Annex 4.12
Climate Resilience Strategy

Northern Powergrid: our business plan for 2023-28

Contents

Executive Summary

Climate change represents a significant ongoing risk to our network and our customers.

Our climate is changing and, despite international efforts to reduce greenhouse gas emissions, it is expected to continue to change over the course of the century:

- winters will be warmer and wetter;
- summers will be hotter and drier; and
- both will bring an increased likelihood of extremes.

Throughout the last price control period, 2010-15 and during the current 2015-23 period, we have worked to understand the risks presented by climate change, delivering an industry leading flood mitigation programme and maintaining a robust vegetation management programme.

As we plan for the 2023-28 period, we have used the latest projections to carry out a full risk assessment, allowing us to identify the priority risks and their impact on the network:

- extreme prolonged or intense rainfall leading to flooding;
- extreme heat leading to a reduction in the performance and efficiency of assets;
- storms leading to operational failure, faults and loss of supplies to customers; and
- gradual increases in temperature and rainfall leading to extended growing seasons.

We recognise the potential for customers to become increasingly reliant on electricity over the next 30 years as their primary source of power for heating, cooking and transportation, and how this could increase the impact of disruption during storms or extreme weather. Therefore, it is essential that throughout the 2023-28 period we continue to work on the foundations built in the 2015-23 period, to ensure that we are working to mitigate risks to the resilience of the network from a changing climate.

We have carried out extensive stakeholder engagement, as described in our annex on detailed engagement findings, to assess appetite and willingness to pay for the adaptations required as a result of climate change. Our stakeholders told us that we should:

- plan for the worst, considering a 4°C global temperature rise as a worst case scenario;
- collaborate with other infrastructure and regional organisations to prevent siloed working and to share knowledge and data;
- understand and look to mitigate interdependencies with other infrastructure providers;
- have ambitious targets, whilst being mindful of the impact on increasing expenditure on the customer; and
- adopt an innovative and holistic approach to climate change adaptation.

During the 2023-28 period we will:

- adopt bespoke adaptations to mitigate the most significant risks – continuing to maintain compliance with industry requirements for flood mitigation and building on our 2015-23 programme of works that ensured that 271 major ‘at risk’ sites (99 per cent) will meet these standards by the end of 2023;

- deliver long-term synergistic resilience through our core asset replacement programmes - ensuring our standards and specifications reflect climate change projections and that all our equipment remains fit for purpose throughout its expected life;

- continue to monitor and adapt our emergency planning protocols - learning from events to inform improvements in our processes and practices;

- use innovation to drive efficiency and enhance resilience - maintaining and improving the resilience of our overhead network through our vegetation management programme, looking to increase efficiency through the use of new technologies and by using innovation to address new and emerging risks; and

- reduce (or mitigate the risk of) system wide interdependencies - understand and seek to mitigate interdependencies with other infrastructure organisations, working towards enhancing regional climate change strategies and cross sector working.

Investment in climate resilience, particularly flood mitigation, has been significant during the 2015-23 period. We will continue to build on this investment in 2023-28 with an anticipated spend per annum of £16.2m for our climate resilience plan as a whole. This represents an overall reduction of 28 per cent against the 2015-23 expenditure. Our major investment areas are as follows:

- flood mitigation - our plan capitalises on the investments made in the 2015-23 period, reducing expenditure to £1.2m per annum (£5.0m lower than the current period), whilst maintaining high levels of resilience in line with national standards; and

- vegetation management - we will continue with our 2015-23 programme, with incremental expenditure required to respond to emerging risks, in particular Ash dieback. Costs are anticipated to be £11.2m per annum, an increase of 19 per cent, compared to the 2015-23 period.

Considering plausible climate change scenarios

Using the Meteorological Office's UK Climate Projections 2018 (UKCP18) information, we have considered a range of scenarios (or climate change pathways) for the effect of climate change on our local weather.

The updated UKCP18[1] were produced by the Meteorological (Met) Office and released in November 2018, superseding UKCP09 which was published in 2009. UKCP18 uses the latest developments in climate science to provide the most up-to-date national climate projections and we have utilised UKCP18 as the definitive source of climate data in our assessments.

To model and predict future climate dynamics, it is necessary to make assumptions about the economic, social and physical changes to our environment that will influence climate change. UKCP18 uses representative concentration pathways (RCPs) to capture those assumptions. These pathways represent a broad range of climate outcomes, including a wide range of assumptions regarding population growth, economic development, technological innovation and attitudes to social and environmental sustainability.

Focus has been directed on two pathways:

- **RCP2.6**, which is roughly in line with the 2°C global warming considered in the Paris agreement; and
- **RCP8.5**, which represents the highest greenhouse gas concentrations and has a best estimate increase in global mean surface temperature of 4.3°C by 2081-2100.

The key findings from UKCP18 indicate that we are likely to experience warmer, wetter winters and hotter, drier summers. We have worked with the Met Office and in collaboration with the rest of the electricity and gas sectors, to assess the hazards impacting our businesses and to identify any regional hotspots and differences, the societal response to climate change and the interconnection between different industry sectors.

It is important to consider worst case scenarios when assessing the risks presented by climate change to our network. The two incidents highlighted below provide evidence of the impact of cascade failures across infrastructure and demonstrate this point:

- In August 2019, over one million customers were affected by a major power disruption that occurred across England, Wales and some parts of Scotland. Though the power disruption itself was relatively short lived with all customers being restored within 45 minutes the knock-on impacts to other services were significant.
- In February 2021, major snow storms led to issues with electricity supplies in Texas. Severe cold weather led to a spike in energy demand, simultaneously a large volume of gas power plants shut down because of fuel shortages and freezing equipment and a number of wind generators also shut down due to low winds and frozen equipment such as turbine blades. The amount of generating capacity unavailable far exceeded the levels included in the state's extreme winter planning scenario and load shedding was employed to prevent the collapse of the grid.

In order to ensure that our plans align with best practice, we have carried out benchmarking comparisons to consider our approach alongside guidance issued for climate resilience.

- The Committee on Climate Change (CCC) published in July 2019 its report into the 'Progress in preparing for climate change', which concluded that England is still not prepared for even a 2°C rise in global temperature and that only a handful of sectors have plans that consider a minimum of 2°C global warming;
    - it considers that the infrastructure sector compares well to the other sectors:

[1] https://www.metoffice.gov.uk/research/approach/collaboration/ukcp/index

    - within the infrastructure sector, electricity distribution is amongst the sub sectors which are performing best; and
    - the energy sector is considered to have a high quality plan but is showing mixed progress in managing risk. A score of 8 out of 9 is achieved on the assessment framework presented.
  - it found that the electricity sector has a well-developed understanding of flooding and that flood protection measures are being implemented at major substations; and
  - it questions a lack of clarity on what other steps are being taken to improve climate resilience within the electricity sector.

- The National Infrastructure Commission in May 2020 published 'Anticipate, React, Recover – Resilient Infrastructure Systems'. This document proposes a framework for resilience which:
  - anticipates future shocks and stresses;
  - improves actions to resist, absorb and recover from them by testing for vulnerabilities;
  - values resilience properly; and
  - drives adaptation before it is too late.

The National Adaptation Programme (NAP) addresses the priority risks identified in the national Climate Change Risk Assessment, setting out the actions that government is taking, outcomes it wants to achieve, and the means by which they will be measuring the progress made towards achieving the objectives. Whilst it primarily sets out the work and approach of government, it also sets out some of the significant actions expected that those outside of government are undertaking in parallel. This includes the work of organisations such as infrastructure operators and public bodies responsible for key services. Through our participation in the Adaptation Reporting Power[2] and collaborative work with the Energy Networks Association (ENA), we feed into the NAP.

The NAP contains a mixture of policies and actions to help us to adapt successfully to future weather conditions, by addressing the risks and making the most of the opportunities. The NAP vision is that we should have 'an infrastructure network that is resilient to today's natural hazards and prepared for the future changing climate'. The electricity sector is considered to have a 'well-developed understanding of the risk faced by flooding and a high level of mitigation is in place'. The key risks to infrastructure set out within the NAP are listed in Table 1 which shows the risks we consider to have an impact on Northern Powergrid.

[2] The Climate Change Act 2008 gives government the authority to ask certain organisations to produce reports on the current and future likely impacts of climate change on their organisation and their proposals for adapting to climate change. This applies to organisations that are responsible for essential services and infrastructure, such as energy or transport companies and is known as the Adaptation Reporting Power.

UK climate change risk assessment 2017	Risk	Applicable to Northern Powergrid
IN1	Risks of cascading infrastructure failures across interdependent networks	✓
IN2	Risks to infrastructure from river, surface/groundwater flooding	✓
IN3	Risks to infrastructure from coastal flooding and erosion	✓
IN4	Risks of sewer flooding due to heavy rainfall	✓
IN5	Risks to bridges and pipelines for high river flows/erosion	✓
IN6	Risks to transport networks from embankment failure	o
IN7	Low/high river flow risks to hydroelectric generation	X
IN8	Subsidence risks to buried/surface infrastructure	✓
IN9	Risks to public water supplies from drought and low river flows	X
IN10	Risks to electricity generation from drought and low flows	o
IN11	Risks to energy, transport, and information and communications technology (ICT) from high winds and lightning	✓
IN12	Risks to shore infrastructure from storms and high waves	✓
IN13	Extreme heat risks to rail, road, ICT and energy infrastructure	✓
IN14	Benefits for infrastructure from reduced extreme cold events	✓

Key: **✓= Direct Risk** **o – Indirect Risk** **X = Not Applicable**

Table 1: Infrastructure Risks from National Adaptation Plan

Assessing impacts on our network

We have assessed the impact of climate change and severe weather on our organisation and asset base to understand the risks and to target adaptations.

Our plan approach aligns with the supplementary Green Book Guidance on 'Accounting for the Effects of Climate Change' published by Department for Environment Food & Rural Affairs (Defra) in November 2020. This document sets out specific guidance for projects, policies and programmes that have a lifespan that goes beyond 2035. The guidance states for these projects we should follow a climate resilient approach using at least two climate scenarios to:

- consider options which include all adaptation measures which would mitigate the known impacts of the 2°C scenario; and
- make decisions based on our own risk appetite about whether we also want to consider adaptation measures aligned with 4°C.

We have developed a climate resilience framework which aligns with the approach laid out by the National Infrastructure Commission (NIC). This can be seen in figure 1. This has been used to structure our approach to climate resilience.

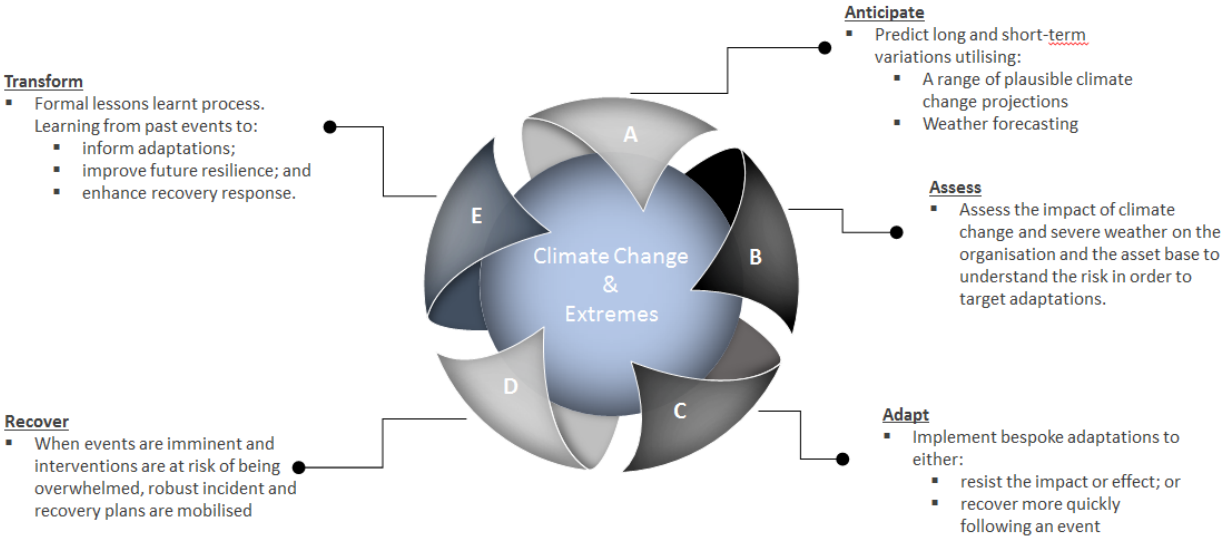

Figure 1: Climate Resilience Framework

In order to fully assess the risk to, and impact on, our network from the climate, we have utilised the information within UKCP18, alongside our work with the Met Office and our collaborative work as an industry, to carry out a comprehensive risk assessment. To aid in the prioritisation of both the risks and the mitigation measures, the risk assessment has been carried out across three timescales for both the 2°C and 4°C scenario:

- short term – current climate;
- medium term – 2050s; and
- long term – 2080s.

No significant divergence in the climate projections or risk to our network were observed between the two scenarios until beyond 2050.

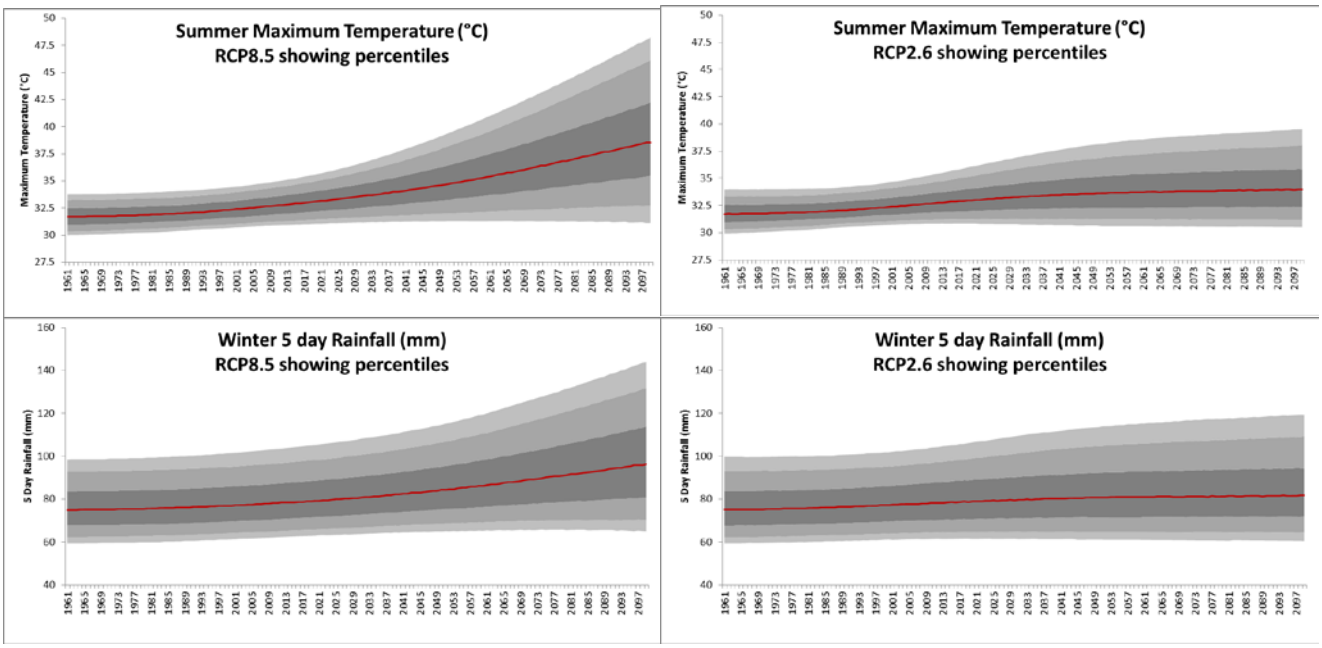

Figure 2: Data extracts for Northern Powergrid region taken from UKCP18

Key climate risks are assessed below:

- **Precipitation** (extreme prolonged rainfall) – long periods of above average precipitation or intense rainfall events result in flooding and erosion. This is associated with a broad range of issues including access issues, asset damage and reduced performance. The accumulation of rainfall over a month and where it exceeds the 90th and 95th percentile of today's climate was considered.
    - Analysis of climate projections show that there are large regional variations in how the frequency of this hazard is expected to change in future climates. In the east of England, the frequency will remain roughly the same however in the west of England and much of Scotland and Wales, the projections are indicating that more prolonged rainfall will result in the thresholds being exceeded more frequently. These events would be expected to be focused in the autumn and winter months.
    - In winter, instances of heavy daily rainfall events are projected to increase across most of the UK, with the greatest increase expected to occur in southern England. There is little suggestion of changes for heavy daily rainfall events in summer.
    - Changes in heavy hourly precipitation events are expected to increase in both winter and summer but decreases may be possible in the south. The largest relative increases are anticipated to occur in autumn. In the current climate, summer has the greatest occurrence of high threshold exceedances, however in the future, summer and autumn are similarly important. This may be important if vulnerability to hazards is increased in autumn due to fallen leaves exacerbating the risks of flooding.
- **Temperature** (extreme heat) – high temperatures may reduce the performance and efficiency of assets. Trends show that the UK climate is warming and the frequency with which high temperature thresholds are exceeded each year is expected to increase. Thresholds were chosen to understand the current frequency of days which constitute 'extreme temperatures' across the UK and how these may change under future climate projections.
    - Trends in observational records show that the UK climate is warming. The average hottest day of the year in the most recently 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 of 26°C.
    - In general, the frequency with which the high temperature thresholds are exceeded each year is expected to increase in the future under RCP8.5. This is consistent with UKCP18 headlines that hot

summers are expected to become more common. During the period between 1981 – 2000, the probability of seeing a summer as hot as the one experienced in 2018 was relatively low (less than 10 per cent). As of now, that probability has already increased due to climate change and is now between 10-25 per cent. With future warming, by mid-century these hot summers could become even more common, near to 50 per cent in all emission scenarios.

- 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. Analysis suggests 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. Organisations in these cooler locations may therefore be able to learn from the warmer locations such as the south east of England and London.

– **Precipitation** (storms) – strong winds are a significant hazard, especially when experienced in conjunction with heavy rain. This can lead to operational failure of above ground assets, increased faults and loss of supply to customers.

    - There is no strong signal within the climate projections for a change to storminess and therefore the risk of strong winds has been assessed in line with the current climate. The current frequency of exceedance of thresholds has been considered across the UK and an indication of year to year variability highlighted.

– **Temperature / Precipitation** (gradual increase in temperature and rainfall) – warmer and wetter conditions may extend vegetation growing seasons, resulting in increased or accelerated growth of vegetation and additional costs associated with maintenance and cutting cycles.

    - 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 a 30 day increase in growing season length. This is reported as largely due to an earlier onset of spring.

Taking these climate variables into account, collaborative working through the ENA identified 15 asset related risks assessed as priority.

A summary of our assessment of these risks across the scenarios and timescales is shown in Table 2.

Asset/Network Effect	Current Rating	Climate Variable	Current Likelihood	Risk Status				Risk Considerations
				Current	2050s	2080s RCP2.6	2080s RCP8.5	
1. Overhead line conductors affected by temperature rise	Moderate	Temperature	Possible	Low	Low	Low	Low	Localised increase in pole heights and age related replacement maintains line clearances. No significant changes in UKCP18 predictions over UKCP09.
2. Overhead line structures affected by Summer drought and consequent ground movement	Minor	Temperature	Possible	Low	Low	Low	Low	Emerging risk. Impact dependent on geology and topology.
3. Overhead lines affected by interference from vegetation due to prolonged growing season	Minor	Temperature/ precipitation	Likely	Low	Low	Low	Low	Increase in growth offset by increase in cutting at each visit.

Asset/Network Effect	Current Rating	Climate Variable	Current Likelihood	Risk Status				Risk Considerations
				Current	2050s	2080s RCP2.6	2080s RCP8.5	
4. Underground cable systems affected by increase in ground temperature	Moderate	Temperature	Possible	Low	Low	Low	Low	Limited data on impact on cable ratings.
5. Underground cable systems affected by Summer drought and consequential ground movement	Minor	Temperature	Possible	Low	Low	Low	Low	Emerging risk. Impact dependent on geology and topology.
6. Substation and network earthing systems adversely affected by Summer drought conditions	Minor	Temperature	Possible	Low	Low	Low	Low	Limited test data available. Anecdotally Grid and Primary substation are buried deep enough to only experience minor impact in performance.
7. Transformers affected by temperature rise	Minor	Temperature	Possible	Low	Low	Low	Low	Temperature rise accommodated in design.
8. Transformers affected by urban heat islands & coincident air conditioning demand	Moderate	Temperature	Possible	Low	Low	Low	Low	Managed through load planning although extended high load may reduce the life expectancy of the transformer.
9. Switchgear affected by temperature rise	Minor	Temperature	Unlikely	Low	Low	Low	Low	Temperature rise accommodated in design.
10. Grid and Primary Substations affected by river flooding due to increased winter rainfall	Moderate	Precipitation	Possible	Low	Low	Low	Medium	Whilst risk of flooding has increased, the asset protection measures employed have offset and reduced the risk.
11. Grid and Primary Substations affected by pluvial (flash) flooding due to increased rain storms in Summer and Winter	Moderate	Precipitation	Unlikely	Low	Low	Low	Medium	Whilst risk of flooding has increased the asset protection measures employed have offset and reduced the risk.
12. Grid and Primary Substations affected by sea flooding due to increased rain storms and/or tidal surges	Significant	Precipitation	Unlikely	Low	Low	Low	Low	Whilst risk of flooding has increased the asset protection measures employed have offset and reduced the risk.
13. Grid and Primary Substations affected by water flood wave from dam burst	Extreme	Precipitation	Very unlikely	Low	Low	Low	Low	Considered unviable to protect against.
14. Overhead lines and transformers affected by increasing lightning activity	Minor	Lightning	Possible	Low	Low	Low	Low	Existing mitigation measures adequate.
15. Overhead lines and underground cables affected by extreme heat and fire smoke damage	Moderate	Wildfire	Unlikely	Low	Low	Low	Low	Based on Saddleworth Moor incidents and increased frequency of California wildfires.

Table 2: Key Asset Risks

The risks listed in Table 2 are those considered to be the top 15. These were identified as part of a full risk assessment which considered all climate conditions and predictions alongside their effects on our network.

Other conditions considered included:

- Snow, ice and extreme cold events: On average the UK sees 15.6 days of lying snow per annum. Although notable snow events have occurred in four years in the last decade, these occurrences have been declining in both number and severity since the 1960s. UKCP18 suggests that winters are going to become warmer so snow and ice related hazards are likely to decrease however it should be noted that extreme cold and snow events are still a possibility. In order to ensure that our network is adequately protected against these events, extensive research has been carried out into the ratings of overhead lines to ensure that specifications are adequate. EU Research COST 727 [3] was carried out in 2006 which determined that existing overhead line designs have adequate structural strength and, more recently, an innovation project has been completed which has examined the ratings and performance of overhead lines in a variety of weather conditions and provided recommendations on any necessary changes to specifications. We have also implemented learning from previous extreme events to ensure that our emergency and operational responses are sufficient (see Longer Term Transformations section).

- Wind: There is no strong signal within UKCP18 for a change to storminess and the risk of strong winds can therefore only be assessed in the current climate. Significant research into wind was carried out between 2011 and 2015 under the RESNET4 [4] project and learning from this project has already been considered in our specifications. The major risk to the network caused by falling trees and tree debris as a result of wind storms is considered and mitigated through our approach to vegetation management.

[3] https://www.researchgate.net/publication/263529195_COST-727_Atmospheric_Icing_on_Structures_Measurements_and_Data_Collection_on_Icing_State_of_the_Art
[4] https://www.tyndall.ac.uk/projects/resnet-resilient-electricity-networks-great-britain

Developing our adaptation plan

We have considered the identified risks and outlined an adaptation plan containing the necessary mitigation measures.

Our adaptations fall into three categories:

- bespoke adaptations to resist threats;
- recovery actions to return to business as usual following an event; and
- longer term transformations to ensure that the latest projections and learning is incorporated into our plans.

Bespoke adaptations

Flood risk management

The greatest climate risk to networks is assessed to be flooding. This applies to present risks and future risks as a result of predicted climate change. In the event of serious flooding, electricity substations can be put out of action and the consequences can be severe. The flooding of a large substation can mean the loss of electricity supply to thousands of people, as well as to other types of infrastructure. The UK Climate Change Risk Assessment (UKCCRA2017) states that 'an increasing frequency and severity of flooding from a range of sources represents the most significant climate change risk to UK infrastructure'.

Our flood mitigation works are designed to comply with ETR 138 - Electricity Substation Resilience to Flooding - which provides national guidance on how to improve the resilience of electricity substations to flooding:

- the risk-based methodology is prescriptive in terms of the level of protection to be applied at substations at risk of flooding;
- it introduces the need to consider the risk of extreme flooding represented by the Environment Agency's one in 1,000 flood maps at larger installations (supply and grid supply points); and
- it prescribes the use of cost-benefit analysis and take into account societal impact of an event, should one of our substations be flooded.

The current version of ETR 138:

- assesses the risks posed by fluvial and coastal flood risk;
- assesses the risks posed by pluvial (surface water) flood risk;
- recommends that primary sites identified as feeding in excess of 10,000 customers should have enhanced mitigation to the same level as 132kV sites; and
- recommends allowances to take account of the impacts of climate change on flood risk as well as uncertainties.

Our original 2015-23 flood mitigation programme ensured that 156 of our major sites deemed to be at risk were addressed and that compliance with ETR138 was achieved across the risks of fluvial and pluvial flooding at these sites. We have expanded this programme of works to ensure that by the end of the 2015-23 period we will have completed works at 271 sites, ensuring that they all achieve compliance with all aspects of ETR138.

A review of ETR138 has taken place in the light of the publication of UKCP18 and it has been determined that this standard remains fit for purpose and a revision is not required at this point in time.

The success of our 2015-23 flood mitigation programme means that by the start of the 2023-28 period we are in a strong position with regards to flood mitigation. Our 2023-28 programme of works will cost £1.2m per annum and will:

- maintain compliance with ETR138 by carrying out minor works at 13 major substations in the period to ensure that existing flood mitigation measures remain fit for purpose;
- deliver synergistic resilience by ensuring that all asset replacement programmes and new assets consider flood risk for the lifespan of the asset; and
- enhance distribution substation flood risk management through the introduction of flood mitigation measures at a small number of strategic distribution substation sites (35 in the period).

Storm resilience - vegetation management

Interference to overhead lines by trees and other vegetation causes a variety of power supply issues ranging from transient interruptions due to vegetation touching the line, through to severe damage from trees, or parts of trees, falling onto the lines. Under abnormal weather conditions the latter can lead to large scale power outages with some supply restorations taking many days. During periods of high wind a considerable proportion of faults are caused by wind-blown branches and other debris, some of which can originate from relatively long distances from the overhead lines that are impacted.

ETR 132 - Improving Resilience of Overhead Networks under Abnormal Weather Conditions Using a Risk Based Methodology - focusses on vegetation management as the first and most important step in improving overhead line resilience. It provides guidance on how to improve network performance under abnormal weather conditions by adopting a risk based methodology to identify the most effective locations to carry out resilience related vegetation management and/or other solutions. Abnormal weather conditions include high winds, ice, snow, prolonged high temperatures and heavy rainfall.

We have an established vegetation management programme that adheres to ETR132. Our 2023-28 programme of works will cost £11.2m per annum and will:

- continue vegetation management programmes of work to ensure clearances to overhead lines, targeting approximately 24,100 spans of the network per annum;
- continue to carry out vegetation management in line with ETR132, providing enhanced resilience cuts to 844km of the overhead line network per annum;
- establish a programme of works to deal with the emerging risk of ash tree dieback. It is predicted that 90 per cent of all ash trees are at risk and our plan assumes we will address 1,450 spans of network over the 2023-28 period;
- carry out clearance work at 118 substations over the 2023-28 period;
- carry out clearance work at 46 tower base locations per annum over the 2023-28 period; and
- introduce innovative technologies, carrying out two full light detection and ranging (LiDAR) surveys of the network in the period, enabling us to assess, monitor and predict vegetation growth and allow us to manage risks in an effective and efficient manner, keeping costs down whilst increasing risk mitigation.

Storm resilience - overhead lines

Our overhead lines are particularly susceptible to damage during storms, predominately wind damage. Specifications must take into account the expected operating conditions for each overhead line based on the topography of its location, as well as the network conditions for operation.

We will strengthen our overhead line network through specification changes and synergies with asset replacement programmes, ensuring that climate projections for the expected lifespan of the asset are considered in the design phase of all replacement works. Design guidance will be updated to ensure that topography and land use is taken into consideration and specifications will be updated to ensure that anticipated changes to climate conditions during the lifespan of the asset are considered.

Synergistic resilience

We will underground and relocate assets located in flood or climate hotspots through consideration of the risks during asset replacement programmes, enhancing our resilience at minimal cost by maximising synergies with other programmes.

Embedding climate resilience into our equipment specifications

Predicted changes in global temperature rises and extremes of temperature could have an effect on the operation of our network. The changes currently predicted for the UK are unlikely to have a large impact due to the fact that all our equipment is designed and manufactured to international standards, where equipment is designed to operate safely in much greater minimum and maximum temperature ranges than those found in the UK. We should, however, be aware that these changes in extremes could have an impact on the capacity and operation of our network over the longer term.

We will ensure our specifications make our equipment capable of withstanding the temperature and climate extremes possible in future decades whilst still supporting the demands of the future network. This will allow us to ensure that when carrying out work, the equipment we install is fit for purpose for its lifespan whilst minimising any additional cost by taking advantage of synergies with our replacement programmes.

Automation

Automation is an important tool in our pursuit of improved resilience. Our automated power restoration system (APRS) provides fault detection, isolation and restoration so that in the event of a fault we are able to locate the problem and often restore supplies remotely in a fast and safe manner. Use of automation ensures that customers are without power for the shortest duration possible. The majority of restorations carried out by APRS typically occur within a minute or less, depending on the communications infrastructure.

The use of automation is particularly important during extreme weather events when issues such as flooding, snow or ice may prevent field crews reaching the fault location. It improves our ability to restore and recover from network incidents, especially where they are transient, such as tree branches clashing with overhead lines. During the 2023-28 period we will:

- continue to install automation of the network, as appropriate, through synergies with our scaled-up reliability programmes; and
- consider the location of assets for ease of access through synergies with asset replacement programmes and changes to design specifications.

Operational resilience

Adaptations fall into two categories, those that enable us to resist the effects of climate change, such as flood mitigation and vegetation management, and those that enable us to respond should events occur. When considering adaptations, it is necessary at all times to ensure that they are cost effective and that they offer benefits to our consumers. In some instances it becomes more cost effective to prepare to respond to events that may occur rather than to try to prevent the impact.

Alongside planning to adapt to the risks presented by climate change, it is also necessary to consider that in some instances, interventions may be overwhelmed and it may be necessary to have robust incident and recovery plans in place to help to quickly restore the network to the expected levels of service.

We assessed the risks to business as usual and customer service as part of our comprehensive climate change risk assessment. The risks of each weather condition were considered on our response and the level of mitigation provided by our current policies and procedures examined.

- Risks to the delivery of routine work were considered to be mitigated by our business-as-usual monitoring procedures, which would flag any potential backlogs and allow recovery and mitigation measures to be implemented.

- We have utilised learning from previous events to ensure that we have adequate provision to allow remote working for office and call centre staff so, should an extreme weather event occur, we are able to continue to provide the required level of customer service and to progress business as usual. The effectiveness of this provision has been tested and proven through the COVID-19 pandemic.

- Examples of existing mitigation measures include policies to ensure business-as-usual during periods of increased absence (for example due to a heatwave or pandemic) through staff re-deployment or to allow business to continue should we experience incidents of territorial denial similar to those experienced in 2001 due to the outbreak of Foot and Mouth in the UK.

We assessed the risks to our emergency response as part of the comprehensive risk assessment of climate change. The risks of each weather condition were considered on our response and the level of mitigation provided by our current major incident management plans and emergency planning processes and procedures examined. Alongside our over-arching major incident management plan, detailed procedures for a number of other events, such as flooding and territorial denial, are laid out.

Our short term recovery cycle follows the same process as our longer term adaptation framework.

- We anticipate the risks through the Met Office data and Environment Agency flood risk warnings - weather forecasts, severe weather warnings, flood warnings and lightning risk levels are received on a 24 hour basis. Weather forecasts are based on statistical analysis and therefore have a confidence level which increases closer to the time of the event. Forecast confidence levels have been built into the comprehensive major incident trigger levels. Examples of non-weather related events that may require a response include territorial denial due to an animal notifiable disease or a declared civil emergency requiring a multi-agency response under the Civil Contingencies Act 2004. We also monitor wildfire risk reports and landslide risk reports from the British Geological Survey.

- We assess the risk and follow a major incident management plan escalation process – our emergency planning team are responsible for analysis of the risk and the escalation of the risk where appropriate. Risks and their trigger levels for escalation, are fully documented in our emergency planning policies and procedures. These include:

    - Wind
    - Lightning
    - Rain
    - Snow and Ice Accretion
    - Blizzards
    - Flooding
    - System incidents
    - Black Start / Demand Control
    - Territorial Denial
    - Civil Emergencies

- We adapt our organisation in the short term to address the imminent risks.

    - We run a three stage escalation process:

- *Yellow (be aware)* – the earlier people with key roles in the response are made aware of an emerging incident, the faster and more effectively they can respond. The principle of an 'awareness' or 'yellow' alert is therefore to warn key front line managers when the potential for a major incident exists.

- *Amber (get ready)* - the earlier the command and control structure is established, the more effective the response. An amber alert is issued to name the key roles and actions required in response to an event that has 80 per cent likelihood or more.

- *Red (respond)* - the declaration of a major incident with all the key roles established under the command and control structure having a part to play in the response process.

– We have designated major incident support roles across our business. All our staff have been designated and trained for specific roles (aside from their business as usual roles) as part of our major incident response. These support roles are implemented at appropriate points in the escalation process.

Along with all other DNOs, we are a member of the North East South West Area Consortium (NEWSAC), the industry mutual aid agreement which contains arrangements for preparation and coordination of resources and support. In an emergency affecting member companies, NEWSAC representatives assess the availability of resources from those least affected and agree the allocation of these resources to other members based on the level of damage. The NEWSAC mutual aid agreement has been in place and utilised over many years.

Under the terms of the Civil Contingencies Act 2004, we are a category two responder and work closely with other utilities, the emergency services and local authorities. This includes working with resilience teams on emergency planning, taking part in exercises and participating in gold, silver or bronze commands.

We participate in all the local resilience forums (LRFs) based within our regional area, in line with a requirement of the Civil Contingencies Act 2004. LRFs are a multi-agency forum consisting of key emergency responders and specific supporting agencies as defined by the Civil Contingencies Act 2004.

Feedback from event recovery loops into the 'transform' element of our adaptation pathway. Following the closure of the event, a full post-event review is carried out. The output of this review will include lessons learned and improvement actions which will be monitored to completion. An important element of the review is asset performance. Any concerns about the performance of specific asset types or unusual failure rates will be highlighted for review and appropriate remedial action.

For more information – see our annex on our approach to resilience.

Longer term transformations

We have identified a number of areas where longer term transformations provide a more robust response to resisting the effects of climate change. Environmental resilience has been embedded within all aspects of our business. Our flood mitigation policies are already well established and flood risk is considered within all our substation design and replacement works to ensure that flood risk for the lifespan of the asset is assessed and mitigated during the design stage. During the 2023-28 period we will further embed environmental resilience through:

– updating standards and specifications to ensure that projected changes in ambient and extreme temperatures over the lifespan of all assets are considered in the design phase;

– reviewing our cable specifications to ensure that ground movements due to climate change will not affect the performance of joints; and

– reviewing overhead line design guidelines to ensure that topography and land use are taken alongside network considerations at the design stage.

We will ensure that we continue to learn from major events on our network. Following the implementation of our major incident management plan, the emergency planning team is responsible for organising and delivering a post-event review with all the relevant attendees. The output of the review will include lessons learned and improvement actions which will be monitored to completion.

Following previous major events, the lessons learnt process has led to the implementation of a number of initiatives to improve our future responses to events. This process will continue throughout the 2023-28 period. Examples of past learning have included:

- a review of overhead line specifications following a series of snapped poles and conductors due to snow;
- a programme of targeted overhead line strengthening following incidents of ice loading;
- provision of additional measures such as arc suppression coils to protect against lightning following a number of lightning storms;
- an expansion of our 4 x 4 fleet to facilitate staff deployment during storm events;
- review of staffing to increase delegation of regular duties during major incident roles to release key people quicker; and
- increased provision of a virtual private network (VPN) to facilitate greater home working during major incidents.

Innovation and research are an important part of our approach to identifying areas for future development. A number of projects have been initiated during the 2015-23 period and work will continue through the 2023-28 period to embed the technology as part of our business as usual operations. These initiatives include:

- Unmanned aerial vehicles (UAV) - we have trialled the use of UAVs as part of our post-fault inspection and restoration procedures. This has proven successful and we now employ them to facilitate a number of functions:
    - to carry out post-fault inspections on medium lengths of overhead lines (a process formerly carried out via helicopter patrols);
    - to assist in the response to major incidents by allowing us to observe and monitor assets from a distance, removing the need to send staff to monitor assets at risk of flooding; and
    - to monitor at-risk assets on a regular basis, for example carrying out surveys to monitor the erosion of river banks in proximity to overhead lines to allow us to optimise the timing of re-location of assets.
- LiDAR - we have trialled the use of LiDAR to carry out more effective and efficient vegetation management. LiDAR data acquired through flying the complete network at the beginning of each major cutting phase will provide the opportunity to prioritise cutting responses and to monitor growth rates to better target future workloads. We anticipate completing two full LiDAR surveys of the network during the 2023-28 period.
- Overhead line ratings - distribution overhead line ratings are based on research work published nearly 30 years ago. Recent work testing these assumptions have found some of them to be erroneous, with the result that existing distribution line ratings are now considered out of date. These ratings take no account of regional differences in climate, nor of any changes in climate that may have occurred over the last 30 years. Future climate change is predicted to put further pressure on line capacity. We therefore, need a cost-effective, up-to-date and robust methodology (supported with the necessary tools) for calculating and optimizing overhead line ratings at both the regional and line specific level, both for today and the future. A previous DNO collaborative project under the Innovation Funding Incentive established an overhead line test rig to monitor weather conditions and temperatures of different conductors at various current levels. A second project was undertaken by WPD - “Improved Statistical Ratings for DNO Overhead Lines” (Ref. 41 WPD_NIA_008) [N2] - which set up a test rig at WPD’s Stoke depot, and over a period of 24 months. The test rig comprised four separate circuits,

each continuously energised to give a range of design temperatures representative of the UK's distribution networks. A revision to standards has now been issued which employs these findings and provides data to enable us to more accurately decide an appropriate rating for any distribution overhead line.

- Self-heal fluid - this project has developed a new cable fluid with can heal itself when exposed to air. Following the completion of the research, we will look to implement this on our network to help to prevent water ingress to cables and, therefore, faults.

- Foresight - this project has improved our understanding of indicative pre-fault behaviour of low voltage cable networks. During the 2023-28 period we will investigate how we can deploy similar technology to help us monitor and predict where we will see faults on the network.

A number of other research initiatives are proposed for development during the ED2 period:

Initiative	Description / Scope	Required Outcomes
Underground Cables Research	It is acknowledged that there is a link between rainfall and underground cable fault. This project will seek to understand and quantify this risk to allow us to look for ways to mitigate the risks.	Understanding of: - Thresholds / trigger levels of quantity and duration of rainfall - Understanding of the impacts of prolonged rainfall on our network performance - Timescales between rainfall and occurrence of cable faults
Substation Design Research	Research into substation design specifications and innovative materials / designs to enhance mitigation of risks from climate change	Amendments to design specifications and building materials to better protect against: - Gradual ambient temperature rises - Periods of prolonged extreme heat
Control Equipment	Investigations to understand the performance limitations of outdoor control equipment during periods of extreme heat.	Confirm need for sunscreens / protection for control equipment Specify and roll out appropriate measures to mitigate the risks.
Ash Dieback	Following initial work to estimate the extent of Ash Dieback experienced on our network, we will analyse available information to allow us to make better estimates of the real scale of the problem	Scale of Ash Dieback accurately reflected in our vegetation management plans.

Table 3: Proposed ED2 research initiatives

Collaboration with other parties

It is vital we understand interdependencies with other parties to ensure whole system resilience on a regional and national level. Table 4 shows our ongoing and forward looking plans for stakeholder engagement in order to identify interdependencies and enhance resilience.

Stakeholder Group	Engagement
Environment Agency / Infrastructure Providers / Local Authorities	Actively seeking appropriate opportunities for cross-sector working through collaboration and/or catchment-based flood mitigation projects.
ENA / Ofgem / Gas and Electricity Transmission & Distribution Companies	Participation in the ENA climate resilience working group. Originally established in 2011 to facilitate the requirements under the Adaptation Reporting Power to assist with the production of reports for the three rounds to date. For the third round, submitted in 2021, this group was expanded to include the gas transmission and distribution operators. The group has now been formalised and terms of references agreed to allow it to continue to coordinate industry's response to climate resilience.
Local Resilience Forums, BEIS, Infrastructure Providers	Joint scenario planning and testing of recovery processes. We currently participate in the seven LRFs which are established across our operating area. These forums work to plan and prepare for localised incidents and catastrophic emergencies, identifying potential risks and producing emergency plans to either prevent or mitigate the impact of any incident on their local communities.
Environment Agency	Involvement in the 'Humber 2100+' consultations[5], a project to develop a strategy for managing tidal flood risk around the Humber Estuary to safeguard the future of the Humber and promote sustainable development and prosperity for the next 100 years.
Yorkshire and Humber Climate Commission	Ongoing work, including participation in the Yorkshire Infrastructure Adaptation Forum. This is an independent advisory body set up to support and guide climate actions across the region which works to enable engagement, support debate and promote best practice. It seeks to bring together public, private and third sector participants to support, guide and track the delivery of climate actions across the region.
Newcastle Climate Change Adaptation Working Group	Membership of a group consisting of local authorities, academics and the NHS trust who are looking to advance the strategies within the Newcastle area.
Defra	Submission of Climate Change Adaptation Reports in line with the requirements laid out in the Adaptation Reporting Power.
BEIS	Participation in the BEIS led CS-N0W Work package D3. CS-N0W is a four-year research programme aiming to enhance national and international scientific understanding of climate impacts, decarbonisation and climate action and to improve the accessibility of UK climate data. Work package D3 is looking at enhancing resilience in UK energy networks and will be run in conjunction with Ofgem, DNOs, National Grid and the Energy Network Association
Local Authorities	Actively seeking appropriate opportunities to enhance our approach to vegetation management
Infrastructure Providers	Interactions on a regional basis to understand and mitigate interdependencies.

Table 4: Stakeholder interactions

[5] https://consult.environment-agency.gov.uk/humber/strategyreview/

Measuring Success

We recognise that it is important to demonstrate the progress we are making in enhancing the resilience of our network to climate change and so we will report annually on the delivery of our climate resilience strategy (see table 2).

Established metrics for flood mitigation and vegetation management are included in our annual regulatory reporting pack (RRP) process. These include the:

- Number of major sites protected to a 1:100, 1:200 and 1:1,000 flood level in line with ETR138.
- Amount of overhead line network which has undergone vegetation management clearance cuts.
- Amount of overhead line network which has undergone enhanced vegetation management in line with ETR132.

We will continue to prepare progress reports to feed into Defra and the National Adaptation Plan in line with the five-yearly reporting cycle laid out under the Adaptation Reporting Power. The third round industry report, facilitated by the ENA was submitted to Defra in March 2021 and our report will be published later in 2021.

A comprehensive set of industry wide resilience metrics will be agreed as part of the work of the ENA Climate Resilience working group. In line with the expectations set out by Ofgem, these will be developed and agreed in the 2023-28 period for full implementation in the 2028-2033 price control period.

Appendix 1: Customer Outcomes

Climate Resilience outcomes	Benefits	Deliverables	Measure[6] (output/*indicative inputs*)	ED1 to date	ED1 forecast	ED2 target
CR1) Maintain flood defence resilience at all major substations	• Improved long-term resilience of the network • Increased protection against flooding events	**CR1.1)** Improve and maintain flood resilience through targeted adaptations in civil defences and installing additional substation defences across the region **CR1.2)** Improve flood resilience at distribution substations, either by moving them out of the line of flooding risk or by implementing mitigation measures **CR1.3)** Share data with infrastructure providers on local-level resilience and identify local dependencies	**High-risk sites protected to flooding (ETR138)**	**93%**	**99%[7]**	**100%**
			Total sites resilient to flooding[8]	*255*	*271*	*48*
			Major substation flood defences installed[3]	*73*	*84*	*13[2]*
			High criticality distribution substations with increased resilience[3]	-	-	*35*
CR2) Reduce the impact of storms on our network through a comprehensive programme of vegetation management	• Maintain resilience of the network • Improved efficiency and, therefore, lower cost due to the use of technology	**CR2.1)** Undertake enhanced resilience cuts in line with Energy Network Association's Engineering Technical Report 132 on our overhead network to comply with enhanced resilience requirements **CR2.2)** Establish and maintain clearance corridors **CR2.3)** Assess and tackle the issues anticipated from ash tree dieback through the management of affected spans **CR2.4)** Undertake a vegetation clearance programme for substations and tower bases **CR2.5)** Utilise light-detecting and ranging (LiDAR) technology to ensure efficient targeting of our vegetation management	**High voltage network resilient to high winds (ETR 132)**	**42%**	**60%**	**75%**
			ETR132 Network clearance (km)	*889*	*1,295*	*844*
			Vegetation management clearance spans (ENATS 43-8)[9]	*24,813*	*25,700*	*24,100*
			No. of full LiDAR network surveys in the period	*0[10]*	*0*	*2*
CR3) Improve resilience through collaborative work on interdependencies to reduce the risk of cascade failures across systems	• Improved resilience in the network, our region, and beyond • Increased efficiency of delivery • Increased collaboration	**CR3.1)** Collaborate with other regional infrastructure operators to identify and mitigate interdependencies **CR3.2)** Collaborate with the Environment Agency and local authorities on the implementation of their regional flood risk management plans and establish support for these where appropriate	**Implement consistent Climate Resilience metrics in collaboration with the industry**	-	-	✓
			Collaboration events p.a.	*8*	*8*	*28*

[6]. Measures are shown to track delivery of our customer outcomes. Whilst some measures may directly relate to deliverables, this may not be true in all cases. Numbers shown may be subject to rounding - see Annex 'A1.4 - key targets & measures' for profiled targets.
[7]. One major scheme and two shared National Grid sites to be completed in 2023-28.
[8]. Cumulative, in price control.
[9]. Annual average, in price control.
[10]. We have completed a trail LIDAR survey in the ED1 period on a partial section of the network. ED2 surveys will be full network surveys.

CR4) Maintain operational resilience and embed long-term resilience across our asset programmes, working with others to better understand future risks	• Improved resilience efficiency – through long-term adaptation • Improved operational response to post-storm restoration • Increased embedded resilience across all our asset programmes • Improved resilience at lower cost	**CR4.1)** Utilise drones for storm damage assessments 💡 **CR4.2)** Undertake collaborative exercises to test our operational response. These simulations test our response to the loss of critical national infrastructure and are often carried out in collaboration with government or in coordination with National Grid or our parent company, Berkshire Hathaway Energy **CR4.3)** Embed resilience across our asset programme designs and specifications to deliver long-term synergistic resilience, for example moving substations out of the line of fire when replacing them for condition drivers and ensuring we have the appropriate ambient future temperature included when we design and establish the rating for overhead lines **CR4.4)** Trial the installation of current flow monitors in areas at risk of wildfire 💡 **CR4.5)** Undertake collaborative research projects to develop predictive analytics for the effects of weather on our underground networks 🌐💡	*Company resilience exercises in the period*	*1*	*1*	*2*
			Update our design policies to consider ambient future temperatures	*-*	*-*	✓

Key: 🌐 - Data and digitalisation, 👥 - Workforce Resilience, 💡 – Innovation

Table 5: Climate resilience strategy outcomes

Appendix 2: Key measures

Key measures		ED1 performance		ED2 performance Phased targets					Customer outcome
KPI	Unit	ED1 to date	ED1 forecast	2023/24	2024/25	2025/26	2026/27	2027/28	
OUTPUTS									
High risk sites protected to flooding (ETR138)	%	*93%*	*99%*	100%	100%	100%	100%	**100%**	CR1
HV network resilient to high winds (ETR132)	%	*42%*	*60%*	63%	66%	69%	72%	**75%**	CR2
INDICATIVE INPUTS									
Total sites resilient to flooding (including surveys)	Count[1]	*255*	*271*	12	21	30	39	**48**[2]	CR1
Total sites resilient to flooding (Upgrades only - excluding surveys)	Count	*199*	*211*	12	21	30	39	**48**[2]	CR1
Major substation flood defences installed	Count[1]	*73*	*84*	5	7	9	11	**13**	CR1
High criticality distribution substations with increased resilience	Count[1]	-	-	7	14	21	28	**35**	CR1
ETR132: Network clearance	km	*889*[3]	*1,295*[2]	844	844	844	844	**844**	CR2
ENATS 43-8: VM clearance	Spans	*24,813*[2]	*25,780*[2]	24,100	24,100	24,100	24,100	**24,100**	CR2
LiDAR network surveys	Count	*0*	*0*[4]	-	-	1	-	**1**	CR2

Table 6: Climate resilience key measures – current period performance and future period phased targets

KPI	Definition
OUTPUTS	
High risk sites protected from flooding (ETR138)	The number of sites that have been protected from flooding to ETR 138 – Electricity Substation Resilience to Flooding: • Level 1: most important grid substations (typically supplying 50,000 to 500,000 customers) - likelihood of flooding should be no more than 1 in 1,000 years. • Level 2: other primary substations (typically supplying 5,000 to 30,000 customers) - likelihood of fluvial flooding should be no more than 1 in 100 years and of sea flooding no more than 1 in 200 years. • Level 3: for sites where level 1 or 2 cannot be justified – other flood resilience measures.
HV network resilient to high winds (ETR132)	The number of kilometres of overhead lines which have undergone enhanced vegetation clearance works in line with ETR 132 – Improving resilience of overhead networks under abnormal weather conditions using a risk based methodology.
INDICATIVE INPUTS	
Total sites resilient to flooding (including surveys)	The count of sites where work has been done to increase their resilience to flooding. This includes major works (i.e. construction of a wall around the perimeter or relocation of the assets), minor works (i.e. installation of flood protection to door openings, raising ventilation holes and sealing cable troughs) and remedials (i.e. works to improve site drainage or rectify issues with existing flood mitigation measures) This also includes where we have conducted a survey and deemed that no work was required as the site was sufficiently protected.
Total sites resilient to flooding (Upgrades only - excluding surveys)	In line with the description above, but excluding where we have conducted a survey and deemed that no work was required as the site was sufficiently protected.
Major substation flood defences installed	The count of flood defences installations at major substations.
High criticality distribution substations with increased resilience	Substations which provide supplies to other infrastructure providers or services or where the general topography means that it is beneficial to implement flood mitigation measures.
ETR132: Network clearance	The length of network which has undergone enhanced vegetation clearance as set out in ETR132 guidelines.
ENATS43-8: VM clearance	The number of spans of overhead networks which have undergone works to ensure compliance with ENATS43-8 – Overhead Line Clearances.
LiDAR network surveys	Complete surveys of the network using LiDAR (Light Detection and Ranging) technology.

Table 7: Climate resilience key measure glossary

[1]. Cumulative, in price control.
[2]. This includes 3 schemes from the ED1 period to be completed. One major internal upgrade and two shared National Grid sites.
[3]. ED1 annual average.
[4]. We have completed a LiDAR survey in the ED1 period, but only on a partial section of the network. ED2 surveys will be full network surveys.

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