JULY 2016

nationalgrid

Climate Change Adaptation Reporting

Second Round Response

NATIONAL GRID
ELECTRICITY TRANSMISSION Plc

Climate Change Adaptation

Second Round Adaptation Response

National Grid Electricity Transmission UK

Contents

1. Introduction

National Grid owns and operates the high voltage electricity transmission system in England and Wales and operates the GB transmission network. As system operator (SO) for England and Wales, we coordinate and direct electricity flows onto and over the transmission system, balancing supply and user demand. We have the same SO role for the two high voltage electricity transmission networks in Scotland and for the offshore electricity transmission network.

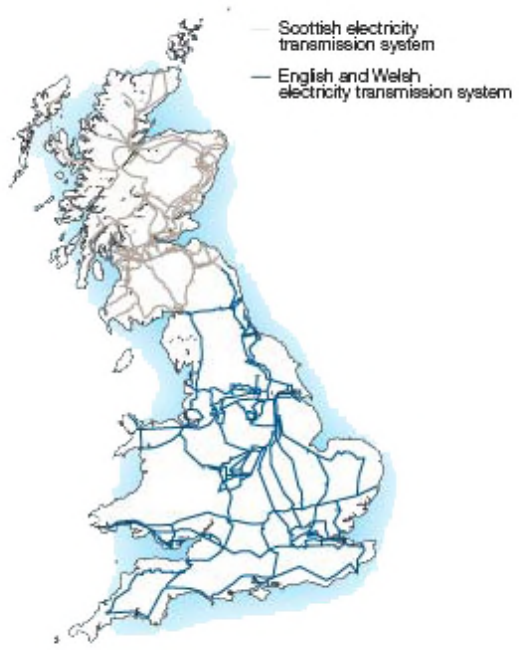
The structure and content of this response has been developed collaboratively by the Energy Network Association (ENA) Electricity environmental subgroup which consists of electricity distribution and transmission network operator members of ENA. The Energy Networks Association (ENA) is the industry body for UK gas and electricity companies. The collaborative approach used the questionnaire template provided by Defra and the Adaptation Sub-Committee ASC as part of the Climate Change Adaptation Reporting Power "guidance for organisations who want to update the government on progress since the first round of adaptation reporting".

This response presents progress made since the First Round of reporting in 2010 reflecting the common issues faced in addressing risks of climate change and maintaining asset resilience. It does this by using the Defra guidance questionnaire as a basis for individual reports identifying issues common to electricity network companies across the UK. It also includes company specific information such as the risks to our assets from climate change, and the actions and plans in place to mitigate these risks.

National Grid has undertaken flood mitigation work for tidal and fluvial flood risk to exponentially reduce the current level of risk through a prioritised investment programme. This work is embedded in our agreed regulatory business plans. Investment has been optimised to focus on the highest risk priority 1:100 year flood risk sites, with further investment in mobile flood barriers.

All electricity transmission and distribution networks are regulated monopoly businesses operating under licences issued by Ofgem. Allowed revenues for the industry are currently set by Ofgem every eight years under the RIIO (Revenue = Incentives + Innovation + Outputs) Price Control Review framework and these reviews govern the costs and income associated with operating regulated activities.

2. The UK Electricity Network



3. National Grid

National Grid owns and operates about 8,500km of high voltage overhead and underground lines that constitute the electricity transmission system in England and Wales and operates the GB transmission network. As system operator (SO) for England and Wales, we coordinate and direct electricity flows onto and over the transmission system, balancing supply and user demand. We have the same SO role for the two high voltage electricity transmission networks in Scotland and for the offshore electricity transmission network.

4. Adaptation – First Round Reports

The Climate Change Act 2008 provides the framework for ensuring the UK's ability to adapt to climate change. Defra established an "Adapting to Climate Change" Programme and in November 2009 laid a strategy before Parliament for using the Adaptation Reporting Power under the Act to request adaptation information from companies. National Grid were approached directly by government to respond to the First Round of Adaptation Reporting in 2010, which was designed to:

- Assess the current and predicted impact of climate change in relation to the companies' functions; and
- Outline the proposals and policies for adapting to climate change in the exercise of those functions and the timescales for introducing those proposals and policies.

The Reports therefore represented individual company assessments of existing assets and business processes and identified areas where the environment is capable of impacting the ability to meet its business objective.

This formed part of the process of ensuring the businesses adapt to the expected climate changes including hotter and drier summers, warmer and wetter winters, coastal, river bed and bank erosion and increasingly extreme weather events such as flooding. The main categories of weather events and environmental risks were identified as follows:

- Flooding and heavy rain fall (including saturated ground conditions);
- Snow and ice;
- Increases in temperature, heat waves and drought conditions;
- Coastal erosion from sea level rise;
- River erosion; and
- Storm events and high winds.

Using information drawn from United Kingdom Climate Projections 2009 (UKCP09) and working alongside the Meteorological Office Hadley Research Centre, the Environment Agency and the Scottish Environmental Protection Agency, the key risks and opportunities facing the businesses were identified. High emissions projections to 2050 and 2080 were used to determine worst case scenarios and for correlation against the lifetimes of existing assets. Account was taken of the expected increase in number, frequency and intensity of weather events.

The risk methodology and categorisation identified a number of potentially vulnerable areas and the mitigation measures that were either in place or needed to be developed further. Decisions on the appropriate controls are dependent on the accuracy of the supporting information and data and whether a quantitative or qualitative assessment has been made.

The Reports highlighted that network assets and processes may be vulnerable to certain aspects of climate change. However, the national and regional infrastructure has a significant degree of resilience to these impacts and none of the identified risks were considered to be high. The management of these risks is now

embedded within companies' overall risk management processes to ensure that any appropriate actions are recorded and completed. Responsibility and ownership of these action plans ensures their timely delivery and climate change adaptation is also subject to the same level of ongoing review and evaluation as other business risks.

Revenue is determined by Ofgem price control mechanisms (currently RIIO- Transmission 1– Revenue = Incentives + Innovation + Outputs) and dictate the expenditure by the businesses, including the level of adaptation investment. Any increase in adaptation related costs will be required over longer medium to long term timescales however.

Any inherent risk to the networks due to change in climate is largely due to the majority of Electricity Transmission assets being above ground where they are exposed to the elements and subject to the climate change parameters as mentioned above.

In addition prolonged periods of extreme weather could have a significant impact on the ability of the workforce to access and carry out their roles, particularly field-based engineers. They could also impact on the ability to conduct 'business as usual' activities as a result of the reliance on appropriate adaptation of other major infrastructures, such as telecommunications and transport. Impacts on the operation of supply chain businesses and the continued availability of equipment also needs to be considered. The environmental impact of companies' assets could be affected by the mobilisation and migration of land contaminants from flooding and ground saturation.

These interdependencies can be mitigated through the implementation of maintenance and inspection regimes, the development of flood defence measures, the availability of necessary equipment, up to date contingency measures and ensuring Business Continuity Management Plans are in place.

5. Understanding climate risk

5.1 How has your understanding of climate risks, impacts and their effects on your sector/organisation and stakeholders advanced since your first round report?

There has been no significant change in the understanding of climate change risks since the first round of Adaptation Reports were submitted in 2010/11. This understanding was based on the UKCP09 data published under the Climate Impacts Programme (UKCIP) that forecast the risks under various scenarios to the end of this century.

The UKCP09 data does continue to provide a valid assessment of climate change impacts.

There have been a number of significant weather events in the UK since 2011, notably the very extreme wet and stormy weather in the UK during the winter of 2013/14, that emphasise the importance of planning for the type of extreme event that could become more common with climate impacts, particularly flooding.

Flooding presents the most serious climate risk to electricity networks, both today and in the future as a result of increased rainfall and higher sea levels. To mitigate this risk National Grid are carrying out a programme of flooding resilience work that will continue to 2021. Resilience measures already in place at our electricity transmission installations have prevented any loss of supplies from National Grid sites due to flooding.

Information on surface water flooding has become more reliable following the work of the Engineering Technical Report 138 (ETR 138) task group and the resulting issue by the ENA of “Resilience to Flooding of Grid and Primary Substations” issue 2 which includes the management of surface water risk and guidance on reservoir risk assessment.

5.2 What climate change evidence or research have you used to better understand the implications for organisational functions?

The Companies are still reliant on UKCP09 as the primary source of information and data and which remains the only such reference available. Updates from the Climate Ready service or other updated research data would therefore be welcomed. The UKCP09 data does continue to provide a valid assessment of climate change impacts.

The greatest climate threat to networks is currently assessed to be flooding. This applies to present risks and as a result of predicted climate change.

Following the 2007 floods in the UK an Industry Task Group was set up to assess 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 Networks Companies, Government Departments and Agencies and the Industry Regulator.

Electricity network 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.

All National Grid planned flood protection is due to be complete by 2021, the end of the current regulatory price control period, with higher risk sites being completed early in the programme. On low risk sites we are deferring investment in these defences. This is to ensure that the timing of any investment is appropriate to the level of risk and allows for asset value and the development and operation of the transmission network. This approach allows us to optimise our investments. We manage the shorter-term risk on these sites through utilising our mobile barrier system. This strategy allows for greater flexibility in utilising new technologies and techniques and manages the high levels of uncertainties on these very low risk sites.

As detailed in our First Round Report, UK electricity networks companies have carried out two research projects with the UK Met Office that investigated the potential impact of climate change on energy companies.

The initial project was a ground breaking initiative that brought climate science closer to business applications. This was 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.

A second project was commissioned with the Met Office to build a risk model that quantifies the relationship between climate and network faults, and also the vulnerability and exposure of the network to these faults. This model includes climate projections to assess how network resilience may be affected by climate change.

In order to increase National Grid's awareness of the longer term risks we participated in the EPSRC-funded Resilient Energy Networks for Great Britain "RESNET" project within the ARCC[1] suite of projects. The aim of RESNET was *"to develop and demonstrate a comprehensive approach to analysis, at a national scale, climate related changes in the reliability of the UK's electricity system, and develop tools for quantifying the value of adaptations that would enhance its resilience." The outcomes form this project are summarised in Appendix 2. A brief summary report is also available* through the ENA Smarter Networks portal http://www.smarternetworks.org/Index.aspx?Site=et

Electricity networks are currently engaged in further 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.

5.3 Has your understanding of thresholds of climate impacts advanced to better pinpoint organisational vulnerability? If so, how?

UKCP09 provides climate information for the UK up to the end of the century. The projections show three different scenarios representing high, medium and low greenhouse gas emissions levels. Information is provided on observed climate data, future climate projections and future marine and coastal projections. These scenarios are still being used and remain the best existing available information.

National Grid 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.

National Grid is now seeking to take the current understanding of flooding further and better establish secondary vulnerabilities from flooding and its role in driving the rise in geo-hazards and the potential for this to further increase.

Flood mapping for surface water has been improved for England and Wales and the industry guidance on flood protection has been updated to take this into account. Similar information is also expected for Scotland.

5.4 How have you developed your quantified assessment and analysis of risk likelihood and impacts?

The original round of Adaptation reporting provided networks with increased confidence in the level of resilience in our asset infrastructure and this allowed the companies to focus on the remaining areas of risk. The existing risk assessments have been reviewed and confirmed as being still fit for purpose and the current risk ratings remain the same based on the available data.

National Grid has expanded the breadth of our risk assessment from our First Round Reporting to include a wider range of natural hazards. We have also assessed 'hazard interaction' to understand how natural hazards interact from a Climatic, Geological or Environmental perspective. No new material risks have been identified, with this process giving us a broader view of the potential risks posed by climate change

A detailed updated assessment of National Grid Electricity Transmission risks is presented in Appendix 1.

[1] Adaptation and Resilience in the Context of Change

Hazard	Climatic, Geological or Environmental Hazard	Assets						Processes and procedures				Short to medium term Impacts 0 - 25years		Long term Impacts 25 years +	
		Substations	Other sites	Existing bridges	Existing Tower assets	Existing Cable assets	New sites and Assets	Emergency Repair	Main Const and Repair	Control Centre	Office Staff	Impact increasing / decreasing concern	Data confidence increasing / decreasing	Impact increasing / decreasing concern	Data confidence increasing / decreasing
Solar Heat	Extreme temperature											↑	↑	↑	↑
	Drought											↑	↑	↑	↑
Fire	Wildfire											↑	↑	↑	↑
												↑	↑	↑	↑
	Polluted ground fires, Old mine workings											↑	↑	↑	↑
Lightning	Increased severity/ intensity of storms											↑	↑	↑	↑
	Increased frequency of storms											↑	↑	↑	↑
Wind and gale	Increased severity/ intensity of storms											↑	↑	↑	↑
	Increased frequency of storms											↑	↑	↑	↑
Snow & Ice	Increased severity/ intensity of storms											↑	↑	↑	↑
	Increased frequency of storms											↑	↑	↑	↑
Flooding	Pluvial - surface water burst water mains											↑	↑	↑	↑
	Fluvial river and coastal flooding											↑	↑	↑	↑
	Reservoir / Canal failure											↑	-	↑	↑
	Sea Level Rise											↑	↑	↑	↑
Erosion												↑	↑	↑	↑
	Coastal											↑	↑	↑	↑

Hazard	Climatic, Geological or Environmental Hazard	Assets						Processes and procedures				Short to medium term Impacts 0 - 25years		Long term Impacts 25 years +	
		Substations	Other sites	Existing bridges	Existing Tower assets	Existing Cable assets	New sites and Assets	Emergency Repair	Main Const and Repair	Control Centre	Office Staff	Impact increasing / decreasing concern	Data confidence increasing / decreasing	Impact increasing / decreasing concern	Data confidence increasing / decreasing
	River - bank stability and scour											↑	↑	↑	↑
	Surface water – scour											↑	↑	↑	↑
	Ground water – Geo Hazards											↑	↑	↑	↑
	Landslips, slope stability ground creep avalanche											↑	↑	↑	↑
Earthquakes	Natural Earthquakes											-	-	-	-
	Fracking											-	-	↑	↑
	Undersea landslip (Tsunami)											↑	↑	↑	↑
Volcanic												-	-	-	-
	Lahar - Inc. Mudflows											-	-	-	-
	Ash											-	-	-	-
Air Quality Pollution and Bio Hazards	Aero Allergens											-	↑	-	↑
	Pollution											↑	↑	↑	↑
	Industrial incident - Internal and external											-	-	-	-
	Diseases, Contagions and Epidemics											↑	↑	↑	↑
Space	Space objects											-	-	-	-
	Solar Storms											-	-	-	-

All electricity network operators 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.

Whenever a customer loses supply details of that interruption are recorded by Transmission and Distribution companies. Distribution networks are more adversely 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. Historic data is available covering the last thirty years with the quality of the data improving significantly over the last fifteen years since the introduction of the Ofgem Interruptions Incentive Scheme (IIS).

ENA Engineering Recommendation G43-3 (Instructions for Reporting to the National Fault and Interruption Reporting Scheme) 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, blizzard, 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 was aggregated at that level, companies actually capture data to a more detailed level, attributing faults to one of 99 different direct causes specified in 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.

6. Understanding uncertainties

6.1 What uncertainties remain in monitoring and evaluating climate risks to your sector's/organisation's functions?

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.

When CP09 is updated by UKCP18 it would be helpful if there was a better understanding of probable event frequencies and relationships.

6.2 What new uncertainties have come to light?

As indicated in Section 5.4 there are now increased concerns about interdependencies between weather events such as very strong winds following prolonged rainfall.

6.3 What further implications do uncertainties have on action your sector/organisation has taken or plans to take?

Any emerging uncertainties will be captured within the risk management approach and addressed within business work plans. This process needs to ensure that any asset investment made is necessary, timely and appropriate

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, must be agreed with Ofgem. This includes any work required to adapt to climate change. Therefore it is extremely important that the industry develops its Adapting to Climate Change (ACC) plans with the regulator to ensure that plans and supporting information meet network operators' and the regulator's requirements.

At present 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 our approach to risk management and information will be shared with the sector via the ENA.

6.4 What progress have you made to address information gaps?

National Grid are working and collaborating with a number of research partners, on a large number of projects that have or will have research papers developed in their own right. The list below gives a flavour of some of the research we are involved in - for more detailed information on these projects please contact us.

- Ongoing investment into flood mitigation on substation sites.
- We are continually working with the Environment Agency (EA) to understand the latest surface water flooding information and update national flood protection guidance.
- The Resilient Energy Networks for Great Britain project (RESNET) see Appendix 2.
- 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.
- Electricity Network 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 each year to discuss the forecast for the following winter and the likely consequences with industry emergency planners and operational managers.

- We have carried out an assessment of the potential of increased 'micro quakes' (magnitude 2.0 or less) which may lead to an increase in stability and maintenance issues. This has shown that whilst there is evidence that there may be an increase in micro quakes, unless there is a significant increase in earthquakes from magnitude 4 or above there should be little impact.
- We are working with the British Geological Survey (BGS) developing an assessment of National Grid sites and assets potentially at risk from individual geo-hazards and the potential of increased risk when combined with all forms of flooding. This project will help us understand which assets may be at an increased vulnerability to the secondary impacts from flooding, such as an increased exposure to erosion and geo-hazards. We have carried out an assessment of which sites and assets are within a geo hazard and flood risk area to evaluate a combined risk potential.
    - Developing a potential cost effective real time geo-hazard monitoring system - PRIME (proactive infrastructure monitoring and evaluation).
- We are working with Liverpool University in developing alternative solutions to combat coastal erosion and flooding. This uses techniques such as sandscaping. Sandscaping is the process of positioning sand to allow natural tidal patterns to nourish beaches, creating new land, which reduces coastal flooding and erosion.
- We are working with Defra to understand the potential system risk from generation constraints during prolonged drought periods. While this is a low risk in Great Britain, it is part of our approach to consider a wide range of risks and how they interact with other climate risks.
- Working with NERC to in order to steer and guide research so that it is more relevant to the areas of risks and gaps in knowledge we seek to understand. This has led to our direct involvement in a number of ongoing proposals under consideration and established research projects.

6.5 What are the strategic business and methodological assumptions that underpin your analysis of impacts and risks?

Company business strategies are driven by both asset life cycles and the regulatory framework within which the sector operates.

The strategic business and methodological assumptions have not changed substantially since the First Round. Our strategy is driven by a number of factors including the following key issues:-

- The absolute need to keep customers/public and employees safe
- The regulatory framework
- Reliability
- Asset life cycles
- And finally, ensuring that customers receive a very high level of service.

These issues were all covered in the first round reports. However, there is no doubt that the winter storms and the subsequent DECC and Ofgem reviews have focussed companies on the critical importance of planning for severe weather events and our processes have been revised and strengthened as a result.

As discussed in the First Round, a particular aspect of electricity networks is that many of the assets have very long lives, typically 30 to 80 years and this means we take account of predicted climate change impacts when planning new installations or safeguarding existing key equipment.

7. Addressing Barriers and Understanding Interdependencies

7.1 Where you've identified interdependencies, how have these assisted or hindered actions to address climate risk?

The First Round Reports highlighted key interdependencies with other sectors, some of which were not previously required to report via the mandatory process.

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 important role is being developed by the Infrastructure Operator's Adaptation Forum, facilitated by the Environment Agency climate ready team, and electricity network companies will play a full part in any collaboration projects that are initiated by this Forum

There are particular concerns regarding transport systems to enable access to key sites and telecommunications for control room SCADA[2] and voice communications. While this is a low risk for National Grid assets we continue to monitor and assess.

There are interdependencies between improving climate knowledge and the current eight year 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.

7.2 What were the main barriers to implementing adaptation actions and why?

UKCP09 continues to provide a valid assessment of climate change. There is 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.

It remains difficult to accurately predict the level of funding needed by the regulated businesses for long term adaptation measures due to the current periodic price control investment cycle. A detailed process of assessment led to Ofgem determining the allowed level of revenue and investment for the companies only covering the period from 2013 – 2021, including any expenditure required for adaptation.

7.3 Have new barriers been identified? Are these being addressed? If so, how?

Only one potential barrier has been identified and that is 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 network companies to have confidence that this type of scheme will provide secure protection in the very long term and that responsibility for the construction and maintenance of the flood protection measures are clearly defined and agreed.

[2] SCADA—Supervisory Control and Data Acquisition

8. Monitoring and Evaluating

8.1 How effectively has consideration of climate change risks been embedded within your sector or organisation?

There is an increasing level of awareness within the companies 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 ENA, the industry body for the sector. ENA represents both the electricity and gas network companies providing opportunities for further liaison and learning opportunities, as all energy sector companies are designated as Reporting Authorities and share some common issues.

Climate change risks are now recognised and monitored at Board level within ENA member companies.

The Committee on Climate Change, Adaptation Sub-Committee (ASC) produced a Progress Report in July '14 —"*Managing climate risks to well-being and the economy"*. This report assessed the state of resilience to weather and climate of infrastructure, businesses, health care system and emergency services. It is therefore particularly pertinent for electricity networks. ENA, together with network companies, provided evidence to the ASC.

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 the electricity transmission and distribution 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.

8.2 How effective have organisational monitoring and evaluation processes been to ensure adaptation responses are implemented and on track? If these have not been effective, what barriers prevented this?

National Grid has incorporated the key actions detailed in the First round of Reports in our company business plans.

National Grid has undertaken flood mitigation work for tidal and fluvial flood risk to exponentially reduce the current level of risk through a prioritised investment programme. This work is embedded in our agreed regulatory business plans. Under the current regulatory price control National Grid has £153m allocated to network resilience, flooding and physical security. Investment has been optimised to focus on the highest risk priority 1:100 year flood risk sites, with £17m of investment at these sites. Other at risk sites have £136m of allocated investment with a target of completion by 2021. Approximately £3 Million has been invested in interim mobile flood defences with supporting equipment and bespoke porting facilities.

As a specific example, in 2007 National Grid experienced flooding at its Walham substation in Gloucestershire which attracted a significant amount of media attention. As a result, permanent flood protection was installed at the substation. The two contrasting aerial photographs below show the effectiveness of flood actions by National Grid.

Walham during 2007 flooding

Walham with permanent protection 2013

8.3 How effective were monitoring and evaluation processes in determining how the organisation/sector handled recent extreme weather conditions?

Electricity network companies manage emergency response to weather related issues on a regular basis, sometimes several times in a year, and therefore have well developed and practiced emergency planning procedures, including a mutual aid agreement. The planning of emergency responses in all conditions is therefore part of business as usual practice, and whilst every severe weather episode provides learning and continuous improvement opportunities, National Grid's Transmission business managed the recent extreme weather conditions without significant unforeseen problems. No unforeseen changes to the sector approach to adaptation have been identified from these events.

8.4 Has the sector/organisation identified any financial benefits from implementing adaptation actions? Perhaps through cost benefit analysis, fewer working days lost, more efficient operations etc?

Minimal financial benefits have been identified by the companies to date, but there is an appreciation of the benefit of early adaptation response where necessary to help mitigate future costs. The costs incurred in resourcing adaptation related work are subsumed within planned operational expenditure.

On sites where the flooding risk is very low National Grid has taken a more prudent incremental deferred investment approach which manages the flooding risks until greater certainties of the risks and future of the sites can be established.

8.5 Has there been sufficient flexibility in the approach to adaptation within the sector/organisation, which allowed you to pursue alternative courses of action? If not what remedial measures could you take to ensure flexibility?

The industry operates within a flexible approach to providing 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.

9. Opportunities and Benefits

9.1 What action have you taken to exploit opportunities?

National Grid have strengthened our relationships with key organisations including Defra, EA, SEPA and the Met Office.

National Grid is directly involved with NERC in order to steer and guide research so that it is more relevant to the areas of risks and gaps in knowledge we seek to understand. This has led to our direct involvement in a number of ongoing proposals and established research projects. Many of these projects are in initial stages.

9.2 How effective were your efforts?

The work with EA has resulted in an important strengthening of substation flooding resilience measures as described in Section 5 & 8.

10. Progress

10.1 Do you consider actions set out in your progress update have allowed your organisation to build adaptive capacity? If so, how?

Long term asset assurance is an essential component of the long term business strategies of the electricity network companies. The Adaptation Reporting and monitoring process has not only provided confidence in the existing framework and plans, but has also contributed to building adaptive capacity as part of a wider framework of business as usual processes. Existing controls were in place for the most serious risks, but there has been an increased awareness in other areas such as increased vegetation growth, urban heat islands and reduced equipment ratings.

10.2 Do you consider that your organisation is more aware of and resilient to the likely impacts from a changing climate? If so, in what ways?

Yes, through climate considerations being built into the asset management and risk management processes.

Exemplars

10.3 Do you feel the actions listed in the update are exemplar? If so, how?

The industry considers that the action it has taken on flooding resilience is an exemplar because the approach taken is held up as an exemplar by the Infrastructure Operators Adaptation Forum which is facilitated by the Environment Agency climate ready team.(Details are published on the IET web site.)

The Committee on Climate Change, Adaptation Sub-Committee (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. The ASC praised the preparations of the networks industry for its activity in climate change adaptation and its preparedness to address key challenges.

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. They reported less evidence available within most other sectors.

The ASC noted that the electricity transmission and distribution 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. The process includes an assessment of the risks from climate change.

10.4 Would you be willing to develop a case study to highlight best practice in conjunction with Defra and the Climate Ready Support Service?

Yes.

11. Challenges

11.1 Where and why have challenges been experienced when making progress on actions?

There have been some challenges in understanding the specific impacts of flooding on certain sites and these will be detailed in companies' separate reports.

The lack of any clear indication of the likely impact of climate change on maximum wind speeds is concerning and the industry will continue to work with the Met Office and academia to better understand the likely impacts.

In this regard, discussions have been held with EU representatives on a proposed EU funded research project to consider climate modelling and impacts.

The use of UKCP09 whilst appropriate has in some cases not been an easy task for less experienced business users we would seek a much more 'user friendly layman' version as part of UKCP18 National Grid participates in UKCP18 workshops.

11.2 Were these challenges expected or have they come to light as part of the process?

The uncertainties with current climate modelling techniques are known and these clearly present a challenge. As this information is enhanced it will be possible to fine tune adaptation responses.

In addition, some challenges have arisen during the process, such as the detailed impact of flooding on certain sites.

11.3 Have climate change communications issues been encountered that Defra/the Climate Ready Support Service or sector bodies/the Regulator could help to address?

The development of further research (such as projected climate impacts rather than just forecasts alone) and consistent parameters have already been outlined as potential areas that haven't moved forward from the submission of the first Adaptation Report, and where additional support would be welcomed by the sector.

In addition, understanding the approaches taken in other sectors is always helpful and this is currently being achieved through the Infrastructure Operators Adaptation Forum (IOAF) which is facilitated by the Environment Agency climate ready team.

12. Interdependencies and barriers

12.1 What challenges have been experienced working through the issues related to interdependencies and barriers?

Establishing clear climate scenarios that all sectors can use to help identify and manage interdependencies has been identified as an issue; this will ensure that all sectors, including those that were exempt from the first round of reporting, are equally advanced in their response to adaptation.

Going forward it is important to address the challenge of aligning both national and international progress on climate change adaptation (and mitigation).

12.2 How effectively and in what ways have barriers been tackled?

As noted above, this is currently being achieved through the Defra sponsored IOAF.

12.3 What wider actions, outside your organisation, within trade bodies, regulators or through government, do you think are necessary to address barriers?

Where issues are identified by the IOAF that cannot be resolved, it is expected that they will be discussed with relevant regulators/regulators group or appropriate government departments to find a solution.

Appendix 1 - Risks

National Grid Electricity Transmission plc Climate Change Adaptation Risk Assessment

Key Assets and Processes		Specific Physical Characteristics of Climate Adaptation Scenarios										
		UKCP09 Characteristics				Met Office Characteristics					NG Characteristics	
Electricity Transmission Assets		**Solar Heat - Temperature rise of up to 8°C**	**Increased Heavy Rainfall (by a factor of 3.5)**	**Sea Level Rises of up to 43cm**		**Increased Lightning**	**Increased Wind and Gale**	**Increased Snow, Sleet, Blizzard, Ice and freezing fog**	**Increased Flooding**		**Increased Coastal / River Erosion**	**Increased Subsidence**
On National Grid Risk Register		**Yes**	**Yes**	**Yes**		**Yes**	**Yes**	**Yes**	**Yes**		**Yes**	**Yes**
Substation Sites (Incl. switchgear, transformers, earthing)		Temperature increases may have an impact on equipment ratings. National Grid sees this as a potential longer term issue that may be managed through changes in operational practices; Under current evidence there is very little firm evidence to justify changes to design standards More work is required to better understand any potential impact and will be carried out once UKCP18 is available	Site drainage may not cope with a sustained extreme rainfall event Work is required to understand the level of an event to impact a site Sites have resilience to Pluvial (flash flooding) to a depth of approximately 300 mm	Shore line management plans currently being reassessed by the EA indicate that a number of sites may be at an increased risk from sea level rise. The level of risk will be subject to what mitigation, ongoing defence options are adopted, improved maintained by the EA announced in 2011		Electrical equipment is designed to withstand lightning impulse levels e.g. a lightning strike Refer to Overhead Line section of this table	Existing design standards account for extreme weather conditions Substation equipment is designed to an relevant wind speed of: 34 m/s (76 mph)	Heavy snowfalls would not normally affect the operation of a substation but ice loading is an issue for which there are existing design standards: Ice Loading: Class 10 (10mm)	A site may become non-operational due to flooding potentially leading to a loss of system resilience or a loss of supply A non-operational site may not lead to a loss in supply		Shore line management plans currently being reassessed by the EA indicate that a number of sites may be at an increased risk from erosion The level of risk will be subject to what mitigation, ongoing defence options are adopted, improved maintained by the EA announced in 2011	Substation sites are normally built on level land so land slip is not generally an issue Substation subsidence issues are being managed via current regulatory allowances and extremely unlikely to impact customer supplies
Expansion of Existing Substation Sites (outside of existing boundary)		Under current evidence there is very little firm evidence to justify changes to design standards Potential impacts of climate change would be evaluated on a case by case basis	Managed by planning policy	Shore line management plans currently being reassessed by the EA indicate that a number of sites may be at an increased risk from sea level rise The level of risk will be subject to what mitigation, ongoing defence options are adopted, improved maintained by the EA announced in 2011		Electrical equipment is designed to withstand lightning impulse levels e.g. a lightning strike Refer to Overhead Line section of this table	Existing design standards account for extreme weather conditions Substation equipment is designed to an relevant wind speed of: 34 m/s (76 mph)	Heavy snowfalls would not normally affect the operation of a substation but ice loading is an issue for which there are existing design standards: Ice Loading: Class 10 (10mm)	Design standards (PPS 25 and ETR 138) of assets and sites account for extreme weather conditions		Shore line management plans currently being reassessed by the EA indicate that a number of sites may be at an increased risk from erosion The level of risk will be subject to what mitigation, ongoing defence options are adopted, improved maintained by the EA announced in 2011	Substation sites are normally built on level land so land slip is not generally an issue Substation subsidence issues are being managed via current regulatory allowances and extremely unlikely to impact customer supplies

National Grid Electricity Transmission plc Climate Change Adaptation Risk Assessment

Key Assets and Processes		Specific Physical Characteristics of Climate Adaptation Scenarios										
		UKCP09 Characteristics				Met Office Characteristics					NG Characteristics	
Electricity Transmission Assets		**Solar Heat - Temperature rise of up to 8°C**	**Increased Heavy Rainfall (by a factor of 3.5)**	**Sea Level Rises of up to 43cm**		**Increased Lightning**	**Increased Wind and Gale**	**Increased Snow, Sleet, Blizzard, Ice and freezing fog**	**Increased Flooding**		**Increased Coastal / River Erosion**	**Increased Subsidence**
On National Grid Risk Register		**Yes**	**Yes**	**Yes**		**Yes**	**Yes**	**Yes**	**Yes**		**Yes**	**Yes**
Substation Sites (Incl. switchgear, transformers, earthing)		Temperature increases may have a marginal impact on equipment ratings. More work is required to better understand any potential impact National Grid see this as a potential longer term issue under current evidence there is very little firm evidence to justify changes to design standards	Site drainage may not cope with a sustained extreme rainfall event Work is required to understand the level of an event to impact a site Sites have resilience to Pluvial (flash flooding) to a depth of approximately 300 mm	Shore line management plans currently being reassessed by the EA indicate that a number of sites may be at an increased risk from sea level rise. The level of risk will be subject to what mitigation, ongoing defence options are adopted, improved maintained by the EA announced in 2011		Electrical equipment is designed to withstand lightning impulse levels e.g. a lightning strike Refer to Overhead Line section of this table	Existing design standards account for extreme weather conditions Substation equipment is designed to an relevant wind speed of: 34 m/s (76 mph)	Heavy snowfalls would not normally affect the operation of a substation but ice loading is an issue for which there are existing design standards: Ice Loading: Class 10 (10mm)	A site may become non-operational due to flooding potentially leading to a loss of system resilience or a loss of supply A non-operational site may not lead to a loss in supply		Shore line management plans currently being reassessed by the EA indicate that a number of sites may be at an increased risk from erosion The level of risk will be subject to what mitigation, ongoing defence options are adopted, improved maintained by the EA announced in 2011	Substation sites are normally built on level land so land slip is not generally an issue Substation subsidence issues are being managed via current regulatory allowances and extremely unlikely to impact customer supplies
Expansion of Existing Substation Sites (outside of existing boundary)		Temperature increases may have a marginal impact on equipment ratings More work is required to better understand any potential impact	Managed by planning policy	Shore line management plans currently being reassessed by the EA indicate that a number of sites may be at an increased risk from sea level rise The level of risk will be subject to what mitigation, ongoing defence options are adopted, improved maintained by the EA announced in 2011		Electrical equipment is designed to withstand lightning impulse levels e.g. a lightning strike Refer to Overhead Line section of this table	Existing design standards account for extreme weather conditions Substation equipment is designed to an relevant wind speed of: 34 m/s (76 mph)	Heavy snowfalls would not normally affect the operation of a substation but ice loading is an issue for which there are existing design standards: Ice Loading: Class 10 (10mm)	Design standards (PPS 25 and ETR 138) of assets and sites account for extreme weather conditions		Shore line management plans currently being reassessed by the EA indicate that a number of sites may be at an increased risk from erosion The level of risk will be subject to what mitigation, ongoing defence options are adopted, improved maintained by the EA announced in 2011	Substation sites are normally built on level land so land slip is not generally an issue Substation subsidence issues are being managed via current regulatory allowances and extremely unlikely to impact customer supplies

Key Assets and Processes		Specific Physical Characteristics of Climate Adaptation Scenarios										
		UKCP09 Characteristics				Met Office Characteristics					NG Characteristics	
Electricity Transmission Assets		**Solar Heat - Temperature rise of up to 8°C**	**Increased Heavy Rainfall (by a factor of 3.5)**	**Sea Level Rises of up to 43cm**		**Increased Lightning**	**Increased Wind and Gale**	**Increased Snow, Sleet, Blizzard, Ice and freezing fog**	**Increased Flooding**		**Increased Coastal / River Erosion**	**Increased Subsidence**
New Sites (Substations, Overhead lines, Tunnel Heads, Cable Sealing Ends)		Under current evidence there is very little firm evidence to justify changes to design standards Potential impacts of climate change would be evaluated on a case by case basis	Planning design standards in PPS25 will provide resilience against rainfall events	An update to PPS 25 will require all new planning applications within a shoreline management area to have coastal erosion assessment		Electrical equipment is designed to withstand lightning impulse levels e.g. a lightning strike Refer to Overhead Line section of this table	Existing design standards account for extreme weather conditions Substation equipment is designed to an average wind speed of: 34 m/s (76 mph)	Heavy snowfalls would not normally affect the operation of a substation but ice loading is an issue for which there are existing design standards: Ice Loading: Class 10 (10mm)	Planning design standards in PPS25 will provide resilience against flooding events		An update to PPS 25 will require all new planning applications within a shoreline management area to have coastal erosion assessment	Any potential subsidence issues would be taken into account during the design phase of the project
Processes												
Emergency		The process of responding to an emergency will be extremely unlikely to be impacted by working in high temperatures	An extreme rainfall event may prevent safe access to the asset requiring emergency repair Work is required to understand the level of event to impact a site	Refer to increased flooding		Access during the event may be restricted to OHLs but extremely unlikely to have a severe impact on fault response	Access during the event may be restricted to OHLs but extremely unlikely to have a severe impact on fault response	Emergency procedures allocate a fleet of 4x4 vehicles in order to ensure staff are able to respond to emergencies in extreme snow fall, ice conditions	Severe or prolonged flooding may make it impossible to reach sites or assets However site plans are being developed for flood defence improvements and allow for road access into the site during flooding events but this does not include the wider road network		Emergency plans are in place to respond to the most credible emergency scenario, e.g. erosion of OHL tower foundations In this instance loss of any one double circuit would not normally result in loss of supply	Emergency plans are in place to respond to the most likely emergency scenario, e.g. erosion of OHL tower foundations In this instance loss of any one double circuit would not normally result in loss of supply

Key Assets and Processes	Specific Physical Characteristics of Climate Adaptation Scenarios									
	UKCP09 Characteristics			Met Office Characteristics				NG Characteristics	
Process	**Solar Heat - Temperature rise of up to 8°C**	**Increased Heavy Rainfall (by a factor of 3.5)**	**Sea Level Rises of up to 43cm**	**Increased Lightning**	**Increased Wind and Gale**	**Increased Snow, Sleet, Blizzard, Ice and freezing fog**	**Increased Flooding**	**Increased Coastal / River Erosion**	**Increased Subsidence**
Maintenance, Construction & Fault Repairs	Milder winters are expected to reduce peak demand and air conditioning load increase summer demand, resulting in a flatter demand curve resulting in difficulty in releasing circuits for maintenance	An extreme rainfall event may prevent safe access to the asset requiring maintenance etc. However delays in these activities would be extremely unlikely to result in a loss of supply event	Refer to increased flooding	Access in the short term may be constrained to equipment but very unlikely to have a prolonged impact on maintenance etc.	Access in the short term may be constrained to equipment but very unlikely to have a prolonged impact on maintenance etc.	Access in the short term may be constrained to equipment but very unlikely to have a prolonged impact on maintenance etc.	Access in the short / medium term may be constrained to equipment but very unlikely to have a prolonged impact on maintenance etc.	This is managed over a long time period therefore access for maintenance and fault repairs expected in normal timescales would not be significantly effected	This is managed over a long time period therefore access for maintenance and fault repairs expected in normal timescales would not be significantly effected
Control Centre Operations	Temperature increases may impact ratings and place greater restraints on the system. This could affect the split between winter / summer/ autumn / spring ratings. Noting that current practice depends on maximum not average temperatures, no significant changes are anticipated in the short term. Future projections from UKCP18 and historic data need to be reviewed on a regular basis so that changes can be made as necessary if and when temperatures rise	If one or more site / route are lost from flooding it may result in a deterioration of resilience and flexibility of operating the system	If one or more site / route are lost from flooding it may result in a deterioration of resilience and flexibility of operating the system	The transmission system is normally resilient to loss of any one double circuit Any potential increase in lightning strikes will increase the probability of short duration outages (normally 15-20s) but there is no evidence of an increased risk to date	The transmission system is normally resilient to loss of any one double circuit Any potential increase in faults due to wind will increase the probability of short duration outages (normally 15-20s) but there is no evidence of an increased risk to date	The transmission system is normally resilient to loss of any one double circuit Any potential increase in faults due to ice loading will increase the probability of short duration outages (normally 15-20s) but there is no evidence of an increased risk to date	If one or more site / route are lost from flooding it may result in a deterioration of resilience and flexibility of operating the system	Any potential impact would be alleviated in normal regulatory timescales The transmission system is normally resilient to the most credible emergency scenario, e.g. erosion of OHL tower foundations In this instance loss of any one double circuit would not normally result in loss of supply	Any potential impact would be alleviated in normal regulatory timescales The transmission system is normally resilient to the most credible emergency scenario, e.g. erosion of OHL tower foundations In this instance loss of anyone double circuit would not normally result in loss of supply
Office Staff	Increased temperatures should not adversely impact National Grid's office based operations	Business Continuity Plans identify alternative office locations for business critical operations	Business Continuity Plans identify alternative office locations for business critical operations	Business Continuity Plans identify alternative office locations for business critical operations	Business Continuity Plans identify alternative office locations for business critical operations	Business Continuity Plans identify alternative office locations for business critical operations	Business Continuity Plans identify alternative office locations for business critical operations	Business Continuity Plans identify alternative office locations for business critical operations	Business Continuity Plans identify alternative office locations for business critical operations

Appendix 2 - Actions

Outcomes from RESNET research into ratings

Increasing ambient temperatures as a result of climate change over the rest of the century are anticipated to impact on asset ratings as they are temperature dependent. Various studies and regular assessments have shown that short term we are resilient to the short-term impacts of increased ambient temperatures but there is a need to understand the longer term risks as well as potential 'tipping points' in the future when the system will require greater resilience. In order to increase National Grid's awareness of the longer term risks we participated in the EPSRC-funded Resilient Energy Networks for Great Britain "RESNET" project within the ARCC[3] suite of projects. The aim of RESNET was *"to develop and demonstrate a comprehensive approach to analysis, at a national scale, climate related changes in the reliability of the UK's electricity system, and develop tools for quantifying the value of adaptations that would enhance its resilience."*

The final RESNET report is complete and some of the results have been shared in public forums. The project has investigated the impacts of climate change starting from circuit component levels up to simplified network models considering likely changes in generation mix and demand scenarios as well as the direct impact of climatic changes.

Note that not all of the outcomes of the RESNET project are summarised here; aspects relating to the impact of increasing temperatures resulting from climate change on equipment ratings are taken from a summary report by Professor Ian Cotton of Manchester University. A copy of the Summary Report and Conclusions is available on request.

A probabilistic approach was developed within Work Package 3 of RESNET to investigate the impacts of climate change on the transmission system capacity. The approach consisted of three parts: simulating future climates, component modelling and, integrating the first two parts, performance assessment.

In the first part, future climates were forecast based on the most severe projections from the UK Climate Projections (UKCP09) Weather Generator. These were combined with a wind model and soil temperature projections based on the weather and wind models. The future climate projections were then used with internationally recognised thermal rating calculations for overhead lines, cables and transformers to determine impact of changing climate on the ratings of these assets. The impact on ratings was considered for a number of different locations and for three timeframes consistent with the UKCP09 approach, namely 2020s (2010 – 2039), 2050s (2040-2069) and 2080s (2070-2099).

The largest impact on ratings was observed in the South of England, represented by results for Slough in the examples that follow under each equipment section. The effect of thermal heat islands that may cause localised increased temperatures around transformers installed in cities such as London was not taken into account.

Factors still to be considered fully include the following:

- Potential impact of heat islands, which may further reduce ratings on transformers in particular
- Soil moisture content and the full range of laying environments for cables
- Transformer and cable cooling options
- The impact on the ratings of circuits by combining the impact on circuit components

The results from Work Package 3 of RESNET show that there will be an impact on ratings and that this will increase through the 21st century. In the short to medium term transmission assets are resilient to climate change. More detailed studies will be required to gain a better understanding as confidence in climate forecast data improves.

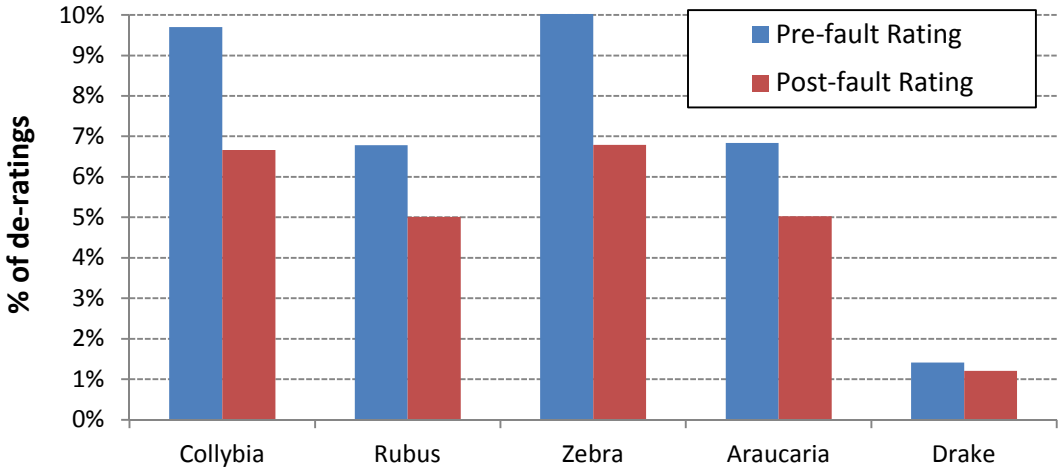
[3] Adaptation and Resilience in the Context of Change

Overhead Lines

A number of overhead line types were examined with different rated temperatures. From a ratings perspective, the most challenging conditions prevail in high ambient temperatures, when there is minimum "leeway" between that and the rated conductor design temperature to allow for conductor heating due to the passage of current. Older overhead lines tend to have lower rated temperatures e.g. 75°C and are more sensitive to climate change especially in normal system conditions in the summer, other seasons and post-fault ratings are affected to a lesser degree. More modern, higher rated overhead lines are more resilient to the effects of climate change. The following observations were made during the study:

- ACSR with a design rated temperature of 75°C is likely to see a downrating of 10.1% in the summer of the 2080s
- In the same situation, ACCR Drake with a design temperature of 240°C would be likely to see a downrating of 1.4%
- These are central assessments based on the probabilistic approach; maximum downratings observed were 27.4%, average downratings were around 10%
- Maximum observed downratings were reduced to 8.4% if the overhead lines were operated dynamically by adjusting permissible current according to ambient conditions for temperature and wind

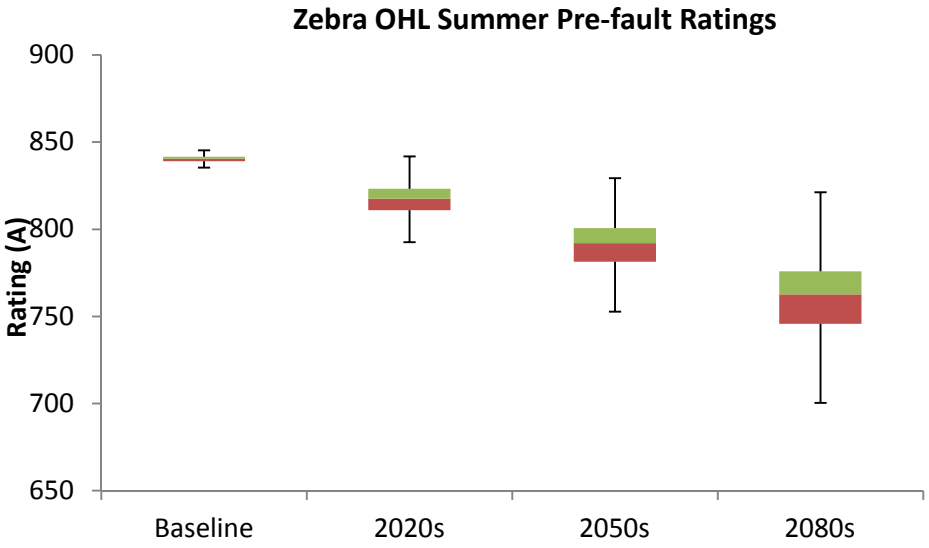
Average deratings for different types of overhead lines are shown below – they apply to Slough in the summer of 2080s in the high emission scenario from UKCP09.



Key parameters of the selected types of overhead line conductors

Type	Material	Diameter (mm)	Rated Temperature (°C)	AC Resistance (ohm/km)
Collybia	ACAR	30.33	75	0.0589
Rubus	AAAC	31.5	90	0.0558
Zebra	ACSR	28.62	75	0.0684
Araucaria	AAAC	37.26	90	0.04
Drake	ACCR	28.6	240	0.0658

The following chart demonstrates the increased uncertainty that exists as climate change develops. Estimates for average downratings for ACSR Zebra are 5% in winter in the 2080s and 7% in the spring and autumn.



Ranges of pre-fault ratings of Zebra ACSR conductor in the high emission scenario are given in more detail in the following table:

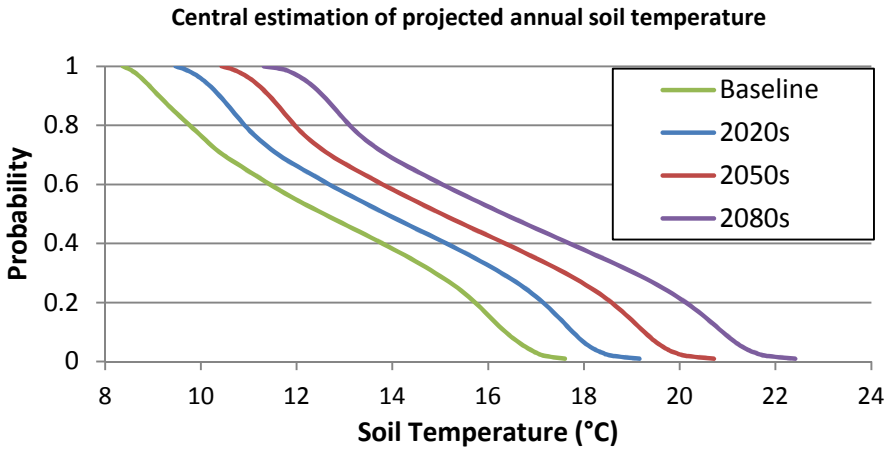
Period	Season	Average	Likely Range	Conservative Range	Full Range
2020s	Summer	816	807 to 827	797 to 835	766 to 855
	Spring	886	877 to 895	870 to 902	842 to 920
	Winter	984	978 to 991	972 to 995	953 to 1011
2050s	Summer	789	775 to 806	755 to 818	698 to 849
	Spring	868	857 to 880	845 to 890	812 to 915
	Winter	973	965 to 981	958 to 987	938 to 1002
2080s	Summer	756	735 to 784	702 to 800	608 to 837
	Spring	845	829 to 865	810 to 877	756 to 906
	Winter	961	952 to 972	941 to 981	914 to 1006

The following table gives the post-fault ratings for the same conditions:

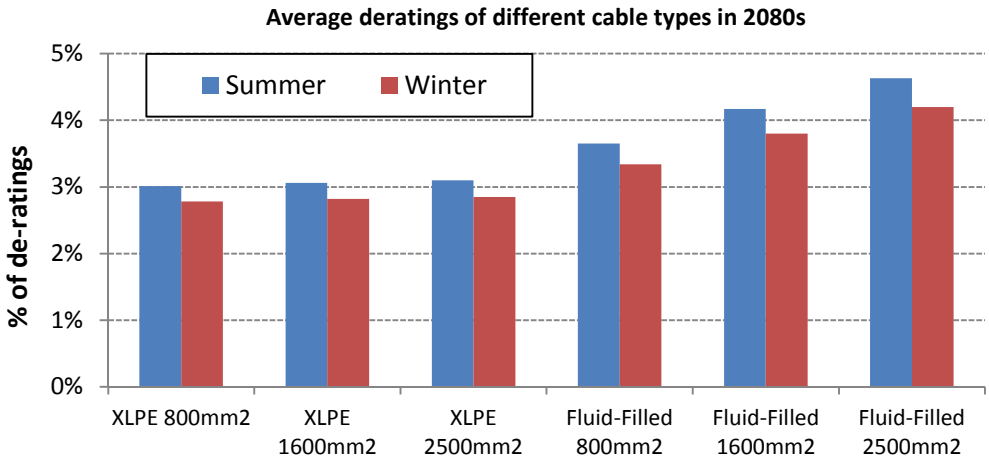
Period	Season	Average	Likely Range	Conservative Range	Full Range
2020s	Summer	941	934 to 950	926 to 955	901 to 970
	Spring	1012	1009 to 1016	1005 to 1019	994 to 1029
	Winter	1079	1076 to 1083	1073 to 1086	1063 to 1093
2050s	Summer	919	909 to 932	894 to 941	850 to 962
	Spring	1000	995 to 1006	990 to 1010	969 to 1024
	Winter	1069	1064 to 1074	1059 to 1078	1044 to 1089
2080s	Summer	895	880 to 914	858 to 927	789 to 959
	Spring	984	976 to 993	967 to 1000	937 to 1020
	Winter	1059	1051 to 1067	1043 to 1073	1021 to 1090

Underground Cables

Buried cables are less affected by ambient air temperatures and the studies required inputs from a soil temperature model using temperature and wind data. This probabilistic assessment shows that the temperature may increase by nearly 4°C in the 2080s and the changes can be seen in the figure below. It is important to note that the moisture content of soil is important for resistivity and a significant reduction in soil moisture would have a detrimental impact on ratings.



As for overhead lines, a number of cable types were studied and more modern XLPE cables were found to be more resilient to changes in the climate than older fluid-filled designs with ratings likely reduced by 3.1% compared with 4.6%. The highest observed probabilistic reduction in rating was 10.3% for fluid filled cables. The relative impact of climate change is exemplified below where deratings of different cable types are shown.

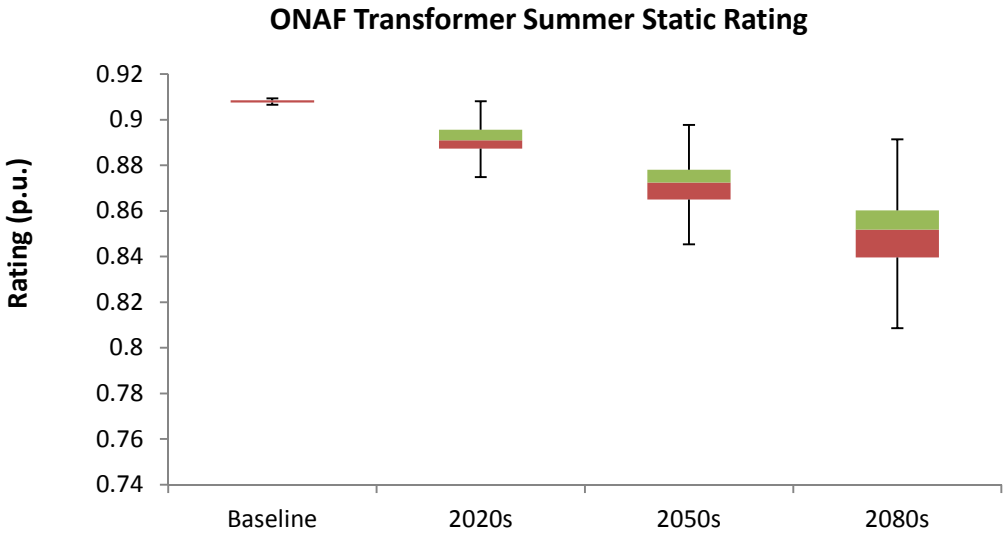


Cables in tunnels will be more vulnerable to climate change if they rely on ambient air for cooling. The ratings of cables in purpose built tunnels with forced air cooling will not impacted in the same way.

Transformers

Transformers were assessed by considering them as having a single cooling state with either forced oil or forced air cooling. Transformers with forced air, but not forced oil (ONAF), are most affected by the increase in ambient temperature with an average reduction of rating of 6.6% in the summer of 2080s and a maximum reduction of 16.9%. Transformers with directed oil flow cooling (ODAN) show slightly less reduction of rating with a 4.9% reduction in summer of 2080s and a maximum reduction of 12.5%. The average temperature for transformers plays a part in the ageing of the transformer and increasing ambient temperatures will result in increased ageing.

Picking ONAF (Oil Natural Air Forced) cooled transformers as an example the following plot shows the impact on ratings as the temperatures rise. Note that transformers are rated at 20°C so the baseline summer rating is below 1 p.u.



The following table shows the relative impact of climate change on transformers using different cooling states.

	Average			Maximum		
	Summer	Spring	Winter	Summer	Spring	Winter
ONAF	6.64%	4.78%	3.22%	16.86%	9.59%	7.09%
OFAN	5.69%	4.09%	2.75%	14.57%	8.25%	6.07%
ODAN	4.86%	3.50%	2.36%	12.48%	7.07%	5.23%

Changes in average ambient temperatures will also have an impact on the ageing of transformers even if load does not increase. A study into ageing of a transformer looking at varying load patterns shows that life loss only has a significant impact when the mean load is above 0.8 p.u. although the shape of the load profile plays a part; a flat load profile reduces ageing.

nationalgrid

National Grid House
Warwick Technology Park
Gallows Hill
Warwick
CV34 6DA
Registered in England and Wales
No. 4031152
www.nationalgrid.com