Climate Change Adaptation Report

Round 4 (ARP4)

2024

Electricity Distribution

nationalgrid

Contents

Introduction

The Adaptation Reporting Power (ARP) set out in the Climate Change Act 2008 provides for the Secretary of State (SoS) to direct reporting organisations (those with functions of a public nature or statutory undertakers) to report on how they are addressing current and future climate impacts.

While the provision gives the Secretary of State the power to mandate reporting, this has not been used since the first round, and the SoS is continuing with a voluntary approach to reporting in round 4.

This report has been developed in response to the requirements placed on reporting authorities by the Climate Change Act under the 4th Round of Adaptation Reporting. Reports should detail:

- the current and future projected impacts of climate change on their organisation,
- proposals for adapting to climate change,
- an assessment of progress towards implementing the policies and proposals set out in previous reports.

ARP aims to ensure that organisations of a public nature with climate-sensitive responsibilities are taking appropriate action to adapt to the impacts of climate change. It does this both directly, through engaging organisations in reporting, and indirectly, through raising awareness, building capacity in organisations, and making examples of good practice publicly available.

The Government's Adaptation Sub-Committee review the outputs of the ARP process and it supports the Government's National Adaptation Programme and future UK Climate Change Risk Assessments.

We have produced an adaptation report for each of our 3 UK business units – National Grid Electricity Transmission (NGET), National Grid Electricity Distribution (NGED) and National Grid Ventures (NGV).

The ARP3 report for NGET can be accessed here. Previous reporting by NGED (as Western Power Distribution) was included as part of the Energy Networks Association (ENA) response and can be accessed here. This is the first time we have reported for our NGV business, following a request from the Department for Environment, Food and Rural Affairs (DEFRA).

National Grid at a glance

National Grid plays a critical role in the energy sector, operating in both the United Kingdom and the United States. With a mission to Bring Energy to Life, we are dedicated to delivering safe, reliable, and sustainable energy solutions to millions of customers. Our company is at the forefront of the energy transition, focusing on the decarbonisation of energy systems and the integration of renewable energy sources into our networks

To achieve our vision of being at the heart of a clean, fair and affordable energy future in a focused way, we have a strategy that sets the bounds of our business. Guiding our efforts within this are five strategic priorities:

1. Enable the Energy Transition for All: We have a pivotal role in enabling the energy transition across all sectors of the economy through our networks. We work with policymakers, regulators and the wider industry to shape the policy and regulatory frameworks needed to reach net zero by 2050.
2. Build the Networks of the Future Now: We will scale a once-in-a-generation increase in capacity to connect to, and transport electricity across, our networks. We will modernise our electricity networks to improve capacity, visibility, security and reliability.

3. Deliver for Our Customers: We will provide excellent service to all our customers, ensuring they can connect to the network in a timely fashion, that their energy provision is reliable and that we are easy to do business with.
4. Operate Safely and Efficiently: Our priority is to keep our colleagues safe. Being efficient means we play our part in making the energy transition affordable by investing in the right projects and solutions, and delivering them on (or ahead of) time and budget
5. Build Tomorrow's Workforce Today: All of this is enabled by our people. The energy transition is happening right now, so we need to build tomorrow’s workforce today, with the diverse talent and skills needed to deliver our vision. Our ambition is to be the employer of choice for people who want to have a career in a company where they can have a clear and positive impact on the energy transition

These strategic priorities reflect our commitment to addressing the challenges of the energy transition while ensuring that our operations are aligned with the needs of customers, communities, and the environment.

Our UK business units that have reported under ARP4 are:

National Grid Electricity Transmission (NGET):

- NGET is responsible for owning and operating the high-voltage electricity transmission network in England and Wales. It plays a critical role in delivering electricity from generation sources to distribution networks and ensuring the stability of the electricity system. Our Transmission business includes our Strategic Infrastructure (SI) business unit, established in April 2023, which focuses on delivering major infrastructure projects under the Accelerated Strategic Transmission Investment (ASTI) framework

National Grid Electricity Distribution (NGED):

- NGED manages the electricity distribution networks for the East Midlands, West Midlands, South West, and South Wales. It is responsible for delivering electricity at lower voltages to homes and businesses and includes a Distribution System Operator (DSO) that oversees the distribution network's operations

National Grid Ventures (NGV):

- NGV is National Grid’s non-regulated arm and focuses on competitive markets. In the UK, NGV operates 6 Interconnectors and a liquefied natural gas (LNG) import and storage facility at Grain. NGV is involved in projects that enhance energy security and facilitate the transition to low-carbon energy sources.

Further information on National Grid Electricity Distribution is set out below.

National Grid Electricity Distribution

National Grid Electricity Distribution (NGED) is part of the largest electricity transmission and distribution business in the UK, putting National Grid at the heart of a clean, fair and affordable energy future.

NGED is the UK's largest electricity distribution network, we distribute power to 8 million homes and business serving over 20 million customers over an area of 55,000km^2 covering the East and West Midlands, South West and Wales. This electricity is distributed over 230,000km of overhead lines and underground cables, fed from 191,000 substations delivering essential power to millions of homes and businesses across its regions.

NGED aims to lead the way in the UK's drive towards a net zero carbon future, committing in our RIIO-ED2 Business Plan (2023-2028) to transform our energy network to drive net zero sooner than 2050 across our region. In achieving this NGED can build a resilient and reliable electricity network making a positive contribution to the environment and reducing the impact of climate change.

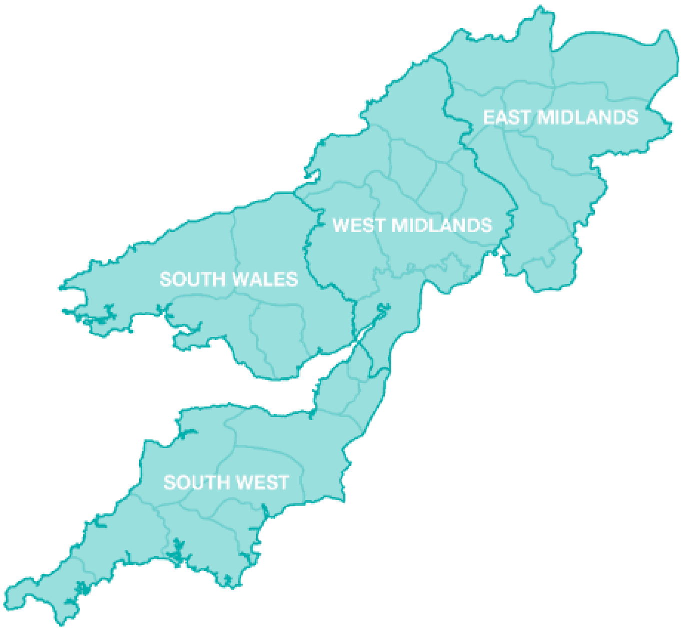

Figure 1. NGED's licence areas

Table 1. NGED network asset summary (2023/24)

Asset Type	Units	West Midlands	East Midlands	South Wales	South West	NGED Total
Overhead Lines	km	23,000	20,000	18,000	27,000	89,000
Underground Cable	km	43,000	55,000	18,000	24,000	141,000
Transformers	Each	51,000	45,000	41,000	54,000	191,000
Switchgear	Each	88,000	105,000	38,000	83,000	314,000
Poles	Each	360,000	275,000	285,000	438,000	1,358,000
Towers (Pylons)	Each	3,000	5,000	2,000	3,000	14,000
Customer Numbers (MPAN's)	Each	2,523,000	2,699,000	1,159,000	1,658,000	8,040,000
Licenced Area	km^2	13,300	16,000	11,800	14,400	55,500

National Grid's Commitment to Climate Resilience

Section Key Points:

- As one of the first companies to participate in the UK's National Adaptation Programme we have a long-established history of reporting on climate resilience.
- We have incorporated each of the Taskforce for Climate Related Financial Disclosures (TCFD) recommendations and will work with the International Financial Reporting Standards Foundation (IFRS) on updating our position in our next annual report.
- Our Responsible Business Charter sets out our sustainability commitments including to "Report on our climate change risks and opportunities and our investment in climate change adaptation activities."

UK National Adaptation Programme

In 2008 the UK Climate Change Act set out a five-year reporting cycle for climate change risk assessments, forming the basis for the country's ongoing action plan to adapt to climate change. National Grid was an early participant in the first adaptation reporting cycle, ensuring that each reporting cycle forms a solid foundation for understanding industry wide climate-related challenges and the corresponding resilience of our network.

In this case, resilience is defined as the ability of the electricity network in England and Wales to withstand disruptive events, and the organisational capability of NGED to reduce the magnitude and/or duration of disruptive events. Including the capability to anticipate, absorb, adapt to and/or rapidly recover from such events. Thus ensuring that electricity continues to reach consumers safely, reliably and efficiently.

Task Force on Climate-Related Financial Disclosures (TCFD)

National Grid has disclosed against the TCFD since 2017/18 and our disclosures now cover all of the TCFD's recommendations and recommended disclosures around governance, risk management, strategy and metrics and targets. NGED contributes to the annual TCFD disclosure by demonstrating how the business is responding to climate change. This may be through case studies such as Ofgem funded net zero innovation projects, performance against our GHG emissions targets and examples of how extreme weather events have impacted NGED networks to outline the long-term risks and opportunities associated with climate change.

It will be necessary for NGED to continually appraise its understanding of climate risk and the potential scale and timing of impacts on its assets. This will be through a range of measures including climate modelling, risk assessment, process development and engagement with external stakeholder and policy makers.

In its final status report, published in 2023, the TFCD remarked that "estimating potential financial impact from climate change requires expertise from different functions within a company. As a result, it may be useful to set up a cross-functional team for such efforts."[2] This statement reflects our understanding of what it will take to appropriately implement the commitments within this document.

How we assess and calculate risk to our network

Climate adaption and mitigation activities to address our physical risks are embedded into our core business processes. The Chief Risk Officer leads the development of climate adaptation frameworks across the Group to ensure there is a consistent approach to assess the vulnerability of our energy assets and to guide strategic investment planning to ensure network resilience. Further delegation is given to our core operational businesses including Business Unit Presidents who are accountable for delivering the net zero roadmaps for their businesses. Corporate Affairs, Group Finance, Sustainability, Safety & Health and People teams support the businesses in achieving their net zero pathways.

National Grid has resilience standards in place to ensure the continuity of services we provide to our customers and the communities we serve:

- The Enterprise Risk and Assurance Standard is used to anticipate and respond to threats and opportunities, thereby successfully delivering our strategy and objectives (Figure 2 Risk Management and Assurance Standard)

- The National Grid Business Resilience Standard drives continual improvement in the way we prepare for, respond to, recover, and adapt from significant business disruptions (Figure 2 Business Resilience Standard).

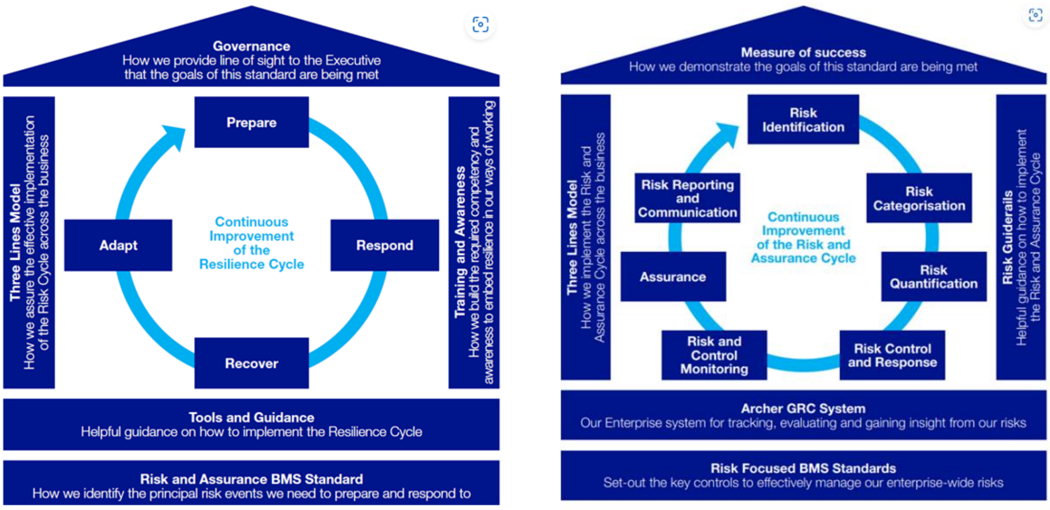

Figure 2 – Our resilience approach

These standards are high level approaches that in themselves do not specifically address climate change hazards and require consideration alongside specific risk assessment and mitigation.

Climate Change and Enterprise Risk Management

Climate change is a significant risk for our organisation, and we have integrated it into our ERM process as one of our Group Principal Risks (GPRs).

Our ERM framework and process consider the physical and transition risks associated with climate change, as well as the potential impact of these risks on our business operations, financial performance, and reputation.

For our climate change GPR risk there are two distinct elements:

1. Climate Change (mitigation GPR): The standalone mitigation risk is aligned to our strategic objective ‘Enable the energy transition for all’, with a focus on delivering clean, decarbonised energy to meet our net zero goals.
2. Significant Disruption of Energy (adaptation GPR): The adaptation, or physical risk activity, absorbed within the control framework associated with the ‘Significant Disruption of Energy’ risk, has helped ensure we continue to deliver energy reliably for our customers, with a focus on resilience.

This allows us to have greater oversight, focus and adoption of two distinct and proportionate control frameworks in line with the new Group risk appetite – mitigating downside risk, and maximising opportunities, where applicable.

How we manage and monitor our climate-related risks

As part of our risk management process, we have assigned key controls to manage both our climate change mitigation and adaptation risks.

The controls for our climate change mitigation GPR are in line with our strategy and regulatory frameworks and are also reflected throughout other relevant risks, for example: regulatory outcomes; political and societal expectations; and significant disruption of energy. The key overarching mitigation controls involve tracking progress against targets, identifying changes that could trigger additional transition risks, and implementing procedures and proposed solutions to overcome them.

Our key climate change adaptation controls include the following:

- Fit for Future of Electricity Strategy: A corporate strategy that considers the steps to ensure our business remains resilient in the future, such as enhancing design standards, and investments on asset hardening and flood protection.
- Engineers Governance forums: Group Chief Risk Officer and engineering duty holders sharing guidance and data on key topics such as resilience.
- Resilience and Asset Management Business Management Standard (BMS): Sets out minimum requirements and a framework for resilience capability and managing asset risk to ensure each business unit is prepared for the next disruptive event.
- Establishment of the Business Resilience and Crisis Management organisation: Reporting to the Group Chief Risk Officer and Group Legal, this team is focused on building resilience to all threats and hazards. This includes the development of crisis management and business continuity plans, training, and exercises to help align and coordinate our response to severe weather and other crisis events; but is also leveraging innovative technologies to improve our intelligence, looking strategically at evolving risks associated with climate change. We are also expanding our network of external stakeholders to identify and leverage industry thought leadership and play an active role in shaping new policies and regulations.

NGED Climate Resilience Strategy

We first introduced our Climate Resilience Strategy (CRS) alongside the 2008 Climate Change Act. Our CRS sets out strategies to minimise the impact of environmental change on our operations, ensuring we can continue to provide a safe and reliable power supply to all our customers. Our CRS analyses how changes to the climate may impact our business activities, and sets out robust and measurable steps to ensure we maintain our industry leading service levels.

We consider how changes to the environment over time may impact upon our overall vision, values and operations. We seek to ensure that the environment, and projected climate change impacts, are considered in conjunction with our aim of providing a safe, efficiently run, and reliable network.

Our Resilience Strategy is built on five key pillars:

Improve our understanding of the likely effects of climate change, including the development and ongoing support of a cross-industry climate resilience working group.

Continue to assess risks and impacts to our network associated with climate change.

Further develop adaptation pathways to enhance network resilience in response to short, medium and long term climate change projections and challenges across NGED's four license areas.

Develop and implement cost effective and impactful climate resilience initiatives in conjunction with other business activities and investment plans.

Regularly review our ambitious climate resilience initiatives and strategy, to ensure good progress is being made, and value for customers is being delivered.

NGED has considered a number of climate change projections such as Met Office UKCP18 (as evidenced in this report) and other credible sources such as the Paris Agreement, the National Infrastructure Commission, the UK Government and Climate Change Committee.
NGED will continue to work with the wider National Grid group to share ideas and learning. We also work alongside Local Authorities and resilience forums to ensure that future planning decisions, developments and policies are factored into our adaptation strategies.
NGED will continue to assess a range of valid publications to account for the greatest possible range of projections.

Risk Matrix

Energy Networks Association (ENA) is a not-for-profit industry body representing the companies which operate the energy networks in the UK and Ireland. It supports member organisations in meeting the challenge of delivering energy to communities across the UK and Ireland safely, sustainably and reliably. The ENA facilitates collaboration across the sector, shares best practices, and promotes and protects the energy industry's reputation.

National Grid are members of the Energy Networks Association climate adaptation group. This cross-industry group has reported on behalf of the Electricity Distribution Network Operators (DNOs) since ARP2, as well as working on establishing a common understanding of the risks faced by energy networks in the UK. They have developed a risk assessment as part of this work, which has been used in their ARP2 and 3 reporting. We have used this risk assessment matrix across all of our reporting businesses.

Risk Matrix Template

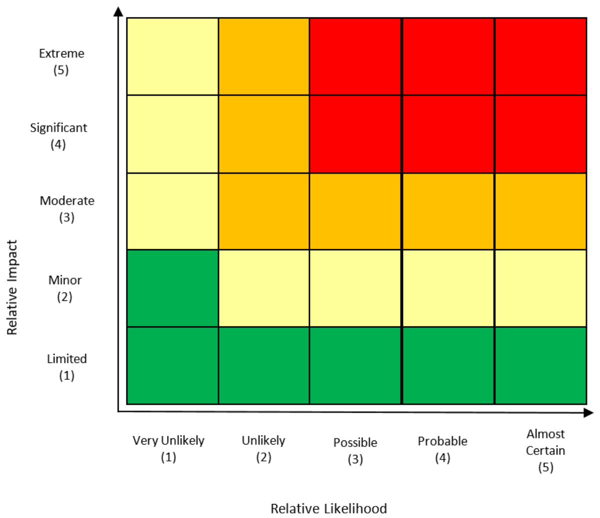

Figure 3 – Risk Impact Matrix

Risk Matrix Impact Definitions

Rating	Definition
Extreme	Regional area affected with people off supply for a month or more OR asset de-rating exceeds ability to reinforce network leading to rota disconnections on peak demand.
Significant	County or city area affected with people off supply for a week or more OR asset de-rating requires a significant re-prioritisation of network reinforcement and deferment of new connection activities.
Moderate	Large town or conurbation off supply for up to a week OR significant increase in cost of network strengthening
Minor	Small town off supply for a 24-hour period OR significant increase in cost of network maintenance requirements.
Limited	Limited impact - can be managed within "business as usual" processes.

Risk Matrix Likelihood Definitions

Rating	Definition
Almost Certain	The risk is expected to be realised and may already be under active management as an event.
Likely	Past events have not been fully resolved, effective mitigations not yet identified, control weakness are known and are being managed.
Possible	Past events satisfactorily resolved, mitigations are in place or are on track to be in place, control improvements are under active management
Unlikely	Events are rare, required mitigations in place, controls are effective
Very Unlikely	No known event or if known extremely rare, extreme industry-wide scenarios

Risk assessment Scenarios

The ARP guidance requests reporting against 4 scenarios:

1. Present day (near term)
2. Mid century 2°C rise
3. End of century 2°C rise
4. End of century 4°C rise

We have used UKCP18 RCP4.5 for present day and mid century scenarios, and RCP 4.5 and 8.5 for end of century scenarios. Further information is on page 12.

Figure 4 -IPCC Representative Concentration Pathways

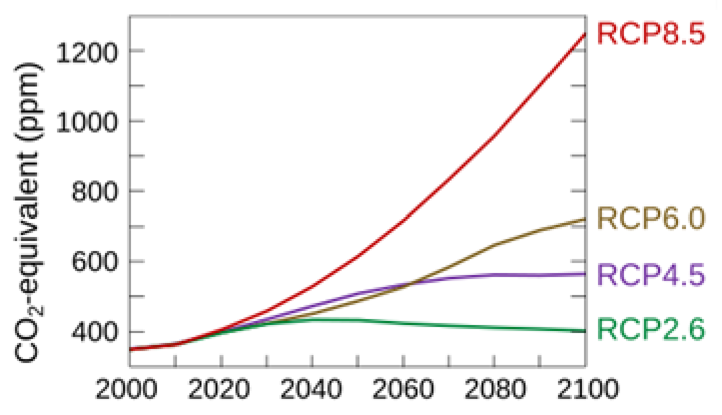

Figure 4 – IPCC Representative Concentration Pathways

Each of our Business Units have developed plans specific to their business based on the principles and approach outlined above.

NGED Climate Risk Assessment

Energy Networks Association

Past rounds of the National Adaptation Programme highlighted the importance of key interdependences between other utility services and sectors. Therefore, a cross-industry **Climate Change Resilience Working Group** (CCRWG) has been established with the ENA. The group, which is chaired by NGED, continues to assess the risks of climate change, and the potential for simultaneous impacts across the different industry sectors.

In spring/summer 2020, on behalf of its members, the ENA commissioned the Met Office to undertake a review of the UKCP18 data and other existing studies to understand a range of potential impacts to energy infrastructure assets from climate change. The CCRWG requested the highest Representative Concentration Pathway (RCP8.5) was used to provide a representation of a high emission scenario out to the end of the century. This energy industry specific report has been used to assess the current climate change risks to NGED and inform future mitigation, adaptation and business decisions.

Because of the number and diversity of the hazards, it was decided by the ENA group to prioritise climate hazards which pose the highest risk to energy network assets. The highest priority hazards are listed below:

- Prolonged rainfall leading to flooding
- Extreme high temperatures
- Heavy rainfall/drought cycles

Since there is currently no strong signal within the UKCP18 climate projections for a change to future storm intensity, the risk of strong winds was assessed in the current climate only.

For the remaining lower priority hazards (as detailed below) a qualitative approach was undertaken.

- Sea level rise
- Warm and wetter conditions, followed by heavy rainfall and/or wind
- Storm surge and wave height
- Warmer and wetter conditions – longer growing/nesting seasons
- Snow and ice
- Wildfire
- Lightning
- Solar storm – not considered as a climate change hazard
- Diurnal temperature cycles

Met Office UK Climate Projections (UKCP)

The UKCP climate projections data set chosen by the ENA CCRWG for climate modelling is RCP8.5. The Representative Concentration Pathways (RCP) 8.5 refers to the concentration of carbon that delivers global warming at an average of 8.5 watts per square meter across the planet. RCP8.5 estimates the highest predicated greenhouse gas concentrations and an estimated global mean surface temperature increase of 4.3°C by 2081-2100. This scenario is the ‘high emissions scenario’ and will ensure mitigation addresses even the most unlikely modelling outputs. A more optimistic scenario, in which emissions are reduced compared to RCP8.5, would produce smaller projected increases in these hazards, such as that of RCP2.6 and 4.5 scenarios, which would represent closer to the 2°C global mean surface temperature increase. These projections represent what the climate could look like if the Paris climate agreement goals are achieved. What happens in reality will depend on how society responds globally to reduce greenhouse gases.

Scenario uncertainty

Scenarios are used to represent possible futures based on assumptions about human activity and greenhouse gas emissions. Two scenarios have been considered in this ARP4 report, RCP4.5 and RCP8.5, to approximate a 2 °C and 4 °C scenarios, respectively. It’s assumed in all UKCP18 scenarios that projections will remain similar in all RCP scenarios up until 2050 regardless of emission reductions. Only post 2050 do RCP scenarios and climate projections begin to differ with greater uncertainties and a decrease in confidence of projections. For this reason we will use RCP4.5 projections to make assessments until 2050, then use both RCP4.5 and RCP8.5 emission scenarios thereafter. Splitting our assessment in this way will highlight any periods of key change which may present risk to the Electricity Distribution network.

NGED own and operate a high volume and range of assets, our four licence areas cover large geographical areas with diverse topographical features. Due to this, climate change impacts our areas in slightly different ways depending on regional geography, historic development, and demand requirements. Therefore, detailed research that considers the use of more granular data sets, such as the UKCP Local (2.2km) and regional (12km) projections can be extremely complex and data intensive. Higher resolution data sets provide more accurate local climate projections, taking into account geography and topography, however, these data sets have greater variance in projections. For this reason we have chosen to use UKCP18 probabilistic projections for an initial high level risk assessment.

NGED Climate Adaptation Framework

We develop and implement adaptation measures to ensure our level of service is maintained, and where possible improved, as shown in figure 5 below.

Our approach to climate **Adaptation** to embed climate resilience is based on four main pillars:

Withstand

Strengthening resilience will increase the networks ability to withstand climate events. This will be achieved by introducing measures that provide physical strength to assets to withstand climate hazards during climate events and mitigations that reduce asset exposure. To date this have been achieved through reviewing and updating policy and upgrading assets to higher resilience design standards.

Absorb

This objective explores resilience measures that reduce impacts to level of service should an asset fail, regardless of physical strengthening. These types of measures limit the level of the service disruption that may occur during a climate event, and include activities such as installing additional protection schemes (which subdivide the network into smaller zones so that fewer customers go off supply), automated restoration schemes and implementation of new technologies, such as trip savers.

Recover

This objective is focused on activities and procedures designed to restore service to normal levels in the aftermath of a climate event. These are incorporated into planning, design, and operational practices, for example, our robust flood and storm response procedures.

Review & Adapt

By learning from past experiences, we are able to make adaptations to ensure resilience is maintained or improved in the event of the distribution network being exposed to a similar climate hazard.

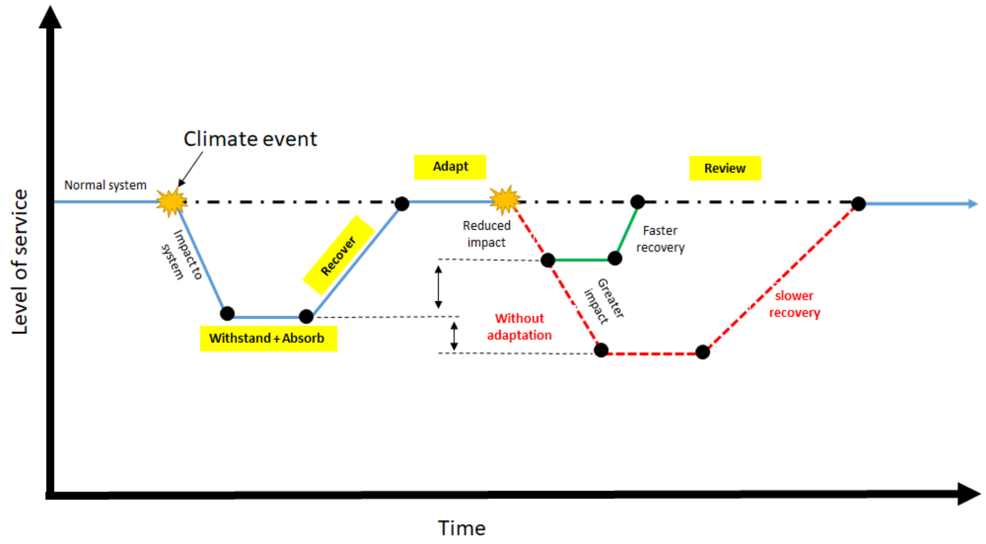

Figure 5. Climate Adaptation Framework

Risk Assessments

Using the risk assessment matrix, developed through the ENA CCRWG, we have identified climate change hazards and prioritised risks. These key hazards (AR) were identified in previous rounds of adaptation reporting and are still considered the most prominent risks when using the latest climate change data. We have also identified 4 additional risks, wind, interdependencies, telecom networks and employee/business operations.

For the purpose of this report we will continue to address the hazards identified from UKCP18 projections. Each hazard/risk has then been assessed using UKCP18 projections for a 2°C+ and 4°C+ scenarios for mid-century and end of century time periods making no assumptions to future adaptations.

This report gives a high level insight to each identified hazard, associated risks and current adaptations, which will help address and mitigate climate hazards, and maintain and improve climate resilience.

However, we remain dynamic in our approach, recognising that as we learn more about climate change we may need to review and update current hazards and risks. In addition, we are mindful of developing unrecognised risks and the need to closely monitor society's action to reducing emissions.

Using the risk assesment maxtrix combind with UKCP18 projections, we have been able to identify the following key climate change hazards and risks specific to electricity networks. The first number in the risk score represents the relative likelihood of the risk, the second number represents the relative impact of the risk.

The next section of this report will explore in further detail each risk code identified in the table below, starting with the hazard posing the highest risk through to the lowest risk.

Table 2. NGED Climate Risk Assessment

Risk Code	Climate Variable	Hazard/Risk/Function	Risk score Present day scenario	Risk score mid-century scenario	Risk score end of century (+2°C) scenario	Risk score end of century (+4°C) scenario
AR1	Temperature	Overhead line conductors affected by temperature rise.	3 x 3	4 x 3	4 x 3	4 x 3
AR2	Temperature	Overhead line structures affected by Summer drought and consequent ground movement	3 x 2	3 x 2	3 x 2	4 x 2
AR3	Temperature / precipitation	Overhead lines affected by interference from vegetation due to prolonged growing season	4 x 2	4 x 2	5 x 3	5 x 3
AR4	Temperature	Underground cable systems affected by increase in ground temperature,	3 x 3	4 x 3	4 x 3	5 x 3
AR5	Temperature	Underground cable systems affected by Summer drought and consequential ground movement	3 x 2	3 x 2	3 x 2	4 x 2
AR6	Temperature	Substation and network earthing systems adversely affected by Summer drought conditions	3 x 2	4 x 2	4 x 2	4 x 2
AR7	Temperature	Transformers affected by temperature rise,	3 x 2	4 x 3	4 x 3	5 x 3
AR8	Temperature	Transformers affected by urban heat islands and coincident air conditioning demand	3 x 3	4 x 3	4 x 3	5 x 3
AR9	Temperature	Switchgear affected by temperature rise	2 x 2	4 x 2	4 x 2	5 x 2
AR10	Precipitation	Grid and Primary Substations affected by river flooding due to increased winter rainfall	3 x 3	4 x 3	4 x 4	4 x 4
AR11	Precipitation	Grid and Primary Substations affected by pluvial (flash) flooding due to increased rain storms in Summer and Winter	2 x 3	3 x 3	4 x 4	4 x 4

AR12	Sea level rise	Grid and Primary Substations affected by sea flooding due to increased rain storms and/or tidal surges	2 x 4	3 x 4	3 x 4	4 x 4
AR13	Precipitation	Grid and Primary Substations affected by water flood wave from dam burst	1 x 5	1 x 5	1 x 5	1 x 5
AR14	Lightning	Overhead lines and transformers affected by increasing lightning activity	3 x 2	3 x 2	3 x 2	3 x 2
AR15	Wildfire	Overhead lines and underground cables affected by extreme heat and fire smoke damage	3 x 2	4 x 2	4 x 2	5 x 2
AR16	Wind	Overhead line assets affected by strong winds / storms	4 x 3	4 x 3	4 x 3	4 x 3
AR17	All climate hazards	Interdependencies between different industry sectors	3 x 2	4 x 2	4 x 3	4 x 3
AR18	All climate hazards	Supporting telecommunication network climate vulnerability	3 x 2	3 x 3	3 x 3	3 x 3
AR19	Temperature / precipitation / Wildfire	Health and productivity affected by climate change	3 x 2	4 x 2	4 x 3	4 x 3

HIGH RISK - Precipitation

UKCP18 projections indicate changes in both prolonged rainfall associated with fluvial flooding and heavy hourly precipitation associated with pluvial flooding.

Rainfall poses two main hazards:

- **Prolonged rainfall** - long periods of above average precipitation leading to fluvial flooding events and river erosion.
- **Short-duration** - intense rainfall events, such as thunderstorms, leading to pluvial or flash flooding events as surface run-off inundates small catchments.

Surface flooding is difficult to predict due to many contributing factors such as surface types and drainage systems, as NGED own and operate a vast number of assets this risk is extremely difficult to quantify.

Increased precipitation increases the potential for flood levels to increase, potentially leading to exceedance of current identified flood levels and the breach of installed flood defences and design considerations. For the purpose of this assessment we presume that external flood defences such as those installed and maintained by the Environment agency remain in place with no adaptation.

Prolonged rainfall is expected to occur more frequently in the autumn and winter months, indicating an increase from an approximately once a year event in todays' climate to twice a year by the **2060**s. Some increases to these events could be seen as early as the **2030**s. Heavy hourly precipitation, associated with pluvial flood events, are expected to increase both in winter and summer. Whilst in the summer the frequency of wet days may decrease, when it does rain average rainfall intensity is expected to be greater. Maximum hourly precipitation is projected to increase by 25% by **2060-2080** in the summer and winter. In winter these are projected to increase across most of the UK, with the greatest increase expected to occur in Southern England.

High risk – Grid and primary substations

Table 3. High risk precipitation hazards - substations

Risk code	Climate variable	Hazard/Risk/ Function	Risk score Present day scenario	Risk score mid century scenario	Risk score end of century (+2°C) scenario	Risk score end of century (+4°C) scenario
AR10	Precipitation	Grid and Primary Substations affected by river flooding due to increased winter rainfall	3 x 3	4 x 3	4 x 4	4 x 4
AR11	Precipitation	Grid and Primary Substations affected by pluvial (surface water) flooding due to increased rain storms in Summer and Winter	2 x 3	3 x 3	4 x 4	4 x 4

Regardless of the source, the impact of flooding on ground located assets is the same. Electrical assets and supporting systems, such as telecommunication assets, can be physically damaged by flood water and water ingress can cause assets to fail, leading to extensive loss of supply. The consequential repair or replacement of assets is costly, time-consuming, and extends restoration times. Flooding also poses other risks such as river bank erosion/landslips which can expose and damage underground assets. These risks are sometimes overlooked, as they can be difficult to identify beforehand. Network operators will often choose to switch out assets in order to avoid water ingress causing a fault and uncontrolled shut down presenting further dangers. Increased rainfall also has potential to affect the telecom communication equipment used to remotely control network devices, such networks underpin the reliable operation of the distribution network. During flood events access to assets can be severely impeded, further delaying supply restoration.

Adaptations

NGED has polices and business objectives to address operational site flood risk planning and mitigation. Our current polices relate to fluvial, pluvial and sea flooding. Our operational site flood policy has recently been updated to include climate change related flood risks and system interdependencies by now including telecommunication sites.

Following the floods of 2007, a task group was set up by the ENA to assess the resilience to flooding of primary and higher voltage substations, and the steps that may be taken to mitigate current and future risks. The work of the task group was documented in Engineering Technical Report 138 (ETR 138) Resilience to Flooding of Grid and Primary Substations. In response to ETR 138, all NGED Grid, Primary and identified strategic substations have been risk assessed for flood risk.

We have achieved our RIIO-ED1 targets, installing flood defences at 86 substations, reducing the risk of both damage to equipment and supply interruptions due to flooding. During RIIO-ED2 (2023-2028) we propose to continue installing permanent flood protection measures at identified sites.

Current flood risk assessments and flood defences are designed for the lifespan of the asset. Many sites risk assessed have a life span of 80 years, with risk assessments carried out considering climate change data to the end of the century. All 33kV and above sites with greater than or equal to 10,000 unrecoverable customers, where flood defences have been installed, have been designed to protect against a 1 in 1,000 year flood event with an additional allowance put in place to take account for climate change.

We uses robust flood warning systems to monitor key substations, the Environment Agency (EA) operates a “Targeted Flood Warning Service (TFWS)”, aimed to provide warning of threats of flooding at various levels for registered sites. In addition the EA and Met Office have launched a joint venture called the Flood Forecasting Centre which aims to provide advance warning (known as flood guidance statements) typically in the time period out to 72 hours before a flood event.

When planning and installing new distribution sites, consideration is given to flood risk. When sites are identified as being within flood zones, flood mitigation is identified at planning stage if relocation of the site is not viable.

NGED recently completed a study investigating the relationship between weather and fault patterns. There was found to be a positive correlation between rainfall events and faults. Cross-correlation analysis showed there is a peak in the number of faults one day after a peak in the rainfall, with the number of LV faults increasing. We will continue to use data science to further our knowledge of climate change risks to support climate change adaptation.

For long term resilience, we will continue to regularly reassess flood risks and monitor emerging flood risks, to identify any further sites at risk of flood water and install defences where required.

HIGH RISK – Sea level rise

The current rate of global sea level rise is 3-4mm per year. Under RCP8.5 this will increase, resulting in global mean sea level rise of between 0.23-0.40m by 2050, in comparison to 0.17-0.32m under the RCP2.6 scenario. Uncertainty in future sea level rise driven by climate change up to 2050 is relatively small, making these projections robust for short-term adaptation planning. The rate of global mean sea level rise is expected to increase to 10-20mm per year by end of the century under RCP8.5. This equates to global mean sea level rise of between 0.61-1.10m by 2100, relative to 1985-2005, and is projected to continue to rise beyond 2100 in all RCP scenarios.

High risk – Grid and primary substations

Table 4. High risk sea level hazard - Substations

Risk code	Climate variable	Risk/ Function	Risk score Present day scenario	Risk score mid century scenario	Risk score end of century (+2°C) scenario	Risk score end of century (+4°C) scenario
AR12	Sea level rise	Grid and Primary Substations affected by sea flooding due to increased rain storms and/or tidal surges/sea level rise	2 x 4	3 x 4	3 x 4	4 x 4

Storm surges, caused by atmospheric forcing on the sea's surface, can pose a significant risk to coastal zones. The likely damage to distribution assets is considered the same as that associated with sea level rise and future change projections are dominated by this factor. However, storm surges pose a more immediate risk compared to gradual, mean sea level rise, as these can occur at short notice with varying intensity; similar to risk associated with pluvial flooding.

Projected future increased sea level pose a long-term high level risk to both coastal assets and assets located in tidal catchments. All four of NGED's licence areas are at risk from sea level rise/tidal surges. Grid and Primary sites have been identified as assets at highest risk however we remain mindful that all other assets located in flood zones such as communication sites and distribution substations will also be at risk.

Coastal inundation of fixed-level assets (known as salinisation) and ground erosion, which results in loss or damage of below ground assets, has two impacts of particular concern during coastal flood events. Firstly, coastal hazards that exist or can arise as a result of sea level rise include, permanent submergence of land, more frequent or intense flooding, enhanced erosion of assets due to salinisation of soils, and impeded drainage. Secondly, changes in temperature and wind patterns will change the production of surf in the sea and the transport of this to land. The consequent changes in concentration of salt deposited on metal surfaces has the potential to increases rates of corrosion for land based assets, such as switchgear and overhead assets.

Adaptations

As discussed in AR10 and AR11, our flood risk assessments carried out in response to ETR 138 include many operational sites in close proximity to the coast and consider coastal flood risks. Installed flood defences take into account sea level rise flooding for the life span of the asset. Further monitoring of relevant sites will be required to ensure that the assumptions regarding current/future flood levels and existing sea defences remain appropriate.

MEDIUM RISK – Extreme high temperatures/ increased average temperatures

Trends in observational records show that the UK climate is warming. The average hottest day of the year, in the most recent available decade within UKCP18 (2008-2017), has been on average 0.1°C warmer than the 1981-2010 average, and 0.8°C warmer than the 1961-1990 average hottest day of 26°C. 2022 was the UK's hottest year on record, with a yearly daily average temperature of over 10°C recorded for the first time and a new record daily maximum temperature was provisionally reached on 19 July 2022, with 40.3C recorded at Coningsby, Lincolnshire, exceeding the previous record by 1.6°C.

For the future projections, the frequency with which the high temperature thresholds are exceeded each year is expected to increase under RCP8.5. This is consistent with UKCP18 headlines, that hot summers are expected to become more common. In the recent past (1981- 2000) the chance of seeing a summer as hot as 2018 was low (<10%). This has already increased due to climate change and is now between 10-25%. With future warming, by mid-century these hot summers could become even more common, near to 50% in all emission scenarios.

The largest increase is expected to occur in South East England, as the number of days in which the temperature exceeds 28°C is expected to rise from around 8-12 days a year to over 30 by 2060. For regions in the South East, projections suggest that by 2040 the frequency with which the temperature exceeds 30°C will be similar to the frequency of exceeding 28°C in the current climate. The rate of change of this hazard is expected to be smaller for cooler regions of the UK, such as the South West and North of England. Projections suggest that by the 2060s the frequency with which this hazard occurs in these areas will be equivalent to that of the warmest areas of the UK in today's climate.

Hot spells will be warmer in the future. The maximum temperature in hot spells is projected to increase, this is seen at all return periods. An event that occurs every 20-years in the 1980-2000 period is projected to occur every **4-5 years in the 2020-2040** period, and every **1-2 years in the 2060-2080** period.

High temperatures have been identified as a key hazard, as they impact the network through reduction in the performance and efficiency of assets. Whilst many asset components are generally rated to withstand temperatures greater than those experienced in the UK today and future scenarios, there is a risk of increased failures, exceedances of design standards, and reduction in performance during heat events and increased average temperatures. All of these factors will reduce the overall resilience of the distribution network.

MEDIUM RISK - Overhead Lines

Table 5. Medium risk temperature hazard – Overhead lines

Risk code	Climate variable	Risk/ Function	Risk score Present day scenario	Risk score mid century scenario	Risk score end of century (+2°C) scenario	Risk score end of century (+4°C) scenario
AR1	Temperature	Overhead line conductors affected by temperature rise.	3 x 3	4 x 3	4 x 3	4 x 3

As overhead lines are fully exposed to the weather, the temperature of a conductor will vary according to the current flowing in it as well as the ambient air temperature, solar radiation, and wind velocity. Thermal expansion of conductors is taken into consideration during design however, overhead lines frequently exposed to prolonged extreme temperatures could exceed Electricity Safety, Quality and Continuity Regulations (ESQCR). All overhead lines are required to be designed and operated such that required electrical clearances to ground and other objects are maintained. However, the height of an overhead line conductor above ground is not constant, being dependent on the temperature of the conductor. Increased heat events could increase the number of incidents where conductor clearance limits are compromised resulting in faults, loss of supply and safety concerns.

Increasing temperature also impacts the capacity of conductors, which are designed to operate at their maximum efficiency up to a maximum core temperature. As air temperature increases, it becomes difficult for the heat from the conductor to radiate. As the core temperature increases so does resistance within the conductor, reducing its ability to carry current, thus reducing its capacity. The drive for NetZero over the coming years will expose overhead networks to new demand challenges not yet seen. The uptake of Low carbon technologies, potential changes in customer behaviours, and energy consumption makes it vital that that overhead constructions are future proofed for the potential changes under all climate scenarios. Significant changes in energy usage profiles coupled with increased heat could see conductor maximum load ratings exceeded more frequently, potentially requiring replacement or rating reductions to accommodate increased heat.

NGED lead an improved statistical ratings project looking at real time weather and effects on overhead lines, the finding identified the potential overhead network system reductions that could be expected if average ambient air temperatures increase (+2°C to +5°C as predicted in the RCP8.5). It is easiest to present the results in terms of a rating reduction per °C rise in average air temperatures, as follows for typical conductors used on the distribution network:

Table 6. OH line ratings

Conductor & Temperature	Rating	Existing Value	Reduction	% reduction per °C
25mm^2 Copper @50	Summer 0%	126 Amps	2Amps/°C	1.6%
100mm^2 Copper @50	Summer 0%	316 Amps	5Amps/°C	1.6%
175mm^2 Lynx ACSR @50	Summer 3%	432 Amps	7Amps/°C	1.6%
400mm^2 Zebra ACSR @75	Winter 12%	1230 Amps	10Amps/°C	0.8%
500mm^2 Rubus AAAC @90	Winter 12%	1600 Amps	10Amps/°C	0.6%

For wood pole lines up to 33kV, sag increases would be small (around 200mm per 5°C for a typical span). In most existing constructions there would be clearance to accommodate this increase. Where conductors would exceed clearances due to temperature increases, ratings will need to be reduced or conductors will need to be raised/upgraded to allow the increase of conductor temperature.

Adaptation

NGED Conductor heights are measured and monitored through routine line patrols, carried out by the NGED Helicopter Unit. 11kV overhead lines are inspected once every four years, 33kV and 66kV every two years, and 132kV every year. These patrols are carried out using LiDAR (Light Detection And Ranging) technology which enables us to build a full model of the distribution network, including all conductor heights. Utilising data science capabilities, we are able to monitor conductor heights/sag periodically and stress test against future climate data to ensure conductors remain within statutory clearances. This data is further supported by routine foot inspections carried out every eight years.

In RIIO-ED1, we have replaced 39.5km of overhead lines with underground cable within Areas of Outstanding Natural Beauty (AONBs) (recently renamed National Landscapes) coincidentally reducing the number of overhead conductors exposed to heat events. We are committed to replacing a further 50km of overhead lines in AONBs and National Parks with underground cables in RIIO-ED2, reducing network exposure to heat events.

Ambient temperatures used for probabilistic ratings were changed in 2019, following findings from a project, led by NGED, to improve the statistical ratings for DNO overhead lines project. The project looked at historic ratings used in ENA ERP 27 (which were developed in the 1970s) and tested their accuracy and if there had been any change over the last 50 years due to climate change. The outcome of the project identified that original summer ratings of ERP 27 were conservative, with the new summer ratings being higher. Conversely, it appeared that winter ratings had been optimistic, with new winter ratings being lower. The original 1986 Issue of P27 used three different seasons – Summer, Winter, and a combined Spring / Autumn. The recent study indicated that a 4-season approach was more appropriate and has since been implemented.

By default, all overhead lines used to have a minimum profile temperature of 50°C. Prior to 1970, this was the maximum temperature allowed by regulations. After 1970, the new regulations allowed for higher profile temperatures, although 50°C was still typically used as the default. Overhead lines have recently been re-profiled for a minimum rated temperature of 55°C. The additional 5°C was added to allow for future climate change effects, however, in order to benefit from the additional current capability of conductors, wherever possible, all new and re-conductored lines are designed to a rated temperature of 75°C, significantly improving network resilience to increased heat.

During peak ambient temperatures, convective cooling dominates the heat balance. Peak ambient temperatures occur in conjunction with high levels of solar radiation, which in turn generates light breezes. This mean that "dead calm" conditions, that are associated with peak conductor temperatures, are extremely unlikely to occur. Therefore, peak conductor temperatures do not coincide with peak ambient temperatures.

Maximum conductor temperatures occur during the night, when natural convection is at its lowest. When coupled with potential changes in customer energy usage (e.g. additional uptake of electric vehicles) which will potentially increase night time demand, this poses a risk. In anticipation of this move from historic cyclic to a sustained load profile on LV networks, ABC ratings are now based on the sustained load pre-fault rating, in order to safely accommodate high, sustained levels of demand also achieving resilience to increase in ambient temperature.

NGED currently use an industry specific weather forecast service which provides daily and short term forecast across the business. This system uses a red, amber and green system (RAG) for identifying key levels of risk. Daily forecasts advise NGED Control Centres of weather warnings for lightning, temperature, gales, rainfall and snow, including line icing risk. Temperature warnings are triggered at 28°C to ensure appropriate fault response arrangements are in place.

NGED's Future Capability Team are currently running an Network Innovation Allowance (NIA) funded project The Running Cool. Running Cool seeks to,

- challenge current Active Network Management (ANM) curtailment arrangements by creating a new post fault capability for overhead lines and a new ANM architecture, which will help to avoid curtailment;
- improve system short term dynamic OHL ratings (informed by real-time conductor temperatures); and
- create a new corresponding ANM control system architecture.

MEDIUM RISK - Underground Cable

Table 7. Medium risk temperature - cables

Risk code	Climate variable	Risk/ Function	Risk score Present day scenario	Risk score mid century scenario	Risk score end of century (+2°C) scenario	Risk score end of century (+4°C) scenario
AR4	Temperature	Underground cable systems affected by increase in ground temperature,	3 x 3	4 x 3	4 x 3	5 x 3

As with overhead lines, increasing temperatures impact on the capacity of cables and of the network as a consequence. Cables are designed to operate at their maximum efficiency up to a maximum core temperature. As the ground temperature increases it becomes difficult for the heat from the conductor to radiate. Increased core temperature, increases resistance within the conductor, reducing its ability to carry current and thus reducing its capacity and increased losses.

Soil moisture directly relates to soil resistivity. Underground cables rely on the thermal resistivity of the surrounding medium to dissipate heat. If surrounding mediums dry out, then the thermal resistivity of the soil will rise, resulting in less efficient heat transfer from the cable. Ultimately, the rate of heat generation in the cable can exceed the rate of dissipation, leading to thermal runaway, and irreversible damage to the cable; leading to costly replacement or potential faults. To avoid this, it is essential that cables insulation ratings are not exceeded. In future periods we may need to de-rate cables to allow for such environmental changes or upgrade with larger cables.

Soil temperatures are predicted to rise steadily over the 21st Century, though at a slightly slower rate than air temperatures, resulting in global average warming in the top 1m of soil of 4.5°C and 2.3 °C for the RCP 8.5 and 4.5 scenarios.

The current seasonal soil ambient temperatures used within NGED for calculating cable ratings are:

- Summer: 15°C
- Spring/Autumn: 12°C
- Winter: 10°C

Within NGED we use a large variety of cables, cable manufactures, cable design and materials. These can vary between licence areas due to historic standards however, they fall into three main categories as detailed in Table 8. Cable ratings.

Table 8. Cable ratings

Cable conductor type	Maximum core temperature
Paper insulated	65°C
PVC	70°C
EPR/XLPE	95°C

We currently use 3 types of cable ratings:

1. **Sustained, Continuous or Steady-State rating:** The maximum continuous current that can be carried, in defined conditions, without the assumed maximum conductor temperature being exceeded.
2. **Cyclic rating – (most common cable rating):** The maximum current that maybe carried during the prolonged application of a succession of identical 24-hour load cycles, without the

assumed maximum conductor temperature being exceeded. The cyclic rating is calculated using load curve G load profile.

3. **Distribution rating:** The ratings calculated for stated conditions commonly occurring on distribution systems. The tabulated ratings given are 3 to 5 day limited time cyclic ratings.

Current cyclic cable ratings are calculated using the 1970s load curve G load profile. During 1960s, prior to load curve G, UK DNOs had always used sustained cable ratings. Following a load study, an average load profile was produced leading to the introduction of cyclic cable ratings. As customer behaviour profiles begin to change, as discussed in AR1, there may be a requirement for cable ratings methods to be re-assed to take into account changes in load profiles and increased conductor temperatures.

Historically, cables were able to cool sufficiently during periods of low load, allowing for higher peak cyclic ratings. In future periods, higher sustained base loads and increased night time loads could see periods of available cooling reduced potentially exceeding thermal limits of cables. When increasing ground temperatures are coupled with changes in customer behaviours, considerations will need to be made to evaluate the accuracy of cable rating calculations and potential changes to installation methods.

Preliminary studies looking into the relationship between soil temperature, soil resistivity and load profiles have identified a reduction factor for cable ratings of **0.7%** per 1°C soil ambient temperature increase. Further to this, studies have shown moving from **cyclic ratings** to **sustained ratings** could see load carrying capabilities reduced by up to **15%**.

The effects of urban heat islands (UHI) is an additional hazard for cables situated within urban environments. Urban areas have a higher temperature due to anthropogenic alterations of land surfaces, higher energy use, and generation of excess waste heat. UHI research has shown that the average air temperature within an urban environment can be 6°C higher than that of a rural environment. Research has shown a linear relationship between mean annual air temperate at non-urban locations and ground temperature at 1m. Ground temperature research and the relationship with UHI is very limited due to many weather stations been located within green spaces within urban environments. It has been recognised that there is an observed increase of ground temperature at 1m within urban environments but the severity in highly urbanised environments under surfaces, such as concrete and tarmac, is unknown.

Adaptation

During RIIO-ED1 larger cables were used when installing new network in Low Carbon Technology (LCT) hotspots. During RIIO-ED1 we have installed 37km of larger cable in LCT hotspots to reduce losses, installing larger cables improves cables resilience to any changes in ground conditions insuring maximum conductor temperatures are not exceeded, and futureproofing network capacity. Standardisation of new 11kV and LV mains cables to larger conductor sizes of 185mm² and 300mm², and LV service cables to 25mm² Copper (Cu) or 35mm² Aluminium (Al). By increasing the size of the standard conductor’s network resilience to higher temperatures and changes in future demand profiles will be significantly improved.

All High voltage network linear cable asset assessments are typically carried out using Autumn Cyclic ratings, and LV cables using autumn sustained ratings this providing adaptation for potential warming winters periods.

MEDIUM RISK -Transformers

Table 9. Medium risk temperature – Transformers

Risk code	Climate variable	Risk/ Function	Risk score Present day scenario	Risk score mid century scenario	Risk score end of century (+2°C) scenario	Risk score end of century (+4°C) scenario
AR7	Temperature	Transformers affected by temperature rise,	3 x 2	4 x 3	4 x 3	5 x 3
AR8	Temperature	Transformers affected by urban heat islands and coincident air conditioning demand	3 x 3	4 x 3	4 x 3	5 x 3

As with cables and overhead conductors, transformers are designed to operate within particular temperature parameters. As air temperature increases it becomes more difficult to expel the heat created by the transformation process. Consequently, transformers can begin to overheat, reducing capacity and life expectancy and, in extreme cases, causing catastrophic failure of the unit.

Localised build-up of heat, particularly in city environments, will lead to increased demand from air-conditioning and ventilation unit operation. Some network operators are now seeing very little difference between summer and winter demand, where traditionally summer was always the season of reduced electricity usage. Increased demand can overload transformers causing tripping, loss of supply and extensive damage. As discussed in AR4, urban heat island (UHI) research has shown that the average air temperature within an urban environment can be 6 °C higher than of that of the rural surroundings. When the uptake of low carbon technologies, changes in customer behaviours as discussed in AR1 and AR4, and potential air conditioning demand is coupled with increases in both maximum and average temperature, potential risks emerge.

Transformer ratings are derived using thermal calculations, taking into account design specifications, ambient air temperature, and load profiles. Distribution transformers are designed to operate within their Sustained Name Plate ratings, which are derived using a maximum temperature rise values using a maximum ambient air temperature of 40°C. This is the maximum load that can be applied continuously for 24 hours a day, without causing transformer damage or accelerating thermal ageing. The primary thermal-related degradation mechanism in transformers is the depolymerisation of paper insulation and the evolution of gases from the insulating oil. Given that the oil could be replaced if required, the primary concern from an asset health/life perspective is the irreversible degradation of the paper winding insulation, leading to significant asset life reduction and potential failure.

The most recent British standard **BS EN 60076-2 2011: Temperature rise for liquid-immersed transformers** states ambient air temperature limits with regard to normal temperature rise requirements. The temperatures at the intended installation sites should not exceed:

- + 40°C at any time;
- + 30°C monthly average, of the hottest month; or
- + 20°C yearly average.

Larger transformers, such as 132/33kV and 66/11kV emergency ratings, are designed around a maximum ambient air temperature of 35°C. If ambient air temperatures exceed 35°C/40°C more frequently, as projected in UKCP18, thermal calculations will need to be adjusted to ensure transformers do not exceed limits. In order to minimise accelerated thermal ageing, transformer capacity will need to be reduced or transformers replaced with bigger units. It is expected that the majority of transformers have sufficient capacity headroom for thermal calculation adjustments without the requirements for costly upgrading.

In future periods we could expect 11kV distribution transformers with limited capacity headroom to be de-rated by some 1% per °C increase in ambient mean air temperature. Whilst the larger 33kV, 66kV and 132kV transformers, that have forced cooling systems, de-rated by some 0.7 % per °C increase in ambient mean air temperature.

The location and environment in which transformers are installed is a significant factor in their ability to cope with heat. Transformers are installed indoors and outdoors, both of which can be affected by heat. Indoor transformers, such as those installed in Glass Reinforced Plastic (GRPs) enclosures are more susceptible to high ambient air temperatures and ventilation is essential to ensure any heat produced from loses is expelled from the enclosure. Keeping stable ambient temperatures of substations is achievable where switchgear is protected from direct sunlight and adequate ventilation is available, however in certain environments indoor substation air temperatures can exceed 40°C, above the maximum optimum operating parameters. As identified through a Met Office research project, some buildings, with an outdoor temperature of less than 22°C, could result in the exceedance of an indoor temperature threshold of 35°C.

Outdoor transformers, such as pole mounted transformers, are also susceptible to temperature increase and are at greater risk from solar gain. As discussed in AR1, peak ambient temperatures occur in conjunction with high levels of solar radiation, which in turn generates light breezes that aids transformer cooling during day time periods of high heat. During night time periods, when natural convection is at its lowest, "dead calm" conditions can be observed. When coupled with the higher average night time temperature and potential increases in LCT load, transformers may exceed design temperatures as their ability to cool sufficiently will be reduced.

Future air-conditioning demand

NGED's DSO have been actively studying future air-conditioning demand as part of larger Distribution Future Energy Scenario (DFES) studies. DFES outline a range of credible futures for connections to the distribution network. DFES makes use of a scenario framework that is consistent with other distribution network operators. Three of the scenarios are compliant with the UK government's net zero emissions target for 2050. Each of these scenarios meets this target in a different way. The four scenarios are defined by different 'speeds of decarbonisation' and 'levels of societal change' and will assist with understanding the impacts associated with network consideration required to adapt to climate change risks.

NGED's Customer behaviour profiles and assumptions report outlines the assumptions we use for customer behaviour as part of strategic network analysis activities. These assumptions are to be used in conjunction with the DFES studies which are run on an annual basis. The DFES studies and subsequent analysis aim to understand how customer requirements for energy will change the development and operation of the distribution network as the UK transitions to a Net Zero future.

Air-conditioning has been considered within forecasts, each air-conditioning unit is geographically allocated to an Electricity Supply Area where it would be most likely to connect to the distribution network. Air-conditioning volumes are provided in number of air-conditioners. The daily profile for all of the demand representative days was assumed to be zero. The reasoning for this was that the peak demand representative days in winter, intermediate warm and summer all coincide with a cold day where domestic air conditioning was assumed not to be in use.

The profile for the Summer Peak Generation representative day was also modelled as zero for network assessments. This does not necessarily coincide with high ambient temperatures, particularly on networks with high wind penetration. There is a risk that modelling air-conditioning demand for the summer peak generation day will mask the worst-case condition.

The current representative profiles do not capture the minimum coincident air-conditioning demand at time of peak generation. This air-conditioning technology currently only captures domestic installations. Non-domestic units are more prevalent and the impact is largely captured in the existing demand behaviour.

As more domestic air-conditioning units connect, demand at times of high ambient temperature could cause a new network edge-case. Similar to hot countries with high levels of air-conditioning, the peak demand can actually occur at high ambient temperatures.

We plan to undertake analysis on domestic and non-domestic air-conditioning operating behaviour. Focussing on existing behaviour at time of network peak and potential for new edge-cases to occur as uptake increases. Consideration of increased energy requirement as average temperature increases could also be reviewed.

The graph below shows the estimated uptake of air-conditioning units, the lowest uptake scenario is associated with governments net zero targets being achieved in a RCP2.6 emission scenario. The highest uptake is associated with the business as usual worst case RCP8.5 scenario. It can be seen that the biggest increase will be between the 2035-2050 periods which coincides with UKCP18 heat projections.

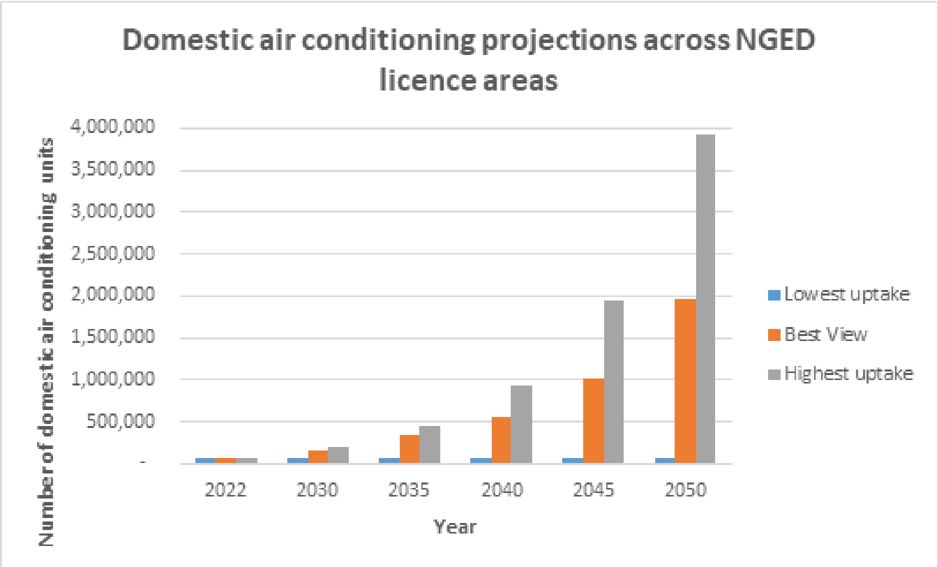

Figure 6. Air-conditioning uptake forecast

Adaptation

Secondary reinforcement of the network is coordinated so that transformers with the greatest forecast utilisation are invested in as early as the rules allow. Replaced transformers are sized in line with its 2034 forecast (pole mounted transformers) or 2050 forecast (ground mounted transformers), as far as is reasonably practicable.

By installing oversized transformers reliance to heat events is increased as well adding sufficient headroom to absorb any future demand increase due to changes in consumer behaviours in relation to climate change. Future distribution transformer assessments are carried out using transformer nameplate ratings, always using sustained ratings to mitigate any future issues than may arise due to changings to cyclic ratings.

MEDIUM RISK - Wind

Table 10. Medium risk wind – overhead line

Risk code	Climate variable	Risk/ Function	Risk score Present day scenario	Risk score mid century scenario	Risk score end of century (+2°C) scenario	Risk score end of century (+4°C) scenario
AR16	Wind	Overhead line assets affected by strong winds / storms	4 x 3	4 x 3	4 x 3	4 x 3

Storm and wind events have always posed risks to electricity assets, therefore consideration is included within design standards and we continue to learn from past events. In addition, we make mitigations through work programs, such as extended resilience tree clearance and have robust response and recover plans in the event of a storm.

Wind and storm events will continue to be a significant risk to distribution networks. Overhead assets, such as wooden poles and steel towers, located in exposed locations are routinely faced with storm events and high wind speeds, making these assets most susceptible. During storm events considerable damage can be caused to assets, either being directly by high wind speeds and/or indirectly by flying debris and vegetation contact. After a fault, restorations can be delayed due to restricted access from blocked roads and high volumes of faults due to a storm event.

There is no strong signal within the UKCP18 projections for a change to future storm intensity. Therefore, the risk of strong winds has been assessed in today's current climate only, however future conditions will continue to be monitored.

If future periods of high wind speeds coincide with periods of increased rainfall and vegetation, due to increased growing seasons, compound risk events begin to emerge. This is an area of interest which NGED will continue to investigate.

Adaptation

Storm Arwen occurred over two days in November 2021, leading to widespread damage across a number of regions. Just under one million homes experienced power loss and over 100,000 homes suffered several days without power across the UK. The Met Office recognised Storm Arwen as one of the most powerful and damaging storms of the last decade. The storm occurred just a week before the RIIO-ED2 business plans were submitted to Ofgem in December 2021.

Following this storm, the Secretary of State for Business, Energy and Industrial Strategy (BEIS) commissioned a report into storm response. The review was carried out in collaboration with industry and Ofgem, with the aim of identifying lessons to be learned and actions to take. Ofgem carried out a separate and complementary report which investigated what network companies did before, during and after the event, and investigated compliance of the relevant licence conditions of the Distribution Network Operators involved. A number of actions and recommendations were made, and for those that could modify the scope of work that DNOs are expected to deliver in RIIO-ED2, Ofgem introduced a re-opener to enable funding in RIIO-ED2 to address these changes.

NGED reviewed the Storm Arwen reports and have identified a number of initiatives to improve resilience and our fault response for customers in future storm events. Some of these are longer term programmes that are proposed to start in RIIO-ED2 but will continue into RIIO-ED3 and beyond.

Preventative actions to improve resilience include; selective undergrounding of overhead lines, targeted conversion of open wire LV circuits to covered conductor, extending HV circuit resilience tree clearance, and rolling out technology that can identify weak points before they turn into faults.

Enhanced response actions include; extending the use of automation to subdivide the network into smaller zones, application of automation to overhead line spurs, using technology to better pinpoint faults reducing patrol times, additional mobile generation and pre-emptive arrangements for early deployment of resources to support areas likely to be impacted by storms.

NGED are currently awaiting a final decision from Ofgem on these proposals in RIIO-ED2.

We also continue to explore further technological enhancements to deliver strategic long-term improvements to network resilience.

LOW RISK – Switchgear

Table 11. Low risk temperature hazard – Switchgear

Risk code	Climate variable	Risk/ Function	Risk score Present day scenario	Risk score mid century scenario	Risk score end of century (+2°C) scenario	Risk score end of century (+4°C) scenario
AR9	Temperature	Switchgear affected by temperature rise	2 x 2	4 x 3	4 x 2	5 x 2

The impact of increasing temperatures will also affect HV and LV switchgear by reducing its capacity or, in extreme cases, lead to tripping, resulting in loss of supply or, if operating incorrectly, damaging the network. Prolonged periods of hot weather will increase the temperature inside switch rooms above the maximum optimum operating parameter for the switchgear, increasing the potential for faults or mal-operation. Whilst the risk of complete switchgear failure is relatively low, connected assets, such as cable terminations, are at greater risk. A cables insulation will not necessarily fail if temperature limits are exceeded, however connected joints and terminations are more susceptible to failure, resulting in damage or complete failure of the attached switchgear. Following internal data studies of past heat waves such as that in July 2022, we experience an uptick in fault rate at temperatures of 30°C and above, with the impact in urban areas being most acute.

As with overhead lines, cables and transformers, increasing temperatures impact switchgear load carrying capacities. Switchgear is designed to carry its maximum load at its maximum tested ambient air temperature rating. If ambient air temperatures were to exceed that of the switchgear design rating, then conductor temperature within the switchgear will increase, as the temperature increases so does the resistance within the conductor, therefore reducing the switchgears ability to carry current and thus reducing its capacity. Excess heat can also lead to premature aging and failure of internal insulation components.

Switchgear exposed to direct solar radiation and switchgear located within urban heat islands is at risk from increases in maximum daily temperatures and heat events. Solar gain also poses a risk to switchgear, especially during heat waves. As with transformers (as discussed in AR7) this is most acute within smaller GRP substations and containerised solutions as they can absorb a lot of heat but not radiate it away well due to having a smaller surface area. They are also prone to large temperature swings exacerbating condensation formation, which causes breakdown within the electrical apparatus in the form of partial discharge and rusting leading to early failure.

Switchgear exposed to direct sunlight, without adequate ventilation or protection, has potential to exceed manufactures specified temperature rise. High voltage switchgear and associated equipment is generally rated for maximum continuous ambient air temperature of 35°C, and can withstand a maximum 40°C temperature for 24 hours, but this has to be followed by a period of time below this to cool down. Switchgear is maintained and monitored and as such has a long design life, typically 40 to 80 years, with assets situated in the same location. Older assets’ design standards may have lower ambient temperature values compared to that of newer switchgear, however this does not mean they are greater vulnerability due to historic over engineering.

Maintaining ambient temperature of substations is achievable when switchgear is protected from direct sunlight and adequate ventilation is available, however in certain environments indoor and outdoor substation air temperatures can exceed 40°C. As discussed in AR7, an ambient air temperature of an indoor substation can exceed 35°C with an outside ambient temperature as low as 22°C even before considering heat produced through losses.

Switchgear auxiliary equipment and supporting equipment, such a telecommunication assets, Protection relays, and batteries are also at risk from heat events. Performance can be significantly reduced during heat events, and in worst case, complete failure can be experienced, highlighting the importance of identifying interdependences between systems.

Adaptations

Many current suppliers specify higher temperatures than the standard requirements, for example 11kV overhead switchgear may be rated for 50°C but in some instances this only applies to certain components and not the switchgear itself.

All new and existing substations that are upgraded or extended at 11kV and 33kV for Primary, Grid and major network substations switch/control rooms are installed with heating, dehumidification and ventilation where practicable to ensure climate resilience.

Under certain levels of solar radiation, appropriate measures, for example roofing and forced ventilation, are utilised. Where this is not possible de-rating may be considered in order not to exceed the specified temperature rise.

LOW RISK – Overhead line and Underground Cable

Table 12. Low risk drought – overhead line and Underground cable

Risk code	Climate variable	Risk/ Function	Risk score Present day scenario	Risk score mid century scenario	Risk score end of century (+2°C) scenario	Risk score end of century (+4°C) scenario
AR2	Temperature	Overhead line structures affected by Summer drought and consequent ground movement	3 x 2	3 x 2	3 x 2	4 x 2
AR5	Temperature	Underground cable systems affected by Summer drought and consequential ground movement	3 x 2	3 x 2	3 x 2	4 x 2

Ground movement can be directly linked to asset damage on the electricity distribution network due to shrink and swell cycles that can expose assets to additional tensile forces, as well as ground instability. Many soils contain clay minerals that absorb water when wet (making them swell) and lose water as they dry (making them shrink). This 'shrink–swell' behaviour is controlled by the type and amount of clay in the soil and by changes in soil moisture content related to rainfall and local drainage. In addition, peat/fenlands soils also having a high susceptibility and vulnerability, both clay and peat is found within NGED licences areas. This shrink–swell variation can cause ground movement, which in turn may affect foundations and utility services, as summarised below:

- Overhead lines: Any structures built on this ground will be subject to movement, this effect is amplified by the height of the structure making overhead lines more vulnerable to this movement.
- Ground mounted assets: Ground mounted structures, such as transformer bases, switch house foundations, and other ground mounted assets will be subject to movement which can lead to instability of the foundations.
- Underground cable: Whilst cables have an inherent tensile strength, joints on the network are more vulnerable and can fail by being effectively pulled apart. In addition, older cables installed on the network may not have been installed with specific backfill such as specified today. Historically excavated soil or basic sand was used to backfill excavations. These types of backfill are more susceptible to drought conditions.
- Third-party damage: Asset damage can also occur as a result of third-party damage, for example water pipes breaking.

Soil moisture deficit (SMD) governs the damaging nature of clay-related shrink-swell. SMD is heavily dependent upon antecedent rainfall conditions and the rate of drying out of the soil has been shown to be directly related to the rainfall accumulation over the preceding 30 and 60 day periods.

Research has shown that the maximum rate at which the SMD increases (i.e. the fastest rate that the soil dries out leading to highest risk of ground movement) occurs in the months May to August. The highest rate of change is dependent upon very low day rainfall accumulations occurring in these high-risk months. There is significant variation in the amount of rainfall occurring throughout the UK with the driest areas in the South East of the UK and wettest areas in the West and the Highlands of the UK. This suggests that assets at greatest risk are those located in clay soils in the driest areas of the UK such as London and the South East.

In general there is very little reduction in seasonal rainfall. The patterns of projected changes of both the 30 and 60 day rainfall accumulations are very similar with the most noticeable changes occurring in areas of the UK which currently experience a wetter climatology. For example the 30 and 60 day minimum accumulations in Wales by the 2060s are projected to reach similar levels to that of today's climatology in the South East of England.

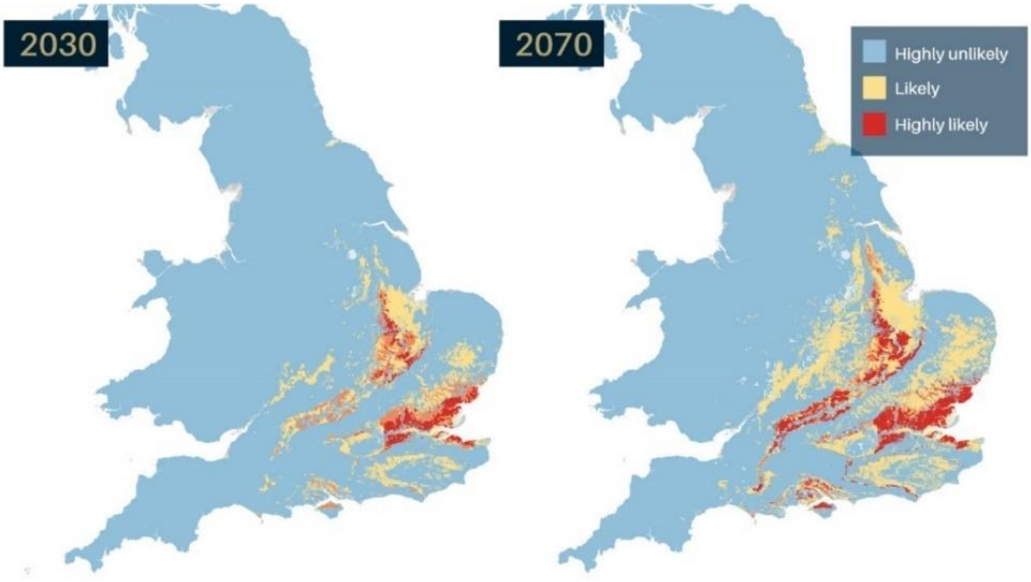

Figure 7. British geographical society – Geo Climate UKCP18 2030 and 2070 projections showing potential changes in shrink swell subsidence

Adaptations

Current overhead line construction standards ensure different ground types are identified at planning stages and constructions are built to accommodate ground types to ensure stability and resilience are not compromised.

When underground cables are installed a surrounding, controlled medium is used to backfill excavations to ensure thermal cooling capabilities. The mediums used are less susceptible to drought conditions therefore, underground assets are at less risk from movement. Cables are installed at depths of 0.45m and over 1m. Cables that are laid deeper are less likely to be affected by a decrease in soil moisture.

LiDAR helicopter patrols have given us capability to digitally map the 11kV to 132kV distribution network. Pole lean is recorded as part of both helicopter and foot patrols allowing overhead line structures to be regularly monitored and rectified if required. If the data collected through the medium term indicates poles are becoming more susceptible to ground movement then current design standards will require updating and intervals between inspections decreased.

LOW RISK – Substation Earthing

Table 13. Low risk temperature hazard – Earthing

Risk code	Climate variable	Risk/ Function	Risk score Present day scenario	Risk score mid century scenario	Risk score end of century (+2°C) scenario	Risk score end of century (+4°C) scenario
AR6	Temperature	Substation and network earthing systems adversely affected by Summer drought conditions	3 x 2	4 x 2	4 x 2	4 x 2

As moisture in the soil reduces, the soil resistivity increases, reducing the effectiveness of the earthing system. Where earthing design parameters are exceeded, system and public safety issues can arise with increased earth potential rise and transferred potentials onto LV, telecommunication, and other systems. Under a worst case scenario performance of protection devices would reduce, resulting in equipment and exposed metal components remaining live. As highlighted for cables, earth electrodes are also at risk from high tensile forces caused from drying out ground and movement of structures which they are attached to.

The resistance of earthing systems restricts available earth fault current. This is particularly relevant where an earth fault occurs on equipment fed via overhead line, since standard overhead lines do not include an earth wire. Fault current is forced to flow through the local earthing system to return to the source substation. In these circumstances, a 20 Ohm earth electrode, for example, will restrict earth fault current to less than 317A. The resistance of the earthing system must be low enough to allow protection devices to detect fault current, discriminate with other protection, and disconnect the fault quickly. If soil resistivity was to increase, there is the possibility of a greater rise of earth potential, decreased fault detection, and increased clearance times.

Soil resistivity varies depending on the type of soil (loam, sandy etc.), grain size, density and moisture content. As the soil moisture decreases, resistance increases, which in turn will lead to a greater earth potential rise, increased HV separation, and reduced performance of protection systems. As the distribution network is upgraded, historical paper insulated lead covered PILC cables, which once helped with earthing, will be replaced with plastic cables, further increasing earthing resistance. Coupled with the uptake of LCTs and embedded generation, increased fault levels will need to be considered. Whilst not directly related to drought conditions, vegetation can also lead to drying out of upper layers of soil during periods of heat, further reducing soil moisture.

Adaptations

At 11kV and below, earthing systems are designed using soil resistivity maps, which are based on legacy measurement values (i.e. from boreholes, civil engineering ground surveys and other soil samples, which British Geological Survey (BGS) then use to estimate values at other locations. Using the identified soil types from maps, we are able estimate values for soil resistivity and then verify that the earth electrode has achieved the design resistance value post installation. Where we don't meet the desired resistance value (i.e. the actual soil resistivity differs from the assumed value) then we modify the electrode design post-installation in order to attain the desired resistance value.

Where the design is based on measured soil resistivity values, such as in the case of a new grid or primary substation, earthing designs are adapted accordingly to measured site values. These sites will generally have an electrode resistance less than 0.5 Ohms.

The data sets currently used by NGED have a climatic sensitivity element helping to identify drought prone areas and give an overview of suggested earthing designs for the given location to ensure the desired resistance values are achieved during all seasons.

Earthing systems are subject to periodic reviews. Where a site's earthing system does not meet the desired resistance values, the cause is normally due to stolen or broken earthing. For instances where the actual soil resistivity reading differs from the point of installation, then the earthing electrode design is modified (i.e. increasing earth mat size) in order to attain the design resistance value.

LOW RISK – Prolonged growing season

Table 14. Low risk prolonged growing season– overhead line and Underground cable

Risk code	Climate variable	Risk/ Function	Risk score Present day scenario	Risk score mid century scenario	Risk score end of century (+2°C) scenario	Risk score end of century (+4°C) scenario
AR 3	Temperature / precipitation	Overhead lines affected by interference from vegetation due to prolonged growing season	4 x 2	4 x 2	5 x 3	5 x 3

It is expected that increases in both temperature and precipitation will lead to increased vegetation growth however, this is a very complex topic. UKCP18 projections suggest growing seasons may be extended due to warmer shoulder and winter months, which may result in a prolonged growing season. There is also uncertainty in future vegetation projections, as it's thought drought conditions could slow some vegetation growth whilst other species may thrive. In addition, warmer winters will allow diseases to thrive, endangering many species and increasing the risk of falling dead trees and potential contact with overhead lines. For trees growing adjacent to the overhead lines, these issues can impact on minimum clearances leading to faults, loss of supply and physical damage. The change in tree growth could also impact supply chain and standard of wood poles currently used within the electricity industry.

The length of the growing season is calculated using mean daily temperature; it begins at the start of a period of five successive days where the daily-average temperature is greater than 5°C and ends on the day before a period of five successive days when the daily-average temperature is less than 5°C. The average growing season length between 1961 and 1990 was 252 days, compared to the recorded length in 2012 of 282 days, indicating approximately 30 day increase in growing season length. This is largely due to an earlier onset of spring.

There is a concern of a compound event, where vegetation will still be present during wetter months, as predicted in UKCP18, increasing the likelihood of wind throw and disruption to the electricity network. The transient nature of tree related faults can cause repeated disruption to supplies. When trees in leaf become wet, vegetation can hang lower due to increased weight resulting in contact with overhead lines and unwanted interruptions.

The majority of vegetation related faults on the distribution network occur during wind/storm events. There is no strong signal within the UKCP18 for a change to storminess however, projections do show an increase in near surface wind speeds over the UK for the second half of the 21st century for the winter season, there is also emerging additional research suggesting windstorms are likely to increase in frequency and intensity over the UK. This is an area we will continue to monitor closely

Increased overhead line conductor sag, during more frequent heat events, combined with an increase of vegetation could cause contact with conductors to become more common. In addition, the impact of climate change on the nesting season, particularly of birds, is of interest due to the impact on maintenance and construction schedules associated with ecological laws on disturbance of nests.

Adaptations

There are two types of tree cutting that take place, cutting to achieve safety clearances in accordance with ENA technical specification 43-08 and cutting to achieve resilience in accordance with ENA Engineering Technical Recommendation (ETR) 132

NGED's vegetation management program is currently a five year cycle for the LV network and EHV network, a four year cycle for the HV network and the 132kV is inspected on an annual basis. Following the ENA Technical report (ETR) 136 Vegetation Management near Electricity Equipment- Principles of Good Practice Target clearance we added to the safety clearances given in ENA-TS 43-8 reasonable allowances for expected re-growth of vegetation over the periods outlined above. In addition to this clearance, we also allow for swaying of vegetation in storms, sag of electricity conductors in high temperatures, the operational risk of airborne debris, snow loading of branches, branch breakages, and windblown trees hitting the overhead lines in major storms.

Following storms in October 2002, existing legislation was amended, which led to the development of ENA Technical Report (ETR 132) “Improving Network Performance under Abnormal Weather Conditions by Use of a Risk-Based Approach to Vegetation Management near Electric Overhead Lines”. This legislation was changed to require DNOs to clear trees from strategic overhead lines to a resilient standard to prevent damage should a tree be blown over. The resilience standard requires a greater distance between trees and overhead lines compared to clearance distances required for routine tree clearance. The government’s impact assessment considered making 20% of the network resilient within 25 years. Note: ETR 132 Issue 2 (the current issue) is presently under review and will likely be issued as EREC G132.

In preparation of the RIIO-ED1 Business Plan, stakeholder engagement showed strong support for additional clearance work. NGED therefore committed to increasing the amount of resilience tree clearance by 40%, with the aim of clearing 700km of overhead lines per year and to complete the 25 year programme five years earlier than originally planned. In addition NGED have the following aims;

- All EHV circuits to be resilient (ETR 132) by end of ED2 (2028). Individual trees which cannot be cut to a resilience standard will be risk assessed and managed. Targeted circuits will then be maintained to ensure network resilience levels remain unaltered.
- Targeted vegetation management aimed at first legs before first stage of protection to reduce Customer Interruptions (CIs) and Customer Minutes Lost (CMLs)

During RIIO-ED1, we have also replaced 39.5km of overhead lines with underground cable within National Landscapes reducing overhead conductors exposed to vegetation.

We have invested in LiDAR technology to enhance our vegetation management capabilities. LiDAR systems are fitted to each NGED helicopter and are capable of measuring the distance to multiple targets, including conductor and vegetation, using a pulsed laser light and measuring the reflected pulses with a sensor. NGED’s helicopter unit inspect 11kV overhead every four years, 33kV and 66kV every two years, and 132kV every year. With captured LiDAR data we are able to identify vegetation location, proximity to conductors, volume and falling risk. Using this data we developed a series of data-driven tools to inform vegetation maintenance and resilience planning. Combining data from across all regions and time points, we developed predictive models using machine leaning to forecast the future state of the vegetation. LV network is inspected by foot by incumbent vegetation management contractors on a 5 year cycle.

A Core commitment of the RIIO-ED2 Business is to improve service for at least 8,260 Worst Served Customers by undertaking 70 schemes. Worst Served Customers are defined as “a Customer of the licensee who customers experiencing 12 or higher voltage interruptions over a three-year period (with a minimum of two interruptions per year)”. The analysis of causes of faults is carried out by local Network Services teams, who have knowledge of the local circumstances for each circuit. Where the cause of fault is identified as vegetation related, vegetation management programs are targeted to improve network performance and level of service for customer’s supplies.

LOW RISK – Dam Burst

Table 15. Low risk precipitation hazard – Substations

Risk code	Climate variable	Risk/ Function	Risk score Present day scenario	Risk score mid century scenario	Risk score end of century (+2°C) scenario	Risk score end of century (+4°C) scenario
AR13	Precipitation	Grid and Primary Substations affected by water flood wave from dam burst	1 x 5	1 x 5	1 x 5	1 x 5

Where substations are located far enough away from dams the impact of water inundation from a dam burst is no different from “standard” pluvial, fluvial or tidal flooding and flooding impacts can be considered similar. Where substations are close enough to dams, to be impacted by the full force of a breach, the damage to a substation would be substantial. Plant and equipment would not only be impacted by water ingress and is likely to be physically damaged or even washed away by the force of water. Where a substation site has been impacted by the full force of a dam breach, it would not be possible to re-establish supply without fully reconstructing and recommissioning the site. Dam bursts are at highest risk during periods of extreme rain fall, where extra loading can be placed upon dams. High water levels can cause dam breeches and accelerated erosion, compromising dam’s structural integrity. When events occur during extreme rainfall, river levels below are most likely to be at their highest further increasing the flood level of extent of damage.

Adaptations

Dam burst is included in NGED’s Operational site Flood Risk Planning and Mitigation policy. All new sites are assessed and consider risks posed by a potential dam burst.

The Environment Agency have made flood extent data publicly available. The data sets have two flooding scenarios shown on reservoir flood maps, a ‘dry-day’, and a ‘wet-day’. The ‘dry-day’ scenario predicts the flooding that would occur if the dam or reservoir failed when rivers are at normal levels. The ‘wet day’ scenario predicts how much worse the flooding might be if a river is already experiencing an extreme natural flood. NGED intends to add these layers to our network plans to support planning activities.

LOW RISK – Increased lightning activity

Table 16. Low risk lightning hazard – Overhead lines

Risk code	Climate variable	Risk/ Function	Risk score Present day scenario	Risk score mid century scenario	Risk score end of century (+2°C) scenario	Risk score end of century (+4°C) scenario
AR14	Lightning	Overhead lines and transformers affected by increasing lightning activity	3 x 2	3 x 2	3 x 2	3 x 2

Increased storm frequency can lead to an increased lightning strike frequency. Where lightning strikes exposed substation plant or, more likely, overhead line assets, the resulting surge will cause circuits to trip under fault condition. In extreme cases, strikes can cause physical damage to the assets or a loss of generation, leading to other network protection systems operating, causing loss of supply and lengthy restorations.

UKCP18 shows no predicted increases in frequency or intensity, however lightning still poses a significant risk to the network in today's current climate.

Telecommunication assets, which are essential to the resilience and reliable operation of the distribution network, are vulnerable to lightning strikes. Assets such as base stations are strategically positioned on geographical high points, increasing vulnerability to strikes, reducing resilience of the electricity network.

The main risk to equipment arises from induced and direct lightning strikes to the overhead systems. In cable systems not connected to overhead lines, overvoltages occur due to faults or switching operations and only in rare cases are lightning induced. During a lightning strike to an overhead line, large overvoltages can be experienced. Where lightning protection is not installed, these overvoltages can exceed insulation voltage limits of equipment causing damage to assets, such as transformers windings and terminations, resulting in lengthy customer interruptions (CIs), increased customer minutes lost (CMLs) and costly repairs.

Adaptation

To minimise disruption, lightning protection is installed on distribution systems at 11kV and above. Historically, simple devices such as arcing horns/duplex air-gaps were used, along with early type surge arrestors. Today we use surge arresters as our standard form of lightning protection, the design being non-linear resistor blocks made of silicon carbide in series with spark gaps, that lower their resistance as the voltage rises. These devices are very efficient at reducing damage to assets caused in the event of a lightning strike. Trigger gaps are also used to supplement surge arrestors on identified overhead systems, however are more effective on 11kV systems than 33kV.

All new 11kV pole mounted transformers are installed with surge arrestors, where required they are also installed at Primary and Grid sites. All new 11kV and 33kV cable terminations are also installed with surge arrestors and where specified are used on 66kV and 132kV systems. The introduction of modern cables such EPR further increase network resilience due to high frequency attenuation characteristics which can protect other connected assets from lighting impulses.

Most overhead systems are protected using auto-reclosing/delayed auto reclose protection, which limits the length of an interruption caused by a transient lightning strike. Where permanent damage is caused strategically designed downstream protection devices and automated restoration sequences minimise the supply interruptions and reduce restoration times.

NGED use a daily weather forecast to inform company operations, lightning risk are categorised using a lightning risk and intensity index. Using this data we are able to produce a RAG system to identify lightning risk and prepare accordingly.

LOW RISK – Wildfire

Table 17. Low risk wildfire hazard – Overhead lines

Risk code	Climate variable	Risk/ Function	Risk score Present day scenario	Risk score mid century scenario	Risk score end of century (+2°C) scenario	Risk score end of century (+4°C) scenario
AR 15	Wildfire	Overhead lines and underground cables affected by extreme heat and fire smoke damage	3 x 2	4 x 2	4 x 2	5 x 2

Wildfires refer to the uncontrolled burning of vegetation. In the UK, the largest wildfires typically occur in moorland areas due inaccessibility and deep peat. These areas pose a risk to supply, fault restoration times, access, safety of staff, and damage or loss of the assets. Wildfires are not limited to moorland, assets situated in other land cover types such as arable crops and woodlands are also at risk. Whilst assets such as overhead lines and substations are at risk from wildfires, supporting operational assets such radio base stations in remote moorland sites are also vulnerable.

Other climate change hazards such as increased vegetation growing season and associated pests and diseases could lead to increased fuel loading, dead trees and surface litter increase the chance of ignition and wildfire spread. Whilst flame/heat damage is the main hazard related to wildfires, smoke can also poses a significant risk. Where higher voltage networks are exposed to dense smoke there is risk of flash over occurring and discharge and telecommunication links suffer from decreased signal propagation.

Projections for fire severity indices under UKCP18 scenarios are not available in published material yet, however this is an active area of research with NGED working in close partnership with key stakeholders within the wildfire research area. In general, UKCP18 projections of hotter, drier summers as well as increases in summer hot spells suggest fire risk in the UK will increase in future climates**.** Simulations suggested an overall increase in wildfires during the summer, with danger sharply increasing after 2070.

Wildfires typically occur in two seasons, spring and summer, with spring characteristics of strong easterly winds and low humidity often elevating fire risk during this period of dead matter build up. Projections for wetter winters does not reduce the likelihood of spring wildfires. Studies project a large increase in drought and fire-prone days in the UK with South coasts, West and East Midlands potentially seeing a 10 times increase in high Fire Index Weather days.

The Forestry Commission classified 258,867 events as wildfires between 2009 and 2017, with satellites recording a burn area of 180km in 2018.

Adaptation

Vegetation management and maintenance of overhead assets significantly improves network resilience to wildfires, as mentioned in AR1 and AR3 adaptations.

NGED receive daily DTN weather forecast with triggers for high temperatures, during these periods we are vigilant for wildfire risk. NGEDs call centres, despatch teams and controls teams work alongside each other and emergency services achieving high levels of fault management and safety. NGED contact centres are able act quickly and effectively when receiving reports of wildfires near assets from either fire services or public reports. On gaining key information for an incident they are able to quickly inform HV control rooms who are able to risk assess the situation and able to de-energise lines if required to minimise safety risks. The recent addition of What3Words and other modern technologies have seen significant advances in the relationship between NGED and fire services.

LOW RISK – Interdependencies

Table 18. Low risk Interdependencies

Risk code	Climate variable	Risk/ Function	Risk score Present day scenario	Risk score mid century scenario	Risk score end of century (+2°C) scenario	Risk score end of century (+4°C) scenario
AR17	Interdependencies	Interconnections between different industry sectors	3 x 2	4 x 2	4 x 3	4 x 3

Interdependencies between different industry sectors is a major source of risk for the energy network, with failures from one sector frequently causing impacts and potential cascading impacts to other sectors. Due to the interdependencies of different industry sectors such as gas, telecommunications, water and road networks, with the operation of the distribution network, it is important to assess common climate change risks to prevent potential cascade events.

Dependency on a reliable electricity network is forever growing. As the uptake of low carbon technologies increases, a resilient, reliable electricity network will be crucial to achieving net zero. As technological advances are made across all sectors, interdependencies with electricity networks will increase. With the phasing out of non-renewable energy sources, the uptake of renewable generation connected at distribution level, and changes in customer's behaviours, new key interdependencies will be exposed. This further highlights the importance of current and future network resilience and how each individual industry selector will need to responsible for its own resilience to mitigate the risks. Other Utilities, such as gas and water companies, also have an ever growing reliance on electricity systems, so emergency plans and backup systems will be required. DNOs will need to take action for their own dependencies, such as transport networks and other utilities.

Road transport is often essential for restoration of supply and access to assets for routine maintenance and emergency events. Road transport will also become more reliant on the electricity industry due to the electrification. Road and other transport links such as aviation, rail and ports all rely on electricity networks to ensure safety of networks.

Distribution networks already have a high level of reliance on telecommunication networks for efficient, safe operation ensuring network resilience and reliable electricity supply. The underpinning telecommunication networks also have a great reliance on electricity supplies for operation, this will require an equal resilience level across all areas.

Adaptation

Understanding interdependencies is a developing area, NGED are involved in multiple research projects looking into interdependencies. To date we have worked with the Climate Change Committee, engaged with multiple Future Capability projects, local authorities and the climate change resilience working group. NGED attend regional and local resilience forums for extended risk horizon scanning and align the Community Risk Register where required. Involvement with DESNZ and resilience forums highlight interdependences and identify mitigations to ensure NGED practices are aligned to ensure compliance with the Civil Contingencies Act 2004 (CCA) and to mitigate the risk of an incident as set out in the Cabinet Offices National Risk Register.

LOW RISK – Telecommunications

Table 19. Low risk Telecommunications

Risk code	Climate variable	Risk/ Function	Risk score Present day scenario	Risk score mid century scenario	Risk score end of century (+2°C) scenario	Risk score end of century (+4°C) scenario
AR18	Telecommunication Network	Supporting telecommunication network climate change vulnerability	3 x 2	3 x 3	3 x 3	3 x 3

Telecommunication systems underpin the reliability and resilience of the electricity network. They are critical for the operation of remotely controlled equipment, network monitoring and for communication with personnel in the field. Reduced performance of the telecommunication network can result in a delayed fault response, delayed supply restorations, limited network visibility/operational flexibly, and overall reduced network performance. Future networks supporting low carbon technologies and EV infrastructure will rely on telecommunication links for efficient operation. Many future technologies, such as CCPs (Connection Control Panels) and ANM (active network management) systems need stable radio connections to operate and maintain network stability.

Telecom networks are vulnerable to climate hazards such as extreme heat, flooding and lightning, whilst hazards such as flooding and heat events present similar risks to those posed to electricity assets, telecommunication networks also faces their own unique hazards and risks. Heat events in particular can increase the likelihood of radio wave refraction leading to unreliable Supervisory Control and Data Acquisition (SCADA) indications and operations, whilst intense rainfall and wildfire smoke has potential to reduce propagation of radio waves causing disruption to SCADA systems.

As with switchgear during heat events, battery operation/life can be adversely effected, the cascade risk of battery failure is the loss of SCADA capabilities essential for system operation. Whilst backup systems, such as batteries and generators are in installed for short power interruptions, there is still a great reliance on batteries for a reliable power supply from distribution networks. This key interdependency will need to be addressed from both sides to ensure overall network resilience.

Adaptation

National Grid Telecoms are key members of the ENA Strategic Telecoms Group. Together the group have identified key climate hazards and the level of potential impact/risk on different systems. This initial assessment sets the foundations for imbedding climate resilience into both current and future Telecom networks.

LOW RISK – Health and productivity

Table 20. Low risk Telecommunications

Risk code	Climate variable	Risk/ Function	Risk score Present day scenario	Risk score mid century scenario	Risk score end of century (+2°C) scenario	Risk score end of century (+4°C) scenario
AR19	Employees/ Business operations	Health and productivity affected by climate change	3 x 2	4 x 2	4 x 3	4 x 3

The UK Health Security Agency (UKHSA) published its first Health Effects of Climate Change (HECC) report in 2023. Amongst the vast number of detrimental effects of climate change one that has received least attention is the impact on workforce productivity.

High temperatures and increased air pollution affect workers' ability to do their jobs and can limit the hours they work. Temperatures will likely continue to increase until at least mid-century. Heat waves often lead to poor air quality. The extreme heat and stagnant air during a heat waves increase the amount of ozone pollution and particulate pollution.

Extreme heat exposes staff to hazards such as heat exhaustion and heat stroke. In addition, indirect effects including, increased risk of infectious diseases, changing distribution and transmission patterns of vector-borne diseases, and water and sanitation problems.

Many insects are highly climate sensitive, and with warmer temperatures it is likely that we will see the introduction and establishment of a number of invasive mosquito species in the UK, as well as the spread of existing species into habitats that were previously inhospitable to them.

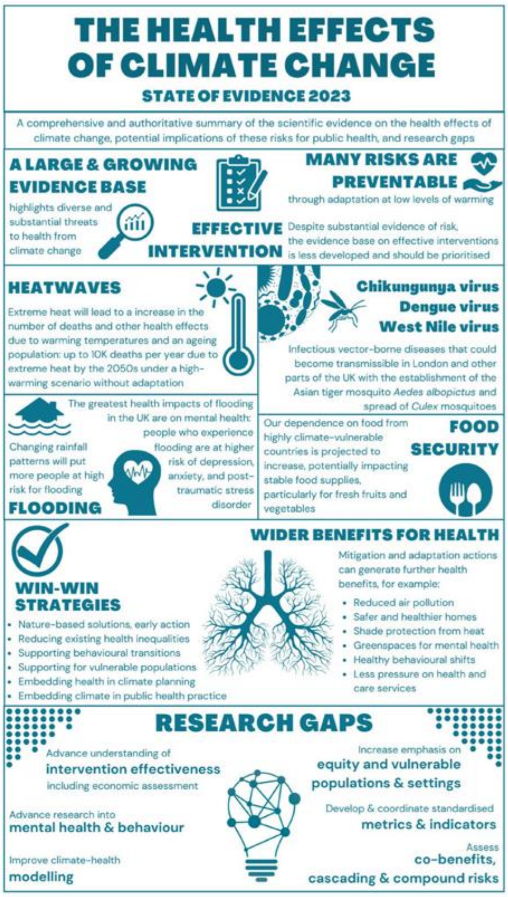

Figure 8 Source – UK Health Security Agency

Increases in faults during heat events will also increase the risk to the staff deployed to restore supplies and carry out repairs Staff are required to carry out strenuous tasks whilst wearing appropriate PPE in remote locations with limited access to shelter and welfare facilities. There is also potential that field staff will be exposed to high temperatures for consecutive days, working long hours. This could reduce the productivity of field staff, increasing both the restoration times and cost.

With the projected increase of wildfires employees potentially may be exposed to risks of burns and smoke related respiratory issues.

During flood events field staff are required to attend incident sites where flood water is present, inundated sewer and drainage systems can cause contamination of flood water exposing disease risk. This risk is not only present during flooding events but is also remains during clean-up operations.

Sea level rise will not only affect NGED assets but may also affect the homes of employees and cause mass displacement in certain regions. This may negatively impact employee's metal health and wellbeing.

Next steps

As evidenced though this report NGED is committed to maintaining and improving network climate resilience. As the ARP4 is a light touch approach, we aim to build from this point by continuing to assess the identified hazards and risks, and establishing a roadmap to embed climate change resilience within NGED. Consideration will be given to how these adaptations can be aligned with business activities and investment plans in order to ensure cost effective solutions are implemented. This may involve changes in existing business processes, as well as targeted industry leading climate resilience initiatives.

We will continue to address climate change as set out in our Climate Resilience Strategy, assessing assets, procedures and systems, establishing new frameworks and methodologies to ensure adaptation is targeted and optimised, particularly in the most high impact areas. We will continue to consider a range of climate scenarios to the end of century and beyond, ensuring assets remain resilient to both climate change any future network changes required to achieve Net Zero.

We will use innovation, data science and past experiences to further our knowledge, develop adaptation pathways and share our learnings across the industry and other sectors whilst remaining dynamic as climate adaptation evolves.

Figure 9. NGED climate resilience strategy cycle

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