Adapting to Climate Change

June 2015

Foreword

Electricity is a central part of everyone's lives and at Northern Powergrid we are proud of our role in delivering a secure electricity supply to our customers. We are committed to providing the highest levels of customer service, network reliability and environmental care.

There is mounting evidence that the UK's climate is changing and that events that we now consider to be 'extreme' will begin to become 'business as usual'. The climate change that will occur in the medium term has already largely been determined by historic greenhouse gas emissions and we must place ourselves in a position to deal with the changes to our weather patterns that this will bring.

Over recent years, Northern Powergrid has had experience of dealing with extreme weather events and, in particular, major floods. This has enabled us to ensure that our emergency plans are sufficient and to examine our performance during extreme weather events as the majority of our assets are affected directly by the weather.

In 2011 we issued our first report on Climate Change Adaptation (CCA). This showed that our existing underlying processes would stand us in good stead for the changes that we expect to experience over the coming years. We made a commitment to ensure that we refined and adjusted these processes to take account of future predictions, in order to continue to maintain the levels of network performance expected from us. This second round report reflects and reports on the progress that we have made since then.

Mark Drye

Director of Asset Management

Northern Powergrid

The move to low carbon networks is an area in which research is currently ongoing. This report acknowledges that this is an important area which will require our network to adapt over coming years but that currently, it is being treated as a separate issue to adaptation. As the future network requirements become known, we must endeavour to integrate the two issues in order to maximise the benefits.

It is important to us that we take all reasonably practicable steps to ensure that the appropriate environmental factors are taken into account in the design, construction, operation, maintenance and decommissioning of our assets and, as such, this report outlines the impact that we anticipate climate change will have on our business and how we propose to mitigate the risks that this poses.

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1 Introduction

Northern Powergrid first formally reported on how it identified climate change impacts on the functions of its two licensed electricity distribution companies, Northern Powergrid (Yorkshire) and Northern Powergrid (Northeast), the proposed mechanisms for monitoring and actions to respond to the likely impacts of climate change in 2011 as part of the first round of reporting initiated by Defra as a result of the Climate Change Act (2008).

In 2013, Northern Powergrid agreed to a request from the Department for Environment, Food and Rural Affairs (Defra) to participate in the second round of reporting, to be carried out during 2015, and to provide an update on their ongoing adaptation to climate change.

Although this report is specific to the geographical areas covered by the two licenses, it was recognised during the first round reporting process that, due to national equipment designs based on International, European and British Standards (BS), many of the issues of Climate Change Adaptation (CCA) related to our physical assets are common to all electricity transmission and distribution companies. A “core” assessment was therefore prepared by a task group of electricity distribution and transmission network operator members of the Energy Networks Association (ENA) - the industry body for the UK. During the production of this “core” report, Northern Powergrid, alongside other ENA members, engaged with government regulators, Defra, the Environment Agency (EA), the Department of Energy and Climate Change (DECC), the Met Office and other organisations. This “core” report considered the issues that are common to companies across the UK and formed the basis of the Northern Powergrid first round report.

Following the initiation of the second round of reporting, this working group reconvened to consider any updates to climate change science, projections and government thinking and their impact on the electricity industry. The output from this group has been incorporated into this Northern Powergrid second round report and forms the basis of the Executive Summary. The executive summary has been presented in line with the template for update reports provided by Defra.

In addition to adaptation to climate change, there are also a wide range of activities being pursued by Government and society in general to “mitigate” climate change: seeking to slow down global warming by reducing greenhouse gas emissions. Examples include:

- Measures to increase the amount of renewable generation connected to the electricity system
- De-carbonising transport through take-up of electric road vehicles and trains
- De-carbonising heating through energy efficiency, use of solar heating and heat pumps

These mitigation actions have significant knock-on effects for electricity networks. The DECC and Ofgem joint chaired Energy Networks Strategy Group (ENSG) and work by Imperial College London with ENA provide useful background[1] of these activities. The latter has pointed to a doubling in UK electricity peak demand from some 60GW to almost 120GW if “smart” network technologies are not employed to intelligently control and time shift demands.

It is not the purpose of this report to cover mitigation measures, though the changes that will be needed to electricity networks to transform them into smart networks will also serve to address a number of the climate change adaptation requirements. These are discussed further in section 8.4 of this report.

[1] These documents are available at http://2010.energynetworks.org/smartmeters/

2 Overview

2.1 Northern Powergrid Overview

Northern Powergrid is responsible for delivering electricity to around 8 million customers across 3.9 million businesses and homes. We operate through our subsidiary companies Northern Powergrid (Northeast) Ltd in the North East and North Yorkshire and Northern Powergrid (Yorkshire) plc in South, East and West Yorkshire and northern Lincolnshire.

The Northern Powergrid network consists of more than 61,000 substations, around 93,000km of overhead line and underground cable and over 2,200 employees. It covers an area of 25,000 square kilometres, our network extends from north Northumberland, south to the Humber and northern Lincolnshire, and from the east coast to the Pennines.

As a Distribution Network Operator (DNO), our role is to ensure safe, secure and cost-effective delivery of electricity to our customers. To do this, we:

- Invest around £340 million a year to maintain and strengthen the resilience of our network.
- Provide customers with new connections to the network. These can range from moving a single domestic supply to providing connections for new housing or commercial developments.

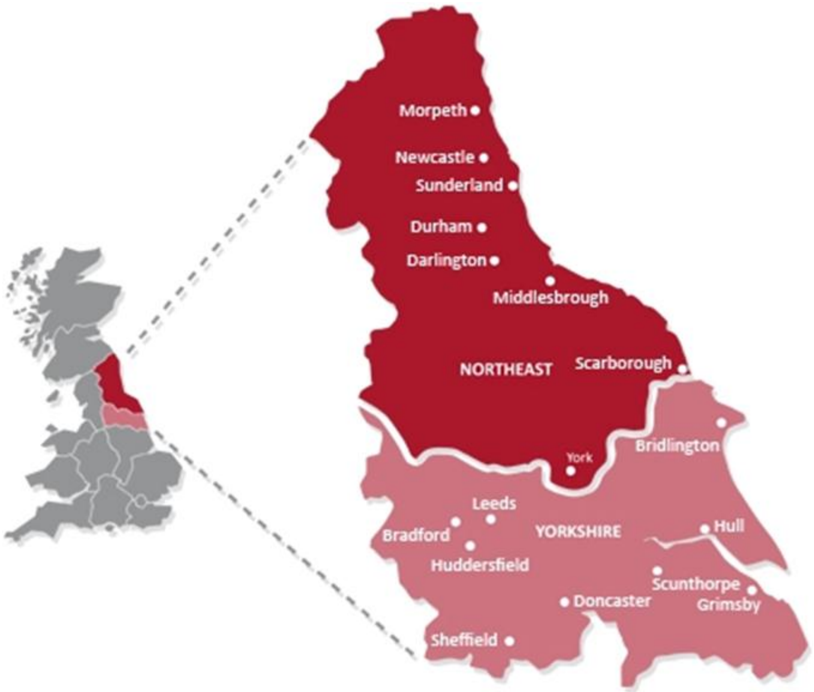


Figure 1 – Northern Powergrid Operating Area

We've recently redefined our operating zones to tailor our services and our response to the needs of our customers and local communities. We have moved to nine zones, defined by their industrial, urban or rural landscape. This operating model is our commitment to improving service and providing locally based managers who strive to meet customers' needs.

2.2 Electricity Networks Companies Overview

In the UK, generation is a competitive market. Energy supply companies buy electricity in bulk from generation companies and pay transmission and distribution companies to transport electricity through their networks to homes and businesses.

Transmission and distribution companies are responsible for providing a reliable supply of electricity to their connected customers across the UK in an efficient manner whilst delivering excellent standards of customer service.

These are regulated businesses, operate under licences issued by Ofgem and are subject to a common regulatory framework. They are also subject to common statutory requirements including The Electricity Act and Electricity Safety Quality and Continuity Regulations (ESQCRs) which are overseen by DECC and the Health and Safety Executive (HSE).

This basis of a common background, asset standards and regulatory processes means that UK Electricity DNOs have very high commonality when approaching the assessment of climate change impacts on their networks. The level of climate change will vary across the UK but the assessment of impact per unit of change, such as degrees centigrade, can be established using common methodology.

As a consequence of these common drivers, UK Electricity DNOs have worked together for many years across a wide range of activity including:

- Establishing UK network owner input to the content, development and modification of national and international standards.
- Establishing common equipment specifications and design standards, across the full spectrum of network assets, to reduce procurement costs and ensure availability of product.
- Providing a unified input to UK Government and Regulators (Ofgem, HSE etc) on development of regulations, processes, reporting etc.
- Collaborating on research and development, including impacts of climate change and work on asset designs/ratings.

Allowed revenues for the industry are currently set by Ofgem with individual network operators and these periodic reviews govern all expenditure, including resilience against natural hazards and emergency planning. This provides common oversight and accountability to Ofgem and DECC.

Any costs associated with CCA would therefore need to be discussed with, and allowances set by, Ofgem to enable DNOs to recover the costs associated. This would include costs directly associated with the network, e.g. overhead lines, underground cables and substations as well as costs linked to the supply chain and "softer" issues concerning potential climate impacts on staff.

2.3 Description of Networks

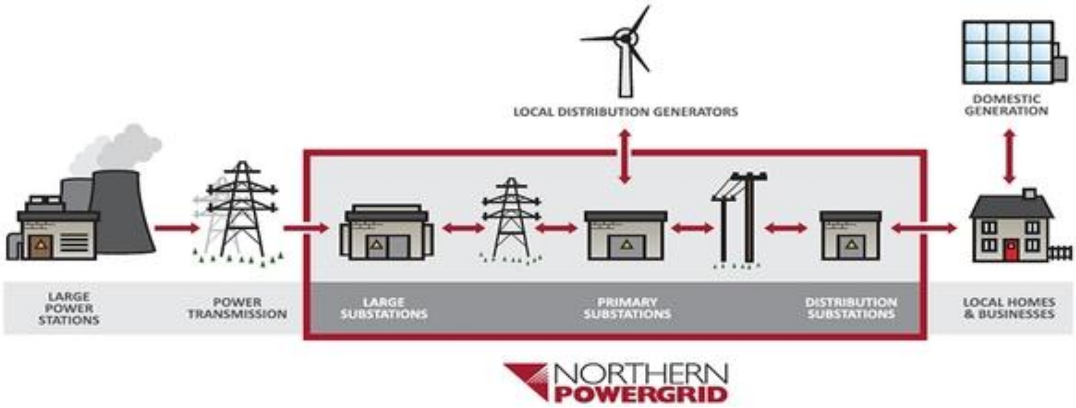


Figure 2 - Typical Electricity Supply Chain

In the UK, electrical power is transported from generating plants to customers over networks managed by transmission and distribution companies. The transmission system operates at typically 400,000volts (400kV) or 275kV (and 132kV in Scotland) and the distribution system operates at voltages from 132kV to the normal household voltage of 230V.

The system comprises a mixture of overhead lines and underground cables. In addition there are sites; called substations, where voltage transformation takes place and switching and control equipment are located. The characteristics of different types of substation are described in Table 1.

Substation Type	Typical Voltage Transformation Levels	Approximate Number Nationally	Number in Northern Powergrid Region	Typical Size	Typical Number of Customers Supplied
Grid					
	400kV to 132kV (owned by transmission companies)	380	36	250m x 250m	200,000 / 500,000
	132kV to 33kV	1,000	115	75m x 75m	50,000 / 125,000
Primary					
	33kV to 11kV	4,800	571	25m x 25m	5,000 / 30,000
Distribution					
	11kV to 400/230V	230,000	27,386	4m x 5m	1 / 500

Table 1 - Types of Electrical Substation

In England and Wales, National Grid own and operate the transmission system and the interface between transmission and distribution systems takes place within grid supply or super grid substations at 132kV. Circuit lengths are shown in Appendix 1: Distribution System Information.

Network design takes account of normal load growth which has historically been around 1.5% to 2% per annum. Although this historical level of growth may reduce due to economic and energy efficiency pressures, load on the network is expected to double over the next forty years.

2.4 Levels of Service

Licensed electricity distribution businesses are obliged, under Condition 21 of our licences, to maintain a Distribution Code detailing the technical parameters and considerations relating to connection to and use of our electrical networks, again approved by Ofgem.

Overall levels of supply security are agreed by Ofgem and contained in ENA Engineering Recommendation P2/6 – Electricity Distribution Network Planning – in England and Wales.

These security standards specify the requirements for the availability of alternative supplies at various levels of customer load. Although these standards allow for the loss of multiple circuits, they do not provide for certain low probability events including multiple failures or the total failure of a grid or primary substation. Particular attention must therefore be given to grid and primary substations when considering network resilience.

Whenever a customer loses supply, details of that interruption are recorded by Transmission and Distribution companies. Distribution networks are much more affected by climate impacts than the transmission system and all supply interruptions on distribution networks are recorded in the NaFIRS (National Fault and Interruption Reporting Scheme) database. This information is shared nationally and summaries are submitted to Ofgem. Data is available for over thirty years but the quality of the data has improved significantly over the last fifteen years since the introduction of the Ofgem Interruptions Incentive Scheme (IIS).

ENA Engineering Recommendation (ER) G43-3 (Instructions for Reporting to the NaFIRS) sets out the details to be captured for each fault. For each interruption, companies will capture a large amount of information and up to 100 separate fields will be populated. These include:

- location
- number of customers affected
- duration
- type of equipment
- manufacturer
- cause of the fault

Using this information, companies can identify trends in all these areas and take action where appropriate. Prior to 2010 companies submitted an annual Medium Term Performance report to Ofgem which summarised the number of faults on overhead and underground networks, at each voltage level, in the following categories:

- lightning
- rain, snow, sleet, blizard, freezing fog, frost & ice
- wind, gale, growing trees, falling trees & windborne materials
- all other due to weather & environment causes plus birds, animals & insects
- company & manufacturer causes
- third party
- any other causes (including unknown & unclassified)

Since 2010, companies have provided the full dataset to Ofgem who perform their own analysis. Although the data is aggregated at this level, companies actually capture data to a more detailed level, attributing faults to one of 99 different direct causes specified in ER G43-3. Eleven of these are weather related:

- lightning
- rain
- snow, sleet, blizzard
- ice
- freezing fog and frost
- wind and gale (excluding windborne material)
- solar heat
- airborne deposits (excluding windborne material)
- condensation
- flooding
- windborne materials

Therefore, using data from the NaFIRS system, companies can monitor how their networks are performing, identify any trends in weather related faults and respond accordingly.

DNOs also have financial incentives to minimise the number and duration of interruptions including those caused by climate impacts. Ofgem introduced the IIS in April 2002. Under this scheme DNOs are set a target for the number of interruptions each year that last over three minutes, and the total length of those interruptions. If they beat these targets they are rewarded and conversely they are penalised if they do not achieve the targets.

Transmission companies have a similar incentive scheme known as Energy Not Supplied.

DNOs are also subject to Guaranteed Standards (GS) of Performance enacted through the Electricity (Standards of Performance) Regulations which is a Statutory Instrument made under powers conferred in the Electricity Act 1989.

The GS' are a set of standards of service agreed with Ofgem, and backed by a financial guarantee – customers receive a payment if the distributor fails to meet these standards.

For both IIS and GS' there are variations in the case of severe weather, recognising the additional difficulties in restoring supply under these conditions.

The aim of this report is to set out a managed mechanism for CCA which allows Northern Powergrid to continue to deliver the reliability of supply currently expected.

Whilst every effort is made to ensure network security, Northern Powergrid has well developed business continuity and emergency plans to ensure an effective response to a range of events that can affect both transmission and distribution networks. Under the terms of the Civil Contingencies Act, Northern Powergrid is a Category Two responder and works closely with other utilities, the emergency services and local authorities. We are also active participants in the DECC Energy Emergencies Executive Committee (E3C).

2.5 International and National Standards

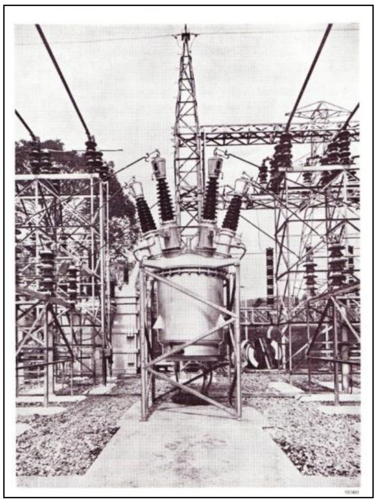
Northern Powergrid's network is made up of many different types of equipment including overhead lines, cables and transformers. Current equipment complies with appropriate International and British Standards listed in detail in Appendix 2: Key Design Standards

Figure 3 - 132kV Grid Transformer and Circuit Breaker in service in the UK

Given that more onerous climate conditions than those predicted for our region are already being experienced in parts of the world where these standards apply, it is apparent that the assets built to these standards will be able to remain in service, albeit with a potentially reduced capacity, even allowing for the changes forecast for the UK by 2100.

Northern Powergrid equipment complies with industry standards that have been developed and enhanced over many years to ensure that UK networks are built using high specification, safe equipment that is fully interchangeable and can be installed and operated in a similar manner across the UK.

Industry standards and engineering practices have been established over the years through ENA and predecessor organisations and therefore, because UK networks are built on a common basis, they will all experience similar impacts from similar changes in climate. This underlines the reason for a common approach to national issues in adaptation.



The production of new ENA documents and the updating of existing documents are covered by an agreed process involving ENA transmission companies and DNOs. Some ENA documents are annexed or are appendices to the Distribution codes and therefore any modifications are subject to governance by the Distribution Code Review Panels.

The development and review of National and International Standards is subject to well established procedures and UK electricity DNOs, via ENA, have experience of leading and influencing this work through BSI and European and International standards organisations.

Figure 4 – EHV 1950s UK manufactured oil circuit breaker (similar to that still operated in the UK) in service in Malaysia where ambient temperature can exceed 30°C

2.6 Emergency Planning

Emergency planning issues of shared interest to the government, industry and the regulator are reviewed and managed through the Energy Emergencies Executive (E3). E3 is made up of a senior representative from DECC, industry and Ofgem, and is supported by a committee (E3C) chaired by a Director of National Grid and comprising representatives from customer organisations, electricity companies, trade bodies, DECC and Ofgem. E3C meets every two months and has a number of active task groups working on various issues.

The ENA led review of the resilience of substations to flooding is an example of the work undertaken within the E3C framework (see section 5.1.1 Work on Flooding Resilience). Through ENA, DNOs, meet regularly to review emergency planning and response arrangements covering issues ranging from wind storms to flu pandemics.

Whilst every effort is made to ensure network security, DNOs have well developed emergency plans to ensure an effective response to a range of events and Northern Powergrid is no exception. A full list of the Northern Powergrid policies and codes of practice can be found in Appendix 3: Northern Powergrid Policies

Northern Powergrid, along with all other DNOs, is a member of NEWSAC. In an emergency affecting member companies, NEWSAC representatives assess the availability of resources from those least affected and agree the allocation of these resources to other members based on the level of damage. The NEWSAC mutual aid agreement has been in place and utilised over many years.

Under the terms of the Civil Contingencies Act, Northern Powergrid is a Category 2 responder and works closely with other utilities, the Emergency Services and Local Authorities. This includes working with Resilience Teams on emergency planning, taking part in exercises and participating in Gold, Silver or Bronze Commands.

The Electricity Act and the ESQCRs include powers for the Secretary of State in relation to continuity of supply, including preserving security of electricity supplies. The Minister twice exercised these powers in 2002 in the setting up of independent reviews of the “Resilience of the Electricity Supply Industry”.

During the exceptional winter weather of 2013/14 DNOs nationally faced an exceptionally demanding sequence of storms from November 2013 to February 2014, mainly as a result of wind storms causing damage to wood pole overhead lines due to falling trees and windborne material.

In particular, between 22 and 28 December 2013, as a result of two severe winter storms and consequent damage to the distribution overhead line network, almost 1 million properties nationwide suffered disruption to electricity supplies. Though 95.3% of customers were restored within 24 hours, 1.7% of customers experienced a disruption to supply in excess of 48 hours, and there were lessons to be learnt to improve the effectiveness of the industry response to disruptive events, and minimise customer inconvenience as much as possible.

Some DNOs experienced particular difficulties with customer communication and resourcing the amount of repair work. However, it was noted independently, that the industry's staff showed remarkable resilience, working long hours in potentially dangerous conditions with no reportable accidents. As a result, staff were thanked for their tremendous efforts at a parliamentary reception.

Ofgem have established criteria that identify certain "exceptional events" that include particularly large interruptions that DNOs have limited ability to prevent. In order to reduce the volatility and impact of these occurrences on their performance (and future target setting), these "exceptional events" are excluded from annual performance figures. Exceptional events are classified as being either a severe weather exceptional event or a one-off exceptional event.

Severe weather exceptional events refer to a level of interruptions occurring for a period of time that result directly from bad weather. To be considered a severe weather exceptional event, a specific and verified number of higher voltage interruptions, directly caused by bad weather, are required to have occurred within a 24 hour period. This is referred to as the severe weather exceptional event threshold and is currently eight times the average daily higher voltage fault rate.

One-off exceptional events are those where a single cause outside the DNO's control causes a significant level of interruption. To be considered a one-off exceptional event, a specific and verified number of interruptions and/or minutes lost are required to have resulted. These numbers are referred to as the one-off exceptional event thresholds and currently stand at 25,000 customers interrupted and two million customer minutes lost.

To justify company claims against these exceptional event criteria, Ofgem undertake an investigation into the incident including the effectiveness of the company's preparations and response.

Due to the serious consequences of the 2013 Christmas Storms, two enquiries took place led by DECC and Ofgem, with DNOs required to report on how performance could be further improved in a number of areas. These resulted in reports by Ofgem and DECC which have now been published.

Following the initial DECC report, the industry undertook a major review of its performance to identify areas of good practice and areas for improvement. This review took place through the framework of the E3C with support from ENA. All the DNOs and DECC were involved and specialist Task Groups were established to address particular issues,

A number of actions to improve future preparedness and response were identified, including:-

- Developing a single national number for customers to call during a power disruption. The complexity of this programme necessitates a longer time frame, and is planned for implementation in April 2016.
- Identifying the levels of recognition amongst customers, and addressing any gaps using appropriate communications strategies. Ensuring that whilst a national power outage number is developed, each DNOs' customers are aware of the correct phone number to call in the event of disruption to power supplies.
- Developing worst case scenarios for customer calls and ensuring that telephony systems and call agents can provide a high level of service.
- Sharing with each other, and key stakeholders, when weather forecast content causes them to trigger pre-emptive escalation.
- Production of a Customer Welfare Good Practice Guide (GPG) which sets down minimum standards for welfare provision during emergency events, with particular emphasis on customers held within its Priority Services Register (PSR).
- Production of a Social Media GPG and development of a social media strategy, based around the recommendations from the GPG.
- Developing and implementing a common framework that clarifies standards expected around the identification and provision of a restoration time to customers and its subsequent proactive update in the manner agreed with the customer.
- Holding a workshop to share their resource and contractor management strategies to ensure the rapid availability of adequate resources to deliver resilience, particularly over extended holiday periods.
- Reviewing and updating the NEWSAC Mutual Aid protocol to ensure it is adequately proactive, and criteria around strategic prioritisation are clear.

These actions are reviewed in a DECC report published in December 2014 which recognises that this work is part of an on-going responsibility to review, maintain and improve the effectiveness of the response to disruptive events. E3C has agreed that an annual review of this work, following each winter, will ensure new lessons are identified and reflected in on-going processes and procedures for preparedness and response.

Record levels of rainfall were experience between April and December 2012 and the events of 28th June 2012 in Newcastle and Gateshead (known locally as Thunder Thursday) led to the reconsideration and improvement of information on surface water flooding. This has become more reliable and is now considered sufficient to justify additional flooding resilience measures. In view of this the ETR 138 task group was reconvened to update the document to include the management of surface water risk.

It should be noted that during the winter flooding, no electricity supplies were interrupted as a result of river flooding at major electricity substations operated by DNOs and a number of substations were protected by new flood defences that incorporate protection against long term climate change. Northern Powergrid however did see some loss of supplies due to the flood defences at a major substation becoming compromised as a result of a coastal surge event in December 2013.

In addition, some sites were protected by portable flood barriers and the NEWSAC agreement was implemented to provide support to the Thames valley area from the North of England. Helicopter transport and high volume pumps were also made available should they be required.

During January 2015, hurricane force winds affected parts of Scotland causing severe damage to the overhead distribution network. Performance of the DNOs was reviewed at the January E3C meeting. The response from public, press and government appeared to be generally positive to the supply restoration efforts. Weather forecasts and contingency plans were shared before the event and at mutual aid conferences and there was a good response to requests for assistance, with staff being sent from a number of other DNOs in areas that had not suffered serious damage.

Overhead line systems are susceptible to severe weather conditions such as wind storms and lightning and consequently we are required to implement our emergency response procedures on a regular basis.

Customer communication for problems affecting customers‘ supplies is the responsibility of Northern Powergrid and we have sophisticated telephony systems that are capable of answering very large numbers of simultaneous customer calls.

Northern Powergrid is continually striving to improve all aspects of its Emergency Planning. In the period since the first round report was issued in 2011, we have introduced additional resilience into our major incident command and control structure to give us the ability to sustain our response to major incidents over a longer period or to cope with an increased frequency.

A dedicated major incident support project has been undertaken which is delivering additional resources to ancillary roles for major incident response – in other words we are already deploying all available operational resources to restore supplies as quickly as possible and are now increasing our ability to deploy non-operational staff to support our customers whilst they are without supply.

Northern Powergrid now subscribes to the EA’s Targeted Flood Warning Service which will enable us to provide a specific response to our primary and grid sites declared at risk of flooding, separating them from the more generic flood warnings.

Northern Powergrid representatives also attend the national Category 2 Chairs forum, organised by the Resilience and Emergencies Division of the Department of Communities and Local Government (DCLG). This is aimed at sharing best practice and incident lessons learned across all Category 2 responders.

Whilst Emergency Planning is vital for managing serious incidents when they occur, it is not appropriate for controlling climate change risks.

3 Effect of Current and Possible Future Impacts of Climate Change

3.1 Current Position

Northern Powergrid has experience in operating in a range of weather conditions and has always used the latest information when considering current threats and potential climate change impacts. For climate projections this is the UK Climate Projections (UKCP09) (see section 3.2). Other information utilised includes:

- COST 727, a European project addressing the measurement and forecasting of atmospheric icing on structures.
- Department of Energy – the Baldock Report – 'Review of Technical Standards for Overhead Lines following Storm Damage in December 1981 & January 1982'.
- ENA Engineering Technical Report (ETR) 111 providing theoretical background to the data and diagrams produced in Technical Specification 43-40 (Specification for single circuit overhead lines on wood poles for use at high voltage up to and including 33 kV). ETR 111 quantifies appropriate snow accretion loadings on overhead lines in different areas of the UK.

3.2 UK Climate Projections

UKCP09 provide projected climate change information to the end of this century based on simulations from climate models. This is the principal source of information for the electricity and gas network companies because the different types of network infrastructure generally have very long operational lives, typically 30 to 80 years. There has been no significant change in the understanding of climate change risks since the first round of the adaptation reports were submitted in 2011 and there are no immediate plans to review these projections. Information recently provided by Defra confirms that, following the publication of the latest Intergovernmental Panel on Climate Change (IPCC) assessment (2014), the Met Office conducted a study which shows that, in general, UKCP09 continues to provide a valid assessment of climate change.

UKCP09 illustrate three scenarios representing high, medium and low greenhouse gas levels, as described in Appendix 4: Extract from UKCP09 - Emissions Scenarios

The types of climate information provided are:

- observed climate data - 20th and 21st century historical information for temperature, precipitation, storminess, sea surface temperatures and sea level.
- future climate projections for temperature, precipitation, air pressure, cloud and humidity.
- future marine and coastal projections for sea level rise, storm surge, sea surface and sub-surface temperature, salinity, currents, and waves.

This report focuses on the main impacts on the Northern Powergrid network from the current climate change projections which are:

- Temperature - predicted increase.
- Precipitation - predicted increase in winter rainfall and summer droughts.
- Sea level rise - predicted increase.
- Storm surge - predicted increase.

3.3 Temperature Effects

Electrical current passing through electrical plant causes the equipment to heat up. The maximum current rating of electrical plant is generally governed by the equipment's maximum permissible operating temperature. This temperature is usually determined by the type of conductor/insulation material involved but there may be other considerations.

For example:

- the sag of overhead line conductors increases with temperature and this could compromise statutory ground clearances if too much sag occurs.
- ambient air temperature affects soil temperature which in turn affects its ability to conduct heat away from underground cables.

Once the ambient and maximum temperatures in which the equipment will operate are agreed, the maximum temperature rise is set and this determines the amount of current that a given piece of equipment can carry. If the ambient temperature increases, the available temperature rise decreases and the maximum current rating is reduced.

Reduced ratings can be a particular problem with transformer ratings in urban areas where air conditioning load is likely to have a coincident peak. A substantial proportion of distribution circuits now see maximum loadings occurring during summer hot spells as opposed to winter cold spells. Current security standards are based on maintenance being carried out during relatively lightly loaded summer conditions and increased summer loadings are likely to cause operational difficulties. Further information can be found in Appendix 5: UK Temperature Charts.

3.4 Precipitation

Increased winter rainfall will result in increased river flow rates and a potential increase in flood levels. Overhead lines are generally not susceptible to flooding but there is a potential for statutory safety clearances to be affected in flood conditions. Equipment operating at substations can be vulnerable to flooding if water reaches certain critical depths. The loss of supply incidents in 2007 in Yorkshire occurred as a result of substation flooding following exceptionally high water levels.

Increased rainfall brings the risk of surface water and ground water flooding which could threaten substations. Within the Northern Powergrid regions, specific problems from surface water flooding were experienced due to record levels of rainfall during the summer of 2012 in the Newcastle area. Events of 28th June 2012 become known locally as "Thunder Thursday". Information on surface water flooding has become more reliable and is now considered sufficient to justify additional flooding resilience measures.

Flooding presents the most serious climate risk to electricity networks and this includes current flood risk and the higher risks forecast as a result of climate change from increased rainfall and higher sea levels. To mitigate this risk, Northern Powergrid is carrying out a programme of flooding resilience work as detailed in section 5.1.1. Resilience measures already in place at major electricity transmission and distribution installations nationally prevented any loss of supplies from these sites due to flooding during the severe weather in 2013/14.

Summer drought conditions can lead to a reduction in the ability of the ground to conduct heat away from underground cables, resulting in the maximum current rating of the cables being reduced. Cable faults may develop that could interrupt customers' supplies if cables are allowed to operate at higher temperatures. This can be a particular concern for higher voltage cables. Droughts can also lead to ground movement that may damage underground cable systems or structures.

3.5 Sea Level Rise and Storm Surge

These types of incident would have a similar effect to river flooding except the volumes of water are potentially far greater with more widespread flooding, greater damage to infrastructure and a longer recovery period. Guidance issued by the EA indicated that high astronomic tides will be at their greatest over the period 2014/15, as September 2015 is the point in a natural 19 year cycle when the sun, moon and earth align to extert the greatest force on the tides in the UK. High astronomic tides alone do not cause a significant coastal flood risk. Significant coastal flooding on the east coast is dependent on the combined effect of high natural tides and weather generated tidal surge and wave conditions. This combination was seen on 5th December 2013, leading to flooding along the east coast of England. Northern Powergrid lost supplies to approximately 10,000 customers for a period of around 3 hours due to the flood defences at a major substation becoming compromised as a result of the coastal surge.

3.6 Other Climate Threats

The most common current weather threats to the Northern Powergrid networks are wind storms, lightning and, to a lesser extent, ice accretion. Wind storms and ice accretion have the potential to cause widespread devastation and there are recent examples across the world of extensive damage to electricity infrastructure.

- **Wind Storms:** Widespread interruptions to customer supplies have occurred in the UK on a number of occasions including in 1987, 1990, 1997, 1998 and 2002. Although this type of incident can be very disruptive, repairs can normally be carried out relatively quickly and most customers' supplies are usually restored within a few days, apart from in the more remote rural areas.

- **Ice Storms:** There is limited recent experience of ice storms in the UK, with incidents occurring mainly in Scotland and Northern England. They have the potential to interrupt customers' supplies for longer periods than wind storms and there have been a number of incidents abroad, notably affecting Canada in 1998.

  At present there is no firm climate change evidence to support increased intensity of wind or ice storms, both of which can cause extensive damage to overhead electricity networks. However, an increase in the frequency of stormy weather is possible and this is likely to lead to more frequent periods of high winds which can pose a threat to electricity distribution networks due to falling trees and windblown material.

- **Heat Waves / Drought:** Heat waves can lead to equipment being damaged due to high operating temperatures. Localised drying of subsoil can increase ground resistivity, reducing the ability of cables to dissipate heat into the ground, leading to rapid degradation and failure.

  At present UKCP09 does not provide any guidance on the potential effects of climate change on these weather threats. DNOs are maintaining close contact with the Met Office and this will ensure that we have the most up to date information on these potential threats, enabling forward planning and the development of adaptation schemes as necessary. Work with the Met Office (Project EP2) concluded that there is no need to change current ground resistivity figures when calculating cable ratings.

- **Lightning:** Lightning storms are regular occurrences in the UK and can damage overhead lines and connected equipment. Distribution circuits are more difficult to protect against lightning and generally suffer more damage than transmission equipment.

- **Vegetation:** Increased vegetation growth rates and extended growing seasons are already affecting overhead lines resulting in higher costs to maintain clearance to conductors.

4 Potential Impacts of Climate Change on Key Stakeholders

4.1 Stakeholder Engagement Process

The Northern Powergrid stakeholder engagement process involves a constant dialogue between us and our stakeholders, enabling us to align our decisions to their priorities and implement solutions to our mutual benefit. In order to maintain the right amount of rigour in our approach we have committed to an annual audit against the assurance AA1000 Stakeholder Engagement Standard to ensure that we continue to develop and improve on our performance. We have been working towards establishing more structured, formal groups for regular engagement with our stakeholder engagement panel drawing from a broad range of individuals and organisations and enabling us to consult on matters where differing opinions would be common. Furthermore, our three independently chaired expert groups are proving valuable in helping us focus more on strategic engagement to develop our plans and services as well as identifying emerging issues. The aims of the three panels are to bring together experts:

- in fuel poverty and customer vulnerability to review our plan and generate ideas for our future approach;
- from customer service organisations to ensure our plans are appropriately customer-focused;
- from the industry to check and feedback on our investment plans, with a particular focus on the low-carbon priorities.

Northern Powergrid produces an annual stakeholder report which provides further details on our stakeholder engagement process.

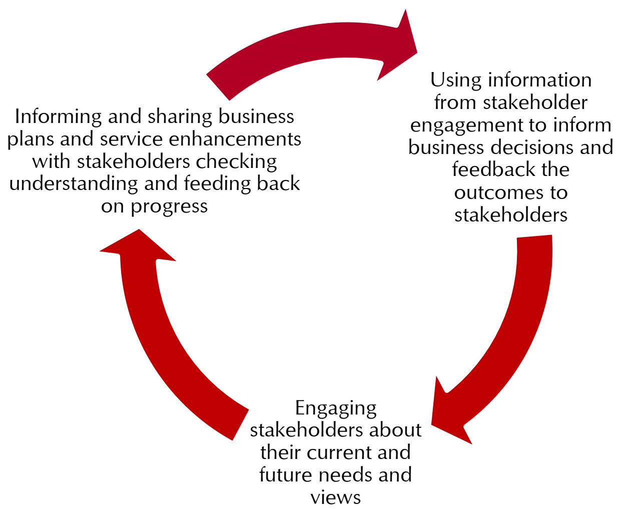


Figure 5 – Northern Powergrid Stakeholder Investment Process

In developing adaptation plans, it is important that they are co-ordinated with key stakeholders to ensure a consistent and effective approach. For example it is essential that Northern Powergrid's plans and Ofgem's plans are in harmony and that equipment providers' plans will enable us to deliver any reinforcement or replacement projects that may be required to safeguard our electricity networks.

Under Ofgem's regulatory requirements, Northern Powergrid must consult with key stakeholders. These include Local Resilience Forums and Regional Resilience Teams with whom companies work to develop Local and Regional Risk Assessments. For the purposes of the Adaptation Programme, the following have been identified as our 'key' stakeholders:

- Multi-level & Local Resilience Forums
- Other utilities & network operators
- Land owners and farmers
- Local Enterprise Partnerships
- Local Authorities
- Ofgem
- EA
- Supply Chain
- Generators
- Connected customers
- Defra
- DECC
- Contractors
- HSE

5 Approach Used to Risk Assess

5.1 Evidence, Methods and Expertise Used to Evaluate Future Climate Impacts

The majority of the evidence base for this report is centred on UKCP09 and considers the 90% probability level with High, Medium and Low emission scenarios to test sensitivity. UKCP09 describes different future climate outcomes in probabilistic terms, based on the strength of evidence associated with them. As such, probability levels associated with a given change should be interpreted as indicating the relative likelihood of the projected change being at or less than the given change.

For example, if a projected temperature change of +4.5°C is associated with the 90% probability level at a particular location in the 2080s for the UKCP09 medium emission scenario, this should be interpreted as it is projected that there is a 90% likelihood that temperatures at that location will be equal to or less than 4.5°C warmer than temperatures in the 1961–1990 baseline period. Conversely, there is a 10% likelihood that those temperatures will be greater than 4.5°C warmer than the baseline period.

The emission scenarios are described in UKCP09 as a plausible representation of the future development of emissions of substances (e.g. greenhouse gases and aerosols that can influence global climate). These representations are based on a set of assumptions about determining factors and their key relationships. The emissions scenarios do not include the effects of planned mitigation policies, but do assume different pathways of technological and economic growth which include a switch from fossil fuels to renewable sources of energy. These scenarios remain the best existing available information.

Information has also been considered from the EA. Northern Powergrid has been engaged in a number of initiatives related to climate change impacts.

5.1.1 Work on Flooding Resilience

The greatest climate threat to networks is assessed to be flooding. This applies to present risks and as a result of predicted climate change. In the event of serious flooding, electricity substations can be put out of action and the consequences can be severe. The flooding of a large substation can mean the loss of electricity supply to thousands of people, as well as to other types of infrastructure. The risk has been highlighted by severe flood incidents in the last few years, particularly those in 2007.

Such events show the need to understand and improve the resilience of substations to flooding. Action is particularly vital because, due to climate change, flooding of all kinds is likely to get worse. The Government has recognised this, and in 2007 asked for a comprehensive assessment of substations' resilience to flooding. Sir Michael Pitt's review of the 2007 floods also called for an improvement in the resilience of substations.

DNOs realised they needed a consistent, sector-wide, approach to flood resilience, but no industry standards existed. Regulations required 'reasonably practicable' measures to be taken to prevent loss of supply, but there was no common view about what this meant. As a result, an Industry Task Group was set up to produce a common approach to the assessment of flood risk and develop target mitigation levels that could be subject to cost benefit assessments. This was enabled by the great improvement in information on flood risk in recent years. The Task Group comprised representatives from the DNOs, Government Departments and Agencies and the Industry Regulator.

The electricity network sector has addressed this gap, developing a systematic approach to flood risk assessment and protection. The approach is documented in the Energy Networks Association's *ETR 138 - Electricity Substation Resilience to Flooding (Issue 1 October 2009)*. This sets out industry guidance on:

- standards of resilience
- how to take account of increasing risk due to climate change
- methods of assessing the likelihood and impact of flooding
- measures to reduce flood risk
- cost-benefit analysis of measures.

Since 2009, flood mapping for surface water has been improved for England and Wales. ETR 138 has been updated to take this into account. Similar information is also expected for Scotland. Northern Powergrid, along with other DNOs, included resilience measures to protect key sites against surface water flooding in their latest regulatory submissions. Further information on the contents of this ETR can be found in Appendix 6: Extract from ENA ETR 138 (Resilience to Flooding of Grid and Primary Substations).

Based on the original and updated ETR, companies are now undertaking a long term programme of work to improve substation resilience to flooding that takes into account predicted climate impacts. This programme was agreed by the industry regulator when they set the current allowances for Transmission and Distribution companies as part of the regulatory control periods. The respective allowances are published and expenditure monitored on an annual basis.

All planned flood protection is due to be complete by 2023 with higher risk sites being completed early in the programme. In the latest floods in the UK in the winter of 2013/14, no customer supplies were interrupted as a result of river flooding at major substations operated by the DNOs. Northern Powergrid has consulted with its stakeholders and recognised the high priority assigned by them to flood protection. As a result of this consultation, we are planning to complete works to protect all major sites at risk from fluvial and tidal flooding by 2019.

Northern Powergrid has carried out detailed analysis on substation flooding resilience and this has greatly assisted the understanding of risk at particular sites and ensured that appropriate protective measures are put in place.

Standards of resilience

The ETR identifies three different levels of acceptable flood risk, depending on the importance of the substation. These standards are the default, but can be raised or lowered if an analysis of the costs and benefits suggests that this is appropriate.

- Level 1: most important grid substations (typically supplying 50,000 to 500,000 customers) - likelihood of flooding should be no more than 1 in 1000 years.
- Level 2: other primary substations (typically supplying 5,000 to 30,000 customers) - likelihood of fluvial flooding no more than 1 in 100 (1 in 200 for Scotland) and 1 in 200 for sea flooding.
- Level 3: for sites where level 1 or 2 cannot be justified – other flood resilience measures.

Data specification

The ETR specifies the data that should be collected for the purposes of assessing flood risk. The specification requires companies to collect, for each substation:

- the likelihood of flooding in any one year from rivers or the sea (and surface water from 2015)
- the potential depth of flood water
- information about historic flooding
- existence and condition of flood defence scheme
- whether the site is in an area where the Environment Agency (EA) provides flood warnings
- the time required to activate flood protection measures.
- Societal risk – number of customers and number of critical / vulnerable customers

Climate change allowances

The ETR recommends allowances to take account of the impacts of climate change on flood risk for both fluvial and sea flooding. An additional allowance is included for uncertainties in data and modelling.

Cross-sector approach

The whole of the electricity network sector collaborated in developing ETR 138. Work was coordinated by the ENA, and included representatives from all electricity network companies, government (DECC), the regulator (Ofgem) the EA, Scottish Environment Protection Agency (SEPA) and the Met Office. The involvement of DECC and Ofgem was particularly important as it helped to support companies' investment plans for flooding resilience.

Benefits

All DNOs now have programmes to raise protection to the agreed standards and the current programme will be completed by 2023.

By setting out industry standards and an agreed approach, companies know how to tackle flood risk. Because government and the regulator were involved from the start, business plans which follow this approach have been approved. The respective allowances are published and expenditure monitored on an annual basis by the Regulator.

Other benefits are:

- The government is clear about the standard of protection of this vital service.
- There is consistency across the country - customers in different areas enjoy the same standards of protection.
- Operators of infrastructure which rely on electricity understand the risks to their service.
- Resilience measures will take account of climate change, so will be robust for the foreseeable future.

Lessons in the development of ETR 138

- Developing a cross-sector approach and acceptable levels of risk.
- Allowing flexibility in the standard, depending on costs and benefits.
- Discussing resilience standards with operators of dependent infrastructure.
- Involving all relevant organisations, including government and the regulator to achieve acceptance.
- Agreeing climate change allowances to handle uncertainty about future risk.
- Keeping standards under review, and updating to take account of new information.

These lessons can read across to other areas. This approach is held up as an exemplar by the Infrastructure Operators Adaptation Forum (IOAF) (facilitated by the EA Climate Ready team) and details are published on the Institution of Engineering Technology web site. The work in developing the ETR is also referenced in the 2014 report on infrastructure resilience by the Adaptation Sub Committee (ASC) of the Committee on Climate Change.

5.1.2 Work With the Met Office

A number of UK energy companies, including Northern Powergrid, commissioned the Met Office to carry out a project to investigate the potential impact of climate change. This report was published in 2008. The Executive Summary is attached within Appendix 7: Work completed with the Met Office.

A second project was carried out in conjunction with the Met Office to build a risk model to quantify the relationship between weather and network faults, and the vulnerability and exposure of the network to these faults. This model was driven with climate projections to assess how network resilience may be affected by climate change. This project concluded in 2010. Further details can be found within the appendix and the key findings are summarised below.

Future Climate Risk Assessment for the UK Electricity Network: National Findings

Using the relationships established in a baseline risk assessment between asset fault rates and severity of specific types of weather conditions, future risk was assessed for climate change out to the 2080s.

- **Wind and gale faults:** for future time periods, estimates of wind and gale faults range from changes that are negative to changes that are positive, therefore it is possible that these faults may increase or decrease in the future. Regionally there is more evidence of a reduction in faults in Northern England and Scotland compared to the South; however, this signal is not consistent over all the regional climate model runs.

- **Lightning faults:** projected to increase in the future as a consequence of more days with higher convection. There is regional variation in the estimates with smallest changes in the Midlands and South East of England and greatest in North England, North Wales and Scotland.
- **Snow, sleet and blizzard (SSB) faults (including ice):** projected to decrease due to a reduction in the number of days when snow falls. This highlights a decrease in the frequency of SSB fault days, but not necessarily a decrease in the intensity of events when snow does fall.
- **Flooding faults:** Projections showed a mean increase in exceedance of rainfall amounts which caused significant flooding events in the baseline period. The possibility of decreases could not be ruled out, however, as some model runs projected slight decreases in exceedance for some of the rainfall events. The absence of a flooding event in a particular area during the baseline period does not mean that that area is not vulnerable to flooding events. Major flooding events are statistically rare and the baseline period is short in terms of the occurrence of these events. The general increase in heavy rainfall projected should therefore be considered as relevant to all areas.
- **Solar heat faults:** the incidence of solar heat faults is expected to increase, due to projected increases in maximum temperatures. The future fault distribution for solar heat faults was not estimated – their rare occurrence in the baseline period meant that statistically robust relationships between fault numbers and weather parameters could not be determined. A threshold exceedance analysis based on maximum daily temperature was used as an indicator.

5.1.3 RESNET

Network companies are currently engaged in work with Newcastle University. This work includes an assessment of the potential changes to wind speeds as result of climate impacts and the risks this could present for electricity networks.

At present there is no firm climate change evidence to support increased intensity of wind or ice storms both of which can cause extensive damage to overhead electricity networks. However, both of these natural hazards continue to be a serious risk to overhead line networks. In order to better understand potential changes in wind impacts, electricity companies have supported the RESNET project, led by Newcastle and Manchester Universities. Initial reports are currently undergoing review.

There are now increased concerns about interdependencies between weather events such as very strong winds following prolonged rainfall. Initial discussions are taking place with Newcastle University regarding dependent heavy rain and wind models.

5.1.4 Other activities related to Climate Change Risk Assessment

As a result of the establishment of an industry wide Task Group to develop the ENA Adaptation report, network operators made a number of new contacts with Defra, EA, Cranfield University, UKCIP and those involved in the National Climate Change Risk Assessment programme. These contacts helped the Task Group test the industry's current evidence base and ensure all relevant sources of evidence were presented in the report. The majority of these contacts were renewed during the Second Round of reporting to ensure that the updates provided as much information as possible.

Under Ofgem's Innovation Funding Incentive (IFI) the industry has carried out a number of projects that provide knowledge about potential climate change impacts. These are listed in Appendix 8: IFI Projects with Climate Change Considerations.

5.1.5 Other Evidence

- **Air Conditioning:** Air conditioning has had an increasing level of adoption in the UK, particularly in city environments where summer peak loads can now be similar to winter peaks from heating.

  Evidence on the future impacts of increased temperature is available from countries with similar infrastructure to the UK such as Australia and New Zealand. Information from an electricity utility in South East Queensland, Australia provided information on the impacts of air conditioning and the potential to manage them by the development of Smart Grids. This provides a clear relationship between a mitigation initiative and a potential adaptation requirement.

  More work is required in the UK to fully understand the potential impact of air conditioning load.

- **Standards:** Current International Standards provide good evidence of the requirements for operating in hotter climates and Northern Powergrid equipment being purchased at present will typically comply with these Standards.
- **Wind Storms:** According to UKCIP, predictions for wind are very uncertain. Information provided by the Met Office at the DECC Resilience workshop in early 2010 clearly indicated that UKCP09 did not provide any conclusive evidence that climate change is likely to increase the severity of high wind events, although there could be a possible increase in their frequency.
- **Seasonal Demand Curve:** Milder winters are expected to reduce winter peak demand and air conditioning load is expected to increase summer demand, resulting in a flattening of the seasonal demand profile.

  At present, networks are designed with a level of security that ensures circuits can be taken out of service at more lightly loaded times in the summer to allow maintenance or construction activities. With a flatter demand curve, this will be more difficult to achieve and current security standards may need to be enhanced.

5.2 Estimation of the impact and likelihood of risks occurring at various points in the future

The Met Office EP2 Project found that because of climate change:

- With a few exceptions, such as the thermal ratings of equipment and apparatus, there is currently no evidence to support adjusting network design standards.
- Soil conditions will change; higher temperatures and seasonal differences in soil moisture are expected. Future conditions could be included in cable rating studies by increasing average summer soil temperatures in the models by approximately 0.5°C per decade.
- The risk profile for transformers will be affected. Design thresholds of temperature will be exceeded more often and there will be more hot nights in cities.
- Wind resource is uncertain and understanding future resource represents a significant challenge. Although we don‘t yet have the answers, this project has highlighted possible strategies for improving our knowledge.

5.3 Evaluation of the costs and benefits of proposed adaptation options

The main options for adaptation are:

a) Electricity Network equipment

- Modify the specification of assets, subject to normal replacement criteria, to ensure they can meet predicted adaptation requirements during their asset life.
- Minor adaption or up-rating of current assets
- Major adaption or up-rating of current assets
- Replace current assets specifically to meet an adaptation requirement

b) Other issues including human factors and supply chain

- Adaptation of internal processes including safety requirements
- Adaptation of relationship with other organisations including suppliers.

It is expected that required adaptation actions will be introduced gradually over time. During the same period, Northern Powergrid will be updating its network as part of the move to the Low Carbon Economy, whilst also continuing business as usual replacing aging assets and building new ones. Any necessary adaptation measures will be built into the specifications and designs for the new plant.

In considering these options it is important for Northern Powergrid to ensure we carry out cost/benefit assessments for each potential issue to determine appropriate action. This should include consideration of customers‘ "willingness to pay" for this type of adaptation as assessed by Ofgem.

This approach has recently been agreed with Ofgem and DECC regarding current and future substation resilience to flooding in ETR 138. An extract of this report showing the approach to cost/benefit assessments is included as Appendix 6: Extract from ENA ETR 138 (Resilience to Flooding of Grid and Primary Substations) and this type of approach may be adopted with respect to Climate Change risk

Further information on cost benefit analysis can be found in the Northern Powergrid additional justification papers produced as part of the 2014 regulatory submissions to Ofgem[2].

All electricity DNOs are committed to providing a safe, reliable and affordable network to deliver energy to customers. Whilst companies will always prioritise safety, reliability is the key measure in monitoring and evaluating whether they are performing effectively.

DNOs also have financial incentives to minimise the number and duration of interruptions including those caused by climate impacts. Ofgem introduced the IIS in April 2002. Under this scheme distribution companies are set a target for the number of interruptions each year that last over three minutes, and the total length of those interruptions. If they beat these targets they are rewarded and conversely they are penalised if they do not achieve the targets.

The incentive rates have varied at each price review, but for the period from 2015 to 2023 they have been set so that the cost of an individual customer going off supply for over three minutes is approximately £15, with every additional minute costing a further £0.37[3].

The amount that DNOs can benefit or be penalised under IIS is capped, with the amount varying with the size of the DNO. For the largest DNO this is set at just over £33m and for the smallest at £14m.

This money is not paid directly to the affected customers, but will be added or deducted from the allowed revenue that distribution companies will collect from suppliers. This will result in adjustments to tariffs for all customers.

DNOs are also subject to Guaranteed Standards of Performance enacted through the Electricity (Standards of Performance) Regulations which is a Statutory Instrument made under powers conferred in the Electricity Act 1989.

The Guaranteed Standards are a set of standards of service agreed with Ofgem, and backed by a financial guarantee – customers receive a payment if the distributor fails to meet these standards. From April 2015 the guaranteed standard for supply restoration has been set so that domestic customers will receive a payment of £75 after they have been without supply for 12 hours and £35 for every subsequent 12 hour period. A non-domestic customer will receive £150 for the first 12 hours and a further £35 every 12 hours. These payments will be made directly to the customers affected.

As mentioned in Section 3.4, new work is being focussed on identifying risk from the possibility of higher wind gusts or more frequent storms. A serious risk for distribution networks occurs during very strong wind storms when trees are uprooted some distance from an overhead line but are close enough to damage the conductors or break supporting poles. During the winter of 2013/14 this was a particular issue because very strong wind storms were combined with prolonged rainfall which made trees more susceptible to uprooting. As a result, a review has been initiated of the industry approach to resilient tree cutting set out in ETR 132 – *Improving Network Performance Under Abnormal Weather Conditions By Use Of A Risk Based Approach To Vegetation Management Near Electric Overhead Lines*.

This ETR was developed in conjunction with DECC and Ofgem and provides guidance for DNOs on how to improve network performance by enhancing the resilience of the network to vegetation (mainly trees) related faults under abnormal weather conditions, including high winds, ice, snow and prolonged high temperatures. This is particularly important due to the possibility of increased rainfall combined with strong winds and extended growth periods as a result of climate impacts. The Terms of Reference for this review are included in the Second Round Report as Appendix 9: Electricity Networks and Futures Group New Task Group—Review of ETR 132 - Draft Terms of Reference.

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[2] Additional Justification for our Flood Defence Forecast 2015 - 2023

[3] Figures quoted in 2012/13 value before application of IQI efficiency factors.

6 Summary of Risks

6.1 Technical Risks

A summary of risks is shown in Figure 6, following which these risks are considered by asset type. Replacement cycles provide an opportunity to build adaptation at an incremental cost and this is discussed under each asset.

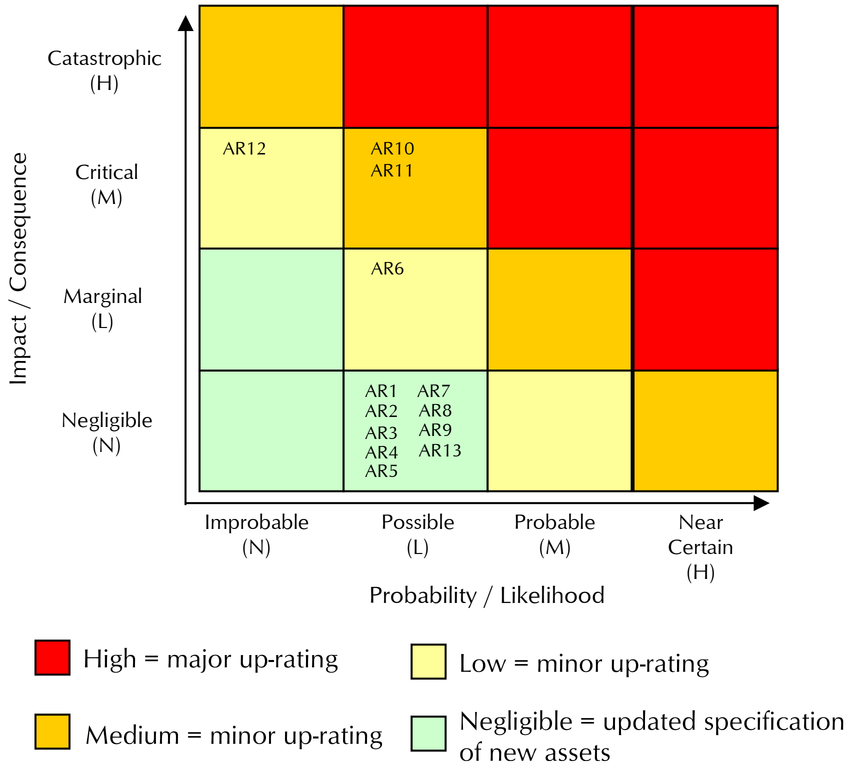


Figure 6 – Northern Powergrid Adaptation to Climate Change Risk Matrix

- AR1 Overhead line conductors affected by temperature rise, reducing rating and ground clearance.
- AR2 Overhead line structures affected by summer drought and consequent ground movement.
- AR3 Overhead lines affected by interference from vegetation due to prolonged growing season.
- AR4 Underground cable systems affected by increase in ground temperature, reducing ratings.
- AR5 Underground cable systems affected by summer drought and consequent ground movement, leading to mechanical damage.
- AR6 Substation and network earthing systems adversely affected by summer drought conditions, reducing the effectiveness of the earthing systems.
- AR7 Transformers affected by temperature rise, reducing rating.
- AR8 Transformers affected by urban heat islands and coincident air conditioning demand leading to overloading in summer months.
- AR9 Switchgear affected by temperature rise, reducing rating.
- AR10 Substations affected by river flooding due to increased winter rainfall.
- AR11 Substations affected by pluvial (flash) flooding due to increased rain storms in summer and winter.
- AR12 Substations affected by sea flooding due to increased sea levels and/or tidal surges.
- AR13 Overhead Lines and transformers affected by increased lightning activity.

Probability – Management judgement on likelihood of hazard occurring		Impact – Anticipated business consequence should hazard materialise	
H	It is judged to be Near Certain that the hazard will occur. (70% < p < 100%)	H	Should the hazard occur it is judged that the impact on the business would be Catastrophic e.g. failure of mission-essential service, death, cost of incident exceeds £10m
M	It is judged to be Probable that the hazard will occur. (40% < p < 70%)	M	Should the hazard occur it is judged that the impact on the business would be Critical e.g. significantly degraded performance, serious injury, cost of incident exceeds £1m
L	It is judged Possible that the hazard will occur. (1% < p < 40%)	L	Should the hazard occur it is judged that the impact on the business would be Marginal e.g. Failure of or degraded secondary performance, minor injury, cost of incident exceeding £100k
N	It is judged to be Improbable that the hazard will occur. (Less than 1%)	N	Should the hazard occur it is judged that the impact on the business would be Negligible e.g. inconvenience, cost of incident below £100k

Table 2 – Northern Powergrid Definitions of Relative Impacts

Confidence Levels

This report considers the predicted effects of climate change in accordance with the UKCPO9 projections for the 90% confidence level at Low, Medium and High emissions. This report demonstrates a high level of confidence in the predicted performance of networks under those conditions.

Thresholds

- Risks AR1, AR2, AR4, AR5, AR6, AR7, AR8, AR9: Warmer drier summers generally have a gradual impact and there are no particular thresholds. However, individual sites/equipment may be subject to thresholds that dictate when reinforcement or replacement is necessary and this will be monitored as part of the forward capital expenditure programme.
- Risk AR3: A warmer climate with wetter winters leads to a longer growing season with vegetation interfering with overhead lines. Again this is expected to be a gradually increasing impact. Thresholds will be linked to the frequency of inspections and tree cutting.
- Risks AR10, AR11: Warmer wetter winters result in increased flood risk from rivers and surface/ground water. Thresholds in this case relate to the height of any flood waters compared with the height/protection at any substations at risk as set out in ETR 138[4].
- Risk AR12: The thresholds in the case of the increased risk of sea flooding relate to the height of any flood waters compared with the height/protection of at risk substations as set out in ETR 138.
- Risk AR13: Lightning faults are projected to increase in the future as a consequence of more days with higher convection. However, there is a wide range in projected changes with regional variations in the estimates and therefore it will be necessary to continue to work with organisations such as the Met Office to understand when and where lightning activity could reach levels that may require additional protective measures to be taken.

The technical risks to the network are discussed in detail in Appendix 10: Technical Assessment of Climate Change

[4] For all potential flooding scenarios it will be necessary to monitor actual flood levels to check that the planned remedial action is appropriate

6.2 Other impacts

We have identified a range of risks which impact on the network assets (premises and processes) that form the key to the Northern Powergrid infrastructure. There are a range of other potential impacts that have been also been considered:

- **Markets:** It is likely that climate change itself will bring about a greater take-up of air conditioning load with increased penetration into the domestic sector. However, against this increased demand there are opposing drivers through new building standards and other Government initiatives on thermal efficiency together with EU Energy Using Products Directives. Of greater impact are climate change mitigation actions in support of the low carbon economy.

- **Finance:** The sector is financed through Price Control mechanisms administered by Ofgem. It will be necessary for the industry to agree with Ofgem and DECC the approach, funding and timescales for adaptation.

- **Logistics:** The industry is not reliant upon a supply of raw material in the same manner, for example, as a coal fired power station. However, it does require a supply of new equipment to install new connections, to build network extensions, to enhance existing infrastructure to meet new demand and to replace old or faulted equipment. Equipment is increasingly drawn from a European and global marketplace, sometimes involving significant shipping distances. Northern Powergrid consider stock holding and replenishment risks as part of resilience planning and has been subject to review by the former Departments of Trade and Industry and for Business, Enterprise and Regulatory Reform. Only the largest items cannot be air-freighted if the need arose and it would require simultaneous disruption of road / sea and air transport to have a major effect.

  The industry staff home life would be subject to the same disruption as the wider public in the event of major water or food shortages. (National Risk Register H49 H50)

  In the event of an outbreak of an animal notifiable disease, Northern Powergrid has plans for dealing with the challenges to and impact upon our business posed by access restrictions. These plans were tested and improved during the 2001 and 2007 outbreaks of Foot and Mouth Disease (FMD).

- **People:** In the event of significant levels of absence due to health/heat impacts, Northern Powergrid would re-deploy staff from longer term work onto fault fixing, curtailing planned work. Plans prepared in 2009 for pandemic flu serve as a model for this approach. Staff may also be affected by disruption to normal travel arrangements caused by extreme events such as flooding, snow and ice or heat waves. There will then be dependencies with the transport sector.

  As part of our commitments to our customers, Northern Powergrid maintains a PSR.[5] This allows us to provide additional services, advice and facilities to our most vulnerable customers.

- **National risk register elements:** The national risk register includes some 50 referenced risks, some of which have a potential relationship with climate change

  H17 Storms and Gales – discussed under the relevant asset.

  H18 Low temperatures and Heavy Snow – Company emergency planning, includes for response to faults. The difficulties in gaining access to fault locations are partly mitigated by widespread use of 4 wheel drive vehicles and the availability of a number of helicopters under direct ownership and control of network operators. It is recognised that road access by 4 wheel drive vehicles can be inhibited by other vehicles blocking roads. However, the climate change forecasts indicate a reduction in this risk.

  HL18, 19 and 20 relate to flooding - see section 5.1.1 above.

  HL21 Land movement – this is referenced in the document as a potential threat to underground cables and structures due to ground drying.

  H23 & H24 Pandemic and emerging diseases – Following the 2009 pandemic flu outbreak, Northern Powergrid has tried and tested policies in place to deal with these situations.

[5] Information on the Northern Powergrid Priority Services Register

H25 Animal disease – Climate change is likely to result in a migration of infectious animal diseases such as Blue Tongue into the UK. Such diseases may well lead to bars on access to areas of agricultural land, in the same manner as for FMD. Northern Powergrid has experience of FMD access restrictions in 2001 and 2007 and has established processes and protocols with Defra. Such restrictions result in a cessation of planned works and inhibit response times to correcting faults on the network. Consequently these have greatest impact when an FMD type access restriction coincides with a period of adverse weather.

H31 & H38 Constraint on supply of fuel – This could arise in the event of transport restrictions caused by extreme weather. The industry has established a range of mitigation actions including self storage, in the light of past fuel emergencies (2000), and is identified by the Government as a priority user class. We also have separate plans for road fuel disruption and hold bunkered stocks to enable us to maintain essential services for up to ten days in the event of disruption.

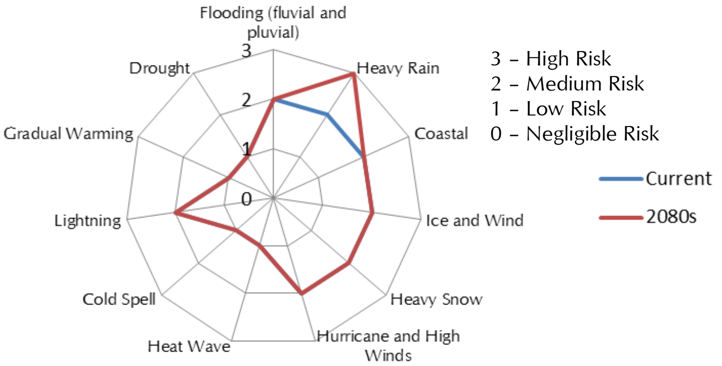
H41 & H45 – Technical failure – E3C oversees plans that are in place for major emergencies including recovery from a total failure of the grid system known as “Black Start”.

H48 Heat wave – The impact of heat waves on assets are described in the relevant sections above. The impacts on staff absence are covered in ‘people’ H23 / H24 above. There are further impacts relating to the ability of staff to work at normal rate and the practicality of wearing current designs of personal protective equipment (PPE), such as flame retardant overalls for cable jointing or flame retardant clothing and insulating gauntlets for ‘hot- glove’ working on live 11kV overhead lines. If staff were unable to work with the current PPE it would mean that fault repairs would be delayed until the heat had reduced (e.g. night time) and planned work would be delayed. It will be necessary to study the PPE aspect of climate change and seek, if necessary, an evolution to PPE more suited to hot environments (noting that hot glove work is already undertaken in hot climates).

6.3 Summary of Technical Risks

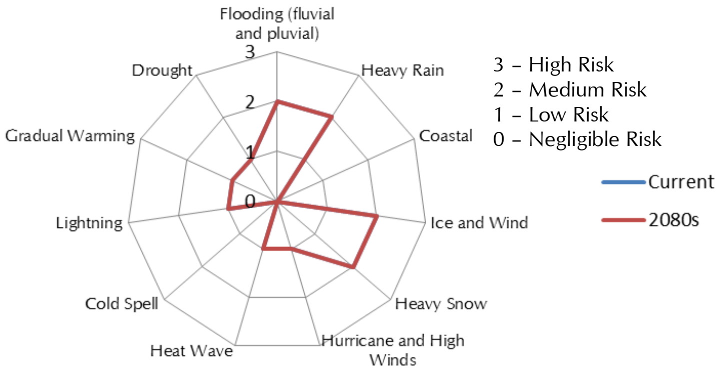
The following sections provide an overview of the assessed risk of climate change to the elements of the electricity network. Full details on the analysis carried out to allow the assessment of these risks can be found in Appendix 10: Technical Assessment of Climate Change

6.3.1 Overhead Lines



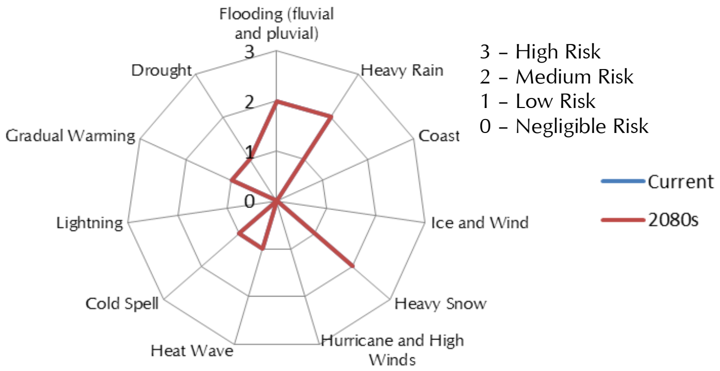
Climate Change Risk	Impact and Consequence	Actions
Flooding (fluvial & pluvial)	• Reduced clearances during a flood event lead to increased risk of third party contact. • Increased corrosion of footings leading to instability of poles / towers.	• Regular review of specifications to ensure designs fit for purpose. • Programme of condition monitoring of assets.
Heavy Rain	• Reduced clearances during a flood event lead to increased risk of third party contact	• Regular review of specifications to ensure designs fit for purpose. • Programme of condition monitoring of assets.
Coastal Flooding	• Reduced clearances during a flood event lead to increased risk of third party contact	• Regular review of specifications to ensure designs fit for purpose. • Programme of condition monitoring of assets.
Ice & Wind	• Ice accretion occurs on overhead lines leading to compromised structural integrity. • Helicopters unable to fly to carry out fault location.	• EU research COST 727 currently investigating impacts of ice loading
Heavy Snow	• Snow and ice build-up occurs on overhead lines leading to compromised structural integrity.	• EU research COST 727 currently investigating impacts of ice loading
Hurricane & High Winds	• Increased frequency of events may weaken poles and fittings.	• Condition based refurbishment programme in place
Heat Wave	• High ambient temperatures lead to a reduction in available capacity. • Additional loadings placed on network due to air conditioning.	• Annual review of network loadings ensure adequate headroom on network.
Cold Spell	• Additional loadings placed on network due to additional heating & electrical appliances. • Increase in mechanical tension in lines leading to accelerated ageing.	• Annual review of network loadings ensure adequate headroom on network. • Condition based refurbishment programme.
Lightning	• Increased lightning storms leading to increased number of faults.	• Lightning protection on network. • Protection policies subject to regular review.
Gradual Warming	• Capabilities of overhead line network reduced due to reduction in ratings. • Ground clearances reduced leading to greater risk of third party contact or infringement of statutory clearances.	• Annual review of network loadings ensure adequate headroom on network. • Programme of condition monitoring of assets.
Drought	• Soil drying and movement undermines pole and tower foundations.	• Programme of condition monitoring of assets.

6.3.2 Vegetation Management



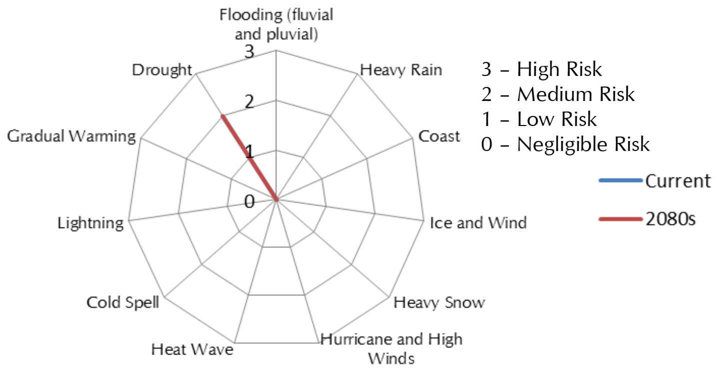
Climate Change Risk	Impact and Consequence	Actions
Flooding (fluvial & pluvial)	• Flooding events undermine tree roots, leading to additional faults due to falling trees.	• Vegetation Management programme subject to regular reviews.
Heavy Rain	• Flooding events undermine tree roots, leading to additional faults due to falling trees.	• Vegetation Management programme subject to regular reviews.
Coastal Flooding	• Flooding events undermine tree roots, leading to additional faults due to falling trees.	• Vegetation Management programme subject to regular reviews.
Ice & Wind	• Ice accretion occurs on trees leading to additional faults due to falling debris	• Vegetation Management programme subject to regular reviews.
Heavy Snow	• Snow and ice build up occurs on trees leading to additional faults due to falling debris.	• Vegetation Management programme subject to regular reviews.
Hurricane & High Winds	• Increased frequency of events may weaken trees leading to additional faults due to falling debris	• Vegetation Management programme subject to regular reviews.
Heat Wave	• High ambient temperatures lead to an extended growing season and hence additional encroachment of vegetation.	• Vegetation Management programme subject to regular reviews.
Cold Spell	• No specific risks identified.	
Lightning	• Increased lightning storms leading to increased number of faults	• Vegetation Management programme subject to regular reviews.
Gradual Warming	• High ambient temperatures lead to a extended growing season and hence additional encroachment of vegetation.	• Vegetation Management programme subject to regular reviews.
Drought	• Change in water content of soil leads to changes in natural habitats of different species.	• Vegetation Management programme subject to regular reviews.

6.3.3 Underground Cables



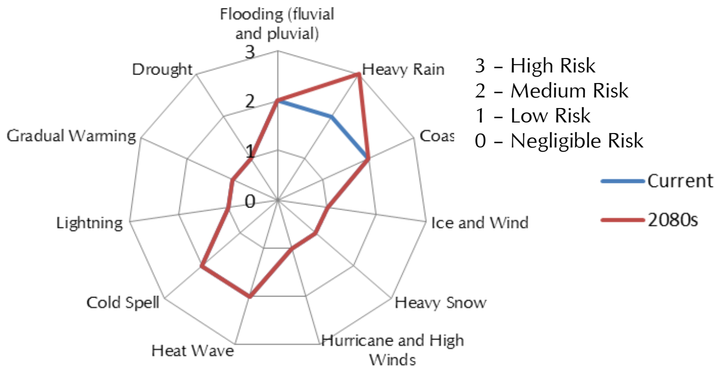
Climate Change Risk	Impact and Consequence	Actions
Flooding (fluvial & pluvial)	• Land surrounding cables is flooded or waterlogged leading to additional faults	• Programme of condition monitoring of assets in place.
Heavy Rain	• Land surrounding cables is flooded or waterlogged leading to additional faults	• Programme of condition monitoring of assets in place.
Coastal Flooding	• Land surrounding cables is flooded or waterlogged leading to additional faults	• Programme of condition monitoring of assets in place.
Heavy Snow	• Following melt, land surrounding cable is waterlogged leading to additional faults.	• Programme of condition monitoring of assets in place.
Ice & Wind	• No specific risks identified.	
Hurricane & High Winds	• No specific risks identified.	
Heat Wave	• High ambient temperatures lead to a change in soil properties and therefore the capacity of the cables.	• Annual review of network loadings ensure adequate headroom on network
Gradual Warming	• High ambient temperatures lead to a change in soil properties and therefore the capacity of the cables.	• Annual review of network loadings ensure adequate headroom on network
Cold Spell	• Additional loadings placed on network due to additional heating and electrical appliances in use.	• Annual review of network loadings ensure adequate headroom on network • Review of specifications to ensure cables are fit for purpose
Drought	• Change in water content of soil has an adverse effect on soil resistivity and hence causes a reduction in cable ratings.	• Annual review of network loadings ensure adequate headroom on network • Review of specifications to ensure cables are fit for purpose
Lightning	• No specific risks identified.	

6.3.4 Earthing Risks



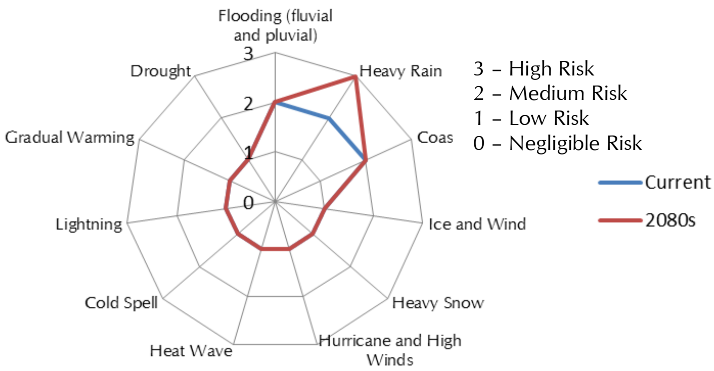
Climate Change Risk	Impact and Consequence	Actions
Drought	• Change in water content of soil has an adverse effect on soil resistivity and may cause a change in the effectiveness of the earthing.	• Climate change to be considered during regular reviews of earthing specifications.

6.3.5 Transformer Risks



Climate Change Risk	Impact and Consequence	Actions
Flooding (fluvial & pluvial)	• Transformer failure due to floodwater (likely to be due to cable terminations, cooling fans, secondary wiring or auxiliary switches)	• Policy in place for flood defending at risk substations and subject to regular review.
Heavy Rain	• Transformer failure due to floodwater (likely to be due to cable terminations, cooling fans, secondary wiring or auxiliary switches)	• Policy in place for flood defending at risk substations and subject to regular review.
Coastal Flooding	• Transformer failure due to floodwater (likely to be due to cable terminations, cooling fans, secondary wiring or auxiliary switches)	• Policy in place for flood defending at risk substations and subject to regular review.
Ice & Wind	• Operation of transformer compromised by ice build up affecting exposed moving parts.	
Heavy Snow	• Tranformer and/or pumps unable to operate due to snow, reducing the transformer ratings	• Annual review of network loadings ensure adequate headroom on network.
Hurricane & High Winds	• Debris falls onto transformers causing damage and faults	• Condition monitoring of substation buildings and vegetation management policies in place.
Heat Wave	• Capacity reduced due to high ambient temperature. • Additional load placed on network due to air conditioning.	• Annual review of network loadings ensure adequate headroom on network.
Cold Spell	• Additional loadings placed on network due to additional heating and electrical appliances.	• Annual review of network loadings ensure adequate headroom on network.
Gradual Warming	• Capacitiy of network reduced due to increase in ambient temperature.	• Annual review of network loadings ensure adequate headroom on network.
Lightning	• Increased number of lightning strikes leading to additional faults.	• Lightning protection in place and policies subject to regular review.
Drought	• Subsidence means that transformer footing become unstable.	• Condition monitoring programme in place for assets.

6.3.6 Substation Risks

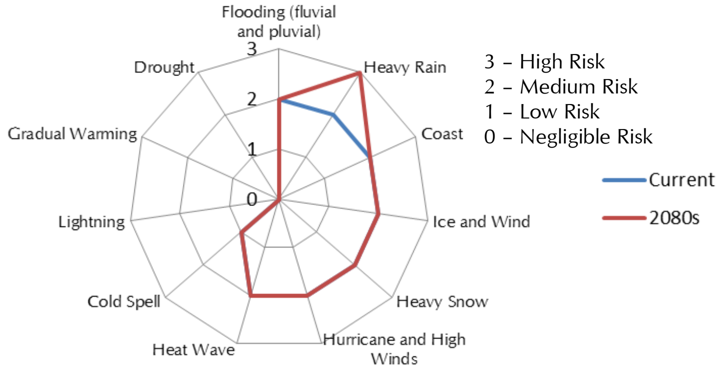


Climate Change Risk	Impact and Consequence	Actions
Flooding (fluvial & pluvial)	• Substation floods due to extension of flood plains. • Substation floods as existing flood defences are inadequate.	• Policy in place for flood defending at risk substations. Policy subject to regular review.
Heavy Rain	• Substation floods due to extension of flood plains. • Substation floods as existing flood defences are inadequate.	• Policy in place for flood defending at risk substations. Policy subject to regular review.
Coastal Flooding	• Substation floods.	• Policy in place for flood defending at risk substations. Policy subject to regular review.
Ice & Wind	• Damage sustained to substation buildings leading to equipment failure.	• Condition monitoring of substation buildings.
Heavy Snow	• Substation buildings unable to support weight of snow.	• Condition monitoring of substation buildings.
Hurricane & High Winds	• Increased frequency weakens or damages substation buildings leading to equipment failure.	• Condition monitoring of substation buildings.
Drought	• Subsidence means that substation footings may become unstable.	• Condition monitoring of substation buildings.
Heat Wave	• Additional load placed on network due to air conditioning.	• Annual review of network loadings ensure adequate headroom on network • Specifications reviewed on a regular basis to ensure adequacy.
Cold Spell	• Additional loadings placed on network due to additional heating and electrical appliances.	• Annual review of network loadings ensure adequate headroom on network • Specifications reviewed on a regular basis to ensure adequacy.
Gradual Warming	• Capacity of network reduced due to increase in ambient temperature.	• Annual review of network loadings ensure adequate headroom on network • Specifications reviewed on a regular basis to ensure adequacy.
Lightning	• Increased number of lightning strikes lead to additional faults.	• Lightning protection and policies subject to regular review.

6.4 Summary of Non-Technical Risks

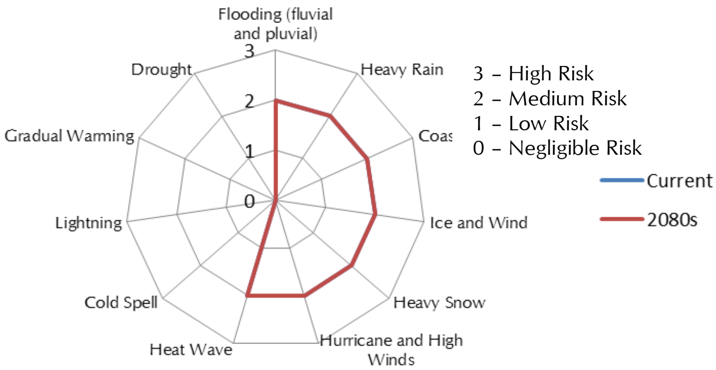
The following sections provide an overview of the assessed risk of climate change to Northern Powergrid's business. Details on the analysis carried out to allow the assessment of these risks can be found in Appendix 10: Technical Assessment of Climate Change

6.4.1 Emergency Response and Planning



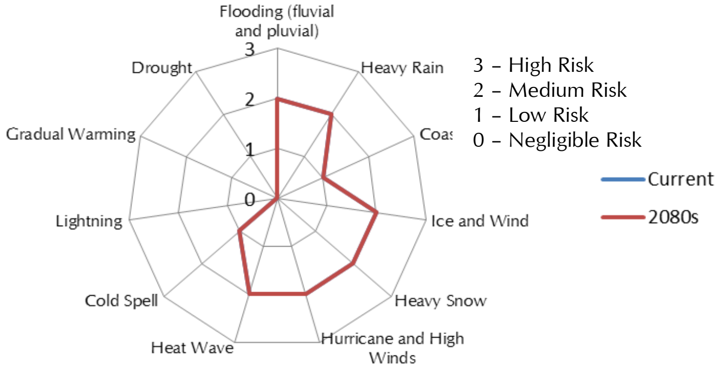
Climate Change Risk	Impact and Consequence	Actions
Flooding (fluvial & pluvial)	• Increased number of substations at risk of flooding.	• Policy for flood defending at risk substations in place and subject to regular review. • Policy for emergency planning (EP) and major incident management in place and subject to regular review.
Heavy Rain	• Increased number of substations at risk of flooding.	• Policy for flood defending at risk substations in place and subject to regular review. • Policy for EP and major incident management in place and subject to regular review.
Coastal Flooding	• Substation floods.	• Policy for flood defending at risk substations in place and subject to regular review. • Policy for EP and major incident management in place and subject to regular review.
Ice & Wind	• An increased frequency of events leads to an increased number of major incidents.	• Policy for EP and major incident management in place and subject to regular review.
Heavy Snow	• Build up of snow causes additional faults and hampers staff movements leading to slow response times.	• Policy for EP and major incident management in place and subject to regular review.
Hurricane & High Winds	• Increased frequency causes additional faults leading to a strain on resources.	• Policy for EP and major incident management in place and subject to regular review.
Cold Spell	• Additional loadings placed on network, leading to additional faults.	• Policy for EP and major incident management in place and subject to regular review.
Lightning	• Increased number of lightning strikes lead to additional faults.	• Policy for EP and major incident management in place and subject to regular review.
Heat Wave	• High staff absence due to sickness leading to a reduced internal workforce.	• Policy to deal with pandemics, staff re-allocation etc in place and subject to regular review.
Gradual Warming	• No specific risks identified	
Drought	• No specific risks identified	

6.4.2 Routine Business (maintenance, restoration & repairs, capital investment)



Climate Change Risk	Impact and Consequence	Actions
Flooding (fluvial & pluvial)	• Increased number of substations at risk of flooding, leading to diversion of resources away from routine business.	• Routine business is monitored for delivery against targets, with appropriate recovery plans implemented as necessary.
Heavy Rain	• Increased number of substations at risk of flooding, leading to diversion of resources away from routine business.	• Routine business is monitored for delivery against targets, with appropriate recovery plans implemented as necessary.
Coastal Flooding	• Increased number of substations at risk of flooding, leading to diversion of resources away from routine business.	• Routine business is monitored for delivery against targets, with appropriate recovery plans implemented as necessary.
Ice & Wind	• Routine business suffers as a result of additional faults on the network.	• Routine business is monitored for delivery against targets, with appropriate recovery plans implemented as necessary.
Heavy Snow	• Build up of snow causes additional faults and hampers staff movements. Routine business suffers as a result.	• Routine business is monitored for delivery against targets, with appropriate recovery plans implemented as necessary.
Hurricane & High Winds	• Increased frequency causes additional faults leading to a strain on resources. • Certain activities postponed due to safety concerns.	• Routine business is monitored for delivery against targets, with appropriate recovery plans implemented as necessary.
Heat Wave	• Certain activities postponed due to unsuitabiliy of PPE for temperature conditions. • High staff absence due to sickness leading to a reduced internal workforce.	• Investigate PPE utilised in other countries with higher ambient temperatures. • Routine business is monitored for delivery against targets with appropriate recovery plans implemented as necessary.
Cold Spell	• No specific risks identified.	
Lightning	• No specific risks identified.	
Gradual Warming	• No specific risks identified.	
Drought	• No specific risks identified.	

6.4.3 Customer Service



Climate Change Risk	Impact and Consequence	Actions
Flooding (fluvial & pluvial)	• Increased number of substations at risk of flooding. Fault restoration times extended due to floodwaters.	• Policies for flood defending at risk substations. • Policies for emergency planning and major incident management. • All policies subject to regular review.
Heavy Rain	• Increased number of substations at risk of flooding. Fault restoration times extended due to floodwaters.	• Policies for flood defending at risk substations. • Policies for emergency planning and major incident management. • All policies subject to regular review.
Coastal Flooding	• Increased number of substations at risk of flooding. Fault restoration times extended due to floodwaters.	• Policies for flood defending at risk substations. • Policies for emergency planning and major incident management. • All policies subject to regular review.
Ice & Wind	• Slow response times and increased fault durations due to large number of network faults and problematic access and travel.	• Policies for emergency planning and major incident management. All subject to regular review.
Heavy Snow	• Slow response times and increased fault durations due to large number of network faults and problematic access and travel.	• Policies for emergency planning and major incident management. All subject to regular review.
Hurricane & High Winds	• Slow response times and increased fault durations due to a large number of network faults. • Certain types of work prevented due to safety issues.	• Policies for emergency planning and major incident management. All subject to regular review.
Heat Wave	• High staff absence due to sickness leading to a reduced internal workforce.	• Policies to deal with pandemics, staff re-allocation etc. All subject to regular review.
Cold Spell	• Vulnerable customers need additional prioitisation.	• Vulnerable customer register maintained and policies in place. • Policies for dealing with customer welfare during outages. • All policies subject to regular review.
Lightning	• No specific risks identified.	
Gradual Warming	• No specific risks identified.	
Drought	• No specific risks identified.	

6.5 Summary of strategic risks from climate change

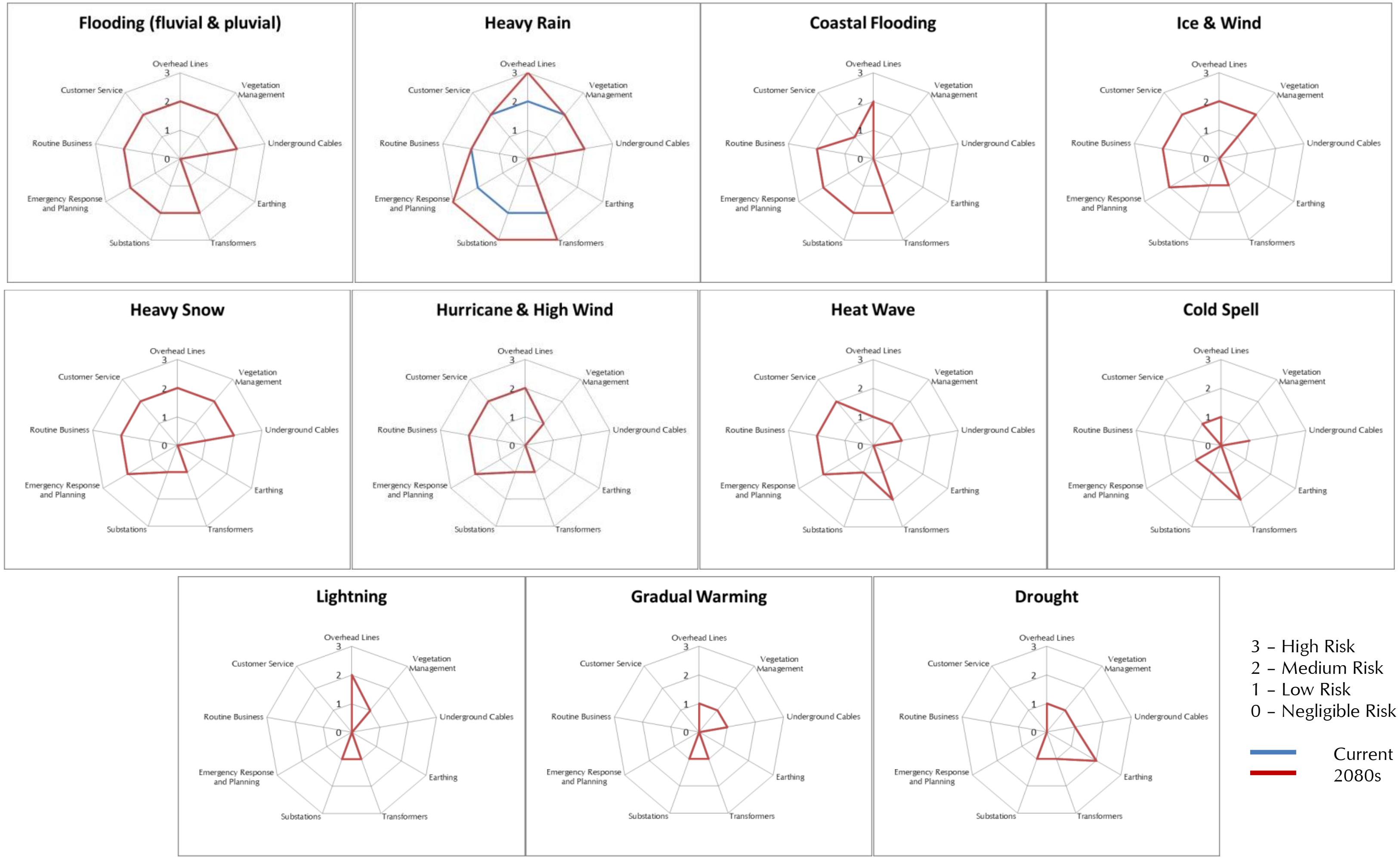


Figure 7 – Northern Powergrid Impacts of Current and Future Climate Change Risks

6.6 Identified short and long term impacts of climate change

Northern Powergrid operates its business through nine geographical zones. Using UKCP09 a detailed assessment has been completed of potential impact of climate change for each of these zones. The identified impacts over time are shown in Appendix 11: – Northern Powergrid Operating Zone Climate Assessment.

6.7 High priority climate related risks

High Priority Risks are not necessarily ones that score High or Very High in the risk overall assessment, but those where there is a need to take action in the short term.

Present experience identifies flooding as the highest priority risk. Flooding resilience is covered in this report in Section 5.1.1 Work on Flooding Resilience and has been the subject of a separate study detailed in ENA ETR 138. This issue has received particular attention due to the increased incidence of flooding affecting electricity substations, notably in 2005 and 2007. ETR 138 has recently been reviewed with respect to surface water flooding. Northern Powergrid have identified substations at risk from fluvial, and more recently pluvial, flooding and agreed with Ofgem a programme of work for the period through to 2023.

Although not a major risk, vegetation management is already a cause for concern and is currently subject to a five year programme to improve network resilience under the ESQCR. Following recent severe weather events, the industry wide task group looking at vegetation management has been reconvened, as discussed in section 5.3.

6.8 Opportunities due to the effects of climate change which can be exploited

COST 727 is mentioned in Section 3.1. The outcome of this study has lead to a better understanding of potential ice loadings and the ability to design more cost effective overhead line structures. In addition, climate change is likely to result in fewer and less severe icing events which should also allow a reduction in design strengths with subsequent cost savings.

7 Actions Proposed to Address Risks

7.1 Adaptation actions for the top priority risks with timescales

Appendix 12: Updated Table of Actions contains details of all the actions across the industry, progress to date and further work / timescales for completion.

7.1.1 Overhead line designs

Section 3.3 identified the extent of the impact on overhead line ratings caused by increasing ambient temperatures; the most onerous impacts being on wood pole types having design operating temperatures of 50°C. An increase of 5°C for example in the design operating temperature to 55°C would mean that a proportion of existing spans of overhead line would sag below required statutory minimum height and would require replacement of the overhead line supports (mainly wood poles) with taller versions.

Given that the normal life of a wood pole support is of the order of 60 years, those that are being installed now, either as part of normal pole replacement or in new lines, will face the range of climate impacts identified in the period out to the 2080s. If the industry were to wait until the need arose to change individual poles because of increased operating temperatures, it would follow that the timing would be unlikely to naturally occur coincident with the need to replace the pole due to deterioration. An assessment of the age profile of the present pole stock is thus warranted and is presented below. This shows (2008 base year) that by 2020, some 53% of poles will be at or approaching 60 year nominal life and are more likely to be approaching need for replacement. The marginal cost of installing a 0.5m taller pole at time of replacement is around £20 (stout) whereas the Ofgem (DPCR5) total unit cost of replacing a single pole is some £1,800 (see Section 1). Northern Powergrid, in conjunction with other ENA Member companies thus propose to engage in discussion with Ofgem and DECC with a view to agreeing revised design standards.

Asset Categories	Number of Supports by Age Profile as at 31/03/2008							
	70+	60+	50+	40+	30+	20+	Unknown	Total
LV Network Overhead Lines								
LV Supports	54,881	77,584	369,576	408,361	224,720	187,886	387,918	1,710,926
HV Network Overhead Lines								
6.6/11kV Supports	40,079	56,919	407,397	623,604	279,878	191,082	449,925	2,048,884
20kV Supports	2,665	3,073	15,901	16,860	7,299	6,437	12,220	64,455
EHV Network Overhead Lines								
33kV Pole	7,110	16,613	51,477	85,731	44,786	25,389	66,985	298,091
33kV Tower	2,888	1,168	2,639	2,417	1,631	324	504	11,571
66kV Pole	460	1,245	8,931	9,449	3,101	1,505	5,740	30,431
66kV Tower	428	94	1,105	1,172	78	26	79	2,982
132kV Network Overhead Line - Supports								
132kV Pole	2	68	1,015	1,647	671	587	3,749	7,739
132kV Tower	4,927	1,849	8,492	9,247	3,832	1,784	3,307	33,438

Table 3 – National age profile of overhead line supports

7.2 Implementation of Adaptation Actions

Adaptation will be incorporated into Northern Powergrid's long term investment programmes. One important aspect is to ensure that new and replacement plant is appropriately specified to take account of possible climate change effects over the lifetime of the equipment. Accordingly it is proposed to review critical industry standards and this is covered in Section 7.3.

It is expected that flooding adaptation work for current known threats including climate change will be completed by 2023.

7.3 Industry specifications and guidance

It is proposed that ENA should carry out a focussed review of those Engineering Documents that are likely to be significantly affected by climate change (e.g. overhead line ratings), identifying any standards that will require updating.

On completion of this review, the ENA Committee governing these standards will agree any programme that may be necessary to amend these standards, prioritising those that require the greatest change, affect assets with long lives or where the expense of modifying the future installed population is greatest. Any programme will use the most appropriate climate data available, where necessary commissioning research to understand potential impacts and probabilities. It will also need to take account of developments in British, European and International Standards.

Northern Powergrid will participate as necessary in this review and programme of work and will ensure that any revisions to specifications are incorporated into our day to day business in an appropriate and timely manner. Details of the current impact of climate conditions can be found in Appendix 13: Climate Conditions in Northern Powergrid Standards and Specifications.

7.4 Cost estimate for adaptation measures and benefits anticipated

Indicative Impact Cost of De-Rating of Assets due to Climate Change 2070-2099 High emission 90% probability							
Asset categories	Risk Factors			Mitigations		Indicative total impact to 2080 £m	Indicative annual impact - straight line model £m
	National qty	Indicative max % de-rating	Unit cost £k/unit	Assumed % length impacted	Notional life		
Overhead lines cct/km							
LV rebuild	64873	14	28.4	10	50	26	0.516
HV rebuild	168953	14	33.5	10	50	79	1.585
EHV pole	28882	14	42	100	50	170	3.397
EHV tower	3253	14	431	100	80	196	2.454
132kV pole	1773	5	79	100	50	7	0.140
132kV tower	14696	5	1162	100	80	854	10.673
Underground cables							
LV	328037	5	98.4	10	80	161	2.017
HV	153883	6.6	82.9	10	80	84	1.052
EHV	21184	6.5	256.8	100	80	354	4.420
132kV	3188	4.9	1047	100	80	164	2.044
Transformers							
HV/LV ground mount	232968	8	13.2	100	50	246	4.920
HV/LV pole mount	355962	8	2.9	100	40	83	2.065
EHV/HV	4587	5.9	386	100	50	105	2.090
132kV/HV	1946	5.9	1018	100	50	117	2.338
Total						**2645**	**40**

Table 4 - Indicative Impact Cost of De-rating of Assets due to Climate Change

Note:
Quantities from aggregated Ofgem DPCR5 FBPQ Table T4 submissions (HV incl 20kV, EHV incl. 66kV)
Costs from tables 17 and 20 of Ofgem DPCR5 - Document 146a/09 issued 7 Dec 2009
Overhead rebuild lengths for wood pole incl conductor and poles - taken from table 20 as above
Overhead rebuild cost for steel tower - costs from Table 17 and assumed 10 supports per km
EHV transformer cost is weighted average cost 33 and 66kV on quantity addition embedded in cell D22
% length impacted is less for LV and HV due to tapering of load down length
% indicative max de-rating from draft ENA report
Indicative total impact to 2080 equals National Quantity x Indicative De-rating x Unit Cost x Percentage Length or Numbers Impacted

An indicative scale of cost of adaptation impact has been calculated using Ofgem data on asset quantities and unit costs, and applying a "worst case" climate de-rating impact for the 2070-2099 high emission scenario 90% probability model, and using a likely pessimistic pro-rata cost / rating assumption. That indicates a total UK cost, based on the extent of the present day network and current costs, of some £2.6 billion over 60 years. Detailed modelling would be required, matching individual asset age profiles and regionality to arrive at annualised spend, but on a simplistic straight line approach it is of the order of £40m per annum nationally. These figures are only presented to give an indication of scale; they do not represent detailed analysis, and adaptation would be interwoven with other investment and timing decisions.

Overall network investment plans need to take account of increasing loads due to normal growth rates and the expected very substantial additional impact of “low carbon” loads/generation such as heat pumps, electric vehicles and solar PV. Current projections indicate that these are likely to have a far greater impact than potential temperature increases and “Smart Grid[6]” technology is being developed to provide minimum cost solutions that also have the potential to provide service enhancements for customers. In view of this it is currently considered that it will be possible to build adaptation requirements into “business as usual”, enmeshed within other work to replace existing assets and in building new networks. The costs of adaptation then predominantly emerge as marginal costs incurred at the time of the other works, rather than an outright adaptation only cost.

Current flooding resilience projects incorporate provision for CCA and this ensures that protection measures should not require rebuilding for the life of the asset. Of course, this is based on our current understanding of climate change and we cannot be sure that if climate change is worse than currently predicted that our defences will be suitable, in which case additional expenditure may be necessary.

Prevention of flooding at substations saves direct costs on repairs and customer compensation and also saves large costs that would have fallen on the community if lengthy and widespread power cuts were to occur.

Detailed information on the justifications for flood defence works and vegetation management can be found within the Northern Powergrid Well Justified Business Plan[7] documentation, published on our internet site.

7.5 Estimate of level of risk reduction and timescales

Because it is planned to incorporate adaptation measures in normal investment programmes and due to the scale of future planned investment in electricity networks, it is considered that adaptation measures can effectively be built into the normal programme of work and covered by Northern Powergrid’s overall risk management processes.

[6] Smart Grids use additional functionality to provide greater capacity and flexibility over their passive equivalents. Using a mixture of modelling, state estimation and active measurement systems they dynamically alter their settings and layouts to accommodate greater levels of load and generation without requiring additional conventional reinforcement.

[7] Northern Powergrid - Your Powergrid

8 Embedding the Management of Risks

8.1 Risk Management Responsibility.

Northern Powergrid recognises that risk management is fundamental to their success in terms of achieving goals, efficiency and effectiveness of business operations, reliable and robust processes and mitigation of financial loss. The overall philosophy and approach to risk management within Northern Powergrid is that it is a systematic and continuous process embedded into the fabric of the organisation at all levels. The overall aim is the prudent application of appropriate risk management techniques to all risks of loss that could significantly affect our personnel, property or the ability to fulfil our responsibilities to shareholders, customers, lenders, partners, and other parties in business relationships with us.

8.2 Risk Management Process

With effect from January 2015, a new framework for identifying and managing risk was introduced to give rigour and clarity to an area that is becoming increasingly important in businesses like Northern Powergrid.

Risk management is a recognised discipline and should be an element of everbody's role. Northern Powergrid have an obligation to take proper notice of the risks and make sure new risks are identified and addressed.

This discipline is encouraged by Northern Powergrid's parent company Berkshire Hathaway Energy (BHE) to adopt the principle of each colleague acting as the 'chief risk officer' to protect the organisation against downside and loss. This is communicated through the value of "if you touch it you own it" at individual level, but in reality there still needs to be a single aggregate picture of the set of threats and risks faced as an organisation,

The increasingly challenging political landscape for utility companies means that it's vital that Northern Powergrid step up their game in avoiding those unwanted outcomes that can damage reputation.

The Northern Powergrid Governance and Risk Management Group (GRMG) oversee the effective operation of governance and risk across all their functions. Membership includes the executive reports to the President, as well as a limited number of other key senior management staff. The group meet on a quarterly basis.

The GRMG's key role is to ensure that the business is effectively operating appropriate controls to manage their governance and risk activity on a trust but verify principal, but nevertheless, respond to issues / risks that are escalated to it by business management.

8.2.1 Risk Grouping and Levels

Within Northern Powergrid, 20 risk sectors have been identified by which all risks should be allocated. They are classified as risk level 1.

- Stakeholder Engagement
- Customer Service
- Safety Management
- Transformation Project Management
- Resources and Internal Infrastructure
- Succession Planning
- Integrated Utility Services (IUS)
- Connections
- Low Carbon Economy (Sector Developments)
- Regulatory and Legislative Change
- Compliance Management
- Energy Affordability
- Networks Stewardship
- Cyber/Information Management
- Supply Chain
- Crisis Management
- CE Gas
- Smart Meter Investment
- Financial Reporting and Management of Financial Resources
- Pensions Liability

Each of the risk sectors has then been mapped to Northern Powergrid's six core principles. BHE's risk categories have also been referred to although at this point in time they do not naturally fit to the Northern Powergrid core principles.

Risk Categories	Risk Management		Disaster Preparedness		Information Security	Physical Security
Core Principles	**Customer Service**	**Employee Commitment**	**Regulatory Integrity**	**Operational Excellence**	**Financial Strength**	**Environmental Respect**
Risk Sectors	Stakeholder Engagement	Safety Management	Regulatory & Legislative Change	Networks Stewardship	Financial Reporting & Management of Financial Resources	Low Carbon Economy
	Customer Service	Transformation Project Management	Compliance Management	Supply Chain	Pensions Liability	
		Resources & Internal Infrastructure	Energy Affordability	Cyber / Information Management		
		Succession Planning		Crisis Management		
				IUS CE Gas Smart Meters Connections		

8.2.2 Risk Reporting

- **Risk Environment Report:** Each sector level 1 risk has a risk environment report which gives a description of the sector, outlines the most important information about the risk, and gives descriptions of the key risks / controls involved. The document illustrates the meetings and forums that assist in the overall management of the risk as well as the control processes and activities that are in place. These risk environment reports are reviewed on an annual basis unless a new risk sector is defined.
- **Quarterly Risk Update Reports:** Quarterly reports are created to update the GRMG on the effectiveness of the risk management and controls. Each of these reports join to make a dashboard report which is presented to the GRMG. It also succinctly summarises the evidence that the forums and activities taking place which will make it clear where there are failings in any oversight of risk management.
- **GRMG Overview:** The GRMG reviews evidence of effective risk management, focussing their attention on areas that have highlighted concerns through the dashboard report. The dashboard report is supported by the quarterly risk updates to allow for the option to drill down into further detail. The information needed for executive oversight is far more transparent with the GRMG being able to focus on the risks which require their attention, while satisfying them that a risk has not been overlooked.

The key elements of the risk management process can be summed up as a three key pillar approach as follows:

- Risks – activities aligned to Northern Powergrid core principles (as well as the BHE risk categorisation)
- Structure – Have a common reporting team structure for all risk reporting into the GRMG.
- Reporting – reflecting on a common reporting style to support the preparation of the risk dashboard which focusses the attention on key risk movements.

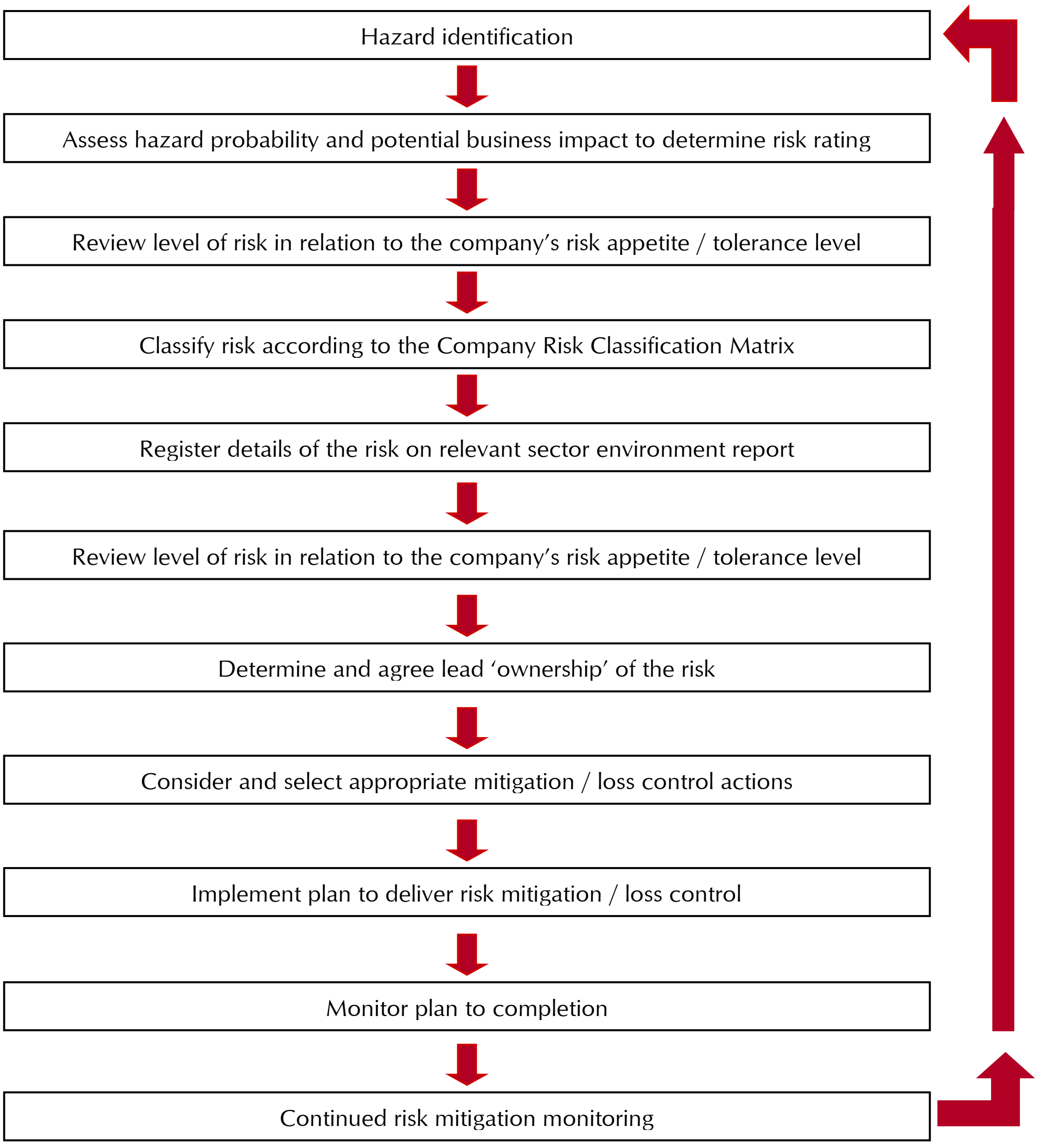


Figure 8 - Overview of Northern Powergrid Risk Management Process

8.3 Climate Change and the Northern Powergrid Risk Register

The physical risks imposed by climate change include increases in the severity and frequency of floods and drought. A number of risks associated with climate change are however easily overlooked, for example changes in political, economic, social and regulatory systems. The likely severity of future climate change will force governments to impose severe regulatory costs on all businesses which are deemed to be contributing to the problem. In addition, there are emerging legal risks for companies if they fail to take climate change seriously. The risks of litigation will be increased if the company was seen to have acted irresponsibly. Delays in taking action on climate change could lead to accusations of incurring higher costs, damaging a company's reputation and failing to disclose investment-relevant information, and as a result, risk being sued by investors and other interested parties.

In February 2003, Northern Powergrid prepared a Risk Quantification Document (RQD) entitled "Climate Change Threatens Future Network Performance". This recognised that the UK Climate was changing and that the design standards of apparatus installed on the network might not be appropriate to cope with the changes in climate and the subsequent increase in events of extreme weather. A copy of this document is included in Appendix 14: Northern Powergrid Summary Risk Assessment. This risk is monitored under the responsibility of the Low Carbon Economy risk sector environment.

8.4 Smart Grids

The move to a low carbon economy introduces new stresses on electricity networks arising from demand from electric vehicles and the electrification of heating and cooling. Work by the ENA and Imperial College indicates a doubling of unconstrained electricity demand within the timescales of this adaptation report.

To avoid the need to massively enhance existing electricity networks to handle this doubling of demand, it is necessary to build monitoring and intelligence into the networks to take automated actions. New and enhanced buildings will have better thermal insulation, meaning that the need for heating and cooling to be "on" for long periods will be diminished, providing the capability to share out and time shift the incidence of demand. In the case of electric vehicles there will also be a need to undertake the same measures though the degree to which time displacement is available will differ between work/shopping and home charging locations.

The ENA / Imperial work indicates that the unconstrained 100% increase in demand can be limited to some 30% through the use of smart network technology. This 70% reduction in impact can also assist in responding to the impact of climate change on de-rating of some network assets. Consequently the use of smart network technology provides an important related adaptation measure, though the prime rationale is facilitating the low carbon economy not adaptation.

The need for and development of smart networks will be overseen by DECC and Ofgem and as such will be captured by existing oversight, monitoring and reporting mechanisms.

9 Uncertainties and Assumptions

9.1 Main uncertainties in the evidence, approach and method used in the adaptation programme and in the operation of the companies

Northern Powergrid's adaptation plans are based on the evidence provided by UKCP09 and this information covers three scenarios for future climate change which are projections and may be subject to error. Defra have confirmed that following the publication of the 2014 IPCC assessment, the Met Office conducted a study which shows that, in general, UKCP09 continues to provide a valid assessment of climate change. However, there is also a need for stronger links between the forecasts and the actual projected impact at the local, regional and national environment level i.e. the level of rainfall, frequency of severe events, change in wind levels, the degree, extent and depth of flooding, increased rates of erosion and the exacerbation of land movement etc that will impact on all sectors. Additionally it would be helpful if there was a better understanding of probable event frequencies when any future update is carried out.

UKCP09 does not provide any particular guidance on the potential effects of climate change on extreme weather threats. Northern Powergrid will continue to maintain close contact with ENA, the Met Office and other agencies to ensure that the most up to date information is available regarding these potential threats. This will enable us to plan ahead and develop adaptation schemes as necessary. The current UKCP09 data does not support further asset investment beyond that already planned. Nevertheless, climate change risk will continue to be monitored as part of the network companies approach to risk management and information will be shared throughout the sector via ENA, who will also update DECC and Defra of any significant developments.

The EU is also proposing to carry out work on Climate Change Services and this could prove a useful source of information. ENA have provided information to the EU on UK energy networks issues and requirements.

Climate change thresholds that start to trigger extreme weather events such as flooding or storms could be critical for Northern Powergrid. Experience indicates these events are likely to cause most disruption to society, with the effects of flooding and ice storms leading to potentially very long repair and restoration times.

Increased incidents of severe lightning or wind storms could cause additional damage to overhead lines.

As indicated in Section 5.1.3, there are now increased concerns about interdependencies between weather events such as very strong winds following prolonged rainfall and initial discussions are taking place with Newcastle University regarding dependent heavy rain and wind models.

A combination of hot periods in the summer combined with very low wind speeds could accelerate the de-rating of overhead lines. Very long droughts with resultant soil drying could cause an increase in soil thermal resistivities resulting in further underground cable de-rating.

Until recently estimates were made for increases in flood heights due to a potential increase in river flows of 20%. EA are now making available information that models the increase in flood height as a result of increased river flows which should remove some of the uncertainty.

An increased likelihood of short-term (severe weather) and long term climate effects may require additional maintenance and emergency management with consequent upward pressure on staffing and skill levels.

There is a need for cross sector planning scenarios to ensure that sectors with interdependencies have used similar assumptions when reporting; this was not fulfilled in the first round of reporting. This is important to address the wide variety of views regarding the extent and impact of climate change on national infrastructure and is being developed by the IOAF.

Any emerging uncertainties will be captured within the Northern Powergrid risk management approach and addressed within business work plans.

This process needs to ensure that any asset investment made is necessary, timely and appropriate. Northern Powergrid, like the other DNOs, is a regulated monopoly business and our expenditure is subject to economic regulation by Ofgem. This is achieved via a periodic price control process known as RIIO (Revenue = Incentives + Innovation + Outputs). The current price controls run from 2015 to 2023 for DNOs.

Unless there are very exceptional or unforeseen circumstances, then the levels of approved revenue needed to accommodate the planned asset infrastructure investment and maintenance for this period, including any work required to adapt to climate change must be agreed with Ofgem when the Price Control is set. This means that it is extremely important that the industry develops its CCA plans with the regulator to ensure that plans and supporting information meet the both the DNOs' and the regulator's requirements.

9.2 Assumptions made when devising the adaptation programme

The base programme makes the following assumptions until 2099:

- Government regulation will continue to operate without major change.
- Appropriate financing will be in place.
- Customers will continue to have similar requirements.
- Demand for electricity will continue to grow at historic rates.
- Electricity transmission and distribution systems will continue to function in a similar manner to the present day.
- Companies will be able to recruit, train and retain the required levels of staff.
- Suppliers and contractors will continue to provide services on a similar basis.
- Installation, access and maintenance in relation to network cables, overhead lines plant and equipment will remain unchanged.
- There will be no major changes to population numbers or distribution across the country.

10 Barriers and Interdependencies

Northern Powergrid are subject to regular price control reviews of our investment programmes by Ofgem to set investment for future periods. These reviews focus strongly on investment programmes, cost efficiency and performance.

Whilst not currently a barrier, the potential exists for a conflict of drivers between cost reduction and early pursuit of adaptation measures, given the long lifetimes of electricity network assets, ranging from 40 – 50 years for transformers, 50 years + for wood pole overhead lines and upwards of 80 years for underground cables and steel tower ("pylon") overhead lines. From an adaptation viewpoint there might be a case for upsizing ratings or allowing more ground clearance on overhead lines to take account of future ambient temperature rises, but such measures would not pass a net present value investment test. If the industry, together with the regulator, took the view that it was appropriate to agree relatively modest changes in design standards now, then the net present value issue could be overcome. This type of question is also likely to arise in other regulated sectors.

The periodic price control reviews have an extremely strong influence on capital investment programmes and operational expenditure. Companies will work with the regulator to achieve a shared view of the potential requirements for adaptation and the associated expenditure. However, companies' plans for adaptation will be dependent on obtaining Ofgem's view of the associated financial investment plans. There are interdependencies between improving climate knowledge and the current eight year RIIO regulatory process, which could result in a delay between any change in climate knowledge and a corresponding change in investment. However, in view of the long term nature of climate considerations this is not considered to be a serious problem.

Electricity networks are extensive interconnected systems that can only be modified or uprated through a systematic process that is likely to require a considerable period of time. Piecemeal upgrades are unlikely to be cost effective or successful.

For electricity DNOs companies there is a further interdependency due to Carbon Reduction Targets designed to limit the amount of climate change. These targets are resulting in a requirement to connect renewable generation and low carbon loads such as heat pumps and electric vehicles and are particularly affecting distribution networks. Smart networks are being designed to accommodate these loads without completely rebuilding existing systems, however, there will still be a need for conventional network reinforcement and this will need to be designed to accommodate climate impacts.

The First Round Report highlighted key interdependencies with other sectors, some of which were not previously required to report via the mandatory process. There are particular concerns regarding transport systems to enable access to key sites and telecommunications for control room SCADA[8] and voice communications. As noted in Section 2.2 there is a need for cross sector planning scenarios to ensure that sectors with interdependencies have used similar assumptions when reporting; this was not fulfilled in the first round of reporting. This is important to address the wide variety of views regarding the extent and impact of climate change on national infrastructure. This role is being developed by the IOAF and DNOs will play a full part in any collaboration projects that are initiated by this forum.

As indicated in Section 5.1.3, there are now increased concerns about interdependencies between weather events such as very strong winds following prolonged rainfall which made trees more susceptible to uprooting, with consequent damage to overhead power lines.

[8] SCADA – Supervisory Control and Data Acquisition

Companies will continue to engage with Local Resilience and Flood Resilience Forums where local interdependencies are discussed and plans put in place to manage potential problems. A potential barrier has been identified with regard to the uncertainty regarding future maintenance of joint flood defence schemes. ETR 138 encourages companies to investigate this type of scheme if it will reduce the overall cost of flood protection to the community and provide reliable protection. However, it is essential for companies to have confidence that this type of scheme will provide secure protection in the very long term and that the responsibility for the construction and maintenance of these flood protection measures are clearly defined and agreed.

10.1 Addressing the barriers identified

Northern Powergrid will continue to jointly examine with Ofgem and other network operators the current assessment of impacts and adaption options, with the aim of agreeing a way forward that will be considered as part of the next round of price control reviews. These discussions will be facilitated by the ENA and DECC will be invited to consider national priorities.

The following initiatives are being undertaken:-

- Work with EA and SEPA to understand the latest surface water flooding information and update national flood protection guidance.
- Current / ongoing work with Newcastle University.
- Support for the EU initiative.
- Project initiated to review current guidance document on resilience tree cutting (ETR 132).
- Information on the impact of recent severe weather has been shared between network companies and a large number of actions to improve emergency response have been co-ordinated through ENA and DECC.
- Companies are taking advantage of the Met Office's latest long range winter forecast. The Met Office are now invited to attend an industry emergency planning forum in the autumn to discuss the forecast and the likely consequences with the industry emergency planners and operation managers. The first meeting took place in December 2014 and further discussions are planned during 2015 including a workshop run by the Met Office.

10.2 Interdependencies including the stakeholders

A parallel challenge for Northern Powergrid concerns the change to "Smart Networks". This initiative is planned to support the requirement that renewable distributed generation and low carbon loads be connected to networks in large numbers, as part of the programme to meet the 2020/2050 carbon reduction targets, whilst still maintaining supplies to customers in a cost effective and reliable manner. This means that networks are likely to undergo considerable change at the same time as work may be carried out to improve resilience to climate change impacts.

The scale of the change to "Smart Networks" is likely to be very large, entailing the re-design and re-building of many circuits and substations. The resultant upgrade may be far larger than required to accommodate potential adaptation requirements and it will be necessary to understand the interdependency of these two requirements fully before financial plans are submitted to Ofgem.

Although it is essential to research fully the potential effects of climate change in order to understand the possible impacts and mitigations, it is probable that the scale of any network upgrades will be dictated by the drive to low carbon networks.

11 Monitoring and Evaluation

Northern Powergrid is licensed and regulated by Ofgem under the powers of The Electricity Act (1989 - as amended). The Act spans a wide range of topics, but of particular relevance are aspects that encompass price control, duties on companies to comply with legislation and on Ofgem to ensure that companies are adequately funded to discharge their duties.

Another key piece of legislation is the ESQCR, which places duties on Northern Powergrid to ensure our equipment is sufficient for the purposes for and the circumstances in which it is used and constructed, installed, protected (both electrically and mechanically), used and maintained as to prevent danger, interference with or interruption of supply, so far as is reasonably practicable.

Northern Powergrid are thus already under an ongoing obligation to ensure the adequacy of our equipment against current "normal" conditions.

Ofgem currently undertakes periodic price control reviews of transmission and distribution companies, looking in depth at their investment plans, performance and cost efficiency, and benchmarking network operators against each other. This is supplemented by an annual regulatory reporting process designed to track progress against these plans. In exceptional circumstances, such as arising from costs imposed by newly introduced legislation within a price control period, Ofgem may agree a "re-opener" against those related areas of cost.

The industry approach to identification, risk assessment and development of mitigation plans for major substations at risk of flooding, as described in section 5.1.1 provides an illustration of the way in which joint work on adaptation can be pursued.

Monitoring of progress on adaptation by Ofgem can be facilitated via a common approach through the periodic price control and the annual regulatory reporting processes which is companies' preferred approach. This process will continue to use latest information as it becomes available.

11.1 Monitoring thresholds & incorporating into future risk assessments

The thresholds at which climate change will start to present a risk to Northern Powergrid is well understood for a number of impacts, e.g. increased temperature causing a reduction in equipment ratings. In these areas it will be necessary to monitor actual climate change effects and updated projections in order to ensure that planned adaptation activity is sufficient and timely.

In other areas of activity, such as earthing systems and vegetation growth, further work will need to be undertaken (both inside and outside the industry) to identify the thresholds at which action needs to be taken. In addition, research into the impact of air conditioning loads, low carbon loads/generation and smart networks is already in hand and climate change impacts will be factored into this work to ensure that the thresholds are fully understood and appropriate action factored into programmes of work.

Low carbon networks and smart grids are an international issue and network operators will be engaged in British, European and International Standards work to ensure standards are developed for the new networks and these will need to take account of the thresholds for climate change impacts on an international scale.

There is an increasing level of awareness within the DNOs and their employees regarding climate change risks and the requirements for both mitigation and adaptation response. This is aided by the sharing of information and best practice via the ENA. ENA represents both the electricity and gas network companies, providing opportunities for further liaison and learning opportunities as all energy sector companies share some common issues. Climate change risks are recognised and monitored at Board level within Northern Powergrid.

The Committee on Climate Change ASC recently produced a progress report—"*Managing climate risks to well-being and the economy*". This report assesses the current state of resilience to weather and climate of infrastructure, businesses, health care system and emergency services. ENA together with DNOs provided evidence to the ASC.

Sector	Risk Assessment	Resilience Measures	Progress Reporting
Electricity transmission & distribution	Green	Green	Green
Rail	Amber	Green	Green
Strategic Road Network	Amber	Amber	Red
Ports	Amber	Amber	Amber
Airports	Amber	Amber	Amber
Water	Amber	Amber	Amber
ICT	Amber	Red	Amber

Table 5 - Assessment of progress - ASC report 2014

Source: Committee on Climate Change ASC recently produced a progress report—"Managing climate risks to well-being and the economy".

Notes: These colours refer to whether there is complete (Green), partial (Amber) or no evidence (Red) for the following:

- Risk assessment: Evidence of detailed assessments to understand how current weather and projected changes in climate are likely to affect operations.
- Resilience measures: Identification of resilience measures to reduce risks based on cost-benefit assessments (sector/companies may not be on track to achieve all their targets).
- Progress reporting: Regular reporting on progress in implementing resilience measures in a clear and publicly available format (this information may not be in a specific publication focusing solely on resilience).
- Note that an Amber may mean that some, but not all, companies within a sector provide evidence.

The ASC reported that they found evidence that the electricity transmission and distribution sector are assessing climate risks, taking action in response, and reporting on progress against plans. The ASC noted that this sector has developed technical standards for managing current and future risks from flooding and storms. These provide a consistent approach across the industry to identifying the most critical assets at the highest level of risk in order to prioritise action. Application of these standards is used to make a business case to the regulator for funding resilience measures that provide value for money to the consumer through the price control process.

Northern Powergrid has incorporated the key actions detailed in this report, alongside progress against actions as appropriate. These can be found in Appendix 12: Updated Table of Actions.

11.2 Monitoring the residual risks of impacts from climate change.

Northern Powergrid is committed to ensuring risks of impacts from climate change are managed from the identification and implementation of mitigation measures to ongoing review and monitoring through our internal risk processes. Policy documents and codes of practice will be updated to reference the impact of climate change on the business. It is clear that an understanding of climate change risk will play an important part in business planning.

Consideration is given to the actions that should be taken to either reduce the probability of occurrence or reduce the consequence in a timely manner. A risk mitigation and loss control plan is established detailing action steps to be taken, responsibility assigned and timetable to completion.

Residual risks are assessed at two stages of the process. An initial forecast of the level of residual risk forecast is completed at the time of preparation of the risk mitigation and loss control plan. The forecast residual risk is considered in determining the adequacy of the action plan. Upon completion of the risk mitigation and loss control plan a review of actual residual risk is undertaken to confirm that the action taken has been effective in mitigating the risk to an acceptable level. It is essential that the overall exposure to risk and the status of individual risks be regularly reviewed.

11.3 Ensuring a flexible response.

Northern Powergrid will continue to work with ENA and other DNOs to review the latest information on climate change projections, including actual recorded climate change outcomes, and update action plans as necessary. This will include maintaining and developing the relationship with holders of key information including Defra, EA and the Met Office. DNOs will also maintain a dialogue with DECC and Ofgem as part of annual regulatory reporting and the periodic price control process. The general position regarding companies' resilience will be continually reviewed via the DECC / E3C bi-monthly meetings and the follow up work in the companies via ENA working groups.

Northern Powergrid operates with industry guidelines to provide a flexible approach to protection. For example, the industry standard on flooding resilience provides a framework for identifying those sites requiring improved resilience and a variety of methods by which that resilience can be achieved to ensure the best value for money. This includes, protecting whole sites, protecting key buildings/equipment or contributing to wide area schemes. Examples of different approaches to flood protection are provided in Appendix 15: Designing Out Flood Risk

11.4 Opportunities presented by adaptation to climate change

Through working collaboratively with the ENA and other DNOs, Northern Powergrid have taken the opportunity to strengthen their relations with key organisations including Defra, EA, SEPA and the Met Office. The work with EA and SEPA has resulted in an important strengthening of substation flooding resilience measures as described in Section 5.1.1.

A report has been commissioned with Newcastle University on wind impacts. The ongoing work with Newcastle University is helping the industry to understand the potential impacts of climate change on wind patterns and further work may help to identify dependencies between climate impacts such as wind and rain as described in section 5.1.3.

Northern Powergrid has participated in an inaugural meeting for a local infrastructure operators adaptation forum for Yorkshire and the Humber and discussions with Newcastle City Council regarding their policies on CCA. We will continue to participate in these and other forums as required going forwards.

Appendix 1: Distribution System Information.

System Voltage	Overhead Lines (km)		Underground Cables (km)		Switchgear (No of)		Transformers (No. of)	
	National	Northern Powergrid	National	Northern Powergrid	National	Northern Powergrid	National	Northern Powergrid
132kV Tower	14,697	1,644	3,191	293	2,588	241	1,946	213
132kV Pole	1,774	33						
EHV Tower	2,563	628	90,991	2,374	39,308	2,129	13,262	1,025
EHV Pole	26,557	2,800						
20kV	5,094	5,117	1,659	1,513	9,496	3,192	8,986	8,684
11kV & 6.6kV	163,868	13,890	152,224	17,561	567,399	54,148	579,944	49,657
LV	64,874	4,261	311,237	42,634	1,112,000	25,607		

Appendix 2: Key Design Standards

This appendix provides some background on the most relevant applicable design standards, together with some illustrations relating to the historical usage of older British Standards in a global context.

Whilst present day standards are dominated by those issued by the International Electrotechnical Commission (IEC) and European Norms (EN), it should be recognised that much electricity network infrastructure still in use was designed according to British Standards (BS) issued many decades ago. It is thus appropriate to briefly describe the climatic conditions used as the basis for equipment ratings in those old standards.

The UK was a major manufacturing base of electricity network equipment from the 1920s, supplying a global market dominated by a British sphere of influence. Consequently both British Standards and equipment designs were arranged to meet climatic demands covering the Middle East, India, Malaysia, South Africa and Australasia, as evidenced by references to peak ambient temperature requirements of 40°C as far back as 1923.

Standard etc.	Date	Title	Comment on climate content
BS116	1923	Oil immersed switches and circuit breakers for a.c. circuits	Ambient air temperature up to 40°C
Electricity Supply Acts 1882 to 1936	1931	Electricity Commissioners 1931 design requirements	
BS 171	1936	Electrical performance of transformers for power and lighting	Peak air temperature 40°C, average over any 24 hour period not greater than 35°C. Also refers to tropical 45°C options
BS 116	1937	Oil circuit breakers oil switches etc for a.c. circuits	Ambient peak up to 40°C with average over any 24 hour period not greater than 35°C
BS 137	1941	Insulators of ceramic material or glass for overhead lines with nominal voltages greater than 1000 V	Lightning withstand, pollution performance and temperature cycling
BS 1320	1946	High Voltage Overhead Lines on Wood Poles for line voltages up to and incl. 11kV	Design for wind load of 16 lb / sq ft (766 N / m2) with factor of safety. Conductor temperature 22 to 122F
Electricity Supply Act ELC 53	1947	Overhead Line Regulations (differs from 1931 ELC 53 in ref to BS 1320)	Lines to withstand simultaneous 50mph wind and (57 lb / cu ft) ice load with factor of safety. Max conductor temperature 122 F
BS 116	1952	Oil circuit breakers for a.c. systems	Ambient peak up to 40°C with average over any 24 hour period not greater than 35°C
BS 171	1970	Power transformers	Not greater than 30°C average air temperature in any one day or average greater than 20°C in one year Lightning withstand
Statutory Instrument 1355	1970	The Electricity (Overhead Line) regulations 1970	Design for 760 N/m2 wind load for conductors up to 35 sq mm and for 380N /m2 simultaneous with augmented (ice / snow load)for conductors > 35 sq mm
BS 137	1973	Insulators of ceramic material or glass for overhead lines with nominal voltages greater than 1000 V	Lightning withstand, pollution performance and temperature cycling

Standard etc.	Date	Title	Comment on climate content
BS 171	1978	Power transformers	Ambient air not greater than 40°C, not below -25°C outdoor or -5°C indoor, not greater than 30°C average in any one day or more than 20°C average in any one year Lightning withstand
BS 7354	1990	Design of HV open terminal substations	Wind speed, ice thickness, pollution and lightning withstand
PD IEC TR 61774	1997	Overhead Lines – Meteorological data for assessing climatic loads – mainly ice models but links to IEC 60826 that includes ref to wind and coincident (work fed into BS EN 50341 and 50423 also COST 727 project on icing) temperature.	Discusses icing models for glaze, rime ice and wet snow. Draws on test span information from Canada, Czech Republic, Germany, Japan, Hungary, Iceland, Norway, UK, USA and Italy
IEC 60265-1	1998	HV switches for rated voltages 1kV to less than 52kV	
IEC 60076-1	2000	Power Transformers	Ambient temperature max 40°C minimum -25°C Lightning withstand
IEC 60694	2002	Common specification for switchgear and control gear (superseded by BS EN 62271-1)	Sets ambient temperatures, pollution etc. E.g. outdoor equipment for -minus 25°C and 10mm ice coating. Also sets lightning overvoltage performance levels The ambient air temperature does not exceed 40°C and its average value, measured over a period of 24 h, does not exceed 35°C
ANSI/IEEE C37.60	2003	American national standard for overhead line pole mounted, dry vault and submersible automatic circuit reclosers and fault interrupters for a.c. systems	Ambient not greater than 40°C or less than – 30°C
BSEN 62271 -105	2004	High-voltage alternating current switch-fuse combinations	Links to 60694. The ambient air temperature does not exceed 40°C and its average value, measured over a period of 24 h, does not exceed 35°C. Minimum minus 5°C indoor minus 25°C outdoor
IEC 60076-7	2005	Loading guide for oil immersed power transformers	Normal service conditions
BSEN 62271-200	2005	A.C. metal-enclosed switchgear and controlgear for rated voltages above 1kV and up to and including 52kV	Links to 60694. The ambient air temperature does not exceed 40°C and its average value, measured over a period of 24 h, does not exceed 35°C. Minimum minus 5°C indoor minus 25°C outdoor.
BSEN 50423	2005	Overhead electrical lines 1kV up to and including 45kV	Design standard for new overhead electricity lines < 45kV, covers wind and ice load structural strength of supports, conductors, foundations and factors of safety
IEC 60947	2007	Low Voltage switchgear and Control Gear	Ambient not greater than 40°C and its average value, measured over a period of 24 h, does not exceed 35°C

Standard etc.	Date	Title	Comment on climate content
IEC 61462	2007	Composite insulators – hollow insulators for use in outdoor and indoor electrical equipment	
BSEN 62271-102	2007	High-voltage alternating current disconnectors and earthing switches	Links to 60694 The ambient air temperature does not exceed 40°C and its average value, measured over a period of 24 h, does not exceed 35°C. Minimum minus 5°C indoor minus 25°C outdoor.
IEC 60137	2008	Insulated bushings fro alternating voltages above 1000 V	Standard for bushings (the external connections into transformers, circuit breakers etc) - covers ambient temperature, ice accretion
IEC 60815	2008	Guide for selection of insulation in respect of polluted conditions	
IEC 60529	2009	Degrees of protection provided by enclosures (IP guide)	Ability to withstand driven rain / immersion etc.
BSEN 62271-100	2009	High voltage circuit breakers	links to 60694 ambient conditions The ambient air temperature does not exceed 40°C and its average value, measured over a period of 24 h, does not exceed 35°C. Minimum minus 5°C indoor minus 25°C outdoor
BS EN 61936-1		Draft standard on substation design	
ENA TS 43-40		High voltage single circuit lines on wood poles	Design includes ref to maps showing combined wind / ice severity by altitude across UK

Extract from IEC 60694

IEC 60694 lays out the normal service conditions expected from switchgear. The following are the service conditions relevant to the climate in which the switchgear operates:

Indoor switchgear and controlgear:

- The ambient air temperature does not exceed 40°C and its average value, measured over a period of 24 hours, does not exceed 35°C
- The minimum ambient air temperature is -5°C for class “minus 5 indoor”,-15°C for class “minus 15 indoor” and -25°C for class “minus 25 indoor”.
- The influence of solar radiation may be neglected
- The altitude does not exceed 1,000m
- The ambient air is not significantly polluted by dust, smoke, corrosive and/or flammable gases, vapours or salt
- The conditions of humidity are as follows:
  - The average value of the relative humidity, measured over a period of 24 hours, does not exceed 95%
  - The average value of the water vapour pressure, over a period of 24 hours, does not exceed 2,2kPa
  - The average value of the relative humidity, over a period of one month, does not exceed 90%
  - The average value of the water vapour pressure, over a period of one month, does not exceed 1,8kPa.

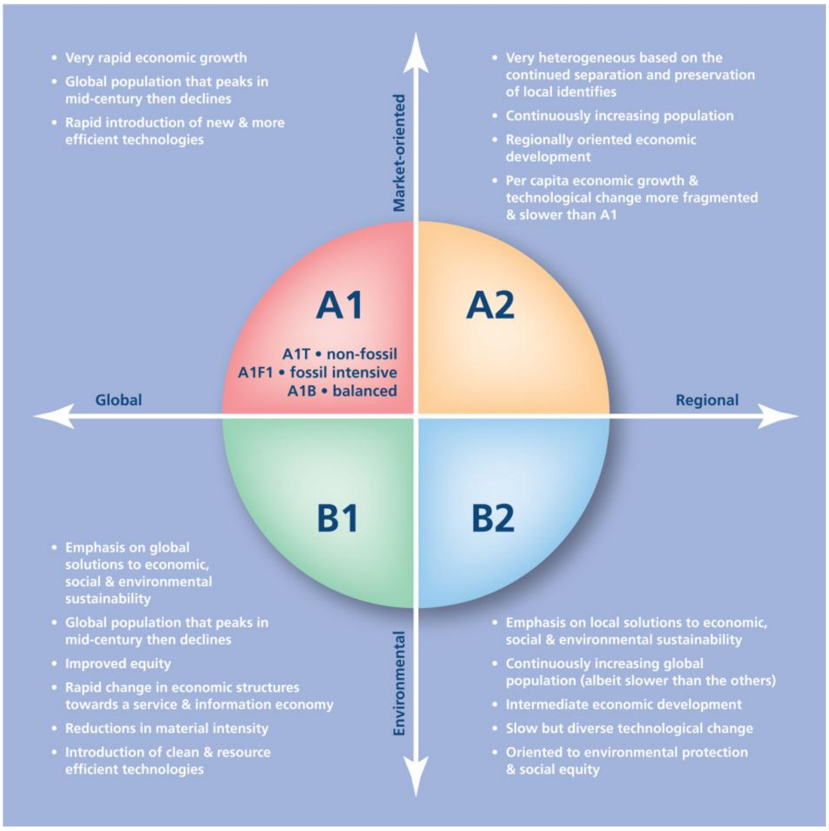
Outdoor switchgear and controlgear:

- The ambient air temperature does not exceed 40°C and its average value, measured over a period of 24 hours, does not exceed 35°C
- The minimum ambient air temperature is -10°C for class "minus 10 outdoor",-25°C for class "minus 25 outdoor" and -40°C for class "minus 40 outdoor". Rapid temperature changes should be taken into account.
- Solar radiation up to a level of 1,000 W/m2 (on a clear day at noon) should be considered.
- The altitude does not exceed 1,000m
- The ambient air may be polluted by dust, smoke, corrosive gas, vapours or salt. The pollution does not exceed the pollution level II – medium according to Table 1 of IEC 60815.
- The ice coating does not exceed 34m/s (corresponding to 700 Pa on cylindrical surfaces)
- Account should be taken of the presence of condensation or precipitation.
- Vibration due to causes external to the switchgear and control gear or earth tremors are negligible

Appendix 3: Northern Powergrid Policies

CDS Ref Number	Document title
EMP / 001	Policy for the Mgt of Major Incidents Affecting the Distribution Network
EMP / 001 / 002	Management of a Major Incident
EMP / 001 / 002 / 001	Strategic Management Centre Action Plans
EMP / 001 / 002 / 002	Strategic Management Centre Secondary Contact Action plans
EMP / 001 / 002 / 003	Area Management Centre Action Plans
EMP / 001 / 002 / 004	Local Management Centre Action Plans
EMP / 001 / 002 / 005	MIMP testing and event specific safety risk assessments
EMP / 001 / 002 / 006	MIMP document control
EMP / 001 / 003	Major Incident Management – Flooding
EMP / 001 / 003 / 001	Flooding - Additional key role action plans
EMP / 001 / 004	System Operations Management Suite Evacuation
EMP / 001 / 005	Major Incident Management - Human Resources Responsibilities
EMP / 001 / 006	Major Incident Mgt – Animal Notifiable Diseases (Foot & Mouth Disease)
EMP / 001 / 007	Total / Partial Shutdown of the UK Electricity Network: Black Start
EMP / 001 / 008	Major Incident Mgt: Managing Fuel Supplies in a period of significant disruption to the supply of road fuel
EMP / 001 / 009	Industrial Action Mitigation and Service Level Recovery Planning Process
EMP / 001 / 010	Media Relations during major Incidents
EMP / 001 / 010 / 001	Media Action Plans
EMP / 001 / 011	Customer Service Management During Major Incidents
EMP / 001 / 011 / 001	Customer Service Action Plans
EMP / 001 / 012	Telecommunications Major incident management
EMP / 001 / 012 / 001	Telecommunications Major Incident Management Action Plan
EMP / 001 / 013	Information Technology Major Incident Management
EMP / 001 / 013 / 001	IT Action Plan
EMP / 001 / 014	Major Incident Import/Export of Resources under NEWSAC Arrangements
EMP / 001 / 015	Civil contingencies obligations
EMP / 001 / 016	Executive team involvement in a major incident
EMP / 001 / 999	Major Incident Management Plan - Contact Details
INV / 001 / 002	Network Investment Risk Mgt Process (now Asset Mgt)
RSK / 002	Policy for Risk Management
RSK / 002 / 001	Framework and Key Responsibilities for Risk Management
RSK / 002 / 002	CE Electric UK Risk Management Process
RSK / 002 / 002 / 001	Guidance on the Administration of the CE Electric UK Risk Mgt System
RSK / 002 / 003	Directorate Risk Management Process
RSK / 002 / 003 / 001	Risk Management in the Information Systems Directorate
RSK / 002 / 003 / 002	Risk Management in the Customer Service Directorate
RSK / 002 / 003 / 003	Risk Management in the Field Operations Directorate
RSK / 002 / 003 / 004	Risk Mgt in the Group Health, Safety and Environment Directorate
RSK / 002 / 003 / 005	Risk Management for Performance and Innovation
RSK / 002 / 003 / 006	Risk Management for the Finance Directorate
RSK / 002 / 003 / 007	Risk Management for the Human Resources Directorate
RSK / 002 / 003 / 009	IUS Risk Management Process

Appendix 4: Extract from UKCP09 - Emissions Scenarios



We need to make some assumptions about future emissions of greenhouse gases (and other pollutants) from human activities in order to make projections of UK climate change over the next century. Because we cannot know how emissions will change, we use instead a number of possible scenarios of these, selected from the IPCC Special Report on Emissions Scenarios (SRES) (Nakicenovic and Swart, 2000). These correspond to a set of comprehensive global narratives, or storylines, that define local, regional and global socio-economic driving forces of change such as economy, population, technology, energy and agriculture – key determinants of the future emissions pathway. The scenarios are alternative conceptual futures to which no probabilities can be attached.

SRES emissions scenarios are structured in four major families labelled A1, A2, B1 and B2, each of which represents a different storyline. They are commonly shown as in the figure above where the vertical axis represents the degree to which society is economically or environmentally oriented in the future, whilst the horizontal axis refers to the degree of globalisation. All scenarios are non-interventionist, that is, they assume that emissions will not be changed in response to concerns over climate change.

The A1 storyline describes a future world of very rapid economic growth, and a population that increases from 5.3 billion in 1990 to peak in 2050 at 8.7 billion and then declines to 7.1 billion in 2100. Rapid introduction of new and efficient technologies is assumed, as is convergence among regions, including large reductions in regional differences in Gross Domestic Product (GDP). Within the A1 family are three subgroups, referring to high use of fossil fuels (A1F1), high use of non-fossil energy sources (A1T) or an intermediate case (A1B).

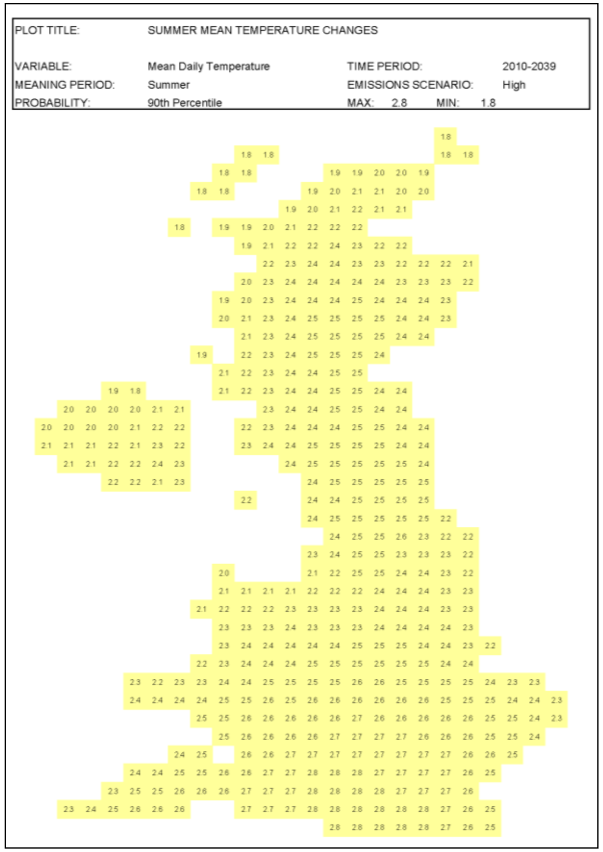
The B1 storyline also describes a convergent, more equitable world, and has the same population scenario as the A1 storyline: however, rapid changes in economic structures towards a service and information economy are assumed, with reductions in material intensity, and the introduction of clean and resource-efficient technologies. Global solutions are found to economic, social and environmental sustainability.

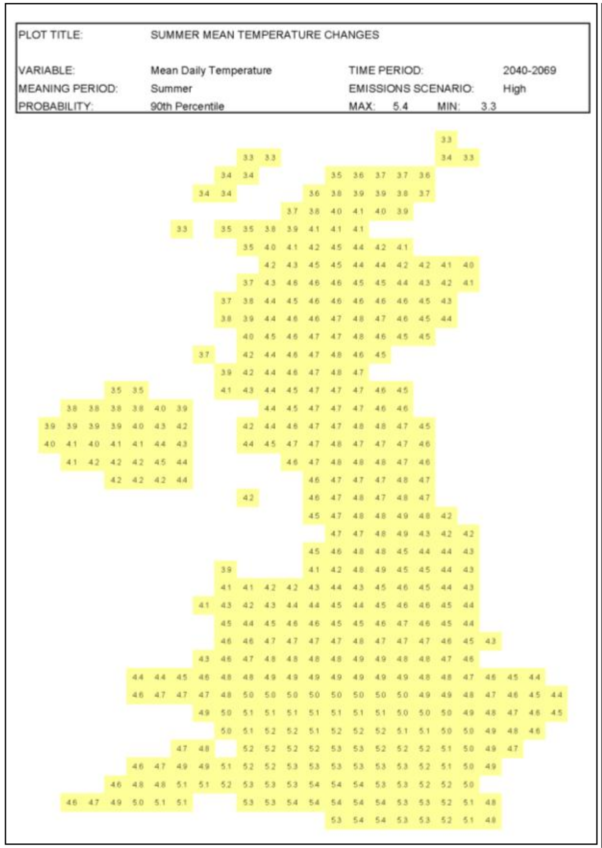
The High, Medium, and Low emission scenarios in the UKCP09 report correspond to the A1F1, A1B and B1 SRES scenarios. The High and Low emission scenarios are the same as those of the same name used in UKCP02. They span almost the full range of SRES scenarios, with cumulative (2000-2100) CO2 emissions of 2189 GtC and 983 GtC respectively. SRES A2 and B2 storylines, with higher, continuously increasing population scenarios (to 15.1 and 10.4 billion in 2100 respectively), are not used in UKCP09, as the population assumed in the A2 storyline is significantly higher than the high end of current projections.

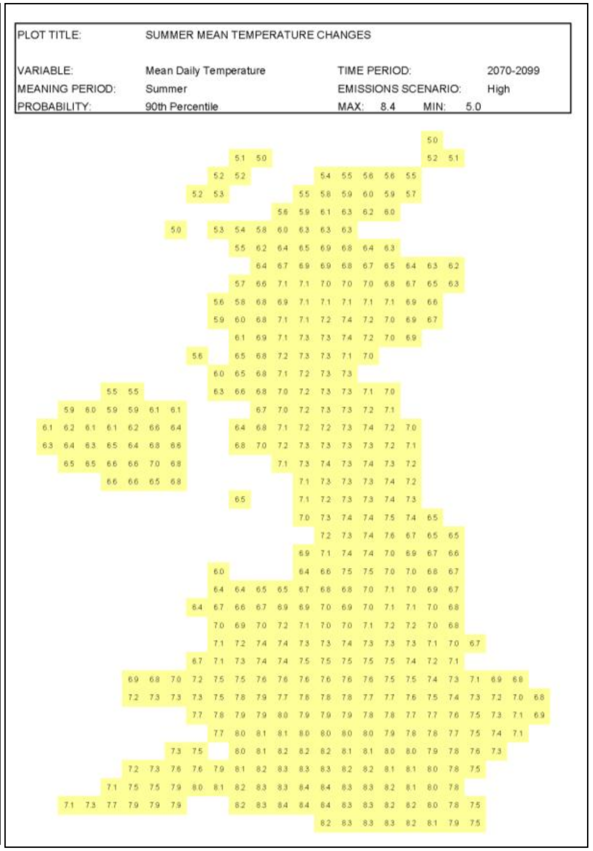
Extreme high or low emissions scenarios, for example very high rates of fossil fuel combustion or strong mitigation in response to concerns over climate change, are also not considered in the projections available from UKCP09. The UKCP09 Low emissions scenario (SRES B1) does, according to some models, result in approximate stabilisation of CO2 concentrations between about 500 ppm and 600 ppm. However, when the full (ocean and land) climate-carbon cycle feedback is included, as is done in UKCP09, then the CO2 concentrations will vary over a wide range.

Appendix 5: UK Temperature Charts

NOTE: Charts for all other emission scenarios and seasonal arrangements are available.







Appendix 6: Extract from ENA ETR 138 (Resilience to Flooding of Grid and Primary Substations)

Resilence Levels without relying on temporary flood protection measures	
Level of flooding that may occur within a 1:1,000 year flood contour	Level 1
Level of flooding that may occur within a 1:100 year fluvial flood contour (1:200 in Scotland) and within the 1:200 contour for sea flooding throughout the UK	Level 2
Other flood protection measures (not meeting Level 1 or Level 2 above) including provision of limited alternative supplies.	Level 3

Electricity supplies may be made resilient through defending key sites against inundation, contributing to a publicly funded area protection scheme or providing network interconnection so that supplies could be maintained even if key sites are disabled due to flooding.

The cost of providing resilience will vary greatly between different sites, depending on the flood depth, work needed to protect the site, the availability of alternative sources of supply if a site is lost and the degree of protection offered by other schemes such as those defences provided by the EA or Scottish local authorities.

Network operators should carry out cost/benefit assessments for each substation at risk in order to determine which resilience level is appropriate in any given case. This will include consideration of customers' "willingness to pay" for this type of network resilience. The cost /benefit assessments will take into account the societal aspects identified in this ETR and other reviews into the recent floods, in particular the Pitt Review, as well as the more usual considerations of reducing customer supply losses and protecting assets.

For grid substations the target level of resilience should be Level 1 unless the company determines through its cost/benefit analysis that Level 2 resilience is appropriate in any given case. If, in exceptional circumstances, a company determines that neither Level 1 nor Level 2 resilience is appropriate for a grid substation, it will provide such level of resilience as is reasonably practicable in the circumstances. If a company is uncertain about the level of resilience, it may consider consulting with Ofgem, DECC and the relevant flood protection authority as a means of resolving such uncertainty.

Key substations that form part of the interconnected UK transmission System and are essential for the maintenance of secure supplies should be considered in the same way as grid substations.

For primary substations the target level of resilience should be Level 2 unless the company determines through its cost/benefit analysis that Level 3 resilience is appropriate in any given case. However, where substantial additional protection can be provided for a primary substation at marginal additional cost e.g. protection increased from Level 2 to Level 1, then companies should consider providing this enhanced level of protection.

Each company should assess their infrastructure, document a programme of work and factor that programme into their investment plans as appropriate. These will be risk based programmes founded on the guidance established in this ERep and will be dependent on the availability of necessary funding.

Joint transmission/distribution sites will be treated as indicated in Appendix 6.

Careful consideration will need to be given to the implementation timescales. The overall timescale will be proposed by network operators when flood depth data is available to measure risk and mitigation for the individual substations. Network operators will need to consider the availability of contractor resources and equipment, the ongoing workload of the network operators in other areas and the inflationary implications of overwhelming the contractor market. Appropriate prioritisation and project planning will be required.

As a general principle network operators will target the completion of agreed protection to grid and primary substations as follows:-

- Transmission Sites: By the end of the Transmission Price Control Review finishing in 2022.
- Distribution Sites (Grid and Primary): By the end of the Distribution Price Control Review finishing in 2020.

However, these timescales may be extended if additional substations are identified to be at risk due, for example, due to increased climate change allowances and/or visibility of risks associated with surface or ground water flooding.

Network operators will prioritise their investment programmes to ensure that risk is appropriately managed during the implementation period consistent with available funding for these programmes. If it is likely to take more than one year to implement permanent mitigation then network operators should attempt to mitigate risk by establishing site specific actions in their emergency plans that will include:-

- Considering the use of temporary barriers and minimising the damage likely to be inflicted by flooding e.g. by ensuring main transmission circuits can remain energised whilst the substation is out of action. These short term actions will also be applied if a substation requires relocation, which is likely to be a lengthy process.
- Working with partner agencies under the Civil Contingencies Act to maximise the use of mutual aid and cooperation in order to minimise the impact of any electricity outage. (For any sites identified as being particularly vulnerable network operators may want to consider submitting them for inclusion in multi-agency flood plans.)
- Identifying the plant and equipment at risk for a range of flood levels.
- Use of temporary protection for the complete site or most vulnerable plant where reasonably practical and identifying suitable trigger levels, such as Environment Agency Flood Warnings
- Identifying emergency switching or other arrangements to minimise the affects of a substation outage.
- Identifying appropriate response staff and training them in flood resilience response.

Appendix 7: Work completed with the Met Office

EP2 — the impact of climate change on the UK energy industry (Jan 2008)

Executive Summary

This project has engaged the Met Office – a world leading authority on climate science. In conjunction with key energy players, it has developed practical ways to respond to the challenge of climate change in the areas of renewable, conventional and nuclear generation, transmission and distribution network planning, and energy trading and forecasting.

The regulator, Ofgem and BERR have been kept informed and advised of the challenges that may need to be addressed. It is hoped their involvement in this project will maximise the chances of influencing future price review decisions.

This has been a year-long project, directed by experts within the industry and supported by the Met Office, which has been delivered on time, to budget and to specification.

Background

This was an industry-funded project involving 11 UK energy companies focussing on the priorities identified by an earlier scoping study. It has been a groundbreaking initiative that has brought climate science closer to business applications; this is the first project sponsored by an entire sector to review the specific impacts of climate change on their industry. Supported by climate scientists, experts from the industry worked together to understand their precise requirements and developed practical applications and business strategies for a changing world.

The project has:

- Developed innovative new techniques that apply climate models to energy applications so that the industry is better placed to adapt to climate change.
- Investigated future wind resource, enabling the industry to understand the continued uncertainty of future wind power. This will assist risk management and investment decisions.
- Modelled future soil conditions and their impact on cables so that companies can understand the cost and benefits of installing cables for a more resilient future network.
- Built a tool to enable UK coastal and marine sites of interest to be screened to assess if sea level rise should be considered in more detail.
- Investigated how the urban heat island effect may change in the future so that Networks can develop plans for their infrastructure in cities.
- Produced guidance to help make best use of public domain information on climate change such as the UKCIP new scenarios of climate change (UKCP09).
- UKCP09 will enhance regional detail and will be available in November 2008.
- Delivered new site-specific climatologies of temperature, wind speed and solar radiation that account for climate change so that decisions can be based on realistic climate expectations.
- Examined the relationship between historic weather patterns and network fault performance with a view to developing a tool to predict future network resilience.

The project has found that because of climate change:

- With a few exceptions, such as the thermal ratings of equipment and apparatus, there is currently no evidence to support adjusting network design standards. For example existing design standards for overhead line conductors do not require change.
- The risk profile for transformers will be affected. Design thresholds of temperature will be exceeded more often and there will be more hot nights in cities.
- Soil conditions will change; higher temperatures and seasonal differences in soil moisture are expected. Future conditions could be included in cable rating studies by increasing average summer soil temperatures in the models by approximately 0.5°C per decade.

- The output of thermal power stations (and in particular combined cycle gas turbines) could be suppressed with higher air temperature meaning lower air density and, in turn, lower mass flow. Conditions at each location should be considered, especially during re-design or new build and, if appropriate, adaptation planned.
- Historical climatologies are no longer valid because climate is not stationary. The new climatologies that take account of climate change are already being adopted and will improve demand forecasting and planning out to 10 years ahead.
- Wind resource is uncertain and understanding future resource represents a significant challenge. Although we don't yet have the answers, this project has highlighted possible strategies for improving our knowledge.

Next steps

To retain momentum it is planned to establish an energy and climate change industry group facilitated by the Met Office which should meet as necessary to discuss latest innovations and developments in climate science with leading experts. The group would share thoughts and ideas on areas of common interest as companies work to adapt to climate change.

Work With the Met Office

Latest project with Met Office addressing network resilience

Following the completion of a feasibility study, a further contract was placed with the Met Office to build a risk model to quantify the relationship between weather and network faults, and the vulnerability and exposure of the network to these faults. This model was then driven with climate projections to assess how network resilience may be affected by climate change.

This research examined some 5.6 million individual faults recorded in NaFIRS over a 20 year period to identify those that were weather related. It then analysed the fault incidence versus the severity of the related weather event to provide a baseline from which to establish future fault trend impacts arising from changes in frequency and severity of weather events.

The results of this work were presented at an ENA Workshop in late 2010 attended by Defra, DECC and Ofgem.

The following weather effects were considered:

- Wind damage to overhead line systems due to gales and severe storms, normally arising from trees or windblown debris, but in very severe conditions breakage due to exceeding mechanical load capability.
- Solar heat faults causing damage to equipment due to overheating.
- Lightning damage to overhead line systems caused by very high voltages being generated in overhead conductors and connected equipment.
- Flooding, referred to elsewhere in this report, which is a particular threat to substations.
- Ice accretion damage to overhead line systems caused by ice build up on conductors or supports causing extreme sag or breakage due to very high mechanical loading.

Baseline climate risk assessment: key conclusions

Hazard and vulnerability were considered where hazard is the occurrence of a fault caused by weather and vulnerability is the magnitude of the impact, measured in the numbers of customers whose supplies are interrupted.

Baseline hazard:

- Wind and gale is the primary cause of weather-related faults. A non-linear relationship was found between wind and gale faults and maximum gust speeds. Networks are not susceptible to faults unless wind gusts speeds are greater than a certain threshold.
- Lightning is the second most common cause of weather-related faults. The meteorological quantity "convective available potential energy" (CAPE) is a good proxy for lightning occurrence.

- The third dominant cause of weather-related faults was snow, sleet and blizzard (SSB). An analysis of England and Wales SSB faults identified that strong wind gusts in addition to snow are necessary to cause a fault.

Baseline vulnerability: key conclusions

- The greatest numbers of weather-related customer interruptions in the historical record are caused by wind and gale or lightning faults.

Although rain and flooding faults occur infrequently they can have a significant impact on the network.

Combining the hazard and vulnerability assessment to measure risk, the baseline risk key conclusions are:

- Wind and gale faults pose the greatest risk to the low voltage distribution network, whilst lightning faults pose the greatest risk to the high voltage distribution network.

Future Climate Risk Assessment for the UK Electricity Network: National findings

Using the relationships established in the baseline risk assessment between asset fault rates and severity of specific types of weather conditions, future risk was then assessed for climate change out to the 2080s

Wind and gale faults

- For future time periods, estimates of wind and gale faults range from changes that are negative to changes that are positive, therefore it is possible that these faults may increase or decrease in the future.
- By the 2080s the projected change in future UK wind and gale faults ranges from a decrease of 23% to an increase of 20% on the distribution network.
- Regionally there is more evidence of a reduction in faults in Northern England and Scotland compared to the South; however, this signal is not consistent over all the regional climate model runs.

Lightning faults

- Lightning faults are projected to increase in the future as a consequence of more days with higher convection.
- By the 2080s the projected change in future UK lightning faults ranges from a decrease of 3% to an increase of 75%.
- There is regional variation in the estimates; the change may be smallest in the Midlands and the South East of England and greatest in North England, North Wales and Scotland.

Snow, sleet and blizzard faults (including ice)

- SSB faults are projected to decrease due to a reduction in the number of days when snow falls. This highlights a decrease in the frequency of SSB fault days, but not necessarily a decrease in the intensity of events when snow does fall.
- In the 2080s the projected change is a decrease of approximately 50% to 90%.

Flooding faults

A UK-wide, event-based analysis has been conducted for flooding. In the 2080s. projections show a mean increase in exceedance of rainfall amounts which have caused significant flooding events in the baseline period. The possibility of decreases cannot be ruled out, however, as some model runs still project slight decreases in exceedance for some of the rainfall events.

The absence of a flooding event in a particular area during the baseline period does not mean that that area is not vulnerable to flooding events. Major flooding events are statistically rare and the baseline period is short in terms of the occurrence of these events. The general increase in heavy rainfall projected by this analysis should therefore be considered as relevant to all areas.

Solar heat faults

- For all time periods, the incidence of solar heat faults is expected to increase, due to projected increases in maximum temperatures.
- The future fault distribution for solar heat faults has not been estimated – their rare occurrence in the baseline period means that statistically robust relationships between fault numbers and weather

parameters cannot be determined. A threshold exceedance analysis based on maximum daily temperature has been used as an indicator.

- In the 2080s the projected change in future exceedance of the 90th percentile maximum temperature ranges from an increase of 88% to an increase of 246%, and the projected change of the 98th percentile from an increase of 137% to an increase of 707%. The 90th and 98th percentiles of maximum temperature vary regionally, so there is little evidence for significant regional variations in the frequencies of exceedance of these thresholds.

Appendix 8: IFI Projects with Climate Change Considerations

Project Title	Project Manager	Project Participants
Vegetation Management	ADAS	NG, UKPN, SP, ENW, CN
Pluvial Flood Risk Modelling	ADAS	CN
Future Network Resilience (ENA)	Met Office	All DNOs
Dynamic Ratings Project	Met Office	CN
Impact of Climate Change on the UK Energy Industry	Met Office	All DNOs
Urban Heat Island Study	Birmingham University	CN
Earthing Information Systems	BGS and NSA	UKPN, CN
Flooding Risk Reduction	Mott McDonald	NG
Investigation to Network Resilience to Weather Events	EA, Met Office	NG, ENA
Flooding Risk Analysis Pluvial Flooding Risks	Total Flood Solutions	NG
Flooding Risk and Severe Weather Mitigation Demountable Flood Barrier Facilitating Work (Phase 1 and 2)		NG

NOTE: NG = National Grid, UKPN = UK Power Networks, ENW = Electricity North West, CN = Central Networks (Now part of Western Power Distribution)

Appendix 9: Electricity Networks and Futures Group New Task Group—Review of ETR 132 - Draft Terms of Reference

Introduction

This ETR provides guidance for Network Operators on how to improve network performance by improving the resilience of the network to vegetation related faults under abnormal weather conditions, including high winds, ice, snow and prolonged high temperatures.

The winter storms of 2013/14 highlighted again the importance of ensuring that DNO overhead line networks are protected, as far as reasonably possible, against falling trees and tree branches which can cause severe damage to wood pole overhead lines.

During discussions with DECC and Ofgem during the Christmas Storm Review process it was agreed that it would be appropriate to take the opportunity to review ETR132 and this should include considering the impact of the recent storms and any lessons learned.

Background to ETR 132

Following changes to the ESQCR in 2007, revised requirements for tree control measures were introduced in the accompanying guidance notes and specifically in ENA ETR 43-8 and ETR 132. Following these changes DNOs have increased tree cutting activities and under wind storm conditions both measures, but particularly ETR132 (clearance to tree falling radius) are effective in reducing overhead line fault volumes.

The consultations and cost impact assessments that preceded these changes limited the funding for ETR132 clearance activities to 0.8% of relevant overhead network length per annum for a period of 25 years. Thus, over this period 20% of the overhead network would be made resilient to tree damage from trees able to fall onto lines. ETR132 requires that clearance work should be prioritised on customer numbers at risk and hence tends to favour those lines feeding large numbers of customers at EHV or in semi rural areas. Those lines in remote rural areas or with lower customer numbers would be much less likely to be cut to ETR132.

Whilst obtaining tree cutting permissions will remain a challenge for DNOs given their present powers, never the less, for wind storms tree cutting and the other measures detailed in ETR132 are some of the most effective ways of reducing the impact of storms on customers.

Draft Terms Of Reference

3.1 Review progress in applying the principles of ETR132 and identify any issues with the current recommendations.

3.2 Review recent experience of overhead line performance during wind storms and identify any learning points that could be incorporated into ETR 132.

3.3 The recent wind storms occurred during a period of very heavy rainfall. The group will assess whether the current recommendation takes sufficient account of the combined effect of high winds and extreme rainfall.

Note: This is against a background where present Climate Change Projections do not indicate that maximum wind speeds will increase significantly but a substantial increase in rainfall is predicted.

3.4 Review the implementation timescale and recommend whether experience with applying the ETR indicates that any change would be appropriate.

3.5 Consider the impact of the current regulatory framework and the new price controls.

Appendix 10: Technical Assessment of Climate Change

1. Overhead Lines (Risks AR1, AR2 and AR3)

Overhead electricity lines background information

Nearly all overhead lines owned by Northern Powergrid are constructed using wood poles or steel towers ("pylons"). A few exceptions use steel or concrete poles. Overhead lines structures are fitted with insulators that support wire conductors, carrying electrical current. The conductors are not normally insulated, are usually copper or aluminium based and are of different sizes to provide different current carrying capabilities.

As all electrical conductors have some electrical resistance, they heat up and expand when current is passed through them, causing them to sag. The amount of sag is impacted by the ambient air temperature, solar radiation and is offset by the any cooling winds.

The amount an overhead line is permitted to sag is determined by the legal minimum heights of live electricity conductors over roads and other ground. Thus the current rating of an overhead line is determined by a heat balance equation:

heat in vs. heat out

and based on a maximum conductor design temperature.

Northern Powergrid networks are designed such that overhead lines of 33kV and above normally connect one large substation to another, with no intermediate connections, hence the current flowing into the circuit is the same as that flowing out of the other end.

At 11kV and below, overhead lines radiate out from substations feeding small transformers or individual customers along the route. Consequently at these voltages, the current flowing in to the circuit gradually reduces as current is fed off to individual customers or small communities / businesses. It is important to make this distinction between the 11kV and below and 33kV and above because of the extent of impact of reduction in ratings caused by climate change.

Climate change will also impact on the structural integrity of overhead lines. Very high winds place structural wind loads on the poles, towers and conductors. These loads increase if there is ice build up ("accretion") on the conductors as it increases the diameter subject to wind load. The wind loading increases as the square of the wind speed. The derivation of the wind load assesses either high wind or high ice conditions. Alternatively a combination of the two, may be used.

Climate change and overhead line ratings

The basic equations governing the derivation of overhead line current ratings are used globally. Typical international examples are set out in IEEE Standard 738 and Cigre Technical Brochure 207.

The above IEEE Standard was used to determine the impacts of changes in climate on ratings and the results of the Met Office ("EP2") research.

From a ratings perspective, the most challenging conditions prevail in high ambient temperatures, high solar radiation and low wind when there is minimum "leeway" between the ambient temperature and the rated conductor design temperature to allow for conductor heating due to the passage of current with little cooling influence.

Most wood pole overhead lines and steel tower lines at 132kV and below in the UK are designed to a 50°C design operating temperature.

The UKCP09 data and Met Office research has not currently identified a change in the prevalence of very low wind speeds (< 0.5 m/s) or in levels of solar radiation used in the current designs, but has identified a range of changes in ambient temperature across the UK in each decade, and for each emission scenario. Previous experience has shown that the limiting condition is the highest daily average ambient temperatures that have the greatest correlation with the highest electrical demands. Further research will be required in future years to check the ongoing validity of this, having regard, for example to uptake of air conditioning.The diagrams attached as Appendix 5: UK Temperature Charts show, from UKCP09, the spread of changes in average daily maximum summer temperature for the high emission scenario for the periods 2010-2039, 2040-2069 and 2070–2099.

The effects of any of the individual temperatures on a representative range of typical overhead conductor types is established by multiplying the °C value, by the % rating reduction per °C figures derived from the Met Office research and is listed in Table 6.

Conductor sizes on standard overhead lines range from 16mm² hard-drawn copper to 850mm² aluminium alloy, with rated temperatures varying from 50°C to 90°C and even up to 170°C. It would clearly be impractical to look at all these cases for the purposes of this assessment, so the following have been selected as being representative of the most common types of overhead line along with the typical limiting rating season:

Conductor & Operating Temperature	Rating	Existing Value	Reduction
25mm² Copper @50°C	Summer	126 Amps	1.6% / °C
100mm² Copper @50°C	Summer	316 Amps	1.6% / °C
175mm² Lynx ACSR @50°C	Summer	432 Amps	1.6% / °C
400mm² Zebra ACSR @75°C	Winter	1,230 Amps	0.81% / °C
500mm² Rubus AAAC @90°C	Winter	1,600 Amps	0.63% / °C

Table 6 - Common Types of Overhead Line

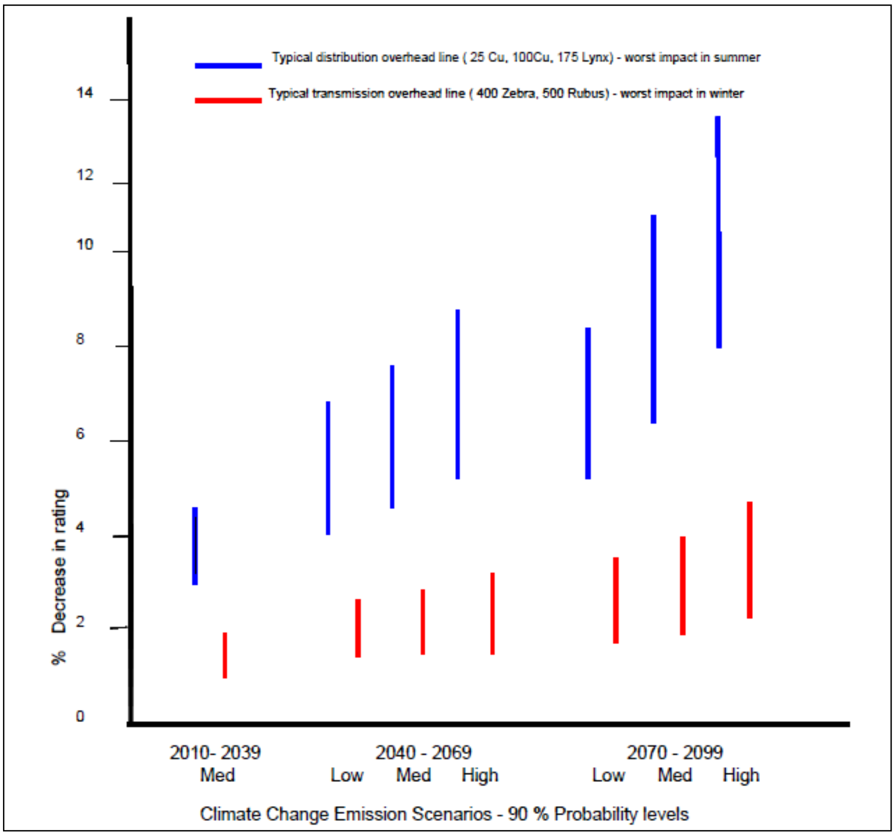


Figure 9 - Ranges of % de-rating across UK

It is important to view the % de-ratings against past DNO experience in response to growth of electricity demand on their networks; effectively the same challenge. The above table indicates a range of de-ratings of distribution overhead lines (in the table, those of 175 mm² and below) of up to 8.6% over the period having a centre point in 2055. That equates to a ratings impact of some 0.19% per annum. Recent demand growth has impacted these same networks at some 1.5% per annum.

The impacts of such reductions in ratings will vary from one circuit to another depending on how close the maximum demand on a particular circuit is to the circuit rating. In the case of 33kV and higher voltage circuits, when that limit is reached, the entire length of the circuit would have to be assessed to determine which locations required action to increase line height by changing supports (poles of towers) or by other action such as re-conductoring with higher operating temperature conductor and any consequential impacts on supports.

For 11kV and LV circuits it is necessary to determine what proportion of the circuit would need to be elevated or re-conductored.

For all wood pole lines up to 33kV, sag increases would be fairly small (around 200mm per 5°C for a typical span) and in many spans there would be enough spare clearance to accommodate such an increase. Where clearance is unavailable, poles can be replaced with taller ones. It is unlikely that many additional poles would be needed in order to keep the existing conductors. Increasing the conductor size, however, will change pole loadings, which is likely to require more pole changes, and possibly additional poles if the wind loading limits of existing intermediate poles are exceeded.

The 2009 price basis unit costs of pole/tower replacement and re-conductoring of overhead lines in Ofgem DPCR 5 assessment are shown in Table 7 - Overhead Line Data.

Overhead Lines GB	Total circuit km	Total no of supports	Unit replacement cost	Full re-build	Conventional re-conductoring
Pole Lines					
LV	64,874	1,710,926	Pole £1.4k	£28.4k/km	
HV (6.6,11,20kV)	168,962	2,113,339	Pole £1.8k	£33.5k/km	
EHV (33,66kV)	28,883	328,522	Pole £2.2k	EHV pole line rebuild £42.0k/km	
132kV	1,774	7,807			
Steel Tower Lines					
EHV (33kV)	3,254	14,553	Tower £39.2k		£39.0k/km
EHV (66kV)			Tower £65.0k		£53.4k/km
132kV (DNO)	14,697	33,438	Tower £108.9k		£82.1k/km

Table 7 - Overhead Line Data

Sources: Component numbers and circuit lengths supplied by Ofgem and are a summation of DNO regulatory returns submitted under the DPCR5 process (Table T4) for closing balances of all 14 licensed UK DNOs as at 31st March 2010.
Costs extracted from Tables 17 and 20 – Ofgem Electricity Distribution Price Control Review – Final Proposals – Allowed Revenue – Cost Assessment appendix Ref 146a/09 – 7th December 2009.

For steel tower lines (at all voltages), structure replacement and/or modification represents significant work. Where de-rating such lines would be problematic, the most practical solution would most often be replacement of the conductors. With the advent of new, low-sag conductor technologies, finding a larger replacement conductor that would minimise, if not eliminate, the need for structural reinforcement no longer presents an insurmountable technical challenge. Such conductors can, however, be relatively expensive compared to the current technology employed.

Table 7 also includes costs for conventional (not low sag) reconductoring of steel tower overhead lines on a per circuit km basis. Many designs have two circuits, one suspended on each side of the tower.

Climate change and structural strength of overhead lines

It has always been recognised that the structural strength of overhead lines should reflect the exposed environment in which they operate. The physical capability of any overhead line is determined by the effect of a maximum probable expected wind force on the conductors usually, although not always, loaded with a maximum probable ice.

There have been UK statutory regulations controlling overhead line design since 1896, when the design criteria was required to be based on 125 mph winds with factors of safety of between 5 and 6 for conductors and between 6 and 12 for structures. A more realistic approach to design was applied in 1924 when the statutory design criteria were changed to reflect the contribution of ice loading; this allowed the wind contribution to be reduced to 50 mph, but this wind pressure was now applied to conductors covered with a ½" of radial ice (a reduced ice loading of 3/8" radial ice was applied to LV conductors). With these more realistic design criteria the factors of safety were also reduced to 2 for conductors and between 2.5 and 3.5 for structures.

Further changes were made to overhead line design involving small section conductor in order to improve the economic viability of extending the electricity network to rural areas and the design standard BS1320:1946 allowed these lines to be constructed without an ice burden, but with 70 mph wind pressure and a 2.5 factor of safety (In these calculations, factor of safety is the ratio of absolute strength (structural capacity) to calculated applied load.). This resulted in a huge increase in overhead line construction during the 1950's and early 1960's.

Following severe storms in 1981 and 1982 it was recognised that the BS1320:1946 design standards were insufficient, but instead of prescribing further specific national criteria, the statutory Electricity Regulations of 1988 required that 'all works shall be sufficient for the purpose for, and the circumstances in which they are used.' This allowed regional variations to be applied and the use of semi-probabilistic designs based on combining the maximum hourly wind pressure likely to occur in a 50 year return period and the maximum radial wet snow accretion likely to occur in the same return period. The regional weather information is contained in ENA ETR111:1991, based on historic weather measurements at Met Office sites.

More recently there has been a return to deterministic overhead line design techniques based on International Standards; BSEN 50423 for lines up to 45kV, and BSEN 50341 for lines of 45kV and above. The adequacy of the overhead line designs introduced since the Electricity Regulations of 1988 has been tested over many years and is subject to post event review by Government (DTI / BERR now DECC).

UKCP09 does not provide information on future high wind speed events, but the Met Office presently advise that there is no evidence of an increase in the severity of high wind events, although there could be a possible increase in their frequency. This increased number of events has the effect of reducing the return period for the currently specified high wind events and will thus increase the wind pressure used in the calculations, if the same level of reliability is required. In respect of wet snow / ice loading, the UK DNOs are participating in COST 727 which is reviewing ice accretion models across the EU. It is currently anticipated that this research will indicate a reduction in the severity requirements used in UK overhead design criteria. Since the design criteria is based on the combined effect of wind and ice, it is expected that existing designs will probably have adequate structural strength and there will be no reason to modify existing networks or change the current design due to climate change impacts.

One related area which might however be affected by climate change is conductor clashing. This is directly related to the gusts associated with the probable wind speeds but, because of the uncertainty in predicting the change in future wind speeds, it is not currently possible to recommend any changes to existing overhead designs. These decisions will need to be reviewed once more accurate climate predictions on wind and ice accretion are available.

Limitations on available information

The following limitations have been identified in available information:

a) There is limited information on future changes in high wind speed events

b) There is no information on the combined probability of low wind speed (dead calm) events with high ambient temperatures. This combination has most effect on reducing overhead line capacity.

c) There is little probabilistic data on increased ambient temperatures generating light winds arising from convection currents generated from ground heating, though these conditions must already prevail in other global regions, albeit not necessarily in the coastal / island context of UK. The generation of winds under these conditions would ameliorate the effect of increased ambient temperatures on overhead line capacity.

d) Improved ice accretion data will be provided by the "COST 727" EU research which should allow overhead lines to be designed more accurately to meet predicted ice loading.

e) Impacts of climate change on air conditioning demand and the timing relationship between peak ambient temperature and peak demand are not known and are subject to multiple other drivers such as building regulations, energy efficiency measures on both buildings and air conditioning units, and energy pricing. These in turn are impacted by "smart grid" technologies employed to mitigate low carbon economy impacts.

Summary of Overhead Line Risks

The following table provides an overview of the risks posed to overhead lines by climate change.

Climate Change Risk	Impact & Consequence	Current	2020s	2050s	2080s	Actions
Flooding (fluvial and pluvial)	Clearances will reduce during a flood event leading to increased risk of third party contact.	M	No predictions available			Regular review of specifications to ensure that designs are fit for purpose. Programme of condition monitoring of assets in place.
	Increased corrosion of footings leading to instability of poles / towers.	M	No predictions available			
Heavy Rain	Clearances will reduce during a flood event leading to increased risk of third party contact.	M	M	M	H	Regular review of specifications to ensure that designs are fit for purpose. Programme of condition monitoring of assets in place.
Coastal Flooding	Clearances will reduce during a flood event leading to increased risk of third party contact.	M	M	M	M	Regular review of specifications to ensure that designs are fit for purpose. Programme of condition monitoring of assets in place.
Ice and Wind	Ice accretion occurs on overhead lines leading to compromised structural integrity of structures.	M	M	M	M	EU research COST 727 currently investigating impacts of ice loading.
	Helicopters unable to fly to carry out fault location.	M	M	M	M	
Heavy Snow	Snow and ice build up occurs on overhead lines leading to compromised structural integrity of structures.	M	M	M	M	EU research COST 727 currently investigating impacts of ice loading.
Hurricane & High Winds	Increased frequency of events may weaken poles and fittings.	M	M	M	M	Condition based refurbishment programme in place.
Heat Wave	High ambient temperatures lead to a reduction in available capacity.	L	L	L	L	Annual review of network loadings ensure adequate headroom on network.
	Additional loadings placed on network due to air conditioning.	L	L	L	L	
Cold Spell	Additional loadings placed on network due to additional heating and electrical appliances.	L	L	L	L	Annual review of network loadings ensure adequate headroom on network.
	Increase in mechanical tension in lines leading to accelerated ageing.	L	L	L	L	Condition based refurbishment programme in place.
Lightning	Increased lightning storms leading to increased number of faults.	M	No predictions available			Lightning protection in place on network. Protection policies subject to regular review.
Gradual Warming	Capabilities of overhead line network reduced due to reduction in ratings.	L	L	L	L	Annual review of network loadings ensure adequate headroom on network.
	Ground clearances reduced leading to greater risk of third party contact or infringement of statutory clearances.	L	L	L	L	Programme of condition monitoring of assets in place.
Drought	Soil drying and movement undermines pole and tower foundations.	L	L	L	L	Programme of condition monitoring of assets in place.

2. Vegetation Growth and Climate Change (Risk AR 3)

Fundamentals

Overhead lines are susceptible to interference from the growth and frailty of vegetation and trees, which can cause a variety of power supply issues ranging from transient or persistent interruptions (due to vegetation touching the line) through to severe damage (due to falling trees or branches). Typically 25% of low voltage overhead interruptions and 6% of high voltage interruptions are related to vegetation induced faults. Under abnormal weather conditions falling trees can lead to large scale power outages.

Overhead lines are normally routed to reduce proximity to vegetation but this is not always possible. It is both socially and environmentally unacceptable to remove all vegetation in proximity to overhead lines and it is necessary to manage vegetation to maintain clearances.

An essential part of this management is understanding the risks associated with vegetation under both ongoing and abnormal conditions. It is important to understand the growth rates of different types of vegetation with respect to the environment at the location and to be able to assess the risks posed by the proximity to the overhead line, combined with the health and condition of the vegetation.

Northern Powergrid has always recognised the importance of efficient vegetation management in maintaining the performance of our overhead lines. Vegetation management is one of the largest annual recurring maintenance tasks that we undertake. We are obliged to carry this out in order to meet our statutory obligations under the ESQCRs, (as amended in 2006). We are required to 'so far as is reasonably practicable, ensure that there is no interference with or interruption of supply caused by an insufficient clearance between any of his overhead lines and a tree or other vegetation.'

Changes in Growing Season

External factors which influence vegetation growth include temperature and rainfall. Climate change will directly impact on growth rates – the number of days with a temperature over 5.6°C will impact the growing season, with an increase resulting in more and denser growth.

In 1999, German[9] research into changes in seasonal plant activity identified that the European growing season had extended by 10.8 days when compared with the early 1960s, with spring growth events (leaf unfolding) starting 6.0 days earlier and the autumn events (leaf colouring) delayed by 4.8 days.

In 2001, American[10] research using NASA satellite data identified that plant life above 40 degrees latitude had been growing more vigorously since 1981. It concluded that the area of vegetation had not extended, but that existing vegetation had increased significantly in density. The timing of both the appearance and fall of leaves had shown dramatic changes over the two decades of recorded satellite data. In Eurasia, the growing season is now almost 18 days longer, with spring arriving a week earlier and autumn delayed by ten days.

The Met Office commented in 2006 that 'the longest thermal growing season in the 230-year daily Central England series occurred in 2000, when it extended for 328 days.... The thermal growing season for this region of the UK is now longer than at any time since the start of the daily temperature series in 1772.'

Vegetation Growth – Changes in Habitat Suitability

In the longer term, the effect of a decrease in summer rainfall will also impact the growth of certain species which are sensitive to drought. One example given in a Defra Report[11] is lowland beech, identified as being particularly susceptible to climate change. Projections based on UKCP09 data are shown in Figure 10.

As habitats change, vegetation will gradually colonise new more suitable areas, but the health of existing susceptible vegetation species will deteriorate, resulting in an increased risk of these trees falling on to overhead lines

[9] Nature Vol. 397 Issue 6721(1999) Growing Season extended in Europe (A. Menzel and P. Fabian)

[10] http://science.nasa.gov/science-news/science-at-nasa/2001/ast07sep_1/

[11] DEFRA Report England Biodiversity Strategy – Towards adaptation to climate change (May 2007)

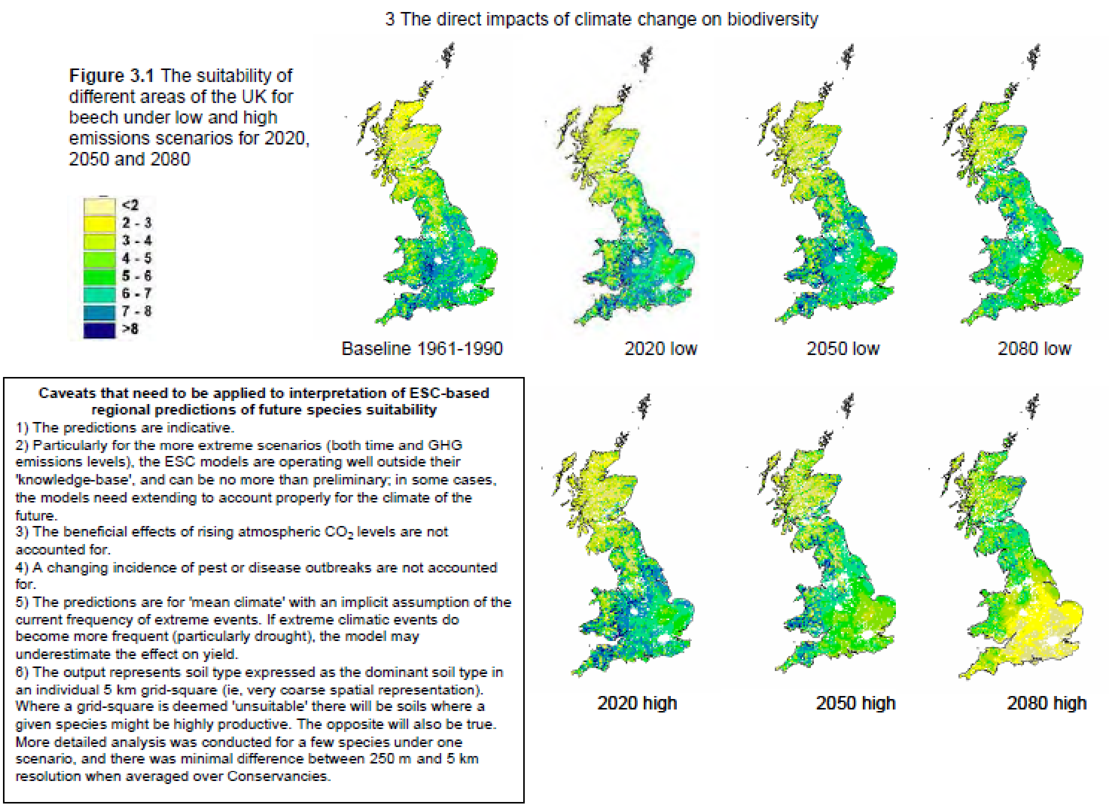


Figure 10 - The suitability of different areas of the UK for beech under low and high emissions scenarios for 2020, 2050 and 2080

Assessing the Impact of Climate Change

While the EP2 report did not include vegetation growth, the Met Office produced a report for the Department of Trade and Industry Network Resilience Working Group in August 2003 entitled 'Extreme Weather Events likely to cause Disruption to Electricity Distribution' which included the following predictions:

- In the South of the British Isles increased energy of storms may intensify and flash rates (lightning) may double.
- It is predicted that deciduous trees will be in leaf for longer periods of time resulting in increased risk from storm related damage.

In ENA ETR132[12], these predictions lead to the following comment: 'It needs to be recognised that if the UK is presented with increasingly adverse climatic conditions over the coming decades, the reliability of the network is likely to become more difficult to manage. The consequence of this is that there will be a need for an increased level of funding and resource to keep network resilience, including vegetation management, at or above its current level.'

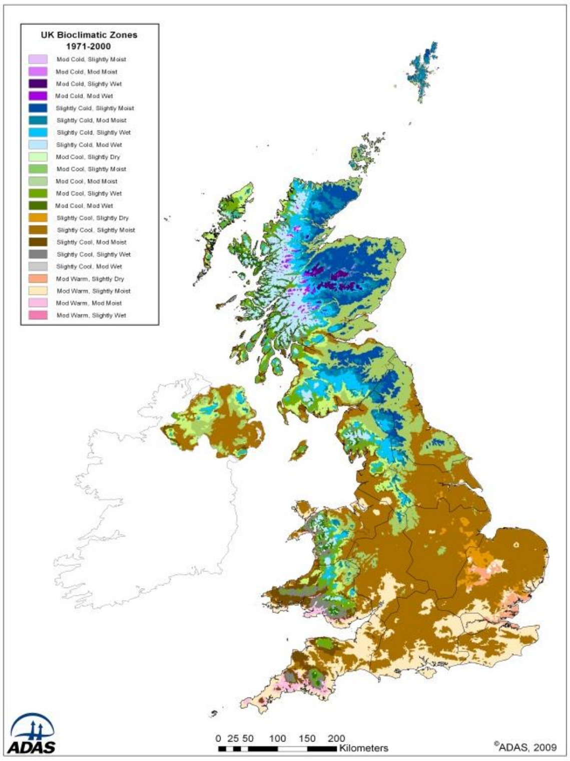


Figure 11 - ADAS bioclimatic zones

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[12] Energy Network Association Engineering Technical Report 132 – Vegetation management near overhead lines for the purpose of improving network performance under abnormal weather conditions

Between 1990 and 2006, prior to the improved management of vegetation, network fault statistics show that tree related faults on the UK electricity network showed a significantly increased trend.

The introduction of the risk based approach to vegetation management under ENA ETR 132 should improve network performance in abnormal weather conditions by the selected removal of high risk trees in the proximity of strategic overhead line circuits. This may have some benefit under normal weather conditions, but is unlikely to prevent further increases in the number of interruptions due to the expected increased vegetation growth rates.

This issue will need to be kept under review to confirm actual climate change impacts when maintenance can be adjusted accordingly.

Vegetation Growth Research Currently Underway

In 2008 several DNO commissioned a four year research project with ADAS, an independent provider of environmental consultancy services to quantify the impact of vegetation growth around overhead lines and in particular the manner in which the Utility Space (that is the physical volume around the utility's apparatus including the volume necessary to ensure its safe and reliable operation) was degraded by vegetation growth over time.

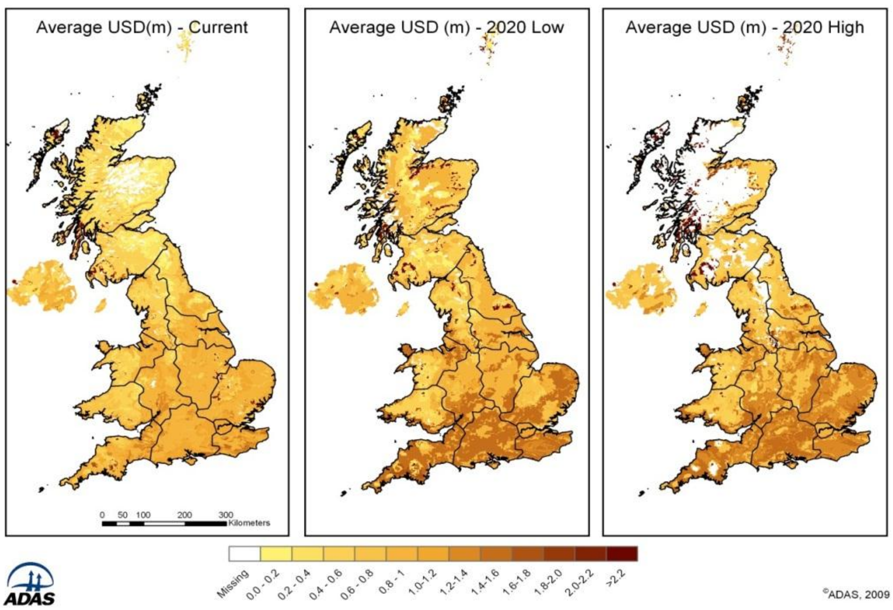
The ADAS Vegetation Management Research Project established approximately 1,700 experimental sites across the country in representative bioclimatic zones determined by the temperature, rainfall and soil conditions (Figure 11).

At each site the Utility Space derogation is being measured on a biannual basis. These measurements are used to infer the net integrated rate of growth at each site and will determine the spatial and temporal growth rates for each bioclimatic zone. The initial results have shown a marked variation in growth rates across the country, which follow the bioclimatic zone areas.

Using UKCP09 data, ADAS predicted the future changes in the size and locations of the bioclimatic zones under different emission scenarios. If the growth rates from the initial observations follow the expected trends then this points towards climate change having a substantial impact on vegetation growth over the next ten years. The maps below show how growth rates will impact on the annual Utility Space Derogation in this period.

This research project is as yet incomplete, but the initial projections indicate that a significantly increased level of vegetation management will be necessary across most areas of the UK.

The potential impact of increase in vegetation cutting can be gauged from the fact that the allowed revenue for the industry set by Ofgem for the five year DNO price control from 2010 is £500m (at a 2007/08 price base)



Summary of Vegetation Management Risks

The following table provides an overview of the risks posed to the distribution network by vegetation due to climate change.

Climate Change Risk	Impact & Consequence	Current	2020s	2050s	2080s	Actions
Flooding (fluvial and pluvial)	Flooding events undermine tree roots, leading to additional faults due to falling trees.	M	No predictions available			Vegetation Management programme in place and subject to regular reviews.
Heavy Rain	Flooding events undermine tree roots, leading to additional faults due to falling trees.	M	M	M	M	Vegetation Management programme in place and subject to regular reviews.
Coastal Flooding	Flooding events undermine tree roots, leading to additional faults due to falling trees.	N	N	N	N	Vegetation Management programme in place and subject to regular reviews.
Ice and Wind	Ice accretion occurs on trees leading to additional faults due to falling debris.	M	M	M	M	Vegetation Management programme in place and subject to regular reviews.
Heavy Snow	Snow and ice build up occurs on trees leading to additional faults due to falling debris.	M	M	M	M	Vegetation Management programme in place and subject to regular reviews.
Hurricane & High Winds	Increased frequency of events may weaken trees leading to additional faults due to falling debris.	L	L	L	L	Vegetation Management programme in place and subject to regular reviews.
Heat Wave	High ambient temperatures lead to an extended growing season and additional encroachment of vegetation.	L	L	L	L	Vegetation Management programme in place and subject to regular reviews.
Cold Spell	No specific risks identified.	N	N	N	N	
Lightning	Increased lightning storms leading to increased number of faults.	L	No predictions available			Vegetation Management programme in place and subject to regular reviews.
Gradual Warming	High ambient temperatures lead to an extended growing season and additional encroachment of vegetation.	L	L	L	L	Vegetation Management programme in place and subject to regular reviews.
Drought	Change in water content of soil leads to changes in natural habitats of different species.	L	L	L	L	Vegetation Management programme in place and subject to regular reviews.

3. Underground Cables (Risks AR4 and AR5)

Underground Cables Background Information

In the UK, electricity cables are installed and operated at all voltages from Low Voltage (400/230 volts) to 400kV. Cables are typically installed in more urban areas but can be used in rural areas where there are particular environmental issues that make them suitable. Lower voltage cables may be installed just 0.45m below the surface whilst higher voltage cables may be buried at depths of 1m or more.

The length of cable operated at the highest transmission voltages is limited due to the substantial costs involved, however as cable voltages reduce, the cost premium compared to an equivalent overhead line falls.

Cable construction typically comprises a central conductor(s) of copper or aluminium immediately surrounded by insulation (the dielectric) with an outer electrically earthed metallic screen. Older and lower voltage cables are typically of three, or at LV four, core construction whilst higher voltage, more recently installed cables are more likely to comprise three single core cables laid close together.

As with other electrical equipment, the rating of cables is typically limited by the maximum operating temperature of the insulation surrounding the conductors.

Older oil-impregnated paper insulated cables have a design maximum conductor temperature of 65°C whilst modern plastic insulated cables have a design maximum conductor temperature of 90°C. Exceeding the maximum operating temperature can have a significant impact on the expected life of the cable. The temperature of the cable is determined by four sources of heat generation:

- Electrical current passing through the electrical resistance of the conductor(s).
- Direct heating of the insulation caused by the alternating voltage, (only significant in higher voltage cables).
- Heating caused by eddy currents which circulate within the earth sheath of single core cables.
- Other external sources of heat in the ground, i.e. adjacent cables.

Balanced against the conduction of heat away from the cable:

- The way cables are laid is a factor in this; cables laid in ducts are usually less able to dissipate the heat than those buried directly in the ground.
- The thermal resistivity of the ground surrounding the cable or duct is affected by the type of soil and the level of moisture it contains.
- The temperature of the surrounding soil is affected by ambient air temperature.

Climate Change

The basic equations governing the derivation of cable ratings have been understood for many years and, within the UK, have been incorporated into a comprehensive suite of cable rating tools called CRATER which can be used to model any range of scenarios in relation to soil temperature and resistivity.

Currently cable ratings in the UK are based on assumptions of temperature (air and soil) and thermal resistivity (soil) made more than 50 years ago. Global warming is predicted to result in generally hotter, drier summers and milder, wetter winters in the UK. These changes will impact directly upon cable ratings due to the increase in ground temperature and the potential for increased soil thermal resistivity if soils become dry. It is also likely that as soils dry out, particularly those rich in clay, that ground movement will occur which in turn may result in damage to cables and cable joints.

The Met Office EP2 report established the effect climate change will have on the industry‘s infrastructure and business. The main findings in relation to cable assets are that air and soil conditions are expected to change, resulting in higher temperatures and in seasonal differences in soil moisture content. This report recommended that:

- For every 1°C rise in air temperature, soil temperatures at depths of 0.45-1.2m can be expected to increase by 0.75°C.
- The effects are similar for different soil types; sand-rich soils offer slightly more resilience to temperature change than types rich in clay or silt, but the variations are small when compared to the effects of changes in the air temperature.
- Reduced precipitation levels will only impact ground resistivity values in extreme, prolonged drought conditions otherwise the effect is small at 1.2m depth.
- Because of the small effect of soil type, climate change driven changes in air temperatures should be considered independent of soil type when calculating ratings.

The diagrams attached as Appendix 5: UK Temperature Charts show, from UKCP09, the spread of changes in average daily maximum summer temperature for the high emission scenario for the periods 2010-2039, 2040-2069 and 2070–2099. In summary, this shows that we are to expect rises of 2.3°C, 4.4°C and 6.8°C respectively for the time periods for Yorkshire and the Humber and 2.5°C, 4.7°C and 7.3°C respectively for the time periods for the North East.

The impact of these, more recent, climate change predictions as applied to cables using the guidance from the EP2 project are considered below

Impact of Climate change on Cable ratings

This section considers the general impact of the UKCP09 climate change predictions on the rating of a range of typical cables used throughout the UK. It is important to note that the predicted reduction in ratings may be exceeded in specific situations such as areas affected by Urban Heat Island[13] effects or localised dry, sandy soil conditions which may be more prone to drying out as temperatures increase.

Table 8 considers a range of commonly used cable types and installation methods and shows the percentage reduction in rating per °C of air temperature change calculated using CRATER.

Figure 12 (overleaf) indicates a range of de-ratings of distribution cables (indicated in the table as 33kV and below) of up to 4.3% over the period having a centre point in 2055. This equates to a ratings impact of some 0.10% per annum. Recent demand growth has impacted these same networks at some 1.5% per annum.

Description	Max °C	Time	Installation	Existing Rating (Amps)	Rating Reduction % / °C Air Temp
LV – 185 Cu Waveform	80	Summer	Direct Lay	339	0.590
LV – 185 AL PILC-STA	80	Summer	Direct Lay	335	0.597
11kV – 185 Al XLPE 1C	90	Summer	Direct Lay	370	0.507
11kV – 185 Al XLPE 1C	90	Summer	Ducted	360	0.521
11kV - 185 Al PICAS 3C	65	Summer	Direct Lay	270	0.787
33kV – 185 Al XLPE 1C	90	Summer	Direct Lay	457	0.492
33kV – 185 Al XLPE 1C	90	Summer	Ducted	430	0.494
33kV – 185 Cu PILC 'H'	65	Summer	Direct Lay	355	0.775
132kV – 630 XLPE 1C	90	Summer	Direct Lay	881	0.511
132kV – 630 XLPE 1C	90	Summer	Ducted	879	0.512
132kV – 630 Cu Lead Sheath	85	Summer	Direct Lay	755	0.579
132kV – 630 Cu Lead Sheath	85	Winter	Direct Lay	827	0.544
400kV – 2000 XLPE 1C	90	Summer	Direct Lay	1429	0.560
400kV – 2000 XLPE 1C	90	Summer	Ducted	1448	0.570
400kV – 2000 XLPE 1C	90	Winter	Direct Lay	1569	0.518
400kV – 2000 Cu Lead Sheath	85	Summer	Direct Lay	1052	0.986

Table 8 - Common Types of Underground Cables

[13] Urban Heat Island is the rise in temperature of any man-made area resulting in a well defined, distinct "warm island" among the "cool sea" represented by the lower temperature of the areas nearby natural landscape.

The impacts of such reductions in ratings will vary from one circuit to another depending on how close the maximum demand on a particular circuit is to the circuit rating. In the case of 33kV and higher voltage circuits, when that limit is reached, it is possible that the entire circuit may need to be replaced with a larger cable size or alternatively the capacity of the network increased by the installation of additional circuits or substations.

For 11kV and LV circuits, where the load on the circuit reduces over its length, it is necessary to determine what proportion of the circuit would need to replaced with a larger cable size or again it may be possible to increase the capacity of the network by the installation of additional circuits or substations.

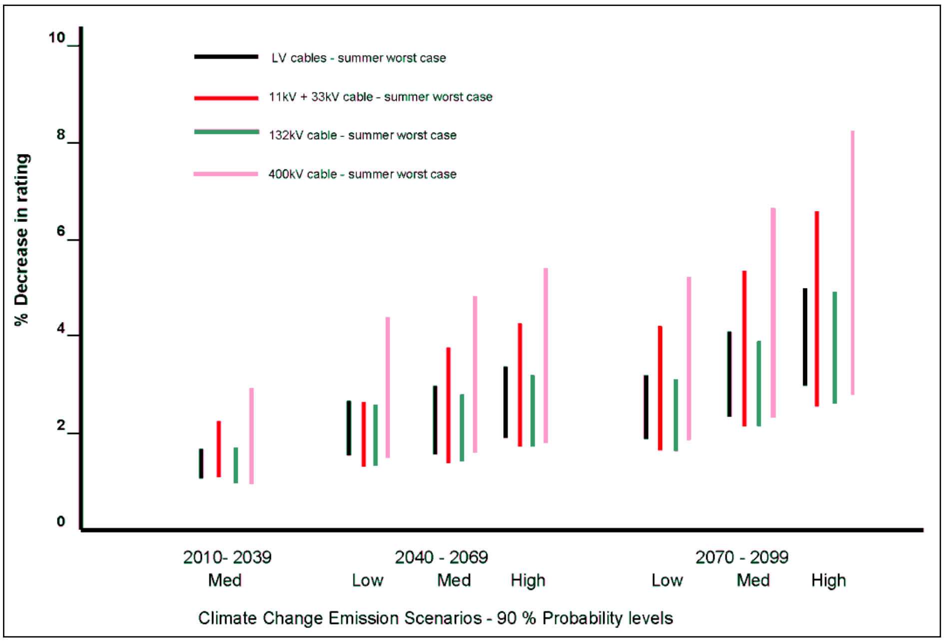


Figure 12 - Ranges of % de-ratings across UK

Where it becomes necessary to take action to replace an overloaded cable an estimate of the likely costs can be calculated using a typical cost per installed kilometre. The estimated unit costs of cable replacement used in Ofgem's DPCR5 investment assessment (direct costs only) are shown in Table 9.

Table 10 shows quantitative information supplied by Ofgem and is a summation of DNO regulatory returns submitted under the DPCR5 process (Table T4) for closing balances of all 14 Licensed UK DNOs as at 31st March 2010.

As with overhead lines it is important to consider de-ratings against past network operator experience in response to growth of electricity demand on their networks; effectively the same challenge.

Underground cable systems may also be affected by summer drought and consequent ground movement, leading to mechanical damage

Cable Type	Cost /km
LV Main (UG Plastic)	£98.4
6.6/11kV UG Cable	£82.9
33kV UG Cable	£256.8
132kV UG Cable	£1,047.1
132 kV Sub Cable	£1,966.7

Table 9 - Extract from Ofgem Electricity DPCR, Final Proposals, Allowed Revenue, Cost Assessment App Ref 146a/09 - 7th Dec 2009

Underground Cables GB	Total Circuit km
LV	328,038
HV (6.6, 11, 20kV)	153,884
EHV (33, 66kV)	21,188
132kV	3,190

Table 10 - Underground Cables Installed in the UK

Summary of Underground Cable Risks

The following table provides an overview of the risks posed to underground cables by climate change.

Climate Change Risk	Impact & Consequence	Current	2020s	2050s	2080s	Actions
Flooding (fluvial and pluvial)	Land surrounding cables is flooded or waterlogged leading to additional faults.	M	No predictions available			Programme of condition monitoring of assets in place.
Heavy Rain	Land surrounding cables is flooded or waterlogged leading to additional faults.	M	M	M	M	Programme of condition monitoring of assets in place.
Coastal Flooding	Land surrounding cables is flooded or waterlogged leading to additional faults.	N	N	N	N	Programme of condition monitoring of assets in place.
Heavy Snow	Following melt, land surrounding cable is waterlogged leading to additional faults.	M	M	M	M	Programme of condition monitoring of assets in place.
Ice and Wind	No specific risks identified.	N	N	N	N	
Hurricane & High Winds	No specific risks identified.	N	N	N	N	
Heat Wave	High ambient temperatures lead to a change in soil properties and therefore the capacity of the cables.	L	L	L	L	Annual review of network loadings ensure adequate headroom on network.
Gradual Warming	High ambient temperatures lead to a change in soil properties and therefore the capacity of the cables.	L	L	L	L	Annual review of network loadings ensure adequate headroom on network.
Cold Spell	Additional loadings placed on network due to additional heating and electrical appliances in use.	L	L	L	L	Annual review of network loadings ensure adequate headroom on network Review of specifications to ensure cables are fit for purpose.
Drought	Change in water content of soil has an adverse effect on soil resistivity and hence causes a reduction in cable ratings.	L	L	L	L	Annual review of network loadings ensure adequate headroom on network Review of specifications to ensure cables are fit for purpose.
Lightning	No specific risks identified.	N	No predictions available			

4. Substation Earthing (Risk AR6)

Purpose

Earthing is essential to enable faults to be detected quickly and automatically made safe. When an earth fault occurs on the distribution network (See Figure 13):

- A large current flows along the cable and returns to the source via the cable sheath and the general mass of earth.
- The current flows until the source protection disconnects the power supply.
- The current flowing through the earth causes a considerable rise in voltage - known as rise of earth potential or earth potential rise - on the ground and any metalwork near the fault, creating a possible danger (touch and step potential) to anyone in the vicinity if this becomes excessive.
- This rise in voltage may be transferred onto adjacent power and communication cables creating possible danger to anyone who might be in contact with them - this can be some distance from the actual fault.

Therefore the purpose of earthing is to:

- Pass the fault current during an earth fault back to the system neutral to ensure the source protection operates to disconnect supplies.
- This will be achieved by an earthing system which is designed to:
- Prevent dangerous voltages appearing on customer installations.
- Prevent dangerous voltages appearing at the substation and causing danger to staff or the public.
- Prevent damage to sensitive equipment (e.g. communications).
- Discharge any lightning surges to earth.

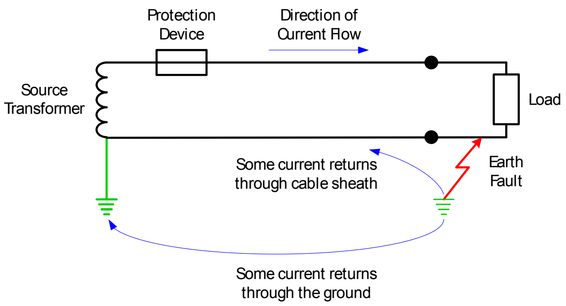


Figure 13 - Earth Fault Current Path

Description of an Earthing System

An earthing system is a collection of one of more electrodes installed in the ground. It usually consists of a number of copper rods interconnected by copper tape or copper conductor. All metallic plant, equipment and structures on a site are then connected to this system. Where necessary some plant and equipment which might otherwise experience excessive rise of earth potential will be deliberately separated from the earthing system and could be provided with their own separate earthing system.

The size of earthing system will depend on the type of site and its complexity. A typical polemounted site will often have a single earth rod whereas a large substation will have an earth mat covering the complete site. - The earthing system at most sites is based around a standard design. The design at larger substations requires measurements and complex calculations to be carried out prior to construction, whereas smaller substations and pole mounted sites rely on measurements carried out during installation to achieve a satisfactory value of earth resistance. Typical values of earth resistance are given in Table 11.

Earthing systems require excavation for installation and are therefore, in order to minimise cost of construction, are designed to provide resistance values which are safe and conservative but not over-engineered.

Substation Type	Typical Voltage Transformation Levels	Approximate number nationally	Resistance Value (Ω)
Grid	400kV to 132kV	380	
	132kV to 33kV	1,000	<0.1
Primary	33kV to 11kV	4,800	<0.1
Secondary ground-mounted	11kV to 400/230V	230,000	<1
Secondary pole-mounted	11kV to 400/230V		<10
LV system	400/230V	millions	<20

Table 11 - Typical Earthing System Resistance Values

Impact of Climate Change on Earth Resistance

The resistance of an earthing system is mainly determined by the soil/geology both in contact with and in the immediate vicinity of the earthing system. Different soil/geology types exhibit different values of resistivity - some typical values are shown in Table 12.

Soil / Geology Type	Typical Soil Resistivity (Ωm)
Loam	25 or less
Chalk	50 or less
Clay	100 or less
Clay/Sand/Gravel	150 - 300
Slate/Shale/Rock	500 or less

Table 12 - Typical Soil and Geology Resistivity Values

Earthing resistance changes with time as the resistivity of the ground varies in response to changes in water content and for shallow installations, temperature. If the variations in moisture and temperature caused by climate change adversely affect the soil resistivity the earth resistance could increase and the earthing installations would no longer satisfy the requirements of the original earthing design. Generally earthing systems are designed to cater for a degree of seasonal and regional variations.

The important point is to understand the relative size of the effects that climate change might have with respect to these regional variations in soil/geology type and with respect to other contributing effects, such as change in soil moisture measurements when made in summer as opposed to winter.

Risk & Mitigation

A standard risk assessment approach is used in earthing design to assess the risk and provide appropriate mitigation. This is based on the staff or customers being exposed to the risk, the likelihood, and the touch and step potentials generated. However to gain a better understanding of the effect of climate change on earthing and to identify the risks and determine a suitable mitigation strategy further research is necessary.

The National Soil Research Institute (NSRI) at Cranfield University and the British Geological Survey (BGS) have been working with UK Power Networks and E.ON (Central Networks) over the last couple of years to produce an earthing mapping system under the Ofgem Innovation Funding and Incentive (IFI) scheme. The earthing mapping system specifies the amount earthing and the type of installation to obtain the required value of earth resistance.

Discussions have been held with NSRI and BGS to extend this work to account for the effects of seasonality and climate change on earthing. It is envisaged that this would include the following:

- An analysis of UKCIP climate models to assess climate variations – especially extended 'dry' periods, and extremes of drought.
- Use of the knowledge from earthing mapping system from phase 1 to highlight those soils and geology types most susceptible to climate change.
- Use of asset databases to cross match assets with 'sensitive' climate/season and soil-geology areas.

- Assess legacy (especially 'very shallow trench') installations to determine suitability for upgrade/remediation to deep drive.
- Provide a modified version of the earthing mapping system which incorporates an allowance for seasonality and climate change.

Mitigation measures are likely to be different for new installations and for existing installations.

For new installations, the mitigation measure will consist of updating design standards. New installations will need to be built to withstand greater temperature and moisture variations than the current seasonal cycle, in order to withstand expected changes to climate. Whilst design costs are unlikely to change, there is likely to be an incremental cost for additional materials and installation time where more rods need to be installed.

For existing installations, the mitigation measure is likely to consist of an inspection regime prioritised by risk. Although earthing is not something that is periodically renewed, the inspection regime would identify any potential risks that need addressing together with the timescales. The work carried out to date by NSRI and BGS provides a quantified basis on which to base the regime. An example inspection regime might be:

- targeting the type of substation (grid, primary, pole-mounted secondary, ground-mounted secondary or LV) representing the greatest risk, balancing the likelihood of exceeding earth potential due to climate changes with the number of people (staff and customers) exposed;
- refine this population by excluding those which are shielded from direct climate effects (such as indoor substations);
- refine this population of substations by targeting those with older earthing installations as a first priority;
- further refine this population by targeting those in areas with known poor soil resistivity;
- further refine this population by choosing a representative sample size to monitor.

Inspection visits would then consist of re-measuring the resistance of the earthing installation, and would need to pay due regard to the season and environmental conditions prevailing during the inspection in order to ensure readings can be correctly interpreted.

To give a context to this, sampling 1% of UK grid sites with 5-yearly inspections would involve a handful of inspections, and negligible cost. Sampling 1% of LV sites with 5-yearly inspections would involve hundreds of thousands of inspections and would be likely to incur several millions in operating expenses.

Costs associated with monitoring by inspections, and replacement/upgrading would need to be recovered through the provision of appropriate allowances for this work via the regulatory regime.

Summary of Earthing Risks

Specific risks to earthing have not been identified except for in the area of the climate change risk of drought. The following table provides an overview of this risk.

Climate Change Risk	Impact & Consequence	Current	2020s	2050s	2080s	Actions
Drought	Change in water content of soil has an adverse effect on soil resistivity and may cause a change in the effectiveness of the earthing.	M	M	M	M	Climate change to be considered during regular reviews of earthing specifications.

5. Transformers (Risks AR7 and AR8)

Introduction

Transformers are used to transform voltage from one level to another. Within Northern Powergrid the most common transformation steps are 132,000 volts (132kV) to 33kV, from 33kV to 11kV and from 11kV to the low voltage (LV) supplies that feed homes and small businesses. Other voltage levels, such as 66kV and 22kV,are also in more limited use but the principles remain the same.

Transformers comprise an iron core with copper or aluminium insulated wire coils wrapped around that, further insulated with a mineral oil and housed in a steel tank, with external connection points to the system. The passage of current through the wire coils (“windings”) causes heating, since no wire is a perfect conductor, and the insulating oil plays a major part in conducting that heat away.

The larger transformers used to transform down from 132kV, 66kV and 33kV are almost all “ground mounted” and carry large amounts of power, necessitating the use of external radiator banks with pumps and fans to dissipate the heat.

Figure 14 - Pole Mounted Distribution Transformer with External Cooling Tubes

The transformers that transform from 11kV down to LV have cooler radiators built into the sides of the tanks. Small capacity units can be mounted on poles (“pole mounted distribution transformers”) whilst others, typically feeding estates and semi - urban / urban businesses are slightly larger, ground mounted, and may be situated in an outdoor walled enclosure or within a building or Glass Reinforced Plastic type enclosure.

The load carrying capability of the transformer is primarily dictated by the maximum temperature at which the windings and insulation can be operated without causing damage or electrical fault. The greater the external ambient temperature the less heating can be permitted from the windings and consequently the rating is reduced. The pattern of demand loading during the day also has an impact.

Northern Powergrid transformers have been purchased against British and International Standards extending back to the 1930s (see Appendix 2: Key Design Standards). These Standards have associated loading guides that provide a mechanism for assessing different loading levels and load patterns against ambient temperature, such as BS CP 1010 (1975) and most recently BSEN 60076-7. These provide a means of assessing the rating reduction impacts from increased ambient temperatures.

Whilst there are innumerable permutations that could be assessed, the objective here is to place some broad scales to the impact of climate change and the impact on continuous rated load represents a reasonable worst case picture, when viewed against the 90% probability levels of the stated emission scenarios. BS CP 1010 provides a relatively straightforward tool and the analysis of a broad range of outputs indicates that 11kV distribution transformers are de-rated by some 1.0%/°C whilst the larger 33kV, 66kV and 132kV transformers that have external cooler banks with fans and pumps are impacted by some 0.7 %/°C

Figure 15 - 33/11kV Ground Mounted Transformers with Coolers

Transformer Type / Season	2010 - 39		2040 – 69						2070 - 2099					
	M		L		M		H		L		M		H	
	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max
11kV Summer	1.8	2.9	2.6	4.5	2.8	4.8	3.3	5.4	3.2	5.3	4.1	6.8	5.0	8.0
11kV Winter	1.6	2.3	2.2	3.2	2.4	3.5	2.5	3.9	2.7	4.1	3.0	4.8	3.5	5.8
33,66,132kV Summer	1.3	2.0	1.8	3.2	2.0	3.4	2.3	3.8	2.2	3.7	2.9	4.8	3.5	5.9
33,66,132kV Winter	1.1	1.6	1.5	2.2	1..7	2.5	1.8	2.7	1.9	2.9	2.1	3.4	2.5	4.0

Table 13 - % Reduction in Transformer Ratings

Quantities of transformers for UK DNOs as at 31st March 2010 and replacement costs		
Transformer Type	Numbers in Service	Replacement Cost £k
11kV pole mounted	348,647	2.9
11kV ground mounted	231,297	3.2
33kV pole mounted	1,588	7.9
33kV ground mounted	7,699	377.9
66kV ground mounted	612	440.2
132kV ground mounted	1,946	1018.7

Table 14 - Extract from Ofgem Electricity Distribution Price Control Review, Final Proposals, App Ref 146a/09 - 7th Dec 2009

Summary of Transformer Risks

The following table provides an overview of the risks posed to transformers by climate change.

Climate Change Risk	Impact & Consequence	Current	2020s	2050s	2080s	Actions
Flooding (fluvial and pluvial)	Transformer failure due to floodwater (likely to be due to cable terminations, cooling fans, secondary wiring or auxiliary switches).	M	No predictions available			Policies in place for flood defending at risk substations. Policy subject to regular review.
Heavy Rain	Transformer failure due to floodwater (likely to be due to cable terminations, cooling fans, secondary wiring or auxiliary switches).	M	M	M	H	Policies in place for flood defending at risk substations. Policy subject to regular review.
Coastal Flooding	Transformer failure due to floodwater (likely to be due to cable terminations, cooling fans, secondary wiring or auxiliary switches).	M	M	M	M	Policies in place for flood defending at risk substations. Policy subject to regular review.
Ice and Wind	Operation of transformer compromised by ice build up affecting exposed moving parts.	L	L	L	L	None.
Heavy Snow	Tranformer and/or pumps unable to operate due to snow, reducing the transformer ratings.	L	L	L	L	Annual review of network loadings ensure adequate headroom on network.
Hurricane & High Winds	Debris falls onto transformers causing damage and faults.	L	L	L	L	Condition monitoring of substation buildings and vegetation management policies in place.
Heat Wave	Capacity reduced due to high ambient temperature.	M	M	M	M	Annual review of network loadings ensure adequate headroom on network.
	Additional load placed on network due to air conditioning.	M	M	M	M	
Cold Spell	Additional loadings placed on network due to additional heating and electrical appliances.	M	M	M	M	Annual review of network loadings ensure adequate headroom on network.
Gradual Warming	Capacitiy of network reduced due to increase in ambient temperature.	L	L	L	L	Annual review of network loadings ensure adequate headroom on network.
Lightning	Increased number of lightning strikes leading to additional faults.	L	No predictions available			Lightning protection in place and policies subject to regular review.
Drought	Subsidence means that transformer footing become unstable.	L	L	L	L	Condition monitoring programme in place for assets.

6. Substations (Risks AR9, AR10, AR11 and AR12)

Introduction

The relative importance of different types of substation are indicated in Table 1. Substations are key installations on the Northern Powergrid network and are built with considerable redundancy, as described below, however, network security requirements do not provide for the complete loss of a Grid or Primary substation, and in these circumstances, customers may be without supply until repairs or other work are carried out.

Typical equipment contained within a substation

Typically a grid substation is made up of batteries, busbars, metering, relays, switchgear and transformers. Transformers ratings are considered in Section 5 of this Appendix.

132kV system design generally establishes substations with duplicate 132kV/lower voltage transformers at practicable and convenient locations in the proposed zones of supply, having regard to current and possible future loadings together with environmental aspects.

33kV or 66kV substations are normally located at the centre of demand in the proposed zone of supply, having due regard to future land use and environmental aspects. Care is always taken ' property, public amenities or environmentally sensitive areas.

Figure 16 - 132kV Grid substation showing 132kV terminal tower and start of 33kV wood pole overhead line

Substations are designed to occupy the minimum practicable site area to reduce future maintenance costs, subject to a reasonable provision for future extension and/or replacement of switchboards and transformers, and any planning requirements.

Wherever possible, new substations are situated on land which is not exposed to the risk of flooding. To establish whether a proposed substation premises is at risk from flooding and the potential scale of a flood event, a flood risk assessment should be carried out in line with risk based on Planning Policy Statement 25 (Development and Flood) as detailed in ETR 138. Where it is necessary to site a substation on low-lying land, the site may need to be elevated or protected.

Figure 17 - An Electricity Substation Protected by Flood Barriers in the 2007 Floods in the North East of England

Distribution Licence Condition 9 requires Northern Powergrid to comply with a Distribution Code which 'is designed so as to permit the development, maintenance, and operation of an efficient, coordinated and economical system for the distribution of electricity'. The adoption of a standard range of plant and equipment across the 132kV system allows economies of scale and management of network risks by facilitating the interchangeability of plant under emergency situations.

Switchgear is to the standard specified in ENA TS 41-37 – switchgear for use on 66kV to 132kV Distribution Systems, or ENA TS 41-36 – distribution switchgear for use up to 36kV (cable and overhead conductor connected) which in turn specify that switchgear will be to the standard specified by IEC 60694 – common specifications for high voltage switchgear and control gear standards. Details of the normal service conditions expected from switchgear can be found in Appendix 2: Key Design Standards.

The selection of switchgear takes into account the following factors:

- Total cost over the lifecycle of the asset,
- Risk of catastrophic failure,
- Substation security,
- Future availability of additional units,
- Available space
- Environmental pollution.

Substation climate change risks

Flood Resilience

From a flood resilience perspective, the following guidance is given in the ETR 138:

- Identify all substations (within scope) that lie within a flood plain using the best available current data from the EA;
- Establish the flood risk for each substation to identify predicted flood depth, where the flood depth is likely to cause damage to key parts of the substation resulting in the loss of supply to customers;
- For each substation deemed 'at risk', identify the flood impact for that site including societal impact;
- Establish if the site is to be protected under a flood protection scheme sponsored by an appropriate public authority;
- Establish the appropriate options for protecting the site with estimated costs. These should include:
  - provision of permanent or temporary barriers
  - protecting all the site or only key areas
  - providing a sufficient level of network interconnection
  - commissioning a replacement substation in an alternative location.
- Propose a solution based on flood risk and cost/benefit assessment;
- Review information from EA on surface water flooding as the data becomes available. Ideally mitigation measures should be designed to protect against the 1 in 100 (river) or 1 in 200 (sea) for primary substations and 1 in 1000 floods for grid supply points as appropriate to the practical limitations of the site and the outcome of the cost benefit assessment.

The floodplain is split into two different areas. These are:

- The area that could be affected by flooding, either from rivers or the sea, if there were no flood defences. This area could be flooded:
  - from the sea by a flood that has a 0.5% (1 in 200) or greater chance of happening each year, or
  - from a river by a flood that has a 1% (1 in 100) or greater chance of happening each year.
- The additional extent of an extreme flood from rivers or the sea. These outlying areas are likely to be affected by a major flood, with up to a 0.1% (1 in 1000) chance of occurring each year.

The predicted flood level for a substation asset will also need to take into account the uncertainties surrounding climate change. Based on current advice from EA, it is recommended in ETR 138 that the potential flood depth is increased by the following amounts:

- Freeboard – By 300mm to allow for uncertainties in data modelling;
- Fluvial flooding – By 20% on the predicted flood depth to allow for climate change impacts;
- Sea Level - Increase by the corresponding amount in the table for climate change impact for the lifetime of the assets, nominally 60 years.

At present, data is issued by EA solely for the current flood risks. It is anticipated that predictions on future risks including pluvial flooding, will be available in future and it will be necessary to re-assess flood mitigation plans and expenditure in line with this data. In addition, the second generation of National Shoreline Management Plans are now available. These include projections for coastal erosion and will also be considered in the assessment of flood risks.

Region	Net sea level rise (mm/yr)			
	1990 - 2025	2025 - 2055	2055 - 2085	2085 - 2115
East of England, East Midlands, London, SE England (south of Flamborough Head)	4.0	8.5	12.0	15.0
South West & Wales	3.5	8.0	11.5	14.5
NW England, NE England, Scotland (north of Flamborough Head)	2.5	7.0	10.0	13.0

Table 15 - Defra Flood and Coastal Defence Appraisal Guidance, FCDPAG3

For existing major substation sites where there are no short-term plans for substantial asset replacement work, one of the following options may be adopted, bearing in mind the cost benefit assessment of the design.

- Construction of a subterranean "wall" around the perimeter of the substation site (including compound and buildings, extending above ground (e.g. concrete, sheet piling)).
- Construction of a waterproof wall within the site to protect critical assets. This option may be adopted where only specific assets are at risk and may be used in conjunction with option 3. Any of the following measures may be used where the flood height is not great, usually 300mm or less:
  - Installation of flood protection to door openings;
  - Raising ventilation holes;
  - Raising walls; and
  - Sealing cable troughs.
- Deployment of a temporary flood barrier around the perimeter of the substation site (or specific assets).
- Relocation of the substation.
- Where a substation has been identified for asset replacement, an assessment of the flood risk shall be undertaken. Should this analysis result in the substation being identified as being at risk, the substation may be built at an elevated level. Standard designs are available for indoor distribution substations elevated at 600mm and 1200mm above ground level.

Resilience Levels without relying on temporary flood protection measures	
Level of flooding that may occur within a 1:1,000 year flood contour	Level 1
Level of flooding that may occur within a 1:100 year fluvial flood contour (1:200 in Scotland) and within the 1:200 contour for sea flooding throughout the UK	Level 2
Other flood protection measures (not meeting Level 1 or Level 2 above) including provision of limited alternative supplies.	Level 3

Table 16 - Resilience Levels

The cost of providing resilience will vary greatly between different sites, depending on the flood depth, work needed to protect the site, the availability of alternative sources of supply if a site is lost and the degree of protection offered by other schemes such as those defences provided by the EA.

ETR 138 states that DNOs should carry out cost/benefit assessments for each substation at risk in order to determine which resilience level is appropriate in any given case. This will include consideration of customers' "willingness to pay". The cost/benefit assessments will take into account the societal aspects identified in ETR 138 and other reviews into recent floods, including the Pitt review, as well as the more usual considerations of reducing customer supply losses and protecting assets.

For grid substations the target level of resilience should be Level 1 unless cost/benefit analysis determines that Level 2 resilience is appropriate. If in exceptional circumstances, a company determines that neither Level 1 nor Level 2 resilience is appropriate for a grid substation, it will provide such level of resilience as is reasonable practicable in the circumstances. If a company is uncertain about the level of resilience, it may consider consulting with Ofgem, DECC and the relevant flood protection authority as a means of resolving such uncertainty.

For primary substations the target level of resilience should be Level 2 unless cost/benefit analysis determines that Level 3 resilience is appropriate. However, where substantial additional protection can be provided for a primary substation at marginal additional cost e.g. protection increased from Level 2 to Level 1, then companies should consider providing this enhanced level of protection.

Summary of Substation Risks

The following table provides an overview of the risks posed to substations by climate change.

Climate Change Risk	Impact & Consequence	Current	2020s	2050s	2080s	Actions
Flooding (fluvial and pluvial)	Substation floods due to extension of flood plains.	M	No predictions available			Policies in place for flood defending at risk substations. Policy subject to regular review.
	Substation floods as existing flood defences are inadequate.	M	No predictions available			
Heavy Rain	Substation floods due to extension of flood plains.	M	M	M	H	Policies in place for flood defending at risk substations. Policy subject to regular review.
	Substation floods as existing flood defences are inadequate.	M	M	M	H	
Coastal Flooding	Substation floods.	M	M	M	M	Policies in place for flood defending at risk substations. Policy subject to regular review.
Ice and Wind	Damage sustained to substation buildings leading to equipment failure.	L	L	L	L	Condition monitoring of substation buildings.
Heavy Snow	Substation buildings unable to support weight of snow.	L	L	L	L	Condition monitoring of substation buildings.
Hurricane & High Winds	Increased frequency weakens or damages substation buildings leading to equipment failure.	L	L	L	L	Condition monitoring of substation buildings.
Drought	Subsidence means that substation footings may become unstable.	L	L	L	L	Condition monitoring of substation buildings.
Heat Wave	Additional load placed on network due to air conditioning.	L	L	L	L	Annual review of network loadings ensure adequate headroom on network Specifications reviewed on a regular basis to ensure adequacy.
Cold Spell	Additional loadings placed on network due to additional heating and electrical appliances.	L	L	L	L	Annual review of network loadings ensure adequate headroom on network Specifications reviewed on a regular basis to ensure adequacy.
Gradual Warming	Capacity of network reduced due to increase in ambient temperature.	L	L	L	L	Annual review of network loadings ensure adequate headroom on network Specifications reviewed on a regular basis to ensure adequacy.
Lightning	Increased number of lightning strikes lead to additional faults.	L	No predictions available			Lightning protection in place and policies subject to regular review.

7. Lightning resilience

The Met Office Project EP2 details likely changes in lightning activity, including a projected change in future UK lightning faults by the 2080s, ranging from a decrease of 3% to an increase of 75% with a regional variaton in the estimates.

Lightning storms may cause damage, latent damage, flashovers and transient interruptions to electricity networks. The effects of lightning can be minimised by including both shielding measures and suppression devices.

Metallically enclosed ground mounted substations have inherent protection from direct lightning strikes, but can be affected by nearby strikes. These can cause surges in connected circuits either by a direct strike, or by inducing current in these lines. To guard against these effects shield wires are installed on grid circuits supported by metal structures to provide a preferential path, reducing the probability of flashovers to the phase conductors. Unearthed circuits mounted on wooden poles form the majority of overhead high-voltage circuits and their physical properties provide a degree of electrical isolation from earth (reducing the likelihood of a direct strike). There are frequent earthed positions which tend to be associated with more vulnerable equipment such as overhead/cable interfaces and pole mounted plant/ transformers. At these positions surge arresters are used to protect the equipment by clamping the voltage below values that can cause damage.

Flashovers caused by lightning normally result in high levels of power follow through current, causing circuit protection to operate. To minimise the effects to customers, autorecloser devices are installed on the network to rapidly reconnect circuits automatically.

Increased lightning activity could result in:-

- Reduction in life of surge arrestors due to increased exposure to lightning strikes
- Requirement to upgrade/modify lightning protection to maintain system performance
- Requirement to upgrade/modify lightning protection to cover assets not currently protected
- Reduced network performance with increased likelihood of supply interruptions in spite of improved lightning protection.

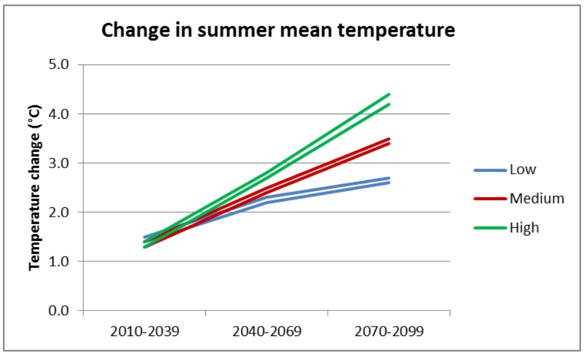
In view of the wide range of likely change in lightning activity and the uncertainty of the overall change in lightning risk, further investigation is require to provide sufficient evidence to support firm recommendations on adaptation requirements.

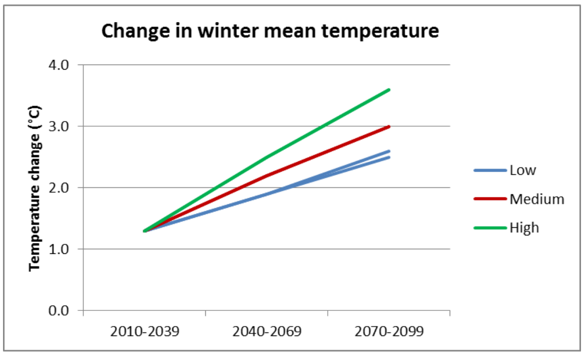
Appendix 11: – Northern Powergrid Operating Zone Climate Assessment

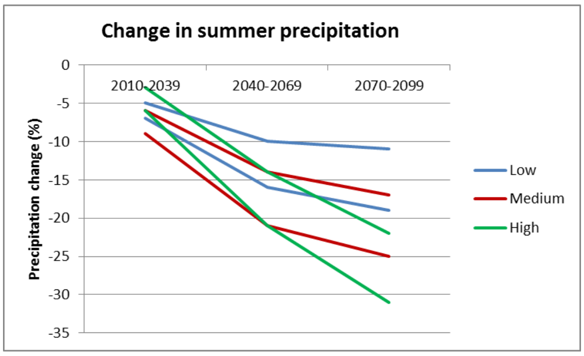
- South Yorkshire

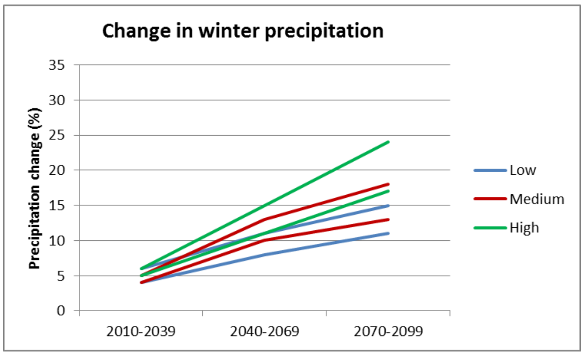
This zone covers the main cities and towns of Sheffield, Rotherham, Doncaster and Barnsley. It extends to Thorne and Hatfield in the east and on its northern boundary it includes Royston, Carcroft and Stocksbridge. The zone has a population of approximately 1.3 million, serves 673,000 homes and businesses and covers an area of 1,686km^2. It is characterised by an extensive underground cable network and a significant number of substations that supply densely populated areas.

Keeping our estimates conservative and using the medium emissions scenario at the 50th percentile, we would expect to see an increase of 3.4°C in summer and 3°C in winter mean temperature of by the end of the century. This would be combined with a 21% reduction in summer and a 15% increase in winter rainfall levels.









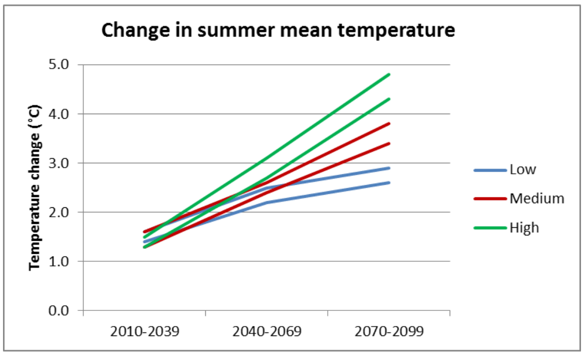
The zone includes a section of the Peak District National Park. Within this area we have 201km of overhead lines. We recognise the vulnerability of these lines and their environmental impact and we are working with the National Parks Authority to underground these lines wherever possible.

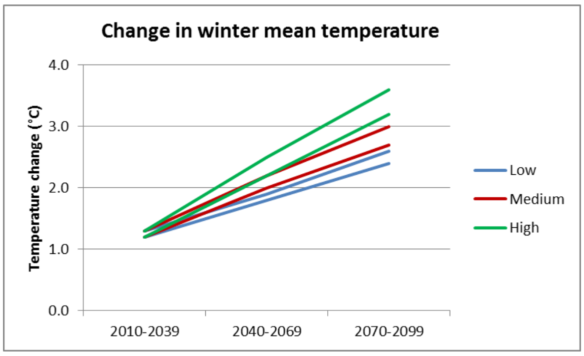
This zone has historically been subjected to flooding. In 2007 the River Don over-topped its banks, causing significant flooding in the Sheffield area. The NGET site at Neepsend suffered significant flooding, with the loss of supply to 40,000 customers and the supplied to many other customers in the centre of Sheffield were threatened when cracks were discovered in the Ulley Reservoir. As a result of this flooding, extensive investment has been carried out on flood defence works. The flood defences have stood the test of further flooding in 2012 and have been constructed, by taking climate change into account, to provide adequate protection for the substations for the lifetime of the asset.

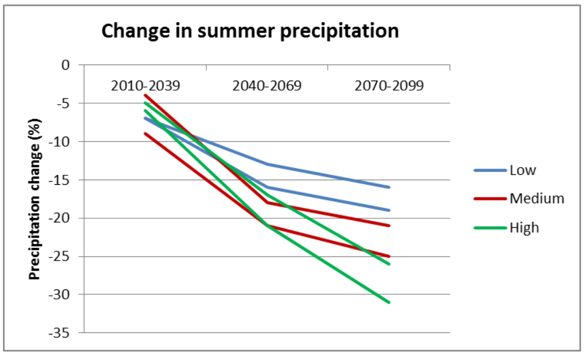
West Yorkshire

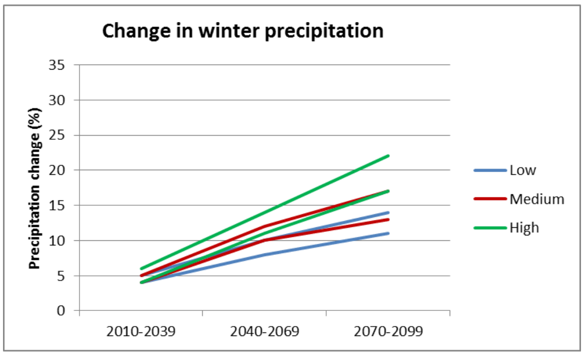
This zone covers the main cities of Leeds, Bradford and Wakefield. It stretches from Keighley, Ilkley and Otley in the north to Penistone in the south; and on its eastern boundary it includes Castleford and Pontefract. The zone has a population of approximately 2.2 million which makes it the 4th most highly populated region in the UK. The zone serves 1,049,000 homes and businesses and covers an area of 2,002km^2. Whilst a compact zone in terms of size, it is huge in terms of cable length and numbers of substations. Of the nine zones, West Yorkshire has the greatest number of customers.

Keeping our estimates conservative and using the medium emissions scenario at the 50th percentile, we would expect to see an increase of 3.6°C in summer and 2.8°C in winter mean temperature of by the end of the century. This would be combined with a 23% reduction in summer and a 15% increase in winter rainfall levels.





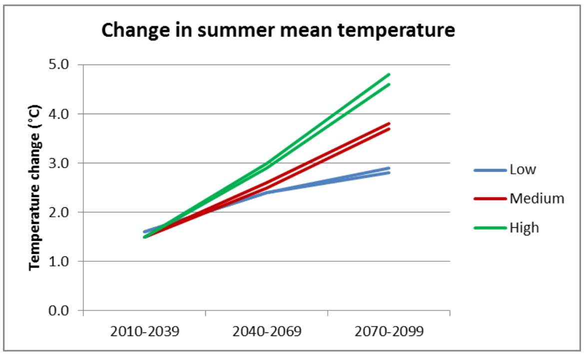


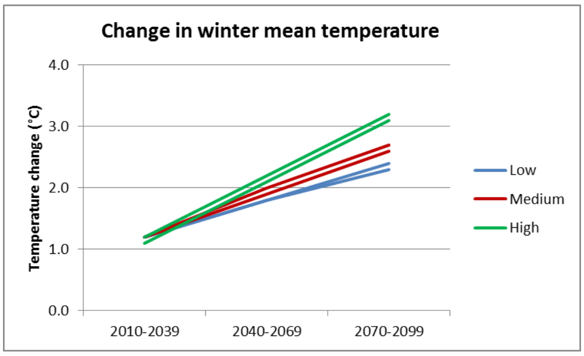


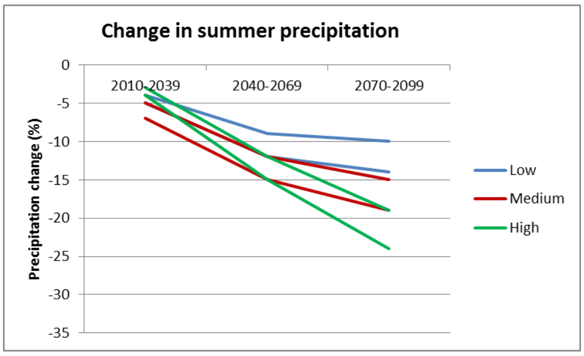
- Tyne and Wear

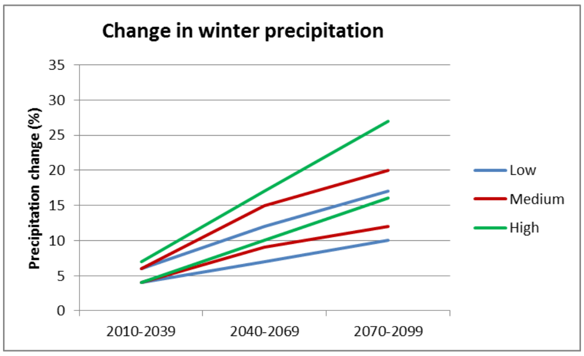
This zone covers the main cities of Newcastle, Sunderland and Durham. It stretches from Blyth in the north to Peterlee in the south; and on its western boundary it includes Ponteland, Stanley and Prudhoe. The zone has a population of approximately 1.1 million, serves 755,000 homes and businesses and covers an area of 1,113km^2.

Keeping our estimates conservative and using the medium emissions scenario at the 50th percentile, we would expect to see an increase of 3.7°C in summer and 2.6°C in winter mean temperature of by the end of the century. This would be combined with a 17% reduction in summer and a 16% increase in winter rainfall levels.







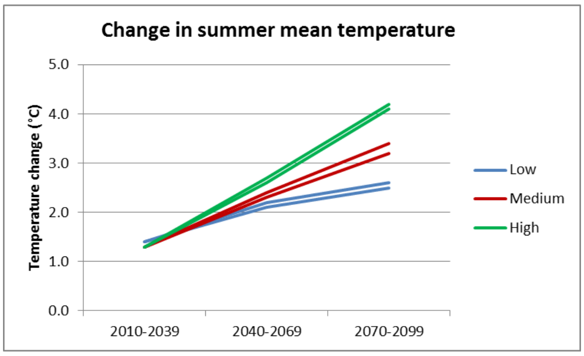


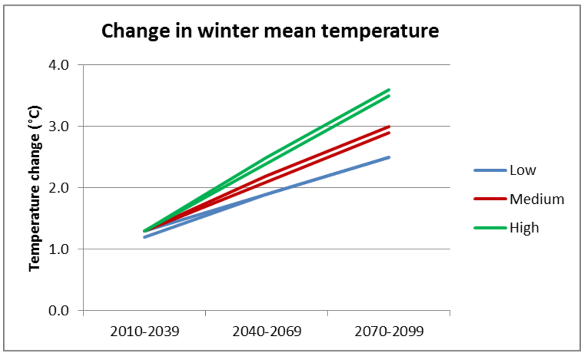
This zone has historically been subjected to flooding. In 2012, the centre of Newcastle suffered from severe surface water flooding and in December 2013, the quayside area was badly affected by a coastal surge. Investment has been carried out on flood defence works in this area and further work is planned. The flood defences will be constructed, by taking climate change into account, to provide adequate protection for the substations for the lifetime of the asset.

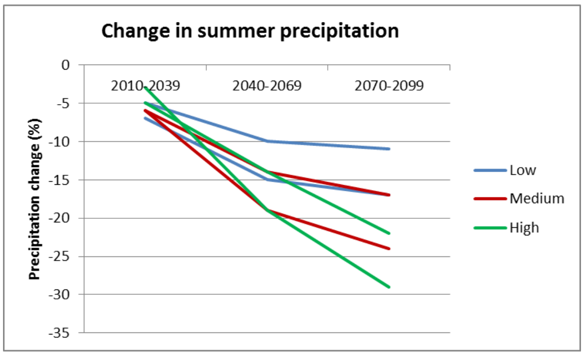
Humber Estuary

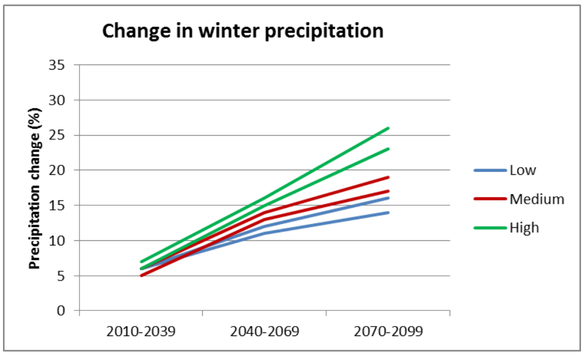
This zone covers the main cities and towns of Hull, Scunthorpe and Grimsby; as well as the area along the River Humber. It stretches from Beverley in the north to Scunthorpe, Grimsby and Cleethorpes in the south; and on its western boundary it includes Goole. The zone has a population of approximately 0.4 million, serves 326,000 homes and businesses and covers an area of 1,561km^2. It presents challenges with regard to heavy industry and other large customers whose continuous reliability of supply is paramount to their businesses.

Keeping our estimates conservative and using the medium emissions scenario at the 50th percentile, we would expect to see an increase of 3.3°C in summer and 2.9°C in winter mean temperature of by the end of the century. This would be combined with a 21% reduction in summer and an 18% increase in winter rainfall levels.







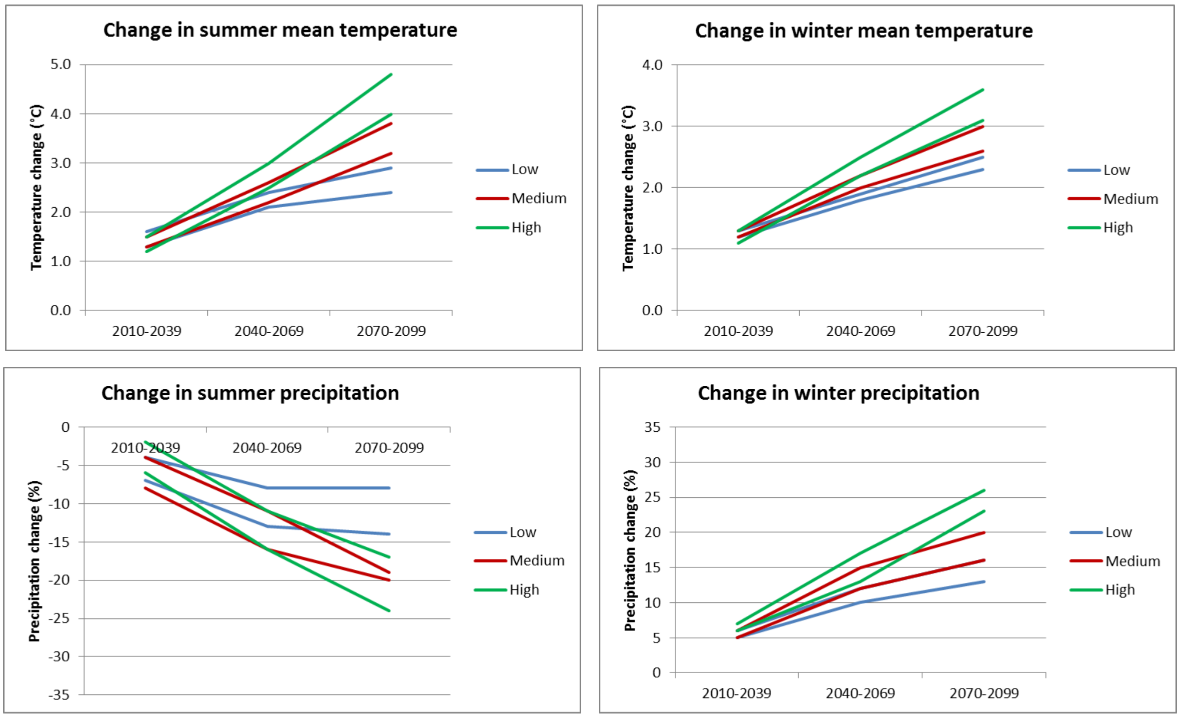


This zone has historically been subjected to flooding. In 2007, 8,600 homes and 1,300 businesses were subjected to severe flooding due to the drainage system becoming overwhelmed. As a result of this flooding, extensive investment has been carried out on flood defence works. The flood defences have been constructed, by taking climate change into account, to provide adequate protection for the substations for the lifetime of the asset.

- Teesside

This zone covers the main towns of Middlesbrough, Stockton and Darlington. It stretches from Hartlepool in the north to Guisborough in the south; and on its western boundary it includes Newton Aycliffe, Darlington and Spennymoor. The zone has a population of approximately 0.7 million, serves 412,000 homes and businesses and covers an area of 1,005km². It presents challenges with regard to heavy industry and other large customers whose continuous reliability of supply is paramount to their businesses.

Keeping our estimates conservative and using the medium emissions scenario at the 50th percentile, we would expect to see an increase of 3.5°C in summer and 2.8°C in winter mean temperature of by the end of the century. This would be combined with a 19% reduction in summer and an 18% increase in winter rainfall levels.

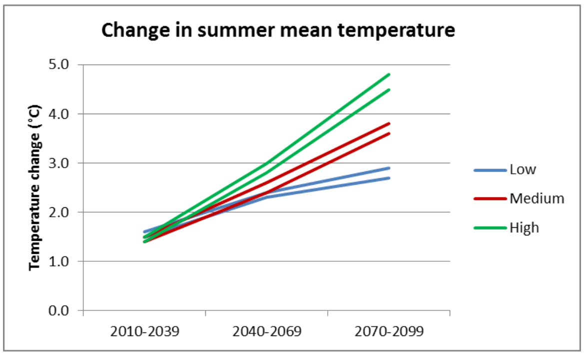


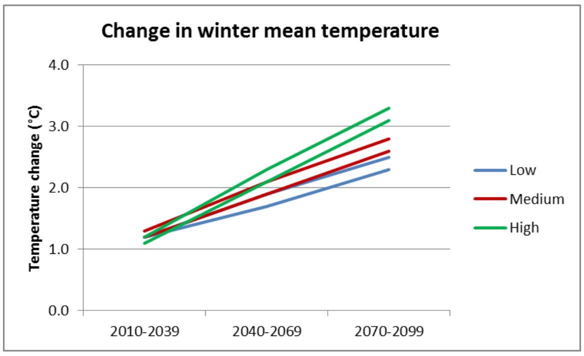
This zone has historically been subjected to flooding. In December 2013, areas of Teesside were affected by a coastal surge. Investment has been carried out on flood defence works in this area and further work is planned. The flood defences will be constructed, by taking climate change into account, to provide adequate protection for the substations for the lifetime of the asset.

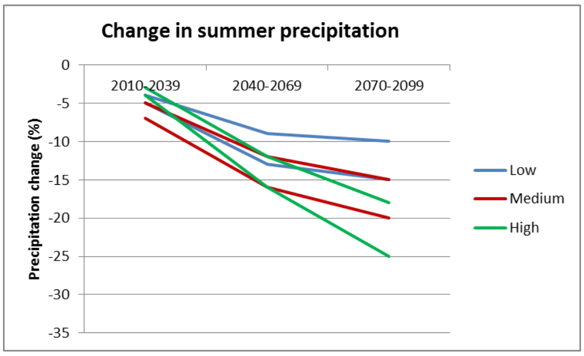
- Northumberland and County Durham

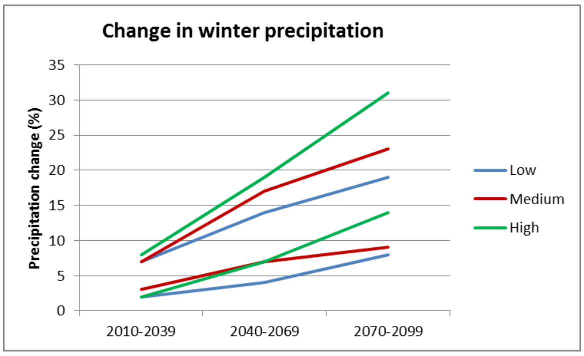
This zone covers the main towns of Alnwick, Morpeth, Hexham and Barnard Castle. It stretches from Wooler and Seahouses in the north to Barnard Castle in the south; and on its eastern boundary it includes Bishop Auckland, Corbridge, Crook and Consett. The zone has a population of approximately 0.8 million, serves 112,000 homes and businesses and covers an area of 6,385km^2 which includes the Northumberland National Park. Many customers in this zone are supplied by long stretches of overhead line.

Keeping our estimates conservative and using the medium emissions scenario at the 50th percentile, we would expect to see an increase of 3.7°C in summer and 2.7°C in winter mean temperature of by the end of the century. This would be combined with an 18% reduction in summer and a 15% increase in winter rainfall levels.







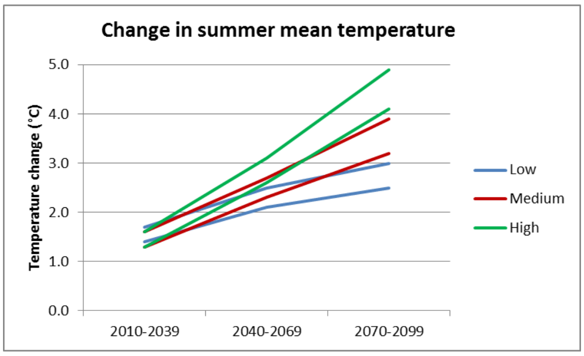


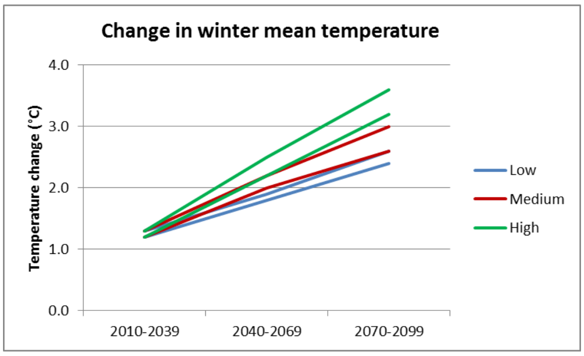
The zone includes a section of the North Pennines Area of Outstanding Natural Beauty and Global Geopark, the Northumberland Coast Area of Outstanding Natural Beauty and the Northumberland National Park. Within this area we have 1,159km of overhead lines. We recognise the vulnerability of these lines and their environmental impact and we are working with the AONB Partnership and the National Parks Authority to underground these lines wherever possible.

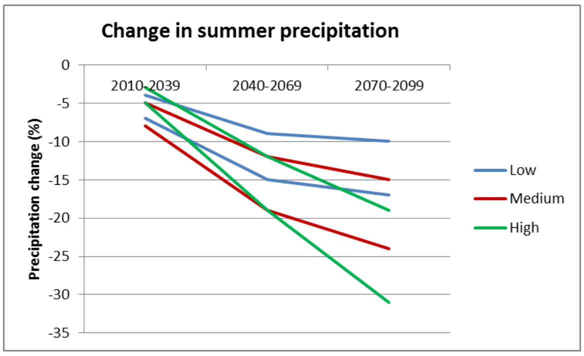
Yorkshire Dales

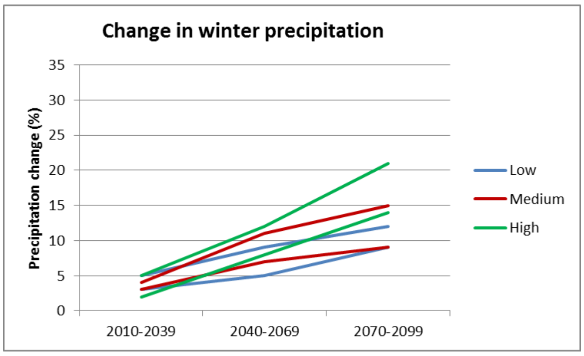
This zone covers the main town of Harrogate and numerous market towns such as Skipton, Richmond and Northallerton. It stretches from Richmond in the north to Harrogate and Skipton in the south; and on its eastern boundary it includes Ripon and Thirsk. The zone has a population of approximately 0.3 million, serves 159,000 homes and businesses and covers an area of 3,698km^2. Many customers in this zone are supplied by long stretches of overhead line.

Keeping our estimates conservative and using the medium emissions scenario at the 50th percentile, we would expect to see an increase of 3.5°C in summer and 2.8°C in winter mean temperature of by the end of the century. This would be combined with a 20% reduction in summer and a 12% increase in winter rainfall levels.







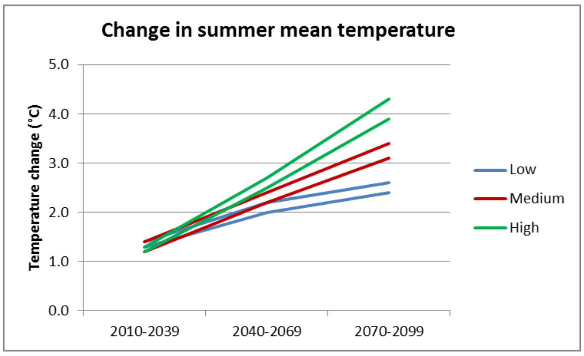


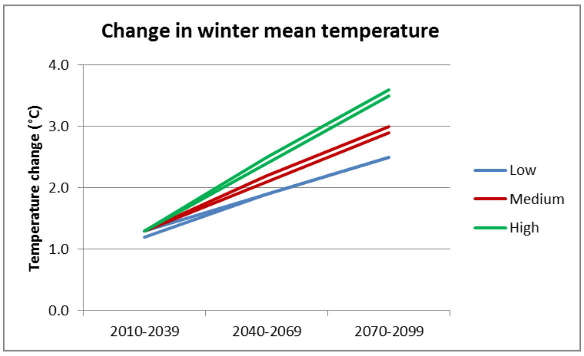
The zone includes the Nidderdale Area of Outstanding Natural Beauty and the Yorkshire Dales National Park. Within these areas we have 1,187km of overhead lines. We recognise the vulnerability of these lines and their environmental impact and we are working with the National Parks Authority and the AONB Partnership to underground these lines wherever possible.

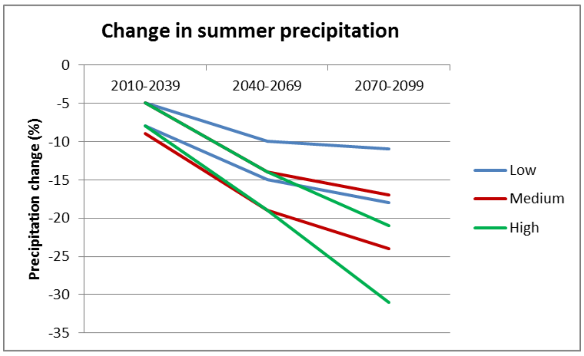
Yorkshire Moors & Wold

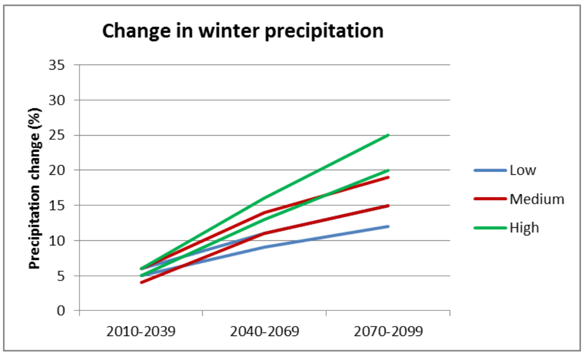
This zone covers the historical city of York and the main towns of Selby, Scarborough and Bridglington. It stretches from Whitby in the north to Hornsea in the south; and on its western boundary it is bordered by the A1/A19 corridor. The zone has a population of approximately 0.8 million, serves 280,000 homes and businesses and covers an area of 5,754km^2, making it our largest operating zone by area. Many customers in this zone are supplied by long stretches of overhead line.

Keeping our estimates conservative and using the medium emissions scenario at the 50th percentile, we would expect to see an increase of 3.2°C in summer and 2.9°C in winter mean temperature of by the end of the century. This would be combined with a 20% reduction in summer and a 17% increase in winter rainfall levels.









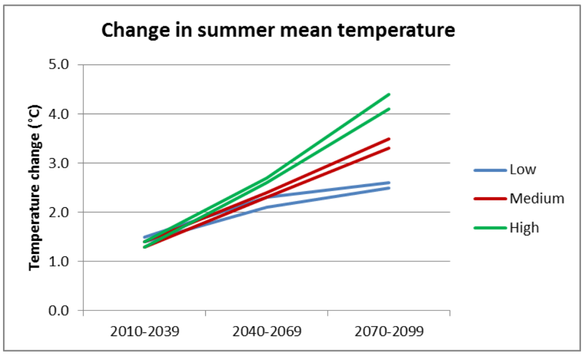
The zone includes the North Yorkshire Moors National Park, which incorporates a large stretch of the East Coast, and the Howardian Hills Area of Outstanding Natural Beauty. Within these areas we have 1,452km of overhead lines. We recognise the vulnerability of these lines and their environmental impact and we are working with the National Parks Authority and the AONB Partnership to underground these lines wherever possible.

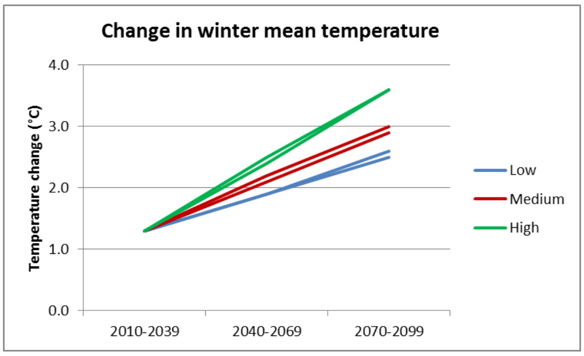
In April 2012, this zone was subjected to an unseasonable snow event and power was lost to 12,000 customers. There is a large amount of reinforcement work ongoing in this area to ensure that the extensive overhead line network remains fit for purpose throughout any future extreme events.

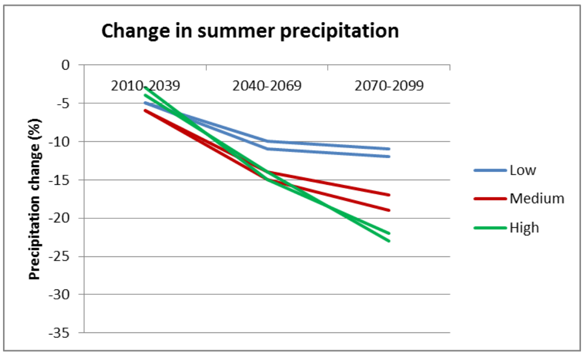
North Lincolnshire

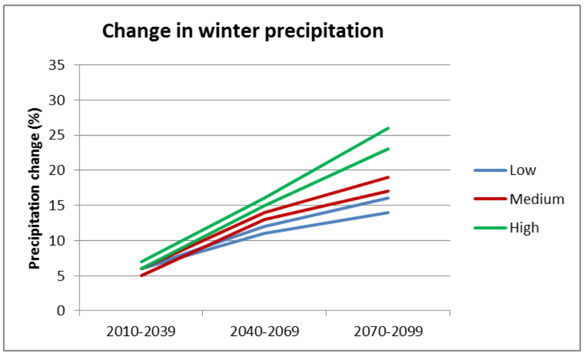
This zone covers the market towns of Louth, Gainsborough and Market Rasen. It stretches from the Isle of Axholme in the west across to the east coast. The zone has a population of approximately 0.2 million, serves 90,000 homes and businesses and covers an area of 1,934km^2. Many customers in this zone are supplied by long stretches of overhead line.

Keeping our estimates conservative and using the medium emissions scenario at the 50th percentile, we would expect to see an increase of 3.4°C in summer and 2.9°C in winter mean temperature of by the end of the century. This would be combined with an 18% reduction in summer and an 18% increase in winter rainfall levels.









The zone includes an area of the Lincolnshire Wolds Area of Outstanding Natural Beauty. Within this area we have 451km of overhead lines. We recognise the vulnerability of these lines and their environmental impact and we are working with the AONB Partnership to underground these lines wherever possible.

Appendix 12: Updated Table of Actions

Summary of actions (as set out in first round report)	Timescale over which action planned	Progress on implementing actions	Assessment of extent to which actions have mitigated risk	Benefits/challenges experienced
It is expected that flooding adaptation work for current known threats including climate change will be completed over the next ten years. Under the current Ofgem price controls, the following expenditure has been agreed on flooding resilience: In the DPCR period from 2010 to 2015 distribution companies have spent £73m with a further £100m planned to be spent in the RIIO period from 2015 to 2023.	2012 to 2021 for the Transmission System. 2015 to 2023 for the Distribution System.	On target. National programme details are held by Ofgem. Progress against the current programme was reviewed by the ASC in their July 2014 report. The ASC found that progress was being monitored and was on target.	Risks are being mitigated as the work proceeds to 2023 with sites prioritised on order of risk.	No loss of supply to customers during the severe weather in 2013/14 due to flooding at major substations operated by network companies.
ENA member companies s propose to engage in discussion with Ofgem and DECC with a view to agreeing revised design standards for overhead lines to take effect from the next price control review, starting in 2015.	The timescale is under review depending on further consideration of work carried out by EATL and other available data both in the UK and internationally.	Work has been carried out by specialist electricity network consultants EATL to consider overhead line ratings. However, the initial results from the study have shown that further work is necessary.	The risk being managed is a decrease in overhead line ratings leading to network overloading. However this is a complex subject and further work will be necessary before any firm recommendations can be made.	Improving understanding of the issues involved in this complex subject.
It is proposed to review critical industry standards	2015	ETR 138 covering substation resilience to flooding has been updated to take account of the latest data on surface water flooding. A review has started on ETR 132 covering resilience tree cutting and draft Terms of Reference are attached as Appendix 2	The inclusion of surface water flooding will provide additional resilience for key electricity substations and should ensure that supplies of electricity to the public are protected against failure of these assets due to the increasing risks of surface water ingress as a result of increasing rainfall.	Strengthened the relationship between electricity transmission / distribution companies and Defra, EA and SEPA.

Summary of actions (as set out in first round report)	Timescale over which action planned	Progress on implementing actions	Assessment of extent to which actions have mitigated risk	Benefits/challenges experienced
The scale of the change to "Smart Networks" is likely to be very large entailing the re-design and re-building of many circuits and substations. The resultant upgrade may be far larger than required to accommodate potential adaptation requirements and it will be necessary to understand these two requirements fully before companies submit their financial plans to Ofgem. Therefore, although it is essential to research fully the potential effects of climate change in order to understand the possible impacts and mitigations, it is probable that the scale of any network upgrades will be dictated by the drive to low carbon networks	Some initial impacts are expected during the current price controls to 2021 and 2023 but significant impacts are not forecast until the following price controls, currently scheduled to 2029 and 2031.	The industry has worked with DECC and Ofgem through the Smart Grid Forum to assess the impacts of Carbon Targets on Transmission and Distribution Networks and how these impacts can be most effectively mitigated by the combination of network reinforcement and the deployment of "smart network" technology. This has resulted in a number of reports, which have provided guidance to both the industry and the regulator on the likely timing of impacts and the most cost effective action that the industry can take to ensure reliable supplies to customers at minimum cost. In addition, Ofgem has introduced initiatives that encourage network companies to carry out research into innovative methods of managing the introduction of low carbon loads and generation on a very large scale. The largest initiative to date, "The Low Carbon Network Fund" had a maximum value of £500 million between 2010 and 2015 and has produced remarkable results with DNOs initiating a wide range of projects, many carried out with partners in manufacturing or academia.	The potential risk is caused by failing to understand the impact of low carbon technologies on transmission and distribution networks. The very wide and detailed research effort should ensure a very full understanding these risks and a range of cost effective initiatives that can be employed to mitigate the risks.	The initiatives outlined have advanced the industry's understanding of the risks and potential solutions, promoted partnership working with industry and academia and taken the UK into the forefront of this type of work internationally.

Summary of actions (as set out in first round report)	Timescale over which action planned	Progress on implementing actions	Assessment of extent to which actions have mitigated risk	Benefits/challenges experienced
The thresholds at which climate change will start to present a risk to companies is well understood for a number of impacts, e.g. increased temperature causing a reduction in equipment ratings. In these areas it will be necessary to monitor actual climate change effects and updated projections in order to ensure that planned adaptation activity is sufficient and timely.	Ongoing monitoring of actual climate impacts, initially over the current price controls to 2021 and 2023	This monitoring will be carried out in conjunction with the work on low carbon networks described above.	Risks will be mitigated as understanding of climate impacts and speed of change improves.	
In other areas of activity such as earthing systems and vegetation growth further work will be undertaken to identify the thresholds at which action needs to be taken. In addition, research into the impact of air conditioning loads, low carbon loads/generation and smart networks is already in hand and climate change impacts will be factored into this work to ensure that the thresholds are fully understood and appropriate action factored into programmes of work.	During the current price controls to 2021 and 2023	ETR 132 Risk based approach to resilience tree cutting is under review with a target to complete by December 2015. The other actions will be considered in the considerable R&D effort targeted at the development of smart networks for low carbon applications described above.	To be assessed and reported.	To be assessed and reported.
Low carbon networks and smart grids are an international issue and DNOs will be engaged in British, European and International Standards work to ensure standards are developed for the new networks and these will need to take account of the thresholds for climate change impacts on an international scale.	These standards are expected to be agreed during the period 2015-2017.	ENA is working closely with BSI and international standards committees to ensure that the UK is well represented in the development of new standards.	To be assessed and reported.	To be assessed and reported.

Summary of actions (as set out in first round report)	Timescale over which action planned	Progress on implementing actions	Assessment of extent to which actions have mitigated risk	Benefits/challenges experienced
Monitoring and evaluation Some of the issues will be company specific and it is expected that companies will establish their own individual monitoring processes and these will be monitored by Ofgem in future years via established processes. The industry approach to identification, risk assessment and development of mitigation plans for major substations at risk of flooding, provides an illustration of the way in which joint work on adaptation could be pursued. As described above, a Task Group was established under the ENA with membership from each of the member electricity network companies together with EA, SEPA, Met Office, DECC and Ofgem. A report was prepared by the group and submitted to the Energy Minister. That report has formed the basis of common standard submissions to Ofgem in the recent price control review and will be regarded by DECC as the industry standard, if necessary by referencing it in the guidance to the ESQCR in a similar manner to other ENA documents. Monitoring of progress on adaptation by Ofgem can then be facilitated via a common approach through the price control and the annual regulatory reporting processes which is companies' preferred approach. This process will continue to use latest information as it becomes available.	Ongoing and for flooding resilience, monitoring will be necessary over the current price controls for the next 8 years.	The recent ASC report confirmed that companies are monitoring progress against flooding and tree cutting resilience and this is being audited by Ofgem	To be assessed and reported.	To be assessed and reported.

Summary of actions (as set out in first round report)	Timescale over which action planned	Progress on implementing actions	Assessment of extent to which actions have mitigated risk	Benefits/challenges experienced
Ensuring a flexible response DNos will continue to work with ENA to review the latest information on climate change projections, including actual recorded climate change outcomes, and update action plans as necessary. This will include maintaining and developing the relationship with holders of key information including Defra, EA and the Met Office. DNOs will also maintain a dialogue with DECC and Ofgem as part of annual regulatory reporting and the periodic price control process. The general position regarding companies' resilience will be continually reviewed via the DECC, E3C bi-monthly meetings and the follow up work in the companies via ENA working groups.	Ongoing monitoring via established resilience groups	This monitoring is already in place through the following groups:- ENA : ACC Task Group, Emergency Planning Managers' Forum, Industry Standards Groups Other: Energy Emergencies Executive Committee (E3C) and associated Electricity Task Group. EA Facilitated--IOAF Cabinet Office led—Infrastructure Operators Security and Resilience Forum.		

Further or new actions planned	Risks addressed by action	Timescale for new/further actions planned
Information on surface water flooding has become more reliable and DNOs now consider it sufficient to justify additional flooding resilience measures. In view of this ETR 138 has been updated to include the management of surface water risk.	Surface water flood risk to grid and primary substation sites.	Protection works implemented by the end of the latest price controls finishing in 2023.

Appendix 13: Climate Conditions in Northern Powergrid Standards and Specifications

Transformers			
	Northern Powergrid Specification	External Design Standard	Climate Conditions
Temperature			
Max Ambient Temp Outdoor			40°C
Max Ambient Temp Indoor			40°C
Min Ambient Temp Outdoor			-25°C
Min Ambient Temp Indoor			-5°C
Overload Ratings Ambient Temp			40°C
Solar Radiation			
Solar Radiation			1000 W/m2
Lightning			
Lightning Impulse LV	NPS/003/0111	ENA TS 35-1	8kV
Lightning Impulse 11kV			95kV
Lightning Impulse 20kV			Ground Mounted – 123kV Overhead Connected – 200kV
Lightning Impulse 33kV	NPS/003/012 NPS/003/021	ENA TS 37-5	Ground Mounted – 170kV Overhead Connected – 200kV
Lightning Impulse 66kV			350kV
Lightning Impulse 132kV			650kV

Switchgear			
	Northern Powergrid Specification	External Design Standard	Climate Conditions
Temperature			
Max Ambient Temp Outdoor			40°C
Max Ambient Temp Indoor			40°C
Min Ambient Temp Outdoor			-25°C
Min Ambient Temp Indoor			-5°C
Overload Ratings Ambient Temp			40°C
Ice Loading			
Ice Loading Class			Class 10
Ice Loading			10mm
Solar Radiation			
Solar Radiation			1000 W/m2
Lightning			
Lightning Impulse LV	NPS/003/005	ENA TS 37-2	8kV
Lightning Impulse 11kV	NPS/003/006 NPS/006/014	ENA TS 41-34	95kV
Lightning Impulse 20kV	NPS/003/006 NPS/006/014	ENA TS 41-34	Ground Mounted – 123kV Overhead Connected – 200kV
Lightning Impulse 33kV	NPS/003/004	ENA TS 41-36	Ground Mounted – 170kV Overhead Connected – 200kV
Lightning Impulse 66kV	NPS/003/007 NPS/003/008	ENA TS 41-37	350kV
Lightning Impulse 132kV	NPS/003/007 NPS/003/008	ENA TS 41-37	650kV

Overhead Lines			
	Northern Powergrid Specification	External Design Standard	Climate Conditions
Mechanical Design Ratings			
LV lines	NSP/004/041	ENA TS 43-12	Wind Pressure: 380 n/m2 Ice: 9.5mm diameter
11 – 33kV	NSP/004/042 NSP/004/044	ENA TS 43-40 ENA TS 43-121 BS EN 50341	Wind Pressure: Normal altitude = 380 n/m2 High altitude = 570 n/m2 Ice: Normal altitude = 19mm dia High altitude = 25mm dia
66kV – 132kV Wood Pole	NSP/004/045 NSP/004/046	BS EN 50341 ENA TS 43-50	Wind Pressure: Normal altitude = 380 n/m2 High altitude = 570 n/m2 Ice: Normal altitude = 19mm dia High altitude = 25mm dia
66 – 132kV Steel Towers		BS EN 50341 ENA TS 43-125 ENA TS 43-7	Wind Pressure: 380 n/m2 Wind Speed: 25m/s Ice: Not < 60mm radial or 10mm radial (wind & ice)
Line Ratings			
LV lines	IMP/001/011		Min line design temp: -5.6°C Max line design temp: 75°C Wind Speed: 0.5 m/s Ambient Temperatures: Winter 2°C Spring / Autumn 9°C Summer 20°C Solar Gain: 1000 W/m2
11 – 33kV			
66kV – 132kV Wood Pole			
66 – 132kV Steel Towers			
Lightning Performance			
LV lines	IMP/001/099	BS EN 60071	
11 – 33kV			Lightning Impulse: 11kV = 95kV 20kV = 125kV 33kV = 200kV
66kV – 132kV Wood Pole			Lightning Impulse: 66kV = 325kV 132kV = 650kV
66 – 132kV Steel Towers			Lightning Impulse: 66kV = 325kV 132kV = 650kV Shielding Angle: 45°

Appendix 14: Northern Powergrid Summary Risk Assessment

SI Risk Register ID: 61 Author: Steve McDonald

Date: 26 February 2003

Executive Summary

1. Risk number SI 61 on the SI register is titled 'Climate change threatens future network performance'.
2. In the UK, there has been a trend towards warmer, wetter winters and hotter, drier summers over the last two or three decades. This trend is predicted to continue in the future and will impact on the operation of the business.
3. The impact of this hazard upon the business is that the design standards of apparatus installed on the network may not be appropriate to cope with the change in climate and the subsequent increase of events of extreme weather. The existing emergency procedures may not be sufficient to deal with such extremes.
4. In summary, the paper recommends that the SIRMM:
   - **accept** the risk associated with climate change to the existing system; and
   - **endorse** the risk management plan presented in this paper for mitigating and controlling the risk to the business from climate change.

Hazard

5. Global climate has changed over the past 100 years or more, and this has been accompanied by changes in the UK climate, principally a year round warming together with precipitation increases during winter and decreases during summer. One effect of this, has been an increase in the occurrence and severity of flooding events experienced within YEDL and NEDL in recent years with catastrophic effects on the company's infrastructure. The risks of flooding on company assets ad performance is covered by a separate document (RQD 004).
6. Climate change is a well documented and publicised phenomenon and vast amounts of research and data are available for review and interpretation. Although there is no specific detail available regarding wind speed or ice loading increases, the effect of climate change has many implications on the operation of the network for future years and poses a threat to the effectiveness of the company. The UK Climate Impact Programme (UKCIP) has determined a number of scenarios based on different predictions of CO2 emissions:
   - UK climate will become warmer (2 – 3.5°C by the 2080s)
   - High temperatures will become more frequent and cold winters will become increasingly rare
   - Heavy winter precipitation intensities that are currently experienced once every two years will become 5 – 20% heavier
   - For some east coast locations, extreme sea levels could occur between 10 and 20 times more frequent by the 2080s
7. The design standards for equipment operating on the network are such that they are appropriate to the operating conditions that are normally encountered. In most cases, apparatus operating on the network is equipped to function under broad ranges of temperature, moisture level, wind and ice loading. As climate conditions change over time, these design operating ranges may no longer be appropriate for the conditions that occur.
8. Loading on the network may become an issue due to increased use of air conditioning equipment during warmer summer months and heating systems during the winter.
9. Severe weather events or more extreme events may become more common place and the company may not be organised to react to such incidents.

Existing Measures

10. The current design standards for equipment operating on the network are such that they are appropriate to the operating conditions that are normally encountered, including severe weather, in the UK.

11. The Distribution Load Estimate (DLE) activity is used to predict the changes in load requirements in future years to enable proactive expansion of the network.

Consequence

12. The potential consequences of climate change are as follows:

- Nominal service life of assets reduced
- Increase in operating costs to the business through increased specification requirements of equipment
- Increase in failures of overhead lines due to wind and ice loading beyond the capability of the equipment through extremes of conditions and more frequent occurrences
- Failure hierarchy of overhead line structures may no longer be appropriate
- Increase in severe flooding events and costs associated with flood protection works
- Increase in demand from customers to power air conditioning and additional heating
- Current emergency response procedures insufficient for the frequency and severity of events e.g. staffing, vehicular access, pole erection
- Current procedures for reacting to severe events may be inappropriate, e.g. load shedding

Issues

13. It is difficult to accurately quantify the effects of climate change over a relatively short period of time, say the next 20 years, but the general trend of increased rainfall is likely to predominantly affect the risk of flooding at operational and non operational sites.

14. The potential effects of climate change will grow in future years and will be gradual. Without proper attention at an early stage, the company may be not be adequately prepared for these changes.

Assessment of Options

15. We could continue to operate the apparatus on the network to existing design standards to get maximum life from our assets and at the time of replacement, review the operating conditions equipment may be subjected to and revise standards as appropriate.

16. Review of equipment utilised in other DNO's and in other countries where extremes of climate are the norm. This would give an understanding of how those companies specify equipment to deal with these extremes (e.g. Holland Floods, Scandinavian snow and ice conditions).

17. Detailed review of all existing research on climate change to establish reliable sources of data and a firm understanding of the likely conditions to be expected in future years. Using this data, the design standards of equipment could be reviewed to establish new equipment specifications going forward.

18. Review of Emergency planning procedures and operational response issues for severe weather events and natural disasters.

19. Consider potential implications of climate change as part of the DLE review process.

Conclusions

20. It is clear that more extreme weather events will continue to occur and adversely affect the apparatus on the network unless proactive measures are taken to deal with changes in the future. The existing standards and procedures are in place to cope with extreme situations, but further work

will be required to ensure the company is prepared for even more onerous conditions. Further understanding of climate change will be required to enable the appropriate response to be made.

Recommendations

21. In summary, the paper recommends that the SIRMM:

- **accept** the risk associated with climate change to the existing system; and
- **endorse** the following risk management plan.

Action Ref	Mitigating Action
1	Archive risk for annual review
2	Consideration given to climate change for new or modified policy / standards
3	Detailed review of all existing research on climate change to establish reliable sources of data and potential impact on design standards
4	Consider implications of climate change when emergency planning procedures are reviewed
5	Consider implications of climate change during DLE review process

Appendix 15: Designing Out Flood Risk

Substation sites protected by a bund wall with gate access

Raised building floors with step access.

Bund wall protecting a site

Bund wall under construction

Incident Response Vehicle designed to carry:

- Multiple water pumps & hoses
- PPE & safety equipment
- Chemical sand bags
- Cleaning / hygiene stock
- Welfare equipment incl. food
- Communications incl. PMR & Mobile
- Additional lighting / generation
- Oil containment kit
- Ladder & tools
- Vehicle will:
- Carry 6/7 people
- Drive through 1m of flood water
- Carry everything to be self sufficient.

(Photo courtesy of WPD)

Temporary Flood Barriers

Substation site protected during a flooding incident