The Drax Power (Generating Stations) Order

Land at, and in the vicinity of, Drax Power Station, near Selby, North Yorkshire

Environmental Statement
Appendix 15.1 – Climate Risk and Vulnerability Assessment

The Planning Act 2008
The Infrastructure Planning (Applications: Prescribed Forms and Procedure) Regulations 2009 – Regulation 5(2)(a)

Drax Power Limited

Drax Repower Project

Applicant: DRAX POWER LIMITED
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1 CLIMATE RISK AND VULNERABILITY

1.1 Introduction

1.1.1. Climate risk and vulnerability should be considered at an early project stage, including during the Environmental Impact Assessment (EIA) process. This will ensure that projects achieve an appropriate level of resilience in the most cost-effective manner.

1.1.2. The requirement to consider a project's vulnerability to climate change has resulted from the 2014 amendment to the EIA Directive (2014/52). The Directive has been fully transposed into UK law in the Infrastructure Planning (Environmental Impact Assessment) Regulations 2017 and came into force in the UK on the 16 May 2017. The Directive requires:

1.1.3. *"A description of the likely significant effects of the project on climate (for example the nature and magnitude of greenhouse gas emissions) and the vulnerability of the project to climate change."*

1.1.4. This document provides a Climate Risk and Vulnerability Assessment (CRVA) for the Drax Re-power Environmental Statement (ES).

1.2 Proposed Scheme

1.2.1. The Proposed Scheme is to repower up to two existing coal-powered generating units (Units 5 and 6) at the Existing Drax Power Station Complex with new gas turbines that can operate in both combined cycle and open cycle modes. The term "repower" is used as existing infrastructure, such as the steam turbine and cooling towers, that are currently used for the coal fired units would be reutilised for the new gas fired generating units/stations.

1.2.2. The repowered units (which each constitute a new gas fired generating station) would have a new combined capacity of up to 3,600 MW in combined cycle mode (1,800 MW each), replacing existing units with a combined capacity to generate up to 1,320 MW (660 MW each).

1.2.3. Each gas generating station (or unit) would have up to two gas turbines, with each gas turbine powering a dedicated generator of up to 600 MW in capacity. The gas turbines in each generating station (or unit), therefore, would have a combined capacity of up to 1,200 MW. The gas turbines in each generating station (or unit), in combined cycle mode, would provide steam to the existing steam turbine (through Heat Recovery Steam Generators (HRSGs)) which would generate up to 600 MW per generating station (or unit). Each generating station (or unit) would have up to two HRSGs. This results in a capacity for each generating station of up to 1,800 MW and, should both Units 5 and 6 be repowered, a combined capacity of up to 3,600 MW. The new gas turbine generating stations (or units) have been designated the terms "Unit X" and "Unit Y".

1.2.4. Each of Unit X and Unit Y would have (subject to technology and commercial considerations) a battery energy storage facility with a capacity of up to 100 MW per

Unit, resulting in a combined battery energy storage capacity of up to 200 MW. The two battery energy storage facilities would be stored in a single building.

1.2.5. The total combined capacity of the two gas fired generating stations, Unit X and Unit Y, and two battery storage facilities (i.e. the total combined capacity of the Proposed Scheme) is therefore 3,800 MW.

1.2.6. For the purposes of this assessment, the assets and supporting infrastructure identified above may be summarised as repowering infrastructure (comprising: gas turbines, HRSGs, above ground gas installation, gas pipeline and sludge lagoons) and supporting infrastructure (comprising: batteries, switchgear banking buildings, electrical connection to local substation); these are henceforth referred to as the 'Proposed Scheme elements'. These elements are used as the lens through which the forthcoming assessments are presented in the sections that follow.

1.2.7. Further detail about the Proposed Scheme can be found in Chapter 3 (Site and Project Description).

1.3 Study area

1.3.1. Drax Power Station is a large power station, comprising originally of six coal-fired units. It was originally built, owned and operated by the Central Electricity Board and had a capacity of just under 2,000 MW when Phase 1 was completed in 1975. Its current capacity is 4,000 MW after the construction of Phase 2 in 1986.

1.3.2. Three of the original six coal-fired units are now converted to biomass (Units 1-3) and this is assessed as the current baseline in the ES. By the latter half of 2018, four units (Units 1-4) will run on biomass with only two units (Units 5 and 6) running on coal. This is assessed as the future baseline in the ES. Units 5 and 6 will be repowered as part of this Proposed Scheme.

1.3.3. The Gas Pipeline route being considered is approximately 3 km in length and crosses agricultural land to the east of the Existing Drax Power Station Complex.

1.3.4. The Site comprises the Power Station Site and the Pipeline Area, within which the Proposed Scheme would be located. The Site is approximately 78.8 ha and lies approximately 4 m Above Ordnance Datum (AOD). The Site Boundary represents the maximum extent of all potential permanent and temporary works required as part of the Proposed Scheme.

1.3.5. Chapter 3 (Site and Project Description) provides a more detailed description of the Proposed Scheme.

1.4 Assessment Approach

1.4.1. This section outlines the approach for mainstreaming the consideration of climate vulnerability and risk into the EIA process. This approach aligns with the following UK and international guidance:

- IEMA (2015) Environmental Impact Assessment Guide to Climate Change Resilience and Adaptation (Ref. 1.1).

- European Commission (2013) Guidance on Integrating Climate Change and Biodiversity into Environmental Impact Assessment (Ref. 1.2).
- European Commission (2016) Climate change and major projects (Ref. 1.3).
- European Commission Non-paper Guidelines for Project Managers: Making vulnerable investments climate resilient (Ref. 1.4).

1.5 Step 1: Identify receptors and analysis of legal requirements

1.5.1. During this stage, relevant receptors which may be affected by climate change are identified with consideration for:

- The impact of extreme weather and changes in climate on the project over its lifetime.
- The impact of the project on the climate resilience of wider (social, environmental and economic) systems over time (reflecting on the climate change issues associated with other relevant assessment areas of the EIA).

1.5.2. These receptors may comprise both known (i.e. receptors affected by historical flooding gleaned from literature review) and unknown (new) receptors.

1.5.3. This stage includes a definition of the policy context.

1.6 Step 2: Climate vulnerability assessment

1.6.1. This stage comprises an assessment of climate vulnerability which identifies the primary receptors that are vulnerable to climate change and weather-related events and the nature of this vulnerability over the life of the project. These vulnerabilities are then used to inform the steps that follow.

1.6.2. The vulnerability of a project to extreme weather and climate change is a function of:

- The typical *sensitivity* of the type of the project to climate variables and hazards.
- The geographic *exposure* of the project to climate variables and hazards.

1.6.3. The climate vulnerability assessment is informed by a qualitative **sensitivity analysis** and an **assessment of exposure** from an evolving baseline. The **sensitivity analysis** focusses on identifying the typical climate sensitivities for receptors to relevant climate variables and climate-related hazards, such as those outlined in Table 1-1. The level of exposure of the primary receptors is then determined based on an analysis of observed climate, scenarios for projected future climate and a literature review of climate hazards associated with the prescribed changes.

Table 1-1 - Typical Climate Variables and Related Hazards

Climate variable	Climate-related hazard
Average (air) temperature change (annual, seasonal, monthly)	Sea level rise (plus local land movements), storm surge/tide
Extreme (air) temperature (frequency and magnitude)	Water availability/drought
Average precipitation (annual, seasonal, monthly)	Flood (coastal and fluvial)
Extreme rainfall (frequency and magnitude)	Subsidence and ground stability
Average wind speed change (annual, seasonal, monthly)	Fog
Gales and extreme winds (frequency and magnitude)	Storms (tracks and intensity), including storm surge
Humidity	Snow, ice and hail
Solar radiation	Storms and lightning

1.6.4. A categorisation is then assigned to each climate variable/hazard in relation to each receptor based on the following scale:

- **High**: High climate sensitivity/exposure.
- **Moderate**: Moderate climate sensitivity/exposure.
- **Low**: No significant climate sensitivity/exposure.

1.6.5. The above is a qualitative assessment informed by expert opinion and supporting literature. The **vulnerability** of primary receptors to relevant climate variables and hazards is then determined using the vulnerability matrix below. High and selected Moderate (based on professional opinion) vulnerabilities are then taken forward to the steps that follow.

Table 1-2 - Vulnerability Rating Matrix

	Exposure		
Sensitivity	Low	Moderate	High
Low	Low	Low	Low
Moderate	Low	Medium	Medium
High	Low	Medium	High

1.7 Step 3: Risk assessment

1.7.1. Firstly, hazards related to the identified Medium and High vulnerabilities are identified. The foundation for this assessment is a qualitative assessment based on expert judgment, engagement with the project team and a review of relevant literature. This process is supplemented with quantitative data and information where available. The assessment focusses on identifying and appraising the specific impact of relevant climate variables and hazards on the Proposed Scheme elements over the life of the Proposed Scheme.

1.7.2. Following the assessment of impacts, a risk assessment is undertaken focussing on identifying the consequence and the likelihood of climate impacts to the Proposed Scheme elements. These determinants are then combined to develop a climate risk rating for each project element in respect to specific climate impacts and associated variables and hazards (Table 3-2).

Table 1-3 - Risk Rating Matrix

	Consequence				
Likelihood	Insignificant	Minor	Moderate	Major	Catastrophic
Almost certain	Low	Medium	High	Extreme	Extreme
Likely	Low	Medium	Medium	High	Extreme
Moderate	Low	Low	Medium	High	Extreme
Unlikely	Low	Low	Medium	Medium	High
Very unlikely	Low	Low	Low	Medium	Medium

1.8 Step 4: Adaptation measures

1.8.1. In the final step, adaptation measures are identified through consultation with the project team and via expert opinion. Taking account of the contribution of the incorporated measures to climate resilience, a summary of the level of climate resilience of the Proposed Scheme elements to significant climate variable/hazards is applied, based on the following rankings:

- **High** - a strong degree of climate resilience, remedial action or adaptation may be required but is not a priority.
- **Moderate** - a moderate degree of climate resilience, remedial action or adaptation is suggested.
- **Low** – a low level of climate resilience, remedial action or adaptation is required as a priority.

1.8.2. Recommendations for supplementary climate change adaptation measures of climate resilience are identified.

2 STEP 1: IDENTIFY RECEPTORS AND ANALYSIS OF LEGAL REQUIREMENTS

2.1 Planning and policy context

National Planning Policy Framework (NPPF) (Ref.1.5)

2.1.1. The National Planning Policy Framework (NPPF)[1] was published on 27 March 2012 and replaces the majority of the Planning Policy Statements and Planning Policy Guidance. Section 4.7 of part 2 of the Report EN-1, the overarching National Policy Statements (NPS) for Energy, details the Government's commitments and strategy for mitigation of, and adaptation to, climate change (Ref. 1.6), including 'generic considerations' to be addressed by applicants to ensure that infrastructure is resilient to climate change:

"…applicants must consider the impacts of climate change when planning the location, design, build, operation and, where appropriate, decommissioning of new energy infrastructure" (*ibid*)

2.1.2. The Climate Change Act (2008) strengthened the institutional framework in respect of planning policy and managing the impact of climate change. In line with the objectives and provisions of the Climate Change Act (2008), the NPPF states that local authorities should adopt proactive strategies to mitigate and adapt to climate change.

Climate Change Act (2008)

2.1.3. The UK passed legislation that introduced the world's first long-term legally binding framework to tackle the risks posed by climate change. The Climate Change Act (2008) created a new approach to managing and responding to climate change in the UK, by:

- Setting ambitious, legally binding reduction targets.
- Taking powers to help meet those targets.
- Strengthening the institutional framework.
- Enhancing the UK's ability to adapt to the impacts of climate change.
- Establishing clear and regular accountability to the UK Parliament and to the developed legislatures.

Key provisions of the Act in respect of climate change adaptation includes a requirement for Government to report, at least every five years, on the risks to the UK of climate change, and to publish a programme setting out how these will be addressed.

[1] Gov.uk. (2012). *National Planning Policy Framework - Publications - GOV.UK*. [online] Available at: https://www.gov.uk/government/publications/national-planning-policy-framework--2 [Accessed 26th April, 2018].

This Act also introduced powers for Government to require public bodies and statutory undertakers to carry out their own risk assessment and make plans to address those risks. The Adaptation Sub-Committee (ASC) of the Committee on Climate Change (CCC) will provide advice to, and scrutiny of, the Government's adaptation work.

Amendment to the EIA Directive (2014/52)

2.1.4. The requirement to consider a project's (or Proposed Scheme's) vulnerability to climate change has resulted from the 2014 amendment to the EIA Directive (2014/52). The Directive has been fully transposed into UK law in the Infrastructure Planning (Environmental Impact Assessment) Regulations 2017 and came into force in the UK on the 16 May 2017. The Directive requires: "*A description of the likely significant effects of the project on climate (for example the nature and magnitude of greenhouse gas emissions) and the vulnerability of the project to climate change*."

2.1.5. Relevant information and guidance will be used in preparing this chapter, including (but not limited to):

- Highways England (2016) Major Projects' Instructions: Environmental Impact Assessment: Implementing the Requirements of 2011/92/EU as amended by 2014/52/EU (EIA Directive) (Ref. 1.7).
- IEMA Environmental Impact Assessment Guide to Climate Change Resilience and Adaptation (IEMA, 2015) (Ref. 1.1).
- UK Climate Projections 2009 (UKCP09) ().
- UK Climate Change Risk Assessment (2017) (Ref. 1.8).
- National Adaptation Programme (Ref. 1.9).
- European Commission Guidance on Integrating Climate Change and Biodiversity into Environmental Impact Assessment (Ref. 1.2).

2.1.6. Climate resilience and climate change adaptation is fast becoming an established issue in EIA policy, practice and organisational and planning policies. This is in response to legislative and regulatory drivers, but also in response to the nature of the risks and associated costs presented to projects and programmes. The consideration of climate resilience issues for the Proposed Scheme is therefore not only important to demonstrate compliance with these legislative and regulatory requirements, but to also demonstrate and respond to the Proposed Scheme's long-term resilience for planning and effective and efficient operation.

2.2 Identification of Receptors

2.2.1. Receptors associated with the Proposed Scheme are summarised below:

- Gas turbines.
- Generators (Heat Recovery Steam Generators - HRSGs).
- Batteries.
- Switchgear banking buildings.
- Above ground gas installations.
- Gas pipeline.
- Sludge lagoons.

2.2.2. As informed by the design team, the following design lifetimes of the proposed assets are as follows:

Table 2-1 – Asset Design Lifetimes

<table>
<tr><th>Asset (receptors)</th><th>Design life (years)</th></tr>
<tr><td>Gas turbines</td><td rowspan="4">30</td></tr>
<tr><td>HRSGs</td></tr>
<tr><td>Batteries</td></tr>
<tr><td>Switchgear banking buildings</td></tr>
<tr><td>Above ground gas installation</td><td>40</td></tr>
<tr><td>Gas Pipeline</td><td>40</td></tr>
<tr><td>Sludge lagoons</td><td>30</td></tr>
</table>

2.2.3. The design lifetimes identified above have been used to inform the selection of appropriate climate change projections in this assessment.

2.2.4. The sensitivity of the above receptors to climate change and weather-related risks is described in Section 3.2.

3 STEP 2: CLIMATE VULNERABILITY ASSESSMENT

3.1 Introduction

3.1.1. This step sets out the climate vulnerability assessment. The sensitivity of the sector (energy) and Proposed Scheme elements to climate change is firstly considered (Section 3.2) before the exposure (focussing on the Yorkshire and Humber region) to climate change is outlined (Section 3.3). Following this, a risk assessment is undertaken (Section 3.4) and a range of adaptation measures are identified (Section 3.5).

3.2 Sensitivity assessment

3.2.1. Using relevant guidance (Ref. 1.10), Table 3-1 shows the climate variables and climate-related hazards for the Proposed Scheme elements. Cells in white in the table indicate where the climate variable or climate-related hazard is not relevant to the Proposed Scheme elements; these climate variables and climate-related hazards have then been omitted from the forthcoming analyses.

3.2.2. The variables that remain in Table 3-1 are subsequently used throughout this report in the assessments of sensitivity (this section), exposure (Section 3.3) and vulnerability (Section 3.3.3).

Table 3-1 - Climate variables and climate-related hazards: Energy

Sector	Project element	Variable																			
		Sea				Precipitation			Temperature			Wind		RH		Water quality and soils			
		Sea level rise	Storm surge and storm tide	Surface temperature	Currents and waves	Change in annual average	Drought	Extreme precipitation events (flooding)	Changes in annual average	Extreme temperature events	Solar radiation	Gales and extreme wind events	Storms (snow, lightning, hail)	Changes in annual average	Evaporation	Soil moisture	Salinity/pH	Runoff	Soil stability
Energy	Repowering infrastruc-ture																		
	Supporting infrastruc-ture																		

Variables screened and adapted from Ref. 1.10. RH = relative humidity.

Sea

3.2.3. Gas (and energy sector) infrastructure are sensitive to changes in sea level, particularly major electrical substations and supporting infrastructure. The Proposed Scheme lies within Flood Zones 2 and 3 (see Chapter 12) therefore, flooding (fluvial and pluvial at this site) can directly cause damage to energy infrastructure (including substations and the Gas Pipeline), potentially reducing earthwork stability and hastening the deterioration of materials. It's worth noting that flood risk may also depend strongly on the design of the new infrastructure as well as its siting (Ref. 1.8). Power outages and threats to business continuity are the main risks associated with sea level rise and storm surge.

Precipitation

3.2.4. Gas (and the energy sector more generally) infrastructure are sensitive to high and low rainfall (Ref. 1.11). Pluvial and fluvial flooding or high ground water levels may also cause pollutants in the soil to be mobilised, potentially affecting building materials.

3.2.5. Prolonged periods of low rainfall or drought can also impact built infrastructure, such as pipelines. Drying out and cracking of soils may affect structural stability and prolonged dry periods can lead to cracking of surfaces and more rapid deterioration of materials. Prolonged dry spells (particularly during the summer months) may also lead to low river flows which will affect the water that is available for cooling via abstraction.

3.2.6. Snow and ice can cause damage to above-ground infrastructure, including roofs and damage to overhead cables.

Temperature

3.2.7. Gas infrastructure is sensitive to high and low temperatures, primarily through exacerbating existing faults *(ibid)*. Higher temperatures over more prolonged periods could lead to overheating of infrastructure or greater demand for cooling. Electronic and ICT equipment and substations are also particularly sensitive to extreme temperatures. Overheating may lead to operational impacts if supporting equipment is damaged or working conditions are unsafe.

3.2.8. Higher temperatures could also affect material structure and fabric and may cause the deterioration of certain materials, including buildings (i.e. battery storage facilities). Higher temperatures will also lead to increased temperature of river flows that are used for cooling, thereby reducing efficiency of this process.

3.2.9. Offshore gas is processed and brought to shore by gas processing companies and fed into the gas transmission system. The transmission system operates at high pressure which is maintained by a number of compressor stations around the UK to ensure that gas delivered to coastal terminals is available at the point of demand (Ref. 1.12). Compressor stations are not designed to run at high temperatures and consequently at high temperatures pressure may be reduced. The operation of some stations is already an issue in the summer and this could be exacerbated in the future.

Wind and storms

3.2.10. High wind speeds and gusts can have impacts on energy infrastructure, including gas infrastructure. It is important to note that whilst the short-term consequences of wind-related disruption are large, repairs may usually be carried out quickly. High winds and storms can affect the stability of above-ground infrastructure and hasten material degradation. High winds can also cause wind-driven rain infiltration into building materials and surfaces (i.e. battery storage facilities) which can increase maintenance costs and operational disruption.

3.2.11. Lightning strike can cause fire as well as power surges and shock waves which can destabilise energy systems, as well as causing damage to electronic and ICT equipment, including substations.

Relative humidity

3.2.12. Humidity affects both the performance of energy systems as well as the comfort of personnel. An increase in humidity can increase condensation, mould growth, mildew, staining and the corrosion and decay of metal surfaces, as well as poor performance of insulation.

Water quality and soils

3.2.13. Water availability can cause a number of impacts to water quality and soils. For example, greater water volumes can increase the mobilisation of pollutants in soils whilst water scarcity can increase the accumulation of chemicals and pollutants which may cause increased salinity and acidification. More acidic soils and/or water will increase the deterioration of building materials.

Climate sensitivity rating

3.2.14. Based on the information described above, literature review and expert opinion, Table 3-2 outlines the climate sensitivity of the Proposed Scheme elements. The sensitivity ratings are defined as:

- High sensitivity (red): Climate variable/hazard may have a significant impact.
- Medium sensitivity (orange): Climate variable/hazard may have a slight impact.
- Low sensitivity (green): Climate variable/hazard has little effect.
- N/A (white): Climate variable/hazard screened out.

Table 3-2 - Climate Sensitivity Rating Matrix

Variable	Sensitivity theme	Proposed Scheme element	
		Repowering infrastructure	Supporting infrastructure
Sea	Sea level rise	High	High
	Storm surge and storm tide	High	High
	Surface temperature		
Precipitation	Change in annual average	Low	Low
	Drought	Medium	Medium
	Extreme precipitation events (flooding)	High	High
	Snow and ice	Low	Low
Temperature	Change in annual average	Low	Low
	Extreme temperature events	High	High
	Solar radiation	Low	Low
Wind	Gales and extreme wind events		Medium
	Storms (snow, hail, lightning)		Medium
RH	Changes in annual average		Medium
Water quality and soils	Soil moisture	Low	Low
	Salinity/pH	Low	Low
	Runoff		Medium
	Soil stability	Low	Medium

3.3 Exposure

3.3.1. This section considers the exposure (of the Yorkshire and Humber region) to extreme weather and climate change. Current and future climate conditions are considered in this assessment.

3.3.2. The vulnerability of the Proposed Scheme to climate change depends on the level of exposure of the Proposed Scheme assets (Section 2) to changes in climate variables. Due to the lag in the climate system and given our past emissions of greenhouse gases (GHGs) some degree of climate change is inevitable in the near-term (<20-30 years); our past GHG emissions mean that we are following a High emissions pathway.

3.3.3. Alongside these more general changes (e.g. wetter summers, warmer winters), extreme events (such as storms and extreme temperatures and precipitation events) will punctuate these trends. In combination, climate change and extreme weather events will bring challenges for the UK's infrastructure over time, including in the short- (2030s), medium- (2050s) and long-term (2080s) scales. Despite the relatively short asset lifetimes noted earlier, good practice suggests that the upper timescale (e.g. 2080s) should be considered in Climate Risk and Vulnerability Assessments (CRVA) to take account of the long expected lifetimes of energy projects, including the decommissioning phase (Ref. 1.2, 1.3, 1.4). In light of the above, the assessment presented here considers the 2030s, 2050s and 2080s timeslices and focusses on the High climate change projection, where appropriate.

3.3.4. The UK Climate Projections 2009 (UKCP09) are the most up-to-date projections of climate change for the UK. Probabilistic projections of a range of climate variables are presented for different emissions scenarios[2] and for a range of timeslices[3] to the end of the 21st Century. The projections are provided at a resolution of 25 km over land, and as averages for administrative and river basin regions.

Overview of climate for the Yorkshire and Humber region

3.3.5. The Existing Drax Power Station Complex is located near Selby, North Yorkshire and is situated in the Yorkshire and Humberside Region. The climate is warm and temperate, although rainfall is significant, even in the driest month (typically February). This climate is Cfb described according to the Koppen-Geiger climate classification, such that:

- Temperature of the warmest month is ≥10 °C, and temperature of coldest month <18 °C but >-3 °C.
- Precipitation is more evenly distributed throughout the year.
- The temperature of the warmest month has an average mean daily temperature of <22 °C.

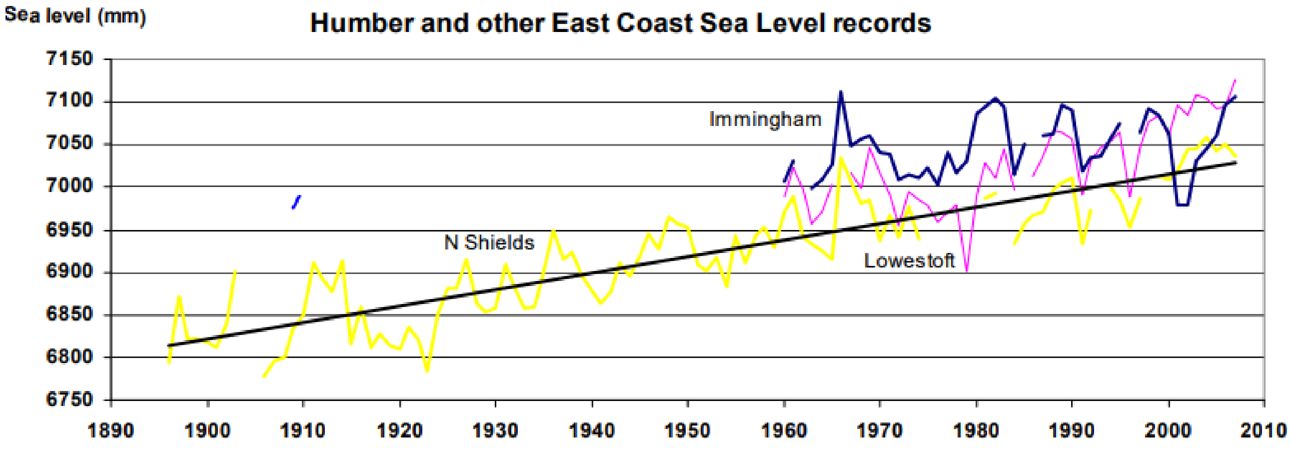
[2] UKCP09 shows data for 3 possible emissions scenarios: low, medium and high. These are the Intergovernmental Panel on Climate Change (IPCC) scenarios B1, A1B and A1FI respectively. More information on the nature of these emissions scenarios can be found in the IPCC's Special Report on Emissions Scenarios (SRES) report.

[3] UKCP09 projections are given for seven overlapping 30-year time periods. Each period steps forward by a decade, with the first time period being 2010-2039. For simplicity, these time periods are referred to by the middle decade, starting with the 2020s (2010-2039) and ending with the 2080s (2070-2099).

Sea

3.3.6. Sea level change is controlled by two main factors: eustatic (changes related to the expansion and contraction of sea water plus changes in the volumne of water stored on land as ice sheets/glaciers) and isostatic (changes related to movement of the land in responses to the effect of glaciers on the Earth's crust). Recent and future sea level change in the region is dominated by the eustatic component resulting from global warming (Ref. 1.30). Local changes (i.e. in geomorphology), modify these broader changes and can have a significant effect on the actual sea level rise experienced along the region's coastline. At present, as described in Table 3-3, sea levels are rising within the region (and along the east coast) at around 4 mm/yr; note, this is the recommended sea level rate allowance for the Humber (relative to 1990) specified by Planning Policy Statement 25 (Ref. 1.13).

Table 3-3 - Humber and Other East Coast Sea Level Records (1890-2010)



Note, Immingham is located on the Humber.

3.3.7. With regard to future changes in sea level, the UKCP09 projections provide predictions for four cities across the UK of which London is the most applicable here. Table 3-4 presents future projections of sea level (with respect to 1990 levels) to the end of the century.

Table 3-4 - Sea level Rise Projections (in cm) for London (Relative to 1990 Levels)

Year	Scenario		
	Low	Medium	High
2020	11.5	9.7	8.2
2030	16	13.5	11.4
2040	20.8	17.5	14.8
2050	25.8	21.8	18.4
2060	31.4	26.3	22.2

2070	37.2	31.2	26.3
2080	43.3	36.3	30.5
2090	49.7	41.6	35
2095	53.1	44.4	37.3

Precipitation

3.3.8. Rainfall in the UK tends to be associated with Atlantic depressions or with convection. The Atlantic lows are more vigorous in autumn and winter and bring most of the rain that falls in these seasons. In summer, convection caused by solar surface heating can form shower clouds and a large proportion of rain falls from showers and thunderstorms in the region during this time (Ref. 1.14).

3.3.9. Altitude also greatly affects rainfall in the Yorkshire and Humber region. The average annual rainfall exceeds 1500 mm in the higher parts of the Pennines. There is a decrease as the land falls eastwards, such that the east coast is one of the driest parts of the UK with less than 600 mm in places such as Teeside and the Northumbrian coast. Relatively low averages are also found in the Vale of York. In contrast, the higher ground of the North York Moors results in averages of over 1000 mm in places. These values can be compared with annual totals around 500 mm in parts of eastern England and over 4000 mm in the western Scottish Highlands.

3.3.10. At the Church Fenton meteorological station (located approximately 15 miles north-east of the village of Drax), an average of 603.2 mm of rain fell annually from 1981-2010. The driest month is February and the wettest month is August. Table 3-5 shows total mean monthly rainfall at Church Fenton whilst, for context, Source: https://www.metoffice.gov.uk/public/weather/climate/gcx4kb837

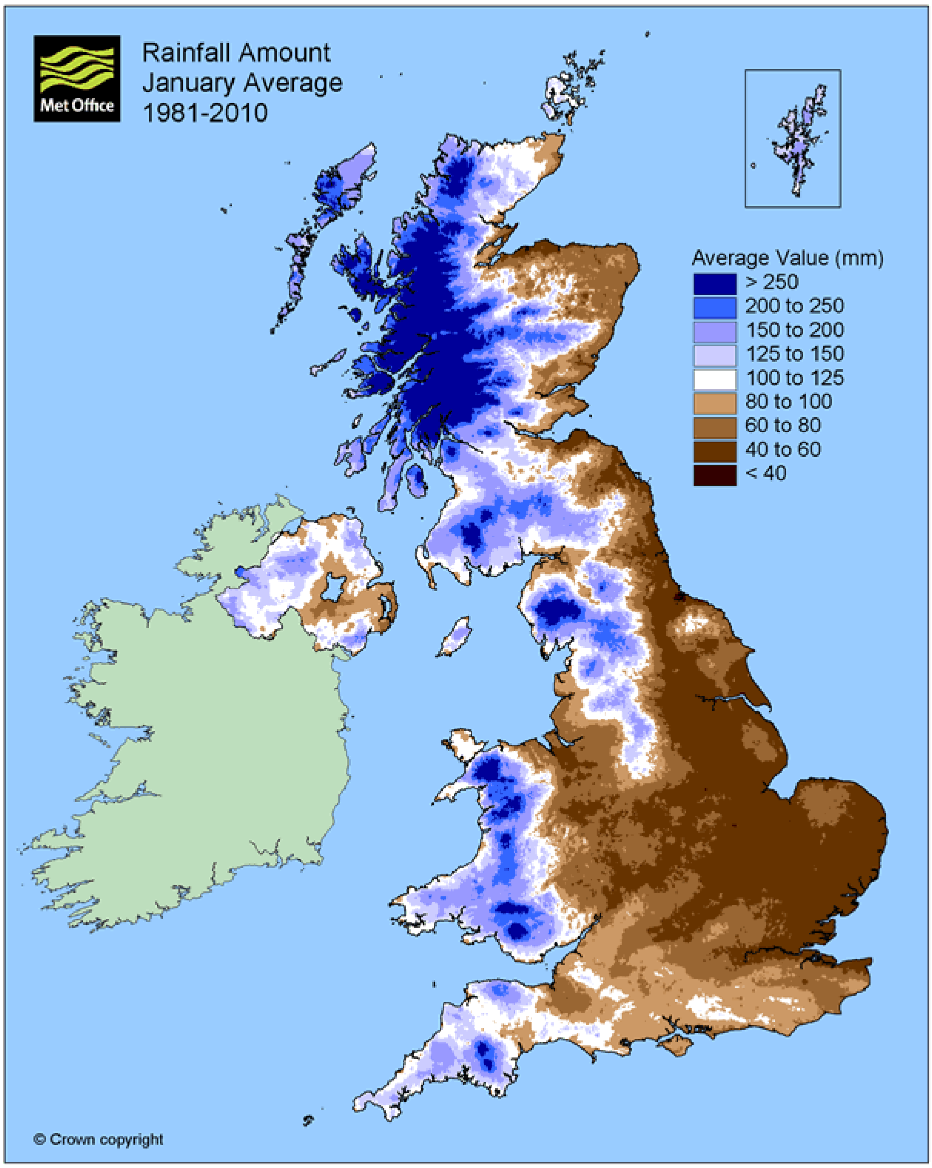
3.3.11. Table 3-5 shows the total annual average rainfall for the UK over the baseline period (1981-2010).

Table 3-5 - Total Monthly Mean Rainfall at the Church Fenton Station (1981—2010)

Precip (mm)	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
	50.3	37.3	45.5	46.3	42.6	54.8	50.2	57.9	51.2	56.7	53.9	56.6

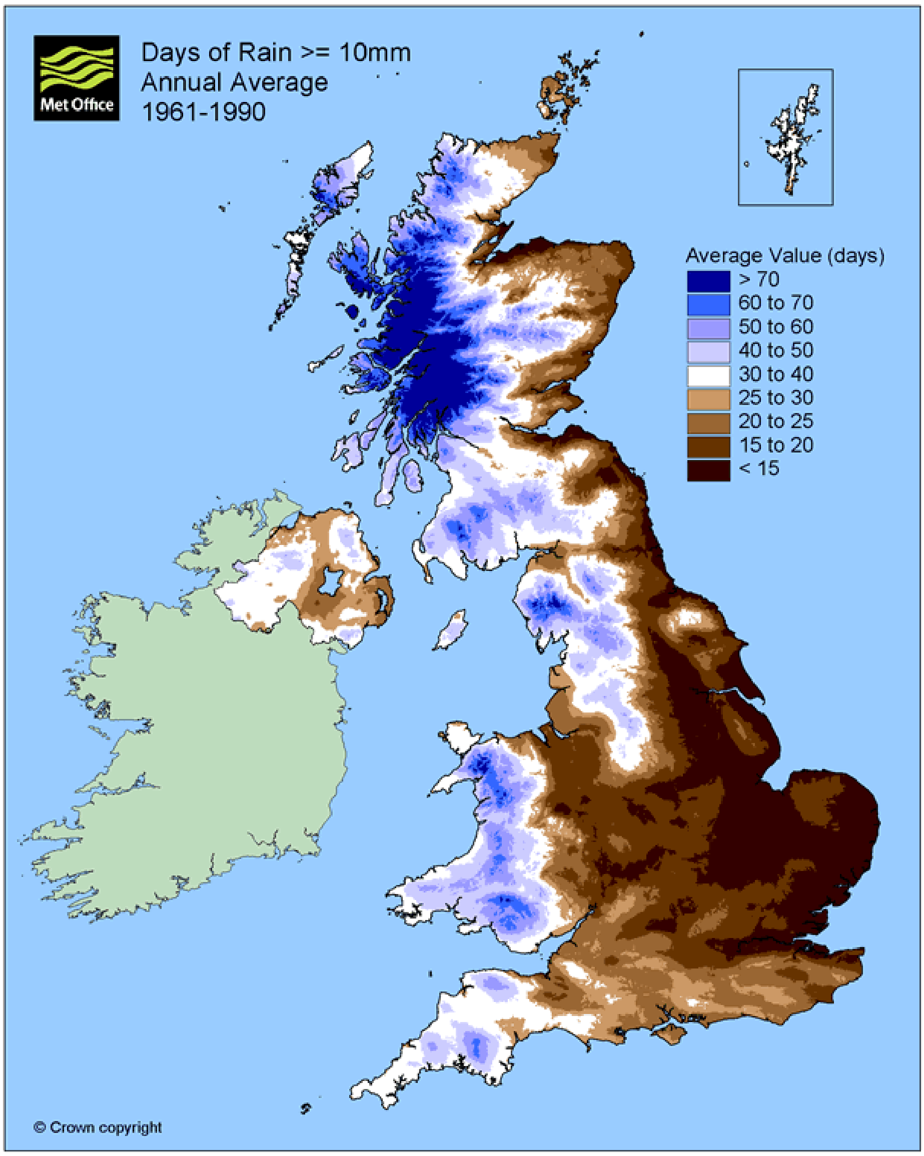
Source: https://www.metoffice.gov.uk/public/weather/climate/gcx4kb837

Figure 3-1 - Total Annual Average Rainfall (1981-2010)



3.3.12. Over much of the Yorkshire and Humber region, the number of days with rainfall totals of 1 mm or more ('wet days') tends to follow a pattern similar to the monthly rainfall totals. In the higher parts in winter (December-February), 45-50 days is the norm but this decreases to about 35 days in summer (June-August). In the drier areas closer to the coast, about 30 days in winter and about 25 days in summer are typical (Ref. 1.14). Periods of prolonged rainfall are often associated with east or NE winds on the northern flank of depressions passing to the south of the area. Figure 3-2 shows annual average days of heavy rainfall (>= 10mm).

Figure 3-2 - Days of Rain >= 10mm (1961-1990)



3.3.13. Thunderstorms are most likely to occur from May to September, reaching their peak in July and August, but are less frequent than in areas further south, and the north of the region can expect only 5 to 8 days with thunder each year. The heaviest falls of rain in the UK are often associated with these summer thunderstorms (*ibid*).

3.3.14. With regard to future projections, climate change is projected to lead to wetter winters and drier summers, with more extreme rainfall events. UKCP09 suggests that by the 2050s, mean winter precipitation is expected to increase by 11% (50^{th} percentile) and by the 2080s, increase by 20% (50^{th} percentile) under the High emissions scenario. For the summer, by the 2050s, mean summer precipitation is expected to decrease by -19% (50^{th} percentile) and by the 2080s, decrease by -28% (50^{th} percentile), under the High emissions scenario. Table 3-6 summarises changes in mean winter and summer precipitation for the 2020s, 2050s and 2080s under the Low, Medium and High emissions scenarios.

Table 3-6 - Change in Mean Summer and Winter Precipitation (mm) for the 2030s, 2050s and 2080s

Period	Low			Medium			High		
	10th	50th	90th	10th	50th	90th	10th	50th	90th
Summer									
2020s	-21	-6	9	-24	-8	10	-20	-5	11
2050s	-34	-15	9	-36	-19	1	-38	-18	3
2080s	-36	-17	4	2	15	33	-52	-28	-1
Winter									
2020s	-3	5	13	-3	4	13	-2	5	13
2050s	0	9	20	1	11	24	2	12	27
2080s	2	12	26	2	15	33	5	20	42

3.3.15. By the 2080s, average winter precipitation may increase by up to 42% and average summer precipitation may reduce by up to 52%. The trend towards wetter winters, the proportion of annual rainfall that falls during the winter season has increased, with a greater proportion of winter rainfall delivered by 'intense' events.

3.3.16. Table 3-7 show the UKCP09 projections for changes in extreme precipitation in Yorkshire and Humber in 2080 under Low, Medium and High emissions scenarios, respectively.

Table 3-7 - Changes in Precipitation Variables in Yorkshire and Humber in 2080 under a) LOW Emissions Scenario b) MEDIUM Emissions Scenario and c) HIGH Emissions Scenario

Climate variable: LOW emissions	Probability of being less than		
	10%	50%	90%
Wettest day in summer (%)	-16	2	23
Wettest day in winter (%)	1	12	26

Climate variable: MEDIUM emissions	Probability of being less than		
	10%	50%	90%
Wettest day in summer (%)	-12	2	18
Wettest day in winter (%)	3	16	33

Climate variable: HIGH emissions	Probability of being less than		
	10%	50%	90%
Wettest day in summer (%)	-21	2	30
Wettest day in winter (%)	5	20	43

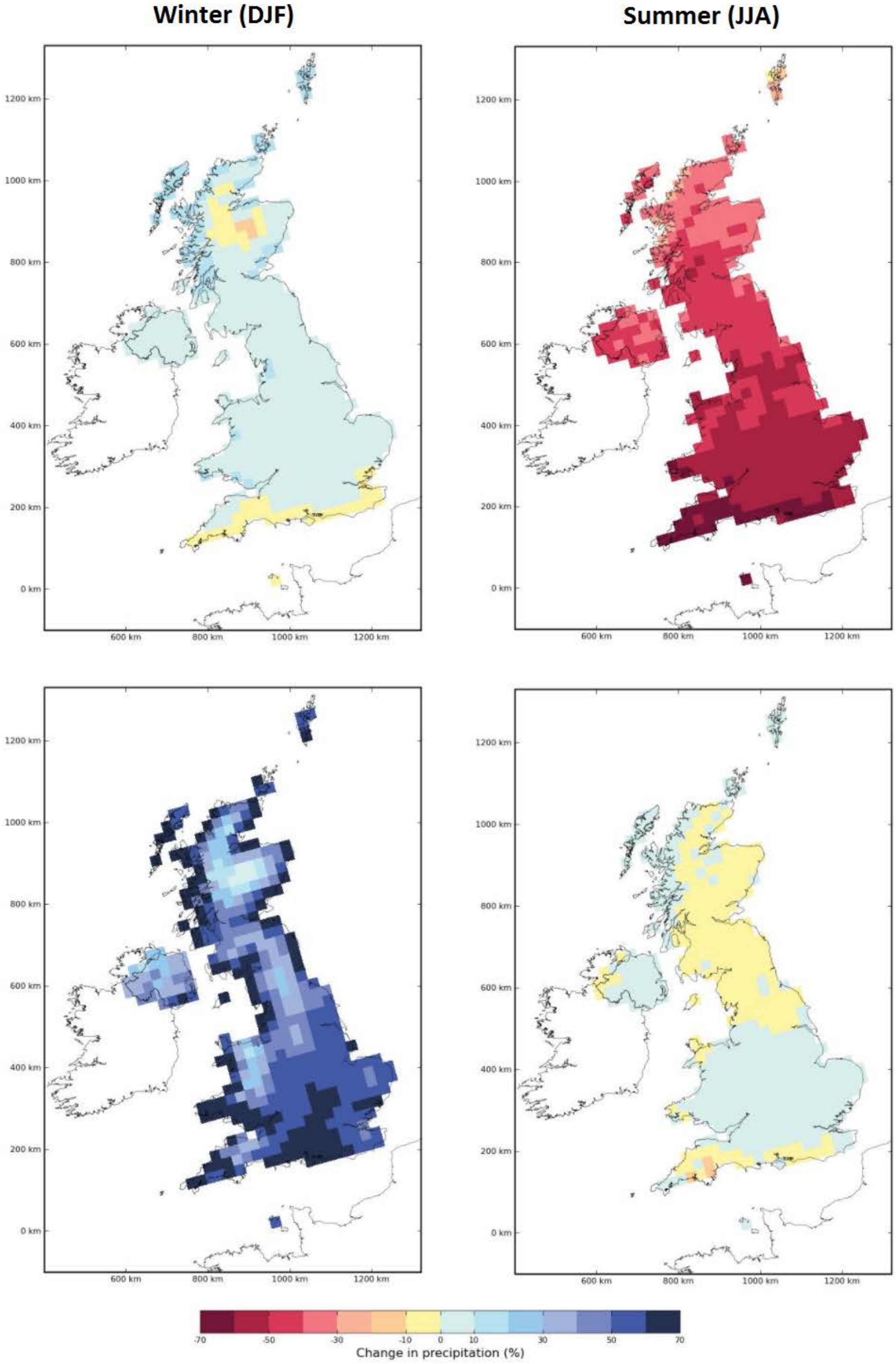
Drought

3.3.17. A combination of higher summer temperatures and reduced summer rainfall could see increases in the risk of drought in the UK. UKCP09 is not suitable for the analysis of low precipitation accumulated over extended time periods (multi-year droughts), however, it does contain some information on changes at the seasonal timescale.

3.3.18. Figure 3-3 shows projected changes in winter (left panels) and summer (right panels) precipitation totals expected by 2070-2099 under the UKCP09 high emissions scenario. The upper panels represent changes at the 10% probability (i.e. driest) level of the probabilistic range. The lower panels represent changes at the 90% probability (i.e. wettest) level.

3.3.19. The overall pattern is a move toward wetter winters and drier summers suggesting that short-term summer droughts may increase in frequency. The range of the projected changes varies considerably across the probability ranges from almost no change through to shifts of greater than 70% of the 30-year average value, therefore there is large uncertainty in the magnitude of change although the direction is agreed (droughts are likely to become more frequent). Other studies, including the recent UK Climate Change Risk Assessment (CCRA) Evidence Report (Ref. 1.15) suggest that the Yorkshire and Humber region is expected to experience a water surplus, of between >100 to ≤ 1,000 Ml/day by the 2080s under a High emissions scenario. Therefore, risk from drought is likely to be lower than other parts of the country but may still pose a threat, particularly in the summer months.

Figure 3-3 - Projected Changes in Winter (left) and Summer (right) Total Precipitation by 2080s



Under the UKCK09 High emissions scenario. The top panel represents changes at the 10% probability (i.e. driest) level of the probabilistic range. The bottom panels represent changes at the 90% probability (i.e. wettest) level.

Snow and Ice

3.3.20. Snowfall is closely linked with temperature, with falls rarely occurring if the temperature is higher than 4 °C. For snow to lie for any length of time, the temperature normally has to be lower than this. Over most of the Yorkshire and Humber region, snowfall is normally confined to the months from November to April, but upland areas can often have falls in October and May. Snow rarely lies on low ground outside the period from November to March but over higher ground lying snow can also occur in October and as late as May.

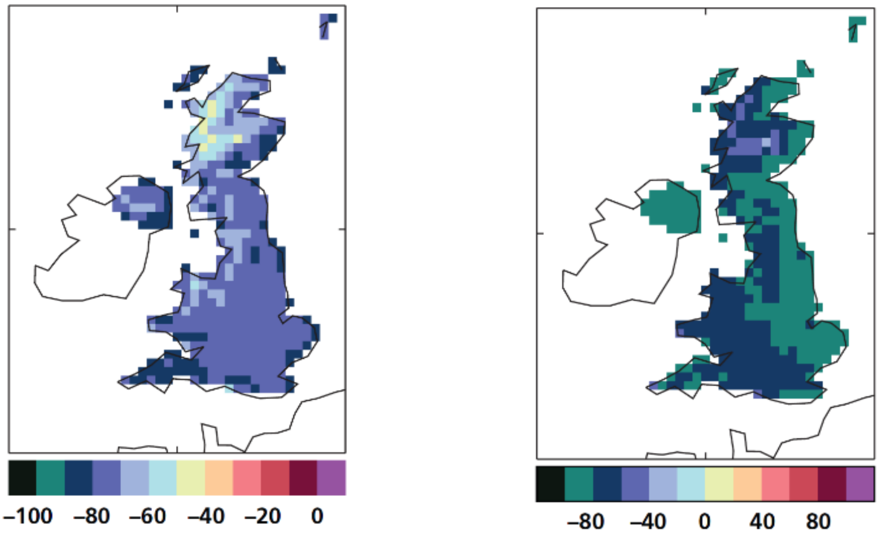
3.3.21. The degree of exposure to northerly winds is critical, and the North York Moors can receive nearly as much snow as the higher ground of the Pennines. Often this is of a showery nature, triggered by the passage of a cold airstream over the North Sea. On average, the number of days with snow falling is about 20 per year near the coast and in low lying areas of south Yorkshire and as much as 50 days over the higher Pennines.

3.3.22. An average increase of about five days of snow falling per year for every 100 m increase in altitude has been found to be typical (Ref. 1.16). The number of days with snow lying is also mainly dependent upon altitude but partly upon proximity to the sea. The number therefore varies from about 10 days per year near the east coast and in low lying areas of south Yorkshire to over 40 days in the higher Pennines. These averages can be compared with parts of the Scottish Highlands, which have about 60 days with snow lying on average and with the coasts of SW England, with less than three days per year. In most places, January is the month with most days of both snow lying and snow falling.

3.3.23. With regards to future changes, rising winter temperatures are likely to reduce the amount of precipitation that falls as snow in winter. UKCP09 projects a reduction of mean snowfall, the number of days when snow falls and heavy snow events by the end of the 21st century (Ref. 1.17). UKCP09 does not provide projections for the nearer-term for snow. While there is less certainty in the magnitude of projected change, there is confidence in the negative sign of the change (i.e. snow fall is generally expected to decrease compared with the baseline) (Ref. 1.18). Projections indicate substantial reductions in snowfall days for all regions in winter (Ref. 1. 17, 1.11)).

3.3.24. Reductions of 70 to 80 % are projected for the majority of England (see Figure 3-4, left pane). Similar magnitude changes are also projected for spring (not shown); autumn and summer have so few snow days per year in England that the impact of climate change is not modelled. The 90th percentile of snowfall rate can be used as a measure of ‘heavy’ snow events. There are no projected results for the 2020s or 2050s reported, however ensemble projections for the 2080s suggest that for most of the UK, the intensity of winter and spring ‘heavy’ snow events could decrease by over 80 percent (Ref. 1.17). Reductions are greatest in eastern and north-eastern areas of England (see Figure 3-4 right pane).

Figure 3-4 - Changes in the Number of Winter Days with Snow Falling (%) (left) and Percentage Changes in the 90th Percentile of Snow Fall Rate for Winter (right) for 2070-99 Relative to 1960-1991 Baseline. This Figure Shows the Ensemble Mean of the 11 Individual RCM Projections (Ref. 1.14)



3.3.25. This study found no published studies on projections of the likely impacts of climate change on ice. However, it is generally assumed that the number of days with temperatures below 0°C will decrease in the future in line with increasing average winter temperatures (Ref. 1.19). As a consequence, it is likely that the number of days with ice will decrease.

Temperature

3.3.26. Mean annual temperatures depend strongly on altitude, with a decrease of about 0.5°C for each 100m increase in altitude, and, to some extent, proximity to coast (Ref. 1.16). The coldest waters around the UK are found off North East England with sea surface temperatures varying from ~5 °C in winter to ~13 °C in summer (compared with a range of 8 °C to 18 °C off South West England). This, coupled with extensive areas of upland, means that temperatures, relative to elsewhere in England, are generally cool throughout the year. In the low-lying areas mean annual temperatures over the region range from ~8.5 °C to ~10 °C. By way of comparison, over the UK, mean annual temperatures range from ~7 °C in the Shetlands to >11 °C in Cornwall and the Channel Islands.

3.3.27. At the Church Fenton meteorological station (located approximately 15 miles north-east of the village of Drax), the minimum annual average temperatures from 1981-2010 was 5.7°C whilst the maximum annual average temperature was 13.6°C. Table 3-8 shows minimum and maximum mean monthly temperatures at Church Fenton.

Table 3-8 - Minimum and Maximum Monthly Mean Temperatures at the Church Fenton Station (1981-2010)

Temp. (°C)	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
Min	1.0	0.9	2.5	3.8	6.6	9.6	11.8	11.7	9.5	6.7	3.5	1.1
Max	7.0	7.5	10.1	12.6	16.0	18.8	21.2	20.8	18.0	13.9	9.9	7.1

3.3.28. From 1961-2006 the Yorkshire and Humber region has experienced an increase in mean annual temperature of 1.5°C. Table 3-9 summarises changes in daily mean annual temperature in each season for the period 1961-2006.

Table 3-9 - Change in Daily Mean Temperature (°C) from 1961 to 2006 by Season

Spring	Summer	Autumn	Winter	Annual
1.45°C	1.66°C	1.15°C	1.9°C	1.5°C

3.3.29. With regard to future projections, climate change is projected to lead to hotter summers and warmer winters, with more extreme high temperature events. UKCP09 suggests that by the 2050s, mean winter temperature is expected to increase by 2.2 ºC (50th percentile) and by the 2080s, increase by 2.5 ºC (50th percentile), under the High emissions scenario. For the summer, by the 2050s, mean summer temperature is expected to increase by 2.3 ºC (50th percentile) and by the 2080s, increase by 2.6 ºC (50th percentile), under the High emissions scenario. Table 3-10 summarises changes in mean winter and summer precipitation for the 2020s, 2050s and 2080s under the Low, Medium and High emission scenarios.

Table 3-10 - Change in Mean Summer and Winter Temperature (°C) for the 2020s, 2050s and 2080s

Period	Low			Medium			High		
	10th	50th	90th	10th	50th	90th	10th	50th	90th
Summer									
2020s	0.6	1.4	2.3	0.5	1.3	2.3	0.4	1.3	2.3
2050s	0.9	2.2	3.6	1.1	2.3	3.9	1.2	2.6	4.4
2080s	1.1	2.5	4.3	1.7	3.3	5.4	2.2	4.2	6.8
Winter									
2020s	0.5	1.3	2.1	0.6	1.3	2.1	0.5	1.3	2.2

2050s	0.9	1.9	3.1	1.1	2.2	3.4	1.4	2.5	3.7
2080s	1.4	2.5	3.9	1.6	3.0	4.6	2.0	3.6	5.5

3.3.30. Temperature shows both a seasonal and a diurnal variation. January is usually the coldest month, with mean daily minimum temperatures varying from below -0.5 °C on the highest ground to ~2 °C along the coast and in South Yorkshire. Minimum temperatures usually occur around sunrise and extreme minima have been recorded in winter, most often in January or February.

3.3.31. With regards to changes in minimum and maximum temperatures, from 1961-2006 the Yorkshire and Humber region has experienced an increase in mean minimum temperatures of ~1.33°C. Table 3-11 summarises the changes in mean annual minimum temperature for each season for the period 1961-2006 for the Yorkshire and Humber region.

Table 3-11 - Change in Daily Minimum Temperature (°C) from 1961-2006 by Season

Spring	Summer	Autumn	Winter	Annual
1.17°C	1.43°C	1.16°C	1.67°C	1.33°C

3.3.32. From 1961-2006, the Yorkshire and Humber region has also experienced an increase in mean maximum temperature of 1.68°C. Table 3-12 summarises the changes in mean annual maximum temperature for each season for the period 1961-2006 for the Yorkshire and Humber region.

Table 3-12 - Change in Daily Maximum Temperature (°C) from 1961-2006 by Season

Spring	Summer	Autumn	Winter	Annual
1.72°C	1.88°C	1.14°C	2.13°C	1.68°C

3.3.33. With regards to future changes, by the 2050s projections for daily minimum summer temperature for the Yorkshire and Humber region suggest increases of 2.4°C (Low), 2.6°C (Medium) and 2.9°C (High) for the central estimate (50^{th} percentile). By the 2080s, projections for daily minimum summer temperature for the Yorkshire and Humber region suggest increases of 2.8°C (Low), 3.7°C (Medium) and 4.7°C (High) for the central estimate (50^{th} percentile).

3.3.34. By the 2050s, projections for daily maximum summer temperature for the Yorkshire and Humber region suggest increases of ~2.9ºC (Low), 3.1ºC (Medium) and 3.5ºC (High) for the central estimate (50th percentile). By the 2080s, projections for daily maximum summer temperature for North East England suggest increases of ~3.4ºC (Low), 4.3ºC (Medium) and 5.6ºC (High) for the central estimate (50th percentile).

3.3.35. Table 3-13 show the UKCP09 projections for changes in maximum temperatures in Yorkshire and Humber in 2080 under Low, Medium and High emissions scenarios, respectively.

Table 3-13 Change in Seasonal Temperature Variables in Yorkshire and Humber in 2080 Under a) LOW Emissions Scenario b) MEDIUM Emissions Scenario c) HIGH Emissions Scenario

Climate variable: LOW emissions	**Probability of being less than**		
	10%	**50%**	**90%**
Summer mean maximum temperature (°C)	1.1	3.4	6.1
Winter mean maximum temperature (°C)	1.0	2	4.4

Climate variable: MEDIUM emissions	**Probability of being less than**		
	10%	**50%**	**90%**
Summer mean maximum temperature (°C)	1.9	4.3	7.6
Winter mean maximum temperature (°C)	0.9	2.9	5.4

Climate variable: HIGH emissions	**Probability of being less than**		
	10%	**50%**	**90%**
Summer mean maximum temperature (°C)	2.5	5.6	9.5
Winter mean maximum temperature (°C)	1.2	3.6	6.7

3.3.36. With regard to heat waves, research published by the Met Office Hadley Centre suggests the European summer heat wave in 2003 could become a normal event by the 2040s. By the 2060s, such a summer would be considered cool according to some climate models (Ref. 1.20). It is very likely (confidence level >90%) that human influence has at least doubled the risk of a heatwave exceeding mean summer temperatures experienced in 2003 (Ref. 1.21). In a study for Australia, Ref. 1.22 concluded that it was very likely (>90% confidence) that there was a fivefold increase in the odds of extreme heat occurring in the country due to human influences using simulations for 2006-2020.

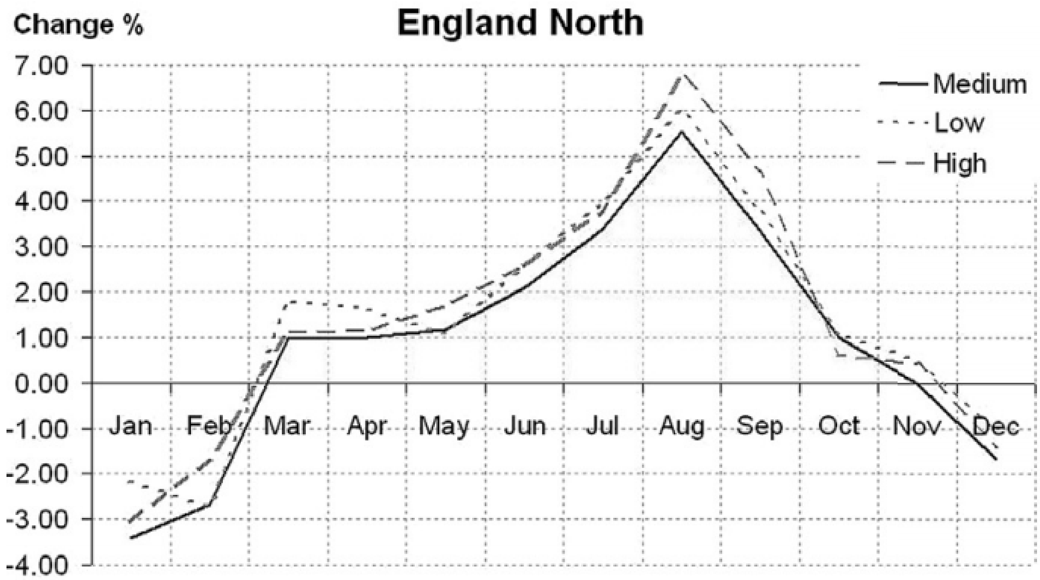
Solar radiation

3.3.37. A recent (regional) study (Ref.1.25) suggests that the North of the UK, including the Yorkshire and Humber region, is likely to see an increase in annual solar radiation by the 2050s of 3.6 Wm-2 (Low), 3.0 Wm-2 (Medium) or 3.8 Wm-2 (High) under the central (50th percentile) estimate. By the 2080s, increases of 3.9 Wm-2 (Low), 4.0 Wm-2 (Medium) or 4.6 Wm-2 (High) under the central (50th percentile) estimate are projected. Table 3-14 outlines the changes in annual solar radiation for the 2050s and 2080s under the UKCP09 emissions scenarios. Note, increases are projected to be largest in the south and south west of the UK. All regions of the UK are likely to have increased cloud cover (although there is large uncertainty around future projections of cloud cover) and therefore slightly less solar radiation during the winter. Figure 3-5 describes the change (%) in solar radiation from the baseline for the 2050s for the North of England. The results suggest that increases in solar radiation are more likely in the spring and summer than in autumn and winter.

Table 3-14 - Changes in Annual Solar Radiation (Wm-2)

Period	Low			Medium			High		
	10th	50th	90th	10th	50th	90th	10th	50th	90th
2050s	-0.5	3.6	8.0	-0.9	3.0	7.2	-0.6	3.8	8.5
2080s	-0.7	3.9	8.7	-0.7	4.0	9.1	-1.5	4.6	11.3

Figure 3-5 - Projected Regional Average Change (%) of Solar Radiation (2050s)



Source: Ref.1.25

Wind

3.3.38. The UKCP09 projections depict a wide spread of future changes in mean surface wind speed, however, there is large uncertainty in projected changes in circulation over the UK and natural climate variability contributes much of this uncertainty (Ref. 1.23). It is therefore difficult to represent regional wind extreme winds and gusts within regional climate models (Ref. 1.24).

3.3.39. Central estimates of change in mean wind speed for the 2050s are small in all ensemble runs (<0.2ms-1). A wind speed of 0.2 ms−1 (~0.4 knots) is small compared with the typical magnitude of summer mean wind speed of about 3.6–5.1 ms-1 (7–10 knots) over much of England (Ref. 1.26). Seasonal changes at individual locations across the UK lie within the range of –15% to +10%. Results suggest that there could be a future reduction in the summer westerly wind flows over the southern half of the UK. There may be an increase in westerly flows in the north during summer and also an increase in southerly flows over the UK in winter.

3.3.40. With regards to storms, the analysis presented here is a summary of expected changes in storm patterns under a changing climate. A storm is defined by the Met Office as a wind event measuring 10 or higher on the Beaufort scale (equivalent to a wind speed of 24.5 m/s or 55 mph).

3.3.41. Thunderstorms are most likely to occur from May to September, reaching their peak in July and August, but are less frequent than in areas further south, and the north of the region can expect only five to eight days with thunder each year. The heaviest rainfall events in the UK are often associated with these summer thunderstorms.

3.3.42. With regard to future projections of storms, studies suggest that climate-driven storm changes are less distinct in the Northern than Southern hemisphere (Ref. 1.29). There is some agreement of a projected poleward shift in storm tracks across the Atlantic Ocean; however, for mid-Atlantic storms, such as those that have affected the UK in early 2014, the signal is more complex (Ref. 1.30). Potentially, those mid-Atlantic storms may become more intense, particularly with the long-term warming of the sub-tropical Atlantic that could increase the amount of moisture that those storms carry (*ibid*). However, such is the wide range of inter-model variation, robust projections of changes in storm track are not yet possible and there is low confidence in the direction of future changes in the frequency, duration or intensity of storms affecting the UK.

Relative Humidity

3.3.43. Relative Humidity is the most common measure of humidity. It measures how close the air is to being saturated. From 1961-2006 the Yorkshire and Humber region has experienced a decrease in relative humidity of ~2.9%.

3.3.44. Table 3-15 summarises the changes in relative humidity in each season for the period 1961-2006 in the Yorkshire and Humber region.

Table 3-15 - Changes in Relative Humidity (%) from 1961-2006 by Season

Spring	Summer	Autumn	Winter	Annual
-2.9%	-3.4%	-2.3%	-2.9%	-2.9%

3.3.45. Table 3-16 show the UKCP09 projections for changes in seasonal mean relative humidity in Yorkshire and Humber in 2080 under Low, Medium and High emissions scenarios, respectively.

Table 3-16 Change in Seasonal Mean Relative Humidity in Yorkshire and Humber in 2080 Under a) Low Emissions Scenario b) Medium Emissions Scenario c) High Emissions Scenario

Climate variable: LOW emissions	**Probability of being less than**		
	10%	**50%**	**90%**
Summer mean relative humidity (%)	-15 to -5	-5 to 0	0 to +5
Winter mean relative humidity	-5 to 0	-5 to +5	0 to 5

Climate variable: MEDIUM emissions	**Probability of being less than**		
	10%	**50%**	**90%**
Summer mean relative humidity	-15 to -5	-10 to 0	0 to +5
Winter mean relative humidity	-5 to 0	-5 to +5	0 to +5

Climate variable: HIGH emissions	**Probability of being less than**		
	10%	**50%**	**90%**
Summer mean relative humidity	-25 to -10	-15 to -5	0 to +5
Winter mean relative humidity	-5 to 0	-5 to +5	0 to +5

Extremes (precipitation and temperature events)

3.3.46. A range of 'extreme' climate change scenarios (produced by Wade *et al*., 2015 (Ref. 1.29) have also been reviewed. Wade *et al*., (2015) considered a range of climate variables including heatwaves, cold snaps, low and high rainfall, droughts, floods and windstorms. The H++ scenarios represent the margins or beyond the 10th to 90th percentile range of the 2080s UKCP09 High emissions scenario as presented in the UKCP09 projections (Ref. 1.19) and reported here. These scenarios provide a high-impact, low-likelihood event to compare against more likely outcomes.

3.3.47. The H++ scenarios suggest that average summer maximum temperatures will exceed 30°C across most of the UK, with temperatures of the hottest days are also likely to exceed 40°C (Ref. 1.29). The H++ scenarios for heavy daily and sub-daily rainfall suggest that, for the same period, there is a 60% to 80% increase in rainfall for summer or winter events based on a consideration of new high resolution modelling and physical processes. This is within the UKCP09 distribution range for the 2080s High emissions “wettest day of the winter” variable but higher than uplifts previously considered for summer.

3.3.48. Wade *et al*., (2015) (Ref . 1.29) recommend that a plausible H++ windstorm scenario is a 50-80 % increase in the number of windstorms over the UK by 2070-2100 compared to 1975-2005. However, it is important to note that this scenario is based on the CMIP5 climate model simulations, which contain biases in the position of the North Atlantic storm track and systematically under-represents the number of intense cyclones.

Exposure rating

3.3.49. Based on the climate change projections for Yorkshire and Humber, Table 3-17 indicates the level of exposure of the Drax Power Station to changes in climate variables.

Table 3-17 Exposure to Change in Climate Variables

Climate variable	Exposure theme	Exposure	
		Repowering infrastructure	Supporting infrastructure
Sea	Sea level rise	High	
	Storm surge and storm tide	High	
Precipitation	Change in annual average	Medium	
	Drought	Medium	
	Extreme precipitation events (flooding)	High	
	Snow and ice	Medium	
Temperature	Changes in annual average	Medium	
	Extreme temperature events	High	
	Solar radiation	Medium	
Wind	Gales and extreme wind events	Medium	
	Storms (hail, lightning)	Medium	
Relative humidity	Change in annual average	Medium	
Water quality and soils	Soil moisture	Medium	
	Salinity/pH	Low	

	Runoff	Low
	Soil stability	Medium

Vulnerability

3.3.50. The sensitivity (Section 3.2) and exposure (Section 3.3) analyses may be combined to provide an overall assessment of vulnerability of the Proposed Scheme elements. Table 3-18 presents the overall assessment of vulnerability for each of the Proposed Scheme elements.

Table 3-18 - Climate Vulnerability Rating: Repowering and Supporting Infrastructure

Sector	Proposed Scheme element	Variable	Type	Sensitivity	Exposure	Vulnerability
Energy	• Repowering infrastructure	Sea	Sea level rise	High	High	High
			Storm surge and storm tide	High	High	High
		Precipitation	Change in annual average	Low	Medium	Low
			Drought	Medium	Medium	Medium
			Extreme precipitation events (flooding)	High	High	High
			Snow and ice	Low	Medium	Low
		Temperature	Change in annual average	Low	Medium	Low
			Extreme temperature events	High	High	High
			Solar radiation	Low	Medium	Low
		Water quality and soils	Soil moisture	Low	Medium	Low
			Salinity/pH	Low	Low	Low

Sector	Proposed Scheme element	Variable	Type	Sensitivity	Exposure	Vulnerability
			Soil stability	Low	Medium	Low
	Supporting infrastructure	Precipitation	Change in annual average	Low	Medium	Low
			Drought	Medium	Medium	Medium
			Extreme precipitation events (flooding)	High	High	High
			Snow and ice	Low	Medium	Low
		Temperature	Change in annual average	Low	Medium	Low
			Extreme temperature events	High	High	High
			Solar radiation	Low	Medium	Low
		Wind	Gales and extreme wind events	Medium	Medium	Medium
			Storms (lightning, hail)	Medium	Medium	Medium
		RH	Changes in annual average	Medium	Medium	Medium
		Water quality and soils	Soil moisture	Low	Medium	Low
			Salinity/pH	Low	Low	Low
			Runoff	Medium	Low	Low
			Soil stability	Medium	Medium	Medium

3.3.51. Based on the assessment provided above, the following variables with High and Medium Vulnerability ratings have been taken forward into the impact (risk) assessment phase. Note, those with an asterisk indicate vulnerabilities common across both Proposed Scheme elements.

- **Impacts on repowering infrastructure**:
  - Sea:
    - Sea level rise*
    - Storm surge and storm tide*
  - Precipitation:
    - Drought*
    - Extreme events (including flooding)*
  - Temperature:
    - Extreme temperature events
- **Impacts on supporting infrastructure**:
  - Sea:
    - Sea level rise*
    - Storm surge and storm tide*
  - Precipitation:
    - Drought*
    - Extreme precipitation events (including flooding)*
  - Temperature:
    - Extreme temperature events
  - Wind:
    - Gales and extreme wind events
    - Storms (lightning, hail)
  - Relative humidity
  - Water quality and soils:
    - Soil stability

4 STEP 3: RISK ASSESSMENT

4.1 Introduction

4.1.1. This section describes the risk assessment. Prior to undertaking the risk assessment, a range of hazards related to the Medium and High climate vulnerabilities (Section 3) of the Proposed Scheme elements are identified.

4.1.2. Following this, as the scale of risks depends on the likelihood of the risks occurring (and the consequence if they do occur), likelihood and consequence are qualitatively assessed and combined to provide an overall assessment of risk.

4.1.3. The risk assessment is informed by the Medium and High climate vulnerabilities of the Proposed Scheme elements output from the step above and as repeated below:

- **Impacts on repowering infrastructure**:
  - Sea:
    - Sea level rise*
    - Storm surge and storm tide*
  - Precipitation:
    - Drought
    - Extreme events (including flooding)
  - Temperature:
    - Extreme temperature events
- **Impacts on supporting infrastructure**:
  - Sea:
    - Sea level rise*
    - Storm surge and storm tide*
  - Precipitation:
    - Drought
    - Extreme precipitation events (including flooding)
  - Temperature:
    - Extreme temperature events
  - Wind:
    - Gales and extreme wind events
    - Storms (lightning, hail)
  - Relative humidity
  - Water quality and soils:
    - Soil stability

4.2 Hazard estimation

4.2.1. Climate- and weather-related risks affecting the Proposed Scheme elements, disaggregated by theme, associated with the identified Medium and High vulnerabilities are described in Table 1-25.

Table 4-1 - Climate Variables and Associated Hazards for the Proposed Scheme Elements

Climate variable	Associated hazards	Impact				
		Structural stability	Structural robustness	Weather proofing and detailing	Material durability	Site contents and business continuity
Sea	Sea level rise and storm surge	Flooding of site and site assets damaging structures				Loss of service due to flooding
Precipitation	Extreme rainfall events	Damage due to increased run-off Soil saturation and water damage Undercutting Increased slope instability, particularly of exposed surfaces		Guttering and drainage becoming overwhelmed during periods of high rainfall Blockages of drainage assets Greater mobilisation of pollutants in soil/ground causing deterioration of materials		Water accumulation causing power outage and associated damage to control system. Risk to operations if assets become unusable due to flooding Stopping of services due to asset failure Scour of embankments leading to

Climate variable	Associated hazards	Impact				
		Structural stability	**Structural robustness**	**Weather proofing and detailing**	**Material durability**	**Site contents and business continuity**
						increased maintenance
	Drought	Lower water levels Loss of vegetation leading to greater erosion risk	Drying out of materials and cracking		Increased rate of deterioration of materials, potentially leading to need for early replacement	Reduced abstraction allowances in summer reducing water volumes necessary for site operation (i.e. cooling) Stopping of services
	Drier summers	Subsidence Failure of earthworks due to desiccation Shrinking and cracking of soils		Increased dust and windborne materials affecting site construction, operation and maintenance, including silting and sedimentation		

Climate variable	Associated hazards	Impact				
		Structural stability	**Structural robustness**	**Weather proofing and detailing**	**Material durability**	**Site contents and business continuity**
	Wetter winters (including flooding and/or repeated wet cycles)	Damage due to increased run-off Soil softening and erosion leading to collapse and settlement of soil structures Increased slope instability Soil saturation	Deformation of rigid structures Undercutting	Blockage of drains and associated assets Water accumulation in low spots and/or on impermeable surfaces Excessive vegetation growth	Greater mobilisation of pollutants in the soil/ground	Increasingly difficult working conditions, including time available to undertake works Reduced opportunities for maintenance
Temperature	Extreme temperature events	Flat roof cracking and expansion Overheating of equipment Increased risk of erosion	Risks to stored equipment, including waste (e.g. batteries, oils and hazardous materials) Damage and disruption (e.g. fires)	Damage to external weather proofing and detailing at ground level Higher day and night-time temperatures	Enhanced reactions when cement is stabilising and drying of concrete	Reduced working periods and increased delays Reduced opportunities for maintenance

Climate variable	Associated hazards	Impact				
		Structural stability	**Structural robustness**	**Weather proofing and detailing**	**Material durability**	**Site contents and business continuity**
	Hotter summers	Overheating of equipment, including ICT equipment and substations			Enhanced reactions when cement is stabilising and drying of concrete	Reduced opportunities for maintenance Greater demand for cooling Higher summer river temperatures Risks to gas distribution at compressor stations due to high temperatures (leading to lower delivery pressures)
	Changes in solar radiation			Increased solar gain (i.e. glare and warming of exposed surfaces)		
Wind	Gales and extreme wind events	Risk of damage to structures and foundations,		Damage from high winds and rain-infiltration into	Increased rate of deterioration of materials,	

Climate variable	Associated hazards	Impact				
		Structural stability	Structural robustness	Weather proofing and detailing	Material durability	Site contents and business continuity
		including from flood scour and/or run-off Damage to signage and site structures Erosion of banks and exposed surfaces		building surfaces and materials	potentially leading to need for early replacement	
	Storms (hail, lighting)	Destabilisation due to lighting strike				Risk to power source Risk to operation and loss of power Electrical surges Fire risk
Relative humidity	Humidity			Damage to external weather proofing and detailing at ground level (i.e. from	Excessive moisture in building materials Excessive moisture in	

Climate variable	Associated hazards	Impact				
		Structural stability	**Structural robustness**	**Weather proofing and detailing**	**Material durability**	**Site contents and business continuity**
				condensation, mould growth and/or mildew)	sheltered (i.e. north-facing) surfaces	
Water quality	Soil stability	Subsidence Failure of earthworks due to desiccation Shrinking and cracking of soils				Increased maintenance costs and risks to operation

4.3 Risk evaluation

4.3.1. The scale of the risks described above depends on the likelihood of them occurring and the consequence if they do occur. Likelihood and consequence can be qualitatively assessed using the descriptions in Table 4-2 and Table 4-3.

Table 4-2 - Qualitative Description of Consequence

Measure of consequence	Description
Insignificant	No infrastructure damage, adverse effects on health, safety and the environment or financial loss. Little change to service.
Minor	Localised infrastructure disruption or loss of service. No permanent damage, minor restoration work required. Small financial losses and/or slight adverse health or environmental effects.
Moderate	Limited infrastructure damage and loss of service with damage recoverable by maintenance or minor repair. Moderate financial losses. Adverse effects on health and/or the environment
Major	Extensive infrastructure damage and/or complete loss of service. Early renewal of infrastructure 50-90%. Permanent physical injuries and/or fatalities. Major financial loss. Significant effect on the environment, requiring remediation.
Catastrophic	Permanent damage and complete loss of service. Early renewal of infrastructure >90%. Sever health effects and/or fatalities. Extreme financial loss (>90%). Very significant loss to the environment requiring remediation and restoration.

Table 4-3 - Qualitative Description of Likelihood

Measure of likelihood	Recurrent or event risks (e.g. extreme events)	Long-term risks (e.g. rising temperatures)
Almost certain	Could occur several times in a year	Has a >90% chance of occurring over the identified time period if risk is not mitigated
Likely	May occur about once a year	Has a 60-90% chance of occurring over the identified time period if risk is not mitigated

Measure of likelihood	Recurrent or event risks (e.g. extreme events)	Long-term risks (e.g. rising temperatures)
Possible	May occur about once in 25 years	Has a 40-60% chance of occurring over the identified time period if risk is not mitigated
Unlikely	May occur about once every 25-50 years	Has a 10-30% chance of occurring over the identified time period if risk is not mitigated
Rare	Unlikely during the next 50 years	Has a <10% chance of occurring over the identified time-period if risk is not mitigated

4.3.2. An overall risk rating is determined based on the assessment of likelihood and consequence where:

- **Extreme risk** – requires immediate action
- **High risk** – requires detailed research and planning at senior management level
- **Moderate risk** – requires change to design standard and/or maintenance of assets
- **Low risk** – requires action through routine maintenance of assets

4.3.3. Table 4-4 presents risk ratings for each of the identified climate risks to the Proposed Scheme elements based on a qualitative assessment of likelihood and consequence. The most significant risks associated with climate- and weather-related risks are:

- Damage to structures, blockage of drainage systems and power outages due to intense rainfall and flooding
- A decrease in the number of days where maintenance can be carried out and reduced working periods (for personnel) due to extreme temperature and rainfall events
- Risks to water abstraction owing to droughts and/or long periods of dry conditions
- Owing to extreme temperature events, increased fire risk
- Damage to structures and signage due to gales and/or wind events

4.3.4. A further risk was identified but is outside of the control of the Proposed Scheme:

- Risks to UK gas distribution (specifically, compressor stations) due to extreme temperature events

4.3.5. Risks which have been assessed as Low are not considered further in this assessment although it is recommended that a watching brief is maintained to ensure that these risks are addressed in the future if their risk status changes.

Table 4-4 - Risk Evaluation

Component	Description of risk		Consequence	Likelihood	Risk rating
	Hazard	Risk			
Structural stability	Sea level rise and storm surge	Flooding of assets	Major	Possible	High
	Extreme rainfall events	Soil saturation and damage	Minor	Possible. The site is within Flood Zones 2 and 3 although risk could change over time due to climate change.	Low
		Undercutting	Minor		
		Increasing slope instability	Minor		
	Drought / long periods of dry conditions	Lower water levels	Moderate	Likely	High
		Loss of vegetation leading to greater erosion risk	Minor	Possible	Low
	Drier summers	Subsidence	Moderate	Possible	Medium
		Failure of earthworks due to desiccation	Moderate	Unlikely	Medium
		Shrinking and cracking of soils	Moderate	Possible	Medium
	Flooding	Soil softening and erosion	Minor	Possible	Low

Component	Description of risk		Consequence	Likelihood	Risk rating
	Hazard	Risk			
		Increased slope instability	Minor	Possible	Low
		Soil saturation	Minor	Possible	Low
	Extreme temperatures	Damage to structures and foundations	Major	Unlikely	Medium
		Overheating	Moderate	Possible	Medium
		Increased risk of erosion	Minor	Possible	Low
	Gales and wind	Damage to structures and foundations	Moderate	Likely	High
		Damage to signage and site structures	Major	Likely	High
		Erosion of banks	Minor	Possible	Low
		Lightning strike	Major	Rare	Medium
	Water quality	Soil stability	Moderate	Unlikely	Medium
	Drought / prolonged dry spells	Drying out/cracking of materials	Moderate	Possible	Medium
	Intense rainfall	Deformation of structures	Major	Unlikely	Medium
		Undercutting	Minor	Unlikely	Low
	Extreme temperatures	Risks to stored equipment, including batteries	Moderate	Possible	Medium
		Fires	Major	Possible	High

Component	Description of risk		Consequence	Likelihood	Risk rating
	Hazard	Risk			
Weather proofing and detailing	Intense rainfall	Guttering and drainage overwhelmed	Moderate	Likely	High
		Mobilisation of soil/ground pollutants	Minor	Likely	Medium
		Water accumulation on impermeable surfaces	Minor	Likely	Medium
	Drier summers	Dust and windborne material	Minor	Likely	Medium
	Extreme temperatures	Damage to external weather proofing	Minor	Possible	Low
		High day and night-time temperatures	Minor	Likely	Medium
	Gales and wind	Damage to weather proofing	Minor	Possible	Low
	Humidity	Damage to external weather proofing	Minor	Possible	Low
Material durability	Drought / prolonged dry spells	Deterioration of materials	Minor	Likely	Medium
	Intense rainfall	Mobilisation of pollutants	Minor	Possible	Low
	Extreme temperatures	Enhanced chemical reactions (i.e.	Minor	Possible	Low

Component	Description of risk		Consequence	Likelihood	Risk rating
	Hazard	Risk			
		cement stabilisation)			
	Gales and wind	Damage to weather proofing	Minor	Likely	Medium
	Humidity	Excessive moisture	Minor	Possible	Low
Site contents and business continuity	Sea level rise and storm surge	Loss of service due to flooding	Major	Possible	High
	Extreme rainfall	Power outage	Major	Possible	High
		Scour	Minor	Possible	Low
	Drought / prolonged dry spells	Reduced abstraction in summer	Major	Possible	High
	Wetter winters	Difficult working conditions	Minor	Likely	Medium
		Reduced opportunities for maintenance	Moderate	Likely	High
	Extreme temperatures	Reduced opportunities for maintenance	Moderate	Likely	High
		Reduced working periods	Moderate	Likely	High
		Greater demand for cooling	Moderate	Possible	Medium
		Higher river temperatures	Moderate	Possible	Medium

Component	Description of risk		Consequence	Likelihood	Risk rating
	Hazard	Risk			
		Risks to gas distribution	Major	Possible	High
	Storms	Loss of power, operational shut-down	Major	Possible	High
		Electrical surges	Moderate	Possible	Medium
		Fire risk	Moderate	Possible	Medium
	Soil stability	Risks to operation	Minor	Possible	Low

5 STEP 4: ADAPTATION MEASURES

5.1 Introduction

5.1.1. This step identifies adaptation measures that will be integrated into the Proposed Scheme. The level of climate resilience of the Proposed Scheme elements is also provided based on the integration of these measures. Following this, supplementary adaptation measures have been identified.

5.2 Identification of adaptation measures (planned and recommended)

5.2.1. In consultation with the project team, a range of adaptation options have been identified in 5-1 to reduce the vulnerability of the Proposed Scheme to the identified climate- and weather-related risks. Taking account of the contribution of the incorporated measures to climate resilience, a resilience rating has been applied based on the following rankings:

- **High** – a strong degree of climate resilience, remedial action or adaptation may be required but is not a priority
- **Moderate** – a moderate degree of climate resilience, remedial action or adaptation is suggested; and
- **Low** - a low level of climate resilience, remedial action or adaptation is required as a priority.

Table 5-1 - Identified Risks and Adaptation Measures (Planned and Recommended) for the Proposed Scheme

Component	Risk	Risk rating	Adaptation measure(s)	Resilience rating
Structural stability	Flooding of assets and site	High	The site is tidally dominated therefore the impact of sea level rise has been allowed for within the breach modelling. The design life of the project is 30 years, however a 50 year life was assumed to allow for an extension of the plant (a worst case scenario). Allowance for climate change was calculated from Flood Risk Assessment: climate change allowances. The infrastructure identified to be at risk of flooding and needing to remain operational during a flood event has been raised above the 1 in 200 year plus 50 years climate change occurring in conjunction with a 1 in 5 year fluvial flow.	High
	Drought / prolonged periods of dry conditions causing lower water levels and drying/cracking of materials	High	Standard design conditions in the UK gas industry are -20°C to +60°C, all of the Proposed Scheme elements consider this requirement. Regular inspections of materials to identify any deterioration.	High
	Subsidence	Medium	The Proposed Scheme will be designed to nationally-recognised standards to minimise risks posed by subsidence.	Moderate

Component	Risk	Risk rating	Adaptation measure(s)	Resilience rating
	Failure of earthworks due to desiccation	Medium	The Proposed Scheme will be designed to nationally-recognised standards to minimise risks posed by desiccation.	Moderate
	Shrinking and cracking of soils	Medium	The Proposed Scheme will be designed to nationally-recognised standards to minimise risks posed by shrinking and cracking of soils.	Moderate
	Damage to structures, signage and foundations due to extreme temperatures and/or wind	Medium	Coatings / cladding provided to minimise corrosion/ deterioration on plant and buildings. Structures will be adequately designed to allow for future worst case wind conditions.	High
	Overheating of equipment	Medium	Temperature monitoring of above ground pipework and hence gas is standard industry practice. The formal process safety assessment processes of HAZID and HAZOP consider the impact of high/ low temperature effects.	High
	Lightning strike	Medium	Lightning protection will be installed on all sites.	High
	Fires	High	Regular maintenance/cleared combustibles to avoid fire spread and reduce catch risk	High

Component	Risk	Risk rating	Adaptation measure(s)	Resilience rating
Weather proofing and detailing	Guttering and drainage systems overwhelmed, including water accumulation on impermeable surfaces	High	Existing drainage systems on Drax site have the capacity to receive additional flows. New drainage designed in accordance with prevailing standards and legislation, including latest available rainfall intensity. Hard standing / covered areas within the plant and within the contractor's compound will be provided for maintenance to minimise disruption caused by increased precipitation. Where maintenance work is required at height (where wind speeds are greatest), railings will be provided to enable fall prevention restraints to be worn. Sophisticated plant control system will be provided to enable remove control of plant equipment, minimising the need for personnel to be out on site. Regular maintenance ensures gullies, manholes, pipes and other drainage apparatus will be clean of debris and kept free-flowing. It is a standard operational maintenance activity to walk the pipeline at regular intervals to look for third party infringements and significant depth of cover loss.	High
	Mobilisation of ground/water pollutants	Medium	Bunds will be adequately sized for spillage of its content plus an additional surplus for rainwater. Where	High

Component	Risk	Risk rating	Adaptation measure(s)	Resilience rating
			contamination with oil, the drainage of the bunds will be directed through oil water separators.	
	Dust and windborne materials	Medium	Coatings / cladding provided to minimise corrosion/ deterioration on plant and buildings. Structures will be adequately designed to allow for future worst case wind conditions.	High
	High day and night-time temperatures	Medium	Insulation provided on hot surfaces in line with international standard and to meet the limit stipulated in the standard at a maximum design temperature of 35°C. Temperature monitoring of above ground pipework and hence gas is standard industry practice. The formal process safety assessment processes of HAZID and HAZOP consider the impact of high/ low temperature effects.	High
Material durability	Deterioration of materials	Medium	Consider high future temperatures when specifying materials.	High
	Damage to weather proofing	Medium	Coatings / cladding provided to minimise corrosion/ deterioration on plant and buildings.	High
	Loss of service due to flooding	High	The site is tidally dominated therefore the impact of sea level rise has been allowed for within the breach modelling. The design life of the project is 30 years,	High

Component	Risk	Risk rating	Adaptation measure(s)	Resilience rating
Site contents and business continuity			however a 50 year life was assumed to allow for an extension of the plant (a worst case scenario). Allowance for climate change was calculated from Flood Risk Assessment: climate change allowances. The infrastructure identified to be at risk of flooding and needing to remain operational during a flood event has been raised above the 1 in 200 year plus 50 years climate change occurring in conjunction with a 1 in 5 year fluvial flow.	
	Extreme rainfall and storms causing power outage	High	Emergency diesel generators in place to safely shut down the site and provide essential supply loads	High
	Insufficient water levels to maintain summer abstraction	High	Design modelling to determine worst-case water level to ensure sufficient abstraction can still take place during drought conditions.	High
	Difficult working conditions	Medium	Sophisticated plant control system will be provided to enable remove control of plant equipment, minimising the need for personnel to be out on site.	High
	Reduced opportunities for maintenance	High	Hard standing / covered areas within the plant and within the contractor's compound will be provided for	High

Component	Risk	Risk rating	Adaptation measure(s)	Resilience rating
			maintenance to minimise disruption caused by increased precipitation.	
	Electrical surges caused by storms	Medium	All power plants and associated electrical infrastructure will be designed to meet National Grid and internationally-recognised standards.	High

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