Consultation

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ED3 Sector Specific Methodology Consultation – Climate resilience stress testing methodological framework Annex

Publication date:	08 October 2025
Response deadline:	03 December 2025
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We are consulting on the methodologies we will apply for the electricity distribution sector in the ED3 price control which will run from 1 April 2028 to 31 March 2033. We would like views from stakeholders with an interest in the regulation of energy networks. We would particularly welcome responses from groups representing consumers of electricity. We would also welcome responses from other stakeholders and the public.

This document provides the framework to the methodology for Phase A stress testing with outputs expected from ED licensed network operators by December 2025. More detailed guidance and templates will be provided to network operators separately. This document is an Annex to the ED3 Sector Specific Methodology Consultation (SSMC) core document and should be read alongside it.

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Contents

1. Introduction

Context

1.1 Great Britain's energy systems must remain resilient to a changing climate whilst it transitions away from fossil fuels and this must be accounted for in long-term investment planning. As set out in our ED3 Framework Decision, we committed to addressing climate risks through a more strategic, long-term approach to climate resilience.[1]

1.2 To enable this long-term approach, we need to understand how the network and its assets will react to both chronic risks and acute risks. Chronic climate risks are driven by changes to both average and ranges of weather conditions, leading to accelerated asset deterioration. Meanwhile, acute climate risks are affected by changes to extreme weather. Climate change is driving the severity and frequency of extreme weather events, ie High Impact Low Probability (HILP) events such as storms or heatwaves, which can cause significant damage to network assets and customer outages.

1.3 To inform our understanding of climate risks, appropriate tools are required. Some tools exist already, including climate scenario planning exercises undertaken by network companies as part of their climate resilience strategies as well as innovation projects developing forward looking simulation models, improving the understanding of climate risks across the sector, particularly the chronic risks. We are also working with network companies to consider how climate might impact aging of assets and how this is captured within the Network Asset Risk Metric (NARM) and evaluated by Common Network Asset Indices Methodology (CNAIM). However, there remains a gap for a consistent, widely used approach to understand HILP events at the network level.

1.4 Stress testing can address this gap. We define stress testing as being a tool or structured approach to simulate the performance of an asset or system under extreme but plausible conditions to identify vulnerabilities. This can support in understanding the costs, benefits and wider implications of addressing vulnerabilities, and support decisions on acceptable levels of resilience. It can also be used to assess the ability of a system to meet agreed resilience goals and standards, as identified by the National Infrastructure Commission (NIC)

[1] www.ofgem.gov.uk/decision/framework-decision-electricity-distribution-price-control-ed3

(now known as National Infrastructure Service Transformation Authority (NISTA)).[2]

1.5 We set out stress testing as a tool in both the RIIO-3 Sector Specific Methodology Decision (SSMD) for electricity transmission and gas sectors[3] and in the ED3 Framework Decision for electricity distribution.[4] We will consider how stress testing regimes linked to network price controls align and interface with other resilience and emergency planning assessments led across the industry, including those delivered by the National Energy System Operator (NESO).

1.6 Stress testing processes and regimes will be developed and strengthened over time as capabilities and understanding evolve. The aims and scope of stress testing are likely to evolve as we build our collective understanding.

Stress testing for ED3

1.7 We are proposing introducing stress testing for network companies across multiple phases to iteratively build capabilities and address information gaps to support government to make informed decisions on resilience standards which in turn will inform a long-term climate resilience goal for ED3. This approach is two-fold, distinguishing between immediate action ie before the start of ED3, and longer-term strategic influence ie during the ED3 period. This is set out in more detail in the ED3 SSMC core document where we are consulting on our phased approach to stress testing, including how it interacts with climate resilience goals and aligns with government work on resilience standards.

1.8 The immediate action for stress testing is split between two phases, shown in Figure 1, namely:

- Phase A - This aims to build evidence to provide greater clarity on a long-term climate resilience goal, ie agreement on what is an acceptable level of resilience in light of the changing climate. In particular, it will improve our understanding of the investment costs required to 'maintain current levels of climate resilience by 2080' (see SSMC for more details) to help inform whether we think this is an appropriate goal. We are expecting Distribution Network Operators (DNOs) to produce outputs from this work by December 2025 so we can use it to inform our SSMD.

[2] https://nic.org.uk/studies-reports/developing-resilience-standards/
[3] RIIO-3 Sector Specific Methodology Decision for the Gas Distribution, Gas Transmission and Electricity Transmission Sectors | Ofgem
[4] Framework decision: electricity distribution price control (ED3) | Ofgem

- Phase B - This aims to take the learnings from Phase A to help inform adaptive pathways and provide qualitative rationale for climate investment decisions in climate resilience strategies and business plans. As part of this, we expect to provide guidance on climate resilience strategies and business plans in 2026. This phase may also address 'quick wins' for any easy to address priority information gaps identified in Phase A.

1.9 This document sets out the methodological framework that we plan to use for Phase A. Due to the need to produce outputs by December 2025, we have already worked closely with DNOs, including through workshops held approximately once a month since January 2025 which are expected to continue until December 2025. We have also worked closely with other experts including the Met Office and academics at Newcastle University. More detailed guidance and templates to support DNOs to carry out some of these steps included in this document will be provided separately (though there is some more information included on the fault data request in Appendix 1).

1.10 We are including this as an Annex to our SSMC as an opportunity to gain views from wider stakeholders. We are interested in stakeholders' views on:

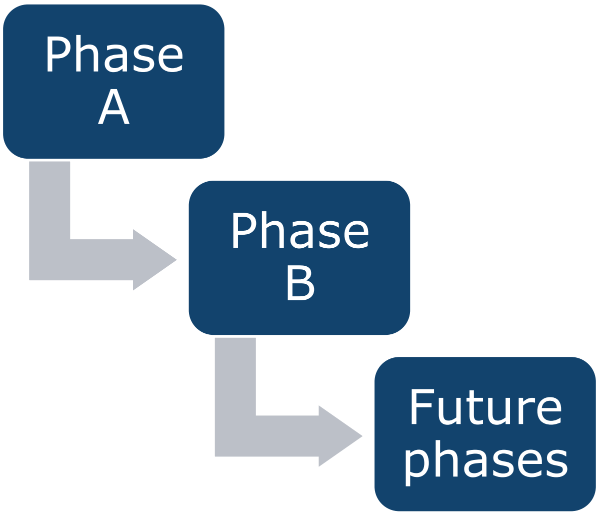
- Does it align with your expectations of the responsibilities of a DNO and current capabilities?
- Can you foresee any support or changes that might improve its effectiveness?
- Do you have any views on priorities for future phases of work?

As set out in our ED3 SSMC, we expect there will be future phases of work which will build on these findings and learnings to further address priority gaps in order to support government in setting resilience standards which will help inform long-term climate resilience goals. These priority gaps include:

- valuation on the benefits of building resilience;
- improved modelling capabilities to allow greater quantification; and
- allow for consideration of a changing, decarbonised energy network.

1.11 Phase B may utilise outputs from Phase A and link to the business planning process with future phases setting out a longer term approach utilising learnings from Phase A and B.

Figure 1: Future phases of climate resilience stress testing



Purpose and related publications

1.12 The purpose of this document is to:

- set out the methodological framework we intend to use for Phase A of stress testing;
- provide more information on the data request in step 1 of the methodology (see Appendix 1); and
- invite feedback, via the SSMC, on how we may take findings from this process forwards within ED3 and inform future work.

1.13 We expect to produce a report on the final approach used for this work alongside high-level findings, which will be published alongside the ED3 SSMD in 2026.

1.14 Related publications include:

- ED3 Sector Specific Methodology Consultation.

2. Glossary

2.1 Definitions of terms used in this document are set out in list below. These may be iterated over time as understanding and capabilities improve.

- Business Plan Data Template (BPDT) - Template used to support network company business plan submissions as part of Ofgem price controls.
- Climate hazard - Plausible atmospheric phenomena in a climate capable of negatively impacting the physical or operational aspects of energy networks.
- Climate impact - Damage to a physical asset or consequences (ie faults, Customer interruptions) resulting from a climate hazard.
- Climate resilience - The capacity of the network to withstand impacts of current and future foreseeable climate hazards to provide a continuation of primary service or facilitate rapid recovery from a climate hazard.
- Customers Interrupted (CI) - The number of customers interrupted per 100 customers on our network.
- Customer Minutes Lost (CML) - The average length of time customers are without power for power cuts lasting three minutes or longer.
- EJP (Engineering Justification Paper) - A document which sets out the scope, costs and benefits for major projects or aggregated investment programmed aimed at reinforcing the network or improving asset health.
- Exposure - The presence of infrastructure assets or people in locations and setting which could be impacted by a climate hazard.
- Fault - Any incident arising on the distribution system, where statutory notification has not been given to all customers affected at least 48 hours before the commencement of the earliest interruption (or such notice period of less than 48 hours where this has been agreed with customer(s) involved).
- Fragility curve - The probability of failure or unwanted outcomes of a structure or structural component.
- Hazard parameter - A graphical output relating the intensity of a hazard parameter (eg wind speed) to the impact parameter (eg conditional

probability of failure or unwanted outcome of a structure or structural component).[5,6]

- Impact Parameter - A variable associated with climate hazards that can be quantified or measured. This could be a specific weather variable, eg daily maximum temperatures, daily max 10m wind gusts or intensity of climate hazard (eg wind in m/s).
- Level of climate resilience - A measure of how resilient the current network is to current and future foreseeable climate hazards. This is defined as the probability of a specific reduction in the level of service of a network when impacted by a climate event with a given return period. Note the level of climate resilience is unlikely to be a single number, rather a range of numbers where large impacts have low probabilities of occurrence and small impacts may be more frequent.
- Level of service - A level of service can be defined as a standard which defines the boundary between acceptable and unacceptable performance. This could be measured in terms of CI and CML for a given return period of a climate hazard.
- Maintain/Maintained - For the purposes of this exercise, once we have determined the current levels of service as above, we will determine a threshold and boundary around this which is defined as maintain.
- Modular approach - The stress testing exercise will consider components or "modules" by climate hazard, eg flooding module. Each module will take an approach which best accounts for the levels of confidence, data availability, existing approaches and hazard parameters.
- For each phase, modules will be built upon, and additional modules may be added.
- National Fault and Interruption Reporting Scheme (NaFIRS) - National fault recording scheme, coordinated and administered by the Energy Networks Association (ENA), which enables participating DNOs to report all interruptions to supply in a consistent manner.
- Phase A - Stress testing exercise ahead of ED3 SSMD to inform overall quantum of investment for maintaining current levels of climate resilience in 2080.

[5] Fragility Curves for Assessing the Resilience of Electricity Networks Constructed from an Extensive Fault Database | Natural Hazards Review | Vol 19, No 1
[6] Fragility Curves for Quantifying Physical Climate Risk in the Electric Power Sector

- Phase B - Stress testing as part of ED3 business planning to inform investment decisions in business plans.
- Rapid Evidence Review - An accelerated review of evidence, designed to quickly summarise existing research literature to inform timely decision making.
- Return period - An estimate of the likelihood of an event to occur, often presented as years, eg 1 in 100 years. This could also be referred to as the expected frequency of an occurrence or event. Return periods will be affected by climate change.
- Reference level - The example reference level that we set out in the ED3 Framework Decision “Maintaining current levels of climate resilience by 2080”.
- Risk - The probability that a hazard could negatively impact network infrastructure, multiplied by the exposure of the asset, multiplied by the magnitude of the impact (ie how much the level of service is reduced).
- Stress testing - A tool or structured approach to simulate the performance of an asset or system under plausible but extreme conditions to identify vulnerabilities.
- Vulnerability - The inherent characteristics of an asset or system that affects its ability to withstand a weather hazard/event. Fragility is one component. This is affected by factors such as design and condition of asset or wider adaptation actions.
- Vulnerability threshold - A specific threshold value of the hazard parameter beyond which a defined level of service is exceeded.
- 2080 - We specified 2080 in the ED3 Framework Decision. For the purpose of this exercise, we will proceed with the 2080 date to ensure long term resilience is considered now, as well as adding in a 2050 date.

3. Stress testing background

3.1 Understanding vulnerability is a key objective for stress testing and informing resilience. Network infrastructure consists of spatially distributed, interconnected and interacting systems of assets. For each asset, several factors can contribute to the likelihood and impact of a fault, including but not limited to:

- vulnerability and exposure to a particular hazard or threat;
- specification of the asset (eg materials, standards);
- age and condition of the asset;
- relative importance/criticality of the asset (eg how many customers supplied); and
- localised contexts such as urban versus rural.

3.2 The number of factors contributing to the resilience of network assets makes understanding the vulnerability of networks to climate risk a challenging task.

3.3 A range of approaches and tools can be considered for stress testing, with varying complexities and requirements associated. We have considered three broad approaches that could be utilised for stress testing: scenario-led, vulnerability-led and decision-led.

3.4 **Scenario-led**: This considers developing a range of scenarios and testing how an asset or system may perform and respond.

3.5 Example: NIC (now NISTA) used the National Infrastructure Systems Model to calculate future water balances under three different scenarios of population growth, climate and drought.[7]

3.6 **Vulnerability-led (also known as reverse stress testing):** This approach considers setting the outcome, such as a reduction in level of service, and then identifying the plausible scenarios which could lead to this outcome.

3.7 Example: The Reserve Bank of New Zealand required banks to undertake this type of stress test, starting by considering different capital ratios, ie measure of bank's capital in relation to risk-weighted assets, to investigate what scenarios could cause them.[8]

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[7] nic.org.uk/app/uploads/NIC-Preparing-for-a-Drier-Future-26-April-2018.pdf
[8] www.rbnz.govt.nz/-/media/project/sites/rbnz/files/publications/financial-stability-reports/2024/nov-2024/exploring-vulnerabilities-through-reverse-stress-testing.pdf

3.8 **Decision-led (also known as 'decision-scaling'):** This approach takes a model of a system and combines it with a climate scenario and a policy objective.

3.9 Example: Denver Water took downscaled daily precipitation and temperature scenarios and then simulated their supply system using the Water Evaluation and Planning System (WEAP) with, and without, measures intended to protect reservoir storage during droughts.[9] Performance metrics and system behaviour were identified through a deliberative and collaborative decision support process with analysts and stakeholders. Accompanying narratives described plausible climate and non-climate drivers.

3.10 Each stress testing approach will have its relative merits and drawbacks. Clarity on the purposes of the stress test, alongside data availability and capabilities, can inform which approach is best suited. For this work, Phase A considers a vulnerability-led approach as, through engagement with academia and DNOs, this was evaluated to best meet the aims of Phase A stress testing within the timeframes. The approach seeks to utilise existing empirical evidence where available and industry knowledge. An overview of the approach is set out in Section 5.

[9] Decision-centric adaptation appraisal for water management across Colorado's Continental Divide - ScienceDirect

4. Stress testing aims and overview

Aims and success criteria

4.1 For the purposes of ED3, Phase A and B of stress testing sets out to deliver and progress aims across three themes. We recognise these are ambitious aims and that it may not be possible to achieve all of them, but we hope to make progress on each of these to improve capabilities which can be further built on for future phases.

4.2 **Capabilities:** Build tools and processes across Ofgem and the DNOs to assess key climate-related vulnerabilities and impacts.

4.3 Success criteria:

- clear and usable guidance allowing consistency across the DNOs;
- challenges and limitations are understood, with agreement on short- and long-term solutions; and
- DNOs start increasing capabilities for future phases of stress testing within the ED3 period.

4.4 **Goals:** Generate insights to inform acceptable levels of climate resilience to extreme weather events.

4.5 Success criteria:

- vulnerabilities identified at maintain current resilience levels (this may be expanded to cover other resilience/service levels); and
- consistent methodology used by DNOs to estimate the total amount of investment required for maintaining current levels of resilience.

4.6 **Investment decisions:** Improve collective understanding of resilience-related investments and associated impacts to enable clearer justification and scrutiny of decisions.

4.7 Success criteria:

- Clear categorisation and qualitative justification of investment options for resilience interventions within business plans. This could be built on over time to provide greater quantification on costs and benefits within future phases and via re-opener.

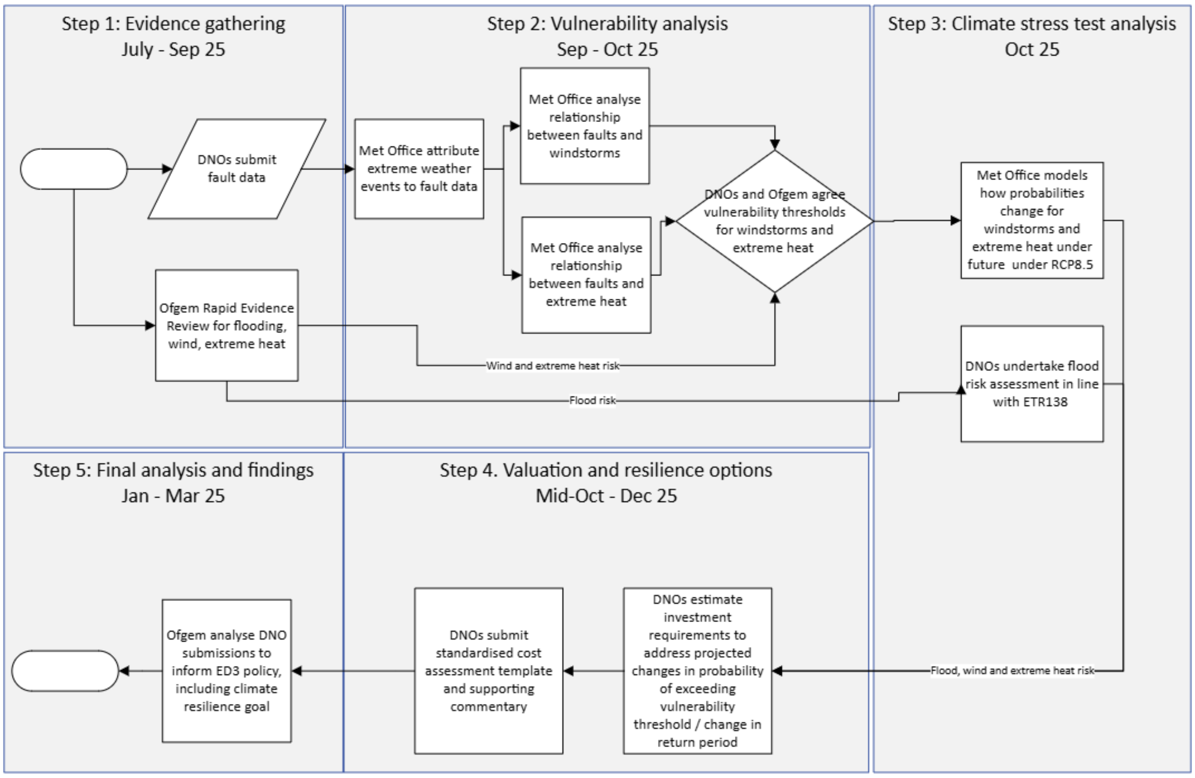
Principles

4.8 To underpin the development and delivery of Phase A stress testing, we set out the following principles:

- **clearly defined objectives -** Ofgem will set out clear objectives, guidance documents (including this framework) and templates to ensure consistency;
- **proportionality -** our stress testing approach will reflect the novelty and complexity of this methodology whilst balancing time and resources within the ED3 regulatory timelines;
- **transparency and credibility -** DNOs will share their data sources, assumptions and confidence levels in the evidence they provide. Ofgem will be transparent about the approach it follows and will seek expert input to ensure its methodology is robust and credible;
- **scrutiny -** Ofgem will review and challenge submissions made by DNOs on the options and valuation for resilience which are unsupported by evidence or clear justification to ensure quality and accountability; and
- **iterative development -** lessons learned from the work will inform future phases and integration with regulatory processes.

Overview of Phase A stress testing

Figure 2: Flow diagram overview of Phase A stress testing, composed of 5 key steps: step 1 evidence gathering; step 2 vulnerability analysis; step 3 climate stress test analysis; step 4 valuation and resilience options; step 5 final analysis and findings



4.9 Phase A of stress testing will use a vulnerability-led approach to understand the vulnerability of current network assets (step 2 in Figure 2) and how this may change in the future under different climate scenarios (step 3 in Figure 2). This should then inform what potential climate resilience measures could be required to mitigate any change in future vulnerability and the associated costs.

4.10 A key part of the methodology utilises fault data, which is routinely collected by DNOs, to develop fragility curves (see definition table). Fragility curves are a recognised approach for understanding vulnerability and informing resilience, used across academia and in the insurance sector.[10]

4.11 It is recognised that there will be limitations to this methodology for stress testing for climate resilience. For example, the use of historical fault data may not be representative of the future system as network assets are replaced and/or upgraded over time. Further, taking a fragility approach may not factor

[10] Fragility Curves for Assessing the Resilience of Electricity Networks Constructed from an Extensive Fault Database | Natural Hazards Review | Vol 19, No 1

in operational considerations, such as the time taken to respond to the fault. These are set out in full in Section 6.

4.12 The methodology of Phase A is comprised of five key steps (for more detail see Chapter 5):

- Step 1 evidence gathering - Ofgem undertakes a Rapid Evidence Review of existing literature and evidence to inform vulnerability of network assets to climate hazards. DNOs attribute location data to fault data and submit to Ofgem;
- Step 2 fragility curves and vulnerability analysis - The Met Office correlates the fault data with weather data to understand the relationship between a specific impact parameter, eg customer minutes lost, and specific weather conditions, namely windstorms and extreme high temperatures. This will produce fragility curves according to asset classes. We will also consider what information is available to understand the impact of events, based on number of customers affected and the duration of outages, to support our assessment on the level of service. We will work with the DNOs to agree vulnerability thresholds based on the fragility curves produced by the Met Office and other sources of evidence, eg from the findings of the Rapid Evidence Review. This stage is not carried out for flooding, as the vulnerability stipulated by industry guidance document Engineering Technical Report 138 Resilience to Flooding of Grid and Primary Substations (ETR138)[11] will be used. We will consider exploring the relationship between faults for flooding in future work;
- Step 3 climate stress test analysis - The Met Office will estimate how the vulnerability thresholds for windstorms and extreme heat are projected to change in 2080 based on climate projections using a 4°C warming scenario using RCP8.5.[12] DNOs consider flood risk assessments for substations in line with ETR138 and, for England, utilising the latest relevant flood maps;
- Step 4 valuation and resilience options - DNOs estimate the investment that will be required to maintain current levels of service and mitigate future changes to vulnerability thresholds by following guidance provided by Ofgem; and

[11] ENA_ET_138_-_Annex_Extract_180902050351.pdf
[12] RCP8.5 refers to Representation Concentration Pathway 8.5, a climate change scenario which specifies a greenhouse gas concentration of 8.5 watts per square metre.

- Step 5 Final analysis and findings - We will analyse the DNOs' submissions and utilise its findings, alongside other evidence, to inform a long-term climate resilience goal for ED3.

5. Methodology

Climate hazards

5.1 Vulnerability and exposure to different climate hazards will vary across DNOs. Phase A will focus on windstorms, high temperature and flooding. These hazards were selected based on a balance between the likelihood of their occurrence and the impact of risks, data availability, ability to identify vulnerability thresholds and opportunity to build insights and capabilities. Future stress testing work could explore other hazards, such as droughts, wildfires or compound hazards (ie concurrent or sequential hazards that interact to increase severity such as heatwave and drought together).

5.2 Each climate hazard has different challenges which can affect the best approach for stress testing. For example, there are differing levels of confidence in the projections data (due in part to level of complexity of the risk and limitations of climate models), differing levels of data on existing impacts and different levels of maturity of managing and understanding risks through existing tools and guidance. The methodology will take a modular approach which identifies the best approach for each climate hazard under the time constraints we have. Table 1 below summaries these views.

Table 1 Summary of climate hazards in terms of confidence in climate data, determining vulnerability thresholds and impacts, and potential outcomes

Hazard	Confidence in Climate data	Understanding impact on assets and networks	Potential outcome
Extreme heat	High confidence for temperature data.	Limited heat related fault data and strength of links	Emerging priority for some DNOs which could provide new information
Flooding	Reasonable confidence via existing flood maps	Vulnerability thresholds are defined by ETR138.	Understood reasonably well compared to other hazards.
Windstorms	Limited confidence	Challenging but potential through fault related thresholds or expert elicitation	High priority area which could provide new information

*Green = confidence, Yellow = Limited confidence

Step 1 evidence gathering

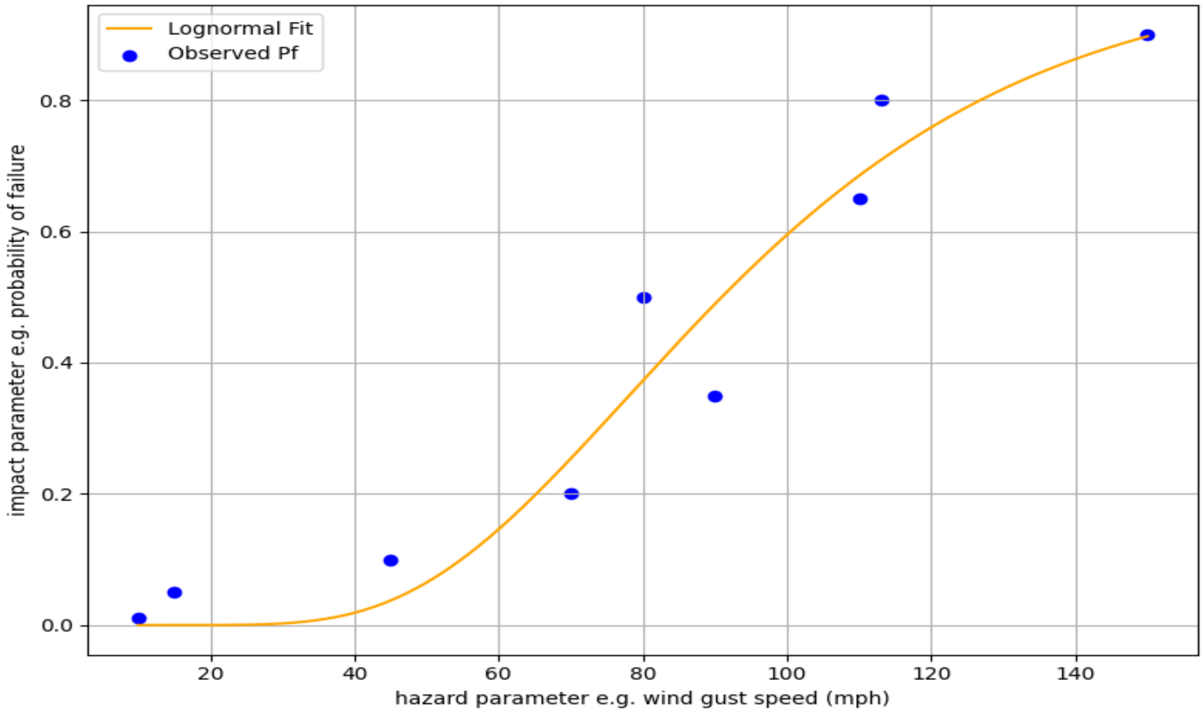
5.3 DNOs routinely record fault data using the NaFIRS, administered by the ENA. Some of this data is reported to us by the DNOs through annual regulatory reporting processes.[13] Phase A seeks to make use of this data by investigating the relationship between weather events and faults. To do this, DNOs will be required to attribute location data to the fault data from 1 April 2010 to 30 March 2025, where it is available. Appendix 1 sets out the guidance for preparing the fault data.

5.4 We recognise there are challenges and limitations to using fault data (set out in more detail in Section 6). To supplement and validate findings from the fault data analysis carried out in step 2, we will undertake a Rapid Evidence Review of existing academic literature, grey literature (for example working papers, white papers etc) and other sources of expert knowledge to inform and validate outputs from step 2 and 3. This will be particularly relevant for extreme heat, as we expect there will be lower confidence in the fault data for this climate hazard.

[13] RIIO-ED2 Regulatory Instructions and Guidance – Interruptions

Step 2 fragility curves and vulnerability analysis

Figure 3: Illustrative fragility curve to inform relationship between hazard parameter (eg wind speeds) and impact parameter (eg probability of failure, number of faults, CML) (example data only) Source: Climate READi[14]



5.5 The Met Office will correlate the fault data for agreed categories of network assets (eg 132-11 kV overhead line) with weather data to understand the relationship between specific weather conditions, namely windstorms and extreme high temperatures, and the impact on the asset or network. This will involve consideration of an appropriate hazard parameter and impact parameter respectively (see glossary for definition). This will produce fragility curves across various asset classes (see Figure 3 for an example). We will work with DNOs to establish vulnerability thresholds at a workshop based on the fragility curves produced by the Met Office and our Rapid Evidence Review.

5.6 A key challenge for developing this stress testing exercise is that there is no agreed metric for measuring climate resilience. DNOs are developing climate resilience metrics and indicators, with support from Ofgem, for implementation at the start of ED3. We will use current levels of service as a proxy for understanding current levels of resilience by utilising fault data to understand the frequency, severity and duration of total disruptions, inclusive of those

[14] Fragility Curves for Quantifying Physical Climate Risk in the Electric Power Sector

caused by severe weather. Exactly what this looks like in practice (eg customer minutes lost, number of faults, customer interruptions) will be determined once the analysis of data is complete and may also be supplemented by the Rapid Evidence Review and discussions with DNOs. If possible within the timeframes, we may also consider 'increased' level of service, which could be a % uplift compared to current levels.

5.7 We will work with DNOs to agree vulnerability thresholds for extreme heat and windstorms. This will require consideration of impact, measured by impact parameter(s), and should be reflective of current levels of service based on today's climate. For flooding, we will align with the return periods outlined in ETR138.

Step 3 climate stress test analysis

5.8 This step looks to consider how climate in 2080 could impact on the impact parameter based on 4°C global warming under RCP8.5. For windstorms and extreme temperatures, this will be done by the Met Office who will explore using ERA5 data to assess past event impacts and produce any necessary bias corrections to wind projections.

5.9 Once the vulnerability threshold is defined, based on the analysis from step 2 producing the fragility curve, the Met Office will perform a statistical analysis to identify the return period of the hazard value in the historical period. Keeping the return period fixed, eg a 1 in 5 year event, future climate projections will be used to identify how the corresponding hazard value would correspond with the target period.

5.10 The UK Climate Projections (UKCP18)[15] will be used to provide projections of future climate change, using the RCP8.5 warming scenario pathway. Temperature data can be provided to 5km grid resolution whilst wind gusts can be provided up to 12km resolution which will affect the level of granularity we can provide on future changes. It should be noted that assessing the climate change signal and robust projections is more challenging for windstorms than for temperature derived metrics.

5.11 For flooding, the impact of climate change will be captured as part of flood mapping risk assessment, as per ETR138 guidance.

[15] The UK Climate Projections (UKCP18) provides a comprehensive set of climate model projections for the UK, showing how the climate is likely to change in the future. They are produced by the Met Office.

5.12 The stress test analysis will produce two main outputs:

- An updated number for the hazard parameter based on future change to climate which can be used to identify a projected impact parameter in light of the changing climate. This will be carried out by the Met Office in collaboration with the University of Newcastle.
- Assessment of substations against the industry standard ETR138 using best available information (for England, risk assessment using updated Environment Agency flood map data; for Scotland, using flood map data by the Scottish Environment Protection Agency, and for Wales, using flood map data by Natural Resources Wales). This will be carried out by the DNOs.

Step 4 climate resilience options and cost analysis

5.13 Step 4 aims to understand the costs of resilience options and actions which:

- Would be required to maintain "current levels of resilience" - specifically, which resilience actions could be taken to reduce the updated impact parameter value (identified in step 3 as change to projected impact expected under climate change) back down the vulnerability threshold level (as agreed under step 2).
- Are identified by applying ETR138 to substations, assuming a climate scenario of RCP8.5 in 2080, using DNOs existing approaches to flood risk assessment alongside any additional investments for other assets at risk of flooding.

5.14 Types of resilience measures will be categorised to support the options assessment process. Appendix 2 sets out early considerations for what these types of investment categories might be. Establishing clear guidance for the cost assessment will be critical for ensuring consistency. We are working with DNOs to create this guidance.

Step 5 final analysis and findings

5.15 We will review the submitted cost analysis of the investment options for resilience submitted from each of the DNOs to understand the overall scale of investment proposed across the three climate hazards. We will use these costs to help inform whether maintaining current levels of resilience is an appropriate long-term climate resilience goal. It will also help identify the remaining information gaps that should be prioritised in future phases which were not possible to include in Phase A, such as consideration of avoided costs and other wider benefits. This could include whether we should consider alternative resilience levels as a more appropriate goal, such as an increase or decrease in levels of resilience.

6. Limitations

Limitations

6.1 The proposed methodology was developed and refined to best meet the aims of Phase A in the time available of ED3 development, making use of existing data, capabilities and progress to date. Given the urgency of taking action on climate resilience, in particular on clarifying an acceptable long-term goal, we consider it is important to drive forward this work at pace. We are aware there are limitations and uncertainties within the methodology which are important to draw attention to and take into consideration throughout the data analysis and when interpreting the results. Future phases of stress testing will seek to address limitations and uncertainties where possible.

6.2 **Levels of resilience and levels of service:** We do not yet have a specified definition of levels of climate resilience or levels of service. Measuring levels of resilience is not straightforward and is being developed as part of the Climate Resilience Metrics and Indicators (CRMI) workstream. For this work, until the CRMI are agreed, we will use a proxy based on levels of service.

6.3 **Linking hazard parameters to probability of impact:** This approach takes a simplified approach using a large dataset to inform the relationship between asset or network faults and climate hazards. It is unlikely that a single hazard parameter, or weather variable, will be the sole contributor to the likelihood of the fault. The location, topology, type, age, condition and operation of an asset can all affect potential fault probabilities.

6.4 **Linking probability of impact to level of resilience:** A key assumption in the approach is the probability of an impact, based on historical fault data, being an indicator of resilience. The fact of a fault occurring does not necessarily provide information on the impact on customers, for example how many customers were impacted (if any), for how long and any complexities associated with the recovery.

6.5 **Future system and resilience**: This method relies on the production of fragility curves for extreme heat and windstorms based on historical fault data of assets. We recognise that fragility curves are based off historical fault data and in reality, fragility curves will adjust over time as resilience actions are brought in to manage the risk (eg replacement of assets) and this work will not account for that given the time constraints. We will review if we can improve on this for future phases, especially as we recognise the energy system is undergoing a major transition towards greater electrification which is likely to affect the fragility of the system and networks.

6.6 **Vulnerability thresholds and levels of service:** This will require assumptions to be made on the relationship between hazard parameters and the proxies used for levels of service.

6.7 **Fault data:** There is varying availability / quality in the fault data across the 15 year time period being requested, which affects our confidence in the data and outputs that can be drawn from it. In particular, location is not standardised as part of NaFIRS and the methodology requires retrospectively recording the location of the fault to the nearest primary substation, or where possible, a secondary closer asset. There will be varying granularity across the time horizons and DNOs. It should also be recognised that fault data can be subject to human error, particularly as operational staff can be navigating challenging conditions during extreme weather events and data recording may not be the immediate priority.

6.8 **Climate hazards:** The scope will be limited to three climate hazards for the initial phases of stress testing (Phase A and Phase B). This does not represent the full range of climate hazards, such as those identified in network companies' adaptation reports (as requested by government under Adaptation Reporting Power) and climate resilience strategy reports.

6.9 **Valuation:** We are aware that many of the steps of this methodology are subject to uncertainty (including uncertainty of projecting changes to extreme weather and their impact on customer level of service) and that this has implications for the findings of this work, including estimates of investment. With this mind, we will be clear on assumptions included and require DNOs to do the same in their investment calculations. Where appropriate, to ensure robustness, sensitivity analysis will also be carried out to understand what impact these assumptions have on the totals.

6.10 **Cost and benefits:** Due to time constraints, the approach for Phase A will not look to account for the associated benefits of resilience (ie avoided costs from managing disruptions associated with extreme weather) and different approaches that could be taken. It is important that these are considered within future work to inform the case for proposed investment.

6.11 **Interdependencies and criticality:** The methodology does not account for criticality of assets, although some of this information could be supported by supplementary information as part of the submissions. Both criticality and interdependencies could be considered as part of future stress testing phases.

7. Conclusions and next steps

7.1 Despite the limitations, as discussed in Section 6, the approach we are taking will inform the direction of price control regulation for climate resilience by using data and processes which already exist. Although there will be limitations in retrospectively attributing location data to historical fault data, the exercise is likely to produce a valuable dataset to DNOs going forward. The Met Office is providing support to this work via its Scalable Climate Services function and it will also consider how learnings through this work might have a broader application for other regulated sectors.

Next steps

7.2 We will work with DNOs and the Met Office to implement the stress testing methodology detailed in this document and will set out further guidance on the cost assessment step following engagement and testing with DNOs. DNOs will be requested to submit information on resilience options and costs. We will work with DNOs to develop further guidance on this. We will analyse the returns to determine what is an acceptable level of resilience.

7.3 We will also consider how the subsequent Phase B stress testing will inform the investment cases for climate resilience within the DNOs' ED3 business plans. We will publish a summary report of the final detailed approach taken for Phase A, its outputs, and recommendations for ED3 as part of the ED3 SSMD publication in Spring 2026. Ofgem will consider which approach(es) will best facilitate an understanding of how such investments may or may not be value for money for consumers and inform the case for investment in business plans.

Appendices

Index

Appendix 1 ED3 Climate resilience stress testing: fault data request

Requested fault data

A1.1 We are requesting data on unplanned interruptions lasting 3 minutes or longer. This includes data already recorded and maintained by DNOs, such as that reported through Regulatory Instructions and Guidance or held in the NaFIRS database.

A1.2 The data includes:

- fault data (Incident reference, stage data, duration, cause code, EE coding);
- temporal data (Start date and time, end date and time);
- equipment identifiers (Voltage and Main Equipment Involved (MEI)); and
- location information (primary location, secondary location).

Fault data information[16]

Ofgem is requesting data for 15 years per license area, from 01 April 2010 to 30 March 2025 where this is available.

A1.3 The following data fields are the same as stipulated in the RIIO-ED2 Regulatory Instructions and Guidance – Interruptions Guidance.

A1.4 Please include the following data fields:

- **Incident Reference Number**
- **Restoration Stage**
- **Voltage** – please provide voltage number where this is available
- **Start Date and Time / End Date and Time**
  (Time of first report of supply loss or abnormality preventing normal circuit operation for ≥3 minutes)
- **Customers Restored**
- **Reinterruption (Y/N)**
- **MEI code**
- **Cause Code**
- **Exceptional Events Coding (EE Coding)**
- **Stage CI / Stage CML**

A1.5 The following data fields seek to attribute location information:

[16] RIIO-ED2 Regulatory Instructions and Guidance – Interruptions

- **Primary name** – Primary Substation A substation name at which the primary voltage is greater than HV and the secondary voltage is HV (covers 132/11kV substations).
- **Primary location (coordinates)** – co-ordinates of primary substation as per recommended CRS.
- **Secondary name** – Network asset where the primary voltage is HV or below which are nearer to the fault.
- **Secondary location (coordinates)** – co-ordinates of secondary HV network asset as per recommended CRS.

A1.6 There is no standardised approach for recording the fault locations, therefore this may vary across network companies. To support consistent analysis, the fields "primary name" and "primary location (coordinates)" should be used to attribute fault location to the primary substation which feeds the relevant asset where the fault occurred. All DNOs should complete this field as fully as possible. Where it is not possible to provide primary name and location information across the timeframe requested, please notify us as soon as this becomes known.

A1.7 In addition, DNOs are encouraged to consider whether supplementary location information is available to improve the accuracy of fault attribution. Where it is possible within the submission timelines, DNOs are encouraged to populate these fields to improve spatial resolution for the analysis. The fields "secondary name" and "secondary coordinates" may be used to attribute a nearby HV network asset closer to the fault. A degree of flexibility is provided to facilitate more granular data where this is available. For example, it may be beneficial to prioritise weather-related faults if attribution for all faults is not possible within the timescales.

Appendix 2 Climate resilience investment categories

A2.1 The table outlined in this annex summarises some options DNOs may consider for increasing the resilience of the network. This will be built upon through further discussions with DNOs and other stakeholders. For Phase A of stress testing, the work is likely to focus on non-load and operations as resilience options, however future work will consider options for load.

Asset Classes	**Load**	**Non-Load**	**Operations**
Substations	Redundancy in network/additional capacity.	Permanent/temporary defence and barriers, Raised platforms, Asset relocation, ground movement sensors, fire breaks, remote sensors, Active cooling, Thermal rating upgrades, monitoring.	Site selection, Flood risk assessment, Redesign with modular flood resilient layout, Waterproofing/sealing, Drainage, Pumping systems, Remote monitoring, Innovation projects, Scenario planning, Vegetation management.
Overhead Pole line (wood/steel 11-33kv)	Redundancy in network/additional capacity.	Foundation reinforcement, elevate equipment heights, pole stress/water level sensors, vegetation management, remote monitoring, guy wire upgrades, OHL upgrade, ice shields, ground movement sensors, heat resistant materials, fire breaks.	Flood risk mapping, drainage systems, vegetation management.
Overhead Tower Line (steel 132kv)	Redundancy in network/additional capacity.	Foundation reinforcement, elevate equipment heights, pole stress/water level sensors, vegetation management, remote monitoring, guy wire upgrades, OHL upgrade, ice shields, ground movement sensors, heat resistant materials, fire breaks.	Flood risk mapping, drainage systems, vegetation management.
Cable	Redundancy in network/additional capacity.	Waterproof cable design, sealing tech, drainage systems, remote monitoring, high rated insulation, duct spacings and ventilation, bury in deeper soil.	Flood risk assessment, scenario planning.

Switchgear	Redundancy in network/additional capacity.	Permanent/temporary defence and barriers, Raised platforms, Asset relocation, Redundancy in network, ground movement sensors, fire breaks, remote sensors, Active cooling, Thermal rating upgrades, monitoring.	Site selection, flood risk assessment, load management, scenario planning, vegetation management.
Transformers	Redundancy in network/additional capacity.	Permanent/temporary defence and barriers, Raised platforms, Asset relocation, Redundancy in network, ground movement sensors, fire breaks, remote sensors, Active cooling, Thermal rating upgrades, monitoring.	Site selection, Flood risk assessment, Redesign with modular flood resilient layout, Waterproofing/sealing, Drainage, Pumping systems, Remote monitoring, Innovation projects, Scenario planning, Vegetation management.