RIIO-ED2 Business Plan
December 2021

SP ENERGY NETWORKS

Annex 4A.7:

Climate Resilience Strategy

PRINCIPAL PARTNER
UN CLIMATE CHANGE CONFERENCE UK 2021
IN PARTNERSHIP WITH ITALY

Contents

1. An Introduction to this Annex

Scope

Our Climate Resilience Strategy (CRS) outlines how we will maintain a safe and resilient network in response to the changing climate, it has been developed using the climate adaptation pathways approach and is split into two parts:

1. The Climate Risk assessment – identifying and assessing the risks to our network & business from climate change.
2. The Adaptation Solutions and Pathways – identifying the resulting optimal actions & mitigation plan.

Our CRS has been produced as part of our RIIO-ED2 Business Plan Submission to Ofgem.

Key highlights

Climate Risk assessment

We assessed the risks from climate change to our network[1] and to our business[2] using global best practice. We did this across four key climate change projection variables (temperature, precipitation, sea level rise, and wind speed/storminess) over three time periods (2030s, 2050s, and 2100s) and two Representative Concentration Pathways (RCP) projection scenarios[3] (RCP6.0 and RCP8.5). The information for which was sourced from the United Kingdom Climate Projections 2018 (UKCP18) data[4].

In the development of the climate risks in this CRS, we considered both observed climate change and extreme weather events. Secondary risks associated with key climate change projection variables were also considered in relation to but not exclusive of the following hazards:

- increased temperature
- drought
- prolonged growing season
- wildfires
- hurricanes & high winds
- increased lightning activity
- ice & snow
- sea level rise and storm-surge
- coastal erosion & flooding
- fluvial & pluvial flooding.

These risks were also determined from building on past work, such as our 2015 Climate Change Adaptation Report[5] and the Energy Network Association (ENA) 2021 3rd round climate change adaptation report and Addendum[6], and further validated through stakeholder engagement interviews and workshops held with our SP Energy Networks colleagues.

In order to determine the significance of each risks to our network and to our business, we considered the relative likelihood and impact for each risk for both RCP6.0 and RCP8.5 climate change projection scenarios,

[1] Network risks are primarily direct risks to network infrastructure (e.g. substation flooding).
[2] Business risks are primarily risks to business operation (e.g. delayed (non-)operational tasks due to heatwaves).
[3] The climate change projection scenarios have been established based on two Representative Concentration Pathways (RCP). These are explained in more detail in section 4.
[4] https://www.metoffice.gov.uk/research/approach/collaboration/ukcp/index
[5] SP Energy Networks. (2015). Climate Change Adaptation Report, Round 2 Update. [Accessed 3rd May 2021]. Available from: https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/479266/clim-adrep-sp-energy-networks-2015.pdf
[6] Energy Network Association. (2021). 3rd Round Climate Change Adaptation Report and Addendum (Sept 2021).

categorising each risk into ‘Very High, ‘High, ‘Medium’ or ‘Low’ risk. Examples of ‘Very High’ or ‘High’ risks identified include:

Increased Temperature: Overhead line conductors affected by temperature rise and increased cooling demand, reducing rating and ground clearance (AR1)

Fluvial and Pluvial Flooding: Substations affected by river flooding due to increased winter rainfall, with loss or inability to function leading to reduced security of supply. (AR10)

Summer Drought: dry-out of the soil surrounding underground cables. This will lead to an increased thermal resistivity, reduced heat transfer from cable to surrounding soil/backfill, and a reduced current (load) carrying capacity (AR16)

For each main risk, we identified their adaptation tipping points (i.e. when will network functions will be compromised, and so when we need to implement our adaptation strategy).

Adaptation Pathways

There may be several different solutions to any one risk. Each solution may have different costs, be suitable for different risk thresholds and be applicable at different points in time. In order to allow future decision makers flexibility, an adaptation pathways approach was adopted, providing solution pathways which help identify the best sequence of actions for different assets. For example, to mitigate the impact of higher temperatures on substations, incorporating passive cooling is a solution we should adopt early; if temperatures rise beyond a certain threshold then we may need to use forced cooling or nature-based solutions such as vegetation to provide shade.

Adaptation pathway diagrams were developed to demonstrate the appropriate pathway we should adopt in relation to each of the identified hazards and their associated risks to ensure we plan and adapt our network and business operations

Contribution to Cross-Sector Work

A reliable and resilient electric power supply is a key enabler of the decarbonisation and adaptation efforts of other sectors which will require a significant amount of electrification, in order to meet the legally binding Net Zero carbon emission targets of UK Governments. Therefore, it is important to understand the many interdependencies between the electric power sector and other critical infrastructure sectors such as water, oil and gas, telecommunications, and transportation.

Like other Distribution Network Operators (DNOs) and the Transmission Network Operators (TNOs), we will continue to work to ensure that the UK electricity network remains one of the most reliable networks in the world and that climate change is one of the impacts considered when developing and reinforcing those networks.

Monitoring and Evaluation

As part of our CRS, we will put in place a framework for Monitoring and Evaluation (M&E) to ensure that the key climate risks are regularly reviewed, and current adaptation approaches are sufficient to mitigate potential impacts. The key elements of the M&E framework are as follows:

1. Review baseline data used to inform the adaptation pathways approach (Climate Risk Assessment and Tipping Points).
2. Evaluate actions against reviewed baseline data.
3. If the current adaptation approach is not achieving its objectives, revise the approach and progress along the appropriate adaptation pathway.
4. Report findings of the review and lessons learned against adaptation solutions, in-line with the 5-yearly price control periods.

We have outlined a number of roles for internal appointment within our business, including a ‘Resilience Coordinator’, and ‘Resilience Champions’ within each function to be responsible for implementing the M&E process.

Benefits

The RIIO-ED2 period aligns with wider societal change. During this time distribution networks will be a key enabler of Net Zero and will stimulate the national Green Recovery.

Network utilisation is forecast to be stressed beyond the original design capacity of the network. Complexity of network operation is increasing significantly as we rely on flexibility, DSO constraint management and innovation for real-time advanced network management. The criticality of our assets is rising as customers transition to Net Zero and connect greater numbers of electric vehicles and heat pumps in response to the climate emergency. All of this is set against the unavoidable and contemporaneous deterioration of our asset base.

Our RIIO-ED2 asset management plans will ensure the safety, reliability, and resilience of the network is maintained by investing in the underlying integrity and health of our existing asset infrastructure. This ensures the network is capable of supporting the forecast growth in demand, generation, complexity of operation and new DSO functionality required to allow our customers to decarbonise, and the UK to transition to Net Zero.

Why Asset Management is important in RIIO-ED2

Our customers depend on us…	We are pushing the network harder…	We are managing an ageing and deteriorating asset base…
our customers are increasingly dependent on a reliable electricity supply as they increasingly use electricity for transport and heating.	the electrification of heat and transport will increase network power flows. Network assets will be operating at a higher level of utilisation, increasing the deterioration ('wear and tear' rate) of assets.	our plans will manage the deterioration of our assets in RIIO-ED2 by targeting modernisation on our poorest condition assets, promoting life extension where possible, and prioritising assets with the greatest consequence of failure.

Embedding climate resilience into the asset management of our network is necessary to ensure the reliability levels our customers expect. As our climate continues to change and the impact of our climate increases, the benefits from proactive climate resilience investment become apparent.

Customer and stakeholder input

We have undertaken significant stakeholder engagement as part of our plan development and have sought feedback from a range of stakeholders. See Annex 3.1: Co-creating our RIIO-ED2 business plan with our stakeholders for more information on this process. Following this engagement, we have developed the below commitments for RIIO-ED2 which are relevant to this Annex:

- We will continue to optimise the level of network risk, reducing asset deterioration from around 5.4% per year without intervention to around 1.1% through our targeted and optimised asset modernisation programme over RIIO-ED2.
- We will improve the reliability of our supply to customers, ensuring that on average customers will be 19% less likely to experience an unplanned interruption, and average duration will reduce by 19%. We will do this over the duration of RIIO-ED2 by investing in new & proven technologies and embedding innovation.
    - Stakeholder feedback phase 3, S3.3 Reliability: Stakeholders praised SPEN's stated focus on short as well as long interruptions.
    - Customer acceptability phase 3, C3.3 Reliability: There was 95.9% acceptability for this commitment.

- 'Adapting and responding to flood risk: We will continue to improve the flood resilience of our network by working with our regional environment agencies and continue to target 100% compliance as flood maps and assessments evolve during ED2.
    - This commitment tested well with stakeholders (S3.8) – 91% either strongly agreed or agreed that the commitment is ambitious enough.
    - This commitment tested well with customers (C3.8) where it tested with a high level of acceptability (Acceptability = 98.6%).

Investing in network asset risk, resilience and reliability is key to reducing the likelihood of customers experiencing an interruption. This Annex supports these commitments in the following ways:

Climate adaptation approach:

- Actively invest in flood management at substations with low criticality given the greater frequency and severity of flood events resulting from climate change,
- Consider natural flood management solutions in addition to concrete solutions, and;
- Engage with networks from foreign countries that have already been confronted with some of SP Energy Networks' incoming challenges.

Climate Risks:

- Give particular thought to rising sea levels, the impact of high temperatures, drought, land slope stability, changing fluvial geomorphology, peatland action programmes and erosion, and;
- Assess the impact of climate change not just on physical assets, but also on staff and business functions, for example, staff's inability to work due to unplanned events such as a heatwave

Example of Stakeholder consultation findings *(Synthesis Report: Phase 2, Biodiversity)*
Climate adaptation approach:

- Actively invest in flood management at substations with low criticality given the greater frequency and severity of flood events resulting from climate change,
- Consider natural flood management solutions in addition to concrete solutions, and;
- Engage with networks from foreign countries that have already been confronted with some of SP Energy Networks' incoming challenges.

Climate Risks:

- Give particular thought to rising sea levels, the impact of high temperatures, drought, land slope stability, changing fluvial geomorphology, peatland action programmes and erosion, and;
- Assess the impact of climate change not just on physical assets, but also on staff and business functions, for example, staff's inability to work due to unplanned events such as a heatwave

[7]

Delivering our Plan

As we progress throughout RIIO-ED2 we shall monitor and evaluate all the climate risks identified within this strategy, including where baseline data or monitoring data updates. Any necessary updates to the adaptation pathway and associated actions shall be assessed and implemented where required.

The detail of how we have applied this strategy and embedded the required investment to ensure we build a network that is resilient to future climate change is presented in Section 9.

Within our RIIO-ED2 plans we shall continue ongoing programmes of work which provide greater climate resilience for our network. These include:

- £9.65m (£5.30m in SPD & £4.34m in SPM) over the RIIO-ED2 price control period to improve the network resilience to flooding and work towards 100% compliance with ETR-138

[7] SPEN (2020). Synthesis Report Sustainability Workstream. SPEN.

- Within RIIO-ED2 we are undertaking an extensive programme of OHL modernisation (£208m) which includes a 171km of EHV and 1,117km of HV OHL re-build in accordance with latest storm resilient standards.
- Within RIIO-ED2 we shall continue to deliver our Tree Cutting Programme (CV29) which has a forecast expenditure of £82.02m (£23.82m in SPD and £58.20m in SPM) over the 5-year period. Within RIIO-ED2 our tree-cutting expenditure has increased slightly to maintain our RIIO-ED1 cyclic-cutting programme in-light of our latest framework costs and the increased growth rates identified in VM6 and VM7.
- We plan that over 25.5% of our Overhead line network at EHV and HV will be built to ETR132 storm resilient standard by the end of RIIO-ED2. Our continuing long-term goal is that by 2034 over 40% of all interconnected 11kV and 33kV OHL networks will be built to ETR 132 storm resilient standard such that an exceptional event should not affect any connected customer for more than 36 hours.
- Incorporate the analysis of the potential impact from ground movement on poles / towers within the statutory 6-yearly inspection cycles and condition assessment

Signpost for Ofgem's business plan requirements

Ofgem BP Guidance No	Page Number
3.29 - As a minimum requirement under Stage 1 of the BPI, Business plans must include a dedicated climate resilience strategy, outlining how DNOs plan to adapt to the impacts of climate change on their networks over the long term. This strategy must include the use of adaptation pathways and be used to inform the programmes of work that the DNO will need to carry out over the price control. The strategy should serve to identify the steps that the DNO needs to take to ensure its network remains resilient to the effects and risks of climate change.	Section 2.2.3 summarises how this Annex complies with RIIO-ED2 requirements. Section 4 shows how we have used adaptation pathways approach to develop our strategy. Section 6 shows how we identified climate change risks we need to remain resilient to. Sections 7, 8 and 9 set out the steps we are taking to manage these risks.
3.30 - One climate resilience strategy must be produced per DNO group. In developing this strategy and planning the actions it will need to take over the RIIO-ED2 period and in the longer term, the DNO must consider a range of plausible climate change projections and the impacts for its region, as demonstrated through the adaptation pathway approach. At a minimum, the DNO must consider the assumptions of temperature rises and/or relevant risks as outlined by the Paris Agreement, the National Infrastructure Commission, the UK Government, and Committee on Climate Change or other equivalent bodies.	We have produced a single CRS for both of our licence areas. Section 4 & 5 detail where our underlying climate assumptions have been taken from. Section 5 shows how we have considered a range of climate projections, with detail in. Appendix I, II and III.
3.31 - We expect an underlying consistency in the assumptions that all DNOs make, that will underpin the planning the DNO undertakes. Where possible, the DNO should coordinate with other parties (both within the energy sector, such as transmission or gas distribution companies, and in other sectors, such as the water or transport sectors) local authorities, and/or other DNOs to develop its strategy and plan the steps it will need to take in RIIO-ED2. We expect this to help when a DNO considers the impacts of climate change in relation to cascading and escalating failures of infrastructure across independent sectors.	Section 3.3 shows how we have participated in cross sector and cross DNO work via the ENA. Section 4.1 summarises industry engagement we have undertaken to develop this strategy. Section 6 details the source of risk assessment information for each hazard. Section 10 sets out our contribution to cross-sector work in detail.
3.32 - While we are not prescribing the structure or content of the strategy, the DNO must identify the steps that it expects to take over the course of RIIO-ED2, and how these steps fit in with the DNO's longer-term planning and other activities. It must also identify how the DNO has considered the impacts on its network(s) and how it proposes to mitigate these impacts. We expect the DNO to outline how it will contribute to cross-sector work on climate resilience, such as through a climate resilience working group. We also expect the DNO to outline its initial plan for demonstrating progress against the strategy.	Section 8 sets out the decision points we have identified for making changes in our strategies. Section 9 sets out what we are doing in RIIO-ED2 to manage the threat of climate change. Section 10 sets out our contribution to cross-sector work in detail. Section 11 explains how we will demonstrate progress through the Climate Adaptation endorsed Monitoring & Evaluation process.

2. Our Network and Strategy

Our Climate Resilience Strategy (CRS) has been produced as part of Scottish Power Energy Networks' (SP Energy Networks) RIIO-ED2 (Revenue = Incentives + Innovation + Outputs) Business Plan submission to the Office of Gas and Electricity Markets (Ofgem). Our CRS will outline how we can maintain a safe and resilient network in response to the future uncertainties around Climate Change.

Climate resilience is a key element in enabling the transition to Net Zero by 2050. The changing role of the Distribution Network Operators (DNO) to a Distribution Systems Operator (DSO) means that operations and activities will become more important to national electricity supplies, with any potential climate-related impacts on the network having a greater consequence on the day-to-day activities of customers.

Building on our 2015 Climate Change Adaptation Report – Round 2 Update[8] and work undertaken by the Energy Network Association (ENA) alongside other DNOs in the UK, this report considers United Kingdom Climate Projections 2018 (UKCP18) data to provide an updated assessment of our network and business risks. In-turn, these risks then inform adaptation pathways for developing a strategy of solutions that build on current practices and investment, further adapting our network and business operations to mitigate against potential future impacts.

Within this strategy, 'Network' resilience looks into the resilience of non-load related activity and load related activity, and network operating costs. 'Business' resilience looks into workforce resilience and business support costs (BSCs).

2.1 SP Energy Networks Overview

SP Energy Networks construct, maintain, and repair the electrical equipment, and network assets that transport electricity to around 3.5 million homes and business in the South of Scotland, Cheshire, Merseyside and North Wales (as outlined in Figure 1). SP Energy Networks operate the distribution network in two licence areas;

- SP Distribution plc (SPD); and
- SP Manweb plc (SPM).

SP Energy Networks operate in a regulated environment where the regulator, Ofgem, sets targets covering defined price control periods of 8 years for RIIO-ED1 and 5 years for RIIO-ED2. SP Energy Networks undertakes the statutory obligations and day-to day management of the three individual license holders, with the aim of maintaining a safe and resilient network and enabling customers' requirements for Net Zero energy.

This CRS covers all key network assets and considers business operations within the distribution license areas, SPD, and SPM.

The CRS is driven by and builds upon a range of other plans, policies, strategies, and risk mitigation already active within SP Energy Networks and builds on sector-based work undertaken by other DNOs and the ENA Adaptation to Climate Change Task group. These are discussed in more detail in the following sections.

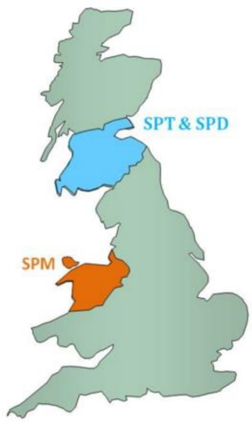


Figure 1 Regions where SP Energy Networks operate

[8] SP Energy Networks. (2015). Climate Change Adaptation Report, Round 2 Update. [Accessed 3rd May 2021]. Available from: https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/479266/clim-adrep-sp-energy-networks-2015.pdf

2.2 Background to Climate Change and our Obligation to Report

2.2.1 National

The UK Climate Change Act 2008[9] requires the Government to present to Parliament an assessment of the climate change risks for the UK every five years. Following the publication of each UK Climate Change Risk Assessment (UKCCRA), the most recent of which was published in 2017 and the next due in 2022, the Government must lay out its objectives, policies, and proposals to address climate change risks and opportunities. The second National Adaptation Programme (NAP2), which sets out these objectives, policies, and proposals, was published in 2018[10].

The devolved administrations also have their own adaptation programme. The Climate Change (Scotland) Act 2019[11] places a duty on ministries to lay a programme for climate change adaptation following each UK NCCRA, the latest Scottish Adaptation Programme being published in 2019. For Wales, this is in the form of The Environment (Wales) Act 2016[12] and the Well-Being of Future Generations (Wales) Act 2015[13]. The Welsh government produced their latest Climate Change Adaptation Plan in 2018.

2.2.2 International

The most recent headline statement from the Intergovernmental Panel on Climate Change (IPCC) states that *"There is a high confidence that global warming is likely to reach 1.5°C between 2030 and 2052 if it continues to increase at the current rate".*[14]

There are a number of policies from international to local scale outlining targets to limit climate change. The Paris Agreement on Climate Change (2016) [15] unites many of the world's nations under a single agreement on tackling climate change. The UK is a signatory and has pledged actions to help mitigate climate change. The Paris Agreement's central aim is to keep a global temperature rise well below 2 degrees Celsius (above pre-industrial levels) and to limit the temperature increase even further to 1.5 degrees Celsius. A range of actions are proposed to support this aim.

Climate Adaptation is also included in the United Nations' Sustainable Development Goals (UN SDGs), and the United Kingdom wishes to demonstrate leadership in the delivery of these goals. As a result, the Greening Government Commitments[16] state that: *"Climate resilience planning and mitigation shall be incorporated at all business levels. Strategic climate impact risk mitigation shall be embedded in strategic programmes and plans including estate rationalisation and disposal. Where climate risks are identified, appropriate adaptation actions shall be undertaken".*

[9] UK Gov. (2008). Climate Change Act 2009. [Online] Legislation.gov.uk. [31 March 2021]. Available from: https://www.legislation.gov.uk/ukpga/2008/27/contents
[10] Defra. (2018). The National Adaptation Programme and the Third Strategy for Climate Adaptation Reporting. [03 June 2021] Available from: https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/727252/national-adaptation-programme-2018.pdf
[11] UK Gov. (2019). Climate Change (Emissions Reduction Targets) (Scotland) Act 2019. [Online]. Legislation.go.uk. [31 March 2021]. Available from: https://www.legislation.gov.uk/asp/2019/15/contents
[12]UK Gov. (2016). Environment (Wales) Act 2016. [Online]. Legislation.gov.uk. [31 March 2021]. Available at: https://www.legislation.gov.uk/anaw/2016/3/contents
[13] UK Gov. (2015). Well-Being of Future Generations (Wales) Act. [Online] Future Generations Commissioner for Wales. [12 May 2021]. Available from https://www.futuregenerations.wales/about-us/future-generations-act/
[14] International Panel on Climate Change (IPCC). n.d. Headline Statements [online] [26 March 2021]. Available at: https://www.ipcc.ch/sr15/resources/headline-statements/#:~:text=Sea%20level%20will%20continue%20to,depend%20on%20future%20emission%20pathways.&text=There%20are%20limits%20to%20adaptation,associated%20losses%20(medium%20confidence).
[15] United Nations Framework Convention on Climate Change (UNFCC). (2015). The Paris Agreement. Available at: https://unfccc.int/files/essential_background/convention/application/pdf/english_paris_agreement.pdf
[16] UK Gov. (2018). Policy Paper – Greening Government Commitments 2016 – 2020 [online]. [26 March 2021] Available from: https://www.gov.uk/government/publications/greening-government-commitments-2016-to-2020

2.2.3 Ofgem RIIO-ED2 Requirements

In December 2020 Ofgem published the RIIO-ED2 Sector Specific Methodology Decision (SSMD) for electricity distribution companies.[17] This sets out the information that should be included in electricity distribution network operator's RIIO-ED2 business plans.

As a part of the RIIO-ED2 business plan submission, Ofgem requires that SP Energy Networks create and publish a Climate Resilience Strategy. We support and welcome the increased regulatory focus in this area and look forward to collaborating with the other DNOs and leading industry experts in this area.

This strategy details how we can continue to build on existing climate resilience interventions and activities to further increase network resilience, ensuring the consideration of the risks and impacts that climate change poses to the network and the appropriate steps that can be taken towards the mitigation of these impacts over the longer-term.

The strategy will also align with and support our existing Sustainable Business Strategy and associated RIIO-ED2 Environmental Action Plan, further to the 2015 Climate Change Adaptation Report – Round 2 Update, whilst also demonstrating the following:

- Consideration of climate trends and risks identified within the Paris Agreement, National Infrastructure Commissions, UK Governments National Climate Change Risk assessment and the UK Committee on Climate Change,
- Incorporation of work undertaken by the ENA Adaptation to Climate Change Task Group, to ensure alignment and consistency between other DNOs; and,
- The incorporation of outputs and suggestions received through stakeholder engagement.

3. Building on Existing Work

3.1 Existing SP Energy Networks Strategies

As a business, we have been focusing on managing key climate risks since the publication of our Adaptation Reports in 2011 and 2015. As a result, we have carried out several adaptive actions across key function areas across the network.

As an example, we have a focus on improving resilience to flooding, we have produced an Engineering Justification Paper (EJP) for Environmental - Flood Resilience[18] as part of the draft RIIO-ED2 submission in July 2021 to "Maintain a Safe & Resilience Network".

This paper outlines the strategy for flood mitigation within the RIIO-ED2 period that SPD and SPM will undertake to reduce the risk of the network from coastal, fluvial, and pluvial flooding, in response to following key risks identified:

- AR10 – Substations affected by fluvial (river) flooding due to increased winter rainfall, with loss of inability to function leading to reduced security of supply.
- AR11 – Substations affected by pluvial (surface water) flooding due to severe rainfall, with loss of ability to function leading to reduced security of supply.
- AR12 – There is a risk that due to extreme sea flooding a substation may be lost or unable to function leading to reduced system security of supply. A number of sites may be at risk from sea level rise/coastal erosion.

This strategy will ensure compliance with the requirement within ETR 138 "Resilience to Flooding of Grid and Primary Substations" to protect substations against a 1:1000 and 1:100-year flood events (refer to Table 1), based on voltage and customer numbers, and provide network security from the effects of flooding, with investment being taken between 2023-2028.

[17] Ofgem (2021) RIIO-ED2 Business Plan Guidance. [13 April 2021]. Available at: https://www.ofgem.gov.uk/system/files/docs/2021/02/ed2_business_plan_guidance_-_published_1_february_2021.pdf
[18] SPEN (2021) Environmental – Flood Resilience ED2 Engineering Justification Paper ED2-NLR(A)-SPEN-003-RES-EJP.

Table 1 – ETR138 Flood Resilience Levels

Substation Type	Flood Resilience Level
Grid Substations	Protection against the level of flooding that may occur within a 1:1,000-year flood contour for fluvial, pluvial, and coastal flooding.
Primary Substations (33kV) (>10,000 unrecoverable connections)	Protection against the level of flooding that may occur within a 1:1,000-year flood contour for fluvial, pluvial, and coastal flooding.
Primary Substations (33kV) (<10,000 unrecoverable connections)	Protection against the level of flooding that may occur within a 1:100 year fluvial and pluvial flood contour (1:200 in Scotland) and within the 1:200 contour for coastal flooding throughout GB
Secondary Substations	Not normally protected but may require protection in certain circumstances

We also have our own stakeholder led Sustainable Business Strategy[19], published in March 2020, which outlines the following Vision:

Our vision is to be a sustainable networks business. We will embed the principles of sustainability in our decision-making by working with our stakeholders to:

Efficiently manage and develop our network in support of the low carbon transition; and,

Achieve neutral or positive environmental and social impacts.

The Strategy outlines a number of key Sustainability Drivers that we have identified in order to help achieve this vision. Climate Resilience is one of these drivers, which has the following objective:

Climate Change Resilience
2.1 Increase resilience of network to extreme weather events.

3.2 Innovation

Providing a reliable supply of electricity to homes and businesses is what we do. Innovation is a key aspect of ensuring we overcome the challenges presented by the potential impacts of a changing climate and the move to a low carbon economy. Innovation enhances multiple aspects of our business, and helps improve our technological, commercial and operational & process driven services.

Our Innovation Strategy lays out three steps; Think Big, Start Small and Scale Fast[20]. An example of an innovation project currently under development within the business is for Landslide Mitigation. Detailed in the below case study, this project has recently gained approval for expansion to cover SPD and SPM assets going forward. See Annex 2.1 Innovation Strategy for more details on how we will innovate in RIIO-ED2.

[19] SPEN (2020) SP Energy Networks Sustainable Business Strategy. [Online] [12th May 2021] Available at: https://www.spenergynetworks.co.uk/userfiles/file/202003_SPEN_Sustainable_Business_Strategy_2020.pdf
[20] SPEN (n.d) Investment & Innovation. [Online] [14 May 2021] Available at: https://www.spenergynetworks.co.uk/pages/why_we_innovate.aspx

Landslide Protection Asset (NIA SPEN 0059).

A landslide in the vicinity of overhead network assets can result in costly repairs and put the network integrity at risks. This Landslide protection project aims to use a steel mesh netting protection system (commonly used in road, rail and water sectors) to protect pylons. By doing so, it will enhance our knowledge of areas of our network vulnerable to landslides and prove that mitigation measures can be deployed safely through a trial on a selected asset.

The objective of the project is to:

- Develop a RAG database of assets which are highly vulnerable to impact from landslides
- To prove that installing mitigation measures can be done safely to a selected asset

The realise these objectives the project will be undertaken in the following two stages:

1. GIS tiling work to develop a RAG database identifying assets which are high risk
2. Trial deployment of a steel netting or mesh system at a selected asset identified as high risk.

The project is expected to realise the following benefits:

- Improved knowledge of network vulnerabilities
- Improved network resilience
- Preventing risk of future events:
    - Lower repair costs
    - Improved safety to staff & public

[21]

3.3 Other Sector Based Work

The basis of a common industry background, asset standards and regulatory processes means that UK electricity network operators have very similar requirements when approaching the assessment of climate change impacts on their networks.

We have worked with the Energy Network Association (ENA) to produce a core assessment for all of the UK transmission and distribution companies, the most recent addition of which is the "ENA's Electricity Networks Climate Change Task Group, 3rd Round Climate Change Adaptation Report, March 2021 and Addendum September 2021"[22].

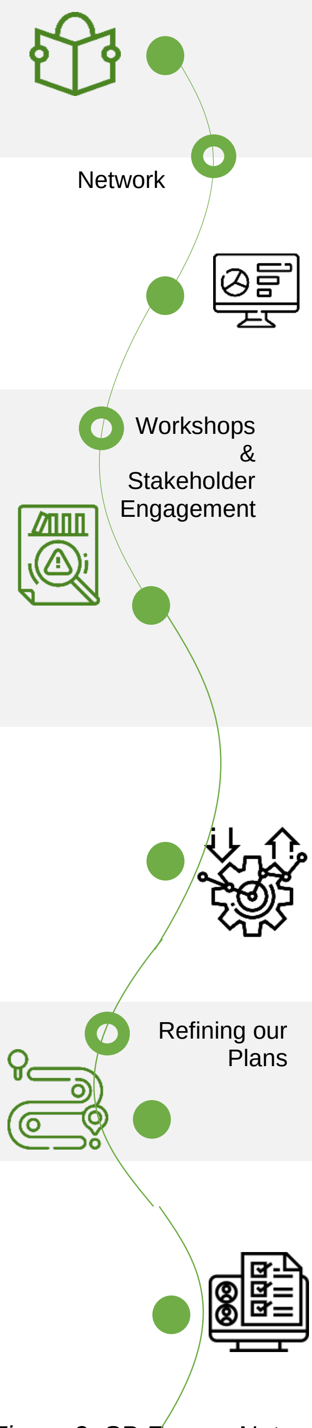
This report includes a summary of headline climate change impacts that electricity networks are expected to face, derived from the latest independent Met Office UKCP18 projections, alongside identifying a total of 37 network and business risk in relation to the climate variables and hazards of Temperature, Precipitation, Wildfires, Sea Level Rise, Lightning and Wind.

[21] Information provided by the SP Energy Networks Innovation Team.

[22] Energy Network Association. (2021). 3rd Round Climate Change Adaptation Report including Addendum Sept 2021.

4. Method / Approach Taken

Our Climate Resilience Strategy (CRS) has been developed using the climate adaptation pathways approach[23][24]. The assessment is split into two stages; the Climate Risk Assessment, and the Adaptation Pathways Assessment, each of which has a set of series of steps and associated actions. The method taken is illustrated in Figure 2.



Climate Risk Assessment

Baseline
The first step verified the current approach to network design, management, and operations. This includes determining the scale and characteristics of our network and its exposure to climate risks, as well as identifying all current risk management approaches and practices within existing policy.

Establish the Climate Scenarios for analysis
The second step established the most likely and worst-case possibilities for what the future climate may be. This included looking at the United Kingdom Climate Projections 2018 (UKCP18) data to gather climate change projections for the UK, in line with the previous risk assessment and the RIIO Business Plan Guidance. This step also included looking at projections for weather extremes and prolonged periods of adverse weather.

Assessment of risks
The third step identified the key risks and adaptation tipping points for critical network and business functions. This includes taking findings from internal & external stakeholder engagement to ensure a full suite of risks have been identified.

This has involved building on previous risk assessments and updating them with the UKCP18 climate projections and the inclusion of business function risks. The focus was on identifying 'headline', 'cascading' and 'in-combination' risks.

A risk matrix was developed through internal workshops which identifies accepted risk levels, asset and function performance threshold levels, and minimum performance requirements. The risk assessment is built on the understanding and identification of the climate tipping point when network functions would be compromised.

Adaptation Pathways Assessment

Identification of Adaptation Actions
The fourth step involves developing solutions for each headline risk, against the climate tipping points. Adaptation actions were identified using our previous risk assessment, Paris Agreement UK Climate Risk Assessment, and actions adopted by comparable organisations. These actions were refined and classified against a hierarchy. Each of the actions was differentiated between actions that reduce exposure (location, attributes, and value of assets that could be affected by a climate risk) and actions that reduce sensitivity (the likelihood that assets will be affected when exposed to a climate risk).

Development of Adaptation Pathways
The fifth step identified routes to achieving our organisation's 'success criteria' against climate adaptation (adaptation pathways). This included developing a pathway diagram/map for each risk theme.

Monitoring and Evaluation
As a final step, a high-level Monitoring and Evaluation approach to the adaptation solutions outlined within this CRS is provided, based on best practice approaches. The approach aligns with the following key elements: track and analyse key climate variables and the associated impacts; review decision criteria and thresholds; lessons learned on adaptation solutions; the tools and reporting that will be in place for this price control period; and, integration with our existing Risk Assessment process.

Figure 2: SP Energy Networks Climate Resilience Strategy Approach

[23] IEEE Power & Energy Society (2020). Technical Report – Resilience Framework, Methods, and Metrics for Electricity Sector. PES-TR83. The Institute of Electrical and Electronic Engineers. Inc.
[24] Haasnoot, M, et al., (2014). Dynamic adaptive policy pathways; A method for crafting robust decisions for a deeply uncertain world. Global Environmental Change 23. 485-298. Elsevier.

4.1 Industry Engagement

Throughout the development of this CRS, a comprehensive and bespoke programme of engagement was undertaken with various SP Energy Networks colleagues, alongside understanding, and leveraging from the information gathered by engagement activities completed by both the Energy Network Association (ENA) and internal colleagues for other similar and interconnected strategies.

This included:

i. Completing a total of six, 1-hour peer to peer, semi-structured interviews, alongside hosting two virtual workshops with internal colleagues. Participants included but were not limited to; sustainability specialists; asset managers; control room managers and engineers.

   The first workshop was one and a half hours in length and was held in March 2021 to discuss and confirm the climate risks and tipping points identified. The second workshop was held in April 2021, to finalise the tipping point evaluation and begin discussing potential adaptation solutions that could build on existing approaches to reduce future risks.

ii. Understanding and incorporating ENA stakeholder engagement output from the Adaptation to Climate Change Task Group, 3rd Round Climate Change Adaptation Report.

iii. Understanding and incorporating the outputs from recently completed engagement activities with around 14,000 customers and external stakeholders between November 2020 and November 2021, including topics on our:

   - Strategy for Biodiversity and Natural Capital Enhancement,
   - Strategy for Business Carbon Reduction, and;
   - Strategy for Sustainable Resource use.

5. Summary of Climate Change Projections

This section looks at the most likely and worst-case possibilities for what the future climate may be. United Kingdom Climate Projections 2018 (UKCP18) data has been used to gather climate change projections for the UK, in addition to the recent Energy Network Association (ENA) Commissioned Met Office review of UKCP18 data in relation to energy infrastructure assets.

This work includes the analysis of projections for weather extremes and prolonged periods of adverse weather, forming the basis for the climate risk assessment. The baseline climate has been used to determine the impact climate risks currently have on SP Energy Networks, and how the climate change projections present the likelihood of climate risks in the future. UKCP18 data is used to inform the findings of the "Committee on Climate Change (CCC) - Progress in preparing for climate" report[25] and the National Infrastructure Commission report on resilient infrastructure systems[26].

The climate change projections have been established for the following future time periods: 2030s, 2050s and 2100s. For each time-period, two scenarios, based on two Representative Concentration Pathways (RCP), RCP6.0[27] and RCP8.5, were used to provide projections of how the climate may change in the future. The best estimate of global average temperature rise by 2100 for RCP8.5 is 4.3ºC (3.2-5.4ºC) and for RCP6.0 is 2.8ºC (2.0-3.7ºC).[28] Comparing more than one RCP is the approach being taken by the UK CCRA. RCP8.5 is the most likely scenario at present, and the highest RCP.

Climate variables have been extracted for the whole of the UK, in alignment with our 2015 Risk Assessment (with the exception of sea level data which were selected from specific tide gauges close to SP Energy Networks regions). The temperature and precipitation variables are taken from the UKCP18 25km land probabilistic projections, whilst the wind speed projections are taken from global 60km-resolution models. In this report, the baseline period of 1981 – 2010 is used for assessing the projected future climate change anomalies. However, due to data availability, it should be noted that the sea level rise projections used in this analysis are relative to a 1981 – 2000 baseline. This section gives consideration to observed climate change, observed extreme weather events and the current situation with respect to drought, severe weather and flooding and management of vegetation growth.

5.1 Observed Climate Change

According to the latest State of the UK climate report (2019),[29] the UK's has experienced headline changes presented below. It is assumed that these changes will continue in a similar trajectory into the future:

- The most recent decade (2009–2018) has been on average 0.3ºC warmer than the 1981–2010 average and 0.9ºC warmer than 1961–1990; moreover, all the top ten warmest years for the UK, in the series from 1884, have occurred since 2002;
- The UK seasonal mean temperature for summer increased by 6% from the 1961 – 1990 average of 13.8ºC to 14.6ºC in the 2010 - 2019 period (Figure 3);
- The most recent decade (2009–2018) has been on average 1% wetter than 1981–2010 and 5% wetter than 1961–1990 for the UK overall (values provided in Table 2).
- Mean sea-level around the UK has risen by approximately 1.4 mm/year from the start of the 20th century, which equates to approximately a 17 cm increase when corrected for land movement, and;
- There are as yet no compelling trends in storminess, as determined by maximum gust speeds, from the UK wind network over the last four decades.

[25] Committee on Climate Change. (2019). Progress in preparing for climate change – 2019 Progress Report to Parliament. [Viewed 09.04.2021]. Available from: https://www.theccc.org.uk/wp-content/uploads/2019/07/CCC-2019-Progress-in-preparing-for-climate-change.pdf
[26] National Infrastructure Commission. (2020). Resilient infrastructure systems. [Accessed 09.04.2021]. Available at: Anticipate-React-Recover-28-May-2020.pdf (nic.org.uk)
[27] Note that for the wind speed and sea level rise projections, RCP4.5 was used as a substitute for RCP6.0 due to UKCP18 data availability limitations.
[28] RCPs specify concentrations of GHG against total radiative forcing targets by 2100. Met Office, 2021, UKCP18 Guidance: Representative Concentration Pathways [online]. Met Office. [viewed 22 March 2021]. Available from: https://www.metoffice.gov.uk/binaries/content/assets/metofficegovuk/pdf/research/ukcp/ukcp18-guidance---representative-concentration-pathways.pdf
[29] *Met Office, 2021, State of the UK climate [online]. Met Office. [viewed 22 March 2019]. Available from: https://www.metoffice.gov.uk/research/climate/maps-and-data/about/state-of-climate*

Table 2: Average annual rainfall values (mm) across the UK and England, Scotland, and Wales.

Area	1961 – 1990 average	1981 – 2010 average	2010 – 2019 average
UK	1100	1150	1158
England	827	853	864
Scotland	1470	1562	1570
Wales	1402	1459	1430

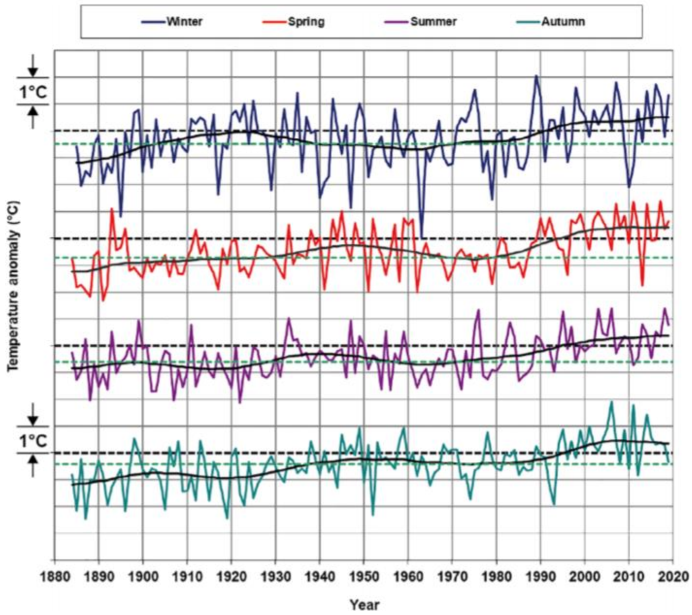


Figure 3: Seasonal T_{mean} (°C) for the UK, 1884–2019, expressed as anomalies relative to the 1981–2010 average. The hatched black line is the 1981– 2010 long-term average. The lower hatched green line is the 1961–1990 long-term average. Light grey gridlines represent anomalies of ±1°C.

5.1.1 Observed Weather Events

As with national trends, areas to which we operate have been experiencing changes to annual temperatures and precipitation since the 1980s, as well as severe extreme weather events that has resulted in disruptions to water supply, energy supply, travel delays and human health impacts.

The impacts of Storm Christoph are outlined in the example below, with other significant weather events that have occurred and impacted SP Energy Networks' operations since 2000 outlined within Table 3. Understanding how we have been impacted in the past by climate risks forms the impact rating given to climate hazards in the climate change risk assessment.

Storm Christoph: 19 – 22 January 2021

<100mm of rain

Flooding in North East England and North Wales, impacting and inundating substations – as seen with the secondary substation pictures to the right. .

Power restored to 13,045 customers, 99% of which occurred within 12 hours.

Source: @SPEnergyNetworks

Table 3: Previous severe weather events which have caused impacts to SP Energy Networks[30]

Type	Date	Description	Impacts
Storms (N.B. Only recent notable events are listed)	21 October - 2 November 2020	Storm Aiden: • 61 mph winds in Scotland, 60mph winds in Wales	13,002 customers across SPD and SPM impacted, all of which were restored within 12 hours.
	25 - 26 August 2020	Storm Francis: • 76mph wind speeds	14, 605 customers impacted, 97% of which were restored within 12 hours.
	15 - 16 February 2020	Storm Dennis • 67 mph wind speed in Scotland and 91mph in Wales.	16,519 SPD and 9,227 SPM customers impacted over, 100% of which were restored within 12 hours.
	13 – 14 January 2020	Storm Brendan • 68 mph wind speed in Scotland, 74 mph wind speed in Wales	7,942 customers across both SPD and SPM, 100% of which were restored within 12 hours.
Drought	2010 - 2012	Much of central, eastern, and southern England and Wales experienced a prolonged period of below average rainfall from 2010 to early 2012	Low reservoir levels: hosepipe bans across north-west England affecting six million consumers; widespread agricultural and environmental issues
Heatwave	July 2006	Sustained warmth and prolonged sunshine resulted in the month of July 2006 being the warmest single month on record over much of the UK[31]. For example, in the first four days of the month maximum temperatures exceeded 28 °C widely across England and Wales, weather that was to recur on many days later in the month.	Disruptions to water and energy supply; Travel delays and disruptions (for example, heat damage to tarmac road surfaces and speed restrictions on railways due to the risk of buckling); Health impacts from heat stress; Strain on health and fire services; Numerous grass/heath/forest fires; Increased tourism
	August 2003	A 10-day UK-wide heatwave, with a record maximum of 38ºC.	Health impacts and fatalities from heat; Low river flows and lake levels; High incidence of forest fires; Reduced water supplies; Fatality of livestock and crop failure; Travel delays and disruptions
Flooding	February 2020	UK-wide flooding brought about by intense rainfall of up to 180mm in a single 18-hour period from Storm Ciara and Storm Dennis, alongside 85mph winds.	Travel delays and disruption Flooding of properties and agricultural land Over the 69-hour duration of the storm, 19,688 customers were affected (92% restored within 3 hours, 100% within 25 hours) across North Wales.

5.2 Climate Projections

This section summarises the projected climate changes for temperature, precipitation, sea level rise and wind using UKCP18 data for the 2030s, 2050s and 2100s time periods.

[30] SP Energy Networks. (2021). Exceptional Events Register

[31] Met Office. (2012). Record breaking heat and sunshine - July 2006. [viewed 12th April 2021]. Available from: https://www.metoffice.gov.uk/binaries/content/assets/metofficegovuk/pdf/weather/learn-about/uk-past-events/interesting/2006/record-breaking-heat-and-sunshine---july-2006---met-office.pdf

5.2.1 Temperature

Human activities are estimated to have caused approximately 1.0°C of global warming above pre-industrial levels, with a likely range of 0.8°C to 1.2°C. There is a high confidence that global warming is likely to reach 1.5°C between 2030 and 2052 if it continues to increase at the current rate.[32]

Headline trends

- There is an expected increase of temperature across all seasons with disproportionate increases in extreme high summer temperatures, leading to increased cooling demand and higher likelihood of SP Energy Networks' assets overheating.

Projected climatic parameters for UK temperature change are presented in Table 4. This presents two scenarios based on RCP6.0 and RCP8.5, for the 30-year averages around the 2030s, 2050s, and 2080s time slices. By the 2080s time period, for the RCP8.5 scenario, 50% of climate model results showed warming of up to 4.32ºC to the mean summer air temperature, 3.03ºC to the mean winter temperature, 3.59ºC to the maximum summer temperature and 3.01ºC to the minimum winter temperature.

Table 4: Projected UK temperature change for three climatic variables under RCP6.0 and RCP8.5 for three time slices, relative to a 1981 – 2010 baseline (10-90% range of models shown in parentheses).

Temperature variable	Climate Hazard	2020 - 2049 (2030s)		2040 - 2069 (2050s)		2070 - 2099 (2080s)	
		RCP 6.0	RCP 8.5	RCP 6.0	RCP 8.5	RCP 6.0	RCP 8.5
Change in mean annual air temperature anomaly at 1.5m (ºC)	Temperature Increase	+0.77 (0.29 to 1.28)	+1.02 (0.47 to 1.63)	+1.17 (0.49 to 1.90)	+1.77 (0.90 to 2.73)	+2.41 (1.27 to 3.63)	+3.45 (1.99 to 5.07)
Change in mean summer air temperature anomaly at 1.5m (ºC)	Heat waves Wildfires	+0.90 (0.18 to 1.64)	+1.20 (0.42 to 2.03)	+1.41 (0.43 to 2.49)	+2.13 (0.91 to 3.42)	+3.05 (1.43 to 4.83)	+4.32 (2.16 to 5.53)
Change in mean winter air temperature anomaly at 1.5m (ºC)	Ice and snow	+0.70 (0.03 to 1.41)	+0.94 (0.17 to 1.76)	+1.07 (0.19 to 2.01)	+1.63 (0.48 to 2.88)	+2.06 (0.67 to 3.53)	+3.03 (1.17 to 5.01)
Change in maximum summer air temperature anomaly at 1.5m (ºC)	Heat waves Wildfires	+0.83 (0.30 to 1.40)	+1.09 (0.48 to 1.75)	+1.23 (0.48 to 2.04)	+1.86 (0.89 to 2.90)	+2.50 (1.27 to 3.85)	+3.59 (1.98 to 5.35)
Change in minimum winter air temperature anomaly at 1.5m (ºC)	Ice and snow	+0.65 (0.19 to 1.19)	+0.90 (0.11 to 1.83)	+1.06 (0.37 to 1.84)	+1.63 (0.41 to 3.10)	+2.29 (1.05 to 3.63)	+3.01 (1.04 to 5.41)

UKCP18 data showed that the UK will experience warmer wetter winters and hotter drier summers on average[33]. Colder than average winters and summers will still occur but will become less likely the further we

[32] *IPCC, 2018. Special Report: Global Warming of 1.5ºC Summary for Policymakers [online]. IPCC. [viewed 19 March 2021]. Available from: https://www.ipcc.ch/sr15/chapter/spm/*
[33] Met Office, UK extreme events – Cold [viewed 12 April 2021]. Available from: https://www.metoffice.gov.uk/research/climate/understanding-climate/uk-extreme-events_cold

go into the 21st century. Additionally, the Intergovernmental Panel on Climate Change (IPCC) noted that cold episodes were projected to decrease significantly in a future warmer climate. However, it has also been suggested that the decrease in sea ice caused by the mean warming could induce, although not systematically, more frequent cold winter extremes over northern continents. Therefore, it is important to still be prepared for extreme cold temperatures and snow in the future as they are likely to occur, even if less frequently.[34]

5.2.2 Precipitation

Projected climatic parameters for UK precipitation change are presented in Table 5. This presents two scenarios based on RCP6.0 and RCP8.5.

Headline trends

- Winter precipitation projected to increase, increasing the risk of flooding at substations
- Extreme hourly rainfall projected to increase in winter
- Decrease in summer precipitation increasing the likelihood of drought, increasing risks of earth and ground movement on SP Energy Networks' assets

For the 2080s time slice (for example, the 30-year average over 2070-2099) for the RCP8.5 scenario, 50% of climate model results showed an annual increase of 3.6% in rainfall, a 15.7% increase in winter rainfall and a 26.8% decrease in summer rainfall.

Under RCP6.0, 50% of climate model results showed an annual increase of 1.6% in rainfall, a 10.5% increase in winter rainfall and a 19.7% decrease in summer rainfall.

Table 5: Projected UK precipitation change under RCP6.0 and RCP8.5 for the Project timeframes, relative to a 1981 – 2010 baseline (10-90% range of models shown in parentheses).

Precipitation variable	Climate Hazard	2020 - 2049 (2030s)		2040 - 2069 (2050s)		2070 - 2099 (2080s)	
		RCP 6.0	RCP 8.5	RCP 6.0	RCP 8.5	RCP 6.0	RCP 8.5
Change in mean annual precipitation rate anomaly (%)	Flooding	1.45 (-1.42 to +4.51)	2.04 (-1.21 to +5.30)	1.07 (-2.79 to +4.89)	2.17 (-2.37 to +6.97)	1.59 (-3.70 to +6.91)	3.60 (-3.15 to +10.47)
Change in mean winter precipitation rate anomaly (%)	Flooding	2.06 (-4.55 to +9.93)	3.99 (-3.99 to +12.12)	4.50 (-4.25 to +13.91)	7.61 (-2.94 to +19.84)	10.49 (-2.98 to +24.73)	15.65 (-1.56 to +35.90)
Change in mean summer precipitation rate anomaly (%)	Drought	-5.51 (-16.29 to 4.95)	-7.08 (-18.59 to 3.85)	-11.88 (-24.99 to 1.05)	-15.90 (-31.23 to -1.15)	-19.71 (-36.41 to -3.85)	-26.76 (-48.95 to -6.01)

5.2.3 Sea Level Rise

The projected increases in mean sea level anomaly by 2100 relative to 1981 – 2000 are shown in Table 6 and Figure 4 . Under RCP8.5 (red in Figure 4), sea level rise projections from UKCP18 models by the end of the century range from 0.3-0.9m in Scotland and 0.4-1m in North Wales and Merseyside. For the lower emissions

Headline trends

- Sea level will continue to rise up-to and beyond the end of the 21st century, with projections up to 1 m by 2100 under a high emissions scenario
- Extreme sea levels will increase due to the rise in mean sea level, increasing the risk of coastal flooding and erosion to our coastal assets

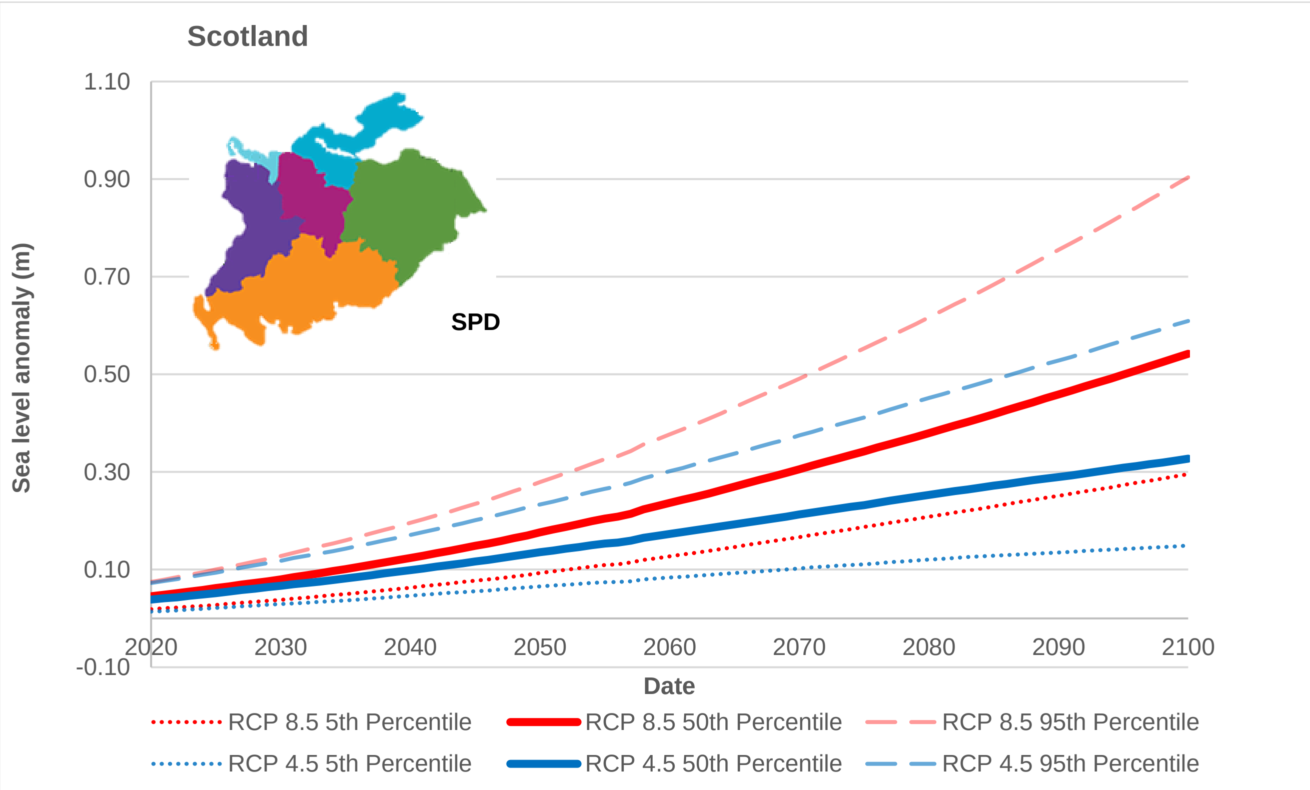
[34] *IPCC (2012) Changes in Climate Extremes and their Impacts on the Natural Physical Environment. Available from: https://www.ipcc.ch/site/assets/uploads/2018/03/SREX-Chap3_FINAL-1.pdf*

scenario RCP4.5[35] (blue in Figure 4), projections range from 0.2-0.6m in Scotland and 0.3-0.7m in North Wales and Merseyside.

Extreme sea levels will increase due to the rise in mean sea level, affecting the likelihood of coastal flooding and coastal erosion. There is potential for changes in the severity of future storm surge events, but it is unknown from the model results whether the frequency and severity of storm surge events will increase.[36]

Table 6: Time-mean sea level anomaly (m) with 5-95% range of models shown in parentheses.

Region	2030		2050		2100	
	RCP 4.5	RCP 8.5	RCP 4.5	RCP 8.5	RCP 4.5	RCP 8.5
SPD						
West Scotland (Portpatrick gauge)	0.08 (0.04 - 0.13)	0.09 (0.05 - 0.14)	0.15 (0.08 - 0.25)	0.19 (0.11 - 0.29)	0.35 (0.17 - 0.64)	0.57 (0.32 - 0.94)
East Scotland (Leith gauge)	0.07 (0.03 - 0.12)	0.08 (0.04 - 0.13)	0.14 (0.07 - 0.23)	0.18 (0.09 - 0.28)	0.33 (0.15 - 0.61)	0.54 (0.30 - 0.90)
SPM						
North Wales & Merseyside (Hilbre Island gauge)[37]	0.11 (0.07 - 0.16)	0.12 (0.08 - 0.17)	0.20 (0.13 - 0.30)	0.24 (0.16 - 0.35)	0.45 (0.27 - 0.74)	0.68 (0.43 - 1.04)



[35] RCP4.5 is a scenario that requires significant mitigation and global reductions in greenhouse gas concentrations. It is used here for sea level rise rather than RCP6.0 due to the availability of data on the UKCP18 Interface.
[36] *Met Office, 2021. UKCP18 Factsheet: Sea level rise and storm surge [online]. Met Office. [viewed 25 March 2021]. Available from: https://www.metoffice.gov.uk/binaries/content/assets/metofficegovuk/pdf/research/ukcp/ukcp18-fact-sheet-sea-level-rise-and-storm-surge.pdf*
[37] Due to very similar levels at North Wales and Merseyside gauges, one location has been used to represent the North Wales & Merseyside area.

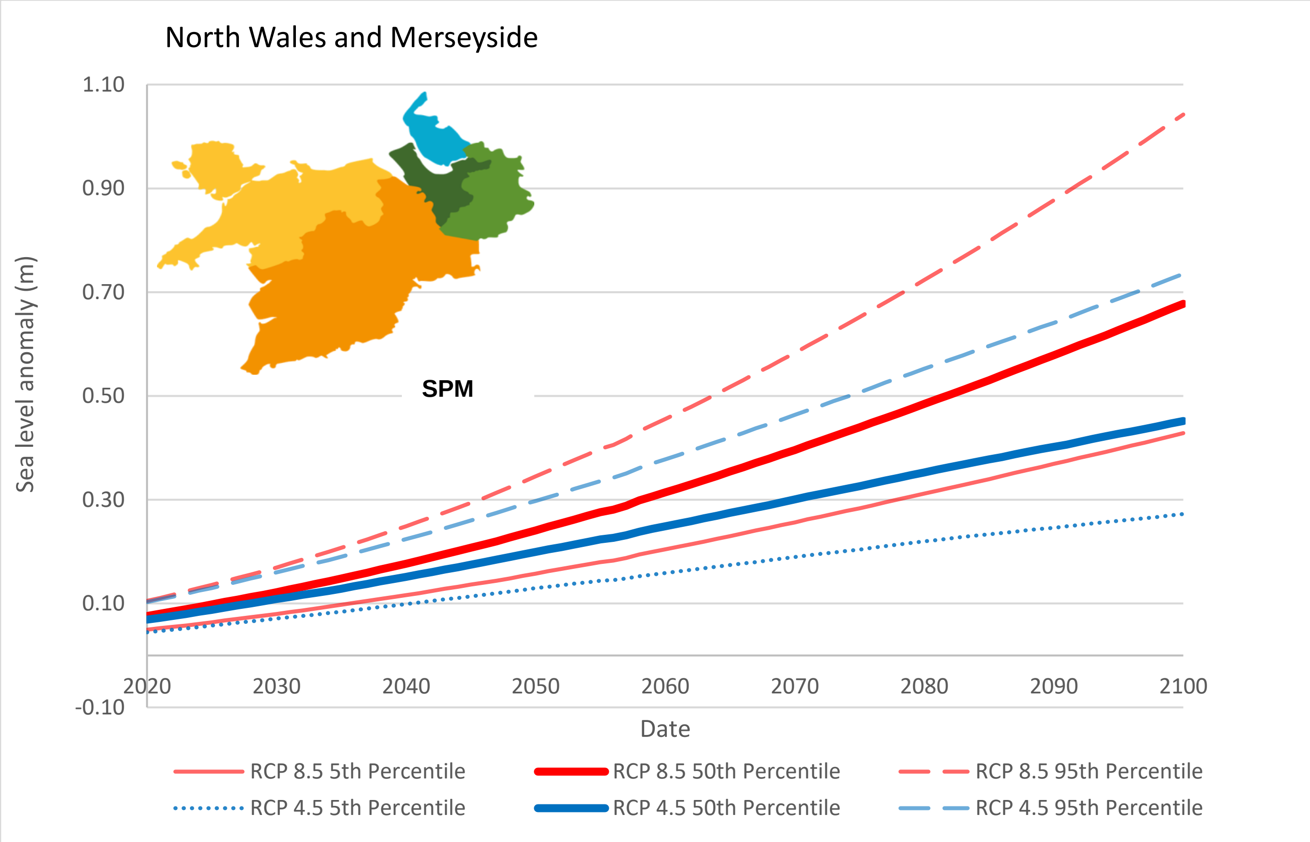


Figure 4: 21st century mean sea level rise anomaly (m) for both regions (SPM & SPD) within SP Energy Networks under RCP4.6 and RCP8.5 relative to 1981-2000.

5.2.4 Wind / Storminess

UKCP18 projections show an increase in near surface wind speeds over the UK for the second half of the 21st century for the winter season, with some climate models in the Met Office PPE-15 (Figure 5) ensemble displaying large peaks in some years. However, the increase in wind speeds is modest compared to interannual variability.

Headline trends

- Interannual and decadal variability of windstorms
- An increase in near surface wind speeds over the UK for the second half of the 21st century for the winter months, increasing the risk of damage to SP Energy Networks' overhead lines
- There is currently no strong signal within the climate projections for a change to future storm intensity
- Poleward shift of storm tracks, increasing storm activity in higher latitudes (GB)

In terms of storminess and lightning, there is currently limited data about the response of these hazards to climate change, so it is not possible to provide projections of change in frequency and severity. Since there is currently no strong signal within the climate projections for a change to future storm intensity, these risks have been assessed as per the current climate, for example the out-of-season storm that impacted the SP Energy Networks in August 2020. It is recognised that prevailing wind direction is a potential hazard for SP Energy Networks, but, like storminess, there is a lack of climate model trends for this variable. However, on a global scale, the IPCC suggests that in a warmer climate there could be a poleward shift of storm tracks, increasing storm activity in higher latitudes, typically associated with increased ocean temperatures[38].

[38] *IPCC. (2018). Global Climate Projections, Chapter 10. [Online]. [Viewed 31/03/2021] https://www.ipcc.ch/site/assets/uploads/2018/02/ar4-wg1-chapter10-1.pdf*

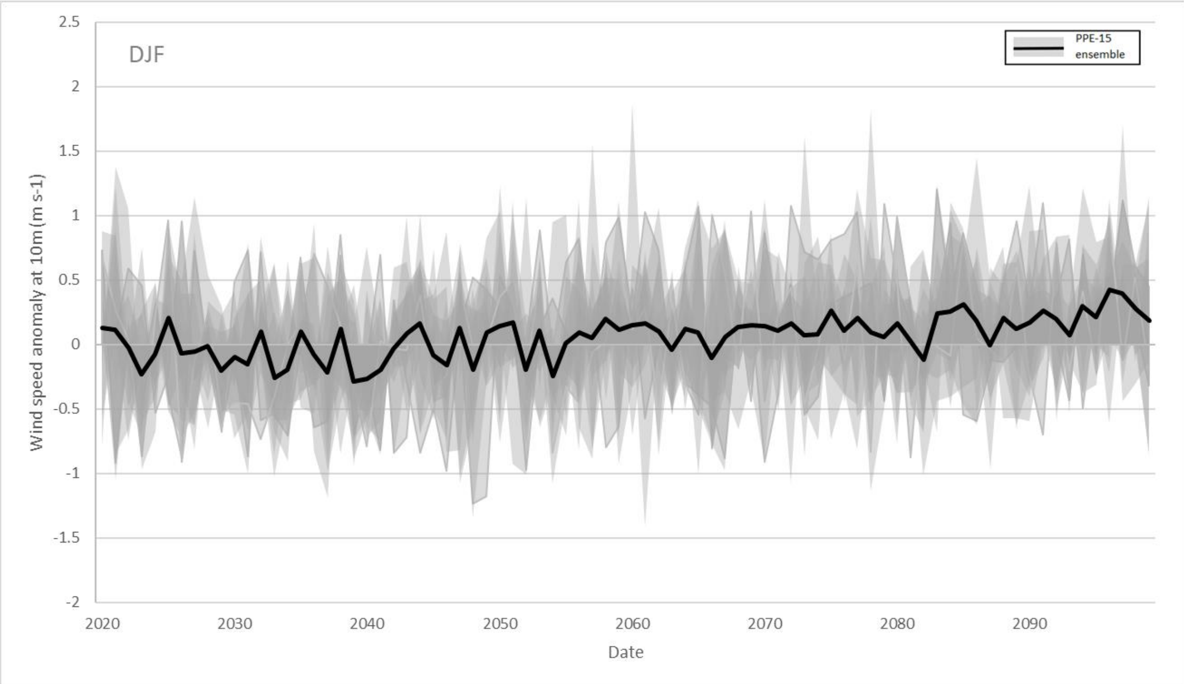


Figure 5: Winter wind speed anomaly at 10m (m s-1) for the UK under RCP8.5 in comparison to the 1981-2010 baseline, from 15 simulations of the Met Office Hadley Centre model (PPE-15).

6. Risk Assessment Summary

This section identifies the key climate risks and determines the adaptation tipping points of our network and business functions. The risk matrix shown below developed in line with the Energy Network Association (ENA) 3rd Round Climate Change Adaptation report[39] identifies accepted risk levels, asset and function performance threshold levels, and minimum performance requirements.

Table 7: Scoring matrix used to determine the significance of risks for SP Energy Networks

Relative Impact						
	Extreme	5	10	15	20	25
	Significant	4	8	12	16	20
	Moderate	3	6	9	12	15
	Minor	2	4	6	8	10
	Limited	1	2	3	4	5
		Very Unlikely	Unlikely	Possible	Expected	Almost Certain
		Relative Likelihood				

The below Table 8 outlines the definitions associated with the relative impact and likelihood classifications of risks. The impact relates to the scale of the area affected by the hazard and the likelihood is based on how frequent the event causing the risk occurs and is likely to occur in the future based on climate projections.

Table 8: Impact and Likelihood classification definitions

Relative impact	
Extreme	Regional area affected with people off supply for a month or more/OR asset de-rating exceeds ability to reinforce network leading to rota disconnections on peak demand.
Significant	County or city area affected with people off supply for a week or more OR asset de-rating requires a significant re-prioritisation of network reinforcement and deferment of new connection activities
Moderate	Large town or conurbation off supply for up to a week OR significant increase in cost of network strengthening.
Minor	Small town off supply for a 24-hour period OR significant increase in cost of network maintenance requirements.
Limited	Limited impact - can be managed within “business as usual” processes
Relative Likelihood	
Very Unlikely	No known event or if known extremely rare, extreme industry-wide scenarios
Unlikely	Events are rare, required mitigations in place, controls are effective
Possible	Past events satisfactorily resolved, mitigations are in place or are on track to be in place, control improvements are under active management
Expected	Past events have not been fully resolved, effective mitigations not yet identified, control weakness are known and are being managed.
Almost Certain	The risk in the process of materialising and may already be under active management as an event

[39] ENA’s Electricity Networks Climate Change Task Group, 3rd Round Climate Change Adaptation Report, March 2021

The risk assessment is built on the understanding and identification of the tipping point of functions in the power system. This is the point when the function of different parts of the power system is no longer viable in relation to the projected climate parameters, such as temperature thresholds and flood capacity, and so adaptation actions are therefore required. The Adaptation Sub-Committee of the Committee on Climate Change Evidence Report[40] identifies and assesses 56 individual climate change risks and opportunities for the UK.

The impact score has been highlighted in each risk table as it is assumed that the impact would remain constant while the likelihood changes in relation to climate projections. Climate hazards associated with each risk are also included in the table and relate to at least one of the climate variables presented in section 5; temperature, precipitation, sea level rise and wind/storminess. The risks presented in this report have been subject to review internally within SP Energy Networks through workshops[41]. The risks have been separated into function categories as follows:

Network Risks

- Overhead lines, poles & towers
- Underground cables
- Transformers
- Substation Sites
- Vegetation management
- Network Loading

Business Risks

- Emergency Response and planning
- Routine business and maintenance
- Customer Service

Table 9 presents the meaning behind the risk ID given to all the risks identified, some of the IDs are legacy ones given in the SP Energy Networks 2015 CCRA[42], the rest have been created in this assessment.

Table 9: Key for risk ID and source of ID

ID	Name, Source	ID	Name, Source
AR	Risk originally identified by the ENA first report, SP Energy Networks CCRA 2015	GN	Generation/Network Loading, RIIO-ED2 Climate Resilience Working Group 2021
NG	Risk originally identified by National Grid Electricity Transmission plc report, SP Energy Networks CCRA 2015	ER	Emergency Response, RIIO-ED2 Climate Resilience Working Group 2021
SP	Risks specific to SP Energy Networks identified, SP Energy Networks CCRA 2015	RB	Routine Business, RIIO-ED2 Climate Resilience Working Group 2021
VM	Vegetation Management, AECOM 2021	CS	Customer Service, RIIO-ED2 Climate Resilience Working Group 2021

The remainder of this section is presented in two parts:

- Section 6.1 – Key Network Risks relating to assets and infrastructure, as set out above.
- Section 6.2 – Key Business Risks relating to people, processes and systems required to operate effectively and safely, and meeting our customers' expectations, as set out above.

[40] Committee on Climate Change. (2017). UK Climate Change Risk Assessment Evidence Report. [Online]. [Accessed on 17/03/2021]. Available from: theccc.org.uk/tackling-climate-change/preparing-for-climate-change/uk-climate-change-risk-assessment-2017/

[41] Risks with the source 'CRS Workshop 1' were derived from the workshop held on the 24th March 2021 to discuss and confirm the climate risks and tipping points identified for this Climate Resilience Strategy

[42] SP Energy Networks. (2015). Climate Change Adaptation Report, Round 2 Update. [Accessed 3rd May 2021]. Available from: https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/479266/clim-adrep-sp-energy-networks-2015.pdf

6.1 Key Network Risks

The following outlines the key network risks posed to SP Energy Networks and the change in risk scores over time for the two Representative Concentration Pathways (RCP) scenarios.

6.1.1 Overhead Lines, Poles and Towers

Overhead lines (OHL), poles and towers are a key element of our infrastructure, consisting of 606,600 poles and towers and 40,000 km of OHL (as per 2020 figures). Risks associated include the direct risk temperature poses to the capability of the asset to operate, and the risk posed by many climate variables on the structural integrity of the asset, in some cases increasing the deterioration.

Table 10: Climate risks posed to overhead lines, cable bridges & towers

Source	Risk ID	Climate Hazard: Risk	Impact Score	Risk score					
				RCP6.0			RCP8.5		
				2030	2050	2100	2030	2050	2100
SP Energy Networks CCRA 2015	AR1	Increased Temperature: Overhead line conductors affected by temperature rise and increased cooling demand, reducing rating and ground clearance.	3	High 9	High 9	High 12	High 9	High 12	High 15
SP Energy Networks CCRA 2015	AR2	Summer Drought: Overhead line structures affected by summer drought and consequent ground movement.	2	Med 4	Med 6	Med 6	Med 4	Med 6	Med 8
SP Energy Networks CCRA 2015	AR3	Prolonged growing season: Overhead lines affected by interference from vegetation	3	High 15	High 15	High 15	High 15	High 15	High 15
SP Energy Networks CCRA 2015	NG3	Increased River Erosion from Increased Precipitation: If foundations are exposed, weakened or soil stability is reduced lines may fail.	3	High 9	High 9	High 12	High 9	High 12	High 15
UK CCRA 2017	AR15	Hurricanes & High Winds: Overhead line structures affected by wind speeds not accommodated for in design.	3	High 9	High 9	High 12	High 9	High 12	High 15
SP Energy Networks CCRA 2015	AR14	Increased Lightning activity: Overhead lines affected by increased lightning activity.	2	Med 6	Med 6	Med 8	Med 6	Med 8	Med 10
SP Energy Networks CCRA 2015	NG1	Sea Level Rise: A number of sites may be at risk from sea level rise. Sites may become non-operational due to sea inundation potentially leading to a loss of system resilience or a loss of supply.[43]	3				Med 3	High 6	High 9
SP Energy Networks CCRA 2015	NG2	Coastal Erosion: A number of sites may be at risk from coastal erosion. (Due to the slow nature of erosion any site that is identified at risk will be either protected or relocated prior to any system impacts, however mitigation costs may be significant.)	3				Med 3	High 6	High 9

[43] Sea level rise projections aren't available for RCP6.0

6.1.2 Underground cables

The risks posed to underground assets can cause moderate to extreme impacts due to the size of the network affected, and access issues related to resolving underground faults. We have around 65,000 km of underground cable assets. Although temperature change experienced underground is not as extreme as the ambient air temperature changes, fluctuations in temperature can cause significant impacts to underground assets.

In recent years, a peak in faults in underground cable joints was experienced associated with high ambient temperatures and a combination of day to night cooling inducting faults in otherwise reliable assets, details can be read in Annex 4A.11 Cable Modernisation Strategy. Ground movement can also pose a detrimental risk to underground assets.

Table 11: Climate risks posed to underground line, tunnels, and cable routes

Source	Risk ID	Source	Risk ID	Risk score					
				Source			Risk ID		
				2030	2050	2100	2030	2050	2100
SP Energy Networks CCRA 2015	AR4	Increased Temperature: Underground cable systems affected by the increase in ground temperature, reducing cable current (load) carrying capacity/ratings.	3	High 9	High 9	High 9	High 9	High 9	High 9
SP Energy Networks CCRA 2015	AR5	Summer Drought: Underground cable systems affected by summer drought and consequent ground movement, leading to mechanical damage/failure.	4	High 8	V High 12	V High 12	High 8	V High 12	V High 16
ED2 Workshop	AR16	Summer Drought: dry-out of the soil surrounding UG cables. This will lead to an increased thermal resistivity, reduced heat transfer from cable to surrounding soil/backfill, and a reduced current (load) carrying capacity	4	High 8	V High 12	V High 12	High 8	V High 12	V High 16
SP Energy Networks CCRA 2015	NG4	Sea Level Rise: A very small number of sites are potentially at increased risk if the level of current protection is not maintained or improved. (Due to the slow nature of sea level rise any cable identified at risk will either be protected or relocated prior to any system impacts; however, mitigation costs may be significant)[44].	3				Med 3	High 6	High 9

6.1.3 Transformers

Transformers are posed with direct risks of temperature change on the functioning of transformers, combined with the increased energy demand associated with temperature changes, such as increased cooling and heating requirements, which can result in overloading the transformers. Lightning is also an ever-constant risk; however, our network assets have lightning protection built in where currently required.

Table 12: Climate risks posed to transformers

Source	Risk ID	Climate Hazard: Risk	Impact Score	Risk score					
				RCP6.0			RCP8.5		
				2030	2050	2100	2030	2050	2100
SP Energy Networks CCRA 2015	AR7	Increase Temperature: Transformers affected by temperature rise, reducing rating. Increasing the operation of cooling fans and pumps fitted for transformers, increasing auxiliary losses	2	Med 6	Med 6	Med 8	Med 6	Med 8	Med 10
SP Energy Networks CCRA 2015	AR8	Increase Temperature: Transformers affected by urban heat islands and coincident air conditioning demand leading to overloading in summer months.	3	High 9	High 9	High 12	High 9	High 12	High 15
SP Energy Networks CCRA 2015	AR14	Lightning: Transformers affected by increased lightning activity.	2	Med 6	Med 6	Med 8	Med 6	Med 8	Med 10

[44] Sea level rise projections aren't available for RCP6.0

6.1.4 Substation Sites (Including transformers, switchgear & earthing)

The highest risk posed to our 30,000 substation sites is associated with flooding: fluvial, pluvial, and coastal. The voltage and size of the substation determines the flood return period that it is built to be resilient to.

Grid and primary substations feeding 10,000-30,000 customers are protected against 1:1000 flood levels, those primary substations that have less than 10,000 recoverable customers are protected against 1:100/1:200 level, and secondary substations are retrospectively protected against flooding where regularly at risk or with vulnerable customers.[45] The real-world return periods of those flood levels are likely to decrease with climate change in the future, increasing the frequency of more severe flooding.

Table 13: Climate risks posed to substation sites

Source	Risk ID	Climate Hazard: Risk	Impact Score	Risk score RCP6.0 2030	RCP6.0 2050	RCP6.0 2100	RCP8.5 2030	RCP8.5 2050	RCP8.5 2100
SP Energy Networks CCRA 2015	AR6	Summer Drought: Substation and network earthing systems adversely affected by summer drought conditions reducing the effectiveness of earthing systems.	2	Med 6	Med 6	Med 6	Med 6	Med 6	Med 8
SP Energy Networks CCRA 2015	AR9	Increased Temperatures: Switchgear affected by temperature rise, reducing rating.	2	Med 6	Med 6	Med 8	Med 6	Med 8	Med 10
SP Energy Networks CCRA 2015	AR10	Fluvial and Pluvial Flooding: Substations affected by river flooding due to increased winter rainfall, with loss or inability to function leading to reduced security of supply.	4	V High 16	V High 16	V High 16	V High 16	V High 16	V High 20
SP Energy Networks CCRA 2015	AR11	Fluvial and Pluvial Flooding: Substations affected by flash flooding due to severe rainfall, with loss or inability to function leading to reduced security of supply.	4	V High 12	V High 12	V High 16	V High 12	V High 16	V High 20
SP Energy Networks CCRA 2015	AR12	Sea level and storm surge: there is a risk that due to extreme sea flooding a substation may be lost or unable to function leading to reduced system security of supply. A number of sites may be at risk from sea level rise/coastal erosion.[46]	5				V High 15	V High 20	V High 25
SP Energy Networks CCRA 2015	AR13	Increased Precipitation: Substations affected by water flood from dam burst.	5	Med 1	Med 1	High 2	Med 1	High 2	High 2
UK CCRA 2017	AR17	Summer Drought: Surface infrastructure foundations affected by summer drought and consequent ground movement, leading to mechanical damage.	4	High 8	V High 12	V High 12	High 8	V High 12	V High 16

6.1.5 Vegetation Management

There are legislative obligations under the Electricity Safety, Quality and Continuity Regulations (ESQCR) associated with Overhead line conductor clearance including from vegetation. There are two elements to the risks associated with vegetation.

1. Increased precipitation and temperatures can prolong the growing season of vegetation, increasing the maintenance requirements.

[45] SUB-01-018 SP Energy Networks Flood Resilience Policy, Issue No.2
[46] Sea level rise projections aren't available for RCP6.0

2. Climate hazards i.e. floods, can also directly damage vegetation, moving vegetation within the clearance zones resulting in network faults.

These can depend upon vegetation density and species type. Although isolated events of vegetation induced risks have a low impact on our network, these can result in a cumulatively higher impact to network resilience.

Table 14: Climate risks posed to vegetation management

Source	Risk ID	Climate Hazard: Risk	Impact Score	Risk score					
				RCP6.0			RCP8.5		
				2030	2050	2100	2030	2050	2100
Adapted from other DNO CRS	VM1	Fluvial and Pluvial Flooding: Flooding events undermine tree roots, leading to additional faults due to falling trees.	3	High 6	High 6	High 9	High 6	High 9	High 12
Adapted from other DNO CRS	VM2	Coastal Flooding: Flooding events undermine tree roots, leading to additional faults due to falling trees. [47]	2				Med 4	Med 6	Med 8
CRS Workshop 1	VM3	Drought events affect tree structure and stability	1	Low 3	Low 3	Low 4	Low 3	Low 4	Low 4
Adapted from other DNO CRS	VM4	Ice and snow accumulation occur on trees leading to additional faults due to falling debris	2	Med 4	Med 4	Med 6	Med 4	Med 6	Med 6
ENA 2021	VM5	Hurricane and high winds: Increased frequency of events may weaken trees leading to additional wind damage causing faults	2	Med 6	Med 6	Med 8	Med 6	Med 8	Med 10
CRS Workshop 1	VM6	Prolonged Growing Season: Increase in precipitation lead to an extended growing season and hence additional encroachment of vegetation.	2	Med 10	Med 10	Med 10	Med 10	Med 10	Med 10
ENA 2021	VM7	Prolonged Growing Season: High raised temperatures leading to increased growth rates and the need for enhanced vegetation clearance and tree cutting schedules	2	Med 10	Med 10	Med 10	Med 10	Med 10	Med 10
Adapted from other DNO CRS	VM8	Lightning: Increased lightning storms leading to increased number tree lightning strikes.	2	Med 6	Med 6	Med 8	Med 6	Med 8	Med 10
Adapted from other DNO CRS	VM9	Drought: Change in water content of soil leads to changes in natural habitats of different species.	1	Low 3	Low 3	Low 4	Low 3	Low 4	Low 4
UK CCRA 2017	VM10	Pests, pathogens, and invasive species: Changes in weather conditions can allow pests, pathogens, and invasive species to appear in the UK, damaging trees leading to additional faults due to falling trees, for example, ash dieback.	2	Med 6	Med 6	Med 8	Med 6	Med 8	Med 8
UK CCRA 2017	VM11	Wildfire: Higher temperatures during summertime can create the conditions for wildfires that can affect trees and electrical infrastructure near them	3	Med 3	Med 3	High 6	Med 3	High 6	High 9

[47] Sea level rise projections aren't available for RCP6.0

6.1.6 Telecoms & Control Infrastructure

Infrastructure used to manage communications around the network are primarily at risk of flooding. A flood event can cause the entire site or equipment to become non-operational.

Table 15: Climate risks posed to control infrastructure

Source	Risk ID	Climate Hazard: Risk	Impact Score	Risk score					
				RCP6.0			RCP8.5		
				2030	2050	2100	2030	2050	2100
SP Energy Networks CCRA 2015	SP3	Fluvial, pluvial and sea flooding: Flooding impacts upon communication and control infrastructure. Whilst control centres are thought not to be at risk from flood, a site may become non-operational due to flooding potentially leading to a loss of system resilience or a loss of supply. Communications are also reliant upon third parties (Information communication technologies, ICT) who may also be impacted by an event.	3	High 9	High 9	High 12	High 9	High 12	High 15

6.2 Key Business Risks

These sections outline the business risks posed to how we operate associated with climate change.

6.2.1 Emergency Response and Planning

An increased frequency and severity of extreme events associated with climate change projections can increase the number of faults experienced and therefore the requirement for emergency response. How emergency events change in the future may require changes to be made to the planning and ultimately the capacity of the emergency response mechanisms we currently have in place.

Table 16: Climate risks posed to emergency response and planning

				Risk score					
Source	Risk ID	Climate Hazard: Risk	Impact Score	RCP6.0			RCP8.5		
				2030	2050	2100	2030	2050	2100
ENA 2021	ER1	Ice: An increased frequency of events leads to an increased number of major incidents.	3	High 6	High 6	High 9	High 6	High 9	High 9
ENA 2021	ER2	Snow: heavy snowfalls leading to excessive loading on buildings, and secondary risks from icing of equipment and road, leading to access issues in emergencies.	3	High 9	High 9	High 6	High 9	High 6	High 6
ENA 2021	ER3	Hurricane & High Winds: Increased frequency and severity of extreme events causes additional faults leading to a strain on resources.	3	High 9	High 9	High 12	High 9	High 12	High 15
AECOM	ER4	Snow and Ice: Increased heating demand causing additional loadings placed on network, leading to additional faults.	3	High 6	High 6	High 9	High 6	High 9	High 9
ENA 2021	ER5	Increased number of lightning strikes lead to additional faults.	2	Med 6	Med 6	Med 8	Med 6	Med 8	Med 10
CRS Workshop 1	ER6	Increased Temperature: Increased cooling demand, causing additional loadings placed on network, leading to additional faults.	3	High 6	High 9	High 12	High 9	High 12	High 15
Adapted from other DNO CRS	ER7	Heat Wave: High staff absence due to sickness leading to a reduced internal workforce	2	Med 4	Med 4	Med 6	Med 4	Med 6	Med 8
UK CCRA 2017	ER8	Slope and embankment failures causes additional faults and hampers staff movements leading to slow response times.	4	High 8	High 8	High 8	High 8	High 8	High 8

6.2.2 Routine Business

An increased number of faults across the network associated with climate change may reduce the capacity of the organisation to carry out routine business activities, such as maintenance, restoration, repairs, and capital investment. The risks are primarily associated with resources being diverted to attend to extreme events and the accessibility of the network either to carry out routine maintenance or respond and repair faults. Extreme events associated with multiple climate variables can impede access, such as flooding affecting access to faults on the network, and severe cold spells affecting the ability of our staff to travel around the network.

Table 17: Climate risks posed routine business

Source	Risk ID	Climate Hazard: Risk	Impact Score	Risk score RCP6.0 2030	RCP6.0 2050	RCP6.0 2100	RCP8.5 2030	RCP8.5 2050	RCP8.5 2100
ENA 2021	RB1	Fluvial and Pluvial: Increased number of substations at risk of flooding, leading to diversion of resources away from routine business	3	High 9	High 9	High 12	High 9	High 12	High 15
ENA 2021	RB2	Coastal Flooding: Increased number of substations at risk of flooding, leading to diversion of resources away from routine business[48]	3				High 9	High 12	High 15
Adapted from other DNO CRS	RB3	Ice: Routine business suffers as a result of additional faults on the network.	2	Med 4	Med 4	Med 6	Med 4	Med 6	Med 6
ENA 2021	RB4	Heavy Snow: heavy snowfalls leading to excessive loading on buildings, and secondary risks from icing of equipment and road, leading to access issues and disruption to operational activities	2	Med 4	Med 4	Med 6	Med 4	Med 6	Med 6
Adapted from other DNO CRS	RB5	Hurricane & High Winds: Certain activities postponed due to safety concerns.	2	Med 6	Med 6	Med 8	Med 6	Med 8	Med 10
Adapted from other DNO CRS	RB6	Heat Wave: Certain operational & non-operational activities postponed/delayed due to unsuitability of PPE for temperature conditions.	2	Med 4	Med 4	Med 6	Med 4	Med 6	Med 6
CRS Workshop 1	RB7	Fluvial and Pluvial: Risks to staff travelling to work from flooding of transport network. And Limiting ability to get to site to repair faults.	2	Med 6	Med 6	Med 8	Med 6	Med 8	Med 10
CRS Workshop 1	RB8	Cold Spells: Risks to staff travelling to work from cold spells and increase snow and ice on the transport network	2	Med 4	Med 4	Med 6	Med 4	Med 6	Med 6
SP Energy Networks CCRA 2015	SP1	Increased Temperatures: Maintenance programme may be impacted as increased temperatures may increase loads during summer reducing opportunity for planned outages and network reinforcement to enable maintenance. Temperature increases could thus lead to a possible reduction in the flexibility of the network (because of the change in load balance through the year).	3	High 9	High 9	High 12	High 9	High 12	High 15
SP Energy Networks CCRA 2015	SP2	Extreme Events: During extreme events teams may have limited safe access to isolate and repair faults. This could result in loss of supply to customers for a greater period of time.	2	Med 6	Med 6	Med 8	Med 6	Med 8	Med 10

6.2.3 Customer Service

Meeting customer service satisfaction requirements is a key priority of our organisation. Ofgem regulates the compliance of customer service requirements by stipulating the maximum response times of unplanned interruptions, appreciating that the frequency of certain climatic hazards can be unpredictable, but there should be adequate mitigation measures in place. Climate change shows an increase in severity and frequency of climate hazards which could slow down response times by impeding network access and affecting the health and safety of our staff and customers. The UK Net Zero carbon emissions by 2050 goal will likely increase electrical demand through increases in electrification of transportation, however at least the same levels of customer service will be needed.

[48] Sea level rise projections aren't available for RCP6.0

Table 18: Climate risks posed to customer service

Source	Risk ID	Climate Variable: Risk	Impact Score	Risk score RCP6.0 2030	RCP6.0 2050	RCP6.0 2100	RCP8.5 2030	RCP8.5 2050	RCP8.5 2100
UK CCRA 2017	CS1	Fluvial & Pluvial Flooding: Increased number of substations at risk of flooding. Fault restoration times extended due to floodwaters.	3	High 9	High 9	High 12	High 9	High 12	High 15
Adapted from other DNO CRS	CS2	Fluvial & Pluvial Flooding: Certain types of work prevented due to safety issues caused by office buildings flooding.	2	Med 6	Med 6	Med 8	Med 6	Med 8	Med 10
UK CCRA 2017	CS3	Coastal Flooding: Increased number of substations at risk of flooding. Fault restoration times extended due to floodwaters. [49]	4				V High 12	V High 16	V High 20
Adapted from other DNO CRS	CS4	All Climate Hazards: Slow response times and increased fault durations due to large number of network faults and problematic access and travel.	2	Med 6	Med 6	Med 8	Med 6	Med 8	Med 10
Adapted from other DNO CRS	CS5	Heavy Snow: Slow response times and increased fault durations due to large number of network faults and problematic access and travel.	2	Med 4	Med 4	Med 6	Med 4	Med 6	Med 6
Adapted from other DNO CRS	CS6	Hurricanes & High Winds: Slow response times and increased fault durations due to a large number of network faults.	2	Med 6	Med 6	Med 8	Med 6	Med 8	Med 10
Adapted from other DNO CRS	CS7	Heat Wave: Risks to staff travelling to work from high temperatures on public transport	2	Med 4	Med 4	Med 6	Med 4	Med 6	Med 8
CRS Workshop 1	CS8	Heat Wave: Vulnerable customers need additional prioritisation.	3	High 6	High 9	High 12	High 9	High 12	High 15
Adapted from other DNO CRS	CS9	Cold Spells: Vulnerable customers need additional prioritisation.	3	High 9	High 9	High 6	High 9	High 6	High 6
UK CCRA 2017	CS10	Slope and Embankment Failures: Slow response times and increased fault durations due to large number of network faults and problematic access and travel.	3	High 6	High 6	High 6	High 6	High 6	High 6
UK CCRA 2017	CS11	Drought: Risks to public water supplies from drought and low river flows affecting workers in offices	2	Med 4	Med 6	Med 6	Med 4	Med 6	Med 8
UK CCRA 2017	CS12	Vector-borne Pathogens: High staff absence due to sickness leading to a reduced internal workforce.	3	High 9	High 9	High 9	High 9	High 9	High 9
UK CCRA 2017	CS13	Coastal Flooding: Certain types of work prevented due to safety issues caused by office buildings flooding. [50]	4				V High 12	V High 16	V High 20

[49] Sea level rise projections aren't available for RCP6.0
[50] Sea level rise projections aren't available for RCP6.0

7. Adaptation Tipping Points

An adaptation tipping point is reached when the magnitude of climate change is such that the current adaptation solution is no longer effective.

For the purpose of this Climate Resilience Strategy (CRS), three types of tipping points have been derived across two pre-defined categories - Stable State; where the formal objective / performance threshold of a solution (standards / laws) is exceeded, and Mechanism; where accessibility, temporal or economic thresholds are surpassed[51].

Developed in order to better reflect the scope of the network and business risks, the three tipping points types as outlined within Table 19, echo both the qualitative and quantitative nature of the climate variables and the suite of assets / operational activity within the scope of SP Energy Networks.

Table 19: Adaptation Tipping Points

Type	Description	Example	Category
i. **Climate Variable / Design Threshold**	Applied where the climatic variable considered has a direct impact on the asset itself. Applied to high risks where possible.	Ambient air temperature that informs the maximum or minimum conductor temperature is exceeded.	Stable State
ii. **Response Led**	Where climate variable/design threshold is not applicable, this is led by available data on SP Energy Networks activity and current approaches	An observed increase in time and cost spent on current vegetation management practices.	Mechanism
iii. **Outcome Led**	Informed by associated impact of an event occurring (apply only to low risks where possible)	Heightened number of customer complaints and an increase in the duration of disruption from climatic events.	Mechanism

For detailed tipping points identified by climate variable vs network and business function, please refer to Appendix I.

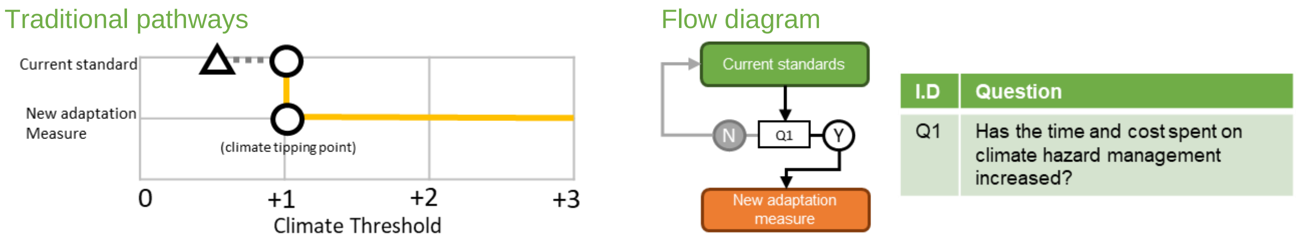
[51] Kees C H van Ginkel et al (2020). Environ. Res. Lett. 15 023001. Available at: https://iopscience.iop.org/article/10.1088/1748-9326/ab6395/pdf

8. Adaptation Solutions and Pathways

The following section presents the proposed adaptation solutions[52] which are organised into adaptation pathways[53] for each of the climate hazards. The solutions address the climate risks identified in Section 6 accounting for tipping points and climate change projection scenarios, with a view of building in climate resilience.

The solutions identified originate from several sources, including the 2015 Risk Assessment, interviews with key internal colleagues, and documentation from the Energy Network Association (ENA). They were updated or adjusted against the Risk Assessment carried out for this strategy and supplemented with findings from workshops.

Two styles of pathways diagrams have been developed (traditional pathways diagram and flow diagram) based upon the type of tipping point data available. Both follow a decision matrix format, and example diagrams are shown in Figure 6.



Led by climatic tipping points *Response or outcome led, focused around questions*

Figure 6: Examples of traditional and flow diagram pathways

We have assigned the following style of diagram and assessment for each hazard based on which approach was better suited to the hazard identified, and the availability of corresponding decision points:

- **High temperatures**; traditional pathways
- **Low temperatures**; flow diagram
- **Flooding**; flow diagram
- **Growing Season**; flow diagram
- **Droughts**; flow diagram
- **Storms & High Winds**; flow diagram
- **Other risk**; no pathways

The adaptation pathways approach enables moving between of adaptation solutions over time as new information and conditions emerge[54].

The solutions in the pathways are arranged by their ease of implementation, which relates to the level of work and resources required to deploy the solution, ranging from our current practices to changes in standards and design.

Appendix II contains further details of each adaptation solution that have pathway diagrams, showing the Risk ID relating to each solution (risks have been assigned different codes determined by the business function to which they relate), and their strategic alignment to our Sustainable Business Strategy. Resilience and sustainability do not align all the time, efficiencies need to be determined that complement the whole life value cost of assets. For example, difficult to implement adaptation solutions should only be taken where the risk has been assessed as being sufficiently high to justify action to mitigate. Section 11 presents the proposed monitoring and evaluation approach to implement the climate adaptation pathways and are regularly reviewed.

8.1 High Temperatures

The expected increase in annual, minimum, and maximum air temperatures across all seasons poses a number of risks, including reduced ratings of transformers, switchgear and cables, and additional faults on our network caused by increased loadings from high cooling demand.

[52] **Definition:** Actions to adapt to climate change
[53] **Definition:** Routes to achieve climate resilience
[54] Vandever,J., Bonham-Carter, C., Kapoor, A. (2021). Navigating Uncertain Futures with the Climate Adaptation Pathways Approach. Available at: https://naep.memberclicks.net/assets/newsletter/Newsletter2021/NAEP%20Winter%202021%20Article%20Navigating%20Uncertain%20Futures.pdf

Figure 7 presents different pathways of adaptation actions that we would apply to reduce the sensitivity or the exposure of our assets.

- Pathways have been established for two climate scenarios, RCP6.0 and RCP8.5, to illustrate when changes in the UK's maximum summer average temperature would be met under different possible futures. The associated time periods for each of the expected changes in temperature are displayed along the x-axis of the diagram.
- All pathways begin in the middle of the diagram with the current policies (shown in yellow text).
- Actions reducing sensitivity are displayed above the current policy, and actions that reduce exposure are displayed below.
- The circles represent the maximum summer average temperatures that are assumed to trigger a change to new adaptation actions. For example, it is assumed that reaching the maximum summer average temperature of 20ºC will trigger us to incorporate comprehensive changes in our network, especially accelerating its efforts to update legacy assets.
- The triangles show which maximum summer average temperatures are assumed to trigger a decision point to incorporate the corresponding new adaptation action.
- It is common that after a decision is made there is a lead time until the decision can be implemented, represented in the diagram by a dotted line between the triangles and circles. As an example, it is assumed that the maximum temperature reaching around 21ºC will trigger the decision to adopt new transformer technologies, but it is assumed that this action will only be implemented once the maximum temperature reaches around 22ºC.
- In this diagram, the only action that has a tipping point (that is, when the action stops being effective) is keeping legacy assets built to old specifications. Its tipping point has a question mark as it is uncertain when all of these assets will be changed. The rest of actions are assumed to reach their tipping points at higher temperatures than the ones plotted in the diagram. That is why their pathways end in arrows.
- Finally, the pathways are colour coded according to the network functions that each action affects.

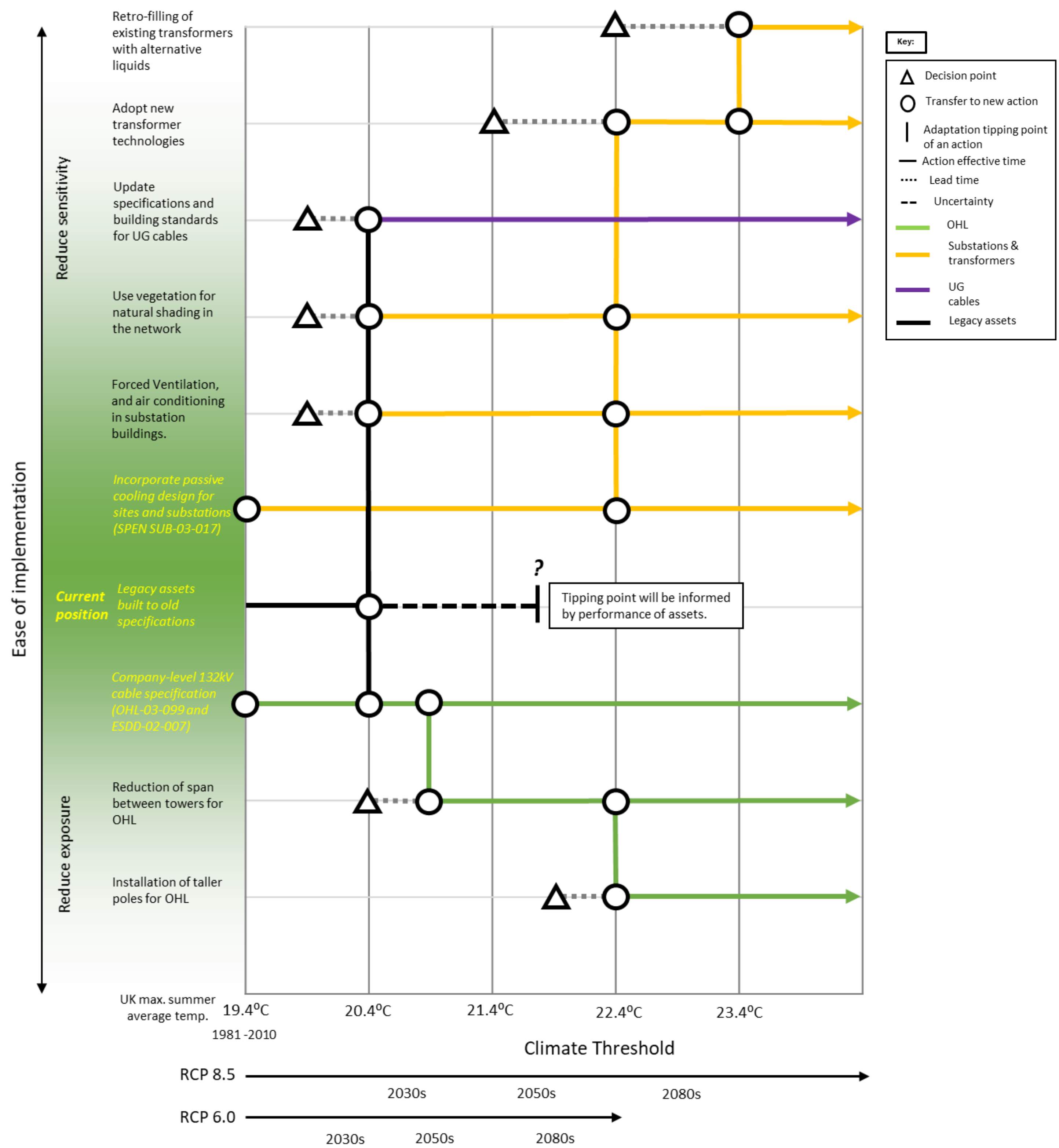
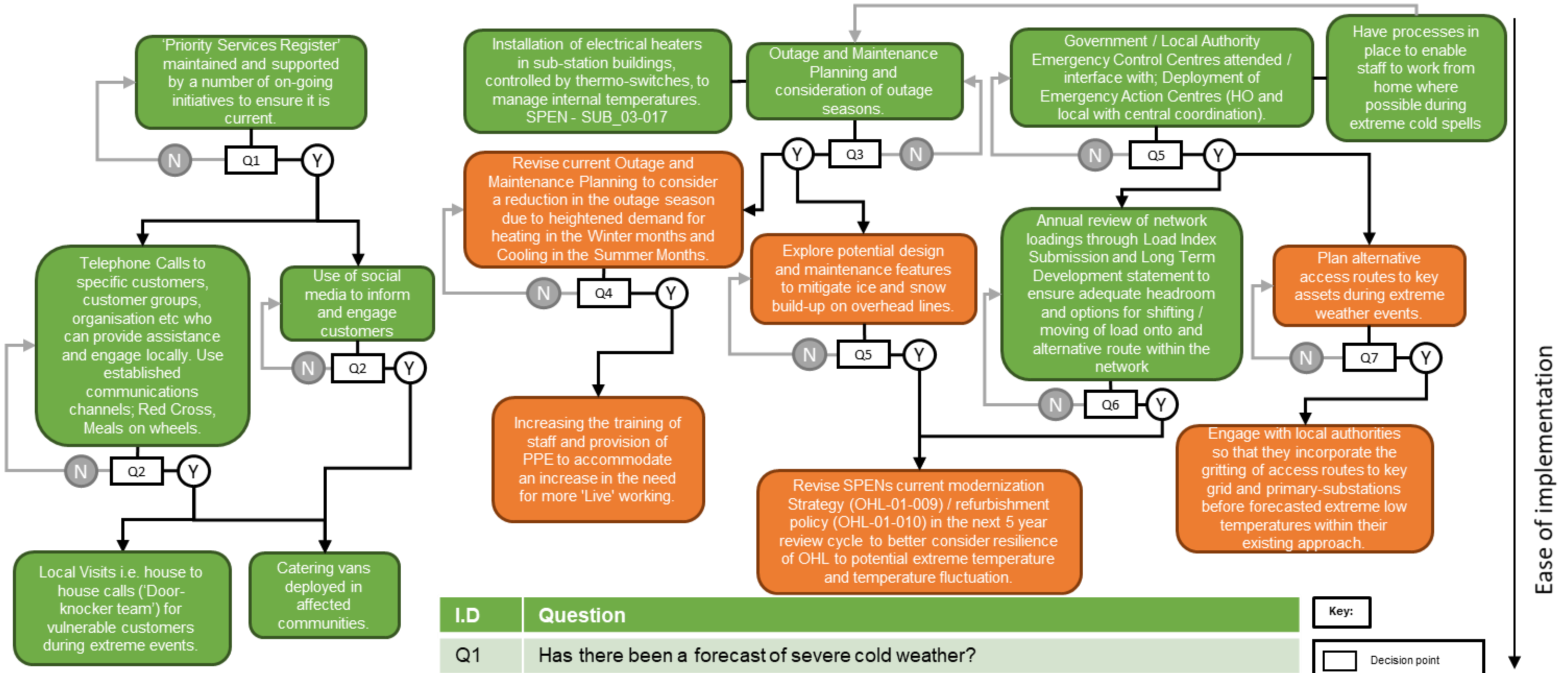


Figure 7: Traditional adaptation pathways diagram for dealing with high temperatures

8.2 Low Temperatures

As discussed in Section 5.2.1, Climate Projections; Temperature, it is likely that colder temperatures will become less frequent, however extreme events will still occur and it is important to plan for them. Prolonged cold spells may lead to additional network faults due to additional loadings caused by increased heating demand. Also, heavy snow events and snow build up may cause travel disruptions for staff, and large numbers of additional network faults may lead to slow response times and cause routine business to suffer. Figure 8 below outlines the adaptation solutions for low temperatures.



I.D	Question
Q1	Has there been a forecast of severe cold weather?
Q2	Have vulnerable customers required the need of assistance?
Q3	Has the outage season changed considerably?
Q4	Are we experiencing a reduction in the length of the outage season?
Q5	Has there been an increased number of sites susceptible to faults associated with ice and snow?
Q6	Have alternative routes within the network for shifting / moving of load been exhausted or not found?
Q7	Have we observed that main and alternative access routes to key assets during extreme weather events are frequently not free of snow or ice?

Figure 8: Flow diagram for climate adaptation pathways approach for dealing with low temperatures

8.3 Flooding

Climate change projections show increases in extreme winter precipitation in the future. This increases the risk of fluvial and pluvial flooding affecting our network, extending fault restoration times, and diverting resources away from routine business operations. Other risks from flooding include transport disruptions for staff travelling to work and falling trees due to tree roots being undermined. Figure 9 below outlines the adaptation solutions for these flooding risks.

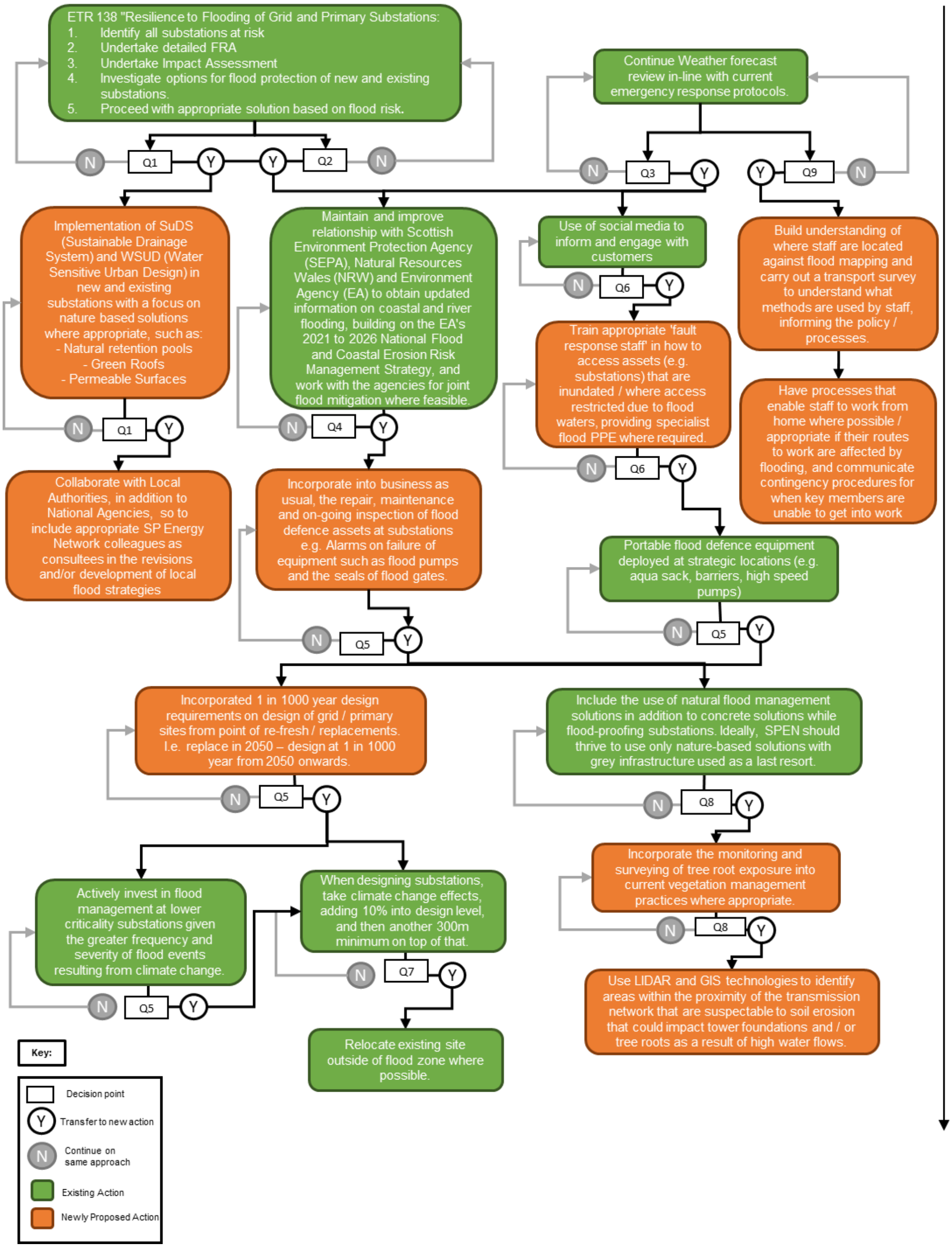


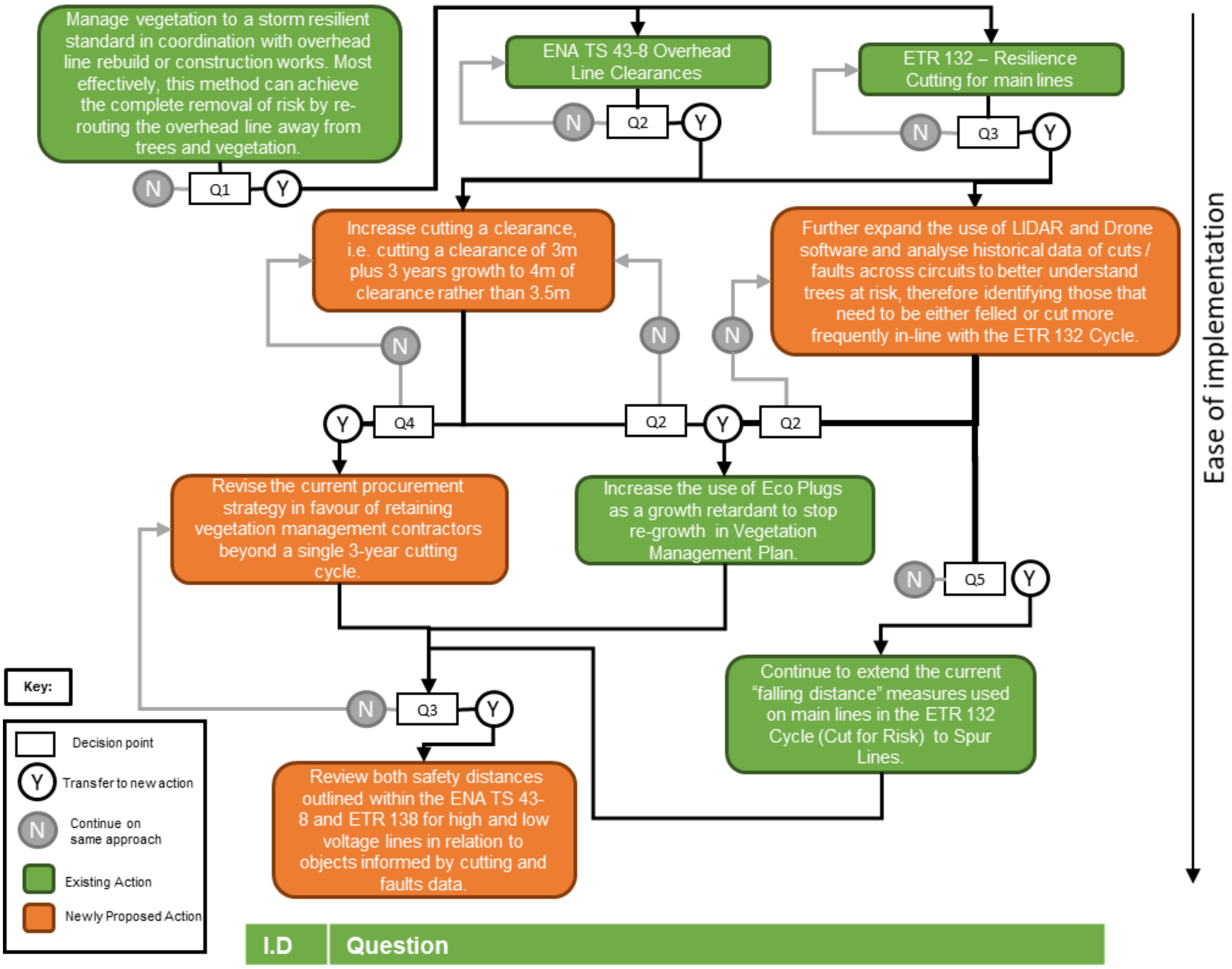
Figure 9: Flow diagram for climate adaptation pathways approach for dealing with flooding

I.D	Question
Q1	Have we experienced an increase in surface flood events?
Q2	Have we experienced an increased frequency and severity of flood events?
Q3	Has a flood warning been issued?
Q4	Have we experienced any failures of flood defences?
Q5	Are the flood defences no longer effective in mitigating the identified impact?
Q6	Was there a heightened number of faults with unacceptable outage timeframes?
Q7	Are the flood defences no longer effective in protecting grid and primary substations
Q8	Has there been an increased amount of falling trees during a flood event?
Q9	Have we experienced any flood events that affected the ability of staff getting into work?

For further information on our RIIO-ED2 Flood Mitigation proposals within RIIO-ED2 refer to Annex 4A.15.

8.4 Growing Season

As previously discussed in this report, a prolonged growing season due to higher temperatures associated with climate change may create risks for SP Energy Networks. Risks include the interference and encroachment of vegetation, affecting overhead lines. Figure 10 below outlines the adaptation solutions for risks from a prolonged growing season.



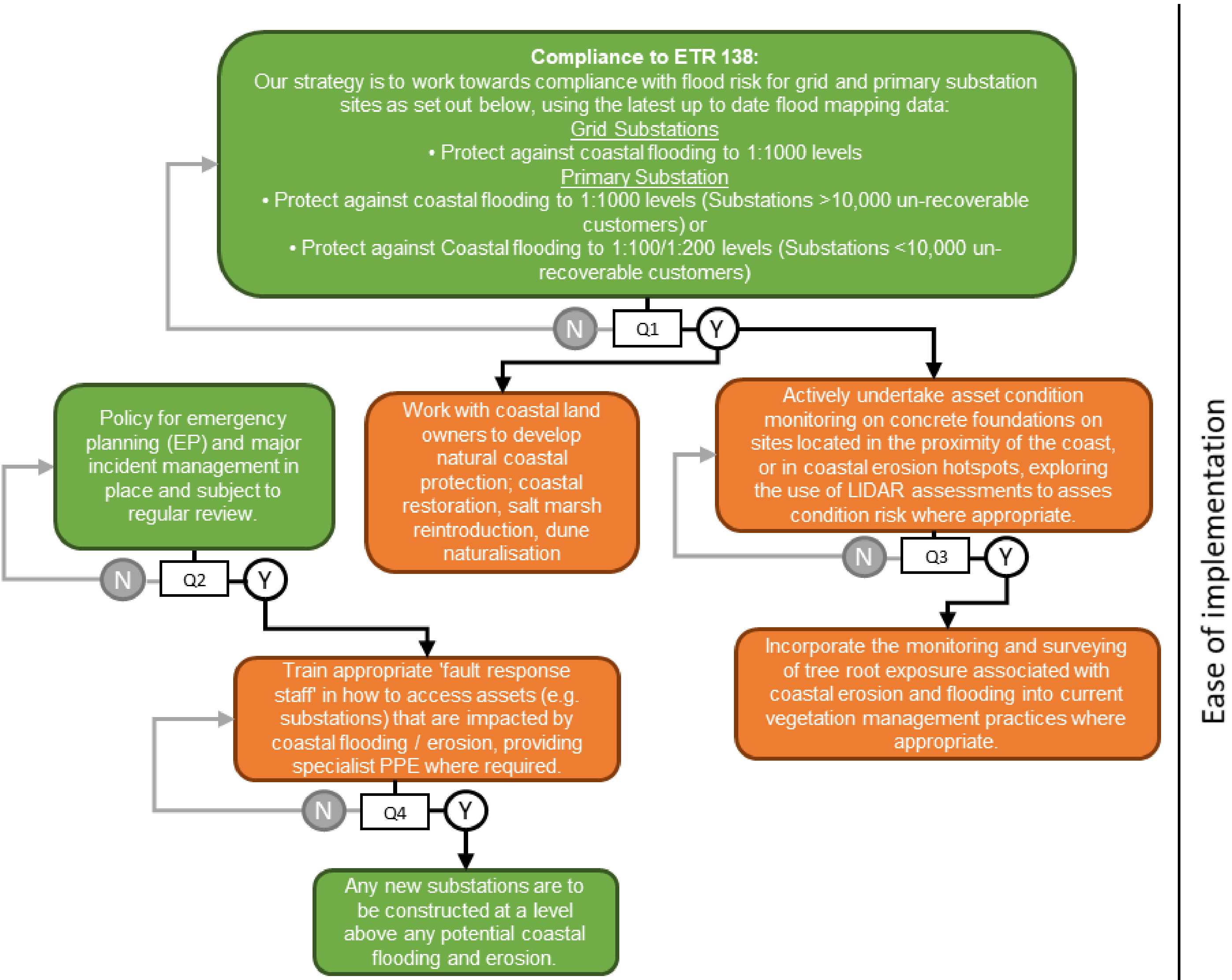
I.D	Question
Q1	Is vegetation encroaching on newly built lines, and therefore required maintenance?
Q2	Are we experiencing faster vegetation growth, and are we therefore needing to cut more frequently and extensively?
Q3	Is the data demonstrating more frequent tree fall related faults on OHL?
Q4	Is it costing more time and money for our contactors to undertake cutting cycles?
Q5	Are Spur lines experiencing a greater number of tree fall related faults?

Figure 10: Flow diagram for climate adaptation pathways approach for dealing with increased vegetation growing season

For more information in relation to our vegetation management within RIIO-ED2 refer to Annex 4A.20.

8.5 Sea Level Rise

Projected mean sea level rise of up to 1 m by the end of the century may impact a number of our sites and cause them to be non-operable due to inundation or erosion. The increased frequency and severity of extreme tidal surge events also has the potential to affect the ability of a substation to function, leading to reduced system security of supply. Figure 11 below outlines the adaptation solutions for sea level rise.



I.D	Question
Q1	Have we experienced an increased rate of coastal erosion?
Q2	Was there a heightened number of faults with unacceptable outage timeframes?
Q3	Has there been an increased amount of falling trees during a coastal flood event?
Q4	Are sea levels exceeding the current coastal defences?

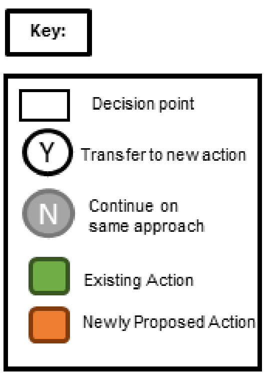
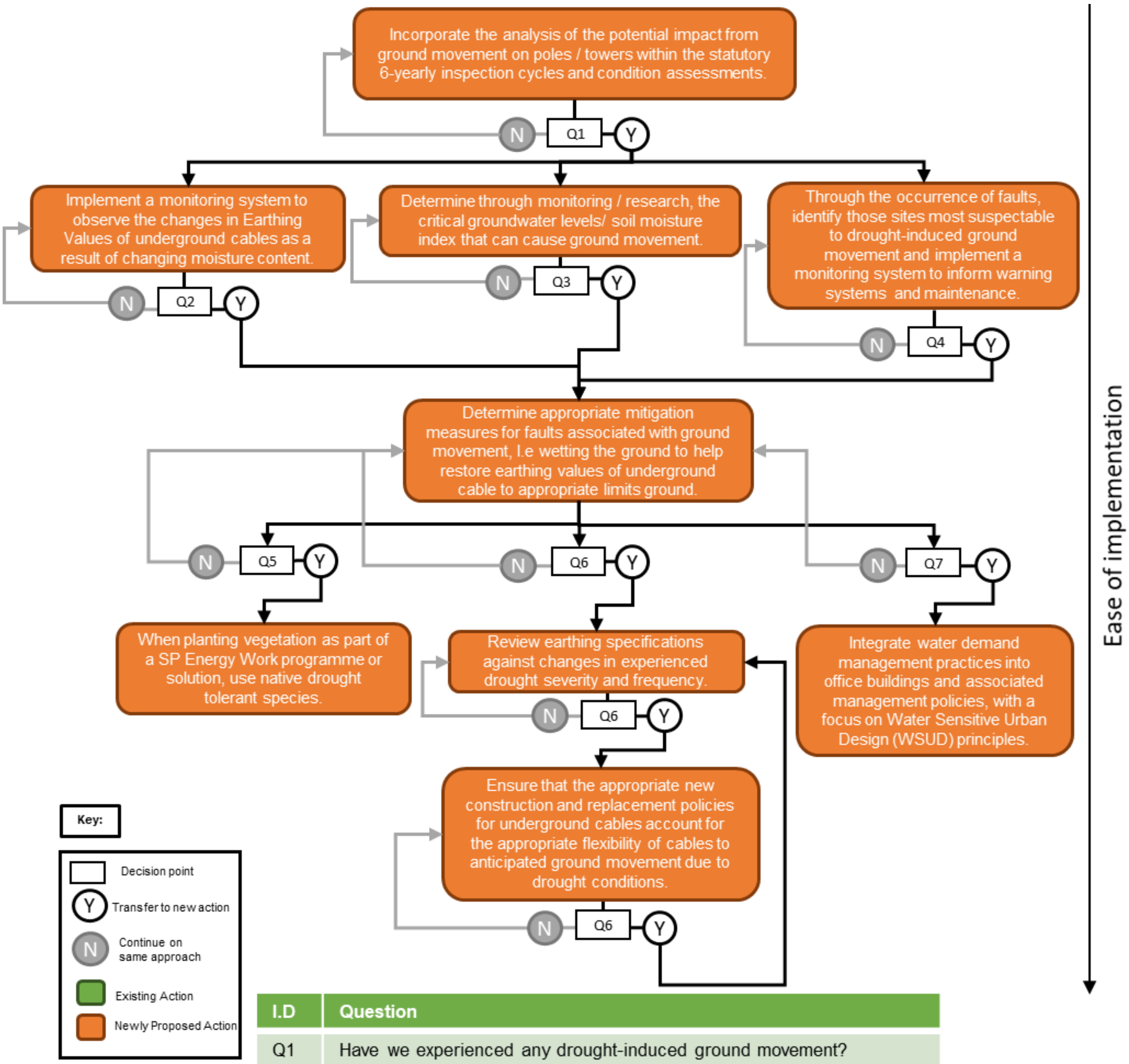


Figure 11: Flow diagram for climate adaptation pathways approach for dealing with sea level rise

For further information on our Flood Mitigation proposals within RIIO-ED2 refer to Annex 4A.15.

8.6 Drought

Climate change projections show a decrease in summer precipitation, increasing the likelihood of drought and the risks of earth and ground movement on our assets. Currently, we have no specific drought mitigation strategy and so all the adaptation actions are classed as new. Figure 12 below outlines the adaptation solutions for drought.

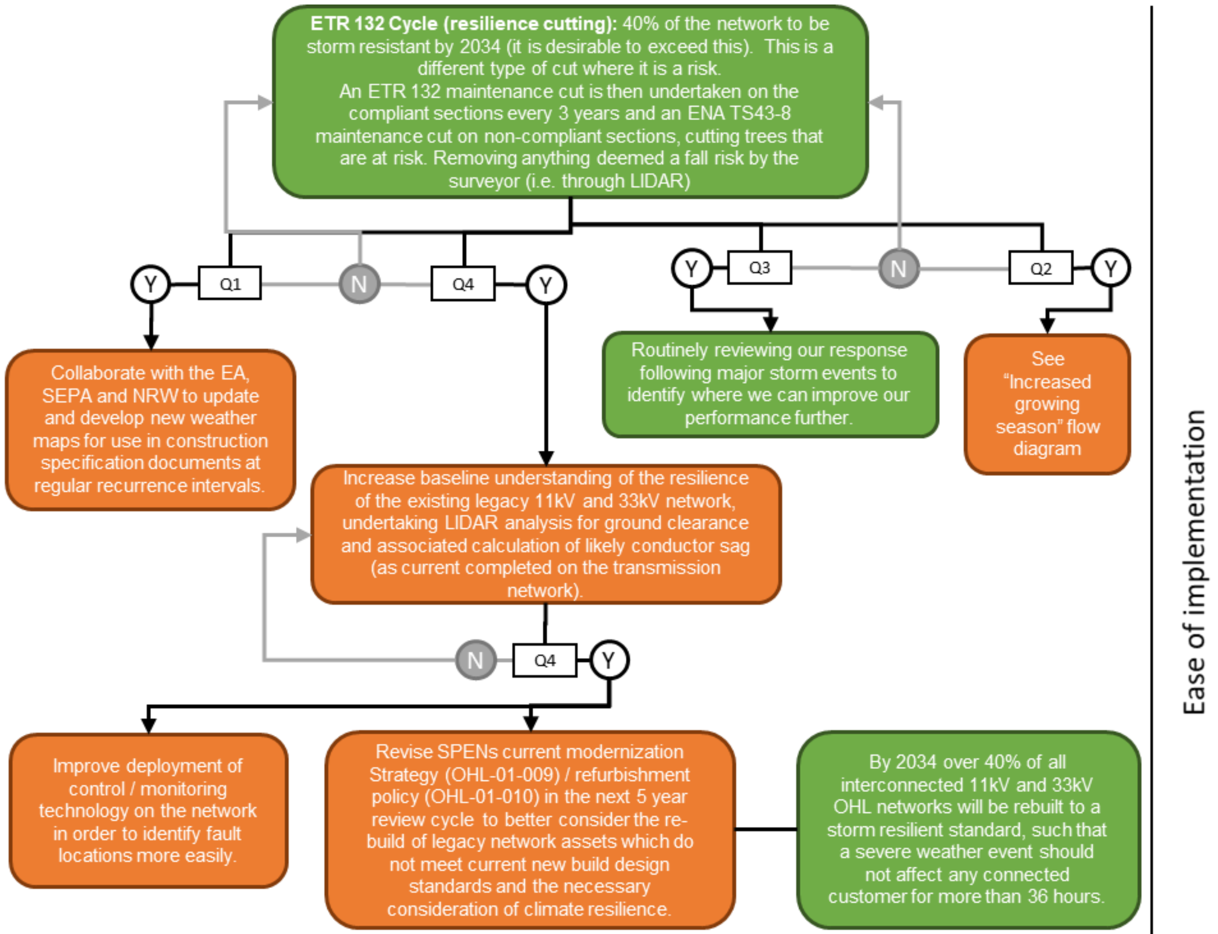


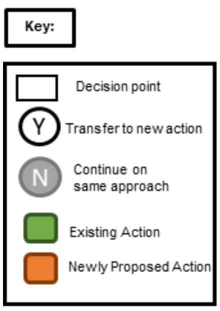
I.D	Question
Q1	Have we experienced any drought-induced ground movement?
Q2	Has there been a significant change in moisture content, resulting in underground cable faults?
Q3	Have critical groundwater levels been met, causing ground movement?
Q4	Has there been an increased number of sites susceptible to faults associated with drought?
Q5	Have we noticed a decrease in biodiversity?
Q6	Have we experienced an increased amount of drought events, and an increased number of faults as a result?
Q7	Have we experienced any water shortages?

Figure 12: Flow diagram for climate adaptation pathways approach for dealing with drought

8.7 High Winds and Storms

UKCP18 projections show an increase in near surface wind speeds over the UK for the second half of the 21st century during the winter season, with some climate models displaying large peaks in some years. Although there is interannual and decadal variance of windstorms and uncertainty in future storm intensities, it is still vital to be prepared for such events. Risks to SP Energy Networks include large numbers of network faults, leading to slow response times, strain on resources and the postponement of work due to safety concerns. Figure 13 below outlines the adaptation solutions for storms and high winds.





I.D	Question
Q1	Are we experiencing storm events that do not correlate with the existing weather maps?
Q2	Are we experiencing a greater number of faults due to tree-falls during storm / high wind events?
Q3	Was there a heightened number of faults with unacceptable outage timeframes?
Q4	Are we experiencing an increased number of faults on the existing legacy 33KV network?

Figure 13: Flow diagram for climate adaptation pathways approach for dealing with storms and high winds

For more information on storm resilience on our overhead line network refer to Annex 4A.13 – OHL and ESQCR Strategy.

8.8 Other Risks

Finally, there are a number of other climate-related risks and hazards which are not included in the categories above. These are lightning, pests and pathogens, wildfires, and embankment failures. As these risks are not in line with a specific climate variable and the solutions are not inter-linked through common response or outcome led tipping points, neither a pathway nor flow diagram has been provided. Solutions have been categorised according to their adaptation type, depending on the stage in the process that they fall under (planning, design, standards/specifications, monitoring, or engagement), and whether they reduce exposure or sensitivity. Any solutions which are Nature-Based Solutions[55] are highlighted. Table 20 defines these categories.

Table 20: Definition of categorisation of adaptation solutions

Term	Definition
Reduce Exposure	Changing the location, attributes, and value of assets that could be affected by a climate risk
Reduce Sensitivity	Reducing the likelihood that assets will be affected when exposed to a climate risk
Adaptation Type	Planning: Determining the level of risk, and developing plans to set out the approach to deal with the climate risk Monitoring: Assessing how the risk changes over time, and any external factors such as load patterns Standards/Specifications: Specific requirements Design: Structural changes Engagement: Communication approach with key stakeholders
Nature-Based Solution	Any solutions using natural approaches have been indicated with this symbol: 

For each adaptation solution, it's alignment with the SP Energy Networks sustainable business strategy and six sustainability drivers has been indicated in the solutions table using the icons displayed in Figure 14.

Figure 14: SP Energy Networks Sustainable Business Strategy Sustainability Drivers

[55] Nature-Based Solutions are defined by the IUCN as "actions to protect, sustainably manage, and restore natural or modified ecosystems, that address societal challenges effectively and adaptively, simultaneously providing human well-being and biodiversity benefits". https://www.iucn.org/commissions/commission-ecosystem-management/our-work/nature-based-solutions

Proposed solutions for other risks are presented below in Table 21.

Table 21: Adaptation solutions for lightning, all risks, pandemics, slope instability and wildfires

Adaptation solution	Risk ID	Source	Sustainability Driver
Lightning Design: By 2034 over 40% of all interconnected 11kV and 33kV OHL networks will be rebuilt to a storm resilient standard, such that a severe weather event should not affect any connected customer for more than 36 hours.	AR14a	SPEN	
Lightning Design: Improved lightning protection including earthing and, surge arresters on plant, and other equipment and automated procedures will be considered if lightning strike frequency increases.	AR14b	SPEN	
Lightning Design: Introducing increasing numbers of reclosers and remotely operated switchgear, which allow electrical faults to be isolated and the network reconfigured remotely	SP2	SP Energy Networks	
Lightning Monitoring: Routinely reviewing our response following major storm events to identify where we can improve our performance further.	ER5	SP Energy Networks	
All Risks Engagement: Use of social media to inform and engage customers.	CS4	SP Energy Networks	
Pandemics Planning: Pandemic strategy; Have processes in place to enable staff to work from home where possible.	CS12	SP Energy Networks	
Slope Failures Monitoring: Monitor weather for seasonal prolonged wet and drying periods which increase the likelihood of slope failures.	ER8 CS9	AECOM	
Slope Failures Design: Identify locations that are susceptible to slope failure and work with appropriate stakeholders and landowners to implement mitigating solutions, for example, planting trees with strong root structures to stabilise the slope.	ER8 CS10	AECOM	
Pest Monitoring: Incorporate the detection of invasive species into existing vegetation management approaches and work with relevant stakeholders to inform and also develop options for mitigating against the invasive species.	VM0	AECOM	
Wildfire Planning: Use LIDAR and GIS technologies, working with appropriate stakeholders (such as Forestry Commission, EA, NRW) to identify and map areas at greater risk to wildfires to help inform appropriate management activities.	VM1	AECOM	
Wildfire Monitoring: Incorporate the removal of dry vegetation litter/fuel build up during periods of high temperatures into current Vegetation Management practices/cutting cycles.	VM1	AECOM	

9. What we are doing in RIIO-ED2

9.1 Embedding Climate Change Resilience throughout our ED2 business plan

The areas identified with the highest Climate Hazard Risk (Section 6) have been evaluated against the future pathways process (Sections 7 and 8) and the future tipping points established in each case. The outcome of this analysis has determined the actions we must now take to ensure that we build a network that is resilient to future climate change, and the trigger points for future actions are identified.

				Risk score			
				RCP6.0	RCP8.5		
Source	Risk ID	Climate Hazard: Risk	Impact Score	2030	2030	Tipping Point Analysis	Resulting Action
SP Energy Networks CCRA 2015	AR5	Summer Drought: Underground cable systems affected by summer drought and consequent ground movement, leading to mechanical damage/failure.	4	High 8	High 8	Tipping point is at Q1: have we experienced any drought induced ground movement?	Incorporate the analysis of the potential impact from ground movement on poles / towers within the statutory 6-yearly inspection cycles and condition assessment.
ED2 Workshop	AR16	Summer Drought: dry-out of the soil surrounding UG cables. This will lead to an increased thermal resistivity, reduced heat transfer from cable to surrounding soil/backfill, and a reduced current (load) carrying capacity	4	High 8	High 8	Tipping point is at Q1: have we experienced any drought induced ground movement?	Incorporate the analysis of the potential impact from ground movement on poles / towers within the statutory 6-yearly inspection cycles and condition assessment.
SP Energy Networks CCRA 2015	AR10	Fluvial and Pluvial Flooding: Substations affected by river flooding due to increased winter rainfall, with loss or inability to function leading to reduced security of supply.	4	V High 16	V High 16	Future tipping point is at Q5 when existing flood mitigation measures stop being effective.	ETR 138 - Resilience to Flooding of Grid and Primary Substations: Identify all substations at risk, undertake detailed FRA and impact assessment; investigate options and proceed with appropriate solution.
SP Energy Networks CCRA 2015	AR11	Fluvial and Pluvial Flooding: Substations affected by flash flooding due to severe rainfall, with loss or inability to function leading to reduced security of supply.	4	V High 12	V High 12	Future tipping point is at Q5 when existing flood mitigation measures stop being effective.	ETR 138 - Resilience to Flooding of Grid and Primary Substations: Identify all substations at risk, undertake detailed FRA and impact assessment; investigate options and proceed with appropriate solution.

SP Energy Networks CCRA 2015	AR12	Sea level and storm surge: there is a risk that due to extreme sea flooding a substation may be lost or unable to function leading to reduced system security of supply. A number of sites may be at risk from sea level rise/coastal erosion.[1]	5		V High 15	Future tipping point is at Q1: have we experienced an increased rate of coastal erosion?	Strategy is to work towards compliance with ETR138: protect against flooding to 1:1000 levels for Grid substations and Primary substations >10k un-recoverable customers, or 1:100/1:200 levels for substations <10k unrecoverable customers
UK CCRA 2017	AR17	Summer Drought: Surface infrastructure foundations affected by summer drought and consequent ground movement, leading to mechanical damage.	4	High 8	High 8	Tipping point is at Q1: have we experienced any drought induced ground movement?	Incorporate the analysis of the potential impact from ground movement on poles / towers within the statutory 6-yearly inspection cycles and condition assessment.
UK CCRA 2017	CS3	Coastal Flooding: Increased number of substations at risk of flooding. Fault restoration times extended due to floodwaters. [1]	4		V High 12	Future tipping point is at Q1: have we experienced an increased rate of coastal erosion?	Strategy is to work towards compliance with ETR138: protect against flooding to 1:1000 levels for Grid substations and Primary substations >10k un-recoverable customers, or 1:100/1:200 levels for substations <10k unrecoverable customers
UK CCRA 2017	CS13	Coastal Flooding: Certain types of work prevented due to safety issues caused by office buildings flooding. [1]	4		V High 12	Future tipping point is at Q1: have we experienced an increased rate of coastal erosion?	Strategy is to work towards compliance with ETR138: protect against flooding to 1:1000 levels for Grid substations and Primary substations >10k un-recoverable customers, or 1:100/1:200 levels for substations <10k unrecoverable customers

The areas of our plan incorporating the investment required are referenced in the following sub-sections.

9.2 Flood Mitigation

Within the RIIO-ED2 period we are proposing to invest £9.65m (£5.30m in SPD and £4.34m in SPM) in flood mitigation (CV16) at our substation's locations. This includes the undertaking of 328 detailed flood risk assessments at sites identified as being at risk based on the latest flood mapping by the environment agencies and forecast flood mitigation works will be required at 105 of these locations.

Our flood mitigation works contribute to mitigating the following risks identified within this strategy:

- **AR10 - Fluvial and Pluvial Flooding:** Substations affected by river flooding due to increased winter rainfall, with loss or inability to function leading to reduced security of supply.
- **AR11 - Fluvial and Pluvial Flooding:** Substations affected by flash flooding due to severe rainfall, with loss or inability to function leading to reduced security of supply.
- **AR12 - Sea level and storm surge:** there is a risk that due to extreme sea flooding a substation may be lost or unable to function leading to reduced system security of supply. A number of sites may be at risk from sea level rise/coastal erosion.

Further details on our RIIO-ED2 Flood Mitigation Programme can be found in our Civils and Flooding Strategy (Annex 4A.15) and our Flood Resilience Engineering Justification Paper (ED2-NLR(A)-SPEN-003-RES-EJP).

9.3 OHL Storm Resilience

Within RIIO-ED2 we are undertaking an extensive programme of OHL modernisation (£208m) which includes a 171km of EHV and 1,117km of HV OHL re-build in accordance with latest storm resilient standards. The OHL re-build programme shall be in compliance with ETR132 Specification (storm resilience vegetation management). The overall programme shall provide benefits in mitigating the below risks identified within this strategy.

AR3 - Prolonged growing season: Overhead lines affected by interference from vegetation

AR15 - Hurricanes & High Winds: Overhead line structures affected by wind speeds not accommodated for in design.

Further details on our RIIO-ED2 OHL Modernisation Programme can be found in our OHL and ESQCR Strategy (Annex 4A.13) and the associated engineering justification papers.

9.4 Vegetation Management

Within RIIO-ED2 we shall continue to deliver our Tree Cutting Programme (CV29) which has a forecast expenditure of £82.02m (£23.82m in SPD and £58.20m in SPM) over the 5-year period. Within RIIO-ED2 our tree-cutting expenditure has increased slightly to maintain our RIIO-ED1 cyclic-cutting programme in-light of our latest framework costs and the increased growth rates identified in VM6 and VM7.

By continuing this programme of vegetation management and adapting to changes in growth rates as they occur within our cyclic programmes of cutting, we shall provide benefit in mitigating the below risks identified within this strategy.

- **VM1 Fluvial and Pluvial Flooding:** Flooding events undermine tree roots, leading to additional faults due to falling trees. This has been described as a high-risk factor.
- **VM2 Coastal Flooding:** Flooding events undermine tree roots, leading to additional faults due to falling trees. This has been described as a medium-risk factor.
- **VM3 Drought**: Events affect tree structure and stability. This has been described as a low-risk factor.
- **VM4 Ice and Snow:** Accumulation occurs on trees leading to additional faults due to falling debris. This has been described as a medium-risk factor.
- **VM5 Hurricane and High Winds:** Increased frequency of events may weaken trees leading to additional wind damage causing faults. This has been described as a medium-risk factor.
- **VM6 Prolonged Growing Season:** Increase in precipitation lead to an extended growing season and hence additional encroachment of vegetation. This has been described as a medium-risk factor.
- **VM7 Prolonged Growing Season:** High raised temperatures leading to increased growth rates and the need for enhanced vegetation clearance and tree cutting schedules. This has been described as a medium-risk factor.
- **VM8 Lightening:** Increased lightning storms leading to increased number tree lightning strikes. This has been described as a medium-risk factor.
- **VM9 Brought:** Change in water content of soil leads to changes in natural habitats of different species. This has been described as a low-risk factor.
- **VM10 Pests, Pathogens, and Invasive Species:** Changes in weather conditions can allow pests, pathogens, and invasive species to appear in the UK, damaging trees leading to additional faults due to falling trees, for example, ash dieback (see Section 6.4.3 of this Annex). This has been described as a medium-risk factor.
- **VM11 Wildfire:** Higher temperatures during summertime can create the conditions for wildfires that can affect trees and electrical infrastructure near them. This has been described as a high to medium risk factor.

Further information on our RIIO-ED2 Vegetation Management (CV29 Tree Cutting) Programme can be found in our Network Operating Costs Strategy (Annex 4A.20) and associated engineering justification papers.

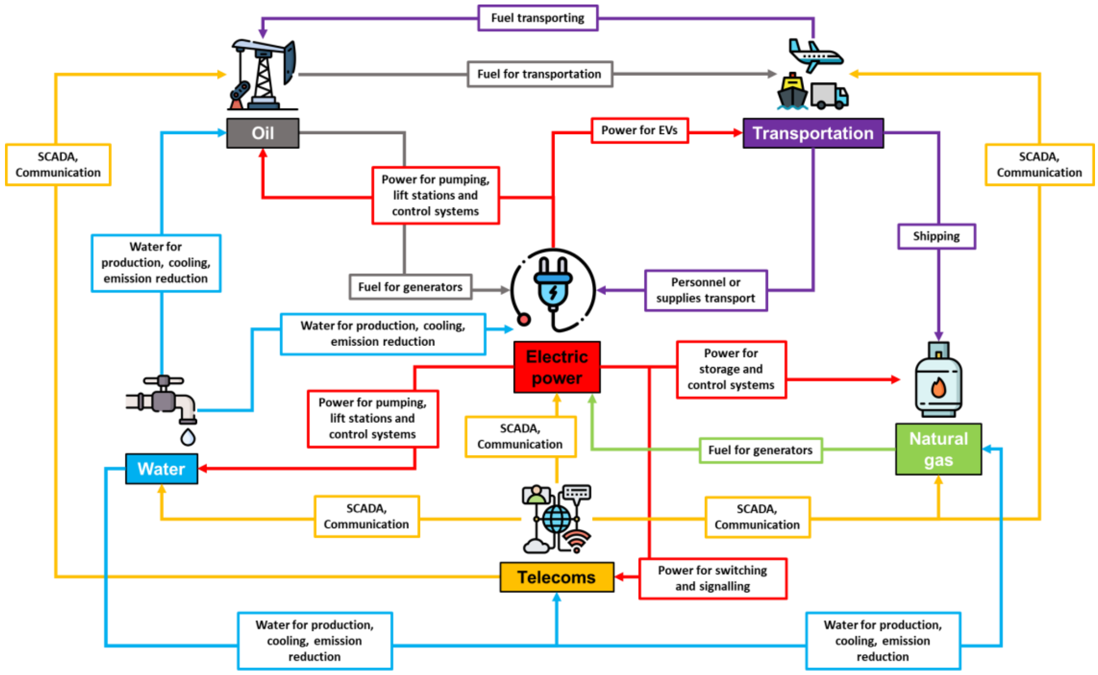
10. Contribution to Cross-Sector Work

Electricity network operators have a crucial role in climate change action since a reliable and resilient electric power supply is a key enabler of the decarbonisation and adaptation efforts of other sectors.

In response to climate change, the UK Government adopted a legally binding obligation to reach Net Zero emissions by 2050. Wales intend to achieve this sooner and Scotland committing to this target by 2045.[56] This ambitious goal requires immediate action across all key technologies and policy areas, and full engagement across society and end consumers, with the energy system evolving to reliably deliver low carbon energy.[57]

In order to achieve Net Zero carbon by 2050 a significant amount of transport and heating will need to be electrified, and renewable electricity generation will need to increase by up to 20.4 GW by 2050.

There are many interdependencies between the power sector and other critical infrastructure sectors such as water, oil and gas, telecommunications, and transportation. These interdependencies are depicted in Figure 15.



Note: SCADA stands for Supervisory Control and Data Acquisition Systems. SCADA is a control system architecture.

Figure 15: Interdependencies between electricity and other critical infrastructure. Adapted from (IEEE, 2020)[58]

One of the most relevant potential interdependencies within the sector in the UK is the knock-on effect that an unreliable electricity supply can have on the gas network. For instance, if electricity supply is interrupted due to a climate impact on the electricity networks, asset operations and gas supplies to customers can be impacted.

Another interdependency can happen when demand for electricity increases. Increasing temperatures, especially during summer times, will lead to the increased use of air-conditioning systems in both commercial and domestic environments, particularly in urban areas.

This in turn will lead to an increase in electricity demand which is often supported by gas-fired generation. This results in a drawdown of gas reserves in the country which could impact domestic supplies as pressures are reduced to meet generation demand. This may also have implications for town and city planning decisions.

To reach Net Zero by 2050, government targets are now for unabated gas generation to be phased out by 2035, increasing pressure on electricity to fill the demand-generation gap[59].

[56] SCOTTISH GOVERNMENT, 2019. Scotland to become a net-zero society [online]. Scottish Government [viewed 26 March 2021]. Available from: https://www.gov.scot/news/scotland-to-become-a-net-zero-society/
[57] NATIONAL GRID, 2020. Future energy scenarios. National Grid [viewed 26t March 2021]. Available from: https://www.nationalgrideso.com/future-energy/future-energy-scenarios
[58] PES-TR83 — Resilience Framework, Methods, and Metrics for the Electricity Sector, IEEE, 2020.
[59] Committee on Climate Change. (2020). The Sixth Carbon Budget; Electricity Generation. [Viewed 13 April 2021]. Available from: https://www.theccc.org.uk/wp-content/uploads/2020/12/Sector-summary-Electricity-generation.pdf

The vulnerabilities associated with interdependencies between the electricity and natural gas systems can be addressed through structural measures (for example, ensuring that natural gas pumping stations have sufficient back-up generation) and improved coordination in planning and operations (for example, ensuring that natural gas supplies are sufficient to meet electricity needs as a result of extreme weather events). The potential impact that can be experienced as a result of the vulnerabilities associated with interdependencies, can be demonstrates by the below case study on the recent Texas Blackouts[60].

Preparing for a resilient energy future; Learning from Texas' rolling blackouts.

February 2021.

As a result of a "significant proportion of power generators not having been sufficiently 'weatherised' to be able to keep operating through severe cold conditions". 45GW of generation was out of action during a snowstorm, with an expected peak demand in Texas of 67GW. This resulted in 4 million electricity customers across Texas undergoing "rolling blackouts".

Lessons learned include:

1. Make sure we can meet demand
2. Understand the complex challenges weather events can pose, specifically in relation to the interdependencies of the of critical infrastructure sectors.
3. Be Prepared: Ensure we are building a system that is resilient to future impacts.

The challenge presented to the electricity distribution network as a result of Net Zero can be presented in many forms. The switch to hybrid or Electric Vehicles (EV) by 2030 in the UK associated with the ban on the sale of new petrol and diesel cars and vans in 2030 and new hybrid cars by 2035, will increase demand on the distribution network from charging infrastructure[61]. Additionally, a greater proportion of renewable generation in the overall mix of the grid, will put greater demand on the distribution system. This will result in the need for an increase in network interventions to facilitate the connection of renewable generation and to enable distribution systems to better manage multi-directional flows of electricity.

The interactions of the electric power sector with other industrial sectors can also produce risks to the electricity sector. These risks can be caused by failures in other industrial sectors that can cascade and affect the effective functioning of the electricity system. For instance, failures in the telecommunications and road transport sectors are thought to present the highest risk to the electric power sector.

Telecommunications are already important for automated and remotely controlled equipment, as well as for communication with personnel in the field. The risk from telecommunications failure has the potential to increase in the future with greater reliance on smart systems (dependent on telecommunications). Road transport is often essential for the restoration of supply and access to assets for routine maintenance and emergency restoration.

Due to the complex nature of these interdependencies, collaboration amongst key stakeholders is vitally important. Addressing system-wide resilience issues will require strategic investment involving the participation of different stakeholders and organisations at different geographical scales. We will build on works from the Energy Network Association (ENA), such as the Climate Change Resilience WG, Open Networks, as well as projects involving multi-energy vectors like Cheshire Energy Hub.

As stated by ENA, the electricity network operators are aware that other infrastructure operators and society in general are reliant on having a reliable and resilient electricity supply. The role in climate change action from electricity networks is crucial as it is a key enabler of the decarbonisation of other sectors such as transport, heat, industry, building and waste and for different adaptation efforts in the UK. SP Energy Networks, like other Distribution Network Operators and National Grid Electricity System Operator, will continue to work to ensure that the UK electricity network remains one of the most reliable networks in the world and climate change is one of the impacts considered when developing and reinforcing those networks.

[60] UKERC (2021). Preparing for a resilient energy future' learning from Texas' rolling blackouts.[ONLINE] [13 May 2021] Available at: https://ukerc.ac.uk/news/preparing-for-a-resilient-energy-future-learning-from-texas-rolling-blackouts/

[61] UK Government. (2020). News Story: end of sale of new petrol and diesel cars by 2030. [Viewed 13 April 2021]. Available from: https://www.gov.uk/government/news/government-takes-historic-step-towards-net-zero-with-end-of-sale-of-new-petrol-and-diesel-cars-by-2030

11. Monitoring and Evaluation

This section outlines the framework for Monitoring and Evaluation (M&E) that we will put into place to ensure that the pathways outlined as part of this Climate Resilience Strategy (CRS) are appropriately implemented.

M&E is a fundamental pillar of the adaptation pathways approach, the processes of which work together to assess the performance of an intervention over time. Effective M&E is an essential part of our CRS and can inform best use of resources, increase understanding of changing risks, and inform decision making and investment.

Monitoring refers to the on-going analysis of the progress of actions as they are being implemented to ensure they are proceeding as planned.

Evaluation is the periodic assessment of the results of monitored resilience actions.

11.1 Roles and Responsibilities

The following roles and associated responsibilities have been identified for internal allocation/appointment within SP Energy Networks as part of the M&E framework, beginning formally prior to RIIO-ED2.

Resilience Coordinator: The Resilience Coordinator, to be appointed internally, will hold the following role:

- To oversee the implementation of the appropriate pathways and application of the M&E approach,
- Help identify Resilience Champions (see below) who will advocate for resilient outcomes in each of the Function categories,
- Collaborate with Resilience champions to ensure proper progress in monitoring and evaluation is completed,
- Coordinate the production of the appropriate reporting requirements; and,
- Communicate with the internal Business Assurance Team to incorporate climate risks into our current Enterprise Risk Management Framework.

Resilience Champions: For each function category identified within the CRS, an internal Resilience Champion will be identified. These individuals would be responsible for monitoring and implementing the M&E process for their function category. Reporting to the Resilience Coordinator, Resilience Champions will determine appropriate stakeholders within the business for data collection and will be responsible for compiling and developing the appropriate reporting content for their function category.

It is expected that Resilience Champions across function categories work collaboratively, especially on cross-cutting pathways, to help ensure efforts to make us more resilient are not ‘siloed’ within one function category.

11.2 M & E Framework

The diagram in **Figure 16** highlights the key elements of the M&E framework to be adopted as part of the adaptation pathways methodology utilised within the CRS.

This framework ensures that the key climate risks identified are regularly reviewed, alongside assessing whether the current adaptation approach being implemented are sufficient to mitigate against the potential impact of future climate risks. If the adaptation approach is currently sufficient, then it should be maintained and monitored on a regular basis. If the approach is not sufficient, then it should be reviewed based on the tipping points and potential future impact of the climate risks.

This monitoring is a continuous process that will be carried out at regular intervals or strategic points in time. The M&E framework for the CRS will be conducted in-line with Ofgem’s 5-year price control review period, with reporting updates provided prior to the next price control submission.

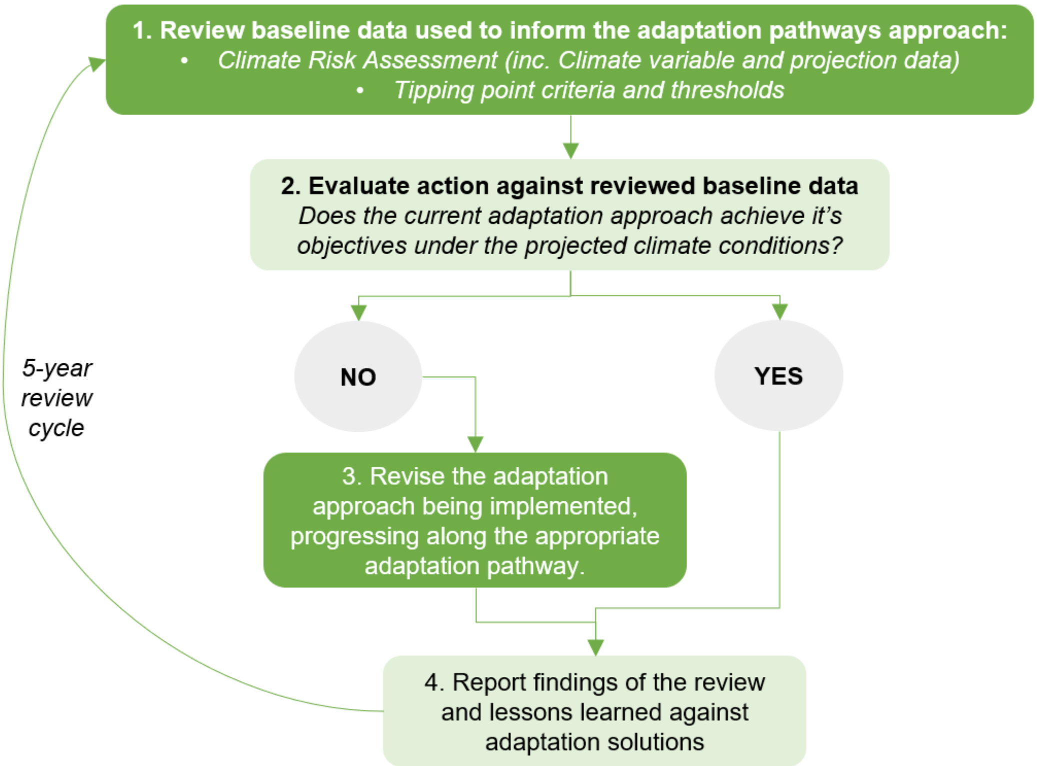


Figure 16: Key monitoring and evaluation steps for SP Energy Networks to maintain climate resilience

1. Monitor and Review Baseline data: Climate Risk Assessment and Tipping Point Criteria/Thresholds.

In order to effectively assess whether the current adaptation approach adopted is enough to mitigate against the impacts of climate change, key climate variables and their associated impacts against the network and business functions should be tracked and analysed to help inform associated consequence ratings applied in the risk assessment. This data will also be evaluated against decision criteria and thresholds used to inform the tipping points within the adaptation pathways approach.

Concurrently, the climate change projection data should be periodically reviewed in the light of any new scientific findings, such as updated Met Office UK Climate Projections or environment agencies (SEPA/EA/NRW) flood risk data.

This review will help inform any required changes to likelihood rating applied to the climate risk assessment, alongside the decision thresholds used by the tipping points. Using a Design Threshold/Climate Variable tipping point perspective example, if the projected maximum temperature values are more severe or climate thresholds are to be reached sooner than originally expected, the adaptation solutions pathway will be revisited, moving to the next solution option in the pathway where necessary.

From a response-led tipping point perspective, if seasonal variability is more severe than expected and therefore growing seasons are extended and this has an impact on the number of observed faults or an increase in the cost/time spent on cutting cycles, then the pathway will be revised. This approach will also help inform current uncertainties within the climate model community, an example being the projections for wind and storminess.

Additionally, the review of the baseline data should also incorporate the latest available information and best practice on climate resilience from our associated stakeholders, such as the Energy Network Association (ENA) Adaptation to Climate Change Task Group. This should also include a review of the risk matrix criteria and definitions applied to ensure they are up to date in light of any new information.

2. Evaluate Actions Against Reviewed Baseline Data.

This stage involves identifying whether each implemented action is having the desired results and impacts, including the evaluation of positive and negative, intended, and unintended long-term effects of the adaptation solutions. This will be undertaken as part of a 'lessons learned' analysis, which is necessary to facilitate learning about what is and what is not working in terms of the adaptation solutions. The review of action performance therefore needs to also identify areas of good practice and areas for improvement. Determining what adjustments need to be made is required in order to maximise the potential for positive impact. Examples of questions to ask include:

- Has there been sufficient flexibility in the adaptation approach to allow alternative courses of action to be pursued?
- Have there been any financial benefits from implementing adaptation actions, for example, cost-benefit analysis, fewer working days lost, more efficient operations?

During this evaluation of the actions, consideration should also be given to whether any observed extreme climate events have had undesired impacts on our network or business operations, or have come close to causing undesired impacts, and review whether operational plans were sufficient.

3. Revise if the adaptation approach being implemented is progressing along the appropriate adaptation pathway.

Based on the review of the baseline information data and the evaluation of the actions, the adaptation pathway should be revised to ensure that an appropriate solution is being implemented that effectively mitigates against future impacts.

4. Reporting

In-line with the 5-yearly price control periods, a report will be produced and presented regarding the CRS which will include a summary of:

- Change in baseline data: Climate Risk Assessment and Tipping Points,
- Action implementation status and any issues encountered including lessons learned,
- Recommendations for revisions to any actions and progression along pathways, and;
- Potential new actions for consideration.

11.3 Integration with existing SP Energy Networks Risk Assessment

We currently apply an Enterprise Risk Management Framework, the purpose of which is to assist in the achievement of both short and long terms goals of the company. The process of which is outlined within the document "BUPR-03-011 Issue No.2[62]".

It is important to ensure that the key climate risks identified within this CRS are integrated and monitored within this risk management framework. Each month, we are required to produce a Key Risk Register (KRR) which is submitted to the SP Energy Networks Holding Board, Iberdrola and the SP Risk Team.[63] In order to produce the monthly KRR, each SP Energy Networks License Area is required to produce an individual KRR and submit it to the Business Assurance for review and consideration.

The individual business unit reports are additionally utilised to populate and update the Asset Risk Register. A draft KRR for the month is tabled at the Executive Performance Meeting for debate, after which it is finalised. It is then submitted to our Holding Board for discussion.

Where possible, Resilience Co-ordinator(s) will communicate with the internal Business Assurance Team and representatives of the areas within SP Energy Networks that the risk reporting covers.

For further information on the risk assessment process, please see SP Energy Networks Guidelines on Risk Reporting document "BUPR-04-011"[62]

[62] SP Energy Networks (2014). Guidelines on Risk Reporting – BPR-04-011. SP Energy Networks.

Appendix I – Adaptation Tipping Points

The following table outlines the detail of the adaptation tipping points utilised within this CRS. It provides the detail around the tipping points that are outlined within section 6 of the main body of the report.

Table 22: Adaptation Tipping Points

Function	New or Legacy	Climate Hazard Flooding *(Surface/Fluvial)*	High Temperatures	Low Temperatures	Growing Season Change	Erosion *(Coastal/Fluvial)*	Drought/Ground Contraction	Storms/High Winds	Sea Level Rise
Network									
Overhead Lines. Cable bridges & towers	Current / New Build	N/A	Conductor temperature for assessing ground clearance, OHL-03-099 and ENA Engineering Recommendation P27: 50°C to 65°C and up to 75°C Ratings for Overhead lines are calculated in relation to the following assumed conditions as per ESDD-02-007 Issue No.7: - Ambient Temperature (Summer) 20°C - Maximum Conductor Temperature: 50°C ENA Engineering Recommendation P27 Seasonal weather parameters Ambient Temperature for HV OHL - Summer (June, July, August) 14°C - Inter. Warm. (May, September, October) 11°C	ENA TS 43-40. Minimum factors of safety on all conductors subject to ice load is 2.0 their nominal breaking loads, with the Maximum Working Tension (MWT) occurring at a minimum conductor temperature of -5.6 °C Ratings for Overhead lines are calculated in relation to the following assumed conditions as per ESDD-02-007 Issue No.7: - Ambient Temperature (Winter) 2°C ENA Engineering Recommendation P27 Seasonal weather parameters Ambient Temperature for HV OHL: - Winter (January, February, December) 4°C - Inter. Cold. (March, April, November) 6°C	Growing Season Change / Maintenance Data ETR 132 - Risk Based Approach	Monitored proximity of Towers and Cable Bridge foundations to, plus erosion rates of riverbanks and costal retreat areas.	N/A	Ratings for Overhead lines are calculated in relation to the following assumed conditions as per ESDD-02-007 Issue No.7 and ENA Engineering Recommendation P27: - Wind Speed: 0.5m/s - Wind Attack Angle: 12°	Capacity of Intervention vs SLR Projections
	Existing / Legacy		Change in the number and duration of faults / Change in maintenance time and cost.	Change in the number and duration of faults / Change in maintenance time and cost.	Change in the number and duration of faults / Change in maintenance time and cost.	Change in the number and duration of faults / Change in maintenance time and cost.	Change in the number and duration of faults / Change in maintenance time and cost.	Change in the number and duration of faults / Change in maintenance time and cost.	
Underground lines, tunnels, and cable routes	New Build Assets	Cable Bridges (BS EN 1990:2002+A1:2005)[64]: - 132KV Cables: 1 in 1000 years plus 500mm - Control cables (pilot, non-electrical cables): 1 in 100 year plus 500mm	ESDD-02-007 Installation parameters of underground cables demonstrates an assumed Summer ground temperature of 15°C (May - October)	ESDD-02-007 Installation parameters of underground cables demonstrates an assumed Winter ground temperature of 10°C (November to April)	N/A	Monitored proximity of UG Cables to, plus erosion rates of riverbanks and costal retreat areas.	ESDD-02-007 Installation parameters of underground cables demonstrates an assumed thermal resistivity of 1.3 K.m/W	N/A	Capacity of Intervention vs SLR Projections
	Existing / Legacy Assets		Change in the number and duration of faults/change in maintenance time and cost.	Change in the number and duration of faults / Change in maintenance time and cost.	Change in the number and duration of faults/change in maintenance time and cost.	Change in the number and duration of faults/change in maintenance time and cost.	Change in the number and duration of faults/change in maintenance time and cost.	Change in the number and duration of faults/change in maintenance time and cost.	

[64] UK Power Networks. 2018. ED2 02-1001. Engineering Design Standard, Cable Design Requirements. V1.0

Function	New or Legacy	Climate Hazard: Flooding *(Surface/Fluvial)*	High Temperatures	Low Temperatures	Growing Season Change	Erosion *(Coastal/Fluvial)*	Drought/Ground Contraction	Storms/High Winds	Sea Level Rise
Substation sites (including switchgear, transformers, cable terminations and earthing)	New Build Assets	ETR 138: Grid Substations 1:1000 year flood contour + 500mm (fluvial, pluvial and coastal) Primary Substations (33kV): (>10,000 unrecoverable connections): 1 :1000 year flood contour +500mm (fluvial, pluvial and coastal) Primary Substations (33kv) (<10,000 unrecoverable connections): 1:100 year fluvial and pluvial flood contour (1:200 in Scotland) and 1:200 contour for coastal flooding throughout GB. Secondary: Sub Not Normally Protected but may require protection in certain circumstances. New stations designed to 1:200 (SPD) and 1:100 / 200 (SPM) Flood maps	Transformers' Current design limits for IEC60076: Max: +40°C New and existing buildings within sub-stations shall be designed to control heating within the daily average ambient external temperature range of -10°C to +30°C SPEN SUB-03-017.[65]	Transformers' Current design limits for IEC60076: Min: -25°C New and existing buildings within substations shall be designed to control heating within the daily average ambient external temperature range of -10°C to +30°C. SPEN SUB-03-017.[6]	N/A	N/A		N/A	Capacity of Intervention vs SLR Projections
	Existing / Legacy Assets		Change in the number and duration of faults/change in maintenance time and cost.	Change in the number and duration of faults/change in maintenance time and cost.	Change in the number and duration of faults/change in maintenance time and cost.	Change in the number and duration of faults/change in maintenance time and cost.	Change in the number and duration of faults/change in maintenance time and cost.	Change in the number and duration of faults/change in maintenance time and cost.	
Network access	N/A	ETR 138: Design access considered to Grid and Primary for 1:1000 year	Number of high-load periods and variation in load balance.	Impact of snow/cold temperature on access to network.	Growing Season Change/Maintenance Data	Monitored proximity of access routes to and erosion rates of riverbanks and coastal retreat areas.	N/A	Impact of storm events and high winds on access to network.	Capacity of Intervention vs SLR Projections
Control infrastructure (communication and control centres)	N/A	Control Infrastructure within Sub-Stations is Designed to ETR138 and associated flood intervals for Grid, Primary and Secondary. Control infrastructure	N/A	N/A	N/A	N/A	N/A	N/A	Capacity of Intervention vs SLR Projections

Business		
Emergency Response & Planning	N/A	Suitability and effectiveness of emergency response / timeframe for recovery
Routine Business (Maintenance, restoration & repairs, capital investment)	N/A	Monitored changes in cost / time spent
Customer Service	N/A	Volume of customer complaints, duration of disruption

[65] SP Energy Networks. N.d. SUB-03-017. Issue No.7. General Specification for the Civil Engineering and Building Design and Construction of Secondary Sub Stations.

Appendix II – Adaptation Solutions

Solutions have been categorised according to their adaptation type, depending on the stage in the process that they fall under: planning, design, standards/specifications, monitoring, or engagement, whether they reduce exposure or sensitivity. Any solutions which are Nature-Based Solutions[66] are highlighted. Table 20 defines these categories.

Table 23: Definition of categorisation of adaptation solutions

Term	Definition
Reduce Exposure	Changing the location, attributes, and value of assets that could be affected by a climate risk
Reduce Sensitivity	Reducing the likelihood that assets will be affected when exposed to a climate risk
Adaptation Type	Planning: Determining the level of risk, and developing plans to set out the approach to deal with the climate risk Monitoring: Assessing how the risk changes over time, and any external factors such as load patterns Standards/Specifications: Specific requirements Design: Structural changes Engagement: Communication approach with key stakeholders
Nature Base Solution	Any solutions using natural approaches have been indicated with this symbol 

For each adaptation solution, it's alignment with the SP Energy Networks sustainable business strategy and six sustainability drivers has been indicated in the solutions table using the icons displayed in Figure 14.

Figure 17: SP Energy Networks Sustainable Business Strategy Sustainability Drivers

[66] Nature-Based Solutions are defined by the IUCN as "actions to protect, sustainably manage, and restore natural or modified ecosystems, that address societal challenges effectively and adaptively, simultaneously providing human well-being and biodiversity benefits". https://www.iucn.org/commissions/commission-ecosystem-management/our-work/nature-based-solutions

Table 24 Adaptation solutions for high temperatures

Adaptation solution	Risk	Source	Sustainability Driver
Planning: Develop a 'Hot Weather Working Plan', which considers flexible working/hours for outsider workers during key heat hours.	ER7 RB6 CS7	CRS Workshop 2[67]	
Planning: Review existing network capacity against anticipated future demand changes caused by increased cooling requirements (for example, air conditions) during hot spells.	AR7 AR8 SP1 ER6	AECOM[68]	
Planning: Identify and purchase (where appropriate) the PPE that is utilised by outdoor workers in other countries such as Spain, which currently experience higher ambient temperatures.	RB6	Adapted from other DNO CRS	
Planning: Have processes in place to enable staff to work from home where possible during heatwaves	ER7 CS7	AECOM	
Planning: Policy to deal with high amounts of staff off sick; staff reallocation	ER7 CS8	AECOM	
Monitoring: Ongoing trials in the Manweb area on the use of dynamic overhead line (OHL) ratings based upon measured weather (solar gain and wind speed) conditions, building on dynamic thermal rating actions in the Load Related Plan.	AR1	SP Energy Networks[69]	
Monitoring: An ongoing research & development project on underground cable rating monitoring, which aims to understand actual rating of power cables, instead of relying on the traditional calculated cable rating	AR4	SP Energy Networks	
Monitoring: Annual review of network loadings ensure adequate headroom and options for shifting / moving of load onto and alternative route within the network	AR7 AR8 SP1 ER6	Adapted from other DNO CRS	
Standards: Company-level 132kV cable specification has been developed jointly with Spain, to apply to assets in both the UK and Spain, given SP Energy Networks is part of Iberdrola. The same cables are specified for both countries, with different ratings due based on different ambient conditions. As a consequence, cables used in the UK will have built-in resilience to future temperature increases, since they are currently also specified for use in Spain.[70]	AR4	SP Energy Networks	
Standards: Cables – ground contraction and overheating. Update specifications / build standards.	AR4	SP Energy Networks	
Design: Locate standard-design substation buildings to ensure that air intake is located on the cooler, shady side of the building	AR9	SP Energy Networks	
Design: Revise substation building specification/design standards to incorporate further passive design considerations such as; orientation, material use, vegetation for natural shading.	AR9	CRS Workshop 2	
Design: SPEN will explore the wider adoption of new transformers with thermally upgraded solid insulation and alternative liquids, while deploying these where it is cost-beneficial to do so.	AR7	CRS Workshop 2	

[67] Risks with the source 'CRS Workshop 2' were derived from the workshop held on the 7th April 2021, to finalise the discussion about the tipping points identified and begin discussing potential adaptation solutions that could build on existing approaches to reduce future risks

[68] All 'AECOM' sourced solutions were developed by consultants specifically for the SP Energy Networks Climate Resilience Strategy based on their experience

[69] All 'SP Energy Networks' sourced solutions were derived from Internal knowledge on the organisation's current practices

[70] The variation in cost due to this additional ambient temperature rating is minimal and it is not anticipated that this drives and inefficiency in procurement, or over-specification of assets.

Design: SPEN will increase the use of alternative liquids (for example, esters) for retro-filling existing mineral oil filled transformers to achieve uprating, while realising fire safety and environmental benefits.	AR7	CRS Workshop 2	
Design: Planting trees for natural shading, with consideration for vegetation management and high winds/storms.	AR9	AECOM	
Design: Switch rooms and plant enclosures are designed to maximise the use of natural ventilation to keep internal temperatures within plant and equipment operating within their optimum parameters. Where heat build-up is perceived to be an issue forced ventilation is used and, in extreme cases or where the path to an external air inlet is problematic, air conditioning is considered.	AR9	SP Energy Networks	
Design: Reduction of span between towers for OHL to counteract the loss of clearance through thermal sagging.	AR2	CRS Workshop 2	
Design: Installation of taller poles during pole replacement programmes in order to counteract the loss of clearance through thermal sagging.	AR1	SP Energy Networks	
Design: Review installation practices/design standards for laying new underground cables with consideration for thermal resistivity. Examples include laying cables in sand or increasing cable depth.	AR4	CRS Workshop 2	
Engagement: Telephone calls and local visits (door-knocker team) to specific customers, customer groups and organisations who can provide assistance and engage locally.	CS8	SP Energy Networks	
Engagement: Priority Services Register maintained and supported by a number of on-going initiatives to ensure it is current.	CS8	SP Energy Networks	
Engagement: Proactively contact vulnerable customers and work with local responders to ensure that vulnerable members are offered advice and assistance where necessary.	CS8	SP Energy Networks	

Table 25: Adaptation solutions for low temperatures

Adaptation solution	Risk ID	Source	Sustainability Driver
Planning: Revise current Outage and Maintenance Planning to consider a reduction in the outage season due to heightened demand for heating in the Winter months and Cooling in the Summer Months.	RB3	AECOM	
Planning: Increasing the training of staff and provision of PPE to accommodate an increase in the need for more 'Live' working.	RB3	CRS Workshop 2	
Planning: Plan alternative access routes to key assets during extreme weather events.	ER2	AECOM	
Planning: Engage with local authorities so that they incorporate the gritting of access routes to key grid and primary substations before forecasted extreme low temperatures within their existing approach	ER2	AECOM	
Planning: Have processes in place to enable staff to work from home where possible during extreme cold spells	RB8	AECOM	
Monitoring: Annual review of network loadings through Load Index Submission and Long-Term Development statement to ensure adequate headroom and options for shifting/moving of load onto and alternative route within the network.	ER4	Adapted from other DNO CRS	
Design: Revise SPENs current modernization Strategy (OHL-01-009)/refurbishment policy (OHL-01-010) in the next 5-year review cycle to better consider resilience of OHL to potential extreme temperature and temperature fluctuation.	ER1	AECOM	
Design: Installation of electrical heaters in sub-station buildings, controlled by thermo-switches, to manage internal temperatures.	RB4	SP Energy Networks SUB-03-017[71]	
Design: Explore potential design and maintenance features to mitigate ice and snow build-up on overhead lines.	VM4 RB4	AECOM	
Engagement: Government/Local Authority Emergency Control Centres attended/interface with; Deployment of Emergency Action Centres (HO and local with central coordination).	CS9	SP Energy Networks	
Engagement: Priority Services Register maintained and supported by a number of on-going initiatives to ensure it is current.	CS9	SP Energy Networks	
Engagement: Telephone Calls to specific customers, customer groups and organisations who can provide assistance and engage locally. Use established communications channels; Red Cross, Meals on wheels.	CS9	SP Energy Networks	
Engagement: Local Visits such as house to house calls ('Door-knocker team') for vulnerable customers during extreme events.	CS9	SP Energy Networks	
Engagement: Catering vans deployed in affected communities	CS9	SP Energy Networks	
Engagement: Use of social media to inform and engage customers	CS4	SP Energy Networks	

[71] General Specification For The Civil Engineering And Building Design And Construction Of Secondary Substations: SUB-03-017

Table 26: Adaptation solutions for flooding

Adaptation solution	Risk ID	Source	Sustainability Driver
Planning: Build understanding of where staff are located against flood mapping. Carry out a transport survey to understand what methods are used by staff, informing the policy/processes. Have processes that enable staff to work from home where possible/appropriate if their routes to work are affected by flooding and communicate contingency procedures for when key members are unable to get into work.	RB7	AECOM	
Planning: Train appropriate 'fault response staff' in how to access assets (for example, substations) that are inundated/where access restricted due to flood waters, providing specialist flood PPE where required.	CS2	AECOM	
Planning: ETR 138, Step 1: Identify all substations at risk of flooding (review substation locations against latest Environment Agencies flood maps)	AR10 AR13	SPEN - ED2-NLR(A)-SPEN-003-RES-EJKP Issue 1 - CV16 Flood Resilience	
Planning: ETR 138, Step 2: Undertake Detailed Flood Risk Assessments (determine site specific flood risk and potential depth of flooding)	AR10 AR13	SPEN - ED2-NLR(A)-SPEN-003-RES-EJKP Issue 1 - CV16 Flood Resilience	
Planning: ETR 138, Step 3: Undertake Impact Assessment (using outcome of Step 2 determine impact of flood even on the substation and wider network).	AR10 AR13	SPEN - ED2-NLR(A)-SPEN-003-RES-EJKP Issue 1 - CV16 Flood Resilience	
Design: ETR 138, Step 4: Investigate options for Flood Protection of new and existing substations, such as: - Permanent Barriers - Demountable Barriers - Temporary Barriers - Re-location	AR10 AR13	SPEN - ED2-NLR(A)-SPEN-003-RES-EJKP Issue 1 - CV16 Flood Resilience	
Design: ETR 138, Step 5: Proceed with Appropriate solution based on flood risk (select favoured option identified in Step 3 that best fits the substation at risk).	AR10 AR13	SPEN - ED2-NLR(A)-SPEN-003-RES-EJKP Issue 1 - CV16 Flood Resilience	
Planning: During the occurrence of a flood event, prioritise the identification and repair of secondary substations that are at risk of flooding, whilst supplying built-up areas that are not impacted by the flood.	AR10 AR13	WORKSHOP	
Monitoring: Incorporate the monitoring and surveying of tree root exposure into current vegetation management practices where appropriate.	VM1	AECOM	
Monitoring: Maintain and improve relationship with Scottish Environment Protection Agency (SEPA), Natural Resources Wales (NRW) and Environment Agency (EA) to obtain updated information on coastal and river flooding, building on the EA's 2021 to 2026	AR10 AR13	SP Energy Networks	

National Flood and Coastal Erosion Risk Management Strategy and work with the agencies for joint flood mitigation where feasible.			
Monitoring: Continue Weather forecast review in-line with current emergency response protocols.	AR10 AR13	SP Energy Networks	
Monitoring: Incorporate into business as usual, the repair, maintenance, and on-going inspection of flood defence assets at substations, for example, alarms on failure of equipment such as flood pumps and the seals of flood gates.	RB1	SP Energy Networks Climate Resilience Interview Minutes - David	
Standards: Compliance to ETR 138 "Resilience to Flooding of Grid and Primary Substations". Our strategy is to work towards compliance with flood risk for grid and primary substation sites as set out below, using the latest up to date flood mapping data: Grid Substations: • Protect against Pluvial, Fluvial and coastal flooding to 1:1000 levels Primary Substation: • Protect against Pluvial, Fluvial and coastal flooding to 1:1000 levels (Substations >10,000 un-recoverable customers) or • Protect against Pluvial, Fluvial and coastal flooding to 1:100/1:200 levels (Substations <10,000 un-recoverable customers)	AR10 AR13 CS1	SP Energy Networks	
Design: Any new substations are to be constructed at a level above any potential flooding	AR10 AR13	SP Energy Networks	
Design: When designing substations, take climate change effects, adding 10% into design level, and then another 300m minimum on top of that.	AR10 AR13	SP Energy Networks	
Design: Incorporated 1 in 1000-year design requirements on design of grid/primary sites from point of re-fresh/replacements. I.e. replace in 2050 – design at 1 in 1000 year from 2050 onwards.	AR10 AR13	SP Energy Networks	
Design: Actively invest in flood management at lower criticality substations given the greater frequency and severity of flood events resulting from climate change.	AR10 AR13	SP Energy Networks	
Design: Portable flood defence equipment deployed at strategic locations (for example, aqua sack, barriers, high speed pumps)	AR10 AR13	SP Energy Networks	
Design: Include the use of natural flood management solutions in addition to concrete solutions while flood-proofing substations. Ideally, SPEN should thrive to use only nature-based solutions with grey infrastructure used as a last resort.	AR10 AR13	SP Energy Networks	
Design: Implementation of SuDs (Sustainable Drainage System) and WSUD (Water Sensitive Urban Design) in new and existing substations with a focus on nature-based solutions where appropriate, such as: - Natural retention pools - Green Roofs - Permeable Surfaces	AR10 AR13	CRS Workshop 2	
Design: Use LIDAR and GIS technologies to identify areas within the proximity of the transmission network that are suspectable to soil erosion that could impact tower foundations and/or tree roots as a result of high-water flows.	NG3	AECOM	
Engagement: Use of social media to inform and engage with customers	SP3b	SP Energy Networks	
Engagement: Collaborate with Local Authorities, in addition to National Agencies, so to include appropriate SP Energy Networks colleagues as consultees in the revisions and/or development of local flood strategies	CS1 CS2	CRS Workshop 2	

Table 27: Adaptation solutions for increased growing season

Adaptation solution	Risk ID	Source	Sustainability Driver
Planning: Revise the current procurement strategy in favour of retaining vegetation management contractors beyond a single 3-year cutting cycle.	AR3 VM6 VM7	SP Energy Networks Climate Resilience Interview Minutes - Graeme	
Planning: Continue to extend the current "falling distance" measures used on main lines in the ETR 132 Cycle (Cut for Risk) to Spur Lines.	AR3	SP Energy Networks Climate Resilience Interview Minutes - Graeme	
Monitoring: Manage vegetation to a storm resilient standard in coordination with overhead line rebuild or construction works. Most effectively, this method can achieve the complete removal of risk by re-routing the overhead line away from trees and vegetation.	AR3 VM8	SP Energy Networks	
Monitoring: Increase cutting a clearance. Cutting a clearance of 3m plus 3 years growth to 4m of clearance rather than 3.5m	VM6 VM7	SP Energy Networks	
Monitoring: Vegetation Management programme subject to regular reviews in line with SP Energy Networks 5-year maximum review cycle.	AR3 VM6 VM7	Adapted from other DNO CRS	
Monitoring: Create an internal "Wildfires Subgroup" (SPD & SPD) and ensure appropriate SP Energy Networks Colleagues participate in international collaborations on Wildfire Risk Management.	VM11	Adapted from other DNO CRS	
Monitoring: Further expand the use of LIDAR and Drone software and analyse historical data of cuts/faults across circuits to better understand trees at risk, therefore identifying those that need to be either felled or cut more frequently in-line with the ETR 132 Cycle.	AR3 VM6 VM7	SPEN Climate Resilience Interview Minutes - Graeme	
Design: Review safety distances outlined within the Vegetation Management Plan for high and low voltage lines in relation to objects, informed by cutting and faults data.	AR3	SPEN Climate Resilience Interview Minutes - Graeme	
Monitoring: Increase the use of Eco Plugs as a growth retardant to stop re-growth in Vegetation Management Plan.	AR3 VM6 VM7	CRS Workshop 2	

Table 28: Adaptation solutions for sea level rise

Adaptation solution	Risk ID	Source	Sustainability Driver
Planning: Policy for emergency planning (EP) and major incident management in place and subject to regular review.	SP3a	Adapted from other DNO CRS	
Planning: Train appropriate 'fault response staff' in how to access assets (for example, substations) that are impacted by coastal flooding/erosion, providing specialist PPE where required.	CS13	AECOM	
Monitoring: Actively undertake asset condition monitoring on concrete foundations on sites located in the proximity of the coast, or in coastal erosion hotspots, exploring the use of LIDAR assessments to assess condition risk where appropriate.	NG1 NG2 NG4 AR10	Adapted from other DNO CRS	
Monitoring: Incorporate the monitoring and surveying of tree root exposure associated with coastal erosion and flooding into current vegetation management practices where appropriate.	VM1	Adapted from other DNO CRS	
Standards: Compliance to ETR 138: Our strategy is to work towards compliance with flood risk for grid and primary substation sites as set out below, using the latest up to date flood mapping data: Grid Substations • Protect against coastal flooding to 1:1000 levels Primary Substation • Protect against coastal flooding to 1:1000 levels (Substations >10,000 un-recoverable customers) or • Protect against Coastal flooding to 1:100/1:200 levels (Substations <10,000 un-recoverable customers)	AR10 RB2 CS2	SPEN	
Design: Any new substations are to be constructed at a level above any potential coastal flooding and erosion.	AR10 RB2 CS3	SPEN	
Design: Work with coastal landowners to develop natural coastal protection; coastal restoration, salt marsh reintroduction, dune naturalisation	AR10 RB2 CS3	AECOM	

Table 29: Adaptation solutions for drought

Adaptation solution	Risk ID	Source	Sustainability Driver
Planning: Determine through monitoring/research, the critical groundwater levels and soil moisture index that can cause ground movement.	AR2 AR5 AR17	AECOM	
Planning: Integrate water demand management practices into office buildings and associated management policies, with a focus on Water Sensitive Urban Design (WSUD) principles.	CS11	AECOM	
Monitoring: Incorporate the analysis of the potential impact from ground movement on poles and towers within the statutory 6-yearly inspection cycles and condition assessments.	AR2	Adapted from other DNO CRS	
Monitoring: Implement a monitoring system to observe the changes in Earthing Values of underground cables as a result of changing moisture content.	AR2 AR5 AR17	SPEN Climate Resilience Interview Minutes - Jamie	
Monitoring: Review earthing specifications against changes in experienced drought severity and frequency.	AR6	Adapted from other DNO CRS	
Monitoring: Through the occurrence of faults, identify those sites most suspectable to drought-induced ground movement and implement a monitoring system to inform warning systems and maintenance.	AR2 AR5 AR17 AR18	AECOM	
Design: Determine appropriate mitigation measures to help restore earthing values of underground cable to appropriate limit, for example, wetting the ground.	New	SPEN Climate Resilience Interview Minutes - Jamie	
Design: When planting vegetation as part of a SP Energy Work programme or solution, use native drought tolerant species.	VM3 VM9	AECOM	
Design: Ensure that the appropriate new construction and replacement policies for underground cables account for the appropriate flexibility of cables to anticipated ground movement due to drought conditions.	AR5	AECOM	

Table 30: Adaptation solutions for storms and high winds

Adaptation solution	Risk ID	Source	Sustainability Driver
Planning: Increase baseline understanding of the resilience of the existing legacy 11kV 33kV network, undertaking LIDAR analysis for ground clearance and associated calculation of likely conductor SAG (as current completed on the transmission network).	AR15	SPEN Climate Resilience Interview Minutes - Jamie	
Monitoring: 40% of the network to be storm resistant by 2034 (it is desirable to exceed this). This is a different type of cut where it is a risk. An ETR 132 maintenance cut is then undertaken on the compliant sections every 3 years and an ENA TS43-8 maintenance cut on non-compliant sections, cutting trees that are at risk. Removing anything deemed a fall risk by the surveyor (through LIDAR).	VM5	SPEN	
Monitoring: Routinely reviewing our response following major storm events to identify where we can improve our performance further.	ER3 RB5	SPEN	
Design: By 2034 over 40% of all interconnected 11kV and 33kV OHL networks will be rebuilt to a storm resilient standard, such that a severe weather event should not affect any connected customer for more than 36 hours.	AR15 NG4	SPEN	
Monitoring: Further expand the use of LIDAR software and analyse historical data of cuts/faults across circuits to better understand trees at risk, therefore identifying those that need to be either felled or cut more frequently.	VM5	SPEN Climate Resilience Interview Minutes - Graeme	
Monitoring: Improve deployment of control/monitoring technology on the network in order to identify fault locations more easily.	ER3 VM5	SPEN Climate Resilience Interview Minutes - Catherine	
Design: Revise the minimum clearance distances (m) for both high and low voltage lines.	VM5	SPEN Climate Resilience Interview Minutes - Catherine	
Design: Collaborate with the EA, SEPA and NRW to update and develop new weather maps for use in construction specification documents at regular recurrence intervals.	AR15	SPEN Climate Resilience Interview Minutes - Jamie	
Design: Revise our current modernization Strategy (OHL-01-009)/refurbishment policy (OHL-01-010) in the next 5 year review cycle to better consider the re-build of legacy network assets which do not meet current new build design standards and the necessary consideration of climate resilience.	AR15	SPEN Climate Resilience Interview Minutes - Jamie	

Appendix III – Pathway Assumptions

The below table outlines the assumption made in the creation of the "high temperature" adaptation pathways diagram displayed in Figure 7.

Risk Action Addresses	Adaptation Solution	Adaptation Solution (Diagram)	Assumptions/Comments
AR7	SPEN will increase the use of alternative liquids (for example, esters) for retro-filling existing mineral oil filled transformers to achieve uprating, while realising fire safety and environmental benefits.	Retro-filling of existing transformers with alternative liquids	Transformers can work well up to temperatures of 40ºC so we pushed the changes in transformers as late as possible. It is assumed that the decision points will happen when the maximum daily temperatures reach more frequently more than 40ºC in the future. It is assumed that these actions will be effective in the long term, that's why they end in an arrow.
AR7	SPEN will explore the wider adoption of new transformers with thermally upgraded solid insulation and alternative liquids, while deploying these where it is cost-beneficial to do so.	Adopt new transformer technologies	
AR4	Cables – ground contraction and overheating. Update specifications/build standards.	Update specifications and building standards for UG cables	The update of specifications for UG cables is connected only to legacy assets. These updates are assumed to be effective in the long term, that's why they end in an arrow.
AR4	Review installation practices/design standards for laying new underground cables with consideration for thermal resistivity. Examples include laying cables in sand or increasing cable depth.		
AR9	Planting trees for natural shading, with consideration for vegetation management and high winds/storms.	Use vegetation for natural shading in the network	It is assumed here that some legacy assets can benefit from vegetation providing natural shading, that's why the pathways are connected. It is also assumed that this is going to be a continuous practice by SPEN, that's why it ends in an arrow.
AR9	Switch rooms and plant enclosures are designed to maximise the use of natural ventilation to keep internal temperatures within plant and equipment operating within their optimum parameters. Where heat build-up is perceived to be an issue forced ventilation is used and, in extreme cases or where the path to an external air inlet is problematic, air conditioning is considered.	Forced Ventilation, and air conditioning in substation buildings.	It is assumed here that some legacy assets will require forced ventilation and air conditioning, that's why the pathways are connected. It is also assumed that this is going to be a continuous practice by SPEN in some sites, that's why it ends in an arrow.
AR9	Locate standard-design substation buildings to ensure that air intake is located on the cooler, shady side of the building	Incorporate passive cooling design for sites and	It is assumed that this is going to be a continuous practice by SPEN, that's why it ends in an arrow.

AR9	Revise substation building specification/design standards to incorporate further passive design considerations such as; orientation, material use, vegetation for natural shading.	substations (SPEN SUB-03-017)	
N/A	N/A	Legacy assets built to old specifications	It is assumed that the max summer temperature reaching 20ºC will trigger changes in the network, especially updates in the legacy assets. The dashed line and the interrogation mark show that there is uncertainty on when all the legacy assets will be updated by SPEN. It is assumed that this will happen around the 2050s.
AR4	Company-level 132kV cable specification has been developed jointly with Spain, to apply to assets in both the UK and Spain, given SP Energy Networks is part of Iberdrola. The same cables are specified for both countries, with different ratings due based on different ambient conditions. As a consequence, cables used in the UK will have built-in resilience to future temperature increases, since they are currently also specified for use in Spain.	Company-level 132kV cable specification (OHL-03-099 and ESDD-02-007)	The specification has been developed for both the UK and Spain. It is assumed that the cables will be resilient to the UK climate if they are to the Spanish climate. It is assumed that the specification will be effective in the long term, that's why it ends in an arrow.
AR2	Reduction of span between towers for OHL to counteract the loss of clearance through thermal sagging.	Reduction of span between towers for OHL	It is assumed that the max summer temperature reaching 20ºC will trigger the decision to reduce spans between towers of OHL. The reduction of spans is assumed to be effective in the long term, that's why it ends in an arrow.
AR1	Installation of taller poles during pole replacement programmes in order to counteract the loss of clearance through thermal sagging.	Installation of taller poles for OHL	It is assumed that the max average summer temperature reaching 22ºC will trigger the decision to install taller poles as an additional measure for OHL. This measure is assumed to be effective in the long term, that's why it ends in an arrow.

SP ENERGY NETWORKS

SP Energy Networks
320 St Vincent Street
Glasgow, G2 5AD

Contact us
facebook.com/SPEnergyNetworks
twitter.com/SPEnergyNetwork
RIIO_ED2@spenergynetworks.co.uk
spenergynetworks.co.uk