, Nuclear Power in the United Kingdom http://www.world-nuclear.org/info/inf84.html*

Table 5.16 Operating Nuclear Reactors in the UK

BNFL Magnox	Capacity (MW)	Published Lifetime
Oldbury	434	1967 – 2008
Wylfa	980	1971 – 2010

British Energy	Capacity (MW)	Published lifetime
Heysham 1	1,150	1989 – 2014
Hinkley Point B	1,220	1976 – 2016
Hunterston B	1,190	1976 – 2016
Dungeness B	1,110	1985 – 2018
Hartlepool	1,210	1989 – 2014
Heysham 2	1,250	1989 – 2023
Torness	1,250	1988 – 2023
Sizewell B	1,188	1995 – 2035

Source: BERR,, Nuclear Power Generation and Development
http://www.berr.gov.uk/energy/sources/nuclear/technology/generation/page17922.html

Location: Figure 5.7 below shows the location of nuclear power reactors within the UK.

In 2006 British Energy (BE) closed four Advanced Gas-cooled Reactors (AGRs) due to boiler degradation in the non-nuclear part of the plants. The units were supposed to restart after a few months, but remained closed until May 2007. In December 2007 a 5-year life extension was granted for the units to 2016. A further life extension will be considered in 2013. Life extensions for other AGR plants will be considered at least three years before the scheduled closure of each unit. Late in 2007 corrosion was found in the structures of two AGRs, and these plus two similar ones were then closed pending fuller[72].

The last remaining two of the UK's Magnox reactors are scheduled for closure in the next few years.

72 *ibidem*

Figure 5.7 Map of nuclear power reactors in the UK - 2005

Source: International Nuclear Safety Center, http://www.insc.anl.gov/pwrmaps/map/united_kingdom.php

5.4.2 Environmental impacts[73]

Nuclear power is a source of electricity that does not rely on fossil fuel and hence does not produce greenhouse gas emissions. However, there are significant environmental impacts arising from this technology, which include long-term waste disposal and the handling and disposal of toxic chemical wastes associated with the nuclear fuel cycle. In addition,

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[73] *This section is based on MIT (2003) and Sustainable Development Commission (2006).*

although visual and landscape impacts are not often at the forefront of the nuclear power debate, the extent of these impacts needs to be considered.

First of all mining is the dominant landscape impact from nuclear power. In many respects, the environmental impacts of a uranium mine are similar to those of other metalliferous mining, its land-take depending on the concentration of ore. But the radioactive content of waste materials (eg spoils and tailings) adds complexity. However, as there are no uranium reserves in the UK, no additional analysis of these potential impacts will be undertaken in this study.

Unlike mining, fuel processing activities (which include enrichment, fabrication, and conversion) are undertaken in the UK and have a much lower land-take, most of which can also be reclaimed. During enrichment, it is estimated that 1 per cent of the site is committed to the storage of waste, and 10 per cent for roads and the plant itself. Cooling towers must also be built if enrichment is performed using gaseous diffusion. The Capenhurst enrichment facility in the UK occupies a 40ha site (about $0.4km^2$.). Both fabrication and conversion facilities in the UK are located at Springfields, Lancashire, comprising 63ha of land.

The land area required by nuclear power plants is comparable to that for coal- and gas-fired stations and around the same as that required by on-shore wind power. It is estimated that the total land-take for a 1000MW nuclear power plant is between 100 and 400ha. Nuclear land requirements will be the highest during the construction phase of a plant, in common with any large-scale electricity generating technology.

Most plants are surrounded by an exclusion zone of anything between 500m and 1,500m, depending on land prices, land availability and reactor size. However, not all of the land within the exclusion zone is necessarily unproductive. The exclusion zone can actually be beneficial to the environment, as it may provide secure undisturbed habitats.

Nuclear power plants require large volumes of cooling water, therefore they tend to favour coastal locations. Water, used in the plant as a coolant is indeed significant. It is estimated older plants need about $40\text{-}60m^3$ of water per second.

The issue of waste, both legacy waste from decommissioned reactors and that which would be produced with replacement or new build is of major importance. There are many radioactive waste streams created in various parts of the nuclear fuel cycle. What deservedly receives the most attention is the high level waste containing the fission products and/or transuranic (TRU) elements created during energy generation. The spent fuel from nuclear reactors contains radioactive material that presents environmental risks that persist for tens of thousands of years. At present no country has yet successfully implemented a system for disposing of this waste.

In most countries, the preferred technological approach is to dispose of the waste in repositories constructed in rock formations hundreds of metres below the earth's surface. Although several experimental and pilot facilities have been built, there are no operating high-level waste repositories, and all countries have encountered difficulties with their programmes.

Table 5.17 below summarizes the main impacts of nuclear power:

Table 5.17 Nuclear power environmental impacts – by operation

Operation	Potential environmental impact
Mining (Uranium)	• Land use (not extensive)
Milling (separation)	• Radioactive wastes • Air • Water • Solid waste
Enrichment	• Minor release of radioactive material
Conversion	• Land use (permanent) • Thermal discharge • Release of radionuclides (minor) • Accident potential • Aesthetics
Reprocessing	• Radioactive air emissions
Radioactive waste disposal	• Accident potential (handling, storage) • Political instability (long term) • Land use

Source: Based on Jain,et al. (2002)

Biodiversity: The most likely biodivesrity impacts arising from nuclear power generation in the UK will be associated with the footprint of the nuclear power stations and associated facilities. Although nuclear facilities cover a relatively large area compared to some other power generation plant, their extent is still relatively low in comparison with the total area of most habitats. Furthermore, many new nuclear facilities are likely to be built alongside existing plants, which may reduce their impacts in some situations.

Nevertheless, local impacts may occur if sensitive sites are not avoided. Furthermore, because nuclear power stations are located along the coast, then some coastal Priority Habitats, such as Coastal Vegetated Shingle and Sand Dunes could be at a more significant risk. On the other hand, the normal provision of extensive exclusion zones around nuclear facilities may provide benefits for some habitats and species, eg as a result of the low levels of disturbance and trampling.

Hossell *et al*. (2000) note that the operational impacts of power stations relate largely to the use of water. This is a particular issue for nuclear power stations because, as noted in the previous section, they use very large quantities of water for cooling. The principal environmental concerns relate to the loss of fish and marine invertebrates as a result of collisions with the filter screens protecting the water intakes and entrainment of small organisms drawn into the water extraction system with the flow of water.

Such problems are likely to be particularly significant if they affect small lakes or estuaries, and in coastal regions where direct-cooled power plants are concentrated. Indeed, power stations are often sited in estuarine nursery areas or on migratory routes (eg for sprat). According to Hossell *et al* (2006, citing Henderson 2004[74]), seventeen power

[74] Henderson P.A., (2004), Power Station Effects. http://www.powerstationeffects.co.uk. Accessed 17/07/04.

stations in the southern North Sea are estimated to kill sole and herring equivalent to about half of the British commercial landings for the region. It is estimated that over 100 different species of fish are killed (either in the egg, larval or adult stages) during cooling water extraction. The commonest species caught are Sprat (*Sprattus sprattus*), Whiting (*Merlangius merlangus*), Flounder (*Platichthys flesus*) and Sand Goby (*Pomatoschistus minutus*). However, there is insufficient information to determine if cooling water intakes are having a direct effect on inshore fish abundance .

The expulsion of the warmed water from the power station also results in thermal pollution (which in turn reduces dissolved oxygen levels and increases acidity). This can affect common shrimp and lobster larvae amongst other marine species (Bamber & Seaby 2004). Alteration of flow regimes and associated physical variables (eg sediments) can also result in a shift in species composition.

There is the possibility of biodiversity impacts from radiation from effluent, waste and accidents. Hossel *et al*. (2006) note that chronic and acute exposure to radiation doses from radioactive waste may result in, reproductive damage, behavioural change, larvae/juvenile survival and, in more extreme cases, DNA damage and genetic mutation. However, they do not provide any evidence of such effects having any population level impacts. At the moment there seems to be no indication that current levels of radioactive contamination in the UK are having any measurable impact on habitats or species populations.

There is of course the (remote) possibility that a serious nuclear accident or terrorist attack could lead to high levels of radioactive contamination with potentially severe human health and environmental impacts. But the possible impacts of such incidents on biodiversity are hard to predict as they are poorly understood and will be highly dependent on their specific circumstances.

Many studies have been carried out on the impacts of the nuclear accident at Chernobyl in 1986, which released 80 petabecquerel of radioactive caesium, strontium, plutonium and other radioactive isotopes into the atmosphere, polluting 200,000 km^2 of land in Europe. These have shown complex associations between high and low levels of radiation and the abundance, distribution, life history and mutation rates of plants and animals (Møller & Mousseau 2006). For example, studies of the Swallow (*Hirundo rustica*) have found that that radioactive contamination in the Chernobyl region has significant negative impact on rates of reproduction and survival, probably as result of effects on antioxidants and/or mutations (Moller *et al*. 2005). Nevertheless, there is little evidence of serious detrimental impacts on wildlife populations, despite the relatively high levels of radioactive contamination that occurred.

Table 5.18 Biodiversity impacts of nuclear power

Selected technology	Nuclear
Direct mortality	Loss of fish and marine invertebrates in cooling water intakes.
Direct habitat loss	Habitat loss from footprints of power stations, processing facilities and waste storage facilities. Most existing sites are on coastal habitats, as new sites probably will be.
Disturbance	Low level disturbance at power stations and other nuclear facilities. Unlikely to have significant effects, particularly because many new sites will be alongside existing nuclear plants.
Indirect habitat degradation	As other power stations - ecosystem disruption from hydrological changes, pollutants and thermal disruption (from warmed cooling water) can reduce food resources. Impacts from new plants may be offset by shutting of existing facilities nearby. Impacts from low-level radiation from effluent and waste are uncertain, but unlikely to be significant.
Secondary impacts	
Potential for mitigation	Avoidance of sensitive sites, and appropriate design will avoid most significant impacts.
Potential for ecological compensation	Variable depending on habitat and site. Exclusion areas may provide some undisturbed areas of habitat and refuges from disturbance for sensitive species.
Impacts outside the UK	Uranium mining is probably the major biodiversity impact of nuclear power. Impacts will vary according to the locations and habitats impacted and the mining and mitigation methods used. Additional variable impacts from fuel transport and processing.

The results of the vulnerability analysis summarised in Tables 5.19 and 5.20 below clearly indicate that overall impacts of nuclear energy production on Priority Habitats and Priority Birds are likely to be extremely low. This is primarily because impacts are likely to be restricted to the loss of habitats from power stations and associated processing facilities etc. However, it is important to note that potential impacts of water use on fish populations is not taken into account in this analysis.

Most of the energy scenarios considered in this study project a reduction in nuclear energy production. In contrast the Purple scenario proposed by the Tyndall Centre projects a very large expansion amounting to an increase of 3929 per cent. However, even this scale of increase is unlikely to lead to significantly increased impacts on most Priority Habitats and Priority Species. But some moderate impacts might be expected on some coastal habitats. Local impacts on fish could also be significant with a large increase in nuclear power.

Table 5.19 The estimated vulnerability of UKBAP Priority Habitats to nuclear energy production under current conditions and the future energy scenarios for 2020 and 2050

Notes: Impacts are based on likely residual impacts assuming basic mitigation measures are implemented effectively. See Section 2.3 for details of the analytical methods and Section 4.2 for the derivation of the energy scenarios. See Appendix 2 for vulnerability assessments for each habitat type.

		UK Government White Paper scenarios				Tyndall scenarios	
	Baseline	Central	Constrained	Central	Constrained	Red	Purple
	2008	2020	2020	2050	2050	2050	2050
% change in scenarios	-	-39.0%	-59.3%	-79.7%	143.9%	-100.0%	3929.7%
Average score	0.004%	0.002%	0.002%	0.001%	0.009%	0.000%	0.153%
Detrimental Impacts							
Critical (100%)	0	0	0	0	0	0	0
High (>10-100%)	0	0	0	0	0	0	0
Moderate (1-10%)	0	0	0	0	0	0	2
Low (0.1-1.0%)	2	0	0	0	2	0	5
Very low (0.01-0.1%)	9	8	8	8	6	0	1
No impact	54	57	57	57	57	65	57
Beneficial impacts							
High (>-10%)	0	0	0	0	0	0	0
Moderate (-1 to -10%)	0	0	0	0	0	0	0
Low (-0.1 to -1.0%)	0	0	0	0	0	0	0
Very low (-0.01 to -0.1%)	0	0	0	0	0	0	0

Table 5.20 The estimated vulnerability of UKBAP Priority birds to nuclear energy production under current conditions and the future energy scenarios for 2020 and 2050

Notes: Impacts are based on likely residual impacts assuming basic mitigation measures are implemented effectively. See Section 2.3 for details of the analytical methods and Section 4.2 for the derivation of the energy scenarios. See Appendix 3 for vulnerability assessments for each species.

		UK Government White Paper scenarios				Tyndall scenarios	
	Baseline	Central	Constrained	Central	Constrained	Red	Purple
	2008	2020	2020	2050	2050	2050	2050
% change in scenarios		-39.0%	-59.3%	-79.7%	143.9%	-100.0%	3929.7%
Average score	0.002%	0.001%	0.001%	0.000%	0.005%	0.000%	0.077%
Detrimental Impacts							
Critical (100%)	0	0	0	0	0	0	0
High (>10-100%)	0	0	0	0	0	0	0
Moderate (1-10%)	0	0	0	0	0	0	0
Low (0.1-1.0%)	0	0	0	0	0	0	6
Very low (0.01-0.1%)	8	8	8	8	8	0	2
No impact	51	51	51	51	51	59	51
Beneficial impacts							
High (>-10%)	0	0	0	0	0	0	0
Moderate (-1 to -10%)	0	0	0	0	0	0	0
Low (-0.1 to -1.0%)	0	0	0	0	0	0	0
Very low (-0.01 to -0.1%)	0	0	0	0	0	0	0

5.5 Wind

5.5.1 Characterisation of the technology in the UK

Current capacity and potential: In 2008 there were 176 operational wind farms in the UK (consisting of about 2,000 turbines) , having together a capacity of more than 2,500 MW. Of this, about 2,100 MW is onshore and 3000 MW offshore. Another 38 farms are under construction (about 700 turbines) and will contribute approximately 1,500 MW to the overall capacity. Consent has been given for another 138 farms (about 1,800 turbines) contributing 6,000 MW. There are another 228 projects (almost 3,200 turbines) that are in the planning process, which could add 8,800 MW of capacity – see Table 5.21.

Table 5.21 Summary of operational and under construction wind farms and consented projects

			England	N. Ireland	Scotland	Wales	Total	Turbines (approx)
Operational	Onshore	no	69	20	55	25	169	2,000
		MW	421	209	1,208	305	2,143	
	Offshore	no	5		1	1	7	
		MW	334		10	60	404	
Under construction	Onshore	no	12	4	12	3	31	700
		MW	206	63	615	16	900	
	Offshore	no	4		2	1	7	
		MW	359		180	90	629	
Consented projects	Onshore	no	51	13	56	11	131	1,800
		MW	702	165	2,469	145	3,481	
	Offshore	no	6			1	7	
		MW	2,490			108	2,598	
Planned	Onshore	no	68	47	88	20	223	3,200
		MW	1,103	1,200	3,624	548	6,475	
	Offshore	no	4			1	5	
		MW	1,635	750			2,385	

Source: Based on BWEA, Statistics, http://www.bwea.com/statistics/ - as of August 2008

The Renewable Energy Strategy Consultation paper (BERR 2008c) suggests that the key area to meet UK RES electricity objectives could be wind power, both on and offshore. Analysis on electricity constraints suggests that up to 33 GW of offshore wind might be achievable by 2030. However, in practical terms it is expected that by 2020 deployment may be closer to 14 GW, ie around 3,000 extra offshore turbines of 5 MW.

BERR also suggests that approximately 14 GW of onshore wind would be also needed – equating to around 4,000 new 3 MW onshore turbines in addition to the approximately 2,000 turbines already installed. Subject to planning permission, it is expected that a large proportion of onshore wind development will take place in Scotland.

It was estimated that theoretical available onshore wind energy resources in the UK could be 1 million GWh (DTI 2000). Taking into account though a number of constraints (eg conservation areas, urban conurbations, low wind speed areas etc) a practical availability could be of 50,000 GWh. In 2005 it was estimated that this would have been sufficient to meet the entire 2010 renewable target of 10 per cent electricity (ie 34,000 GWh) (CSD 2005). Offshore practical resources are also substantial, estimated at around 100,000 GWh (DTI 2001).

Location: The majority of operational onshore and offshore wind farms are currently in England. Scotland has 55 onshore and 1 offshore wind farms. Wales has 25 onshore and 1 offshore, and Northern Ireland has 20 onshore and no offshore. See Figure 5.8 for actual location of installations in 2007.

Figure 5.8 Operational Wind Farms in the UK (2007)

Source: BWEA, Operations, http://www.bwea.com/statistics/.

The Crown Estate is the landowner of the UK seabed and of part of the foreshore area, and since 2000 has granted leases, in two subsequent rounds, for the construction of 8 GW of offshore wind farms within 12 nautical miles of the coast, which are now currently under development. These sites are mostly in relatively shallow waters off NW England, the Thames estuary, East Anglia, the Wash and Lincolnshire[75]. Recently a new leasing round has been launched for the delivery of further 25 GW of new offshore windfarm sites by 2020[76].

5.5.2 Environmental impacts

Carbon dioxide emissions and/or reduction potential: Wind turbines do not produce GHG emissions when generating electricity, but are responsible for some embodied emission resulting from the energy used in their manufacture. It is estimated that wind turbines take between 3 to 10 months to produce the electricity consumed during their life cycle (Danish Wind Turbine Manufacturers Association 1997), or up to one just over one year according to other studies (House of Lords Science & Technology Select Committee 2004).

It is estimated that the current installed capacity of wind farms (about 2,500 MW) leads to 5.8 million tonnes of CO_2 reduction – ie about 2,300 tonnes per MW[77]. Taking into consideration 2007 levels of CO_2 emissions in the UK (about 543.7 million tonnes – BERR,2008), it can be stated that current wind farm installations contribute to a CO_2 reduction of about 1 per cent.

Physical impacts: The average size of onshore wind developments in the UK is around 10-20 turbines. Onshore wind turbines vary in size and visual characteristics, and can generate up to 3 MW each. The most common have three blades that sweep at a radius of between 40 and 45 m, and the hub is typically located 90m above the ground. The total height from the ground to the tip of the vertical rotor is hence about 130m.

Land-take is on average around 0.18 ha/MW for the turbines, access roads and substations (SDC 2005)[78]. Taking this as a reference value, and considering the capacity of operating, under construction and consented wind farms (about 6,500 MW), it can be estimated that in the short term wind farms will require about 1,170 ha. If planned projects are also taken into consideration, the overall land coverage will be about 2,340 ha.

Offshore turbines are often of larger capacity than onshore (up to 5 MW). They share some of the same visual characteristics, although they can also include other devices such as navigational markings and onshore grid connections. They are usually placed at distances of 2-10 km from the shore, in relatively shallow water, but new applications are expected to be submitted for sites much further out to sea, including some beyond the UK's territorial waters, in the newly established Renewable Energy Zones[79]. In this case

[75] http://www.thecrownestate.co.uk/our_portfolio/interactive_maps/70_interactive_maps_marine.htm

[76] *The Crown Estate – Offshore Wind Energy. http://www.thecrownestate.co.uk/offshore_wind_energy*

[77] *BWEA, UKWED, http://www.bwea.com/ukwed/index.asp*

[78] *Based on calculations using data from the proposed Black Law wind farm (143 MW) being developed by ScottishPower.*

[79] For instance in the Beatrice Wind Farm Demonstrator Project , for the first time two large offshore wind turbines had been installed at a depth of 40 metres, some 12 miles off the Scottish coast (BERR, 2008c).

the type and extent of impacts will depend on their actual location. For example, Dogger Bank and the North Norfolk Sandbanks have significant potential for the development of offshore wind yet both areas are currently being considered for designation as protected European sites (BERR 2008c).

Assuming that all offshore turbines have a capacity of 5 MW and onshore turbines of 3 MW (this being a very broad simplification, based on the maximum size of turbines currently available), and a capacity factor of 0.27 for offshore turbines and 0.30 for onshore, it is possible to make a (very) rough estimate of the number of turbines that would have to be installed to achieve the electricity production levels foreseen in each scenario (Table 5.21). Furthermore, assuming a land uptake of 0.18 ha/MW (CSD 2005) it is possible to estimate the possible land coverage of onshore turbines. Although these are crude estimates of turbines and land take, they illustrate the general the scale of the number of turbines and land coverage requirements implied by the energy scenarios.

According to these calculations, by 2050 the number of offshore turbines may range from about 2,150 (White Paper – Constrained) to 42,500 (Tyndall purple), while onshore turbines may range from 673 (White Paper – Constrained) to 13,000 (Tyndall purple) – with a land uptake between 600 and 12,000 ha. At most this would take up less than 0.05% of the UK's total land area of some 24 million ha.

Table 5.21 Estimate of number of turbines and land uptake for different energy scenarios

	White Paper				Tyndall	
	Central 2020	Constrained 2020	Central 2050	Constrained 2050	Red	Purple
Capacity offshore (MW)	6,449	3,200	6,449	8,024	24,072	127,302
Capacity onshore (MW)	3,367	1,684	3,367	4,209	12,538	65,305
Number of offshore turbines	2,150	1,067	2,150	2,675	8,024	42,434
Number of onshore turbines	673	337	673	842	2,508	13,061
Land uptake onshore (ha)	606	303	606	758	2,257	11,755

Transmission issues: The greatest proportion of new transmission network will be that needed to connect offshore wind farms – eg sub-sea cables to take the electricity generated onshore. Further upgrades to the onshore network may be needed to transport that power to the end users (businesses and homes) (BERR 2008c).

A study by Sinclair, Knight and Merz (SKM) commissioned by BERR estimated that over 6,000 km of DC and around 1,900 km of AC submarine cable will be required. In contrast, assuming that certain presently approved and planned reinforcements have been commissioned by 2020, no significant additional on shore reinforcements will be needed beyond those already consented or planned.

Biodiversity: A wide range of habitats may be affected by wind farm developments, though those most likely to be affected are in upland or coastal locations or shallow offshore waters. The footprint and loss of habitat from an individual wind turbine is insignificant in most habitats (though poorly located turbines could still significantly damage a feature of interest). The development of large wind farms can lead to more significant loss of habitat as a result of the combined footprint of new construction and service roads, but typically actual habitat loss amounts are small, eg 2-5 per cent of the total development area according to Fox *et al*. (2006).

Roads and associated drains can also lead to indirect habitat loss and degradation as a result of hydrological disruption (Drewitt & Langston 2006). It has been pointed out that permanent losses as a result of a projected development of 6000 wind turbines and associated infrastructure on blanket bogs in Scotland would be very low compared to other causes of habitat loss, including past afforestation, gully erosion and agricultural conversion (Dargie 2004).

Nevertheless, the impacts of wind turbines and access roads can have significant impacts on sensitive peatlands. They have the potential to alter the hydrology of the peatland, leading to drying and cracking, and potential instability in peat bodies, which can result in the down-slope mass movement of peat (SDC 2005). In turn these impacts on the hydrology of peat-based soils can cause the release of sequestered carbon/methane which could reduce the carbon savings from the installed wind turbines. The resulting increase in dissolved organic carbon and sediment concentrations in the stream systems are also likely to lead to be significant impacts through discolouration, reduction of light transmission through the water column and siltation of salmonid spawning gravels. Furthermore, suspended sediment losses may continue to remain high, even after construction activities at the site have ceased.

Disturbance of marine habitats for piling etc will temporally increase water turbidity and silt deposition levels, which may have longer-term impacts on sensitive habitats and species.

However, if important and sensitive habitats are avoided and appropriate mitigation measures are taken, then the direct impacts of wind farms on habitats is likely to be low in most cases.

Disturbance impacts, particularly on birds, can lead to more significant impacts as a result of effective habitat loss. This is likely to be particularly substantial during construction phases (but can be reduced by avoiding sensitive times and other mitigation measures) but can also be significant during operation as a result of the presence and noise of the turbines. Disturbance effects of wind farms seem to be species specific and vary amongst sites and seasons. Further research is also required, for example into the effects of the layout and size of turbines, differences between nocturnal and diurnal use of habitats in the vicinity of wind farms and the capacity for individuals to become habituated to regular disturbance sources. Thus it is difficult to predict disturbance impacts reliably. Nevertheless, Langston and Pullan (Langston & Pullan 2003) note that there are reliable studies that indicate negative effects up to 600m from wind turbines (ie a reduction in bird use of, or absence from, the area close to the turbines), for some species including Whooper Swan (*Cygnus cygnus*), Pink-footed Goose (*Anser brachyrhynchus*), European White-fronted Goose (*Anser albifrons*) and Eurasian Curlew (*Numenius arquata*). A recent study of Golden Plovers (*Pluvialis apricaria*) in the UK found evidence of significant avoidance of wind turbines by breeding birds to a distance of at least 200 metres. Furthermore, wind farm sites appeared to support lower densities of Golden Plover compared to sites without wind farms (Pearce-Higgins *et al*. 2008).

Disturbance from maintenance operations may also be substantial in some cases on large wind farms. For example, birds were observed to avoid an offshore wind farm in Denmark with 90 turbines as a result of the frequent boat traffic to the site.

Consequently, the disturbance effects of some wind farms may be significant where disturbance sensitive species occur, but whether this results in population impacts will depend on other factors, in particular the availability and carrying capacity of alternative habitats.

Wind farms may form partial barriers to birds, causing them to fly around a wind farm rather then over it or between the turbines (Drewitt & Langston 2006; Langston & Pullan 2003). This may affect the time and energy needed to move amongst feeding, breeding and roosting areas, which may in turn affect the suitability and productivity of the habitat for breeding and the survival rates of adults and young. Such impacts can be reduced by appropriate designs of wind farms, eg, by avoiding obvious flight lines (which is also necessary to reduce collisions) and by wide corridors between clusters of turbines.

There is well documented evidence that wind turbines kill birds that collide with them (Crockford 1992; de Lucas *et al*. 2007; Drewitt & Langston 2008; Drewitt & Langston 2006; Gill *et al*. 1996; Huppop *et al*. 2006; Langston & Pullan 2003; SGS Environment 1996). In some cases existing turbines have killed large numbers of birds including some species of high conservation importance, most notably raptors such as Golden Eagles (*Aquila chrysaetos*) at the Altamont Pass in California (Smallwood & Thelander 2008), but also Eurasian Griffon Vultures (*Gyps fulvus*) at Tarifa (Barrios & Rodriguez 2004) and Navarra in Spain (Lekuona *et al*. 2007). However, such recorded collision rates are unusual and a review of the available literature by Drewitt and Langston (2006) found that where collisions have been recorded, the rates per turbine are low, though variable with averages ranging from 0.01 to 23 bird collisions annually. The higher figure here is the value (following correction for scavenger removal), for a coastal site in Belgium and relates to gulls, terns and ducks amongst other species (Everaert *et al*. 2001; Everaert & Stienen 2007).

Typical bird collisions rates with wind turbines are low compared to those with overhead power lines (as described in Section 5.9), which range from 2.95 to 489 birds per km per year (Faanes 1987; Alonso & Alonso 1999a; Erickson *et al*. 2005). But average collision rates need to be considered with great caution because in many cases estimates are based on found corpses, which may result in an underestimation of actual mortality rates due to the removal of corpses by scavengers (see also Section 5.9). There is also great variability between turbines in collision rates because these vary according to the design of the turbine, its location, the species that may come across it and their numbers and behaviour. The greatest losses seem to occur at wind farms situated on narrow migration routes (with, for example, many raptors killed in south-west Spain), or near wetlands, which attract large numbers of gulls and other large birds (de Lucas *et al*. 2007). Much also depends on the species involved, with large, less-manoeuvrable species, species that habitually fly at rotor height and species that fly at night being at most risk (Garthe & Huppop 2004; Langston & Pullan 2003).

To date no wind farms appear to have been built at high risk sites for birds in the UK. Consequently Drewitt and Langston reported that, as of 2006, there have been no significant impacts on birds at any wind farms in the UK. Nevertheless, although the situation in the UK and the majority of studies indicates that collision mortality rates per turbine are low, this does not necessarily mean that collision mortality is insignificant, especially for rarer longer-lived species (Langston & Pullan 2003). Furthermore, the majority of developments in the UK to date have been relatively small, consisting of 1–20 turbines with less than 10 MW output. This is in contrast to recent and proposed developments, especially offshore, which are of a much larger scale in terms of the number of and size of turbines and wind farm extent. Thus the evidence of impacts to date may not be a good predictor of future impacts. Given the rapid expansion of offshore wind developments off the UK, further research is also needed on the impacts of offshore wind on birds, as casualty rates are difficult to estimate at sea (Camphuysen *et al*. 2004; Desholm *et al*. 2006; Desholm & Kahlert 2005; Fox *et al*. 2006; Hötker *et al*. 2004).

There is also growing evidence that some bats may be vulnerable to collisions with wind turbines (Hötker *et al*. 2004; Kunz *et al*. 2007; UNEP/Eurobats 2005), though it is not possible to assess the population impacts of this from currently available information.

The creation of wind farm construction and maintenance roads may lead to some secondary impacts as a result of increased access, though few such roads are likely to allow unrestricted public access. Where increased and unregulated access does occur, biodiversity impacts may result from increased disturbance, accidental fires, fly-tipping and littering, hunting and other illegal activities.

Offshore wind farms involve the use of underwater power cables to transmit the generated electricity to shore. These may have some impacts on fish and cetaceans as a result of electromagnetic fields, as described in Section 5.9.

A potential beneficial impact of offshore wind farms may be in the creation of refuges from fishing pressure (as fishing boats cannot normally operate within the vicinity of wind farms for practical reasons). These may reproduce some of the benefits of fishery no-take zones and marine reserves, which have been found to enhance fish stocks by reducing mortality rates and providing safe spawning grounds etc (Partnership for Interdisciplinary Studies of Coastal Oceans 2007). The turbine bases may also provide new hard substrates that can support additional marine communities that may further benefit fish and other marine fauna by providing shelter, breeding sites and food resources.

Table 5.23 Biodiversity impacts of wind

Selected technology	Wind
Direct mortality	Some birds and bats are vulnerable and impacts may be significant where turbines are inappropriately placed.
Direct habitat loss	Normally insignificant from turbine, but service roads can be significant.
Disturbance	Some species avoid breeding close to turbines. Possible disturbance or attraction of fish and cetaceans by electromagnetic fields from underwater cables.
Indirect habitat degradation	Can cause some hydrological disruption (eg as a result of service roads) siltation from offshore works.
Secondary impacts	Increased disturbance, littering, fires and hunting from increased access.
Potential for mitigation	Avoidance of sensitive sites, and appropriate turbine layout and design.
Potential for ecological compensation	Measures to increase survival or productivity rates of vulnerable species.
Impacts outside the UK	None other than possibly turbine manufacture.

The results of the vulnerability analysis summarised in Tables 5.24 and 5.25 below suggest that overall impacts of wind energy production on Priority Habitats and Priority Birds are currently likely to be very low. This is primarily due to the low sensitivity of most habitats to wind farms (when appropriate mitigation measures are implemented) and the low exposure of most habitats to wind developments. Similarly, most bird species are either at low risk of collisions and/or disturbance or currently unlikely to occur in habitats with high densities of wind turbines.

In future, avoidance of significant impacts from wind energy development will very much depend on the appropriate location and design of wind farms, which should be informed through comprehensive and adequately researched SEAs and EIAs (eg see English Nature *et al*. 2001). If appropriate avoidance and mitigation measures are implemented effectively, then its seems likely that a moderate increase in wind farms in the UK would have relatively low impacts on most habitats and species.

All of the energy scenarios considered in this study project a significant increase in the use of wind power, especially under the Tyndall Centre projections, with an increase of over 1,600 per cent under the red scenario and a huge increase of 8,900 per cent under the purple scenario.

However, the vulnerability assessments suggests that even such large increases would be unlikely to significantly increase overall impacts on most Priority Habitats and Priority Species. Nevertheless, there will be a greater risk with very large increases in turbine numbers that increasingly sensitive sites will come under pressure for development.

Table 5.24 The estimated vulnerability of UKBAP Priority Habitats to energy production from wind under current conditions and the future energy scenarios for 2020 and 2050

Notes: Impacts are based on likely residual impacts assuming basic mitigation measures are implemented effectively. See Section 2.3 for details of the analytical methods and Section 4.2 for the derivation of the energy scenarios. See Appendix 2 for vulnerability assessments for each habitat type.

		UK Government White Paper scenarios				Tyndall scenarios	
	Baseline	Central	Constrained	Central	Constrained	Red	Purple
	2008	2020	2020	2050	2050	2050	2050
% change in scenarios		355.1%	127.6%	355.1%	468.9%	1603.8%	8916.0%
Average score	0.004%	0.019%	0.009%	0.019%	0.024%	0.071%	0.375%
Detrimental Impacts							
Critical (100%)	0	0	0	0	0	0	0
High (>10-100%)	0	0	0	0	0	0	0
Moderate (1-10%)	0	0	0	0	0	1	1
Low (0.1-1.0%)	1	1	1	1	1	17	17
Very low (0.01-0.1%)	17	17	17	17	17	0	0
No impact	47	47	47	47	47	47	47
Beneficial impacts							
High (>-10%)	0	0	0	0	0	0	0
Moderate (-1 to -10%)	0	0	0	0	0	0	0
Low (-0.1 to -1.0%)	0	0	0	0	0	0	0
Very low (-0.01 to -0.1%)							

Table 5.25 The estimated vulnerability of UKBAP Priority birds to energy production from wind under current conditions and the future energy scenarios for 2020 and 2050

Notes: Impacts are based on likely residual impacts assuming basic mitigation measures are implemented effectively. See Section 2.3 for details of the analytical methods and Section 4.2 for the derivation of the energy scenarios. See Appendix 3 for vulnerability assessments for each species.

		UK Government White Paper scenarios				Tyndall scenarios	
	Baseline	Central	Constrained	Central	Constrained	Red	Purple
	2008	2020	2020	2050	2050	2050	2050
% change in scenarios		355.1%	127.6%	355.1%	468.9%	1603.8%	8916.0%
Average score	0.002%	0.008%	0.004%	0.008%	0.009%	0.028%	0.150%
Detrimental Impacts							
Critical (100%)	0	0	0	0	0	0	0
High (>10-100%)	0	0	0	0	0	0	0
Moderate (1-10%)	0	0	0	0	0	0	3
Low (0.1-1.0%)	0	1	0	1	1	6	8
Very low (0.01-0.1%)	42	41	42	41	41	36	31
No impact	17	17	17	17	17	17	17
Beneficial impacts							
High (>-10%)	0	0	0	0	0	0	0
Moderate (-1 to -10%)	0	0	0	0	0	0	0
Low (-0.1 to -1.0%)	0	0	0	0	0	0	0
Very low (-0.01 to -0.1%)	0	0	0	0	0	0	0

5.6 Tidal

5.6.1 Characterisation of the technology in the UK

Potential: Tidal energy technologies have not been implemented yet in the UK. Nevertheless there is now a strong political interest in this energy source and its potential for electricity generation has been explored. The UK Sustainable Development Commission (SDC 2008) explored the potential of different technologies (tidal streams, lagoons and barrages) and estimated that tidal resources could contribute 10 per cent of electricity production in the country, ie through 5 per cent from tidal stream and 5 per cent from tidal range.

One of the applications that has been most investigated so far is the installation of a tidal range installation in the Severn Estuary – the so called Severn Barrage. This would be a very large structure across the estuary with a significant physical footprint. A variety of schemes have been explored, but in this study we focus on one of smaller capacity (Shoots scheme) and the largest scheme (Cardiff-Weston):

- The Shoots scheme would imply the construction of an embankment of 4.1 km, and would have a generation capacity of 1.05 GW producing about 2.75 TWh/year, contributing 0.7 per cent of UK electricity supply or 0.1 per cent of total energy supply.

- The Cardiff-Weston scheme instead would require an embankment 16.1 km long, and would have a generating capacity of 8.64 GW producing about 17 TWh/year, covering 4.4 per cent of electricity supply or 0.6 per cent of total energy supply.

Overall, the potential for energy production from possible tidal range and tidal stream schemes at the top ten UK sites for tidal power has been estimated to be about 18.5 TWh/year (assuming the Cardiff-Weston scheme will be implemented in the Severn barrage) – divided as shown in Table 5.26 below.

Table 5.26 Potential tidal sites and estimated electricity production

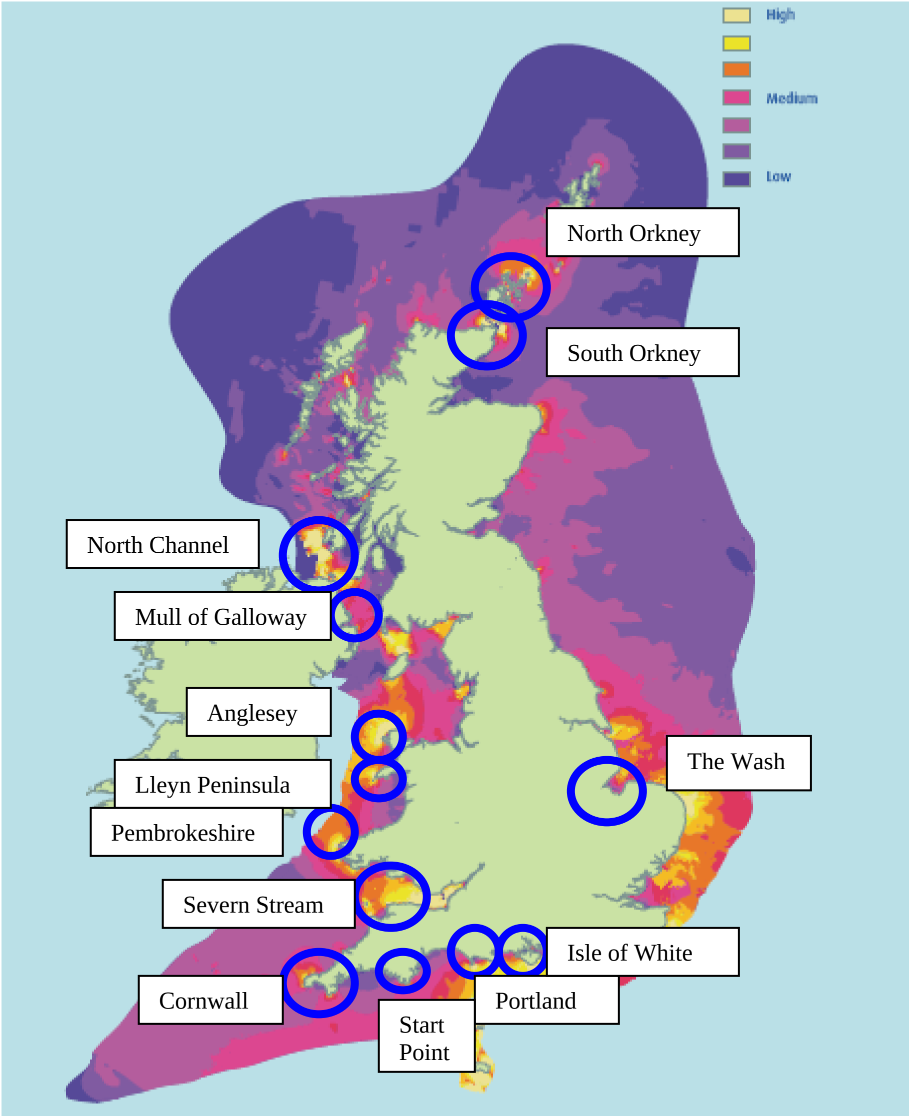
Tidal range sites		Tidal steam site		
Site name	**Resource (TWh/year)**	**Site name**	**Area**	**Resource (TWh/year)**
Severn	17	Pentland Skerries	Pentland Firth	3.9
Mersey	1.4	Strøma	Pentland Firth	2.8
Duddon	0.212	Duncansby Head	Pentland Firth	2
Wyre	0.131	Casquets	Alderney	1.7
Conwy	0.06	South Ronaldsay	Pentland Firth	1.5
		Hoy	Pentland Firth	1.4
		Race of Alderney	Alderney	1.4
		South Ronaldsay	Pentland Firth	1.1
		Rathlin Island	North Channel	0.9
		Mull of Galloway	North Channel	0.8

Source: Based on SDC 2007

Location: The SDC identified possible locations for the implementation of tidal devices (see also maps in Figures 5.9 and 5.10 with site locations in Great Britain).

Tidal stream devices could be developed in the Bristol Channel, in the North of Scotland, in north Wales, Northern Ireland and the Channel Islands. The most promising location for tidal barrages is the Severn Estuary, although other options are also being investigated, e.g in the Mersey Estuaries and other locations in the west coast. Small-scale tidal lagoons could be built alongside tidal barrages.

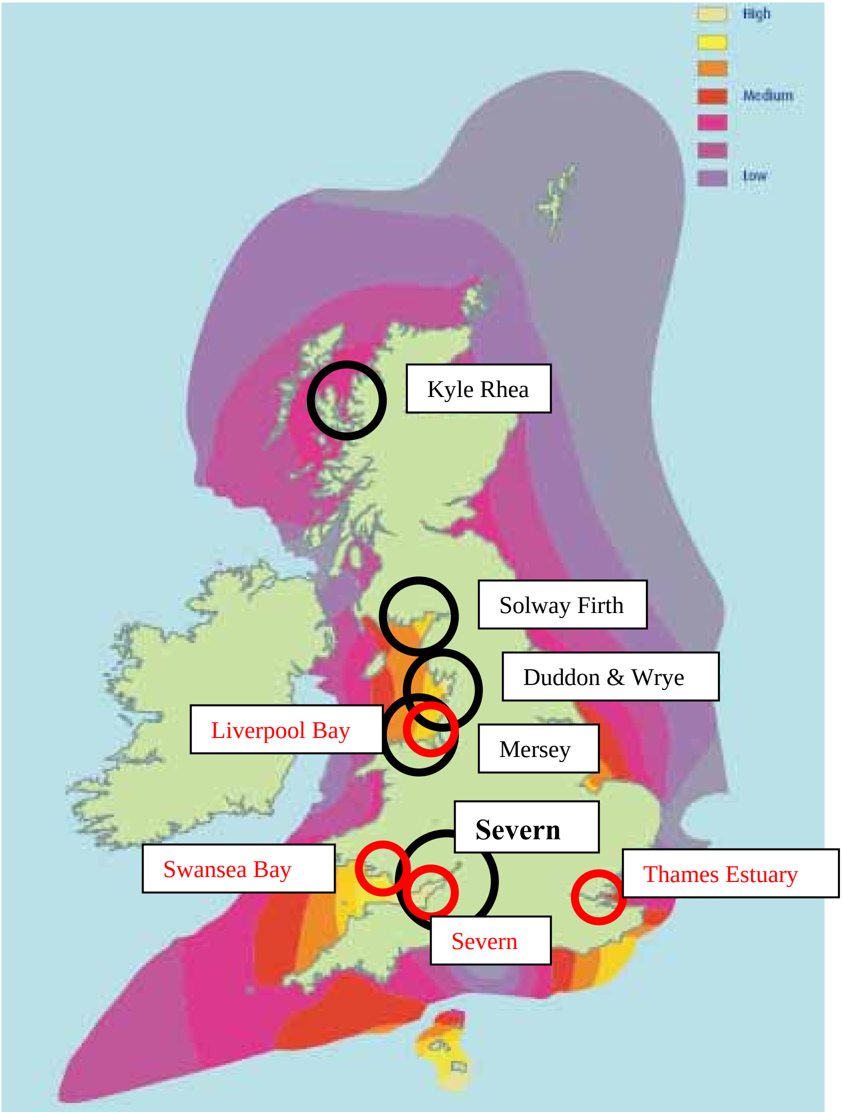
Figure 5.9 Tidal stream resource and possible sites



Source: adapted from SDC 2007

Key: possible stream tidal site

Figure 5.10 Tidal range resource and possible sites



Source: adapted from SDC 2007

Key: Possible tidal range site Possible tidal lagoon site

5.6.2 Environmental impacts

The analysis only considers the potential impacts from tidal barrage and tidal stream technologies, because there is little information available on possible tidal lagoon schemes and their potential impacts are highly uncertain.

Carbon dioxide emissions and/or reduction potential: despite some emissions embedded in the construction, transport of material, operation and commissioning operations, electricity production from tidal energy is considered a low carbon technology, and as such can help the UK achieve its Kyoto target.

The carbon payback for tidal range schemes (at the Severn barrage) is considered to be 5-8 months, and its emission factor could range between 2.42 and 1.58 g/CO_2/kWh (depending on the scale/option chosen), ie the lowest available for power generation. It is assumed that tidal energy would displace new-build gas-fired plants, which have a carbon intensity of around 90tC/GWh, rather than older coal plants. This is because a tidal range system such as the Severn barrage is unlikely to be operational within the next ten years, by which time most of UK's coal capacity is expected to be taken out of service due to the Large Combustion Plant Directive. It is estimated that, for instance, the Severn barrage range tidal system could reduce UK carbon emission by between 0.15 per cent and 0.92 per cent compared to 1990 baseline.

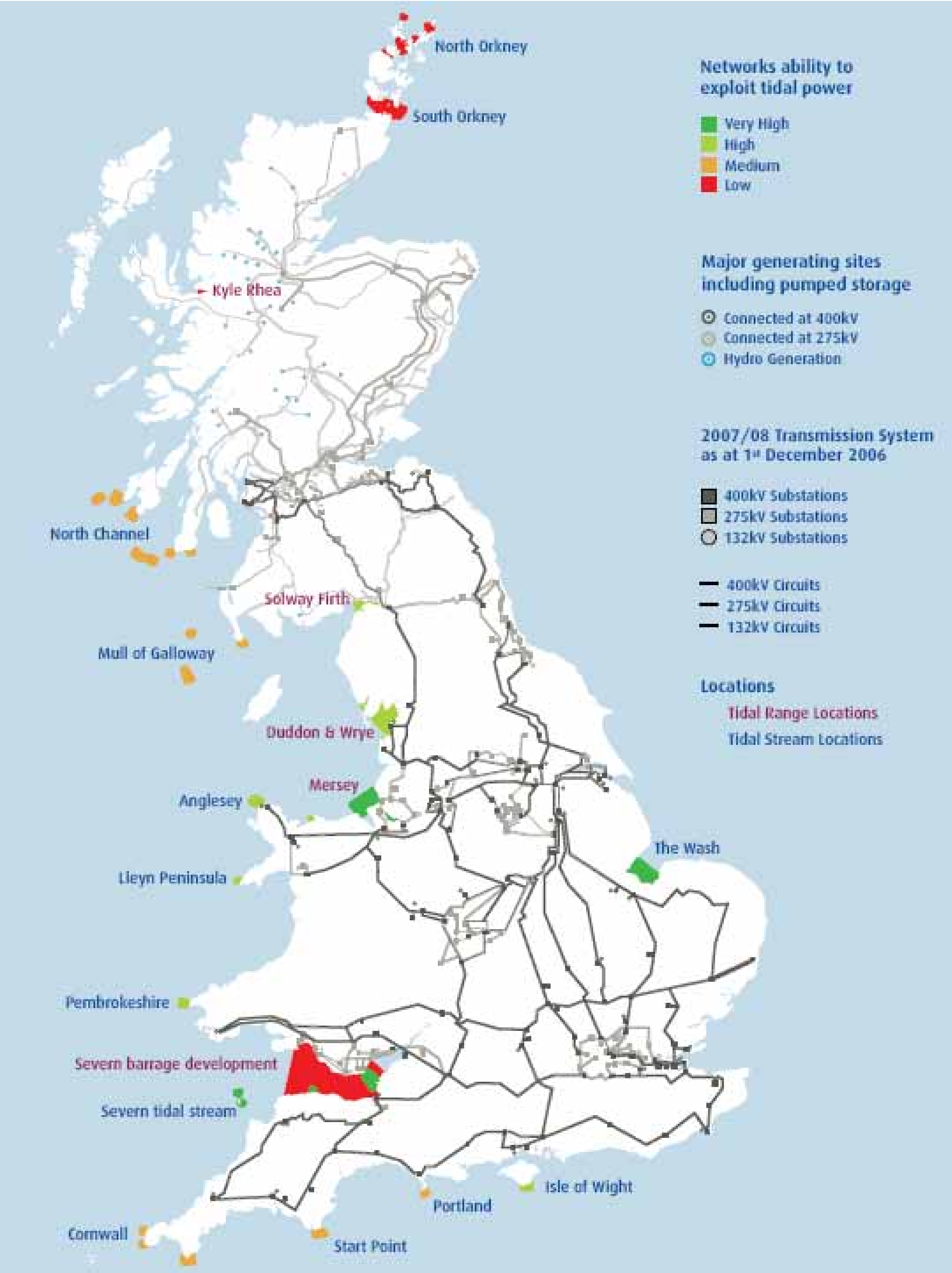
Physical impacts: Tidal devices can lead to a number of physical effects on the environment, such as changes in water flow and tidal mixing, wave action, tidal inundation, patterns of sedimentation and erosion, and disturbance to the seabed by construction and cabling. Water quality can be affected by leakage of lubricants and hydraulic fluids, and possible increased levels of vessel traffic associated with the activity.

Tidal barrages can lead to substantial physical changes by reducing the tidal range and changing the water levels within the barrage basin (upstream) and outside of the barrage (downstream). The Severn barrage for instance is expected to reduce the tidal range by 50 per cent. Downstream, the effects of changes in water level would decrease with distance – although in the case of the Cardiff-Weston scheme decreases in high levels may be detectable up to 75 km seawards. These changes in tidal range are likely to lead to loss of intertidal habitat (ie the area between high and low tide exposed to both water and air), and reduce the strength of currents, which for instance affects suspended sediments.

In some cases barrages can also affect wave regimes. The Cardiff-Weston scheme, for example, is expected to increase wave energy which could affect soft shorelines and the margins of the estuary.

Transmission-related issues: At present there are significant transmission entry capacity (TEC) constraints in the north of England and Scotland which are preventing the connection of new generation projects (see Figure 5.11). In order to connect new generation, areas of the transmission network will need to be upgraded to higher voltage levels (measured in kV) to increase the TEC – eg the line between Beauly and Denny and in Scotland. This is an issue in particular for tidal stream installations, while tidal range schemes are expected to be located in areas where grid constraints are less pronounced, and closer to high capacity transmission lines and to centres of demand.

Figure 5.11 Electricity transmission network and grid constraints on tidal power



Source: SDC 2007

Biodiversity:

<u>Tidal range/barrage:</u>

The assessments of biodiversity impacts in this study focus on the impacts identified for the Severn barrage, since this is where a large percentage of the UK's tidal range resource is concentrated and where the potential impacts of tidal schemes have been examined. However, it is considered that many conclusions drawn for the Severn barrage may be applicable to other barrage proposals - eg to the well-developed proposal for the Mersey Estuary – although further investigation into other barrage options will be needed. A summary of the typical impacts of tidal barrages is provided in Table 5.27.

Table 5.27 Potential biodiversity impacts of tidal barrages

Selected technology	Tidal range (barrage)
Direct mortality	Potentially significant losses of fish in turbines.
Direct habitat loss	Normally substantial loss of intertidal habitats (but depends on scheme, coastal topography and operating regime).
Disturbance	Disturbance impacts near barrage structures, esp if a road is present.
Indirect habitat degradation	Changes in tidal flow will cause significant and wide-ranging changes (eg to sediments, salinity, nutrient loads, turbidity and oxygen levels) and ecosystem changes which affect food availability.
Secondary impacts	Developments stimulated by possible combination of barrages with road and/or rail links.
Potential for mitigation	Fish passes may reduce impacts, but other mitigation measures are limited.
Potential for ecological compensation	Difficult for intertidal habitats, and potential areas probably inadequate to compensate for habitat loss from the Cardiff-Weston barrage and other large schemes.
Impacts outside the UK	No significant impacts.

Tidal barrages will normally result in considerable habitat changes within the intertidal zone as a result of the changes in tidal range and the duration of inundation. The Severn barrage for instance is expected to reduce the area of intertidal habitats (mostly mudflats) by 3,400 - 5,500 ha under the Shoots scheme, and 5,800 - 14,400 ha under the Cardiff-Weston scheme (Sustainable Development Commission 2007). This would amount to losses of 70 per cent of the inter-tidal habitats upstream of the Shoots Scheme during neap tides and 76 per cent under spring tides. Under the Cardiff-Weston scheme the losses would amount to 59 per cent during neap tides and 76 per cent during spring tides. However, the proportional losses are substantially less if compared to the total 23,000 ha area of inter-tidal habitats within the estuary complex.

Barrages can also lead to marked contractions of saltmarsh habitats, due to less frequent inundations. In the Severn Estuary, a reduction of 540 ha is expected for a Cardiff-Weston alignment, and 133 ha for a Shoots alignment. Upper marsh zones that become more permanently exposed are likely to be colonised by vegetation of the upper shore zone, such as *Spartina*.

Muddy and sandy subtidal habitats are likely to increase in area due to decreased intertidal area and also due to morphological, hydrodynamic and sedimentary changes. Some rocky intertidal areas are likely to become subtidal under a barrage.

Transitional coastal habitats could experience less frequent inundation, affecting their composition and structure and the species they support – eg in the case of the Severn barrage these will include wetlands, grazing marsh, reedbeds and woodlands.

These habitat and vegetation changes are likely to have substantial impacts on their associated species. Impacts in the Severn estuary could be particularly profound due to the strong tidal currents and high loads of suspended sediments that it currently carries. These hyper-tidal conditions create a hostile environment for some benthic species resulting in species-poor benthic communities. However, the nutrient-rich conditions support high numbers and a high overall biomass of those invertebrates that inhabit such habitats (Sustainable Development Commission 2007). According to the SDC report, studies in the 1980s suggested that the creation of a barrage would reduce tidal flows and sediment loads leading to an increase in the abundance and biomass of invertebrates.

Although the Severn estuary does not support high densities of waterbirds, its shear size holds an internationally important assemblage of waterbirds (ie over 20,000 individuals) amounting to some 93,000 birds[80]. It also holds internationally and nationally important passage and wintering populations of several species, and is consequently designated as a wetland of international importance under the Ramsar Convention, a Special Protection Area (SPA) under the EU Birds Directive, a Special Area of Conservation (SAC) under the EU Habitats Directive and a national SSSI.

The numbers of some birds have changed over recent years, but according to RSPB data (cited by Sustainable Development Commission 2007) internationally important species include Shelduck (*Tadorna tadorna*), Dunlin (*Calidris alpina*), Redshank (*Tringa totanus*), Teal (*Anas crecca*) and Pintail (*Anas acuta*). Nationally important species are Tundra Swan (*Cygnus columbianus*), European White-fronted Goose (*Anser albifrons*), Wigeon (*Anas penelope*), Shoveler (*Anas clypeata*), Pochard (*Aythya ferina*), Ringed Plover (*Charadrius hiaticula*), Curlew (*Numenius arquata*), Black-tailed Godwit (*Limosa limosa*), Whimbrel (*Numenius phaeopus*) and Spotted Redshank (*Tringa erythropus*).

As with any tidal barrage, the principal potential impacts of a Severn barrage on bird populations would probably result from the loss of intertidal habitat, reduced exposure of intertidal habitats (and hence reduced feeding time for many species) and possible changes in prey resources (type, abundance, size and overall biomass). As noted above both Severn barrage schemes would result in substantial losses of upstream habitat (of up to 76%).

However, it is difficult to predict the impacts of such changes on individual species' populations with the estuary. An important complication is that changes in feeding time may not be directly related to changes in inter-tidal habitat (West & Caldow 2006). Population impacts will also depend on the distribution of each species (in response to the distribution of different types of inter-tidal habitat) and the carrying capacity of the various habitat types. If some habitats are not at carrying capacities then at least some individuals may be able to move to other suitable areas. On the other hand, even if birds are able to relocate to other areas of habitats there may be density-dependent effects, eg as a result of increased competition between individuals. For example, a recent study of the impacts of habitat loss from the Cardiff Bay amenity barrage, found that displaced birds that moved to the Severn estuary were not able to maintain their body condition (Burton *et al*. 2006). This led to a 44% increase in mortality rate, which is sufficient to cause a decline in the local population size (unless overcome by an increase in the recruitment of first-winter birds). Furthermore, the poor condition of surviving birds might also lead to reductions in breeding productivity and eventual recruitment.

[80] *http://www.jncc.gov.uk/default.aspx?page=2066*

The impacts of a barrage may also depend on changes in habitat types and associated changes in food resources (Clark 2006). For example, studies of the potential impacts of the Mersey barrage indicated that as a result of changes in habitat morphology bird numbers would not decline in direct proportion to the predicted loss of 42% of the inter-tidal area (Austin *et al*. 1996, cited in Clark 2006).

Some studies of the proposed Severn barrage have suggested that the increases in invertebrate biomass in the estuary might offset some of the loss of intertidal area (Sustainable Development Commission 2007). However, as the SDC notes, "these predictions remain very controversial and uncertain in the absence of a greater understanding of basic physical, hydrological and operational information and advanced modelling of morphological change on which to base accurate predictions". Thus, without good evidence it would seem appropriate to take the precautionary view that losses of existing feeding habitat would not be compensated for by increases in food resources or availability.

In relation to a Shoots barrage, the loss of intertidal area would be considerably less and the resulting impact on birds would be significantly less than for a Cardiff-Weston scheme. Furthermore, many key areas of bird usage (eg for Dunlin) are seaward of the Shoots barrage line, so the impact on such species would be minimal.

Estuaries are important feeding, spawning and nursery grounds for a variety of fish of conservation concern and importance for fisheries. Many are also used by migratory fish. The Severn estuary is particularly important in this respect, with Salmon (*Salar salar*) Twaite Shad (*Alosa fallax*), Allis Shad (*Alosa alosa*), Sea Lamprey (*Lampetra fluviatilis*) and River Lamprey (*Petromyzon marinus*) being designated or qualifying SAC features.

A Severn barrage could have substantial impacts on fish populations (Sustainable Development Commission 2007). Firstly, it is expected that fish would be sensitive to barrage construction as a result of noise and effects on water quality. Operational impacts would principally be the result of the physical barrier in the estuary, but also potential changes to water quality including dissolved oxygen, turbidity, and contaminants. Other important factors could include increases in juvenile predation rates by birds and fish, change in prey resources, changes to spawning and feeding grounds, as well as delays to migration and the movement of smolt (spawn) and the identification of natal rivers.

The SDC notes that there could be significant mortality of fish as they move through barrage turbines. Studies of the proposed turbines for the Cardiff-Weston barrage predicted injury rates for adult Salmon of 40% (or 10% for smolt), Eel of 28% and juvenile shad of 53%. However, according to the SDC, the Environment Agency's view is that Salmon, Sea Trout and shad in particular, would potentially face high to very high mortality rates. Actual injury rates would of course be sensitive to precise turbine designs, rotation speeds, fish pass size and location and patterns of generation.

The effects of a Severn barrage on fish would also depend greatly on its location within the estuary. In particular, being higher up the estuary, the Shoots barrage would not 'block' the River Usk (a SAC in its own right) and so the impacts for fish (especially shad, lamprey and Salmon) would be directly reduced.

It is clear from this analysis that the prediction of impacts of tidal barrages are complex and are likely to depend considerably on the site of the barrage (including its location within an estuary), its design and operational influence on tidal regimes. It is not therefore feasible or appropriate to provide an estimate of the impacts of tidal barrages according to projected tidal energy use under the selected study scenarios. Nor is there an existing scheme to assess or use as a baseline for scaling-up impacts.

The SDCs summary of the likely impacts of the Cardiff-Weston and Shoots schemes on the designated SAC and SPA features is provided in Table 5.28 instead of our own vulnerability assessment. Although this is not a comprehensive assessment of biodiversity impacts (and does not cover all UK BAP Priority Habitats or birds) it is illustrative of the likely impacts of the two schemes that are being seriously considered. The use of tidal barrages is not necessary in our interpretation of the UK Government White Paper scenarios (see Chapter 4), but is envisaged in the Tyndall scenarios. Under the red Tyndall scenario it is likely that a small scheme would be required, such as the Severn Shoots scheme, whilst the tidal energy needed under the purple scenario would require the implementation of the Cardiff-Weston scheme.

It is clear from the summary of impacts on SAC and SPA features, that there would be considerable and significant residual impacts, especially from the Cardiff-Weston scheme. As a result the Severn barrage would only be able to go ahead without contravening the Habitats Directive (under Article 6(4)) if it could be shown that there are no alternatives and if there are imperative reasons of overriding public interest. Furthermore, if a barrage project was to go ahead, compensatory measures would be necessary to ensure that the overall coherence of the Natura 2000 network is protected.

Although it seems plausible that both schemes could be considered to be of over-ridding public interest, the absence of suitable alternatives is less certain. For example, alternatives could include other less environmentally damaging forms of renewable energy or energy conservation measures (eg see Frontier Economics 2008). It also seems highly unlikely that adequate compensation measures could be provided in practice, especially for the Cardiff-Weston scheme given the area of habitat involved. Compensation measures would need to meet stringent EU criteria (European Commission 2001, 2007) including the provision of like-for-like habitats in greater areas than would be lost (as contingency for possible failures and lower habitat quality). Compensation would need to cover all habitat and species features, and though this might be feasible for some, such as some birds, the provision of marine habitat or enhancement measures for fish and other marine species does not seem feasible.

Thus, it seems inevitable that any large-scale barrage scheme in Severn estuary would result in significant residual impacts that would be in contravention of the EU Birds and Habitats Directives.

Table 5.28 Assessment of the impact on some designated SPA features (and some supporting habitats) and some pSAC features

Receptor	Cardiff-Weston Scheme	Shoots Scheme
SPA		
SPA feature: Annex 1 species – Bewick's Swan	No specific assessment available – possible impacts to population	No specific assessment available – possible impacts to population
SPA feature: overwintering assemblage of waterfowl	Species specific assessments generally lacking; broad overview studies suggest that overall populations may be relatively unaffected	No specific assessment available; limited impact likely based on existing information on bird distributions
Intertidal mudflats and sandflats*1	Potential loss of up to c.14,500 ha of intertidal habitat	Potential loss of up to c.5,500ha of intertidal habitat
Saltmarsh*1	Unquantified but substantial loss of existing 539ha resource	Unquantified but substantial loss of existing 133ha resource
Intertidal rock and shingle*1	Unquantified loss of intertidal rock and shingle	Unquantified loss of intertidal rock and shingle
cSAC Features		
• Atlantic saltmeadows/ saltmarsh • Estuary • Mudflats and sandflats • Reefs (*Sabellaria*)Q • Subtidal sandbanksQ • Fish (Allis*2 and Twaite Shad) • Fish (River and Sea Lamprey)	• Unquantified but substantial loss of existing 539ha resource • Reduction in tidal range and flows u/s barrage; small local reduction in tidal range d/s of barrage • Potential loss of up to c.14,500 ha of intertidal habitat • Unquantified, but significant • Unquantified change • Very high risk of very high mortality. Potential stock eradication. • Medium risk of high mortality	• Unquantified but substantial loss of existing 133ha resource • Reduction in tidal range and flows u/s of barrage; small local reduction in tidal range d/s of barrage • Potential loss of up to c.5,500ha of intertidal habitat • Unquantified but minor • Unquantified change • Very high risk of very high mortality. Potential stock eradication. • Medium risk of high mortality
River Usk SAC Features • Fish (AllisQ and Twaite Shad) • Fish (River and Sea lamprey) • Fish (Atlantic Salmon)	• Very high risk of very high mortality. Potential stock eradication • Medium risk of high mortality • High risk of high mortality	• Low risk of impact • Low risk of impact • Low risk of impact
River Wye SAC Features • Fish (AllisQ and Twaite Shad) • Fish (River and Sea lamprey) • Fish (Atlantic Salmon)	• Very high risk of very high mortality. Potential stock eradication • Medium risk of high mortality • High risk of high mortality	Very high risk of very high mortality. Potential stock eradication • Medium risk of high mortality • High risk of high mortality

Source: (Sustainable Development Commission 2007), modified according to the JNCC SAC citations[81] and SPA citations[82].

*Notes: *1 These are not designated features (although they are listed as such in the SDC table), but are import habitats that support some of the species features. *2 This is not a designated feature. Q This is a qualifying feature, but not one of the primary reasons fort designation.*

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[81] *http://www.jncc.gov.uk/page-1458*

[82] *http://www.jncc.gov.uk/page-1400*

Tidal stream:

Very few tidal stream systems have been developed so far, and only at prototype level, hence information on environmental impacts of full scale devices is still very limited. Nevertheless existing studies identify some of the key implications for the environment.

Tidal stream installations are in general considered to have relatively low environmental effects compared to tidal barrages and lagoons. Key physical effects in relation to each phase of a tidal stream project's lifetime include:

- *Construction stage:* Direct effects on the seabed are greatest at this stage. Key impacts relate to drilling and piling activities, noise, increased activity and pollution risk associated with construction boats and activity.
- *Operation and maintenance:* effects on water movements and sediment, as energy is extracted from the tidal flows. Underwater noise is likely to be low due to the low speed of operation (Fraenkel 2006), though its transmission and impacts my vary according to complex factors such as estuary shape. Impacts of underwater cables on the seabed and possible electromagnetic effects.
- *Decommissioning* (usually after 20 years): similar effects to commissioning. Further disturbance to new communities of marine organisms that have become established on devices.

- Additional impacts may be caused by onshore infrastructures, in particular power transmission lines and onshore works can affect terrestrial habitats and species.

The principal biodiversity impacts of tidal stream energy production are likely to be during the construction and decommissioning phases as a result of the potential noise, pollution and disturbance of the seabed. However, these impacts are likely to be relatively short-lived.

Longer-term and operational impacts will include the loss of benthic habitats from the footprint of each turbine. Although this will vary depending on the design, overall losses are likely to be insignificant in relation to the area of most benthic habitats. Nevertheless, there could, as with other technologies, be more significant impacts if particularly important sites with rare or other important habitats (and associated species) are potentially affected. There could also be potentially serious cumulative impacts if tidal stream technologies become too concentrated within estuaries. But serious impacts should be avoidable by appropriate SEAs and EIAs involving adequate site surveys etc.

Other operational phase impacts on biodiversity could result from changes to the physical environment (eg in water flow or erosion), which have knock-on effects on habitats and food-webs etc. However, major impacts seem unlikely as the schemes would be designed to avoid taking too much energy by adding too many turbines as this would reduce the overall energy capture and deliver diminishing returns (Fraenkel 2006).

There is of course also a risk of collisions between animals and the turbines, with the following coastal species being particularly at risk:

- Fish, eg Salmon and particularly Basking Shark (*Cetorhinus maximus*).
- Diving birds, eg grebes, divers, Shag (*Phalacrocorax aristotelis*), Cormorant (*Phalacrocorax carbo*) and sea duck.
- Common/Harbour Seal (*Phoca vitulina*) and Grey Seal (*Halichoerus grypus*).
- Coastal cetaceans, in particular Bottlenose Dolphin (*Tursiops truncatus*) and Harbour Porpoise (*Phocaena phocaena*).

The greatest impacts are likely to affect migrating species where underwater turbines are located in enclosed waters such as estuaries (Dadswell & Rulifson 1994), or where they form a line and therefore a potential barrier to movement. According to Gill (2005), little information exists concerning collisions between aquatic fauna and energy devices. However, Fraenkel (2006) notes that as a result of the design and slow speed of underwater turbine rotors (which is very low compared with wind turbines) the chances of contact with an animal passing through are low. Furthermore, if physical contact occurred, it would in most cases be glancing (ie at a slight angle) off a smooth and not very fast moving surface, so the likelihood of injury or mortality would be small. But it is clear that little direct evidence of the potential collisions risks with underwater tidal stream turbines exist and further research is needed on this subject.

Tidal stream schemes are likely involve the use of underwater power cables to transmit the generated electricity to shore. These may have some impacts on fish and cetaceans, as described in Section 5.9.

As with offshore wind farms, some possible positive effects could be the creation of refuge areas for fish populations around tidal installations where fishing is not possible.

Table 5.29 Biodiversity impacts of tidal stream

Selected technology	**Tidal stream (flow)**
Direct mortality	Uncertain: potential losses of fish, diving birds, seals and cetaceans, but likely to be low.
Direct habitat loss	Low impact on sub-littoral tidal habitats.
Disturbance	Uncertain, but likely to be low from turbines. Possible impacts from underwater cables (see Section 5.9).
Indirect habitat degradation	Uncertain, but unlikely to be any significant impacts.
Secondary impacts	
Potential for mitigation	May require measures to deter seals and cetaceans.
Potential for ecological compensation	Not practical
Impacts outside the UK	No significant impacts.

5.7 Biomass

5.7.1 Characterisation of the technology in the UK

Potential: Currently a large proportion of the biomass used in the UK is co-fired with conventional fuels in existing coal-fired power stations. Biomass fuel currently accounts for about 1.5 per cent of electricity and 1 per cent of heat production in the UK (Biomass Task Force 2005), but the potential is far higher. For example, the Royal Commission on Environmental Pollution (2004) suggested that biomass could deliver up to 12 per cent of the UK's end use energy requirements, implying up to 6 million hectares of energy crops. In its study of 'environmentally sustainable' bioenergy production the European Environment Agency (2006) also found that a very large share of Europe's energy could come from biomass, amounting to 10 per cent or more of total supply after 2010. A significant share of this was to come from municipal solid waste incineration, but it also assumed 30 per cent of arable land would be dedicated to energy crops in countries such as the UK.

In Scotland development of SRC has been limited, and it may be that future biomass demands are mostly met by forestry products.

National targets/objectives: The UK has set a short-term commitment to generate 10 per cent of the nation's electricity from renewable sources by 2010. It is anticipated that in order to meet this target 1,500 MW of new electrical capacity might come from energy crop and forestry residue combustion; this would imply planting approximately 125,000ha of energy crops (Britt *et al* 2002).

Location: Energy crops such as short-rotation coppice (SRC) and *Miscanthus* are best grown on moisture-retentive soils. They prefer mild climates and are generally grown only at altitudes below 200m (McDonald *et al*. 2004). Soils prone to water logging are unsuitable owing to the need for mechanised harvesting during the winter. Biomass crops are most likely to be grown on medium to poor quality agricultural land (ie Agricultural Land Classes 3 and 4 in England and Wales, and equivalents elsewhere in the UK), avoiding both very poor quality land (ie Land class 5 in England and Wales) and high quality land (ie Land classes 1 and 2 in England and Wales) on which production of higher value crops will be more profitable (RCEP 2004).

According to McDonald *et al*. (2004), at the time of their paper 98% of biomass crops were being grown on farmland, with the remaining 2% on reclaimed land from coal workings and on sewage drying land. None was being grown on ecologically rich sites.

The DEFRA website includes maps by region of existing sites for short rotation coppice (SRC) and *Miscanthus*[83], and these illustrate that both are now widespread in some counties, but much less so in others.

Land coverage: In 2007, by far the most important bioenergy crops for commercial deployment were *Miscanthus* and SRC, currently accounting for 12,627 and 2,600 ha respectively of planting under the Energy Crops Scheme in England and Wales. In total this amounts to only 0.13% of the 11.67 million ha of crops and grassland (excluding rough grassland) in the UK in 2006 (DEFRA 2007b).

As noted above, a considerable increase in uptake is likely, amounting at least to hundreds of thousands of hectares, or even millions under some scenarios.

5.7.2 Environmental impacts

As with biofuels, it is likely that a significant share of future biomass demand will be from imported feedstocks such as woodchips and waste from palm oil processing. However, this section focuses on domestic energy crops, and in particular *Miscanthus* and SRC. There may be additional impacts from the use of forest products, but it has not been possible to review these impacts within the time-scale of this study.

Waste products including municipal solid waste are potentially also an important source of biomass for combustion. Provided that they are not contaminated with toxic materials, using waste for heat and electricity generally represents a 'win-win' option in terms of environmental benefits; that is, as well as generating useful energy it can reduce the need

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83 DEFRA, Opportunities and optimum sitings for energy crops http://www.defra.gov.uk/farm/crops/industrial/energy/opportunities/index.htm for landfilling, cut landfill gases, etc. There are second order impacts of transporting materials to sites of incinerators and of siting extra incineration capacity.

Carbon dioxide emissions and/or reduction potential: Some greenhouse gas emissions are incurred in the growing, transporting and preparing of biomass sources as fuels. However, such inputs are generally significantly lower than for biofuel crops. At the same time, energy crops such as SRC are much more efficient at accumulating usable energy content, and the conversion efficiencies of burning them are far higher. As a result, biomass fuels have very low life cycle CO_2 emissions (RCEP 2004), and can be regarded as largely carbon-neutral.

Other pollutants/emissions: Fertiliser demands and other inputs for energy crops are very low, and they have few important pests or diseases. As a result there are few pollutant/emission issues raised. In fact, the replacement of intensive arable farmland with biomass crops would probably provide substantial water quality benefits as a result of reduced fertilizer inputs and reduced soil erosion rates (due to its near-continuous cover and absence of annual tillage).

Other emissions and physical impacts: Energy crops typically take up more water than other crops so they can have hydrological implications. Soil compaction during winter harvesting can also be an issue.

Transmission issues: Biomass fuels are solid, stable and fairly inert as long as fire risk is avoided. They offer few issues in terms of spillage. Having lower energy density than fossil fuels, they do engender an increased need for transportation unless they are produced locally. The latter is likely to be the case for many new combustion plants.

Biodiversity: The potential impacts of biomass will largely depend on the habitats that they replace and its scale of uptake. Since most SRC will be on farmland and will displace other agricultural crops, McDonald *et al* (2004) conclude that SRC is broadly beneficial in biodiversity terms. They highlight a range of habitat and biodiversity benefits of SRC in particular:

- It differs from the habitat normally available on farms;
- It typically forms larger blocks (>10ha);
- It is relatively long-lived in comparison to conventional annual crops;
- It is physically and chemically undisturbed for long periods;
- It may provide linking corridors between other habitats.

However, it also needs to be borne in mind that some SRC and *Miscanthus* will be grown on former set-aside land. Prior to its abolition, set-aside land accounted for up to 1 million ha of the total UK 17.5 million ha of agricultural land, but dedicated energy crops were allowed to be grown on this land and the pressure for bioenergy was arguably instrumental in the ending of set-aside.

Sage *et al* (2006) point out that SRC crop sites are often left weedy, and that this provides important opportunities for some birds. Very few studies of the actual use of biomass crops (especially *Miscanthus* and other grasses) by birds and other fauna have been carried out. And caution should be given to interpreting the results of the studies to date, as they have all been based on small crop areas and a limited number of trial sites, and thus may not be representative of the potential impacts of future commercial-scale biomass cropping systems.

Nevertheless, a number of studies have recently indicated that a wide range of farmland birds (including some declining species) could benefit from biomass SRC if it replaces intensive arable crops (Anderson & Fergusson 2006; Anderson *et al*. 2004; McDonald *et al*. 2004; Rowe *et al*. 2007; Sage *et al*. 2006; Semere & Slater 2004). Hedgerow and woodland edge species would probably benefit most, whilst open-field species would be displaced by the dense established crops. However, there is some evidence that some open-field species, such as Skylark (*Alauda arvensis*) and Lapwing (*Vanellus vanellus*) will use and nest within SRC and *Miscanthus* when the crops are at ground-level after harvesting. Thus SRC could provide benefits for such open-field species provided that rotational cropping provides some suitable open nesting habitat each year.

Some preliminary results from a current Rural Economy and Land Use (RELU) study of the impacts of biomass[84] are also showing potential benefits for a number of other taxa, including butterflies (Angela Karp and Alison Haughton *pers comm*.).

Overall, the positive benefits of biomass crops for birds would probably outweigh potential disbenefits (eg from habitat loss, reduced openness of the landscape and predator increases) provided that they are grown in appropriate locations and do not reduce habitat diversity in the landscape.

McDonald *et al* (2004) dismiss fears that energy crops will themselves become a monoculture, arguing that current practice suggests SRC concentration of no more than 2 per cent in the areas around biomass plants. However, more extreme projections of the use of energy crops imply much higher densities than this. Anderson and Fergusson (2006) highlight these issues of scale, and also point out that economic pressures will tend to lead to a concentration of energy crops in the areas around combustion plants.

Table 5.30 Biodiversity impacts of biomass production from short-rotation coppice and *Miscanthus* crops

Selected technology	Biomass (SRC and *Miscanthus*)
Direct mortality	None likely, if harvesting if carried out at appropriate times.
Direct habitat loss	Variable depending on the habitat replaced. Most likely to be grown on previous arable or grassland with benefits if at appropriate scales and locations. But a risk of some loss of semi-natural marginal farmland (eg wet grasslands) and possibly some post industrial sites of biodiversity importance.
Disturbance	Insignificant if operations are carried out at appropriate times.
Indirect habitat degradation	Uncertain, but probably mainly beneficial impacts if grown on former arable, due to lower fertiliser and agro-chemical use. Possible reduction in run-off into water-courses. Hydrological disruption if grown on wet grasslands etc.
Secondary impacts	
Potential for mitigation	Uncertain as technology is still under development. Mitigation requirements likely to be low.
Potential for ecological compensation	Variable depending on type of habitat lost. In most cases unlikely to be necessary.
Impacts outside the UK	Possible displacement of agricultural production (inc biofuels) to other countries with potentially high biodiversity impacts.

[84] *www.relu-biomass.org.uk*

The results of the vulnerability analysis summarised in Tables 5.31 below suggest that there will be few negative impacts of energy production from biomass crops on Priority Habitats and most of these will be low or very low under most of the selected future energy scenarios. However, there could be some moderate detrimental impacts on some of the habitats that may be targeted for biomass crops (ie Lowland Meadows, Coastal and Floodplain Grazing Marsh, Calamarian Grasslands and Open Mosaic Habitats on Previously Developed Land) under the Tyndall purple scenario, which projects an increase in biomass crops of over 2,300%.

The vulnerability analysis for UK BAP Priority birds suggests that there would be no significant detrimental impacts on any species under the selected scenarios, assuming that particularly sensitive sites are avoided (Table 5.32). Moreover, as discussed above, there would be some beneficial impacts for 26 species, though these would have very low or low impacts at a UK population level with the projected areas of biomass crops.

However, it is important to point out that the maximum increase in biomass use in the Tyndall purple scenario would require approximately 358,000 ha, which is a relatively small area compared to the potential for biomass crops (of perhaps 6 million ha) as described above under Section 5.7.1. Thus the impacts of such large-scale biomass production could be very different to those projected in this study.

Table 5.31 The estimated vulnerability of UKBAP Priority Habitats to energy production from biomass crops under current conditions and the future energy scenarios for 2020 and 2050

Notes: Impacts are based on likely residual impacts assuming basic mitigation measures are implemented effectively. See Section 2.3 for details of the analytical methods and Section 4.2 for the derivation of the energy scenarios. See Appendix 2 for vulnerability assessments for each habitat type.

		UK Government White Paper scenarios				Tyndall scenarios	
	Baseline	Central	Constrained	Central	Constrained	Red	Purple
	2008	2020	2020	2050	2050	2050	2050
% change in scenarios	-	159.0%	52.8%	121.0%	334.0%	253.0%	2352.0%
Average score	0.007%	0.018%	0.011%	0.015%	0.030%	0.024%	0.169%
Detrimental Impacts							
Critical (100%)	0	0	0	0	0	0	0
High (>10-100%)	0	0	0	0	0	0	0
Moderate (1-10%)	0	0	0	0	0	0	4
Low (0.1-1.0%)	4	4	4	4	4	4	3
Very low (0.01-0.1%)	3	3	3	3	3	3	0
No impact	49	49	49	49	49	49	49
Beneficial impacts							
High (>-10%)	0	0	0	0	0	0	0
Moderate (-1 to -10%)	0	0	0	0	0	0	0
Low (-0.1 to -1.0%)	0	0	0	0	0	0	5
Very low (-0.01 to -0.1%)	9	9	9	9	9	9	4

Table 5.32 The estimated vulnerability of UKBAP Priority birds to energy production from biomass crops under current conditions and the future energy scenarios for 2020 and 2050

Notes: Impacts are based on likely residual impacts assuming basic mitigation measures are implemented effectively. See Section 2.3 for details of the analytical methods and Section 4.2 for the derivation of the energy scenarios. See Appendix 3 for vulnerability assessments for each species.

		UK Government White Paper scenarios				Tyndall scenarios	
	Baseline	Central	Constrained	Central	Constrained	Red	Purple
	2008	2020	2020	2050	2050	2050	2050
% change in scenarios		159.0%	52.8%	121.0%	334.0%	253.0%	2352.0%
Average score	-0.006%	-0.015%	-0.009%	-0.012%	-0.024%	-0.020%	-0.138%
Detrimental Impacts							
Critical (100%)	0	0	0	0	0	0	0
High (>10-100%)	0	0	0	0	0	0	0
Moderate (1-10%)	0	0	0	0	0	0	0
Low (0.1-1.0%)	0	0	0	0	0	0	0
Very low (0.01-0.1%)	0	0	0	0	0	0	0
No impact	33	33	33	33	33	33	33
Beneficial impacts							
High (>-10%)	0	0	0	0	0	0	0
Moderate (-1 to -10%)	0	0	0	0	0	0	1
Low (-0.1 to -1.0%)	0	4	0	1	4	4	14
Very low (-0.01 to -0.1%)	26	22	26	25	22	22	11

5.8 Biofuels

5.8.1 Characterisation of the technology in the UK

Potential: Very unclear at present. Technical potential is large, but supply of first generation biofuels is likely to be limited by sustainability concerns over feedstock sources. The European Commission has proposed a 10 per cent target for road fuels for 2020, but this is proving controversial and the Commission itself emphasises that not all of this would come from first generation liquid biofuels.

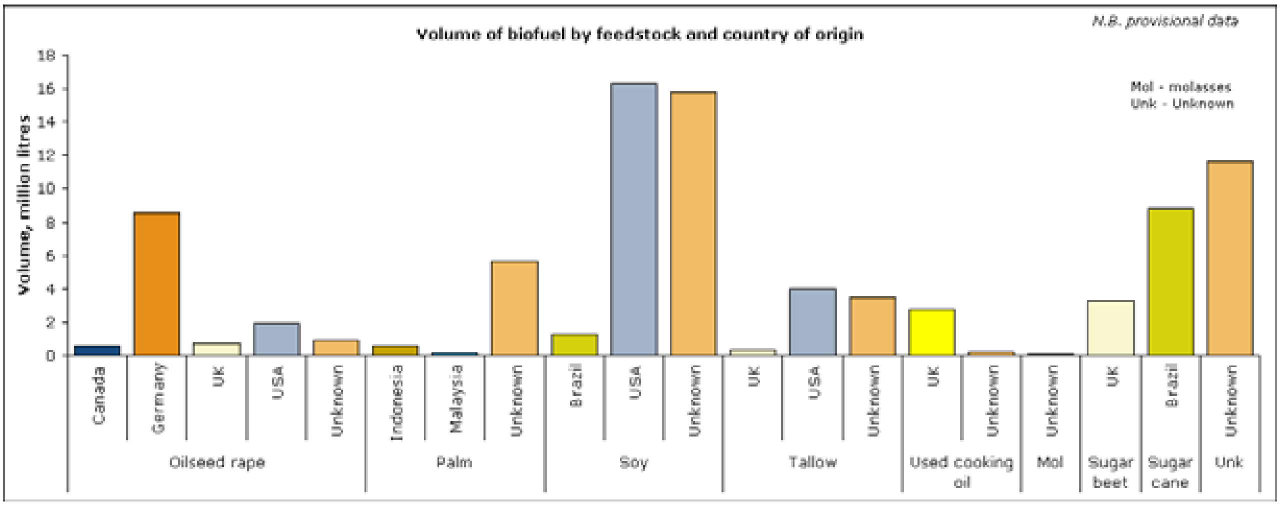
National targets/objectives: The UK's Renewable Transport Fuel Obligation (RTFO) requires that, by 2010, 5 per cent of all road vehicle fuel supplied to UK consumers should be from sustainable renewable sources – ie primarily biofuels. This will create a demand for 2.5 billion litres of biofuels a year.

Location: Any arable land suitable for growing similar crops (eg rapeseed, sugar beet) can be used. Production is likely to be concentrated around plants where feedstocks are converted into fuels.

Land coverage: As Figure 5.12 illustrates, however, only a very small proportion of UK biofuel use is currently from UK agricultural feedstocks. From calculations based on recent RFA reports on monthly biodiesel production (3.88 million litres) and bioethanol production (3.26 million litres) it is estimated that approximately 26,000 ha are used for biofuel production in the UK (6,000 ha as oil-seed-rape and 20,000 ha as sugar beet). This amounts to just 0.57% of the 4.56 million ha of arable crops in the UK in 2006 (DEFRA 2007b).

Potentially a large proportion of arable land could be used for biofuel production, although this will depend upon the relative economics of growing biofuel crops versus food or other end uses.

Figure 5.12 Source of biofuels used in the UK



Source: RFA 2008a

5.8.2 Environmental impacts

Carbon dioxide emissions and/or reduction potential: Smokers *et al* (2006) concluded that biofuels grown in Europe typically offer around a 50 per cent greenhouse gas reduction relative to their fossil fuel equivalents. The actual value varies according to fuel, feedstock and production process, and can be 10 per cent to 20 per cent higher or lower than this indicative average. Note that bioethanol from Brazilian sugarcane typically gives larger savings of 80 per cent or more.

Other pollutants/emissions: Commercial fuel conversion processes do not pose significant emissions problems, and in most respects fuels burnt in vehicles do not significantly affect tailpipe emissions. Blending ethanol into petrol increases evaporative emissions that contribute to tropospheric ozone formation. Home production and use of biodiesel can lead to increased pollutant emissions, but this is thought to be small in scale.

Other physical impacts: Growing crops for fuel use may open the way for increased deployment of GM crops, which might lead to changed levels of use of fertilisers or pesticides.

Transmission issues: Not significant; biofuels are generally safer to transport than their fossil equivalents, although lower energy density leads to some increase in the number of cargoes needed. Ethanol is highly toxic so spillage could cause local problems on land, but if spilt at sea it would rapidly disperse as it is water-soluble. Spillages offer no long term consequences as all biofuels are biodegradable.

- ***Domestic Production***

Biodiversity: In most respects, crops for biofuel production are identical to similar crops grown for food, so on a like-for-like basis there should be little difference in biodiversity or other environmental impacts if one is substituted for the other. Impacts that do arise will arise mainly from the knock-on effects of growing crops to meet increased demand for biofuels – eg loss of set-aside land, growing use of marginal land, changing crop patterns, and possibly more intensive agricultural production, see for example IEEP (2004).

- ***Imports***

Globally, in contrast, the land use implications of growing demand for biofuels can be very diverse and are currently attracting controversy. Concerns have been widely raised over the indirect impacts of this demand in terms of encouraging destruction of natural carbon sinks such as rainforests, wetlands and permanent grasslands. RSPB (2008) for example summarises some major impacts of new demand for biofuel feedstocks. As yet however, UK demand for imports from the most affected countries is small and unlikely to be contributing greatly to such effects. However, demand is predicted to grow substantially in both Europe and the US, so the likelihood of adverse effects is also likely to increase significantly unless suitable controls are put in place to favour sustainably-sourced biofuels.

Biodiversity: Major losses of biodiversity, and even global extinctions, are possible where biodiverse habitats are converted to plantations to grow biofuel crops for feedstocks such as soya or palm oil (Aratrakon *et al*. 2006; Koh 2007; Koh & Wilcove 2008). Reports of such displacement from countries such as Malaysia are now widespread, but are difficult to quantify and detailed analysis is beyond the scope of this study.

Table 5.33 Biodiversity impacts of biofuels

Selected technology	Biofuel
Direct mortality	Some incidental losses during harvesting, but unlikely to be significant.
Direct habitat loss	Variable depending on the habitat replaced. Most likely to be grown on previous arable land sometime with no change in crop type. But large expansion would increase the risk of loss of grassland and other habitats.
Disturbance	No increase in disturbance compared to existing arable farmland.
Indirect habitat degradation	Impacts are identical or similar to those of current arable crop production, with impacts from high rates of fertiliser use, pesticides, soil disturbance, hydrological disruption and silty run-off into water courses. Very low habitat diversity.
Secondary impacts	
Potential for mitigation	Uncertain, sustainable production of biofuels (eg with low fertiliser and pesticide use) probably technically feasible, but may not be viable or effective without a global accreditation scheme.
Potential for ecological compensation	Variable depending on type of habitat lost. In most cases unlikely to be necessary.
Impacts outside the UK	High use will require high imports (eg of ethanol from sugar cane or biodiesel from palm oil etc), with potentially substantial detrimental impacts on habitats of high biodiversity value (directly or via displacement). Production in the UK may also cause displacement of agricultural production to other countries.

The results of the vulnerability analysis summarised in Table 5.34 below suggests that 14 Priority Habitats are currently negatively affected by biofuel production and that there are no benefits. At the moment, these impacts are all very low or low as a result of the currently limited production of biofuels, and hence minimal influence on the farmland landscape. However, all of the selected energy scenarios project considerable increases in the use of biofuels in the UK, with a maximum increase of over 26,000 percent foreseen in the Tyndall purple scenario. If UK production increases proportionally then several grassland habitats could be vulnerable to moderate or even high impacts as a result of habitat conversion (see Appendix 2).

It is important to point out, however, that the assumption that UK biofuel production would increase in proportion to demand is highly uncertain and particularly unrealistic with regard to the Tyndall purple scenario. The total amount of land required (c. 6.76 million ha) under the purple scenario for biofuels would be greater then the current area of arable farmland (4.56 million ha) and would clearly require a massive conversion of grasslands to be achieved. Most of the biofuel demand would therefore need to be met by imports. Consequently, the impacts of domestic biofuel production projected under the other selected scenarios are probably more realistic.

Table 5.34 The estimated vulnerability of UKBAP Priority Habitats to energy production from biofuels under current conditions and the future energy scenarios for 2020 and 2050

Notes: Impacts are based on likely residual impacts assuming basic mitigation measures are implemented effectively. See Section 2.3 for details of the analytical methods and Section 4.2 for the derivation of the energy scenarios. See Appendix 2 for vulnerability assessments for each habitat type.

		UK Government White Paper scenarios				Tyndall scenarios	
	Baseline	Central	Constrained	Central	Constrained	Red	Purple
	2008	2020	2020	2050	2050	2050	2050
% change in scenarios		1906.0%	1310.0%	1691.0%	4275.0%	1878.0%	26426.0%
Average score	0.005%	0.103%	0.072%	0.092%	0.225%	0.102%	1.363%
Detrimental Impacts							
Critical (100%)	0	0	0	0	0	0	0
High (>10-100%)	0	0	0	0	0	0	3
Moderate (1-10%)	0	3	2	2	3	2	6
Low (0.1-1.0%)	2	6	7	7	6	7	4
Very low (0.01-0.1%)	11	4	4	4	4	4	0
No impact	52	52	52	52	52	52	52
Beneficial impacts							
High (>-10%)	0	0	0	0	0	0	0
Moderate (-1 to -10%)	0	0	0	0	0	0	0
Low (-0.1 to -1.0%)	0	0	0	0	0	0	0
Very low (-0.01 to -0.1%)	0	0	0	0	0	0	0

The vulnerability analysis for UK BAP Priority birds indicates that impacts would be in line with those projected for Priority Habitats, with 19 species potentially subject to detrimental impacts (Table 5.35). No benefits are envisaged. With current production levels, impacts are mostly very low, but several species could be vulnerable to moderate impacts under all the White Paper scenarios and the Tyndall red scenario.

Table 5.35 The estimated vulnerability of UKBAP Priority birds to energy production from biofuels under current conditions and the future energy scenarios for 2020 and 2050

Notes: Impacts are based on likely residual impacts assuming basic mitigation measures are implemented effectively. See Section 2.3 for details of the analytical methods and Section 4.2 for the derivation of the energy scenarios. See Appendix 3 for vulnerability assessments for each species.

		UK Government White Paper scenarios				Tyndall scenarios	
	Baseline	Central	Constrained	Central	Constrained	Red	Purple
	2008	2020	2020	2050	2050	2050	2050
% change in scenarios	-	1906.0%	1310.0%	1691.0%	4275.0%	1878.0%	26426.0%
Average score	0.012%	0.244%	0.171%	0.218%	0.532%	0.240%	3.224%
Detrimental Impacts							
Critical (100%)	0	0	0	0	0	0	0
High (>10-100%)	0	0	0	0	0	0	5
Moderate (1-10%)	0	5	4	5	7	5	11
Low (0.1-1.0%)	4	11	12	11	10	11	3
Very low (0.01-0.1%)	15	3	3	3	2	3	0
No impact	40	40	40	40	40	40	40
Beneficial impacts							
High (>-10%)	0	0	0	0	0	0	0
Moderate (-1 to -10%)	0	0	0	0	0	0	0
Low (-0.1 to -1.0%)	0	0	0	0	0	0	0
Very low (-0.01 to -0.1%)	0	0	0	0	0	0	0

5.9 Impacts of electricity transmission cables / power lines

The energy technologies that produce large quantities of electricity (ie coal, gas, nuclear, wind, tidal and, in part, biomass) will require linkages to the National Grid via transmission lines. There will therefore be additional impacts associated with these technologies that are not described in the sections above. These impacts will mostly affect birds and possibly some marine fauna, including fish and cetaceans.

It is well know that birds may be killed by over-head power-lines as a result of collisions or electrocution (Bevanger 1998; Drewitt & Langston 2008). Electrocution is a particular problem for large raptors, but risks are highly dependent on the design of power-lines (Haas *et al*. 2003). Bird mortality from electrocution appears to be uncommon in the UK, presumably as a result of the design of power lines.

However, large numbers of birds are killed in the UK as a result of collisions with overhead power cables. Death rates appear to vary considerably amongst species according to their flight characteristics. (Bevanger 1994 1998; Savereno *et al*. 1996; Janss 2000). Mortality rates can be high particularly amongst species such as herons, rails, cranes, game birds, and wildfowl that have small wings relative to body mass and a broad wing profile, making them less manoeuvrable in flight and thus less able to avoid unexpected obstacles.

From an analysis of ringed birds, Rose and Baillie (1989) found that the most vulnerable species in the UK were Mute Swan (*Cygnus olor*) and Canada Goose (*Branta canadensis*), as well as raptors, including Merlin (*Falco columbarius*), Peregrine (*Falco peregrinus*), Eurasian Buzzard (*Buteo buteo*) and Red Kite (*Milvus milvus*).

Passerines are generally thought to have a low risk of collisions, but some studies have recorded high numbers of fatalities. For example, Scott *et al*. (1972) recorded 1285 corpses of 74 species under 1 km of power lines at a migration hot-spot at Dungeness in Kent over a 6-year period. Most of the fatalities were nocturnal migrants including rails, thrushes, and warblers. Furthermore, after accounting for the loss of corpses to scavengers, it became apparent that less than 20% of corpses of small birds were located. Thus, it seems likely that some studies of collision rates (with power lines and wind turbines) may seriously underestimate fatalities if they do not measures and adjust for removal by scavengers.

Estimates of the numbers of birds killed by particular stretches of overhead line range from 2.95 to 489 birds per km per year (Faanes 1987; Alonso & Alonso 1999a; Erickson *et al*. 2005).

Despite the large numbers of individuals of some species (eg, Brown *et al*. 1992; Weaver & St Ores 1974), that are killed, Drewitt and Langston (2008) observe that nearly all studies of bird mortality resulting from collisions with overhead lines conclude that collision is not a significant cause of mortality (eg, Heijnis 1980; Beaulaurier 1981; Faanes 1987; Alonso & Alonso 1999a) and is not sufficient to affect national populations (Rose & Baillie 1989; Alonso &Alonso 1999a). However, they also point out that locally or regionally at least, collision mortality might be significant at the population level for some species, especially given the likelihood of underestimating collision mortality.

In the marine environment high voltage alternating current (AC) and direct current (DC) cables that transmit power have the potential to interact with aquatic animals that are sensitive to electric and magnetic fields (Gill 2005). This affects mainly fish, particularly the elasmobranchs, and marine mammals that use the Earth's magnetic field to navigate. In addition, some species utilize electric fields behaviourally.

The electromagnetic field emissions from underwater cables are tiny from a human perspective but they come within the range of bioelectrical emissions utilized by electrosensitive species. If the induced E fields emanating from submarine cables can be detected by electrosensitive species, then at levels that approximate the bioelectric fields of natural prey there is potential for these species to be attracted to them. Whether such species will be attracted or repelled by stronger fields is unknown at present, but will be dependent on them passing close to them.

Magnetosensitive species occur in coastal waters world-wide (eg migratory fish, elasmobranchs, mammals, chelonians and crustaceans) and these species are thought to be sensitive to the Earth's magnetic fields. Such species could therefore be affected by underwater cables, but whether there are any individual effects or population impacts is unknown.

According to Gill (2005) further research into the effects of underwater cables from off-shore energy devices on sensitive species, particularly benthic ones, is required, especially when assessing their impact at important local feeding or breeding grounds or nursery areas.

Table 5.36 Biodiversity impacts of electricity transmission lines

Selected technology	Power lines and pylons
Direct mortality	Collisions can be significant, especially if placed on flight-lines near wetlands etc. Electrocutions unlikely to be significant in UK.
Direct habitat loss	Insignificant in most habitats, but possible significant impacts on specific features if poorly sited.
Disturbance	Normally insignificant, though electro-magnetic fields from underwater power cables may affect fish and cetaceans.
Indirect habitat degradation	Normally insignificant, but construction works in sensitive habitats may be significant, eg soil compaction and hydrological disruption and erosion on peatlands.
Secondary impacts	
Potential for mitigation	Particularly sensitive sites can be avoided by re-routing or burial. Measures can be used to reduce collisions at high risk areas, but these are only partly effective.
Potential for ecological compensation	Variable, but not normally necessary.
Impacts outside the UK	None

6 COMPARISON OF POTENTIAL ENERGY SCENARIOS

6.1 Impact risk assessment for each environmental component.

The vulnerability assessments described above for each individual key technology have been combined to produce an overall assessment of the projected vulnerabilities of each Priority Habitat and Priority Species of bird to each energy scenario. This analysis is summarised in Tables 6.1 and 6.2 below, with habitats and species that are considered to be of moderate or high vulnerability listed in Tables 6.3 and 6.4 respectively (see Appendices 3 and 4 for all individual habitats and species). It should, however, be remembered that the combined analysis does not include the potential impacts of tidal barrages; because, although potentially significant, they are highly site-specific (see Section 5.6). Nor does the analysis take into account the possible impacts of additional transmission lines and associated infrastructures associated with the various technologies (see Section 5.9).

The results of the combined analysis indicate that all of the scenarios project increases in the vulnerability of most habitats, although there is also an increase in the proportion of Priority Habitats that are not impacted. However, these increases are rather small for all the White Paper based scenarios, especially with regards to 2020. In fact the number of habitats classed as moderately vulnerable drops in the two 2020 scenarios (though some habitats move from very low to low vulnerabilities).

All the scenarios project for 2050 an increase in the proportions of habitats in the moderate vulnerability class, though there is little change in the other categories under the White Paper scenarios.

The Tyndall red scenario shows an increases in the moderate and low vulnerability classes, but is not substantially different to the White Paper scenarios. The Tyndall purple scenario projects high vulnerabilities for three habitats (see Table 6.3), primarily as a result of the potential impacts from biofuels. There are also increases in the proportions of habitats occurring in the moderate and low categories under this scenario. However, at the same time the number of habitats that are considered to have no risk of significant impact doubles under this scenario.

The analysis also suggests that the potential benefits of some of the technologies are insufficient to overcome detrimental impacts from other technologies, such that only one habitat (Lowland Beech and Yew Woodland) has an overall positive assessment and only under one scenario (Tyndall purple).

Table 6.1 The estimated vulnerability of UKBAP Priority Habitats to all key energy production technologies under current conditions and the future energy scenarios for 2020 and 2050

Notes: Impacts are based on likely residual impacts assuming basic mitigation measures are implemented effectively. See Section 2.3 for details of the analytical methods and Section 4.2 for the derivation of the energy scenarios. See Appendix 2 for vulnerability assessments for each habitat type.

		UK Government White Paper scenarios				Tyndall scenarios	
	Baseline	Central	Constrained	Central	Constrained	Red	Purple
	2008	2020	2020	2050	2050	2050	2050
Average score	0.264%	0.361%	0.295%	0.512%	0.578%	0.517%	2.135%
Detrimental Impacts							
Critical (100%)	0	0	0	0	0	0	0
High (>10-100%)	0	0	0	0	0	0	3
Moderate (1-10%)	10	3	3	13	14	14	14
Low (0.1-1.0%)	10	22	20	10	12	22	18
Very low (0.01-0.1%)	39	31	33	33	30	20	11
No impact	6	9	9	9	9	9	18
Beneficial impacts							
High (>-10%)	0	0	0	0	0	0	0
Moderate (-1 to -10%)	0	0	0	0	0	0	0
Low (-0.1 to -1.0%)	0	0	0	0	0	0	0
Very low (-0.01 to -0.1%)	0	0	0	0	0	0	1

Table 6.2 UKBAP Priority Habitats that are considered to have moderate or high vulnerabilities under current conditions or any of the future energy scenarios for 2020 and 2050

Key. Moderate impacts = blue & underlined, High impacts = red and bold.

UK BAP Priority Habitat		UK Government White Paper				Tyndall	
		Central	Constrained	Central	Constrained	Red	Purple
	Current	2020	2020	2050	2050	2050	2050
Ponds	0.05%	0.41%	0.30%	0.38%	0.88%	0.40%	5.19%
Arable Field Margins	0.05%	0.98%	0.69%	0.87%	2.14%	0.95%	**13.03%**
Hedgerows	0.03%	0.40%	0.28%	0.35%	0.87%	0.38%	5.39%
Upland Oakwood	1.00%	0.86%	0.74%	1.96%	1.36%	1.58%	0.00%
Upland Mixed Ashwoods	1.00%	0.86%	0.74%	1.96%	1.36%	1.58%	0.00%
Lowland Mixed Deciduous Woodland	0.04%	0.21%	0.16%	0.20%	0.44%	0.20%	2.54%
Upland Birchwoods	1.00%	0.86%	0.74%	1.96%	1.36%	1.58%	0.00%
Lowland Dry Acid Grassland	0.13%	0.30%	0.23%	0.39%	0.58%	0.36%	2.66%
Lowland Calcareous Grassland	0.12%	0.30%	0.23%	0.39%	0.58%	0.36%	2.66%
Lowland Meadows	0.25%	2.37%	1.63%	2.11%	4.96%	2.46%	**29.72%**
Upland Hay Meadows	1.00%	0.86%	0.74%	1.96%	1.36%	1.58%	0.00%
Coastal and Floodplain Grazing Marsh	0.43%	2.48%	1.76%	2.20%	4.99%	2.57%	**30.39%**

UK BAP Priority Habitat		UK Government White Paper				Tyndall	
		Central	Constrained	Central	Constrained	Red	Purple
	Current	2020	2020	2050	2050	2050	2050
Upland Heathland	1.01%	0.90%	0.76%	2.01%	1.42%	1.75%	0.90%
Upland Flushes, Fens and Swamps	1.01%	0.90%	0.76%	2.01%	1.42%	1.75%	0.90%
Purple Moor Grass and Rush Pastures	0.03%	0.08%	0.05%	0.09%	0.11%	0.22%	1.15%
Lowland Fens	0.04%	0.25%	0.18%	0.23%	0.50%	0.25%	2.91%
Blanket Bog	1.02%	0.91%	0.76%	2.01%	1.44%	1.75%	1.30%
Mountain Heaths and Willow Scrub	1.00%	0.86%	0.74%	1.96%	1.36%	1.58%	0.00%
Calaminarian Grasslands	0.60%	0.70%	0.53%	1.21%	1.12%	1.14%	2.45%
Open Mosaic Habitats on Previously Developed Land	0.31%	0.42%	0.32%	0.35%	0.55%	0.40%	2.96%
Limestone Pavements	1.00%	0.86%	0.74%	1.96%	1.36%	1.58%	0.00%
Maritime Cliff and Slopes	0.13%	0.48%	0.25%	0.49%	0.59%	1.72%	9.03%
Coastal Vegetated Shingle	0.13%	0.12%	0.08%	0.08%	0.31%	0.18%	4.94%
Coastal Sand Dunes	0.13%	0.12%	0.08%	0.08%	0.31%	0.18%	4.94%
Intertidal mudflats	5.00%	5.00%	5.00%	5.00%	5.00%	5.00%	5.00%

The combined vulnerability analysis for UK BAP Priority Species of birds shows a similar pattern of results for birds (Table 5.28). However, there is a more obvious increase in the vulnerabilities of species from the current baseline (under which no species is considered to have more than a low vulnerability). As with the habitat analysis results, there is a clear increase in vulnerabilities across all the White Paper scenarios and the Tyndall red scenario, with several species moving into the moderate category (see Table 5.29).

It is clear that the most substantial impacts on UK BAP Priority birds would result from the Tyndall purple scenario, under which 5 species would considered to be highly vulnerable and 13 moderately vulnerable. Most of these species are currently associated with grasslands, mixed farmland or relatively low intensity arable farmland and are vulnerable to the extremely high increases in biofuel production that result in losses of grasslands and increasing arable intensification. However, as noted in the preceding chapter, it is highly unlikely that the production of biofuels in the UK would in practice increase in proportion to the increased use projected in the purple scenario.

Table 6.3 The estimated vulnerability of UKBAP Priority birds to all key energy production technologies under current conditions and the future energy scenarios for 2020 and 2050

Notes: Impacts are based on likely residual impacts assuming basic mitigation measures are implemented effectively. See Section 2.3 for details of the analytical methods and Section 4.2 for the derivation of the energy scenarios. See Appendix 3 for vulnerability assessments for each species.

		UK Government White Paper scenarios				Tyndall scenarios	
	Baseline	Central	Constrained	Central	Constrained	Red	Purple
	2008	2020	2020	2050	2050	2050	2050
Average score	0.047%	0.253%	0.183%	0.240%	0.539%	0.295%	3.314%
Detrimental Impacts							
Critical (100%)	0	0	0	0	0	0	0
High (>10-100%)	0	0	0	0	0	0	5
Moderate (1-10%)	0	5	4	5	7	6	13
Low (0.1-1.0%)	9	13	13	13	12	18	13
Very low (0.01-0.1%)	45	35	36	36	33	28	19
No impact	5	5	5	5	5	5	5
Beneficial impacts							
High (>-10%)	0	0	0	0	0	0	0
Moderate (-1 to -10%)	0	0	0	0	0	0	0
Low (-0.1 to -1.0%)	0	0	0	0	0	0	1
Very low (-0.01 to -0.1%)	0	1	1	0	2	2	3

Table 6.4 UKBAP Priority birds that are considered to have moderate or high vulnerabilities under current conditions or any of the future energy scenarios for 2020 and 2050

Key. Moderate impacts = blue & underlined, High impacts = red and bold.

UK BAP Priority Species		UK Govn White Paper				Tyndall	
		Central	Constrained	Central	Constrained	Red	Purple
	Current	2020	2020	2050	2050	2050	2050
Sky Lark	0.02%	0.36%	0.26%	0.32%	0.84%	0.33%	5.62%
European White-fronted Goose	0.21%	0.05%	0.02%	0.05%	0.06%	0.57%	1.30%
Stone-curlew	0.02%	0.57%	0.40%	0.51%	1.25%	0.55%	7.62%
Common Linnet	0.04%	0.38%	0.27%	0.33%	0.85%	0.34%	5.64%
Yellowhammer	0.02%	0.33%	0.24%	0.29%	0.76%	0.27%	5.15%
Reed Bunting	0.03%	0.18%	0.13%	0.15%	0.41%	0.14%	2.99%
Wood Lark	0.04%	0.41%	0.30%	0.39%	0.89%	0.42%	5.26%
Common Scoter	0.05%	0.67%	0.46%	0.61%	1.40%	0.85%	9.31%
Corn Bunting	0.10%	1.97%	1.40%	1.79%	4.32%	1.94%	**26.04%**
Yellow Wagtail	0.17%	2.99%	2.11%	2.69%	6.52%	2.94%	**39.44%**
Eurasian Curlew	0.67%	0.02%	0.02%	0.03%	0.02%	1.32%	1.31%
Eurasian Tree Sparrow	0.10%	1.93%	1.38%	1.75%	4.24%	1.88%	**25.56%**
Grey Partridge	0.05%	1.10%	0.80%	1.01%	2.43%	1.04%	**14.66%**
Hedge Accentor	0.01%	0.19%	0.14%	0.18%	0.42%	0.19%	2.56%
European Turtle Dove	0.00%	0.31%	0.24%	0.29%	0.71%	0.27%	4.35%
Common Starling	0.10%	1.98%	1.40%	1.77%	4.34%	1.95%	**26.37%**
Song Thrush	0.01%	0.19%	0.14%	0.18%	0.42%	0.19%	2.56%
Northern Lapwing	0.05%	0.22%	0.16%	0.20%	0.47%	0.20%	3.30%

7 CONCLUSIONS AND RECOMMENDATIONS

7.1 Evidence of impacts

This study has attempted to review the evidence of environmental impacts of a range of existing and developing energy technologies, especially with regards to biodiversity, geo-diversity, landscape and access, and from this develop projections of possible impacts from a range of selected energy scenarios.

The review has provided clear evidence that energy production can have significant impacts on the environment, particularly as a result of land take, disturbance, pollution and the accidental killing of some species (see summary in Table 3.1). However, it is also clear that the actual impacts of future developments of each energy technology will vary considerably as a result of three key factors:

- Their scale of use, as this directly affects their land requirements, and with increasing requirements there will an increasing likelihood that sensitive habitats and sites will be considered for use. This is most relevant to the production of energy from wind, tidal range (ie barrages), and especially biomass and biofuel crops, as these require large areas to produce significant energy contributions.

- Their location and in particular the degree to which particularly sensitive sites are avoided (eg through planning and licensing decisions that reflect the findings of adequate SEAs and EIAs). By avoiding sensitive sites it should be possible to avoid many of the most potentially significant impacts identified in this review (especially regarding the siting of new power stations, open cast coal mines, pipelines, wind farms and tidal barrages).

- The degree to which mitigation measures are identified and implemented, as some measures such as those that reduce emissions, noise, hydrological disruptions, disturbance and collisions have a major effect on potential impacts.

This study has attempted to strike a balance in its assessments by assuming that the most sensitive sites would be avoided and basic mitigation measures would be introduced. <u>Without such measures, the vulnerability of each habitat and species to each technology and scenario would be considerably higher than indicated in this study</u>. In particular, there is sufficient evidence to indicate that several habitats and species would be threatened if sensitive sites are not avoided. However, there is considerable uncertainty over the degree to which sensitive sites may be fully avoided in future, as illustrated for example by the renewed consideration of a Severn barrage. As discussed in Chapter 5.6, it seems very unlikely that such a project could go ahead without significant biodiversity impacts and without contravening the Habitats and Birds Directives.

7.2 Projections of potential future impacts

A key component of this study has been the review and selection of energy scenarios, as this provides the basis for the projections of future biodiversity impacts (which are based on a vulnerability assessments for UK BAP Priority Habitats and Priority Birds). However, the conclusions that can be drawn from these scenarios are limited for a number of reasons. In particular, the scenarios have been developed using fundamentally different approaches (which are understood in the research community, but which are often difficult for policymakers and the public to understand). There are bottom-up engineering models, top-down econometric models, scenarios involving hypothetical ‘storylines’, models where specific constraints (such as a -60 per cent target, or no nuclear) are fixed in advance, models where costs are not explicitly considered, and more.

These problems are exacerbated because little emphasis is often placed on explaining the design and assumptions behind modelling and scenarios, which are in fact of utmost importance to the outcomes. Furthermore, it is often difficult to obtain information about the way numbers are generated. For example, the European Commission often commissions work from the National Technical University of Athens and its Primes model, which is therefore quite influential – but for many policymakers and national experts it remains a ‘black box’ due to a lack of access to its inner workings.

At a more mundane level, there are difficulties comparing scenarios due to the different units used (capacity vs. energy produced; Mtoe vs. Twh; etc.), and the nature and detail of the breakdown of energy types. This is more than just a challenge for researchers; it presents barriers to any users of the material and can influence policy discussions. There is particular confusion in the way renewable energy is dealt with in the models, because many are often grouped in varying ways and specifics are ignored.

Many technologies are the subject of specific ongoing policy discussions, such as whether or not to use nuclear, tidal barrages and CCS etc. Estimates of wind power based on actual locations or requests for permitting are possible. But it is not often clear from summary data presented in modelling work whether the practical limits to technologies have been considered.

It should therefore be emphasised that the scenarios selected for this study are a few from a potentially wide and complex range of scenarios and merely represent plausible projections of an uncertain future; because many decisions will be driven by political and economic drivers, which are more difficult to predict than technological developments. This study has also needed to make some rather bold and simplistic assumptions regarding the contribution of specific renewable energy technologies to each scenario as these were not broken down in detail in the original studies.

Nevertheless, despite the limitations of this assessment, some clear patterns of potential impact are evident from the analysis of the current situation and projections from the selected energy scenarios. It is clear that the main biodiversity, geodiversity, landscape and access impacts of energy production that arise from fossil fuels and nuclear power come from the extraction / mining of the fuel (which include significant impacts outside the UK). The land take and hence habitat loss from power stations and associated facilities is relatively low and therefore there are likely to be few biodiversity and geodiversity impacts under most scenarios (provided that sensitive sites are avoided). However, more significant impacts could arise from a major expansion of nuclear power (as envisaged under the Tyndall purple scenario) as nuclear plants are concentrated on the coast and in remote areas. Many coastal habitats are of high biodiversity and landscape value and are accordingly designated as protected areas.

In the past the combustion of coal has been the primary source of emissions of sulphur dioxide and nitrogen oxides, which contribute to acidification and eutrophication of vegetation and aquatic habitats in particular. However, as a result of the decline in the use of coal and the introduction of technological developments that can reduce emissions, such impacts are now less significant than those from the transport sector. Nevertheless, many habitats are threatened by widespread eutrophication as a result of nitrogen deposition and the UK is unlikely to meet its EU Emissions Ceilings Directive target for nitrogen oxides. Future energy policies will therefore need to take these emissions into account.

Renewable energy resources are much less intensive in terms of their energy production than fossil fuels and nuclear power. They therefore require a large area to be viable, especially at sea. Consequently, their impacts potentially include large-scale habitat change as a result of hydro-power dams, tidal barrages, biomass and biofuel crops. The specific location of dams and barrages will profoundly affect their potential impacts and should be adequately regulated through impact assessments, the planning system and other policy/technical tools.

In contrast, the impacts of biomass and biofuel crops will not tend to be site specific and will be less regulated. Their impacts will very much depend on their scale and the type of habitats that they replace. At the moment biofuel production probably merely displaces existing arable crops (and consists in some case of the same crop). But a major expansion in biofuels (as would be needed under the Tyndall purple scenario) would probably lead to further intensification and expansion of arable farming with possible losses of grasslands (some of which may be of high biodiversity value).

Under most scenarios and with appropriate management, it seems likely that the production of biomass crops could lead to some biodiversity benefits (from the provision of habitats and reductions in nutrient pollution in water courses), if concentrated within existing arable farmland or improved grasslands. However, as with biofuels, large scales of production could lead to the loss of grasslands and other habitats of high biodiversity importance with potentially significant landscape, access and biodiversity impacts. Furthermore, declines in the viability of livestock farming in the UK could increase the risks of large-scale conversion of grassland to biomass and biofuel production.

A large number of wind turbines, tidal turbines and wave devices will also be needed to produce substantial amounts of energy (as for example would be necessary under the Tyndall scenarios). But their combined footprints will usually be of less significance than other indirect impacts. Wind turbines have obvious impacts on the landscape and poorly sited wind farms may pose a significant threat to some bird and bat populations. However, appropriate siting and mitigation measures should normally be able to adequately address biodiversity issues and reduce landscape impacts.

7.3 Recommendations for further work

As described in Section 2, this study has been carried out in a short-time scale and has therefore not been able to include a thorough review or analysis of evidence or address all environmental issues comprehensively. It is therefore suggested that a follow up study should be undertaken to explore the key results in more detail and fill the most significant gaps. In particular, it is suggested that such as study should:

- Fill information gaps for which there is available information (eg from EIAs and ongoing research).

- Consider other energy scenarios (especially for 2020).

- Review and refine the vulnerability assessments, eg by linking assessments for habitats and species to evidence more directly (as most assessments are inferred from generic impacts) and enabling peer reviews of the assessments.

- Increasing the range of species used as indicators of impacts (eg using other taxa groups, to better assess potential impacts on species) that are not currently threatened.

- Carry out a more-in depth review of impacts on landscapes, geodiversity and access.

- Further review impacts on biodiversity outside the UK.

However, any further assessment will still be constrained by numerous significant knowledge gaps. These will need to be further investigated by primary research, and some suggested priority issues include:

- Impacts of tidal barrages on marine ecosystems, including effects on planktonic and benthic food-webs and communities, productivity and impacts on fish and birds.

- Collision risks and possible population level impacts of underwater turbines.

- Impacts of underwater noise (eg from oil rig works, demolition, wind turbines and tidal turbines) on cetaceans and other potentially sensitive species.

- Further research into collisions rates from wind turbines (and overhead power lines) particularly offshore, and their impacts on populations; and potential mitigation measures.

- Probable growing locations and management practices for bioenergy crops (including novel crops).

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APPENDIX 1. IMPACTS OF RENEWABLE ENERGY TECHNOLOGIES SUMMARISED BY BAP BROAD HABITAT

Source: Hossell *et al.* (2006)

Key:
Impacts: Bold & Red = significant negative impact predicted post-mitigation.
Not bold & Green (or lower cell, where present) = significant positive impact predicted post-mitigation.

Taxa groups impacted: P = Plants; TM = Terrestrial/freshwater mammals; Bi = Birds; TI = Terrestrial invertebrates; A = Amphibians; R = Reptiles; Ba = Bats; Fu = Fungi; FI = Freshwater invertebrates; Fi = Fish (Marine or freshwater); MM = Marine mammals.

Notes: Novel technologies comprise photovoltaic cells, solar water heat panels, hydrogen fuel-cells and ground source heat pumps. Symbols for marine invertebrates were missing from the original report and are not included here.

	Energy Technology						
	Biomass	**On-shore Wind**	**Off-shore Wind**	**Hydro- electric**	**Tidal**	**Wave**	**Novel Technologies**
Terrestrial/ urban/ freshwater habitats							
Broadleaved, mixed and yew woodland (includes *Lowland beech and yew woodland, Upland mixed ashwoods, Upland oakwood* and *Wet woodland*)	**P TM Bi TI Ba Fu**			**P TM Bi TI R A Fu**			**P TI**
Coniferous woodland (includes *Native pine woods*)	**P TM Bi TI R Ba Fu**			**P TM Bi TI R A Fu**			**P TI**
Arable and horticulture (includes *Cereal field margins)*	**P TM Bi TI**	**P TM Bi R A Ba**					**P TI**
	P TM Bi TI R A Ba						
Bogs (includes *Blanket bog* and *Lowland raised bog*)		**P TM Bi R A Ba**		**P TM Bi TI R A**			**P TI**

	Energy Technology						
	Biomass	On-shore Wind	Off-shore Wind	Hydro- electric	Tidal	Wave	Novel Technologies
Boundary and linear features (includes *Ancient and species rich hedgerows*)	TM Bi TI A	P TM Bi R A Ba		P TM Bi TI R A			P TI
	P TM Bi TI R A Ba						
Dwarf shrub heath	P TM Bi TI R A Ba	P TM Bi R A Ba		P TM Bi TI R A			P TI
	P TM Bi TI R A Ba						
Bracken	P TM Bi TI	P TM Bi R A Ba		P TM Bi TI R A			
	P TM Bi TI R A Ba						
Built up areas and gardens							B
Fen, marsh and swamp (includes *Aquifer fed naturally fluctuating water bodies, Reedbeds and Fens*)		P TM Bi R A Ba		P TM Bi TI R A			
Improved grassland	P TI	P Bi		P TM Bi TI R A			P TI
	P TM Bi TI R A Ba						
Neutral grassland	P TM Bi TI R A	P Bi TI		P TM Bi TI R A			P TI
	P TM Bi TI R A Ba						
Calcareous grassland (includes *Lowland calcareous grassland* and *Upland calcareous grassland*)	P TM Bi TI R A Fu	P Bi TI		P TM Bi TI R A Fu			P TI
	P TM Bi TI R A Ba						

	Energy Technology						
	Biomass	**On-shore Wind**	**Off-shore Wind**	**Hydro- electric**	**Tidal**	**Wave**	**Novel Technologies**
Acid grassland (includes *Lowland dry acid grassland*)	**P TM Bi TI R A Fu**	**P Bi TI**		**P TM Bi TI R A**			**P TI**
	P TM Bi TI R A Ba						
Inland rock (includes *Limestone pavement*)		**P**		**P TM B TI R A**			
Montane habitats		**P TM B TI R A**		**P TM B TI R A**			
Rivers and streams (includes *Chalk Rivers)*				**P TM B Fi FI**	**B Fi**	**P B Fi**	**P TI**
Standing open water and canals (includes *Eutrophic standing water, Mesotrophic lakes* and *Saline lagoons)*				**P TM B Fi FI**	**B Fi**	**P B Fi**	**P TI**
				P TM B Fi FI	B Fi		
Urban							**B**
Marine/estuarine habitats							
Continental shelf slope			**Fi MM**				
Inshore sublittoral rock			**Fi MM**		**Fi**	**P Fi**	
						B Fi MM	
Inshore sublittoral sediment (includes *Sublittoral sand and gravel*)			**Fi MM**		**Fi**	**P Fi**	
						B Fi MM	

	Energy Technology						
	Biomass	On-shore Wind	Off-shore Wind	Hydro- electric	Tidal	Wave	Novel Technologies
Littoral rock			B $\bar{\text{F}}$i		B $\bar{\text{F}}$i	P B $\bar{\text{F}}$i	
						B Fi E	
Littoral sediment (includes *Mudflats*)			B $\bar{\text{F}}$i		B $\bar{\text{F}}$i	P B $\bar{\text{F}}$i	
Oceanic seas			Fi MM		$\bar{\text{F}}$i	P $\bar{\text{F}}$i	
						B Fi MM	
Offshore shelf rock			$\bar{\text{F}}$i MM		$\bar{\text{F}}$i	P $\bar{\text{F}}$i	
						B Fi MM	
Offshore shelf sediment			$\bar{\text{F}}$i MM		$\bar{\text{F}}$i	P $\bar{\text{F}}$i	
						B Fi MM	
Supralittoral rock (includes *Maritime cliffs and slopes*)		P B	B $\bar{\text{F}}$i MM		B $\bar{\text{F}}$i	B $\bar{\text{F}}$i	
Supralittoral sediment (includes *Coastal saltmarsh, Coastal vegetated shingle, Coastal sand dunes* and *Machair*)		P B	B $\bar{\text{F}}$i MM		B $\bar{\text{F}}$i	B $\bar{\text{F}}$i	

APPENDIX 2. VULNERABILITY ASSESSMENTS FOR UK BAP PRIORITY HABITATS

Impacts are based on likely residual impacts assuming basic mitigation measures are implemented effectively. Complete avoidance of protected habitats and features is not assumed.

Sensitivity estimates the maximum extent of degradation of a habitat that would be likely from the activity taking into account direct and indirect impacts. 0 = no impact, 1 = total destruction. Adaptation estimates the capacity for the habitat to recover or be restored or recreated. E.g. 0.1 indicates that only 10% of impact will last. 2 indicates habitats that are under severe stress for which impacts will be particularly severe. Exposure estimates the proportion of the habitat that may be potentially impacted under current conditions and the selected energy scenarios.

Coal	**Current**				**UK Govn White Paper**				**Tyndall**	
	Sensitivity	**Adaptation**	**Exposure**	**Impact**	**Central**	**Constrained**	**Central**	**Constrained**	**Red**	**Purple**
			Baseline		**2020**	**2020**	**2050**	**2050**	**2050**	**2050**
Relative exposure increase / decrease from scenarios					**-14.2%**	**-26.5%**	**96.1%**	**36.3%**	**57.6%**	**-100.0%**
Broad Habitat (bold) / Priority Habitat					**Impact**	**Impact**	**Impact**	**Impact**	**Impact**	**Impacts**
Rivers and Streams										
Rivers	10.0%	100%	0.10%	0.01%	0.01%	0.01%	0.02%	0.01%	0.02%	0.00%
Standing Open Water and Canals										
Oligotrophic and Dystrophic Lakes	10.0%	100%	0.01%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Ponds	100.0%	100%	0.01%	0.01%	0.01%	0.01%	0.02%	0.01%	0.02%	0.00%
Mesotrophic Lakes	10.0%	100%	0.10%	0.01%	0.01%	0.01%	0.02%	0.01%	0.02%	0.00%
Eutrophic Standing Waters	1.0%	100%	0.10%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Aquifer Fed Naturally Fluctuating Water Bodies	10.0%	100%	0.01%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Arable & Horticultural										
Arable Field Margins	100.0%	20%	0.01%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Boundary & Linear Features										
Hedgerows	100.0%	20%	0.01%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Broadleaved, Mixed and Yew Woodland										
Traditional Orchards	100.0%	100%	0.01%	0.01%	0.01%	0.01%	0.02%	0.01%	0.02%	0.00%
Wood-Pasture & Parkland	100.0%	100%	0.01%	0.01%	0.01%	0.01%	0.02%	0.01%	0.02%	0.00%
Upland Oakwood	10.0%	100%	10.00%	1.00%	0.86%	0.74%	1.96%	1.36%	1.58%	0.00%
Lowland Beech and Yew Woodland	100.0%	100%	0.01%	0.01%	0.01%	0.01%	0.02%	0.01%	0.02%	0.00%
Upland Mixed Ashwoods	10.0%	100%	10.00%	1.00%	0.86%	0.74%	1.96%	1.36%	1.58%	0.00%
Wet Woodland	100.0%	100%	0.01%	0.01%	0.01%	0.01%	0.02%	0.01%	0.02%	0.00%
Lowland Mixed Deciduous Woodland	100.0%	100%	0.01%	0.01%	0.01%	0.01%	0.02%	0.01%	0.02%	0.00%
Upland Birchwoods	10.0%	100%	10.00%	1.00%	0.86%	0.74%	1.96%	1.36%	1.58%	0.00%
Coniferous Woodland										
Native Pine Woodlands	100.0%	100%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Acid Grassland										
Lowland Dry Acid Grassland	10.0%	100%	1.00%	0.10%	0.09%	0.07%	0.20%	0.14%	0.16%	0.00%

Coal	Current				UK Govn White Paper				Tyndall	
	Sensitivity	Adaptation	Exposure	Impact	Central	Constrained	Central	Constrained	Red	Purple
			Baseline		2020	2020	2050	2050	2050	2050
Calcareous Grassland										
Lowland Calcareous Grassland	10.0%	100%	1.00%	0.10%	0.09%	0.07%	0.20%	0.14%	0.16%	0.00%
Upland Calcareous Grassland	100.0%	100%	0.01%	0.01%	0.01%	0.01%	0.02%	0.02%	0.02%	0.00%
Neutral Grassland										
Lowland Meadows	100.0%	100%	0.01%	0.01%	0.01%	0.01%	0.02%	0.01%	0.02%	0.00%
Upland Hay Meadows	10.0%	100%	10.00%	1.00%	0.86%	0.74%	1.96%	1.36%	1.58%	0.00%
Improved Grassland										
Coastal and Floodplain Grazing Marsh	100.0%	100%	0.01%	0.01%	0.01%	0.01%	0.02%	0.01%	0.02%	0.00%
Dwarf Shrub Heath										
Lowland Heathland	100.0%	100%	0.01%	0.01%	0.01%	0.01%	0.02%	0.01%	0.02%	0.00%
Upland Heathland	10.0%	100%	10.00%	1.00%	0.86%	0.74%	1.96%	1.36%	1.58%	0.00%
Fen, Marsh and Swamp										
Upland Flushes, Fens and Swamps	10.0%	100%	10.00%	1.00%	0.86%	0.74%	1.96%	1.36%	1.58%	0.00%
Purple Moor Grass and Rush Pastures	100.0%	100%	0.01%	0.01%	0.01%	0.01%	0.02%	0.01%	0.02%	0.00%
Lowland Fens	100.0%	100%	0.01%	0.01%	0.01%	0.01%	0.02%	0.01%	0.02%	0.00%
Reedbeds	100.0%	100%	0.01%	0.01%	0.01%	0.01%	0.02%	0.01%	0.02%	0.00%
Bogs										
Lowland Raised Bog	100.0%	100%	0.01%	0.01%	0.01%	0.01%	0.02%	0.01%	0.02%	0.00%
Blanket Bog	10.0%	100%	10.00%	1.00%	0.86%	0.74%	1.96%	1.36%	1.58%	0.00%
Montane Habitats										
Mountain Heaths and Willow Scrub	10.0%	100%	10.00%	1.00%	0.86%	0.74%	1.96%	1.36%	1.58%	0.00%
Inland Rock										
Inland Rock Outcrop and Scree Habitats	100.0%	100%	0.01%	0.01%	0.01%	0.01%	0.02%	0.01%	0.02%	0.00%
Calaminarian Grasslands	100.0%	50%	1.00%	0.50%	0.43%	0.37%	0.98%	0.68%	0.79%	0.00%
Open Mosaic Habitats on Previously Developed Land	0.0%	50%	1.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Limestone Pavements	10.0%	100%	10.00%	1.00%	0.86%	0.74%	1.96%	1.36%	1.58%	0.00%
Supralittoral Rock										
Maritime Cliff and Slopes	100.0%	100%	0.01%	0.01%	0.01%	0.01%	0.02%	0.01%	0.02%	0.00%
Supralittoral Sediment										
Coastal Vegetated Shingle	100.0%	100%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Machair	100.0%	100%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Coastal Sand Dunes	100.0%	100%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Littoral rock										
Intertidal chalk	10.0%	100%	0.01%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Intertidal boulder communities	10.0%	100%	0.01%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Sabellaria alveolata reefs	10.0%	100%	0.01%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Littoral sediment										
Coastal saltmarsh	0.0%	100%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Intertidal mudflats	10.0%	100%	0.01%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Seagrass beds	10.0%	100%	0.01%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Sheltered muddy gravels	0.0%	100%	0.01%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%

Coal	Current				UK Govn White Paper				Tyndall	
	Sensitivity	Adaptation	Exposure	Impact	Central	Constrained	Central	Constrained	Red	Purple
			Baseline		2020	2020	2050	2050	2050	2050
Peat and clay exposures	0.0%	100%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Sublittoral rock										
Subtidal chalk	0.0%	100%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Tide-swept channels	0.0%	100%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Fragile sponge & anthozoan communities on subtidal rocky habitats	10.0%	100%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Estuarine rocky habitats	10.0%	100%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Seamount communities	0.0%	100%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Carbonate mounds	0.0%	100%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Cold-water coral reefs	0.0%	100%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Deep-sea sponge communities	0.0%	100%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Sabellaria spinulosa reefs	10.0%	100%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Sublittoral sediment										
Subtidal sands and gravels	0.0%	100%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Horse mussel beds	10.0%	100%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Mud habitats in deep water	0.0%	100%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
File shell beds	0.0%	100%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Maerl beds	10.0%	100%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Serpulid reefs	10.0%	100%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Blue mussel beds	10.0%	100%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Saline lagoons	10.0%	100%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%

Gas	Current				UK Govn White Paper				Tyndall	
	Sensitivity	Adaptation	Exposure	Impact	Central	Constrained	Central	Constrained	Red	Purple
			Baseline		2020	2020	2050	2050	2050	2050
Relative exposure increase / decrease from scenarios					-13.2%	-5.5%	-25.5%	-43.3%	-91.1%	-87.9%
Broad Habitat (bold) / Priority Habitat					**Impact**	**Impact**	**Impact**	**Impact**	**Impact**	**Impacts**
Rivers and Streams										
Rivers	0.0%	100%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Standing Open Water and Canals										
Oligotrophic and Dystrophic Lakes	0.0%	100%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Ponds	100.0%	100%	0.01%	0.01%	0.01%	0.01%	0.01%	0.01%	0.00%	0.00%
Mesotrophic Lakes	0.0%	100%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Eutrophic Standing Waters	0.0%	100%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Aquifer Fed Naturally Fluctuating Water Bodies	0.0%	100%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Arable & Horticultural										
Arable Field Margins	100.0%	20%	0.01%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Boundary & Linear Features										
Hedgerows	100.0%	20%	0.01%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Broadleaved, Mixed and Yew Woodland										
Traditional Orchards	100.0%	100%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Wood-Pasture & Parkland	100.0%	100%	0.01%	0.00%	0.01%	0.01%	0.01%	0.01%	0.00%	0.00%
Upland Oakwood	0.0%	100%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Lowland Beech and Yew Woodland	100.0%	100%	0.01%	0.00%	0.01%	0.01%	0.01%	0.01%	0.00%	0.00%
Upland Mixed Ashwoods	0.0%	100%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Wet Woodland	100.0%	100%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Lowland Mixed Deciduous Woodland	100.0%	100%	0.01%	0.01%	0.01%	0.01%	0.01%	0.01%	0.00%	0.00%
Upland Birchwoods	0.0%	100%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Coniferous Woodland										
Native Pine Woodlands	0.0%	100%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Acid Grassland										
Lowland Dry Acid Grassland	100.0%	100%	0.01%	0.00%	0.01%	0.01%	0.01%	0.01%	0.00%	0.00%
Calcareous Grassland										
Lowland Calcareous Grassland	100.0%	100%	0.01%	0.00%	0.01%	0.01%	0.01%	0.01%	0.00%	0.00%
Upland Calcareous Grassland	0.0%	100%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Neutral Grassland										
Lowland Meadows	100.0%	100%	0.01%	0.00%	0.01%	0.01%	0.01%	0.01%	0.00%	0.00%
Upland Hay Meadows	0.0%	100%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Improved Grassland										
Coastal and Floodplain Grazing Marsh	100.0%	100%	0.10%	0.10%	0.09%	0.09%	0.07%	0.06%	0.01%	0.01%
Dwarf Shrub Heath										
Lowland Heathland	100.0%	100%	0.01%	0.01%	0.01%	0.01%	0.01%	0.01%	0.00%	0.00%
Upland Heathland	0.0%	100%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%

Gas	Current				UK Govn White Paper				Tyndall	
	Sensitivity	Adaptation	Exposure	Impact	Central	Constrained	Central	Constrained	Red	Purple
			Baseline		2020	2020	2050	2050	2050	2050
Fen, Marsh and Swamp										
Upland Flushes, Fens and Swamps	0.0%	100%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Purple Moor Grass and Rush Pastures	0.0%	100%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Lowland Fens	100.0%	100%	0.01%	0.00%	0.01%	0.01%	0.01%	0.01%	0.00%	0.00%
Reedbeds	100.0%	20%	0.01%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Bogs										
Lowland Raised Bog	0.0%	100%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Blanket Bog	0.0%	100%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Montane Habitats										
Mountain Heaths and Willow Scrub	0.0%	100%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Inland Rock										
Inland Rock Outcrop and Scree Habitats	0.0%	100%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Calaminarian Grasslands	100.0%	100%	0.01%	0.00%	0.01%	0.01%	0.01%	0.01%	0.00%	0.00%
Open Mosaic Habitats on Previously Developed Land	100.0%	100%	0.10%	0.10%	0.09%	0.09%	0.07%	0.06%	0.01%	0.01%
Limestone Pavements	0.0%	100%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Supralittoral Rock										
Maritime Cliff and Slopes	100.0%	100%	0.01%	0.01%	0.01%	0.01%	0.01%	0.01%	0.00%	0.00%
Supralittoral Sediment										
Coastal Vegetated Shingle	100.0%	100%	0.01%	0.01%	0.01%	0.01%	0.01%	0.01%	0.00%	0.00%
Machair	100.0%	100%	0.01%	0.01%	0.01%	0.01%	0.01%	0.01%	0.00%	0.00%
Coastal Sand Dunes	100.0%	100%	0.01%	0.01%	0.01%	0.01%	0.01%	0.01%	0.00%	0.00%
Littoral rock										
Intertidal chalk	100.0%	100%	0.01%	0.01%	0.01%	0.01%	0.01%	0.01%	0.00%	0.00%
Intertidal boulder communities	100.0%	100%	0.01%	0.01%	0.01%	0.01%	0.01%	0.01%	0.00%	0.00%
Sabellaria alveolata reefs	100.0%	100%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Littoral sediment										
Coastal saltmarsh	100.0%	100%	0.01%	0.01%	0.01%	0.01%	0.01%	0.01%	0.00%	0.00%
Intertidal mudflats	1.0%	100%	0.01%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Seagrass beds	1.0%	100%	0.01%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Sheltered muddy gravels	1.0%	100%	0.01%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Peat and clay exposures	100.0%	100%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Sublittoral rock										
Subtidal chalk	100.0%	100%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Tide-swept channels	100.0%	100%	0.01%	0.01%	0.01%	0.01%	0.01%	0.01%	0.00%	0.00%
Fragile sponge & anthozoan communities on subtidal rocky habitats	100.0%	100%	0.01%	0.01%	0.01%	0.01%	0.01%	0.01%	0.00%	0.00%
Estuarine rocky habitats	100.0%	100%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Seamount communities	0.0%	100%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Carbonate mounds	100.0%	100%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Cold-water coral reefs	100.0%	100%	0.01%	0.01%	0.01%	0.01%	0.01%	0.01%	0.00%	0.00%
Deep-sea sponge communities	0.0%	100%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Sabellaria spinulosa reefs	100.0%	100%	0.01%	0.01%	0.01%	0.01%	0.01%	0.01%	0.00%	0.00%

Gas	Current				UK Govn White Paper				Tyndall	
	Sensitivity	Adaptation	Exposure	Impact	Central	Constrained	Central	Constrained	Red	Purple
			Baseline		2020	2020	2050	2050	2050	2050
Sublittoral sediment										
Subtidal sands and gravels	100.0%	100%	0.01%	0.01%	0.01%	0.01%	0.01%	0.01%	0.00%	0.00%
Horse mussel beds	100.0%	100%	0.01%	0.01%	0.01%	0.01%	0.01%	0.01%	0.00%	0.00%
Mud habitats in deep water	100.0%	100%	0.01%	0.01%	0.01%	0.01%	0.01%	0.01%	0.00%	0.00%
File shell beds	100.0%	100%	0.01%	0.01%	0.01%	0.01%	0.01%	0.01%	0.00%	0.00%
Maerl beds	100.0%	100%	0.01%	0.01%	0.01%	0.01%	0.01%	0.01%	0.00%	0.00%
Serpulid reefs	100.0%	100%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Blue mussel beds	100.0%	100%	0.01%	0.01%	0.01%	0.01%	0.01%	0.01%	0.00%	0.00%
Saline lagoons	100.0%	100%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%

Oil	Current				UK Govn White Paper				Tyndall	
	Sensitivity	Adaptation	Exposure	Impact	Central	Constrained	Central	Constrained	Red	Purple
			Baseline		2020	2020	2050	2050	2050	2050
Relative exposure increase / decrease from scenarios					-32.5%	-32.5%	-49.7%	-69.6%	-59.2%	-2.4%
Broad Habitat (bold) / Priority Habitat					**Impact**	**Impact**	**Impact**	**Impact**	**Impact**	**Impacts**
Rivers and Streams										
Rivers	0.0%	100%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Standing Open Water and Canals										
Oligotrophic and Dystrophic Lakes	0.0%	100%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Ponds	100.0%	100%	0.01%	0.01%	0.01%	0.01%	0.01%	0.00%	0.00%	0.01%
Mesotrophic Lakes	0.0%	100%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Eutrophic Standing Waters	0.0%	100%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Aquifer Fed Naturally Fluctuating Water Bodies	0.0%	100%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Arable & Horticultural										
Arable Field Margins	100.0%	20%	0.01%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Boundary & Linear Features										
Hedgerows	100.0%	20%	0.01%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Broadleaved, Mixed and Yew Woodland										
Traditional Orchards	100.0%	100%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Wood-Pasture & Parkland	100.0%	100%	0.01%	0.01%	0.01%	0.01%	0.01%	0.00%	0.00%	0.01%
Upland Oakwood	0.0%	100%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Lowland Beech and Yew Woodland	100.0%	100%	0.01%	0.01%	0.01%	0.01%	0.01%	0.00%	0.00%	0.01%
Upland Mixed Ashwoods	0.0%	100%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Wet Woodland	100.0%	100%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Lowland Mixed Deciduous Woodland	100.0%	100%	0.01%	0.01%	0.01%	0.01%	0.01%	0.00%	0.00%	0.01%
Upland Birchwoods	0.0%	100%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Coniferous Woodland										
Native Pine Woodlands	0.0%	100%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Acid Grassland										
Lowland Dry Acid Grassland	100.0%	100%	0.01%	0.01%	0.01%	0.01%	0.01%	0.00%	0.00%	0.01%
Calcareous Grassland										
Lowland Calcareous Grassland	100.0%	100%	0.01%	0.01%	0.01%	0.01%	0.01%	0.00%	0.00%	0.01%
Upland Calcareous Grassland	0.0%	100%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Neutral Grassland										
Lowland Meadows	100.0%	100%	0.01%	0.01%	0.01%	0.01%	0.01%	0.00%	0.00%	0.01%
Upland Hay Meadows	0.0%	100%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Improved Grassland										
Coastal and Floodplain Grazing Marsh	100.0%	100%	0.10%	0.10%	0.07%	0.07%	0.05%	0.03%	0.04%	0.10%
Dwarf Shrub Heath										
Lowland Heathland	100.0%	100%	0.01%	0.01%	0.01%	0.01%	0.01%	0.00%	0.00%	0.01%
Upland Heathland	0.0%	100%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Fen, Marsh and Swamp										

Oil	Current				UK Govn White Paper				Tyndall	
	Sensitivity	Adaptation	Exposure	Impact	Central	Constrained	Central	Constrained	Red	Purple
			Baseline		2020	2020	2050	2050	2050	2050
Upland Flushes, Fens and Swamps	0.0%	100%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Purple Moor Grass and Rush Pastures	0.0%	100%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Lowland Fens	100.0%	100%	0.01%	0.01%	0.01%	0.01%	0.01%	0.00%	0.00%	0.01%
Reedbeds	100.0%	20%	0.01%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Bogs										
Lowland Raised Bog	0.0%	100%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Blanket Bog	0.0%	100%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Montane Habitats										
Mountain Heaths and Willow Scrub	0.0%	100%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Inland Rock										
Inland Rock Outcrop and Scree Habitats	0.0%	100%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Calaminarian Grasslands	0.0%	100%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Open Mosaic Habitats on Previously Developed Land	100.0%	100%	0.10%	0.10%	0.07%	0.07%	0.05%	0.03%	0.04%	0.10%
Limestone Pavements	0.0%	100%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Supralittoral Rock										
Maritime Cliff and Slopes	100.0%	100%	0.01%	0.01%	0.01%	0.01%	0.01%	0.00%	0.00%	0.01%
Supralittoral Sediment										
Coastal Vegetated Shingle	100.0%	100%	0.01%	0.01%	0.01%	0.01%	0.01%	0.00%	0.00%	0.01%
Machair	100.0%	100%	0.01%	0.01%	0.01%	0.01%	0.01%	0.00%	0.00%	0.01%
Coastal Sand Dunes	100.0%	100%	0.01%	0.01%	0.01%	0.01%	0.01%	0.00%	0.00%	0.01%
Littoral rock										
Intertidal chalk	100.0%	100%	0.01%	0.01%	0.01%	0.01%	0.01%	0.00%	0.00%	0.01%
Intertidal boulder communities	100.0%	100%	0.01%	0.01%	0.01%	0.01%	0.01%	0.00%	0.00%	0.01%
Sabellaria alveolata reefs	100.0%	100%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Littoral sediment										
Coastal saltmarsh	100.0%	100%	0.01%	0.01%	0.01%	0.01%	0.01%	0.00%	0.00%	0.01%
Intertidal mudflats	1.0%	100%	0.01%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Seagrass beds	1.0%	100%	0.01%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Sheltered muddy gravels	1.0%	100%	0.01%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Peat and clay exposures	100.0%	100%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Sublittoral rock										
Subtidal chalk	100.0%	100%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Tide-swept channels	100.0%	100%	0.01%	0.01%	0.01%	0.01%	0.01%	0.00%	0.00%	0.01%
Fragile sponge & anthozoan communities on subtidal rocky habitats	100.0%	100%	0.01%	0.01%	0.01%	0.01%	0.01%	0.00%	0.00%	0.01%
Estuarine rocky habitats	100.0%	100%	0.00%	0.01%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Seamount communities	0.0%	100%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Carbonate mounds	100.0%	100%	0.00%	0.01%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Cold-water coral reefs	100.0%	100%	0.01%	0.01%	0.01%	0.01%	0.01%	0.00%	0.00%	0.01%
Deep-sea sponge communities	0.0%	100%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Sabellaria spinulosa reefs	100.0%	100%	0.01%	0.01%	0.01%	0.01%	0.01%	0.00%	0.00%	0.01%
Sublittoral sediment										

Oil	Current				UK Govn White Paper				Tyndall	
	Sensitivity	Adaptation	Exposure	Impact	Central	Constrained	Central	Constrained	Red	Purple
			Baseline		2020	2020	2050	2050	2050	2050
Subtidal sands and gravels	100.0%	100%	0.01%	0.01%	0.01%	0.01%	0.01%	0.00%	0.00%	0.01%
Horse mussel beds	100.0%	100%	0.01%	0.01%	0.01%	0.01%	0.01%	0.00%	0.00%	0.01%
Mud habitats in deep water	100.0%	100%	0.01%	0.01%	0.01%	0.01%	0.01%	0.00%	0.00%	0.01%
File shell beds	100.0%	100%	0.01%	0.01%	0.01%	0.01%	0.01%	0.00%	0.00%	0.01%
Maerl beds	100.0%	100%	0.01%	0.01%	0.01%	0.01%	0.01%	0.00%	0.00%	0.01%
Serpulid reefs	100.0%	100%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Blue mussel beds	100.0%	100%	0.01%	0.01%	0.01%	0.01%	0.01%	0.00%	0.00%	0.01%
Saline lagoons	100.0%	100%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%

Nuclear	Current				UK Govn White Paper				Tyndall	
	Sensitivity	Adaptation	Exposure	Impact	Central	Constrained	Central	Constrained	Red	Purple
			Baseline		2020	2020	2050	2050	2050	2050
Relative exposure increase / decrease from scenarios					-39.0%	-59.3%	-79.7%	143.9%	-100.0%	3929.7%
Broad Habitat (bold) / Priority Habitat					**Impact**	**Impact**	**Impact**	**Impact**	**Impact**	**Impacts**
Rivers and Streams										
Rivers	0.0%	100%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Standing Open Water and Canals										
Oligotrophic and Dystrophic Lakes	0.0%	100%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Ponds	100.0%	100%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Mesotrophic Lakes	0.0%	100%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Eutrophic Standing Waters	0.0%	100%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Aquifer Fed Naturally Fluctuating Water Bodies	0.0%	100%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Arable & Horticultural										
Arable Field Margins	100.0%	20%	0.01%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.08%
Boundary & Linear Features										
Hedgerows	100.0%	50%	0.01%	0.01%	0.00%	0.00%	0.00%	0.01%	0.00%	0.20%
Broadleaved, Mixed and Yew Woodland										
Traditional Orchards	100.0%	100%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Wood-Pasture & Parkland	100.0%	100%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Upland Oakwood	100.0%	100%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Lowland Beech and Yew Woodland	100.0%	100%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Upland Mixed Ashwoods	100.0%	100%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Wet Woodland	100.0%	100%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Lowland Mixed Deciduous Woodland	100.0%	100%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Upland Birchwoods	100.0%	100%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Coniferous Woodland										
Native Pine Woodlands	100.0%	100%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Acid Grassland										
Lowland Dry Acid Grassland	100.0%	100%	0.00%	0.01%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Calcareous Grassland										
Lowland Calcareous Grassland	100.0%	100%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Upland Calcareous Grassland	100.0%	100%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Neutral Grassland										
Lowland Meadows	100.0%	100%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Upland Hay Meadows	100.0%	100%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Improved Grassland										
Coastal and Floodplain Grazing Marsh	100.0%	100%	0.01%	0.01%	0.01%	0.00%	0.00%	0.02%	0.00%	0.40%
Dwarf Shrub Heath										
Lowland Heathland	100.0%	100%	0.01%	0.01%	0.01%	0.00%	0.00%	0.02%	0.00%	0.40%
Upland Heathland	100.0%	100%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Fen, Marsh and Swamp										

Nuclear	Current				UK Govn White Paper				Tyndall	
	Sensitivity	Adaptation	Exposure	Impact	Central	Constrained	Central	Constrained	Red	Purple
			Baseline		2020	2020	2050	2050	2050	2050
Upland Flushes, Fens and Swamps	100.0%	100%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Purple Moor Grass and Rush Pastures	100.0%	100%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Lowland Fens	100.0%	100%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Reedbeds	100.0%	100%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Bogs										
Lowland Raised Bog	100.0%	100%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Blanket Bog	100.0%	100%	0.01%	0.01%	0.01%	0.00%	0.00%	0.02%	0.00%	0.40%
Montane Habitats										
Mountain Heaths and Willow Scrub	100.0%	100%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Inland Rock										
Inland Rock Outcrop and Scree Habitats	100.0%	100%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Calaminarian Grasslands	100.0%	100%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Open Mosaic Habitats on Previously Developed Land	100.0%	100%	0.01%	0.01%	0.01%	0.00%	0.00%	0.02%	0.00%	0.40%
Limestone Pavements	100.0%	100%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Supralittoral Rock										
Maritime Cliff and Slopes	100.0%	100%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Supralittoral Sediment										
Coastal Vegetated Shingle	100.0%	100%	0.10%	0.10%	0.06%	0.04%	0.02%	0.24%	0.00%	4.03%
Machair	100.0%	100%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Coastal Sand Dunes	100.0%	100%	0.10%	0.10%	0.06%	0.04%	0.02%	0.24%	0.00%	4.03%
Littoral rock										
Intertidal chalk	0.0%	100%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Intertidal boulder communities	0.0%	100%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Sabellaria alveolata reefs	0.0%	100%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Littoral sediment										
Coastal saltmarsh	100.0%	100%	0.00%	0.01%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Intertidal mudflats	0.0%	100%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Seagrass beds	0.0%	100%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Sheltered muddy gravels	0.0%	100%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Peat and clay exposures	0.0%	100%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Sublittoral rock										
Subtidal chalk	0.0%	100%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Tide-swept channels	0.0%	100%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Fragile sponge & anthozoan communities on subtidal rocky habitats	0.0%	100%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Estuarine rocky habitats	0.0%	100%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Seamount communities	0.0%	100%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Carbonate mounds	0.0%	100%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Cold-water coral reefs	0.0%	100%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Deep-sea sponge communities	0.0%	100%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Sabellaria spinulosa reefs	0.0%	100%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Sublittoral sediment										

Nuclear	Current				UK Govn White Paper				Tyndall	
	Sensitivity	Adaptation	Exposure	Impact	Central	Constrained	Central	Constrained	Red	Purple
			Baseline		2020	2020	2050	2050	2050	2050
Subtidal sands and gravels	0.0%	100%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Horse mussel beds	0.0%	100%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Mud habitats in deep water	0.0%	100%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
File shell beds	0.0%	100%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Maerl beds	0.0%	100%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Serpulid reefs	0.0%	100%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Blue mussel beds	0.0%	100%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Saline lagoons	100.0%	100%	0.00%	0.01%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%

Wind	Current				UK Govn White Paper				Tyndall	
	Sensitivity	Adaptation	Exposure	Impact	Central	Constrained	Central	Constrained	Red	Purple
			Baseline		2020	2020	2050	2050	2050	2050
Relative exposure increase / decrease from scenarios					355.1%	127.6%	355.1%	468.9%	1603.8%	8916.0%
Broad Habitat (bold) / Priority Habitat					**Impact**	**Impact**	**Impact**	**Impact**	**Impact**	**Impacts**
Rivers and Streams										
Rivers	0.0%	100%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Standing Open Water and Canals										
Oligotrophic and Dystrophic Lakes	0.0%	100%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Ponds	0.0%	100%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Mesotrophic Lakes	0.0%	100%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Eutrophic Standing Waters	0.0%	100%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Aquifer Fed Naturally Fluctuating Water Bodies	0.0%	100%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Arable & Horticultural										
Arable Field Margins	100.0%	100%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Boundary & Linear Features										
Hedgerows	100.0%	100%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Broadleaved, Mixed and Yew Woodland										
Traditional Orchards	100.0%	100%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Wood-Pasture & Parkland	100.0%	100%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Upland Oakwood	100.0%	100%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Lowland Beech and Yew Woodland	100.0%	100%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Upland Mixed Ashwoods	100.0%	100%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Wet Woodland	100.0%	100%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Lowland Mixed Deciduous Woodland	100.0%	100%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Upland Birchwoods	100.0%	100%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Coniferous Woodland										
Native Pine Woodlands	100.0%	100%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Acid Grassland										
Lowland Dry Acid Grassland	100.0%	100%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Calcareous Grassland										
Lowland Calcareous Grassland	100.0%	100%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Upland Calcareous Grassland	100.0%	100%	0.01%	0.01%	0.05%	0.02%	0.05%	0.06%	0.17%	0.90%
Neutral Grassland										
Lowland Meadows	100.0%	100%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Upland Hay Meadows	100.0%	100%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Improved Grassland										
Coastal and Floodplain Grazing Marsh	100.0%	100%	0.01%	0.01%	0.05%	0.02%	0.05%	0.06%	0.17%	0.90%
Dwarf Shrub Heath										
Lowland Heathland	100.0%	100%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Upland Heathland	100.0%	100%	0.01%	0.01%	0.05%	0.02%	0.05%	0.06%	0.17%	0.90%
Fen, Marsh and Swamp										

Wind	Current				UK Govn White Paper				Tyndall	
	Sensitivity	Adaptation	Exposure	Impact	Central	Constrained	Central	Constrained	Red	Purple
			Baseline		2020	2020	2050	2050	2050	2050
Upland Flushes, Fens and Swamps	100.0%	100%	0.01%	0.01%	0.05%	0.02%	0.05%	0.06%	0.17%	0.90%
Purple Moor Grass and Rush Pastures	100.0%	100%	0.01%	0.01%	0.05%	0.02%	0.05%	0.06%	0.17%	0.90%
Lowland Fens	100.0%	100%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Reedbeds	100.0%	100%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Bogs										
Lowland Raised Bog	100.0%	100%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Blanket Bog	100.0%	100%	0.01%	0.01%	0.05%	0.02%	0.05%	0.06%	0.17%	0.90%
Montane Habitats										
Mountain Heaths and Willow Scrub	100.0%	100%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Inland Rock										
Inland Rock Outcrop and Scree Habitats	100.0%	100%	0.01%	0.01%	0.05%	0.02%	0.05%	0.06%	0.17%	0.90%
Calaminarian Grasslands	100.0%	100%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Open Mosaic Habitats on Previously Developed Land	100.0%	100%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Limestone Pavements	100.0%	100%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Supralittoral Rock										
Maritime Cliff and Slopes	100.0%	100%	0.10%	0.10%	0.46%	0.23%	0.46%	0.57%	1.70%	9.02%
Supralittoral Sediment										
Coastal Vegetated Shingle	100.0%	100%	0.01%	0.01%	0.05%	0.02%	0.05%	0.06%	0.17%	0.90%
Machair	100.0%	100%	0.01%	0.01%	0.05%	0.02%	0.05%	0.06%	0.17%	0.90%
Coastal Sand Dunes	100.0%	100%	0.01%	0.01%	0.05%	0.02%	0.05%	0.06%	0.17%	0.90%
Littoral rock										
Intertidal chalk	100.0%	100%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Intertidal boulder communities	100.0%	100%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Sabellaria alveolata reefs	100.0%	100%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Littoral sediment										
Coastal saltmarsh	100.0%	100%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Intertidal mudflats	100.0%	100%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Seagrass beds	100.0%	100%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Sheltered muddy gravels	100.0%	100%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Peat and clay exposures	100.0%	100%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Sublittoral rock										
Subtidal chalk	0.0%	100%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Tide-swept channels	0.0%	100%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Fragile sponge & anthozoan communities on subtidal rocky habitats	100.0%	100%	0.01%	0.01%	0.05%	0.02%	0.05%	0.06%	0.17%	0.90%
Estuarine rocky habitats	0.0%	100%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Seamount communities	0.0%	100%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Carbonate mounds	0.0%	100%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Cold-water coral reefs	0.0%	100%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Deep-sea sponge communities	0.0%	100%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Sabellaria spinulosa reefs	100.0%	100%	0.01%	0.01%	0.05%	0.02%	0.05%	0.06%	0.17%	0.90%
Sublittoral sediment										

Wind	**Current**				**UK Govn White Paper**				**Tyndall**	
	Sensitivity	**Adaptation**	**Exposure**	**Impact**	**Central**	**Constrained**	**Central**	**Constrained**	**Red**	**Purple**
			Baseline		**2020**	**2020**	**2050**	**2050**	**2050**	**2050**
Subtidal sands and gravels	100.0%	100%	0.01%	0.01%	0.05%	0.02%	0.05%	0.06%	0.17%	0.90%
Horse mussel beds	100.0%	100%	0.01%	0.01%	0.05%	0.02%	0.05%	0.06%	0.17%	0.90%
Mud habitats in deep water	100.0%	100%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
File shell beds	100.0%	100%	0.01%	0.01%	0.05%	0.02%	0.05%	0.06%	0.17%	0.90%
Maerl beds	100.0%	100%	0.01%	0.01%	0.05%	0.02%	0.05%	0.06%	0.17%	0.90%
Serpulid reefs	100.0%	100%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Blue mussel beds	100.0%	100%	0.01%	0.01%	0.05%	0.02%	0.05%	0.06%	0.17%	0.90%
Saline lagoons	100.0%	100%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%

Biomass	Current				UK Govn White Paper				Tyndall	
	Sensitivity	Adaptation	Exposure	Impact	Central	Constrained	Central	Constrained	Red	Purple
			Baseline		2020	2020	2050	2050	2050	2050
Relative exposure increase / decrease from scenarios					159.0%	52.8%	121.0%	334.0%	253.0%	2352.0%
Broad Habitat (bold) / Priority Habitat					**Impact**	**Impact**	**Impact**	**Impact**	**Impact**	**Impacts**
Rivers and Streams										
Rivers	-10.0%	100%	0.010%	-0.001%	-0.003%	-0.002%	-0.002%	-0.004%	-0.004%	-0.025%
Standing Open Water and Canals										
Oligotrophic and Dystrophic Lakes	0.0%	100%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%
Ponds	-10.0%	100%	0.050%	-0.005%	-0.013%	-0.008%	-0.011%	-0.022%	-0.018%	-0.123%
Mesotrophic Lakes	-10.0%	100%	0.010%	-0.001%	-0.003%	-0.002%	-0.002%	-0.004%	-0.004%	-0.025%
Eutrophic Standing Waters	-1.0%	100%	0.050%	-0.001%	-0.001%	-0.001%	-0.001%	-0.002%	-0.002%	-0.012%
Aquifer Fed Naturally Fluctuating Water Bodies	0.0%	100%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%
Arable & Horticultural										
Arable Field Margins	-10.0%	100%	0.130%	-0.013%	-0.034%	-0.020%	-0.029%	-0.056%	-0.046%	-0.319%
Boundary & Linear Features										
Hedgerows	-10.0%	100%	0.050%	-0.005%	-0.013%	-0.008%	-0.011%	-0.022%	-0.018%	-0.123%
Broadleaved, Mixed and Yew Woodland										
Traditional Orchards	0.0%	100%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%
Wood-Pasture & Parkland	0.0%	100%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%
Upland Oakwood	0.0%	100%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%
Lowland Beech and Yew Woodland	-10.0%	100%	0.010%	-0.001%	-0.003%	-0.002%	-0.002%	-0.004%	-0.004%	-0.025%
Upland Mixed Ashwoods	0.0%	100%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%
Wet Woodland	-10.0%	100%	0.100%	-0.010%	-0.026%	-0.015%	-0.022%	-0.043%	-0.035%	-0.245%
Lowland Mixed Deciduous Woodland	-10.0%	100%	0.050%	-0.005%	-0.013%	-0.008%	-0.011%	-0.022%	-0.018%	-0.123%
Upland Birchwoods	0.0%	100%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%
Coniferous Woodland										
Native Pine Woodlands	0.0%	100%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%
Acid Grassland										
Lowland Dry Acid Grassland	0.0%	100%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%
Calcareous Grassland										
Lowland Calcareous Grassland	0.0%	100%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%
Upland Calcareous Grassland	0.0%	100%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%
Neutral Grassland										
Lowland Meadows	100.0%	100%	0.130%	0.130%	0.337%	0.199%	0.287%	0.564%	0.459%	3.188%
Upland Hay Meadows	0.0%	100%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%
Improved Grassland										
Coastal and Floodplain Grazing Marsh	100.0%	100%	0.100%	0.100%	0.259%	0.153%	0.221%	0.434%	0.353%	2.452%
Dwarf Shrub Heath										
Lowland Heathland	0.0%	100%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%
Upland Heathland	0.0%	100%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%
Fen, Marsh and Swamp										

Biomass	Current				UK Govn White Paper				Tyndall	
	Sensitivity	Adaptation	Exposure	Impact	Central	Constrained	Central	Constrained	Red	Purple
			Baseline		2020	2020	2050	2050	2050	2050
Upland Flushes, Fens and Swamps	0.0%	100%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%
Purple Moor Grass and Rush Pastures	100.0%	100%	0.010%	0.010%	0.026%	0.015%	0.022%	0.043%	0.035%	0.245%
Lowland Fens	100.0%	100%	0.010%	0.010%	0.026%	0.015%	0.022%	0.043%	0.035%	0.245%
Reedbeds	100.0%	100%	0.010%	0.010%	0.026%	0.015%	0.022%	0.043%	0.035%	0.245%
Bogs										
Lowland Raised Bog	0.0%	100%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%
Blanket Bog	0.0%	100%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%
Montane Habitats										
Mountain Heaths and Willow Scrub	0.0%	100%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%
Inland Rock										
Inland Rock Outcrop and Scree Habitats	0.0%	100%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%
Calaminarian Grasslands	100.0%	100%	0.100%	0.100%	0.259%	0.153%	0.221%	0.434%	0.353%	2.452%
Open Mosaic Habitats on Previously Developed Land	100.0%	100%	0.100%	0.100%	0.259%	0.153%	0.221%	0.434%	0.353%	2.452%
Limestone Pavements	0.0%	100%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%
Supralittoral Rock										
Maritime Cliff and Slopes	0.0%	100%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%
Supralittoral Sediment										
Coastal Vegetated Shingle	0.0%	100%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%
Machair	0.0%	100%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%
Coastal Sand Dunes	0.0%	100%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%
Littoral rock										
Intertidal chalk	0.0%	100%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%
Intertidal boulder communities	0.0%	100%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%
Sabellaria alveolata reefs	0.0%	100%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%
Littoral sediment										
Coastal saltmarsh	0.0%	100%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%
Intertidal mudflats	0.0%	100%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%
Seagrass beds	0.0%	100%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%
Sheltered muddy gravels	0.0%	100%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%
Peat and clay exposures	0.0%	100%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%
Sublittoral rock										
Subtidal chalk	0.0%	100%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%
Tide-swept channels	0.0%	100%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%
Fragile sponge & anthozoan communities on subtidal rocky habitats	0.0%	100%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%
Estuarine rocky habitats	0.0%	100%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%
Seamount communities	0.0%	100%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%
Carbonate mounds	0.0%	100%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%
Cold-water coral reefs	0.0%	100%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%
Deep-sea sponge communities	0.0%	100%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%
Sabellaria spinulosa reefs	0.0%	100%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%
Sublittoral sediment										

Biomass	Current				UK Govn White Paper				Tyndall	
	Sensitivity	Adaptation	Exposure	Impact	Central	Constrained	Central	Constrained	Red	Purple
			Baseline		2020	2020	2050	2050	2050	2050
Subtidal sands and gravels	0.0%	100%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%
Horse mussel beds	10.0%	100%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%
Mud habitats in deep water	0.0%	100%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%
File shell beds	0.0%	100%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%
Maerl beds	10.0%	100%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%
Serpulid reefs	10.0%	100%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%
Blue mussel beds	10.0%	100%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%
Saline lagoons	10.0%	100%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%

Biofuel	Current				UK Govn White Paper				Tyndall	
	Sensitivity	Adaptation	Exposure	Impact	Central	Constrained	Central	Constrained	Red	Purple
			Baseline		2020	2020	2050	2050	2050	2050
Relative exposure increase / decrease from scenarios					1906.0%	1310.0%	1691.0%	4275.0%	1878.0%	26426.0%
Broad Habitat (bold) / Priority Habitat					**Impact**	**Impact**	**Impact**	**Impact**	**Impact**	**Impacts**
Rivers and Streams										
Rivers	10.0%	100%	0.01%	0.001%	0.020%	0.014%	0.018%	0.044%	0.020%	0.265%
Standing Open Water and Canals										
Oligotrophic and Dystrophic Lakes	0.0%	100%	0.00%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%
Ponds	20.0%	100%	0.10%	0.020%	0.401%	0.282%	0.358%	0.875%	0.396%	5.305%
Mesotrophic Lakes	10.0%	100%	0.01%	0.001%	0.020%	0.014%	0.018%	0.044%	0.020%	0.265%
Eutrophic Standing Waters	1.0%	100%	0.10%	0.001%	0.020%	0.014%	0.018%	0.044%	0.020%	0.265%
Aquifer Fed Naturally Fluctuating Water Bodies	0.0%	100%	0.00%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%
Arable & Horticultural										
Arable Field Margins	10.0%	100%	0.50%	0.050%	1.003%	0.705%	0.896%	2.188%	0.989%	13.263%
Boundary & Linear Features										
Hedgerows	20.0%	100%	0.10%	0.020%	0.401%	0.282%	0.358%	0.875%	0.396%	5.305%
Broadleaved, Mixed and Yew Woodland										
Traditional Orchards	0.0%	100%	0.00%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%
Wood-Pasture & Parkland	0.0%	100%	0.00%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%
Upland Oakwood	0.0%	100%	0.00%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%
Lowland Beech and Yew Woodland	0.0%	100%	0.00%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%
Upland Mixed Ashwoods	0.0%	100%	0.00%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%
Wet Woodland	10.0%	100%	0.01%	0.001%	0.020%	0.014%	0.018%	0.044%	0.020%	0.265%
Lowland Mixed Deciduous Woodland	10.0%	100%	0.10%	0.010%	0.201%	0.141%	0.179%	0.438%	0.198%	2.653%
Upland Birchwoods	0.0%	100%	0.00%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%
Coniferous Woodland										
Native Pine Woodlands	0.0%	100%	0.00%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%
Acid Grassland										
Lowland Dry Acid Grassland	100.0%	100%	0.01%	0.010%	0.201%	0.141%	0.179%	0.438%	0.198%	2.653%
Calcareous Grassland										
Lowland Calcareous Grassland	100.0%	100%	0.01%	0.010%	0.201%	0.141%	0.179%	0.438%	0.198%	2.653%
Upland Calcareous Grassland	0.0%	100%	0.00%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%
Neutral Grassland										
Lowland Meadows	100.0%	100%	0.10%	0.100%	2.006%	1.410%	1.791%	4.375%	1.978%	26.526%
Upland Hay Meadows	0.0%	100%	0.00%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%
Improved Grassland										
Coastal and Floodplain Grazing Marsh	100.0%	100%	0.10%	0.100%	2.006%	1.410%	1.791%	4.375%	1.978%	26.526%
Dwarf Shrub Heath										
Lowland Heathland	0.0%	100%	0.00%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%
Upland Heathland	0.0%	100%	0.00%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%
Fen, Marsh and Swamp										

Biofuel	Current				UK Govn White Paper				Tyndall	
	Sensitivity	Adaptation	Exposure	Impact	Central	Constrained	Central	Constrained	Red	Purple
			Baseline		2020	2020	2050	2050	2050	2050
Upland Flushes, Fens and Swamps	0.0%	100%	0.00%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%
Purple Moor Grass and Rush Pastures	0.0%	100%	0.00%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%
Lowland Fens	100.0%	100%	0.01%	0.010%	0.201%	0.141%	0.179%	0.438%	0.198%	2.653%
Reedbeds	100.0%	100%	0.00%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%
Bogs										
Lowland Raised Bog	0.0%	100%	0.00%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%
Blanket Bog	0.0%	100%	0.00%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%
Montane Habitats										
Mountain Heaths and Willow Scrub	0.0%	100%	0.00%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%
Inland Rock										
Inland Rock Outcrop and Scree Habitats	0.0%	100%	0.00%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%
Calaminarian Grasslands	0.0%	100%	0.00%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%
Open Mosaic Habitats on Previously Developed Land	0.0%	100%	0.00%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%
Limestone Pavements	0.0%	100%	0.00%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%
Supralittoral Rock										
Maritime Cliff and Slopes	0.0%	100%	0.00%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%
Supralittoral Sediment										
Coastal Vegetated Shingle	0.0%	100%	0.00%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%
Machair	0.0%	100%	0.00%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%
Coastal Sand Dunes	0.0%	100%	0.00%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%
Littoral rock										
Intertidal chalk	0.0%	100%	0.00%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%
Intertidal boulder communities	0.0%	100%	0.00%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%
Sabellaria alveolata reefs	0.0%	100%	0.00%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%
Littoral sediment										
Coastal saltmarsh	0.0%	100%	0.00%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%
Intertidal mudflats	0.0%	100%	0.00%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%
Seagrass beds	0.0%	100%	0.00%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%
Sheltered muddy gravels	0.0%	100%	0.00%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%
Peat and clay exposures	0.0%	100%	0.00%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%
Sublittoral rock										
Subtidal chalk	0.0%	100%	0.00%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%
Tide-swept channels	0.0%	100%	0.00%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%
Fragile sponge & anthozoan communities on subtidal rocky habitats	0.0%	100%	0.00%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%
Estuarine rocky habitats	0.0%	100%	0.00%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%
Seamount communities	0.0%	100%	0.00%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%
Carbonate mounds	0.0%	100%	0.00%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%
Cold-water coral reefs	0.0%	100%	0.00%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%
Deep-sea sponge communities	0.0%	100%	0.00%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%
Sabellaria spinulosa reefs	0.0%	100%	0.00%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%
Sublittoral sediment										

Biofuel	Current				UK Govn White Paper				Tyndall	
	Sensitivity	Adaptation	Exposure	Impact	Central	Constrained	Central	Constrained	Red	Purple
			Baseline		2020	2020	2050	2050	2050	2050
Subtidal sands and gravels	0.0%	100%	0.00%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%
Horse mussel beds	10.0%	100%	0.00%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%
Mud habitats in deep water	0.0%	100%	0.00%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%
File shell beds	0.0%	100%	0.00%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%
Maerl beds	10.0%	100%	0.00%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%
Serpulid reefs	10.0%	100%	0.00%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%
Blue mussel beds	10.0%	100%	0.00%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%
Saline lagoons	10.0%	100%	0.00%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%

APPENDIX 3. VULNERABILITY ASSESSMENTS FOR UK BAP PRIORITY BIRDS

Adaptability score = an added weighting given to threatened species to reflect their potentially increased sensitivity. Additional scores are as follows: globally threatened (GT) = +100%; Rapid decline in UK (RD) = +100%; Moderate decline in UK (MD) = +50%; Rare breeder (RB) = +100%.

Coal						**Current**				**UK Govn White Paper**				**Tyndall**	
						Sensitivity	**Adaptation**	**Exposure**	**Impact**	**Central**	**Constrained**	**Central**	**Constrained**	**Red**	**Purple**
								Baseline		**2020**	**2020**	**2050**	**2050**	**2050**	**2050**
Relative exposure increase / decrease from scenarios										-14.2%	-26.5%	96.1%	36.3%	57.6%	-100.0%
	GT	RD	MD	RB	Adaptability					Impact	Impact	Impact	Impact	Impact	Impacts
Aquatic Warbler	Y				100%	100.0%	200%	0.01%	0.02%	0.02%	0.01%	0.04%	0.03%	0.03%	0.00%
Marsh Warbler		Y		Y	200%	10.0%	300%	0.01%	0.00%	0.00%	0.00%	0.01%	0.00%	0.00%	0.00%
Sky Lark		Y			100%	10.0%	200%	0.01%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
European White-fronted Goose		Y			100%	100.0%	200%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Greenland White-fronted Goose					0%	100.0%	100%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Tree Pipit			Y		50%	100.0%	150%	0.01%	0.02%	0.01%	0.01%	0.03%	0.02%	0.02%	0.00%
Greater Scaup				Y	100%	100.0%	200%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Great Bittern		Y		Y	200%	100.0%	300%	0.01%	0.03%	0.03%	0.02%	0.06%	0.04%	0.05%	0.00%
Dark-bellied Brent Goose					0%	100.0%	100%	0.01%	0.01%	0.01%	0.01%	0.02%	0.01%	0.02%	0.00%
Stone-curlew		Y		Y	200%	100.0%	300%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
European Nightjar		Y			100%	100.0%	200%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Lesser Redpoll			Y		50%	100.0%	150%	0.01%	0.02%	0.01%	0.01%	0.03%	0.02%	0.02%	0.00%
Common Linnet		Y			100%	10.0%	200%	0.01%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Twite					0%	100.0%	100%	0.10%	0.10%	0.09%	0.07%	0.20%	0.14%	0.16%	0.00%
Hawfinch			Y		50%	100.0%	150%	0.01%	0.02%	0.01%	0.01%	0.03%	0.02%	0.02%	0.00%
Corn Crake	Y	Y			200%	100.0%	300%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Common Cuckoo			Y		50%	100.0%	150%	0.01%	0.02%	0.01%	0.01%	0.03%	0.02%	0.02%	0.00%
Tundra Swan					0%	100.0%	100%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Lesser Spotted Woodpecker		Y			100%	100.0%	200%	0.01%	0.02%	0.02%	0.01%	0.04%	0.03%	0.03%	0.00%
Cirl Bunting		Y			100%	100.0%	200%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Yellowhammer		Y			100%	10.0%	200%	0.01%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Reed Bunting		Y			100%	10.0%	200%	0.01%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Black-throated Diver				Y	100%	100.0%	200%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Eurasian Wryneck		Y		Y	200%	100.0%	300%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Red Grouse			Y		50%	100.0%	150%	0.01%	0.02%	0.01%	0.01%	0.03%	0.02%	0.02%	0.00%
Red-backed Shrike		Y		Y	200%	100.0%	300%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Herring Gull			Y		50%	10.0%	150%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Black-tailed Godwit				Y	100%	100.0%	200%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Savi`s Warbler		Y		Y	200%	100.0%	300%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Common Grasshopper Warbler		Y			100%	10.0%	200%	0.01%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Scottish Crossbill	Y				100%	100.0%	200%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%

Coal						Current				UK Govn White Paper				Tyndall	
						Sensitivity	Adaptation	Exposure	Impact	Central	Constrained	Central	Constrained	Red	Purple
								Baseline		2020	2020	2050	2050	2050	2050
Wood Lark		Y			100%	100.0%	200%	0.01%	0.02%	0.02%	0.01%	0.04%	0.03%	0.03%	0.00%
Common Scoter		Y		Y	200%	100.0%	300%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Corn Bunting		Y			100%	100.0%	200%	0.01%	0.02%	0.02%	0.01%	0.04%	0.03%	0.03%	0.00%
Yellow Wagtail			Y		50%	100.0%	150%	0.01%	0.02%	0.01%	0.01%	0.03%	0.02%	0.02%	0.00%
Spotted Flycatcher		Y			100%	100.0%	200%	0.01%	0.02%	0.02%	0.01%	0.04%	0.03%	0.03%	0.00%
Eurasian Curlew					0%	100.0%	100%	0.01%	0.01%	0.01%	0.01%	0.02%	0.01%	0.02%	0.00%
Willow Tit		Y			100%	100.0%	200%	0.01%	0.02%	0.02%	0.01%	0.04%	0.03%	0.03%	0.00%
Marsh Tit		Y			100%	10.0%	200%	0.01%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
House Sparrow		Y			100%	1.0%	200%	0.01%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Eurasian Tree Sparrow		Y			100%	100.0%	200%	0.01%	0.02%	0.02%	0.01%	0.04%	0.03%	0.03%	0.00%
Grey Partridge		Y			100%	100.0%	200%	0.01%	0.02%	0.02%	0.01%	0.04%	0.03%	0.03%	0.00%
Red-necked Phalarope				Y	100%	100.0%	200%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Wood Warbler		Y			100%	100.0%	200%	0.01%	0.02%	0.02%	0.01%	0.04%	0.03%	0.03%	0.00%
Hedge Accentor		Y			100%	10.0%	200%	0.01%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Balearic Shearwater					0%	0.0%	100%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Common Bullfinch		Y			100%	10.0%	200%	0.01%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Arctic Skua		Y			100%	100.0%	200%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Roseate Tern		Y		Y	200%	100.0%	300%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
European Turtle Dove		Y			100%	10.0%	200%	0.01%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Common Starling		Y			100%	10.0%	200%	0.01%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Black Grouse		Y			100%	100.0%	200%	0.10%	0.20%	0.17%	0.15%	0.39%	0.27%	0.32%	0.00%
Western Capercaillie		Y			100%	100.0%	200%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Fair Isle Wren					0%	0.0%	100%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
St Kilda Wren					0%	0.0%	100%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Song Thrush		Y			100%	10.0%	200%	0.01%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Hebridean Song Thrush					0%	0.0%	100%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Ring Ouzel		Y			100%	100.0%	200%	0.01%	0.02%	0.02%	0.01%	0.04%	0.03%	0.03%	0.00%
Northern Lapwing		Y			100%	50.0%	200%	0.01%	0.01%	0.01%	0.01%	0.02%	0.01%	0.02%	0.00%

Gas						Current				UK Govn White Paper				Tyndall	
						Sensitivity	Adaptation	Exposure	Impact	Central	Constrained	Central	Constrained	Red	Purple
								Baseline		2020	2020	2050	2050	2050	2050
Relative exposure increase / decrease from scenarios										-13.2%	-5.5%	-25.5%	-43.3%	-91.1%	-87.9%
	GT	RD	MD	RB	Adaptability					Impact	Impact	Impact	Impact	Impact	Impacts
Aquatic Warbler	Y				100%	100.0%	200%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Marsh Warbler		Y		Y	200%	10.0%	300%	0.01%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Sky Lark		Y			100%	1.0%	200%	0.01%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
European White-fronted Goose		Y			100%	100.0%	200%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Greenland White-fronted Goose					0%	100.0%	100%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Tree Pipit			Y		50%	10.0%	150%	0.01%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Greater Scaup				Y	100%	100.0%	200%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Great Bittern		Y		Y	200%	100.0%	300%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Dark-bellied Brent Goose					0%	100.0%	100%	0.01%	0.01%	0.01%	0.01%	0.01%	0.01%	0.00%	0.00%
Stone-curlew		Y		Y	200%	10.0%	300%	0.01%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
European Nightjar		Y			100%	10.0%	200%	0.01%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Lesser Redpoll			Y		50%	10.0%	150%	0.01%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Common Linnet		Y			100%	1.0%	200%	0.01%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Twite					0%	1.0%	100%	0.01%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Hawfinch			Y		50%	100.0%	150%	0.01%	0.02%	0.01%	0.01%	0.01%	0.01%	0.00%	0.00%
Corn Crake	Y	Y			200%	10.0%	300%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Common Cuckoo			Y		50%	1.0%	150%	0.01%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Tundra Swan					0%	100.0%	100%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Lesser Spotted Woodpecker		Y			100%	100.0%	200%	0.01%	0.02%	0.02%	0.02%	0.01%	0.01%	0.00%	0.00%
Cirl Bunting		Y			100%	10.0%	200%	0.01%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Yellowhammer		Y			100%	1.0%	200%	0.01%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Reed Bunting		Y			100%	1.0%	200%	0.01%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Black-throated Diver				Y	100%	100.0%	200%	0.01%	0.02%	0.02%	0.02%	0.01%	0.01%	0.00%	0.00%
Eurasian Wryneck		Y		Y	200%	100.0%	300%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Red Grouse			Y		50%	10.0%	150%	0.01%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Red-backed Shrike		Y		Y	200%	100.0%	300%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Herring Gull			Y		50%	10.0%	150%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Black-tailed Godwit				Y	100%	100.0%	200%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Savi`s Warbler		Y		Y	200%	100.0%	300%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Common Grasshopper Warbler		Y			100%	10.0%	200%	0.01%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Scottish Crossbill	Y				100%	100.0%	200%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Wood Lark		Y			100%	10.0%	200%	0.01%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Common Scoter		Y		Y	200%	10.0%	300%	0.01%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Corn Bunting		Y			100%	10.0%	200%	0.01%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Yellow Wagtail			Y		50%	10.0%	150%	0.01%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Spotted Flycatcher		Y			100%	100.0%	200%	0.01%	0.02%	0.02%	0.02%	0.01%	0.01%	0.00%	0.00%
Eurasian Curlew					0%	10.0%	100%	0.01%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%

Gas						Current				UK Govn White Paper				Tyndall	
						Sensitivity	Adaptation	Exposure	Impact	Central	Constrained	Central	Constrained	Red	Purple
								Baseline		2020	2020	2050	2050	2050	2050
Willow Tit		Y			100%	100.0%	200%	0.01%	0.02%	0.02%	0.02%	0.01%	0.01%	0.00%	0.00%
Marsh Tit		Y			100%	100.0%	200%	0.01%	0.02%	0.02%	0.02%	0.01%	0.01%	0.00%	0.00%
House Sparrow		Y			100%	1.0%	200%	0.01%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Eurasian Tree Sparrow		Y			100%	10.0%	200%	0.01%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Grey Partridge		Y			100%	10.0%	200%	0.01%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Red-necked Phalarope				Y	100%	100.0%	200%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Wood Warbler		Y			100%	100.0%	200%	0.01%	0.02%	0.02%	0.02%	0.01%	0.01%	0.00%	0.00%
Hedge Accentor		Y			100%	1.0%	200%	0.01%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Balearic Shearwater					0%	0.1%	100%	0.01%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Common Bullfinch		Y			100%	10.0%	200%	0.01%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Arctic Skua		Y			100%	0.1%	200%	0.01%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Roseate Tern		Y		Y	200%	0.1%	300%	0.01%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
European Turtle Dove		Y			100%	10.0%	200%	0.01%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Common Starling		Y			100%	1.0%	200%	0.01%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Black Grouse		Y			100%	100.0%	200%	0.01%	0.02%	0.02%	0.02%	0.01%	0.01%	0.00%	0.00%
Western Capercaillie		Y			100%	100.0%	200%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Fair Isle Wren					0%	0.0%	100%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
St Kilda Wren					0%	0.0%	100%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Song Thrush		Y			100%	1.0%	200%	0.01%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Hebridean Song Thrush					0%	0.0%	100%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Ring Ouzel		Y			100%	10.0%	200%	0.01%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Northern Lapwing		Y			100%	10.0%	200%	0.01%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%

Oil						Current				UK Govn White Paper				Tyndall	
						Sensitivity	Adaptation	Exposure	Impact	Central	Constrained	Central	Constrained	Red	Purple
								Baseline		2020	2020	2050	2050	2050	2050
Relative exposure increase / decrease from scenarios										-32.5%	-32.5%	-49.7%	-69.6%	-59.2%	-2.4%
	GT	RD	MD	RB	Adaptability					Impact	Impact	Impact	Impact	Impact	Impacts
Aquatic Warbler	Y				100%	100.0%	200%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Marsh Warbler		Y		Y	200%	100.0%	300%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Sky Lark		Y			100%	100.0%	200%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
European White-fronted Goose		Y			100%	100.0%	200%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Greenland White-fronted Goose					0%	100.0%	100%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Tree Pipit			Y		50%	100.0%	150%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Greater Scaup				Y	100%	100.0%	200%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Great Bittern		Y		Y	200%	100.0%	300%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Dark-bellied Brent Goose					0%	100.0%	100%	0.01%	0.01%	0.01%	0.01%	0.01%	0.00%	0.00%	0.01%
Stone-curlew		Y		Y	200%	100.0%	300%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
European Nightjar		Y			100%	100.0%	200%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Lesser Redpoll			Y		50%	100.0%	150%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Common Linnet		Y			100%	100.0%	200%	0.01%	0.02%	0.01%	0.01%	0.01%	0.01%	0.01%	0.02%
Twite					0%	100.0%	100%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Hawfinch			Y		50%	100.0%	150%	0.01%	0.02%	0.01%	0.01%	0.01%	0.00%	0.01%	0.01%
Corn Crake	Y	Y			200%	100.0%	300%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Common Cuckoo			Y		50%	100.0%	150%	0.01%	0.02%	0.01%	0.01%	0.01%	0.00%	0.01%	0.01%
Tundra Swan					0%	100.0%	100%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Lesser Spotted Woodpecker		Y			100%	100.0%	200%	0.01%	0.02%	0.01%	0.01%	0.01%	0.01%	0.01%	0.02%
Cirl Bunting		Y			100%	100.0%	200%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Yellowhammer		Y			100%	100.0%	200%	0.01%	0.02%	0.01%	0.01%	0.01%	0.01%	0.01%	0.02%
Reed Bunting		Y			100%	100.0%	200%	0.01%	0.02%	0.01%	0.01%	0.01%	0.01%	0.01%	0.02%
Black-throated Diver				Y	100%	100.0%	200%	0.01%	0.02%	0.01%	0.01%	0.01%	0.01%	0.01%	0.02%
Eurasian Wryneck		Y		Y	200%	100.0%	300%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Red Grouse			Y		50%	100.0%	150%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Red-backed Shrike		Y		Y	200%	100.0%	300%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Herring Gull			Y		50%	100.0%	150%	0.01%	0.02%	0.01%	0.01%	0.01%	0.00%	0.01%	0.01%
Black-tailed Godwit				Y	100%	100.0%	200%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Savi`s Warbler		Y		Y	200%	100.0%	300%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Common Grasshopper Warbler		Y			100%	100.0%	200%	0.01%	0.02%	0.01%	0.01%	0.01%	0.01%	0.01%	0.02%
Scottish Crossbill	Y				100%	100.0%	200%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Wood Lark		Y			100%	100.0%	200%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Common Scoter		Y		Y	200%	10.0%	300%	0.01%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Corn Bunting		Y			100%	100.0%	200%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Yellow Wagtail			Y		50%	100.0%	150%	0.01%	0.02%	0.01%	0.01%	0.01%	0.00%	0.01%	0.01%
Spotted Flycatcher		Y			100%	100.0%	200%	0.01%	0.02%	0.01%	0.01%	0.01%	0.01%	0.01%	0.02%
Eurasian Curlew					0%	100.0%	100%	0.01%	0.01%	0.01%	0.01%	0.01%	0.00%	0.00%	0.01%

Oil						Current				UK Govn White Paper				Tyndall	
						Sensitivity	Adaptation	Exposure	Impact	Central	Constrained	Central	Constrained	Red	Purple
								Baseline		2020	2020	2050	2050	2050	2050
Willow Tit		Y			100%	100.0%	200%	0.01%	0.02%	0.01%	0.01%	0.01%	0.01%	0.01%	0.02%
Marsh Tit		Y			100%	100.0%	200%	0.01%	0.02%	0.01%	0.01%	0.01%	0.01%	0.01%	0.02%
House Sparrow		Y			100%	10.0%	200%	0.01%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Eurasian Tree Sparrow		Y			100%	100.0%	200%	0.01%	0.02%	0.01%	0.01%	0.01%	0.01%	0.01%	0.02%
Grey Partridge		Y			100%	100.0%	200%	0.01%	0.02%	0.01%	0.01%	0.01%	0.01%	0.01%	0.02%
Red-necked Phalarope				Y	100%	100.0%	200%	0.01%	0.02%	0.01%	0.01%	0.01%	0.01%	0.01%	0.02%
Wood Warbler		Y			100%	100.0%	200%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Hedge Accentor		Y			100%	10.0%	200%	0.01%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Balearic Shearwater					0%	0.1%	100%	0.01%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Common Bullfinch		Y			100%	100.0%	200%	0.01%	0.02%	0.01%	0.01%	0.01%	0.01%	0.01%	0.02%
Arctic Skua		Y			100%	0.1%	200%	0.10%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Roseate Tern		Y		Y	200%	0.1%	300%	0.01%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
European Turtle Dove		Y			100%	100.0%	200%	0.01%	0.02%	0.01%	0.01%	0.01%	0.01%	0.01%	0.02%
Common Starling		Y			100%	10.0%	200%	0.01%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Black Grouse		Y			100%	100.0%	200%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Western Capercaillie		Y			100%	100.0%	200%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Fair Isle Wren					0%	0.0%	100%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
St Kilda Wren					0%	0.0%	100%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Song Thrush		Y			100%	10.0%	200%	0.01%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Hebridean Song Thrush					0%	0.0%	100%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Ring Ouzel		Y			100%	100.0%	200%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Northern Lapwing		Y			100%	100.0%	200%	0.01%	0.02%	0.01%	0.01%	0.01%	0.01%	0.01%	0.02%

Nuclear									Current				UK Govn White Paper		Tyndall
						Sensitivity	Adaptation	Exposure	Impact	Central	Constrained	Central	Constrained	Red	Purple
								Baseline		2020	2020	2050	2050	2050	2050
Relative exposure increase / decrease from scenarios										-39.0%	-59.3%	-79.7%	143.9%	-100.0%	3929.7%
	GT	RD	MD	RB	Adaptability					Impact	Impact	Impact	Impact	Impact	Impacts
Aquatic Warbler	Y				100%	100.0%	200%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Marsh Warbler		Y		Y	200%	100.0%	300%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Sky Lark		Y			100%	100.0%	200%	0.01%	0.02%	0.01%	0.01%	0.00%	0.05%	0.00%	0.81%
European White-fronted Goose		Y			100%	100.0%	200%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Greenland White-fronted Goose					0%	100.0%	100%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Tree Pipit			Y		50%	100.0%	150%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Greater Scaup				Y	100%	100.0%	200%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Great Bittern		Y		Y	200%	100.0%	300%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Dark-bellied Brent Goose					0%	1.0%	100%	0.01%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Stone-curlew		Y		Y	200%	100.0%	300%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
European Nightjar		Y			100%	100.0%	200%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Lesser Redpoll			Y		50%	100.0%	150%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Common Linnet		Y			100%	100.0%	200%	0.01%	0.02%	0.01%	0.01%	0.00%	0.05%	0.00%	0.81%
Twite					0%	100.0%	100%	0.01%	0.01%	0.01%	0.00%	0.00%	0.02%	0.00%	0.40%
Hawfinch			Y		50%	100.0%	150%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Corn Crake	Y	Y			200%	100.0%	300%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Common Cuckoo			Y		50%	100.0%	150%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Tundra Swan					0%	100.0%	100%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Lesser Spotted Woodpecker		Y			100%	100.0%	200%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Cirl Bunting		Y			100%	100.0%	200%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Yellowhammer		Y			100%	100.0%	200%	0.01%	0.02%	0.01%	0.01%	0.00%	0.05%	0.00%	0.81%
Reed Bunting		Y			100%	100.0%	200%	0.01%	0.02%	0.01%	0.01%	0.00%	0.05%	0.00%	0.81%
Black-throated Diver				Y	100%	100.0%	200%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Eurasian Wryneck		Y		Y	200%	100.0%	300%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Red Grouse			Y		50%	100.0%	150%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Red-backed Shrike		Y		Y	200%	100.0%	300%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Herring Gull			Y		50%	0.0%	150%	0.01%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Black-tailed Godwit				Y	100%	100.0%	200%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Savi`s Warbler		Y		Y	200%	100.0%	300%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Common Grasshopper Warbler		Y			100%	100.0%	200%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Scottish Crossbill	Y				100%	100.0%	200%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Wood Lark		Y			100%	100.0%	200%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Common Scoter		Y		Y	200%	100.0%	300%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Corn Bunting		Y			100%	100.0%	200%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Yellow Wagtail			Y		50%	100.0%	150%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Spotted Flycatcher		Y			100%	100.0%	200%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Eurasian Curlew					0%	100.0%	100%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%

Nuclear									Current				UK Govn White Paper		Tyndall
						Sensitivity	Adaptation	Exposure	Impact	Central	Constrained	Central	Constrained	Red	Purple
								Baseline		2020	2020	2050	2050	2050	2050
Willow Tit		Y			100%	100.0%	200%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Marsh Tit		Y			100%	100.0%	200%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
House Sparrow		Y			100%	0.0%	200%	0.01%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Eurasian Tree Sparrow		Y			100%	100.0%	200%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Grey Partridge		Y			100%	100.0%	200%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Red-necked Phalarope				Y	100%	100.0%	200%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Wood Warbler		Y			100%	100.0%	200%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Hedge Accentor		Y			100%	100.0%	200%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Balearic Shearwater					0%	0.0%	100%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Common Bullfinch		Y			100%	100.0%	200%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Arctic Skua		Y			100%	100.0%	200%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Roseate Tern		Y		Y	200%	100.0%	300%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
European Turtle Dove		Y			100%	100.0%	200%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Common Starling		Y			100%	10.0%	200%	0.01%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.08%
Black Grouse		Y			100%	100.0%	200%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Western Capercaillie		Y			100%	100.0%	200%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Fair Isle Wren					0%	0.0%	100%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
St Kilda Wren					0%	0.0%	100%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Song Thrush		Y			100%	100.0%	200%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Hebridean Song Thrush					0%	0.0%	100%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Ring Ouzel		Y			100%	100.0%	200%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Northern Lapwing		Y			100%	100.0%	200%	0.01%	0.02%	0.01%	0.01%	0.00%	0.05%	0.00%	0.81%

Wind						**Current**				**UK Govn White Paper**				**Tyndall**	
						Sensitivity	**Adaptation**	**Exposure**	**Impact**	**Central**	**Constrained**	**Central**	**Constrained**	**Red**	**Purple**
								Baseline		**2020**	**2020**	**2050**	**2050**	**2050**	**2050**
Relative exposure increase / decrease from scenarios										355.1%	127.6%	355.1%	468.9%	1603.8%	8916.0%
	GT	RD	MD	RB	Adaptability					Impact	Impact	Impact	Impact	Impact	Impacts
Aquatic Warbler	Y				100%	0.1%	200%	0.01%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Marsh Warbler		Y		Y	200%	0.1%	300%	0.01%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Sky Lark		Y			100%	0.1%	200%	0.01%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
European White-fronted Goose		Y			100%	5.0%	200%	0.10%	0.01%	0.05%	0.02%	0.05%	0.06%	0.17%	0.90%
Greenland White-fronted Goose					0%	5.0%	100%	0.10%	0.01%	0.02%	0.01%	0.02%	0.03%	0.09%	0.45%
Tree Pipit			Y		50%	0.1%	150%	0.01%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Greater Scaup				Y	100%	5.0%	200%	0.10%	0.01%	0.05%	0.02%	0.05%	0.06%	0.17%	0.90%
Great Bittern		Y		Y	200%	5.0%	300%	0.01%	0.00%	0.01%	0.00%	0.01%	0.01%	0.03%	0.14%
Dark-bellied Brent Goose					0%	5.0%	100%	0.01%	0.00%	0.00%	0.00%	0.00%	0.00%	0.01%	0.05%
Stone-curlew		Y		Y	200%	1.0%	300%	0.01%	0.00%	0.00%	0.00%	0.00%	0.00%	0.01%	0.03%
European Nightjar		Y			100%	1.0%	200%	0.01%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.02%
Lesser Redpoll			Y		50%	0.1%	150%	0.01%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Common Linnet		Y			100%	0.1%	200%	0.01%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Twite					0%	0.1%	100%	0.01%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Hawfinch			Y		50%	0.1%	150%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Corn Crake	Y	Y			200%	1.0%	300%	0.01%	0.00%	0.00%	0.00%	0.00%	0.00%	0.01%	0.03%
Common Cuckoo			Y		50%	1.0%	150%	0.01%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.01%
Tundra Swan					0%	5.0%	100%	0.10%	0.01%	0.02%	0.01%	0.02%	0.03%	0.09%	0.45%
Lesser Spotted Woodpecker		Y			100%	0.1%	200%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Cirl Bunting		Y			100%	0.1%	200%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Yellowhammer		Y			100%	0.1%	200%	0.01%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Reed Bunting		Y			100%	0.1%	200%	0.01%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Black-throated Diver				Y	100%	5.0%	200%	0.10%	0.01%	0.05%	0.02%	0.05%	0.06%	0.17%	0.90%
Eurasian Wryneck		Y		Y	200%	0.1%	300%	0.01%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Red Grouse			Y		50%	5.0%	150%	0.01%	0.00%	0.00%	0.00%	0.00%	0.00%	0.01%	0.07%
Red-backed Shrike		Y		Y	200%	0.1%	300%	0.01%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Herring Gull			Y		50%	5.0%	150%	0.10%	0.01%	0.03%	0.02%	0.03%	0.04%	0.13%	0.68%
Black-tailed Godwit				Y	100%	1.0%	200%	0.01%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.02%
Savi`s Warbler		Y		Y	200%	0.1%	300%	0.01%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Common Grasshopper Warbler		Y			100%	0.1%	200%	0.01%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Scottish Crossbill	Y				100%	0.1%	200%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Wood Lark		Y			100%	0.0%	200%	0.01%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Common Scoter		Y		Y	200%	5.0%	300%	0.10%	0.02%	0.07%	0.03%	0.07%	0.09%	0.26%	1.35%
Corn Bunting		Y			100%	0.1%	200%	0.01%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Yellow Wagtail			Y		50%	0.1%	150%	0.01%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Spotted Flycatcher		Y			100%	0.1%	200%	0.01%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Eurasian Curlew					0%	1.0%	100%	0.01%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.01%

Wind						Current				UK Govn White Paper				Tyndall	
						Sensitivity	Adaptation	Exposure	Impact	Central	Constrained	Central	Constrained	Red	Purple
								Baseline		2020	2020	2050	2050	2050	2050
Willow Tit		Y			100%	0.1%	200%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Marsh Tit		Y			100%	0.1%	200%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
House Sparrow		Y			100%	0.1%	200%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Eurasian Tree Sparrow		Y			100%	0.1%	200%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Grey Partridge		Y			100%	0.1%	200%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Red-necked Phalarope				Y	100%	1.0%	200%	0.01%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.02%
Wood Warbler		Y			100%	0.1%	200%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Hedge Accentor		Y			100%	0.1%	200%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Balearic Shearwater					0%	5.0%	100%	0.01%	0.00%	0.00%	0.00%	0.00%	0.00%	0.01%	0.05%
Common Bullfinch		Y			100%	0.1%	200%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Arctic Skua		Y			100%	1.0%	200%	0.10%	0.00%	0.01%	0.00%	0.01%	0.01%	0.03%	0.18%
Roseate Tern		Y		Y	200%	10.0%	300%	0.01%	0.00%	0.01%	0.01%	0.01%	0.02%	0.05%	0.27%
European Turtle Dove		Y			100%	0.1%	200%	0.01%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Common Starling		Y			100%	0.1%	200%	0.01%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Black Grouse		Y			100%	5.0%	200%	0.01%	0.00%	0.00%	0.00%	0.00%	0.01%	0.02%	0.09%
Western Capercaillie		Y			100%	5.0%	200%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Fair Isle Wren					0%	0.1%	100%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
St Kilda Wren					0%	0.1%	100%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Song Thrush		Y			100%	0.1%	200%	0.01%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Hebridean Song Thrush					0%	0.1%	100%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Ring Ouzel		Y			100%	0.1%	200%	0.10%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.02%
Northern Lapwing		Y			100%	1.0%	200%	0.01%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.02%

Biomass						**Current**				**UK Govn White Paper**				**Tyndall**	
						Sensitivity	**Adaptation**	**Exposure**	**Impact**	**Central**	**Constrained**	**Central**	**Constrained**	**Red**	**Purple**
								Baseline		**2020**	**2020**	**2050**	**2050**	**2050**	**2050**
Relative exposure increase / decrease from scenarios										159.0%	52.8%	121.0%	334.0%	253.0%	2352.0%
	GT	RD	MD	RB	Adaptability					Impact	Impact	Impact	Impact	Impact	Impacts
Aquatic Warbler	Y				100%	100.0%	200%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%
Marsh Warbler		Y		Y	200%	-20.0%	300%	0.001%	-0.001%	-0.002%	-0.001%	-0.001%	-0.003%	-0.002%	-0.015%
Sky Lark		Y			100%	-20.0%	200%	0.050%	-0.020%	-0.052%	-0.031%	-0.044%	-0.087%	-0.071%	-0.490%
European White-fronted Goose		Y			100%	100.0%	200%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%
Greenland White-fronted Goose					0%	100.0%	100%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%
Tree Pipit			Y		50%	-20.0%	150%	0.001%	0.000%	-0.001%	0.000%	-0.001%	-0.001%	-0.001%	-0.007%
Greater Scaup				Y	100%	100.0%	200%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%
Great Bittern		Y		Y	200%	100.0%	300%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%
Dark-bellied Brent Goose					0%	100.0%	100%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%
Stone-curlew		Y		Y	200%	-10.0%	300%	0.050%	-0.015%	-0.039%	-0.023%	-0.033%	-0.065%	-0.053%	-0.368%
European Nightjar		Y			100%	100.0%	200%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%
Lesser Redpoll			Y		50%	-20.0%	150%	0.001%	0.000%	-0.001%	0.000%	-0.001%	-0.001%	-0.001%	-0.007%
Common Linnet		Y			100%	-20.0%	200%	0.050%	-0.020%	-0.052%	-0.031%	-0.044%	-0.087%	-0.071%	-0.490%
Twite					0%	100.0%	100%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%
Hawfinch			Y		50%	100.0%	150%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%
Corn Crake	Y	Y			200%	100.0%	300%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%
Common Cuckoo			Y		50%	-20.0%	150%	0.050%	-0.015%	-0.039%	-0.023%	-0.033%	-0.065%	-0.053%	-0.368%
Tundra Swan					0%	100.0%	100%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%
Lesser Spotted Woodpecker		Y			100%	100.0%	200%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%
Cirl Bunting		Y			100%	-20.0%	200%	0.005%	-0.002%	-0.005%	-0.003%	-0.004%	-0.009%	-0.007%	-0.049%
Yellowhammer		Y			100%	-20.0%	200%	0.100%	-0.040%	-0.104%	-0.061%	-0.088%	-0.174%	-0.141%	-0.981%
Reed Bunting		Y			100%	-20.0%	200%	0.050%	-0.020%	-0.052%	-0.031%	-0.044%	-0.087%	-0.071%	-0.490%
Black-throated Diver				Y	100%	100.0%	200%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%
Eurasian Wryneck		Y		Y	200%	100.0%	300%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%
Red Grouse			Y		50%	100.0%	150%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%
Red-backed Shrike		Y		Y	200%	100.0%	300%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%
Herring Gull			Y		50%	100.0%	150%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%
Black-tailed Godwit				Y	100%	100.0%	200%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%
Savi`s Warbler		Y		Y	200%	100.0%	300%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%
Common Grasshopper Warbler		Y			100%	-20.0%	200%	0.001%	0.000%	-0.001%	-0.001%	-0.001%	-0.002%	-0.001%	-0.010%
Scottish Crossbill	Y				100%	100.0%	200%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%
Wood Lark		Y			100%	-10.0%	200%	0.010%	-0.002%	-0.005%	-0.003%	-0.004%	-0.009%	-0.007%	-0.049%
Common Scoter		Y		Y	200%	100.0%	300%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%
Corn Bunting		Y			100%	-20.0%	200%	0.050%	-0.020%	-0.052%	-0.031%	-0.044%	-0.087%	-0.071%	-0.490%
Yellow Wagtail			Y		50%	-20.0%	150%	0.050%	-0.015%	-0.039%	-0.023%	-0.033%	-0.065%	-0.053%	-0.368%
Spotted Flycatcher		Y			100%	-10.0%	200%	0.001%	0.000%	-0.001%	0.000%	0.000%	-0.001%	-0.001%	-0.005%
Eurasian Curlew					0%	0.0%	100%	0.010%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%

Biomass						Current				UK Govn White Paper				Tyndall	
						Sensitivity	Adaptation	Exposure	Impact	Central	Constrained	Central	Constrained	Red	Purple
								Baseline		2020	2020	2050	2050	2050	2050
Willow Tit		Y			100%	-10.0%	200%	0.001%	0.000%	-0.001%	0.000%	0.000%	-0.001%	-0.001%	-0.005%
Marsh Tit		Y			100%	-20.0%	200%	0.001%	0.000%	-0.001%	-0.001%	-0.001%	-0.002%	-0.001%	-0.010%
House Sparrow		Y			100%	-20.0%	200%	0.001%	0.000%	-0.001%	-0.001%	-0.001%	-0.002%	-0.001%	-0.010%
Eurasian Tree Sparrow		Y			100%	-20.0%	200%	0.100%	-0.040%	-0.104%	-0.061%	-0.088%	-0.174%	-0.141%	-0.981%
Grey Partridge		Y			100%	-20.0%	200%	0.130%	-0.052%	-0.135%	-0.079%	-0.115%	-0.226%	-0.184%	-1.275%
Red-necked Phalarope				Y	100%	100.0%	200%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%
Wood Warbler		Y			100%	100.0%	200%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%
Hedge Accentor		Y			100%	-20.0%	200%	0.010%	-0.004%	-0.010%	-0.006%	-0.009%	-0.017%	-0.014%	-0.098%
Balearic Shearwater					0%	0.0%	100%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%
Common Bullfinch		Y			100%	-20.0%	200%	0.005%	-0.002%	-0.005%	-0.003%	-0.004%	-0.009%	-0.007%	-0.049%
Arctic Skua		Y			100%	100.0%	200%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%
Roseate Tern		Y		Y	200%	100.0%	300%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%
European Turtle Dove		Y			100%	-20.0%	200%	0.100%	-0.040%	-0.104%	-0.061%	-0.088%	-0.174%	-0.141%	-0.981%
Common Starling		Y			100%	-10.0%	200%	0.050%	-0.010%	-0.026%	-0.015%	-0.022%	-0.043%	-0.035%	-0.245%
Black Grouse		Y			100%	100.0%	200%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%
Western Capercaillie		Y			100%	100.0%	200%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%
Fair Isle Wren					0%	0.0%	100%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%
St Kilda Wren					0%	0.0%	100%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%
Song Thrush		Y			100%	-20.0%	200%	0.010%	-0.004%	-0.010%	-0.006%	-0.009%	-0.017%	-0.014%	-0.098%
Hebridean Song Thrush					0%	0.0%	100%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%
Ring Ouzel		Y			100%	100.0%	200%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%
Northern Lapwing		Y			100%	-20.0%	200%	0.020%	-0.008%	-0.021%	-0.012%	-0.018%	-0.035%	-0.028%	-0.196%

Biofuel						Current				UK Govn White Paper				Tyndall	
						Sensitivity	Adaptation	Exposure	Impact	Central	Constrained	Central	Constrained	Red	Purple
								Baseline		2020	2020	2050	2050	2050	2050
Relative exposure increase / decrease from scenarios										1906.0%	1310.0%	1691.0%	4275.0%	1878.0%	26426.0%
	GT	RD	MD	RB	Adaptability					Impact	Impact	Impact	Impact	Impact	Impacts
Aquatic Warbler	Y				100%	100.0%	200%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%
Marsh Warbler		Y		Y	200%	100.0%	300%	0.001%	0.003%	0.060%	0.042%	0.054%	0.131%	0.059%	0.796%
Sky Lark		Y			100%	10.0%	200%	0.100%	0.020%	0.401%	0.282%	0.358%	0.875%	0.396%	5.305%
European White-fronted Goose		Y			100%	100.0%	200%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%
Greenland White-fronted Goose					0%	100.0%	100%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%
Tree Pipit			Y		50%	100.0%	150%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%
Greater Scaup				Y	100%	100.0%	200%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%
Great Bittern		Y		Y	200%	100.0%	300%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%
Dark-bellied Brent Goose					0%	100.0%	100%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%
Stone-curlew		Y		Y	200%	100.0%	300%	0.010%	0.030%	0.602%	0.423%	0.537%	1.313%	0.593%	7.958%
European Nightjar		Y			100%	100.0%	200%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%
Lesser Redpoll			Y		50%	100.0%	150%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%
Common Linnet		Y			100%	10.0%	200%	0.100%	0.020%	0.401%	0.282%	0.358%	0.875%	0.396%	5.305%
Twite					0%	100.0%	100%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%
Hawfinch			Y		50%	100.0%	150%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%
Corn Crake	Y	Y			200%	100.0%	300%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%
Common Cuckoo			Y		50%	0.0%	150%	0.010%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%
Tundra Swan					0%	100.0%	100%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%
Lesser Spotted Woodpecker		Y			100%	100.0%	200%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%
Cirl Bunting		Y			100%	10.0%	200%	0.010%	0.002%	0.040%	0.028%	0.036%	0.088%	0.040%	0.531%
Yellowhammer		Y			100%	10.0%	200%	0.100%	0.020%	0.401%	0.282%	0.358%	0.875%	0.396%	5.305%
Reed Bunting		Y			100%	10.0%	200%	0.050%	0.010%	0.201%	0.141%	0.179%	0.438%	0.198%	2.653%
Black-throated Diver				Y	100%	100.0%	200%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%
Eurasian Wryneck		Y		Y	200%	100.0%	300%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%
Red Grouse			Y		50%	100.0%	150%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%
Red-backed Shrike		Y		Y	200%	100.0%	300%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%
Herring Gull			Y		50%	100.0%	150%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%
Black-tailed Godwit				Y	100%	100.0%	200%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%
Savi`s Warbler		Y		Y	200%	100.0%	300%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%
Common Grasshopper Warbler		Y			100%	100.0%	200%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%
Scottish Crossbill	Y				100%	100.0%	200%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%
Wood Lark		Y			100%	100.0%	200%	0.010%	0.020%	0.401%	0.282%	0.358%	0.875%	0.396%	5.305%
Common Scoter		Y		Y	200%	100.0%	300%	0.010%	0.030%	0.602%	0.423%	0.537%	1.313%	0.593%	7.958%
Corn Bunting		Y			100%	10.0%	200%	0.500%	0.100%	2.006%	1.410%	1.791%	4.375%	1.978%	26.526%
Yellow Wagtail			Y		50%	100.0%	150%	0.100%	0.150%	3.009%	2.115%	2.687%	6.563%	2.967%	39.789%
Spotted Flycatcher		Y			100%	100.0%	200%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%
Eurasian Curlew					0%	0.0%	100%	0.050%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%

Biofuel						**Current**				**UK Govn White Paper**				**Tyndall**	
						Sensitivity	**Adaptation**	**Exposure**	**Impact**	**Central**	**Constrained**	**Central**	**Constrained**	**Red**	**Purple**
								Baseline		**2020**	**2020**	**2050**	**2050**	**2050**	**2050**
Willow Tit		Y			100%	100.0%	200%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%
Marsh Tit		Y			100%	100.0%	200%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%
House Sparrow		Y			100%	0.0%	200%	0.010%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%
Eurasian Tree Sparrow		Y			100%	10.0%	200%	0.500%	0.100%	2.006%	1.410%	1.791%	4.375%	1.978%	26.526%
Grey Partridge		Y			100%	10.0%	200%	0.300%	0.060%	1.204%	0.846%	1.075%	2.625%	1.187%	15.916%
Red-necked Phalarope				Y	100%	100.0%	200%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%
Wood Warbler		Y			100%	100.0%	200%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%
Hedge Accentor		Y			100%	10.0%	200%	0.050%	0.010%	0.201%	0.141%	0.179%	0.438%	0.198%	2.653%
Balearic Shearwater					0%	100.0%	100%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%
Common Bullfinch		Y			100%	100.0%	200%	0.001%	0.002%	0.040%	0.028%	0.036%	0.088%	0.040%	0.531%
Arctic Skua		Y			100%	100.0%	200%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%
Roseate Tern		Y		Y	200%	100.0%	300%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%
European Turtle Dove		Y			100%	10.0%	200%	0.100%	0.020%	0.401%	0.282%	0.358%	0.875%	0.396%	5.305%
Common Starling		Y			100%	50.0%	200%	0.100%	0.100%	2.006%	1.410%	1.791%	4.375%	1.978%	26.526%
Black Grouse		Y			100%	100.0%	200%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%
Western Capercaillie		Y			100%	100.0%	200%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%
Fair Isle Wren					0%	100.0%	100%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%
St Kilda Wren					0%	100.0%	100%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%
Song Thrush		Y			100%	50.0%	200%	0.010%	0.010%	0.201%	0.141%	0.179%	0.438%	0.198%	2.653%
Hebridean Song Thrush					0%	100.0%	100%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%
Ring Ouzel		Y			100%	100.0%	200%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%
Northern Lapwing		Y			100%	50.0%	200%	0.010%	0.010%	0.201%	0.141%	0.179%	0.438%	0.198%	2.653%