Climate Resilience Strategy

SP Energy Networks
RIIO-T3 Business Plan

SP Energy Networks

Index

1. Glossary

Acronym:	Description:
AOD	Above Ordnance Datum
ARP	Adaptation Reporting Power
CCC	Climate Change Committee
CCRA	Climate Change Risk Assessment
CRS	Climate Resilience Strategy
DEFRA	Department for Environment, Food and Rural Affairs
ENA	Energy Networks Association
EAP	Environmental Action Plan
GHG	Greenhouse gas
HILP	High Impact Low Probability
IPCC	Intergovernmental Panel for Climate Change
NbS	Nature-based Solutions
Ofgem	Office of Gas and Electricity Markets
RCP	Representative Concentration Pathway
RIIO-T3	Revenue = Incentives + + Outputs
SEPA	Scottish Environment Protection Agency
SPD	SP Distribution plc
SPEN	Scottish Power Energy Networks
SPM	SP Manweb plc
SPT	SP Transmission plc
SSEN	Scottish and Southern Electricity Networks
SSP	Shares Socio-Economic Pathways
UKCP18	United Kingdom Climate Projections 2018

2. Introduction

Climate change is creating unprecedented risks and uncertainties for businesses globally, with extreme weather events and climate hazards expected to increase and worsen in the coming decades. (IPCC, 2022) The Energy Sector plays a key role in enabling Scotland and the UK more broadly to reach their decarbonisation targets including Net Zero by 2045 and 2050 respectively.

SP Transmission (SPT) plays a crucial role in connecting renewable and low carbon energy generation within our licence area. We own a high voltage transmission network that facilitates the reliable transfer of renewable energy to customers in our licence area and across the UK. For this to be achieved we must first ensure that we have a climate resilient energy network.

This Climate Resilience Strategy (CRS) outlines how SPT will maintain a safe and resilient transmission network in response to climate change and its associated risks. The CRS has been developed as part of our RIIO-T3 Business Plan submission to Ofgem. Further detail on the requirements for SPEN to undertake a CRS can be found in Error! Reference source not found..

The scope of our CRS is split into two main parts:

The Climate Risk Assessment – this section identifies and assesses the climate risks that pose a threat to our transmission network within our SPT licence area.

The Adaptation Solutions and Pathways – this section identifies and outlines the subsequent adaptation measures and pathways to mitigate the impacts of the climate risks.

The CRS will build upon our work already undertaken to date with regards to climate change risk and resilience, as well as utilising the findings and outcomes from the SPEN Climate Change Adaptation Report – Round 3 Update (2021) (SPEN, 2021). This will allow us to establish a solid understanding of climate risk and best practice climate adaptation decision making that will support our long-term response to climate change.

2.1. SPEN Transmission Network Overview

SPT's transmission network is located in Central and Southern Scotland providing supply to the SP Distribution Network and connection to other transmission networks to the north and the south. Our transmission network operates at voltages of 400kV, 275kV, 132kV and 33kV and provides connections to many renewable generation sources.

The scope of this CRS will be limited to assessing our transmission network's vulnerability and resilience to climate change in the SPT licence area. The transmission network consists of three main asset types as shown in Figure 2

Figure 1: SPEN Transmission Asset Types

2.2. Legislation, Regulation, Policy and Guidance Documents

This section outlines the key legislation, policies and guidance documents used to inform the methodology and content of the CRS.

Table 1: Policy and Guidance Review

Name of Document	High level overview of the Document	Relevance to CRS
The UK Climate Change Act 2008[1]	Carbon management. Transition to a low carbon economy. Investment in low carbon goods. Provide an international signal.	Sets government requirement to report on the climate change risks expected to impact GB, along with a programme on how these risks will be addressed, at a minimum of every five years. Climate change risks identified and assessed in these national reports helped to inform the climate change risk assessment in our CRS.
UK The Third National Adaptation Programme (NAP3)[2]	Actions that government and others take to adapt to the impacts of UK climate change from 2023 to 2028. Contains the strategy for the fourth round of climate adaptation reporting under the ARP.	The climate risks and subsequent actions to address these risks, outlined in the NAP3, were considered when developing the adaptation measures for this CRS.
Adaptation Reporting Power (ARP)[3]	Gives UK Government the power to require companies to report on their preparedness for climate change, under the ARP.	Our responses to the ARPs were used to inform this CRS.
The Climate Change (Scotland) Act 2009[4]	Emissions target for the year 2050 for a reduction of at least 80% from the baseline year 1990.	Findings from these strategic programmes helped to inform this CRS highlighting key climate risks facing Scotland and subsequent adaptation measures. Scottish Government required to prepare strategic climate change adaption programs following each round of UK Climate Change Risk Assessments.
Climate Change (Emissions Reduction Targets) (Scotland) Act 2019[5]	More ambitious emissions reduction target to reach net zero by 2045.	Scottish Government must prepare Scottish Climate Change Adaptation Programmes, considering and addressing the risks set out in the UK Climate Change Risk Assessment 2017. The requirements under this Act helped inform this CRS.
The Scottish Climate Change Adaptation Programme (SCCAP) 2019-2024[6]	Addresses the impacts identified for Scotland in the UK Climate Change Risk Assessment. Sets out the Scottish Governments objectives in relation to adaptation to climate change.	The findings of the SCCAP were used to identify and inform the climate change risks and subsequent adaptation measures for this CRS.
Climate Change Committee (CCC) independent assessment of SCCAP2[7]	The Climate Change Act requires the CCC's Adaptation Committee to prepare two independent assessment reports within the lifetime of each programme.	Both reports were reviewed and used to guide this CRS, making sure that this Strategy is in line with the recommendations and advice of the CCC.
Ofgem RIIO-T3 Business Plan Guidance Final (September 2024)][8]	Ofgem guidance document for gas and electricity network companies to set regulated revenues and required outputs that they must follow for RIIO-T3 and a creation of a CRS is required. This will detail how the company will address climate change risks, along with suitable adaptations plans and pathways to address the identified climate hazards and risks.	The requirements set out in this guidance document relating to climate change risks and resilience was the basis of this CRS being undertaken. The CRS was developed to align with the requirements set out in the guidance document.

[1] *https://www.legislation.gov.uk/ukpga/2008/27/contents*
[2] *https://www.gov.uk/government/publications/third-national-adaptation-programme-nap3*
[3] *https://www.gov.uk/government/collections/climate-change-adaptation-reporting-third-round-reports*
[4] *https://www.legislation.gov.uk/asp/2009/12#:~:text=An%20Act%20of%20the%20Scottish,power%20on%20Ministers%20to%20impose*
[5] *https://www.legislation.gov.uk/asp/2019/15/section/25/enacted*
[6] *https://www.gov.scot/publications/climate-ready-scotland-second-scottish-climate-change-adaptation-programme-2019-2024/*
[7] *Is Scotland climate ready? – 2022 Report to Scottish Parliament. Climate Change Committee. Available at: https://www.theccc.org.uk/publication/is-scotland-climate-ready-2022-report-to-scottish-parliament/*
[8] *Ofgem RIIO-T3 Business Plan Guidance Final, September 2024.*

2.3. Linking our CRS to Ofgem's Business Plan Guidance

The table below highlights how our CRS links to Ofgem's business plan guidance released September 2024.

Section	Ofgem Business Plan Guidance	Location in SPEN CRS
5.8	Business plans should include a dedicated Climate Resilience Strategy (CRS) and should aim to provide added value by identifying links between their business plan and CRS while avoiding duplication of other reporting mechanisms. In particular, we aim to better understand justifications for investment in climate resilience.	CRS Annex in SPEN T3 BP Submission
5.9	One Climate Resilience Strategy should be produced per network company.	CRS Annex in SPEN T3 BP Submission
5.10	Significant work to embed climate resilience needs to begin as soon as possible. Network companies should develop an iterative approach, do as much work as possible within the across the RIIO-3 price control period, and where it isn't realistic, clearly explain why. Companies should set out their planned approach and timeline for this work, and then updates will be required as part of their annual reporting.	Section 3.6.1 describes how our CRS splits the projects required into High, Medium and Low-Level Risks. This sets out how we plan to carry out the High-Level Risk in the T3 period. The Medium and Low T4 and beyond.
5.11	Climate Resilience Strategies should clearly signpost to any other submitted documents which relate to climate resilience, such as load strategies, explaining their influence on your business case if requesting additional funding for climate resilience.	Section 3.4.1 points towards our EAP. Our request for additional funding is purely based on assets that are perceived to be high risk and need mitigation work carried out during T3. Section 6 explains how our current standards and policy documents are adequate to meet current CR standards
5.12	Climate Resilience Strategies should also signpost to any other material relating to climate resilience, such as climate related financial disclosures and ARP reporting.	Section 2 points towards RIIO-ED2 CRS. Section 3.1.1 and 3.2.1 points towards ARP 3. And we do also point to external references as well
5.13	CRS should outline any other climate resilience work network companies are undertaking or planning to undertake, Development of tool, innovations, projects, and technologies identifying the steps they expect to take over the course of RIIO-3 and beyond. This could include: Risk Assessments, Development of rationale for investments in climate resilience, Development of adaptive pathways, Development of tools, innovations, projects, and technologies.	Section 3.2 point towards Risk Assessment method, Section 3.3 points towards Adaptation Measures and costings. Nature Based Solutions are innovative and are described in Section 3.6.1 and in Appendix C. Section 5.5 points to work with Network Rail and Scottish Water on Cascading Risk Innovation. Using Dynamic Line Rating as an Innovation detailed in Appendix C.
5.14	Network companies should signpost to their relevant climate hazards and risk assessment at 2 and 4 degrees as outlined by their most up to date ARP reporting	Section 4 points towards Climate Change projection data and the key trends that result. Section 5 points toward the detailed risk assessment undertaken
5.15	Network companies should outline a breakdown of expenditure (CapEx and OpEx) relating to a weather event or compound event which has occurred in the last 10 years and has been caused by or exacerbated by climate hazards or risks which have caused loss of supply or other detrimental impacts, submitting any supporting evidence, including but not limited to :	Appendix A gives example of landslip but may need more details to satisfy all of 5.15

	identifying the costs of response and recovery, identifying how this information is being used for future decision making.	
5.16	This event or events does not need to be attributed to anthropogenic climate change. Ofgem is seeking this information to better understand potential future costs as the effects of climate change intensify.	Appendix A gives example of landslip but may need more details to satisfy all of 5.16
5.17	Each climate resilience strategy should outline the key categories identified in the Business Plan Data Template (BPDT) memo table for climate resilience and provide context as to why this category is affected by climate resilience: through current activities and workstreams; through new climate resilience projects; and the plan for investment until the end of the RIIO-3 price control period.	Section 7.5.2 shows clear linkages from the High-Level Costs to the Individual Projects to the cost breakdowns and the BPDTs where they are populated
5.18	In addition, companies should also complete the climate resilience memo table within the BPDT submitting estimates of spend associated with climate resilience. Each category should link to a climate hazard and explanation as to how it affects resilience to the hazard, and how this investment is weighed up against other options, for example, recovery versus protection.	CR Memo table will be completed, and words added to commentary to show how this work will make us more resilient. App D shows example of recovery vs protection
5.19	Explain any alternative financial assessment tools outside of CBAs and EJPs used for climate resilience justification, such as social return on investment.	We only have example in App D to show for now, but we can state that other methods will be used once we have more detailed information from AECOM
5.20	Each network company should explain any barriers to making a viable business case for climate resilience projects. If possible, network companies should outline how they might use the Resilience Reopener to mitigate these issues.	Section 8.7 states we do not foresee any barriers to making a viable case. Section 8.8 states we see a CR reopener being used when it becomes clear during T3 there is a material change to the climate change projection data which has a significant impact on identified risks to assets.

3. Building on Existing Work

Given the nature of SPT and SPEN's operations we continually assess and adapt our strategies to manage climate resilience. This includes previously developing several reports relating to the impact that climate change hazards will have on SPT's assets and operations. This section highlights some of the key reports and documents that were reviewed and used to inform the climate hazards, climate risks and subsequent adaptation measures and pathways for this CRS.

3.1. SPEN Climate Resilience Strategy - RIIO-ED2 Business Plan submission (2021)

Within our RIIO-ED2 Business Plan for our two distribution licensee areas we outlined our commitments to managing climate risk across our distribution networks from 2023 to 2028. The commitments and findings from this plan informed this CRS where relevant to SPT.

3.2. SPEN Climate Change Adaptation Report – Round 3 Update (2021)

Under the ARP we report on our preparedness and ability to adapt to the impacts of climate change. We published a first response to the ARP in 2011, second in 2015 and third in 2021. The third instalment of the report included an assessment of:

- The current and future predicted effects of climate change on our organisation (including how we have identified and assessed the risks to our network & business from climate change)
- Our proposals for adapting to climate change (including how we have identified the resulting optimal actions & mitigation plan to the threats from climate change)

The findings from these reports supported the climate risks and adaptation measures outlined in this CRS.

3.3. SPEN Climate Change Resilience Metric – Heads of Terms Draft Document (2024)

As part of RIIO-ED2 price control development, and the ongoing draft RIIO-T3 development Ofgem have requested that companies develop a Climate Change Resilience Metric (CRM). Ofgem are working with companies to support the development of their individual CRMs. Companies are also being asked to identify the more long-term climate change impacts that could affect the networks through collaborating with the Energy Network Association (ENA) working group.

CRMs will help to provide a common fall-back for climate principles and key topics, allowing the Climate Change Resilience Working Group to focus on developing a collective CRM. Our draft of the CRM (2024) helped to develop and guide this CRS.

The following climate variables: Precipitation, Sea level rise, Coastal erosion & flooding, Temperature and Storm & wind events, were listed in the CRM document as the "...umbrella grouping of weather and climate factors that contribute to hazards and risks to energy infrastructure.', and as a result were used within the CRS.

3.4. Flood Mitigation Documents and Programmes

SPT's flood mitigation measures were also reviewed and used to inform the climate risks associated with flooding and the identification of appropriate adaptation measures.

Box 1: Case Study – *Coastal flooding risk of the Kincardine 275kV Substation.*

Kincardine is a 275kV substation situated on reclaimed land with ground level of between 1.1m – 2.2m AOD. It was protected by coastal defences comprising an earth embankment with revetment on the seaward slope, a small wave wall, a pumping station and underground storage tanks.

Early in the RIIO-T1 period it was recognised that the Kincardine 275kV substation was at risk from coastal flooding, from waves overtopping the coastal defence wall. For a 1 in 100-year flood event all critical equipment in the substation was predicted to be inundated rendering the site non-operational and reducing the flow of power across the B5 transmission boundary. For a 1 in 1000-year flood level was predicted to reach 5.15m AOD.

Several solutions were investigated to mitigate against flood risk. These included:

- Raising defences around the substation perimeter with for example a wall of embankment up to 5m AOD.

it was decide by 6.0m AOD using an elevated platform.

4. Methodology

The methodology presented in this section has been developed to be compliant with Ofgem requirements set out in Ofgem Final 30th September 2024 RIIO-T3 Business Plan Guidance on climate change resilience for electricity networks.

Industry best practice and guidelines for undertaking climate change risk assessments and developing subsequent adaptation measures and pathways, were also applied when developing this methodology. In addition, previous SPEN reports (refer to Section 0 and Section 3) relating to climate change risk and resilience were also consulted. An overview of the key methodology stages is summarised in **Figure 2**, with detail on the individual methods outlined in the subsections below.

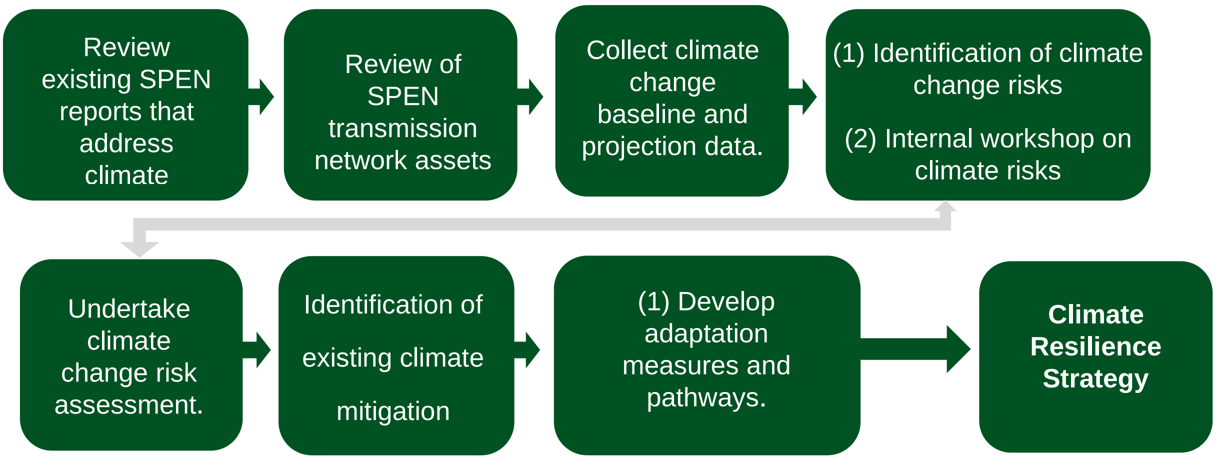

Figure 2: Stages of the Climate Resilience Strategy

4.1. Climate Data

4.1.2 Climate Variables

The climate variables and climate hazards used within this strategy are based on the findings of the ARP3, recommendations outlined in the CRM document and the requirements set in the draft (September 2024) RIIO-T3 Business Plan Guidance document. These climate variables and hazards were used to identify climate risks within the transmission network.

Table 2: Climate Variable and Hazards

Climate Variables	Climate Hazards
Temperature	High Temperatures – Extreme / Prolonged / Seasonal Low Temperatures – Extreme / Prolonged / Seasonal Wildfires Heat Wave Cold Spell Landslide
Precipitation	Rainfall – Intense / Heavy / Prolonged / Seasonal Snow/Ice/Hail – Intense / Heavy / Prolonged / Seasonal Fluvial (river) Flooding Pluvial (surface) Flooding High / Low Soil Moisture Landslide
Sea level, coastal erosion and flooding	Sea Level Rise Coastal Erosion Coastal Flooding e.g. storm surge
Storms and wind events	Wind Speeds – Extreme / Prolonged / Seasonal Lightning – Intensity / FrequencyStorms – Intensity / Severity / Duration / Frequency

4.1.3 Climate Change Baseline Data

Historical / observed climate data was collected from four weather stations, ensuring any variances in climatic conditions were captured. Weather stations were chosen as follows to represent coverage of the Scottish Power Network area:

- Northern area (Stirling Weather Station).
- Western area (Paisley Weather Station).
- Eastern area (Royal Botanic Gardens Edinburgh Weather Station).
- Southern area (Eskdalemuir Weather Station).

This observed climate data was collected from the UK Met Office website, for the period 1981-2010.

4.1.4 Projection Climate Data

To inform the assessment of climate risk and the development of this CRS, two climate change scenarios were reviewed to provide a holistic understanding of the range of potential climate futures possible, this was essential to understanding risk and developing appropriate adaptation measures. These climate change projections were based on RCP 4.5 and RCP 8.5.

- RCP 4.5 is an intermediate emissions scenario in which CO_2 emissions start declining by approximately 2045.
- RCP 8.5 was also used as it represents a worst-case scenario, which is essential in risk and contingency planning. This pathway has the highest emissions concentration and is marked by inadequate policy response and increased potential for physical asset damage.

The climate change projection data was gathered from the UK Climate Projections (UKCP18)[9] portal and collected for the periods 2030 and 2050, representing the near-term including the RIIO-T3 period and the long-term, respectively. This projection data is provided in **Section 5.2**.

4.1.5 Climate Hazard Mapping

To inform the climate risk assessment and the selection of adaptation solutions, climate hazard maps were developed to help pinpoint SPT assets vulnerable to climate change. The asset-specific information was sourced from SPEN's Open Data Portal[10] whilst the climate hazard information was based on publicly available data on landslides and flooding from BGS[11],[12] and SEPA,[13] respectively.

The flooding hazard map illustrates the SPT assets within the following flood zones:

- **Coastal Flooding** – Medium Probability and Climate Change Flood Zone
- **River Flooding** – Medium Probability and Climate Change Flood Zone
- **Surface Water Flooding** – Low Probability and Climate Change Flood Zone

The landslide hazard map illustrates our transmission network assets located in either a significant susceptibility landslide zone or within 100m of a past occurrence of a landslide. It also shows the location of the historic landslides as well, according to the BGS National Landslide Database. Refer **Appendix B** for the climate hazard maps.

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[9] *https://ukclimateprojections-ui.metoffice.gov.uk/*
[10] https://spenergynetworks.opendatasoft.com/pages/home/
[11] https://www.bgs.ac.uk/datasets/bgs-geosure-landslides/
[12] https://www.bgs.ac.uk/geology-projects/landslides/national-landslide-database/
[13] https://www.sepa.org.uk/environment/water/flooding/developing-our-knowledge/#Floodmaps

4.2. Risk Assessment

4.2.1. Risk Assessment Approach

A custom risk framework was developed for the CRS, based on the risk matrix outlined in the Energy Network Association (ENA) '3rd Round Climate Change Adaptation' report[14] and risk matrix outlined in the European Commission's 'Technical guidance on climate proofing of infrastructure in the period 2021-2027[15]' document. We also developed impact/ consequence categories in relation to both financial constraints and financial penalties.

Risk is evaluated by determining both its likelihood and consequence of impact on a sensitive/exposed asset. The combination of these two factors determines the risk rating for a specific climate risk. Risk 'likelihood' refers to how likely the identified climate hazard or extreme weather event is to occur and cause the identified climate risk within a given timescale. Risk 'impact' refers to the severity or magnitude of the impact on assets, should the climate risk eventuate.

The likelihood analysis criteria, impact analysis criteria and risk matrix are presented in **Error! Reference source not found.**,

Table 4, and

Table 5 respectively. Based on the assigned risk rating each climate risk was categorised as severe, major, moderate, and minor, the key for this is presented in

Table 6 below.

Table 3: Likelihood Criteria

Term	Quantitative
Very unlikely	5%
Unlikely	20%
Possible	50%
Expected	80%
Almost certain	95%

[14] CCRA3 report v1.0 final.pdf (energynetworks.org)
[15] https://ec.europa.eu/newsroom/cipr/items/722278/

Table 4: Impact/Consequence Criteria

Risk Areas	Limited	Minor	Moderate	Significant	Extreme
Network Risk / Supply interruptions	Limited impact - can be managed within "business as usual" processes	Damage / or increased risk to OHL or cable route. Damage to periphery of substation. No loss of supply. Damage managed by enhanced repair process with timescales in weeks to months.	Loss of single OHL or cable route or loss of plant within substation resulting in reduction in security of supply. No loss of supply. Damage requires extensive repairs requiring external contractors in timescales of months.	Loss of entire OHL or cable route or small transmission site resulting in loss of supply to customers in the region of up to 40,000. Could include windfarm generation. Customer restoration available by additional means such as backfeeds from Distribution network or Emergency Response OHL System.	Loss of OHL route on key system boundary impacting power flow or loss of key OHL route or cable route feeding large substation or loss of large transmission substation. Loss of customers greater than 100,000 with only 40% being able to be backfed. Or loss of boundary circuit / route costing constraint costs of £500,00 a day.
Safety and Health	First aid case	Minor injury, medical treatment	Serious injury or lost work	Major or multiple injuries, permanent injury or disability	Single or multiple fatalities
Environment	No impact on baseline environment. Localised in the source area. No recovery required	Localised within site boundaries. Recovery measurable within one month of impact	Moderate harm with possible wider effect. Recovery in one year	Significant harm with local effect. Recovery longer than one year. Failure to comply with environmental regulations / consent	Significant harm with widespread effect. Recovery longer than one year. Limited prospect of full recovery
Social	No negative social impact	Localised, temporary social impacts	Localised, long-term social impacts	Failure to protect poor or vulnerable groups (1). National, long-term social impacts	Loss of social licence to operate. Community protests
Financial (constraint costs)	Negligible impact to system boundary capacity, insignificant balancing market impact (<£1m)	Short term impact to system boundary capacity, minor balancing market impact (£<5m)	Medium term impact to system boundary capacity, appreciable balancing market impact (<£10m)	Significant reduction in boundary capability for short period resulting high constraint costs through balancing market (<£50m)	Significant reduction in system boundaries for a long period resulting in hundreds of millions impact to end consumer through balancing market (>£50m)
Financial (penalties, i.e. from OFGEM for failed service)	Short duration interruption resulting in non-incentivised energy not supplied penalty	Short duration interruption resulting in incentivised energy not supplied penalty (~£100k)	Short duration (1-2h) interruption resulting in significant incentivised energy not supplied penalty (~ £500k ENS loss)	Long Duration (>12-24h) interruption resulting in significant incentivised energy not supplied (£1-2m)	Long duration interruption resulting in maximum penalty under ENS measure (-£6.25m)
Reputation	Localised, temporary impact on public opinion	Localised, short-term impact on public opinion	Local, long-term impact on public opinion with adverse local media coverage	National, short- term impact on public opinion; negative national media coverage	National, long-term impact with potential to affect the stability of the government
Cultural Heritage and cultural premises	Insignificant impact	Short term impact. Possible recovery or repair.	Serious damage with wider impact to tourism industry	Significant damage with national and international impact	Permanent loss with resulting impact on society

Table 5: Risk Matrix

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

Table 6: Risk Rating Key

Risk Rating Key	
15-25	Severe
8-12	Major
4-6	Moderate
1-3	Minor

4.2.2. Identification and Assessment of Climate Risks

Based on the observed and projected climate change data, gathered for the CRS, a series of climate hazards and subsequent climate risks were identified. These climate risks were assessed as potential threats to the integrity and operation of our transmission network assets. For each of the climate risks identified the type of assets (Substation, Overhead lines and Underground cables) that could be impacted by the climate risk was noted. During the review of internal reports and standards, any existing mitigation measures for extreme weather events or climate risks were noted.

Following this, a climate change risk assessment was conducted. This assessment was based on analysing the likelihood of the climate risk occurring, the impact if the climate risk were to occur, and the level of existing controls in place to mitigate the impact of the given climate risk.

4.2.3 Identification of Adaptation Measures

Based on the climate hazards and risk identified, suitable adaptation measures were chosen to address the potential impacts on our transmission network and assets. These adaptation measures were drawn from industry white papers, scientific reports, case studies and best practice for increasing the transmission network resilience to climate change and have been categorised as High, Medium and Low Risk. These adaption measures have used innovation where appropriate.

Once adaptation measures were identified they were then split into two time periods, 'short term' which considers the RIIO-T3 period where we plan to complete the mitigations classed as High Risk. The 'long term' will look at ongoing measures that can roll over each year, as well as those to be implemented after the RIIO-T3 period for mitigations we have classed as Medium to Low Risk.

After separating the measures into 'short term' and 'long term', they were then categorised and grouped into three main categories: soft measures, nature-based solutions, or hard measures (see Section 0 and Appendix C for further information).

In addition to the nature-based solutions identified for each asset, we also identified a short-list of innovative potential wider scale nature-based solution pilot projects that SPT could support. These have been treated differently, given these projects will need to be implemented by other stakeholders on land that is not owned by SPT. A short-list of potential pilot projects has been identified using a similar approach as the other adaptation actions – by reviewing the hazards impacting our assets and the locations of the most vulnerable assets. to identify the most relevant action we reviewed existing best practice literature and utilised external expertise and experience.

In the short term, SPT will work with local climate adaptation partners to identify five priority areas and develop project plans by the end of 2027 for implementation by the end of 2031 –Refer to the SPEN T3 Environmental Action Plan T3 EAP Master.docx Climate Resilience Section for further details.

4.2.4 Costing of Adaptation Measures

As a part of our CRS a high-level cost estimate has been prepared covering the priority climate adaptation measures identified for SPT's network over the RIIO-T3 period.

The unit costs for the soft and hard adaptation measures, in particular the costs for materials and labour were provided from the Spon's Architects' and Builders' Price Book 2024[16] and the costs for the nature-based solution pilots were estimated from a range of sources[17,18,19] . Both were supplemented by our independent Climate Consultants.

Having determined the priority, short-term adaptation measures to cost, high-level climate hazard mapping was used to provide an indication of the quantity of adaptation measures required. For example, the implementation of the adaptation solution 'Gabion baskets' was determined to be applicable to the substations located in either a flood zone[20], in a significant susceptibility landslide zone[21] or 100m from a location of past landslide occurrence[22]. Analysis of the climate hazard mapping provided the number of substations that fulfilled these criteria, this was then used to determine costings.

4.3. Stakeholder Engagement

Increasing climate change impacts result in greater risks to our network resilience. In developing our first Transmission Climate Change Resilience Strategy we were keen to learn from others, identify best practice, share challenges, and the opportunities to work together. We started with a fact-finding exercise reviewing strategies of other infrastructure organisations and mapping who to engage with to develop and test our approach to achieving a climate resilient network.

This engagement included:

- Establishing a TO Climate Resilience Working group
- Extensive bilateral engagement with Adaptation Scotland (managed by Sniffer) to review our Strategy, help us to identify priority resilience measures for investment and build collaboration partnerships with regional climate adaptation organisations such as Climate

[16] https://www.routledge.com/spon-press
[17]: https://www.moorsforthefuture.org.uk/__data/assets/pdf_file/0017/91214/Annex-8.Payments-for-Ecosystem-Services.a.pdf and
[18] *Okumah, M., Walker, C., Martin-Ortega, J., Ferré, M., Glenk, K. and Novo, P. (2019). How much does peatland restoration cost? Insights from the UK. University of Leeds - SRUC Report.*
[19]https://assets.publishing.service.gov.uk/media/6034eefdd3bf7f264e517436/Cost_estimation_for_land_use_and_run-off.pdf
[20]https://www.sepa.org.uk/environment/water/flooding/developing-our-knowledge/#Floodmaps
[21] https://www.bgs.ac.uk/datasets/bgs-geosure-landslides/
[22] https://www.bgs.ac.uk/geology-projects/landslides/national-landslide-database/

Ready Clyde and Climate Ready South-East Scotland. These regional partnerships will be critical in the delivery of our pilot catchment area NbS projects.

- Membership of ENA Climate Change Resilience Working Group. We have joined this working group along with our ScottishPower Distribution and Manweb colleagues to work together to share best practice and develop common metrics.

- SPEN, Network Rail and Scottish Water have set up the Climate Ready Scottish Infrastructure forum, established Autumn 2024. The objectives of this forum will help infrastructure organisations in Scotland to work together to deliver the following outcomes: the identification of climate related risk interdependencies; vulnerable location identification and adaptation planning and future partnership working opportunities. Further to this Network Rail and Scottish Water acted as critical friends by conducting a peer review of this Strategy.

- SPEN Sustainability Stakeholder Working Group has representation from key sustainability stakeholders in Scotland including those with a specific interest in climate change resilience and NbS including Scottish Government, Nature Scot, Sniffer, SEPA, Scottish Wildlife Trust, Keep Scotland Beautiful, Sustainable Scotland Network and Academia. This group has contributed their expertise to this Strategy, with a practical focus on NbS.

- In 2022, SPEN established the Independent Net Zero Advisory Committee (INZAC), bringing together 15 external experts to provide challenge and specialist external knowledge to our business. The INZAC has evaluated the quality and ambition of the RIIO-T3 Business Plan throughout development, including reviewing this Strategy and our Environmental Action Plan which presents synergies between climate change resilience, natural capital, biodiversity and social sustainability.

4.4. Stakeholder feedback

Our Sustainability Stakeholder Working Group reviewed our RIIO-T3 Environmental Action Plan (EAP) Annex which provides further detail on our Nature-based Solutions (NbS) for climate resilience. Feedback included the importance of prioritise NbS and implement pilot projects in RIIO-T3 and how we made an approach to multiple outcomes layering climate resilience, natural capital and biodiversity. For further information on stakeholder feedback on NbS please see our Environmental Action Plan (EAP) (Link Required please).

Adaptation Scotland review of this Strategy highlighted clear opportunities to work with them and the place-based climate change resilience networks to develop collaboration projects and target priority areas to implement adaption measures. We welcome this and will continue to develop these partnerships to facilitate the delivery of this Strategy.

Network Rail and Scottish Water peer reviews highlighted the comprehensive nature of this Strategy, both particularly supported the inclusion of decision-making pathways. Network Rail recommended carrying out further analysis using 2070’s/ 80s climate projections.

Our INZAC highlighted the need for future scenarios to assess any impact on asset condition.

5. Climate Change Context

5.1. Observed Climate Change

It is important to understand not only future climate change projections, but also extreme weather events recently experienced in Scotland. Understanding the impact of previous climate risks to our organisation has supported the risk ratings assigned to climate hazards in our assessment.

In line with national trends, Scotland has experienced changes in temperatures and precipitation since the 1980s. Additionally, extreme weather events have disrupted water supply, energy supply, caused travel delays, and affected human health. **Table 7** outlines the extreme weather events that have impacted Scottish Power's Transmission and Distribution networks some of which have caused damage to our assets, with a case study highlighted in **Box 2** below.

Box 2: River Erosion impacting an SPT transmission Tower.

In 2020, extreme rainfall was experience across the central and southern regions of Scotland which led to river flooding. This impacted several SPT assets, such as overhead lines and substations.

In this example, fluvial flooding led to increased river erosion which encroached on a SPT overhead line transmission tower near the River Carron in Denny.

To protect this asset rock armour was installed on the riverbank to act as a barrier and reduce the level of erosion. The measure also helped direct water flow, to protect the SPT asset. **Total costs for this were £92k.**

Table 7: Past Extreme Weather Events that impacted SPEN Transmission and Distribution

Type of weather event	Location and Date of Weather Event	Description of Weather Event	Impact to SPT
Storms	October/November 2020	Storm Aiden – high winds	Storm Aiden – 61 mph wind speeds in Scotland: 13,002 customers across SPD (Scottish Power Distribution) and SPM (Scottish Power Manweb) were impacted by Storm Aiden, but all power was restored within 12 hours. The SPT Network demonstrated resilience with no customer loss being attributed to transmission system faults.
	February 2020	Storm Dennis – high winds	Storm Dennis – 67mph winds. 16,519 SPD customers were impacted by Storm Dennis, but power was restored within 12 hours. SPT demonstrated resilience with no customer loss being attributed to transmission system faults.
	January 2020	Storm Brendan – high winds	Storm Brendan – 68mph winds. 7,942 customers across SPD were impacted by Storm Brendan, 100% of power was restored within 12 hours. SPT demonstrated resilience with no customer loss being attributed to transmission system faults.
	November 2021	Storm Arwen – high winds	Storm Arwen – 78mph winds. SPT demonstrated a good level of resilience. Several transient line faults during the storm but no damage or customers lost.

Flooding	February 2020	Storm Ciara and Storm Dennis – flooding and high winds.	Storm Ciara and Storm Dennis – 180mm of rain in 18 hrs, 85 mph wind speeds. The storms, heavy rainfall and subsequent flooding led to travel delays and disruption, along with flooding of properties and agricultural land.
Increased precipitation	Re-occurring	Increased precipitation resulting in increased vegetation growth.	A wetter and windier climate has influenced vegetation growth rates, leading to vegetation encroaching on assets sooner than expected and at a faster rate. As a result, a more aggressive approach to clearing vegetation is required.
Landslide	August 2019	Prolonged period of torrential rainfall after a dry period.	August 2019 saw a landslide occur which had a direct impact on Tower YW102. The cost of the repair was approx. £1m. **Appendix A** contains more detail of this event.
Erosion	Renfrew	Prolonged and heavy river flows	Prolonged and heavy river flows have eroded the riverbanks and concrete bags protecting the 132kV cables crossing the Black Cart and White Cart Rivers. This resulted in the exposure of the cables. 
	Elvanfoot / Elvan Water	Erosion of riverbanks	Erosion caused exposure of 275kV cables. Remedial work involved Horizontal Directional Drilling to install the cable system below Elvan Water. high density drilling was required with total costs around £2.5m and a significant outage to allow the repairs to be carried out. 

5.2. Climate Change Projection

This section summarises the projected future changes for temperature and precipitation using UKCP18 data for the 2030 and 2050 time periods for RCP 4.5 and RCP 8.5. The climate baselines and projections are separated into four regions in the SPT licence area (North, South, East, and West).

As a whole, Scotland is expected to experience a warmer and wetter climate in both the 2030 and 2050 timeframes, with variations depending on proximity to the coast and elevation. Summers will experience the greatest degree of warming and are expected to be drier, while winters will become milder but wetter. Frost and snow days are currently in decline and are expected to continue to decrease annually. Climate projections indicate a substantial increase in the likelihood of Scotland experiencing the anomalously high temperatures of 2018 between the present day and 2050.

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. Projected climatic parameters for temperature change are presented in

Table 8, illustrating two scenarios based on RCP 4.5 and RCP 8.5. Across all seasons, average temperatures are expected to increase.

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 od temperature-related impacts on SPT's assets in the absence of adaptive measures.

Table 8: Temperature baseline and projection data for the SPT licence area

Region	Baseline (1981-2010)	RCP 4.5 2030	RCP 4.5 2050	RCP 8.5 2030	RCP 8.5 2050
Royal Botanic Gardens (Southern Scotland East)					
Mean annual air temperature (°C)	12.7	0.23 to 1.27	0.43 to 1.88	0.36 to 1.51	0.77 to 2.53
Mean summer air temperature (°C)	18.45	0.19 to 1.54	0.41 to 2.40	0.34 to 1.86	0.81 to 3.29
Mean winter air temperature (°C)	1.39	-0.08 to 1.41	0.15 to 1.97	0.04 to 1.86	0.36 to 2.57
Maximum summer air temperature (°C)	19.4	0.04 to 1.71	0.27 to 2.71	0.19 to 2.06	0.65 to 3.68
Minimum winter air temperature (°C)	1.33	-0.08 to 1.51	0.13 to 2.22	0.00 to 1.76	0.29 to 2.93
Paisley (Southern Scotland - West)					
Mean annual air temperature (°C)	12.92	0.22 to 1.24	0.40 to 1.83	0.35 to 1.48	0.74 to 2.48
Mean summer air temperature (°C)	19.03	0.17 to 1.51	0.30 to 2.33	0.33 5o 1,83	0.73 to 3.21
Mean winter air temperature (°C)	1.74	-0.10 to 1.40	0.14 to 1.97	0.02 to 1.58	0.35 to 2.56
Maximum summer air temperature (°C)	19.73	0.01 to 1.64	0.12 to 2.55	0.17 to 1.99	0.49 to 3.46
Minimum winter air temperature (°C)	1.67	-0.09 to 1.51	0.12 to 2.23	-0.02 to 1.75	0.28 to 2.94
Stirling (Southern Scotland - North)					
Mean annual air temperature (°C)	12.94	0.23 to 1.27	0.42 to 1.99	0.36 to 1.51	0.77 to 2.54
Mean summer air temperature (°C)	18.97	0.18 to 1.55	0.39 to 2.42	0.34 to 1.87	0.79 to 3.32
Mean winter air temperature (°C)	1.1	-0.09 to 1.43	0.14 to 2.01	0.03 to 1.62	0.36 to 2.61
Maximum summer air temperature (°C)	19.67	0.02 to 1.72	0.23 to 2.72	0.19 to 2.08	0.62 to 3.71
Minimum winter air temperature (°C)	0.76	-0.08 to 1.55	0.13 to 2.28	0.003 to 1.80	0.30 to 3.00
Eskdalemuir (Southern Scotland - South)					

Mean annual air temperature (°C)	11.16	0.28 to 1.61	0.56 to 2.25	0.46 to 1.92	0.97 to 3.04
Mean summer air temperature (°C)	17.3	0.10 to 1.97	0.46 to 2.92	0.30 to 2.36	0.96 to 4.00
Mean winter air temperature (°C)	4.4	-0.05 to 1.79	0.23 to 2.37	0.08 to 2.00	0.50 to 3.08
Maximum summer air temperature (°C)	18.15	-0.17 to 2.18	0.27 to 3.32	0.04 to 2.63	0.74 to 4.49
Minimum winter air temperature (°C)	4.96	-0.09 to 1.91	0.22 to 2.71	-3.88 to 9.56	0.43 to 3.56

5.2.2. Precipitation

Scotland will also see an increase in rainfall, with an increasing proportion of this coming from extreme rainfall events. Projected climatic parameters for the UK precipitation change are presented in

Headline Trends

Winter precipitation projected to increase, increasing the risk of flooding at substations.

Extreme hourly rainfall projected to increase in winter.

Table 9.

Table 9: Precipitation baseline and projection data for the SPT Licence Area

Region	Baseline (1981-2010)	RCP 4.5 2030	RCP 4.5 2050	RCP 8.5 2030	RCP 8.5 2050
Royal Botanic Gardens (Southern Scotland - East)					
Mean annual precipitation (mm)	704.22	-3.04 to 8.54	-3.65 to 9.39	-3.31 to 9.15	-4.27 to 10.98
Summer precipitation rate anomaly (mm)	62.16	-13.68 to 10.07	-21.85 to 4.57	-15.86 to 9.62	-27.79 to 4.14
Winter precipitation rate anomaly (mm)	58.78	-5.53 to 13.04	-3.90 to 29.51	4.41 to 25.07	-1.94 to 36.91
Paisley (Southern Scotland - West)					
Mean annual precipitation (mm)	1245.1	-2.24 to 7.32	-2.51 to 9.53	-2.33 to 8.10	-2.43 to 11.48
Summer precipitation rate anomaly (mm)	77.4	-16.86 to 8.47	-23.69 to 4.30	-18.89 to 8.00	-29.45 to 3.68
Winter precipitation rate anomaly (mm)	130.08	-6.00 to 17.24	-3.89 to 23.20	-5.03 to 18.88	-2.19 to 29.71
Stirling (Southern Scotland - North)					
Mean annual precipitation (mm)	1018.92	-3.29 to 7.26	-3.60 to 8.33	-3.58 to 7.78	-4.30 to 9.85
Summer precipitation rate anomaly (mm)	66.09	-16.68 to 9.37	-24.76 to 4.18	-18.96 to 8.93	-31.03 to 4.07
Winter precipitation rate anomaly (mm)	105.99	-5.31 to 20.24	-3.52 to 26.04	-4.12 to 22.19	-1.71 to 32.83
Eskdalemuir (Southern Scotland - South)					
Mean annual precipitation (mm)	1742	-3.68 to 8.77	-4.03 to 9.65	0.01 to 2.24	-4.57 to 11.17
Summer precipitation rate anomaly (mm)	1118.67	-16.23 to 11.67	-26.35 to 4.77	-18.87 to 10.86	-33.56 to 3.85
Winter precipitation rate anomaly (mm)	178	-5.60 to 22.70	-3.20 to 29.23	-4.67 to 25.70	-1.39 to 38.12

5.2.3. Sea level rise

The projected increases in mean sea level anomaly by 2030 and 2050 relative to a 1981 – 2000 baseline are shown in Table 10. Under RCP8.5, sea level rise projections from UKCP18 models for the end of the century range from 0.11 to 0.21m, whereas for the lower emissions scenario RCP4.5 the range from 0.1 to 0.16m. Sea levels will continue to rise, increasing the likelihood of coastal flooding and coastal erosion occurring.

Headline Trends

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

Table 10: Sea level rise projections for the SPT licence area

Region	2030		2050	
	RCP 4.5	RCP 8.5	RCP 4.5	RCP 8.5
East Scotland[23]	0.096 (0.05 to 0.16)	0.11 (0.06 to 0.17)	0.162 (0.08 to 0.28)	0.21 (0.11 to 0.33)
West Scotland[24]	0.1 (0.05 to 0.16)	0.11 (0.06 to 0.17)	0.16 (0.08 to 0.28)	0.21 (0.11 to 0.33)
South Scotland[25]	0.125 (0.08 to 0.18	0.15 (0.10 to 0.20)	0.20 (0.13 to 0.29)	0.26 (0.16 to 0.26)

5.2.4. Storm events

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. Compared to storminess and lightning there is 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. It is recognised that prevailing wind direction is a potential hazard for our 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.[26]

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 SPT 's overhead lines.
- There is currently no strong signal within the climate projections for a change to future storm intensity.

[23] *Data gathered from UKCP data source for coastal location (56.06N,-3.08E)*
[24] *Data gathered from UKCP data source for coastal location (55.83N, -4.92E)*
[25] *Data gathered from UKCP data source for coastal location (54.94N, -3.25E)*
[26] *IPCC. (2018). Global Climate Projections, Chapter 10.https://www.ipcc.ch/site/assets/uploads/2018/02/ar4-wg1-chapter10-1.pdf*

6. Risk Assessment

6.1. Key Network risks

This section gives an overview of the climate change risks identified during the climate change risk assessment for this CRS. A total of 35 risks were identified, which have been separated out depending on the asset or assets the risk is impacting. Each risk was assessed under the two RCPs, for both the 2030s period and 2050s period.

Figure 3 gives an overview of the number of risks associated with a given asset or assets, all of which are elaborated on in the forthcoming subsections.

Figure 3: Type of asset and number of climate risks impacting a given asset.

6.1.1. Overhead Lines

Our transmission network is made up of around 3700 km of Overhead Line conductors, with the key risks to the asset mainly linked to changing temperatures. Changing temperatures are having a direct impact on the structural integrity of overhead lines, with extreme heat resulting in increased conductor sagging. **Table 11** below gives a detailed description of each of the climate risks to overhead lines, and their subsequent risk ratings for the two RCPs and time periods.

Table 11: Climate risks posed to overhead lines.

		Risk Score			
Risk ID	Climate Hazard: Risk	RCP4.5		RCP8.5	
		2030	2050	2030	2050
OH1	**Changing Temperatures:** Increasing temperatures can cause thermal expansion of conductors, which can result in the overhead line sag exceeding the current overhead line design parameters. This could lead to an increase in the number of incidents where conductor clearance limits are compromised. This Overhead line sagging could then result in flashover to nearby vegetation or structures causing the circuit to fault which could also result in power outages.	Minor 2	Moderate 4	Minor 2	Moderate 4
OH2	**Storm Events:** Increased storm intensity coupled with strong winds and varying wind direction can result in physical damage to the assets (from the storm itself and associated debris e.g. vegetation) leading to overhead line faults, possible power outages, and increased fault and repair costs. This can be further hindered by local roads becoming blocked by the storm preventing necessary staff access to the overhead lines to undertake restoration and repairs.	Moderate 6	Moderate 6	Moderate 6	Moderate 6
OH3	**Increasing Temperatures and Changing precipitation:** Warmer temperatures and prolonged periods of heat, coupled with increased precipitation can alter the growing seasons and create optimal growing conditions. This impacts overhead lines as increased vegetation growing adjacent to the overhead lines can impact on minimum clearances leading to faults and physical damage.	Major 8	Major 8	Major 8	Major 8
OH4	**Flooding:** Extreme rainfall can lead to nearby rivers exceeding their natural capacity causing flooding and river erosion. If foundations are exposed,	Major 9	Major 12	Major 9	Major 12

	weakened or soil stability is reduced then overhead line structures like poles or towers may be damaged or fail.				
OH5	**Drought:** Drought conditions can result in soil becoming dried out causing it to shrink. Structures built on this ground will be subject to movement which as well as being amplified by the height of the structure, can lead to instability of foundations. Overhead line structures can be impacted by this instability which could lead to the structures becoming damaged. Without intervention this could cause the structure to fail with subsequent system faults/power outages.	Minor 2	Minor 2	Minor 2	Minor 2
OH6	**Storm Events:** Increased storm frequency can lead to an increase in lightning strikes. Overhead lines struck by lightning can lead to flashovers causing the circuit to trip. In extreme cases lightning strikes could lead to physical damage to the OHL assets, which if left unattended could lead to asset failure and potential loss of supply.	Major 9	Major 9	Major 9	Major 12

6.1.2. Substations

SPT currently owns and operates 166 substations including 33kV, 132kV, 275kV and 400kV substations. Of these a small percentage are at risk from sea level rise and coastal flooding. The substations are mainly impacted by climate risks related to extreme precipitation such as fluvial and pluvial flooding. Table 12 gives a detailed description of the climate risks that were identified as a risk to substations, and their subsequent risk ratings for the two RCPs and time periods.

Table 12: Climate risks posed to Substations.

		Risk Score			
Risk ID	Climate Hazard: Risk	RCP4.5		RCP8.5	
		2030	2050	2030	2050
S1	**Flooding:** Extreme rainfall can lead to nearby rivers exceeding their natural capacity causing flooding. Substations located near rivers may be affected by the river flooding. This could result in the loss or inability for the substation to function impacting the infrastructure of the substation, as well as the equipment housed within. This could lead to action being taken to de-energise the site which could lead to increased network risk, reduced security of supply, and power outages.	Major 12	Major 12	Major 12	Major 12
S2	**Sea level rise:** Long-term sea-level rise can create increased occurrences of coastal flooding, sea inundation and coastal erosion. This may impact the substations located near the coast resulting in action being taken to de-energise the site which could lead to increased network risk, reduced security of supply, and power outages.	Minor 3	Minor 3	Minor 3	Minor 3
S3	**Changing Temperatures:** As temperatures increase transformers can become overheated resulting in reduced capacity, reduced design life, increased auxiliary losses and an increased need for maintenance and replacement.	Moderate 6	Moderate 6	Moderate 6	Major 8
S4	**Changing Temperatures:** Increasing temperatures and heatwaves can lead to increased demand for air-conditioning and ventilation unit operations, particularly in urban areas. This increase in demand can cause overloading of transformers	Moderate 6	Major 9	Moderate 6	Severe 16

	causing tripping and loss of supply if network designs are not adapted to increasing demand.				
S5	**Changing Temperatures:** Increasing temperatures and heatwaves can create hot and humid temperatures inside the switch and equipment rooms. This can lead to the switchgear and electronic devices operating above their maximum rated operating temperature, resulting in an increase in the likelihood of failure of this critical equipment.	Major 9	Major 9	Major 9	Major 12
S6	**Drought:** Drought conditions can result in soil becoming dried out and shrinking, causing ground movement. Surface infrastructure foundations e.g., concrete bunds can be affected by these drought conditions, resulting in cracks occurring from the ground movement, leading to damage and potential leakage of hazardous materials.	Minor 2	Minor 2	Minor 2	Moderate 4
S7	**Flooding:** Extreme rainfall can lead to flash flooding in the vicinity of substations, which could result in the loss or inability of the substation to function, leading to the need to de-energise the substation causing increased Network Risk, reduced security of supply and potential disruption to supply.	Major 12	Severe 16	Major 12	Severe16
S8	**Storm Events:** Increased storm frequency can lead to an increase in lightning strikes. If lightning strikes an exposed substation this can result in a very high voltage rise and subsequent damage to equipment, causing circuits to trip under fault condition. In extreme cases lightning strikes could lead to physical damage to the assets, resulting in circuit outage.	Minor 3	Moderate 6	Minor 3	Moderate 6
S9	**Drought:** Drought conditions can result in soil becoming dried out. As moisture in the soil reduces the soil resistivity increases reducing the effectiveness of the earthing system. Where earthing design parameters are exceeded, staff and public safety issues can arise, leaving exposed metal components inside and outside the site boundary with inadequate earthing.	Minor 2	Minor 2	Minor 2	Minor 2
S11	**Flooding:** Extreme rainfall events, in combination with storm surge, causes coastal flooding. This may impact the substations located near the coast resulting in loss of function leading to the need to de-energise the substation causing increased Network Risk, reduced security of supply and potential disruption to supply.	Minor 3	Minor 3	Minor 3	Minor 3
S12	**Flooding:** Extreme rainfall can lead to groundwater flooding as the water table rises above the ground surface. Substations located on peatland are more susceptible to ground instability and sinking as a result of flooding. This could result in the loss or inability for the substation to function impacting the infrastructure of the substation, as well as the equipment housed within, leading to increased network risk, circuit outages and a reduced security of supply.	Moderate 6	Moderate 6	Moderate 6	Moderate 6

6.1.3. Underground cables

Our transmission network has around 600 km of underground cables servicing the network and although changing temperatures are not expected to have as significant an impact on underground assets as those above ground, this risk still impacts the underground cables. Changing temperatures are causing fluctuations and increases in underground temperatures which can cause assets to deteriorate and under perform. **Table 13** gives an overview of the climate risks impacting underground cables.

Table 13: Climate risks posed to underground cables.

Risk ID	Climate Hazard: Risk	Risk Score			
		RCP4.5		RCP8.5	
		2030	2050	2030	2050
UC1	**Drought:** Drought conditions can result in soil becoming dried out and shrink which can occur in areas surrounding underground cables. This can lead to an increased thermal resistivity, reduced heat transfer from cable to surrounding backfill and soil, and a reduced current (load) carrying capacity.	Moderate 4	Moderate 4	Moderate 4	Moderate 4
UC2	**Changing Temperatures:** Increasing temperatures impact the capacity of cables which in turn impact's ability to transfer power across the network. Cables are designed to operate at their maximum temperature. As ground temperatures increase, it is difficult for the heat from the conductor to radiate, which reduces its current carrying capability	Moderate 6	Moderate 6	Moderate 6	Moderate 6
UC3	**Drought:** Drought conditions can result in soil becoming dried out, causing it to shrink. Ground movement caused by drying and shrinkage will exert strain on cables. Joints in the network are vulnerable and can fail by being pulled apart, resulting in direct damage to cables. Damage to cables can result in a failure of the cable system causing the circuit to trip. This can lead to increased network risk and power outages.	Minor 2	Minor 3	Minor 2	Minor 3
UC4	**Flooding:** Extreme rainfall can lead to nearby rivers exceeding their natural capacity causing flooding and river erosion. Flooding and erosion could lead to underground cables being exposed which could result in damage and potential failure of the cable system causing it to trip increasing Network Risk and chances of power outages.	Major 9	Major 12	Major 9	Major 12

6.1.4. Overhead lines and Substations

As previously mentioned, there are several climate risks identified that impacted multiple assets. The climate risks presented in **Table 14** below are relevant to both overhead lines and substations.

Table 14: Climate risks posed to overhead lines and substations.

		Risk Score			
Risk ID	Climate Hazard: Risk	RCP4.5		RCP8.5	
		2030	2050	2030	2050
OH&S1	**Wildfires:** Increasing temperatures and heatwaves can create optimal conditions for wildfires. Wildfire poses a risk to overhead lines and substations, from heat/fire damage, or damage from associated debris. They can also present a Health and Safety hazard to staff and prevent access to assets.	Major 9	Major 9	Major 9	Major 9
OH&S2	**Drought:** Drought conditions can result in soil becoming dried out. These conditions can result in suboptimal growing conditions for trees and vegetation, resulting in trees becoming more unstable and more likely to become uprooted or branches breaking off. This could result in damage, as well as circuit failures or trips, to overhead lines and substations.	Minor 2	Minor 3	Minor 3	Minor 3
OH&S3	**Increasing temperatures coupled with changing precipitation patterns:** Warmer temperatures and prolonged periods of heat, coupled with increased precipitation can alter the growing seasons and create optimal or suboptimal growing conditions. These conditions may result in an extended growing season, which could cause an increase in vegetation growth and potentially vegetation encroaching on assets. Vegetation interacting with assets can result in disruption and potential loss of supply.	Moderate 6	Major 8	Moderate 6	Major 8
OH&S4	**Wildfires:** Increasing temperatures and heatwaves can create optimal conditions for wildfires. In such conditions sparking of an OHL or substation component (through technical fault or lightning strike) can result in a wildfire occurring, leading to damage to transmission network assets or third-party damage.	Major 12	Severe 16	Major 12	Severe 16

6.1.5. Network Wide

Of the 35 climate risks identified, 10 of these related to the entire transmission network rather than for a specific asset. This subsection presents the climate risks that were identified as a threat to all three asset types and are listed in **Table 15** below.

Table 15: Climate risks posed to network wide assets.

		Risk Score			
Risk ID	Climate Hazard: Risk	RCP4.5		RCP8.5	
		2030	2050	2030	2050
All1	**Landslides:** Dry periods followed by intense rainfall and prolonged periods of heavy rainfall can both create optimal conditions for landslides to occur. Assets located on land susceptible to landslides could become damaged which could result in the loss or inability for the asset to function, leading to failure of the asset, circuit tripping and potential power outages. .	Major 8	Major 12	Major 8	Major 12

All2	**Flooding:** Extreme rainfall events, in combination with storm surge, causes coastal flooding. This may result in dangerous working conditions for staff carrying out maintenance work on the asset which can pose health and safety risks.	Minor 3	Minor 3	Minor 3	Minor 3
All3	**Flooding:** Any form of flooding may result in tree roots and vegetation becoming loose or uprooted. This could result in trees, branches and other debris impacting assets and causing disruption and potential loss of supply.	Major 9	Major 12	Major 9	Major 12
All4	**Sea level rise:** Long-term sea-level rise can create increased occurrences of coastal flooding and coastal erosion. Assets located in proximity or along the coast may be at risk from sea level rise. Assets may become non-operational due to sea inundation, coastal erosion, and flooding, potentially leading to a loss of system resilience and or a loss of supply.	Minor 3	Moderate 4	Minor 3	Moderate 4
All5	**Flooding:** Extreme rainfall and associated pluvial flooding can result in dangerous working conditions for staff carrying out maintenance work on the asset which can pose health and safety risks.	Moderate 4	Moderate 6	Moderate 4	Moderate 6
All6	**Storm Events:** Storm events including strong winds, lightning and associated debris can create health and safety risks to workers carrying out maintenance work on assets.	Moderate 4	Moderate 6	Moderate 4	Moderate 6
All7	**Wildfires:** Increasing temperatures and an increase in storms (incl. lightning strikes) can cause wildfires which are a health and safety hazard for maintenance staff and others near any asset impacted by the wildfire.	Moderate 6	Major 9	Moderate 6	Major 9

6.1.6. High Impact Low Probability

The Ofgem RIIO-T3 Business Plan Guidance requires the consideration of high-impact, low probability (HILP) climate hazards in the CRS. These events represent risks that are unlikely to occur but would have significant consequences on our operations if they did. Examples of these events in literature may include ice storms, cyclones, severe windstorms, coastal storm surges. Given type and location of SPT's network and the methodology adopted for the climate risk assessment the primary HILP climate risks identified relate to landslides and sea level rise (i.e., risk ID 'All1' and 'All4').

We will continue to engage across the energy sector to identify high-impact, low-probability climate hazards and collaboratively develop solutions to mitigate these.

6.2. Cascading Network Risks

The risks identified in Table 16 are classified as cascading network risks. These risks are associated with interdependencies across the network or across sectors and result when impacts cascade, combine or multiply due to the interconnectedness between systems.

We are currently working with Network Rail and Scottish Water on an innovation scheme looking at Cascading Risks between industry sectors.

Table 16 Cascading climate risks.

Risk ID	Climate Hazard: Risk	Risk Score			
		RCP4.5		RCP8.5	
		2030	2050	2030	2050
All8	**Cascading climate risk:** Climate impacts to the transportation sector (e.g., road network) limits the ability to adequately respond to climate impacts on the transmission network e.g. roads blocked from flooding or storm debris may delay emergency repairs to overhead lines or access to other network assets such as substations.	Major 9	Major 12	Major 9	Major 12
All9	**Cascading climate risk:** Climate impacts to the Information Communication Technologies (ICT) sector, may indirectly impact transmission network operations that rely upon communications technology. This could result in loss of the systems required to trip circuits out of service in fault conditions which may have consequent impact on Network Risk.	Minor 3	Moderate 6	Minor 3	Major 8
All10	**Cascading climate risk:** Climate impacts to SPT's transmission network resulting in loss of supply or downtime, has cascading impacts on other sectors or local areas reliant on their supply of energy e.g., transportation, health sector, water etc.	Moderate 4	Moderate 4	Moderate 4	Major 9

7. Baseline Level Resilience

This section presents the baseline level of resilience for our transmission network, based on the existing embedded measures that are already being delivered to mitigate climate risks. Our existing standards and policy documents demonstrate how climate resilience is incorporated in the design of new assets. This ensures that our Load Programme for RIIO-T3 will meet the current levels required for Climate Resilience.

When undertaking a climate risk assessment, it's important that these existing embedded measures are captured as they may be mitigating the climate risks, and as a result the climate risk rating may be lower. **Table 17** provides a high-level overview of the documents and standards that were reviewed as part of the strategy formation alongside the existing climate resilience measures and climate hazards the measure addresses for a given asset.

Table 17: Baseline Level Resilience in Transmission Network

Name of Document	Climate Hazard	Climate Risk ID	Asset Impacted	Existing embedded climate resilience measures
(SUB-01-018) Substation Flood Resilience Policy - Issue No. 3	Flooding	All2, All3, All5, S1, S7 and S12	Substations	Modification of existing drainage, or installation of new drainage. Raising the level of plant items and equipment. Barriers may be erected around individual plant and equipment items. A flood wall or embankment may be constructed around the site perimeter, designed to protect the entire site. Consideration for site or asset relocation. All grid and primary substations shall be protected to a 1:1000-year flood risk return period.

				Flood protection installed on a new substation shall be designed and constructed to include at a minimum freeboard level of 600mm above the design flood level.
(SUB-03-026) General Specification for the Civil Engineering and Building Design and Construction of 132kV Grid Substations - Issue No.6	Flooding	All2, All3, All5, S1, S7 and S12	Substations	Substations shall be designed such that there is no loss of supply or damage to strategic equipment during a 0.1% (1 in 1000) annual exceedance probability (AEP) flood event. Access routes to the substation shall also be considered to ensure access will be available during flood conditions and consideration of staff access to the key plant and buildings during the 0.1% (1 in 1000) annual flood event. 132kV substation platforms shall be constructed at a minimum level of 600mm above the 0.1% or (1 in 1000) designed flood level, the 600mm freeboard allows for uncertainties in data and modelling. The designed flood level shall include an allowance for climate change for a 50-year design life, in accordance with the requirements of the relevant national environment agency. Where climate change guidance is not available then a minimum of 200mm shall be applied. The flood design should consider Pluvial, Fluvial, Coastal and Reservoir flooding, as well as combinations of these. Surface water drainage systems shall be designed to ensure there is no flooding of the drainage system during the 1:25 return period event. The system shall be designed to include an allowance for Climate Change in accordance with the requirements of the relevant national environment agency. Surface water drainage systems shall be designed to ensure there is no standing water that could impact on the operation, inspection, and maintenance of the substation during the 1:1000 return period event, including an allowance for climate change.
(SUB-03-034) General Specification for the Civil Engineering and Building Design and Construction of 275kV & 400kV Substations - Issue No.4	Flooding	All2, All3, All5, S1, S7 and S12	Substations	Substations shall be designed such that there is no loss of supply or damage to strategic equipment during a 0.1% (1 in 1000) annual exceedance probability (AEP) flood event. Access routes to the substation shall also be considered to ensure access will be available during flood conditions and consideration of staff access to the key plant and buildings during the 0.1% (1 in 1000) annual flood event. 275/400kV substation platforms shall be constructed at a minimum level of 600mm above the 0.1% or (1 in 1000) designed flood level, the 600mm freeboard allows for uncertainties in data and modelling. The designed flood level shall include an allowance for climate change for a 50-year design life, in accordance with the requirements of the relevant national environment agency. Where climate change guidance is not available then a minimum of 200mm shall be applied. The flood design should consider pluvial, fluvial, coastal and reservoir flooding, as well as combinations of these.

				Surface water drainage systems shall be designed to ensure there is no flooding of the drainage system during the 1:25 return period event. The system shall be designed to include an allowance for Climate Change in accordance with the requirements of the relevant national environment agency. Surface water drainage systems shall be designed to ensure there is no standing water that could impact on the operation, inspection, and maintenance of the substation during the 1:1000 return period event, including an allowance for climate change.
(OHL-03-080) Safety Clearance Specification for Overhead Line Vegetation Management Works - Issue No.9	-Storms -Lightning -Wildfire -Drought -Increasing temperatures coupled with changing precipitation patterns	All6, OH1, OH2, OH3, OH6, OH&S1, OH&S2, OH&S3, OH&S4, OH&S5	Overhead lines	Clearance Specification Distance (Climbable Vegetation) Up to and including 33kV: 3.0m Up to and including 66kV: 3.2m Up to and including 132kV: 3.6m Up to and including 275kV: 4.6m Up to and including 400kV: 5.3m
(ENA TS 43-08) Technical Specification 43-8 Overhead Line Clearances - Issue 5	-Storms -Lightning -Wildfire -Drought -Increasing temperatures coupled with changing precipitation patterns	All6, OH1, OH2, OH3, OH6, OH&S1, OH&S2, OH&S3, OH&S4, OH&S5	Overhead lines	Line conductors to trees in Orchards and Hop Gardens. less than 33kV: 3m 66kV: 3.2 132kV:3.6 275kV: 4.6 400kV:5.3 These clearances shall be obtained vertically when any part of a tree is within 7.5m horizontally of a line. For hop gardens, the clearances apply to the strain wires forming the mesh supporting system.
(INS 54.46.07) Single core power cables A.C. with extruded insulation and associated accessories for 220kV to 400kV - Issue 1	-Storms -Lightning -Wildfire -Drought -Changing temperatures	UC1 and UC2	Underground cables	The temperature of the medium in direct contact with the termination shall not be less than −30 °Celsius, and more than +40 °Celsius. For apparatus terminations, the temperature of the medium in direct contact with the termination (ambient inside enclosure) shall not exceed 55 °Celsius. The devices designed for this service shall be connected to the equipment bus which may, at full load, reach a maximum temperature of 85 °Celsius.
(EPS-03-033) Ratings and general requirements for Plant and Apparatus for connection to The Company's system - Issue 2	-Storms -Lightning -Wildfire -Drought -Changing temperatures	S3, S4, S5, S8, S9, S10, OH&S1, OH&S4, OH&S5	Substations	Indoor Plant and Apparatus shall be suitable for normal service conditions as defined in clause 4.4.2.1 of IEC 61936-1. Indoor Plant and Apparatus shall be suitable for normal service conditions as defined in; The ambient air temperature does not fall below -5 °C (Class "-5 indoor"). The ambient air temperature does not exceed 40 °C and its average value, measured over a period of 24 h, does not exceed 35 °C. The average value of the relative humidity, measured over a period of 24hrs, does not exceed 95 %. All Plant and Apparatus housed indoors shall have a minimum degree of protection of IP21 as defined in IEC 60529. Higher degrees of protection are required for some

				types of Plant and Apparatus as specified in lower lever specifications pertaining to that type of Plant and Apparatus. All Outdoor Plant and Apparatus shall be suitable for normal service conditions as defined in clause 4.4.2.2 of IEC 61936-1. All Outdoor Plant and Apparatus shall be suitable for normal service conditions as defined as the ambient air temperature does not fall below -25 °C (Class "-25 outdoor"). All Outdoor Plant and Apparatus shall be suitable for normal service conditions as defined as the ambient air temperature does not exceed 40 °C and its average value, measured over a period of 24 h, does not exceed 35 °C. All Outdoor Plant and Apparatus shall be suitable for normal service conditions as defined as the solar radiation up to a level of 1000 W/m2 (on a clear day at noon) shall be considered. All Outdoor Plant and Apparatus shall be suitable for normal service conditions as defined as the ice coating up to 10 mm (Class 10) 1). All Outdoor Plant and Apparatus shall be suitable for normal service conditions as defined as wind speeds up to 34 m/s 1).

8. Adaptation Solutions and Pathways

As outlined in the sections above, we have summarised a range of climate risks that could impact our organisation in the future under different climate scenarios. In this section, we present possible adaptation measures that could be implemented to reduce the risk and enhance our resilience to future climate change.

As summarised in **Section** Error! Reference s ource not found., the adaptation measures were identified from a range of sources including our ED2 CRS (2021), documents from the Energy Network Association (ENA), the UK's third CCRA Report[27], the UK's guidance on adapting to climate change, through interviews/workshops with key stakeholders across our organisation, as well as inputs from external experts.

The adaptation measures[28] identified have been organised into adaptation pathways[29]. An adaptation pathway is a decision-making approach that will guide our response to climate change. It will enable us to identify what actions can be taken now and, in the future, to build our adaptation capacity, prioritise strategies, stagger investment, maintain flexibility, and communicate critical climate adaptation concepts both internally and externally, as we pursue our adaptation goals. This approach also allows for the transition between different adaptation solutions over time as new information and conditions emerge.

Box 3: Types of adaptation solutions.

Climate change adaptation is the process of adjustment to actual or expected climate and its effect to increase resilience, moderate harm and exploit beneficial opportunities. There are a range of measures or options that are available and appropriate for addressing climate change adaptation: Soft, Green, or Hard.

- **Soft Actions -** involve the alterations in behaviour, regulation, or systems of management such as increased monitoring of climate change impacts during operation, or the consideration of climate risk in asset management plans. They are generally relatively flexible and inexpensive to implement.
- **Green Actions** - seek to use nature-based solutions to enhance the resilience of human and natural systems. For example, the addition of green spaces to linear infrastructure projects to counteract urban heat island effect, or the use of drought and heat tolerant species in landscaping.
- **Hard Actions** (or sometimes referred to as 'Grey solutions')- involve technical or engineering oriented responses to climate impacts, for example the consideration of climate change projections in the design of drainage structures.

We have prepared two pathways – one that identifies various trigger points when adaptation actions to address climate change (both current and future) should be considered. The second pathway can be used to make decisions on the type of adaptation action that can be implemented on an asset-by-asset basis for a range of climate hazards (as identified in the risk assessment). Both have been prepared combining two standard pathway approaches - traditional pathway and a flow diagram, to present the best approach for addressing risks to our transmission network.

The solutions outlined in the pathways are examples of activities we can implement following each decision point. For a detailed overview of all the proposed adaptation measures refer to **Appendix**

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[27] https://www.ukclimaterisk.org/
[28] *Definition: Actions to adapt to climate change*
[29] *Definition: Routes to achieve climate resilience*

AC. We have summarised possible actions for implementation both in the short term (i.e. for implementation during the RIIO-T3 price control period of 2026-2031), and longer-term actions for SPEN to deliver in subsequent price control periods.

Each action has also been categorised as either a soft, green, or hard solution (as summarised in **Box 3**). The pathway suggests the initial consideration and implementation of soft, no-regret solutions that are cost-effective now and under a range of future climate scenarios. These then provide the basis for the hard measures subsequently implemented. Nature-based solutions (NbS) are also considered and prioritised early in our adaptation journey considering these represent win-win actions that deliver a range of co-benefits as well as climate resilience. The maximum benefits of these measures are also often realised in the medium to long term and so consideration of nature-based solutions will be prioritised early on. We have identified five nature-based solution pilot projects to be implemented during the RIIO-T3 period. These pilots are more landscape-scale, and require partnership with external stakeholders, to be implemented on land not owned by SPEN. Please see our Environmental Action Plan Annex T3 EAP Master.docx

for more detail of NbS for climate resilience and how these will link with natural capital, biodiversity, and social sustainability.

This staggered approach to the implementation of adaptation measures will assist in managing funding allocations and ensure that adequate research, planning, and feasibility studies are undertaken. In addition, it supports the implementation of the higher cost, harder to implement solutions by improving our maturity in this area and pursing that the most cost-efficient and effective solutions are prioritised.

Section 9 outlines the proposed monitoring and evaluation plan for implementing climate adaptation pathways, ensuring they are regularly reviewed.

8.1. Adaptation Decision Making Pathways.

8.1.1. Pathway 1: When should climate adaptation measures be implemented?

As the impacts of climate change intensify in the coming years, it is imperative that our transmission network continuously improves and bolsters its resilience to the effects of climate change on our overall transmission infrastructure. As a starting point, we have developed an initial adaptation decision making pathway as an overarching framework for our organisation to consider when climate change adaptation and resilience interventions need to be implemented. This overarching decision-making pathway is outlined in **Figure 4**.

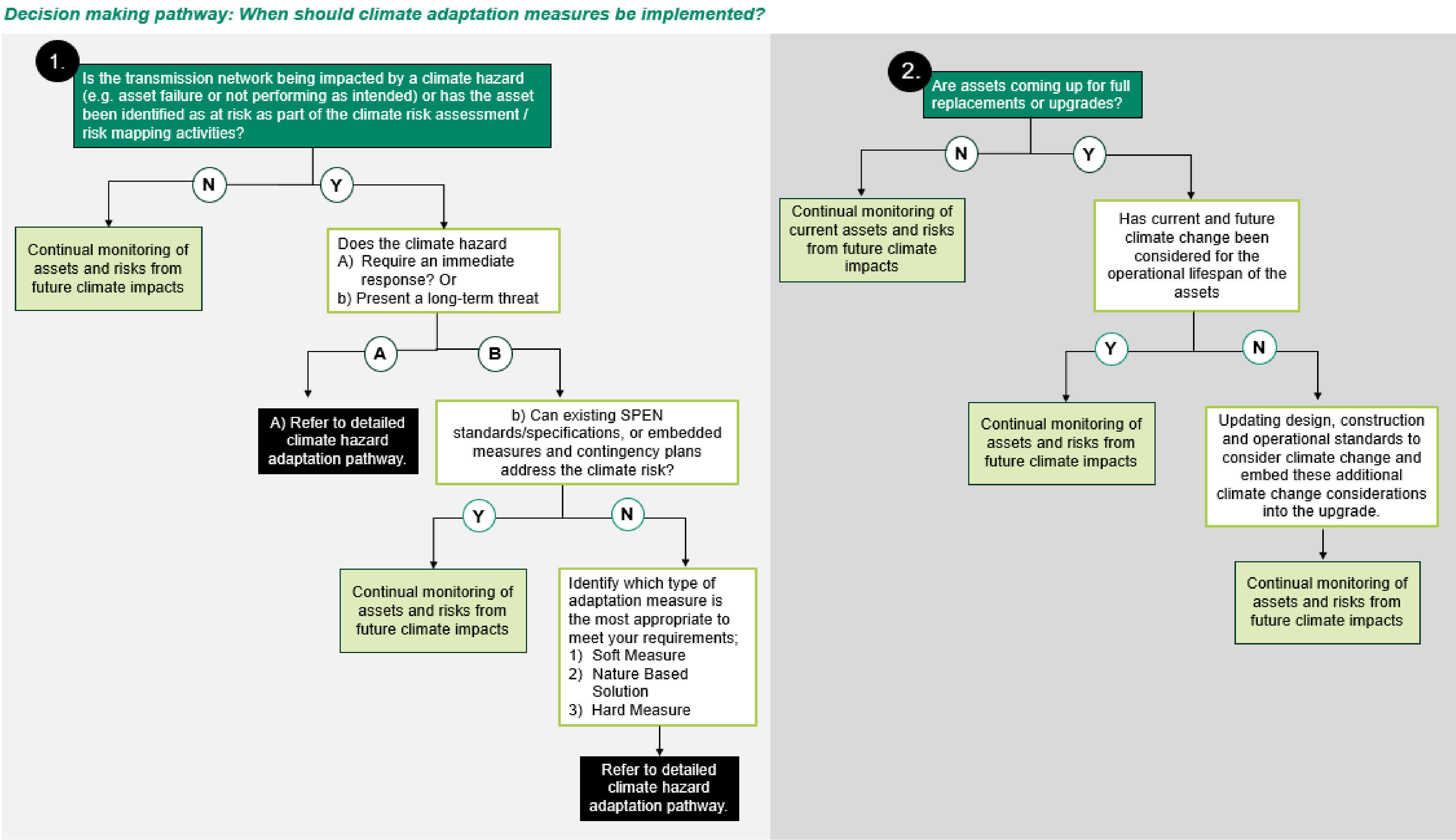
This pathway aims to guide our organisation on the trigger points for when climate change adaptation should be considered and the key decision-making questions to ask during these situations. It highlights two key scenarios, including if an asset(s):

1. Has been impacted by climate change, and thus is either not performing as it should, or has failed.

Is requiring refurbishment or a full replacement.

This adaptation pathway directs the user to the appropriate next steps.

Figure 4: Adaptation decision making pathway: When should climate adaptation measures be implemented?



8.1.2. Pathway 2: Addressing climate risks on SPT's network assets.

Figure 5 presents the pathway that we will use to select the adaptation action to apply to reduce the sensitivity or the exposure of our assets to climate change, both in the short and long term. The pathway covers the two climate scenarios, RCP4.5 and RCP8.5 included in the risk assessment.

The pathways start in the top left with our current position and guides the user through various decision points to establish the best course of action (see 'decision making point questions' highlighted in the black circles).

Following each 'decision making point question' there are a series of consideration questions that will direct the user on how to proceed. The pathway prioritises the implementation of actions starting with soft solutions, then nature-based solution and then hard solutions. These are navigated as you move down the axis on the left-hand side of the pathway.

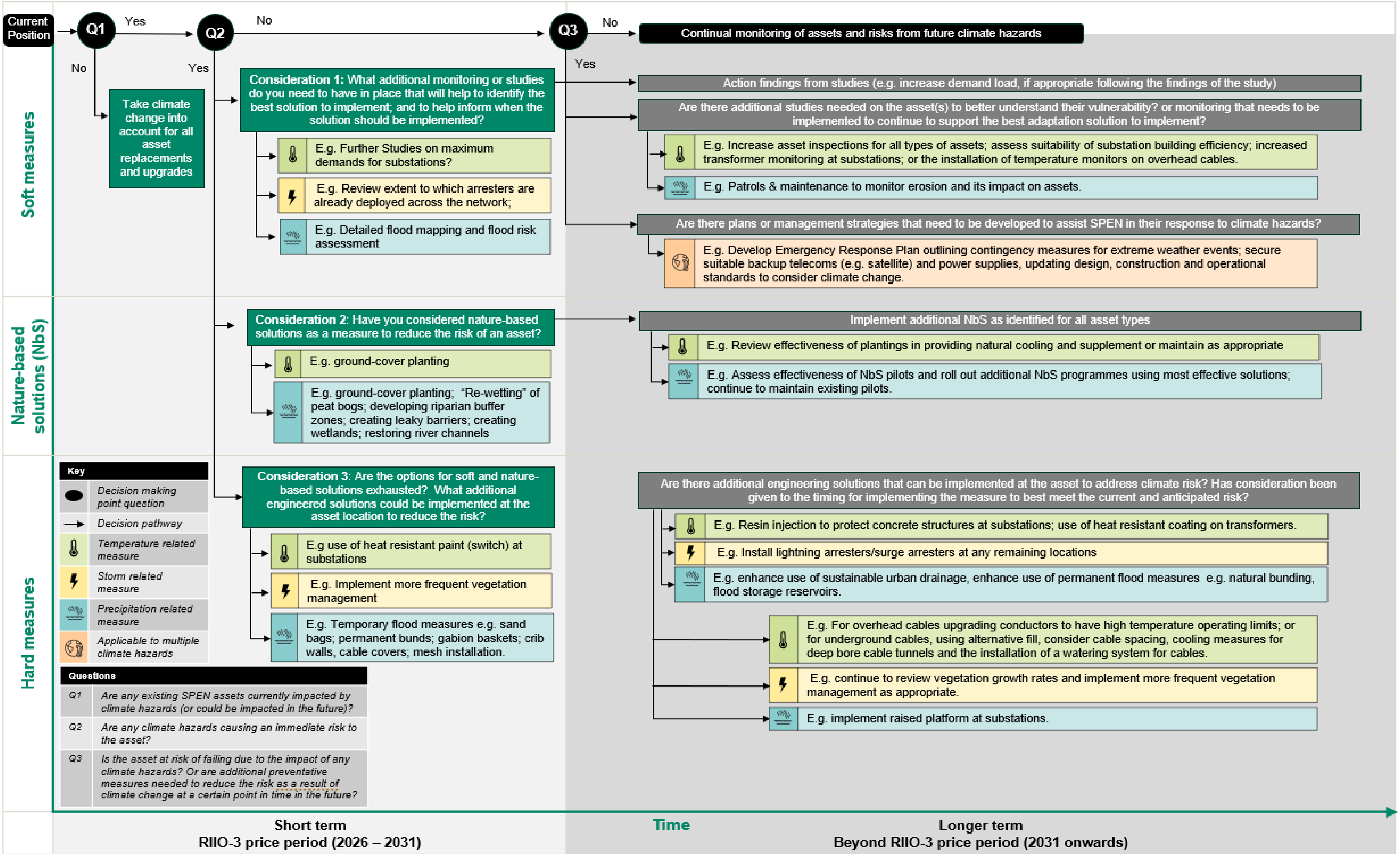
A range of example adaptation solutions have been provided for illustrative purposes that cover the three key assets included in this risk assessment: substations, overhead lines, and underground cables. The examples are presented by the key hazards that are and will impact our assets:

- Changing temperatures (which includes extreme heat, heatwaves, and drought)
- Changing precipitation (which includes changes to frequency and intensity of precipitation events as well as outcomes that arise from increasing precipitation including landslides and flooding)
- Increasing severity of storms (including wind, lighting, and extreme weather events).

For the full range of adaptation measures identified for each climate risk, these are outlined in **Table 19** and **Table 20**, in **Appendix C**, and this should be referred to for further granularity on each measure.

Whilst we have undertaken comprehensive research and engaged with experts across our organisations to develop suitable pathways and adaptation strategies to ensure climate resilience for our Transmission Network, there is the inherent risk that we cannot predict with certainty the future impacts of climate change and the effects it will have on our organisation. While we are confident in our current approach, we remain vigilant and open to considering additional measures as new information and technologies emerge to ensure robust adaptation in the future. We are therefore committed to continually reviewing our adaptation measures and decision-making pathways, not only throughout the RIIO-T3 period, but beyond, and will make appropriate updates as required.

Figure 5: Adaptation pathway to address climate risks on specific SPEN transmission network assets.



8.2. Adaptation Measures and Costs for RIIO-T3 Period

8.2.1. Adaptation Measures

Appendix A presents several adaptation measures which are identified to address specific climate risks from our climate change risk assessment (refer **Section 6**). These have been categorised into short-term and long-term actions. Short-term actions are intended to be scheduled for implementation during the RIIO-T3 period, while long-term measures are planned for beyond this timeframe over the subsequent 45 years. The short-term actions that were prioritised specifically address climate risks rated as 'Major' or 'Severe', and therefore pose a potentially higher threat to our assets and operations. The long-term measures address lower rated risks and are therefore scheduled for implementation later to try and prioritise the actions that will have a greater impact.

The adaptation actions presented in **Appendix A** are not targeted at specific locations (this is likely to change as we develop our plans) or assets but are designed to be broad responses to reduce and adapt to the identified risks. In the future we plan to carry out location specific assessments to take in to account the variety of risks that are impinging on our assets.

A mapping exercise has been undertaken to identify the key flooding and landslide areas within our licence area and to provide a high-level overview of the most vulnerable assets[30]. The adaptation measures are intended to be applied to these identified locations and assets and will require a more detailed feasibility and suitability assessment.

As outlined in the previous sections of this Strategy it is important to highlight that these actions are based on our current understanding of the key climate risks, as well as the available solutions to reduce or adapt to the risks we identified in **Section 6**. We recognise the need for an adaptable approach to address future climate change, where we can incorporate the latest scientific developments and innovative solutions to effectively manage risks to our operations and delivery. It is our intention to continually review our design specifications and standards to incorporate best practice into Business as Usual, thus enhancing our existing embedded controls across all new and existing assets.

8.2.2. Costs for RIIO-T3 Period

The cost for the priority climate adaptation measures identified for our transmission network over the RIIO-T3 period is £35.078m. **Table 18** provides a breakdown of these costs for the three asset types assessed including substations, underground cables, and overhead lines, as well as the total cost for several network wide adaptation solutions, and the nature-based solutions pilot projects.

For the nature-based solution pilot projects, this includes the maintenance costs over a subsequent 45-year period.

Table 18: Costs for climate adaptation over the RIIO-T3 period

Description	Total
Substations	£ 15.818m
Underground Cables – we need to consider some costs in here for river erosion / flooding risks to cable systems. But we may not have specific examples in time for Final Draft	£3.335m
Overhead Lines	£ 12.85m
Nature Based Solutions (NbS)	£3.075m
Total	**£35.078m**

[30] Note that the hazard mapping exercise utilised publicly available data sets from SEPA and BGS.

These costs are split across 2 business plan data tables 8.7 NOCs Other and 8.8 Flood Mitigation as follows:

NOCs Other

Heat Resistant Paint for Substations	£0.240
Gabion Baskets for Ground Stabilisation	£9.075
Crib Walls for Steel Towers	£12.000
Crib Walls for Wood Poles	£0.850
NBS – OHL Ground Cover Planting	£1.210
Total	**£23.375m**

Flood Mitigation

Permanent Substation Bunds 132kV	£2.520
Permanent Substation Bunds 275kV	£2.172
Permanent Substation Bunds 400kV	£1.190
Permanent Substation Bunds 33kV	£0.452
NBS - Rewetting Peat Bogs	£0.978
NBS - Riparian Buffer Zone	£0.276
NBS - Leaky barrier on its own or paired with targeted rock armour	£0.123
NBS - Restoring River Channels	£0.486
River Erosion Cable Surveys	£0.200
Cost of Mitigating Erosion	£3.135
Total	**£11.534m**

Appendix D provides an example comparison of the estimated costs and resources required if a Climate Event such as a Landslip happened which brought down a Transmission tower.

It is expected that future price control periods will identify additional investment requirements for climate adaptation. These will be determined based on the effectiveness of the RIIO-T3 adaptation solutions for example the protection of overhead line routes and the nature-based solution pilot projects, as well as subsequent analysis and feasibility assessments where appropriate.

9. Monitoring, Evaluation and Risk

This section outlines the framework for monitoring and evaluation that we will put into place to allow for the pathways outlined as part of this CRS to be appropriately implemented. Monitoring and evaluation 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 monitoring and evaluation are an essential part of the 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.

9.1. Roles and Responsibilities

To ensure the ongoing management and review of the climate change risks identified in this study and the implementation of the associated adaptation measures, it is important that adequate resourcing is allocated to climate resilience in. In particular, the following roles are included in our business plan submission to manage the monitoring and evaluation framework within the RIIO-T3 period:

- A **Resilience Coordinator** to oversee the implementation of the appropriate pathways and application of the monitoring and evaluation approach, 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.
- Additional resources for asset inspections to enable more frequent and comprehensive monitoring that incorporates climate change criteria. For example, inspections following periods of high temperature or following storm events; monitoring of erosion and its impact on assets.
- The development and delivery of **Climate Resilience training** material for relevant SPT staff to increase awareness of climate risk within the organisation and empower staff to identify and report climate-related impacts and implement the adaptation pathways approach.

9.2. Monitoring and evaluation framework

Error! Reference source not found. highlights the key elements of the monitoring and evaluation f ramework 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 and assesses whether the current adaptation approach being implemented is 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 potential future impact of the climate risks.

This monitoring is a continuous process that will undertake at regular intervals or strategic points in time. The monitoring and evaluation 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.

9.3. Monitor and review baseline data: Climate Change Risk Assessment:

We will need to assess effectively whether the current adaptation approach adopted is sufficient to mitigate against the impacts of climate change. Key climate variables and their associated impacts on the network should be tracked and analysed to help inform associated impact ratings applied in the risk assessment. This data will also be evaluated against decision criteria within the adaptation pathways approach.

Concurrently, climate change projection data will be periodically reviewed in the light of any new scientific findings, such as updated Met Office UK Climate Projections or Scottish Environment Protection Agency (SEPA) flood risk data. This review will help inform any required changes to likelihood ratings applied to the climate risk assessment. This approach will also help keep up to date of any changes associated with current uncertainties within the climate model community, an example being the projections for wind and storminess.

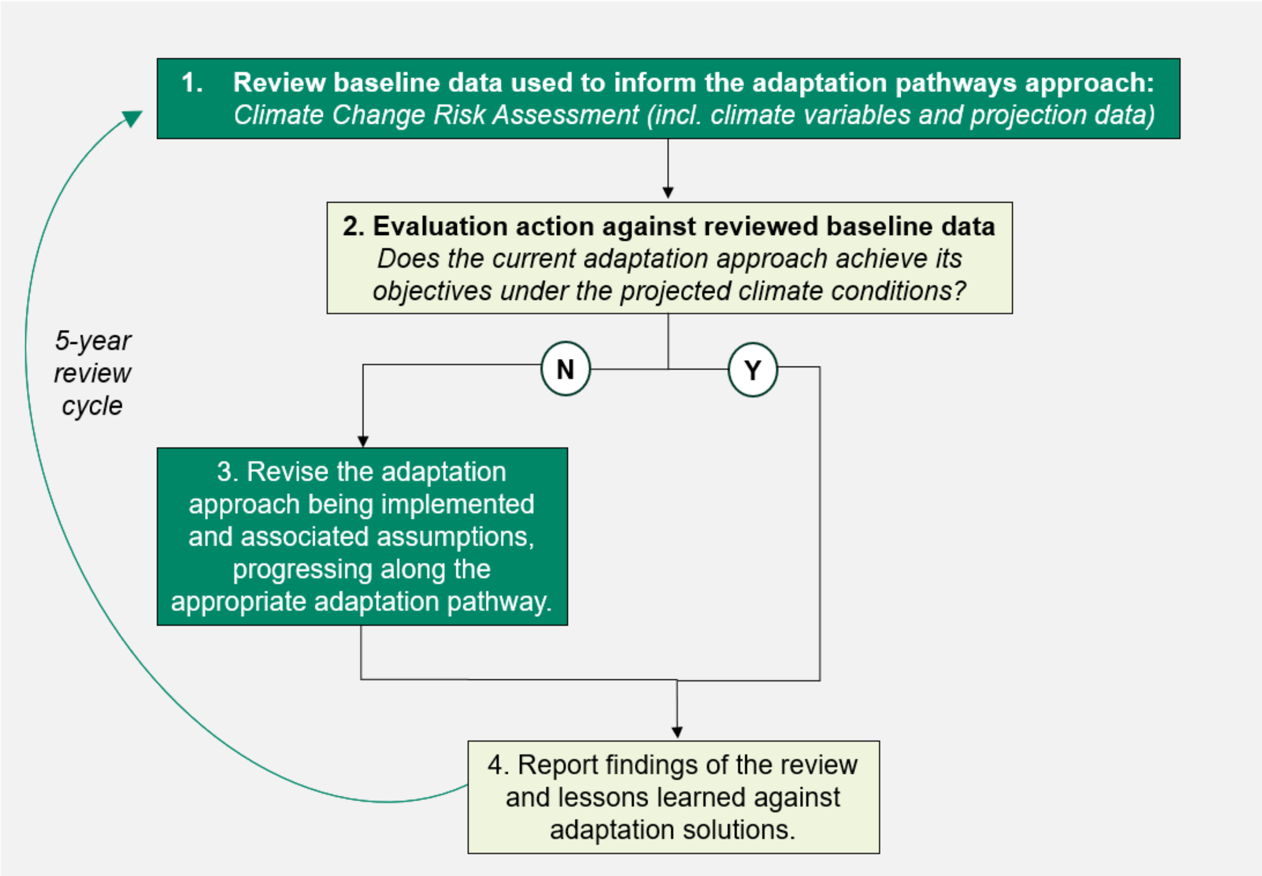


Figure 6: Key monitoring and evaluation steps for SPEN to maintain climate resilience.

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 Networks 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 considering any new information.

1. 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 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.

2. 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.

3. 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,
- Updates from SPEN's ARP4 report (once available)
- 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.

9.4. Integration with existing SPEN Risk Framework

It is important to ensure that the key climate risks identified within this CRS are integrated and monitored within the SPEN Risk Management Framework.

The Resilience Coordinator will communicate with the internal Business Assurance Team and representatives of the key areas within SPEN that the risk reporting covers.

Further information on the risk assessment process is contained in SPEN Guidelines on Risk Reporting document "BUPR-04-011"62.

9.5. Barrier to Implementing our CRS.

We don't foresee any barriers to making a viable case for Climate Resilience in our organisation. Our wider business has already seen the impacts of Climate change not only on our own network but around the world. As outlined earlier in our CRS we have already carried out significant work such as at Kincardine to mitigate against key risks already. There may be external barriers such as scarce resources for key contractors and equipment when set against the resource intensive RIIO-T3 investment plan. Further external barriers may be encountered when engaging with stakeholders to implement some of our Nature Based Solutions.

9.6. Climate Resilience Re-Opener

We see a Climate Resilience Reopener being used when it becomes clear during RIIO-T3 that there has been a material change to the climate change projection data which has had a significant impact on identified risks to our assets. If this were to occur, we would prepare the necessary business cases to justify any additional expenditure.

Appendix A - Further Detail of YW Route Landslip 2019

After a period of heavy rain during summer 2019 it was discovered **in August 2019** that a landslip had occurred on a 275kV overhead line route in Argyll.

The landslip was severe enough to have damaged the legs of a tower. The location of the tower meant access was very difficult and access roads had to be constructed into the tower to allow access for staff and required machinery. The 275kV OHL route is a key route providing access to the transmission network for a large, pumped storage power station.

3 Contractor Organizations were engaged to carry out remedial works ranging from civils to OHL and a more specialist contractor to construct a rockfall barrier.

The work took from August 2019 in o early 2020 to complete **– some 6 months**. Ongoing monitoring of the verticality of the tower is required.

Cost of the remediation works has been over £1m.

Aug 2019 – Footage from drone after Landslip

1st Picture Evidence of Damage to Steel Work of Tower.

2nd Picture showing excavator clearing track and the steep angle of the slope.

3rd Picture Georope rockfall Barrier.

Appendix B Climate Hazard Mapping

Figure 7 SPEN Transmission Network | Flood Hazard Map

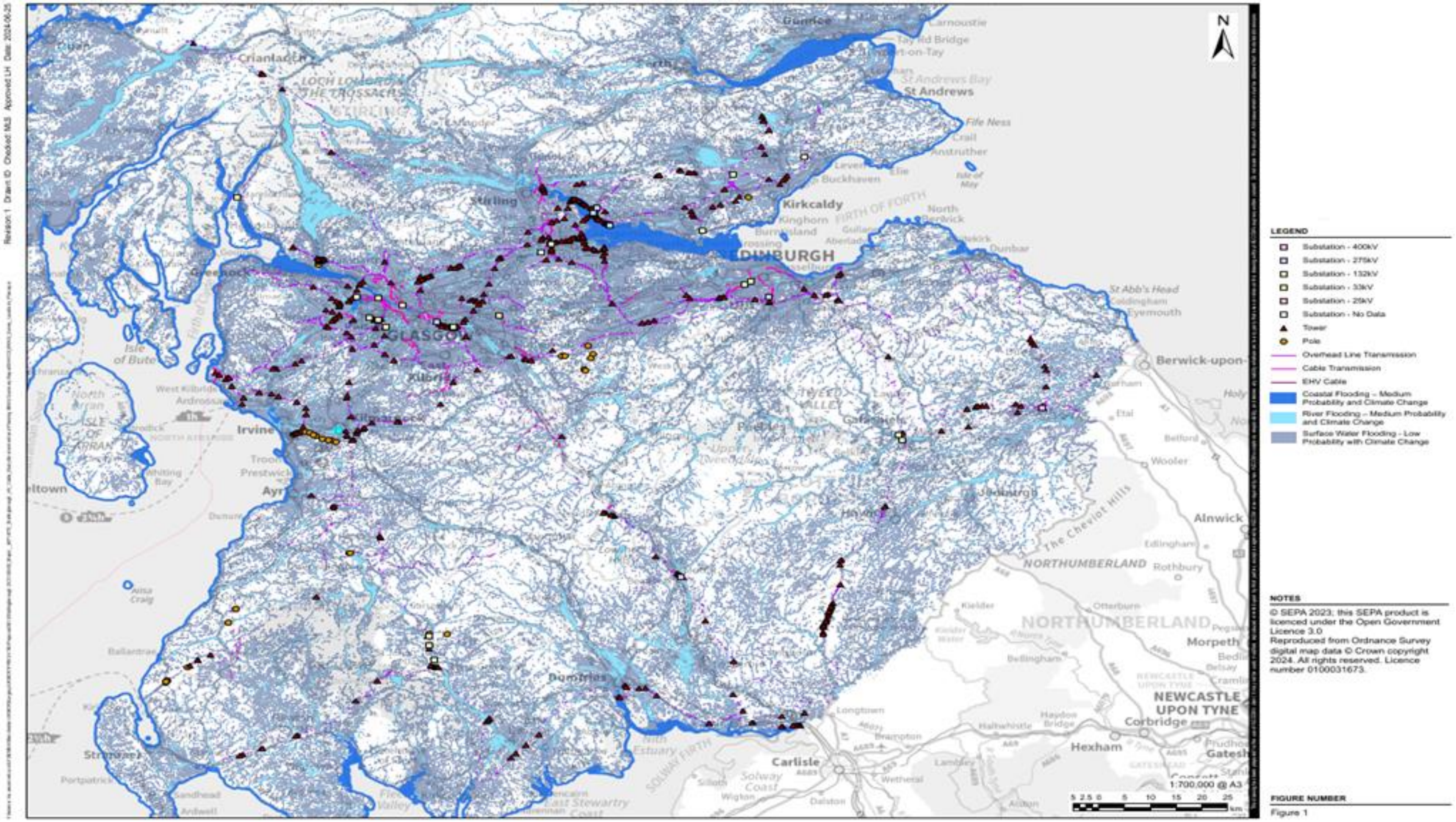
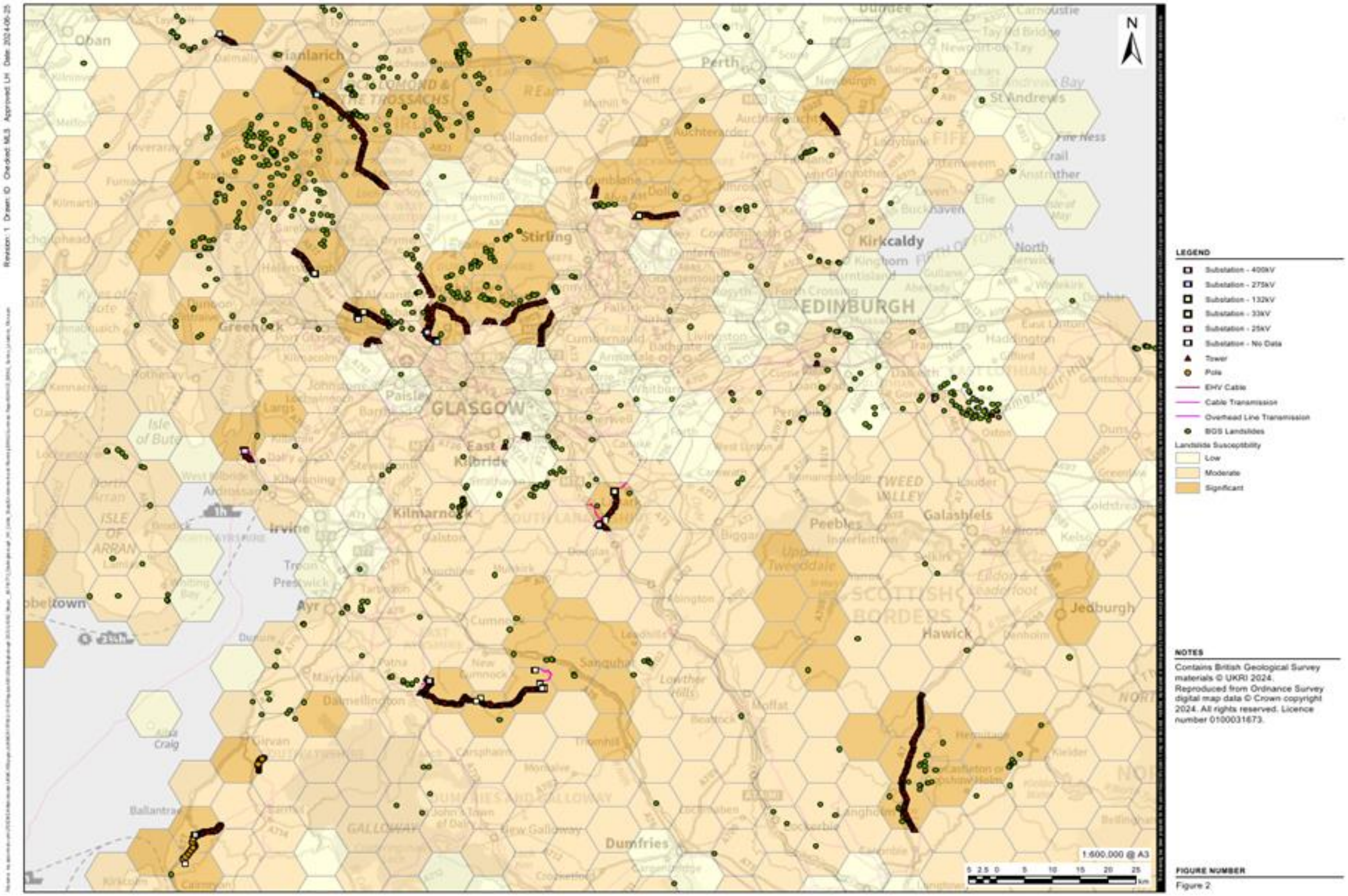


Figure 8 SPEN Transmission Network | Landslide Hazard Map



Appendix C Proposed adaptation measures

The information in this section presents a more detailed overview of adaptation measures proposed in Section 0. **Table 19** outlines the short-term adaptation measures that SPEN should implement during the RIIO-T3 price period (2026-2031) on existing assets[31]. **Table 20** outlines the longer-term adaptation measures that could be implemented, i.e. those that would be rolled out beyond the RIIO-T3 price period.

Table 19: SPEN's short term adaptation measures (implemented during the RIIO-T3 price period)

Action Name	Adaptation Measure	Action Type
Heat resistant paint (switch rooms)	Where suitable and appropriate, the exterior of switch rooms should be coated with a heat-resistant coating that will be resistant to extreme heat e.g. resistant to prolonged heat exposure up to a temperature of 600 °C	Hard Measure
Resin Injection	Inspect substation transformer and flood defence bunds to identify if any cracks are present. If cracks are identified they should be injected with resin, where feasible, to prevent water seeping in during flood events or heavy rainfall. This measure has been included in our T3 Civil Remediation Programmed	Hard Measure
Monitoring and Maintenance	All patrols & maintenance to monitor erosion and its impact on assets. This will include substation, overhead line, and cable inspections teams	Soft Measure
Permanent flood measures	Install, where suitable, permanent flood defence measures to a substation. Such measures can include flood doors and gates, drainage systems and pumping stations, flood storage reservoirs, bunding, land management-based measures e.g. natural bund.	Hard Measure
Gabion baskets	Assets located in areas more susceptible to flooding and associated landslide and erosion should be reinforced with gabion baskets to help stabilise the foundation and or soil around them.	Hard Measure
Crib walls	Assets located in areas more susceptible to flooding and associated landslide and erosion should be reinforced with crib walls to help stabilise the foundation/soil around them.	Hard Measure
Emergency Response Plan	Enhance Emergency Response Plans to outline contingency measures that should be implemented following an extreme weather event that may impact access to SPEN assets and delay necessary maintenance e.g. due to climate impacts to the transportation sector	Soft Measure
Surge Arrester Survey	Review extent to which surge arresters are already deployed across the network as per SUB-01-020 and identify what type of arresters are currently being used in different locations. While undertaking this review, arresters should be assessed to determine if upgrades or replacements are needed.	Soft Measure
Vegetation management	Implement more frequent vegetation monitoring and maintenance procedures taking into consideration faster growing rates due to climate change (e.g. increase annual growth rate assumption). The growth rate assumptions should be informed by a study on changing vegetation growth rates in SPT's licence area	Soft & Hard Measure
Restoration / "Re-wetting" of peat bogs[32]	Restoration / "Re-wetting" of upland peat bogs as natural storage reservoirs to slow/prevent water moving to downstream landslide areas and reduce severity of flooding. This can be considered an innovative solution	**PILOT:** Nature-based solution
Overhead Line Ground Cover Planting	Using ground cover planting to protect OHL towers at risk from landslides during period of heavy rainfall and flooding. This can be considered an innovative solution	**PILOT:** Nature-based solution
Riparian buffer zone [32]	Develop a riparian buffer zone around riverbanks to help stabilise them and prevent erosion and landslide during periods of heavy rainfall and flooding. This can be considered an innovative solution.	**PILOT:** Nature-based solution

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[31] Important to note that whilst the adaptation measures have been identified for existing SPEN assets to reduce or mitigate the risk of future climate change; however, the intention is for these measures to also be incorporated/applied to new assets as well (where applicable). This will form part of the exercise outlined in Section 7 where existing SPEN design specifications will be updated to include relevant actions as a business-as-usual measure.

[32] Given the landscape focus of the nature-based pilot initiatives, these would unlikely be implemented on SPEN owned land. SPEN would therefore support the implementation of these activities, but unable to implement the activity itself.

Leaky barrier on its own or paired with erosion protection activities [32]	Leaky barriers can be used to slow water flow in streams and ditches; or divert high water flows and create areas to store water and can be considered innovative (i.e. Swales and SUDS) While creating a leaky barrier investigate sections which would be suitable for rock armour. Rock armour can be used to help change the direction of water flow as a method of minimising fluvial flooding. Prioritise nature-based erosion protection activities (such as rock armour solutions) e.g. using local materials or softer materials such as sand scaping. Note that flooding modelling must inform the implementation to ensure that there are no adverse downstream impacts.	**PILOT:** Nature-based solution
Restoring river channels[32]	Restoring river channels and meanders can be used to slow the flow, reducing the volume of water in downstream areas, reducing the risk of flooding. This can be considered an innovative solution.	**PILOT:** Nature-based solution

Table 20: SPT's longer-term adaptation measures (implemented beyond the RIIO-T3 price period)

Action Name	Adaptation Measure	Action Type
Re-routing OHL	Option of diverting OHL sections in areas of high flood risk, high landslide risk or high wildfire risk – this would be very expensive so would need to be done when looking at replacing or refurbishing assets. But for new builds we need to make sure we are avoiding these hazards.	Hard Measure
Dynamic Line rating	Deploy Dynamic Line rating (DLR) on OHL spans at most risk. This can be considered an innovative solution.	Soft Measure
Vegetation removal	Removal of invasive, fire-prone species were agreed with grantors.	Hard Measure
Reinforce access roads	Reinforcement of access roads in areas susceptible to landslide.	Hard Measure
Flood mapping and risk assessment	Undertake more detailed flood mapping and flood risk assessments that take into consideration appropriate allowances for climate change. These should be carried out at an asset level, as well as this a more overarching transmission network flood mapping and risk assessment should be developed.	Soft Measure
Upgrade conductors	Install conductors with higher temperature operating limits. During our network design process when re-conducting overhead line routes consideration is given to changes in ambient temperature when selecting conductor systems to achieve the required ratings for the route. –	Hard Measure
Heat resistant paint (transformers)	Where suitable, transformers should be coated with a heat-resistant coating that will be resistant to extreme heat e.g. resistant to prolonged heat exposure up to a temperature of 600 °C.	Hard Measure
Watering	Installing a watering system for underground cables that would provide cooling. Consider sprinkler system.	Hard Measure
Ground cover planting	Planting of ground-cover shrubs can contribute to the mitigation of shallow landslides (depth of sliding surface <2m), enhance soil strength and reinforce soil layers, provide anchors into deeper and more stable substrates through dense lateral root systems, act as barriers against the movement of rock, debris and soil movement, limit landslide run-out distance, lower soil moisture levels through interception, support balance water pressures in slopes, evaporation and transpiration, and improve drainage. For flood mitigation, additional plantings will help to increase water absorption, catch rainfall and slow down surface water run-off. Improve soil cover with plants also reduces water pollution and run-off in near vicinity of substations, and overhead cable towers.	Nature-based solution
Creating (/restoring) coastal wetlands[32]	Creating (/restoring) coastal wetlands and/or salt marshes and/or, mudflats to reduce damage on assets and linear facilities, reduce maintenance costs, reduce erosion surrounding coastal infrastructure, as well as providing carbon sequestration services. Biodiversity benefit of supporting the recovery of degraded, damaged, or destroyed ecosystems	PILOT: Nature-based solution
Temperature monitors	Temperature monitoring may need to be installed. This initial could apply to substation equipment but with suitable technology could be applied to underground cables systems and overhead lines.	Hard Measure
Cable covers	Underground cables, that are not sealed within cable ducts, but located in areas susceptible to flooding/erosion/landslide should be upgraded or retrofitted with more robust cable covers and jackets to prevent water incursion and damage to the cabling – expensive measure. May be cheaper deviating the cables	Hard Measure

Mesh installation	Underground cables that are in areas more susceptible to flooding/erosion/landslide should be upgraded or retrofitted with mesh caging to help stabilise the foundation/soil around – **very expensive measure. Retro fit would require a lot of excavation on land we mostly do not own. Upgrade would be making this part of the design spec for new cable systems but again this would increase the costs significantly**	Hard Measure
Minimising work in dangerous conditions	In line with current practice across our operations, maintenance and non-essential work should cease if extreme weather events create dangerous working conditions. Workers will be advised on best practice protocols to follow during extreme weather events, to minimise potential injury to workers and potential damage to assets. E.g. during a heatwave workers will be instructed to take more frequent water breaks and wear suncream while outdoors – do our current H and S policies for work in extreme conditions cover this well enough or do we need to update?	Soft Measure
Riparian buffer zone	Develop a riparian buffer zone around riverbanks to help stabilise them and prevent erosion and landslide during periods of heavy rainfall and flooding.	Nature-based solution
Planting	Planting of trees or vegetation can help to mitigate the impact of rising temperatures on infrastructure through processes including evapotranspiration and shade provision. Evapotranspiration can lead to cooling of local temperatures and reduced peak summer temperatures Onsite assessments should be carried out prior to additional trees or vegetation being planted to make sure they align with security policies this would be a balance as potentially we would need planting on land we don't own and to ensure the planting doesn't grow such that infringes safety clearances.	Nature-based solution
Elevation above flood level	Implement an elevated substation (e.g. using raised platform like at Kincardine) which would allow for site resilience up to 7 days. This would mainly apply to new sites but also to existing sites that are going through a process of refurbishment or reinforcement and have been identified as at risk to future flooding. Existing substation design policy would need regular review to ensure it meets current climate / flooding forecasts.	Hard Measure
Surge Arrester Implementation	Based on the findings from the surge arrester survey, additional surge arresters or retrofitting of existing surge arresters may require as per SUB-01. Scope and cost of this to be reviewed during T3 with implementation in T4	Soft Measure
Communication contingency measures	Review current communication contingency measures to determine if they're sufficient and equipped to deal with an increase in the frequency of extreme weather events, and the potential disruption they can cause on the transmission network. Based on this, additional backup telecoms (e.g. satellite) and power supplies may need to be put in place to deal with primary communications failing due to extreme weather events.	Soft Measure
Assessment of substation efficiency	Assess suitability of substation building efficiency (material, layout, façade) to increase ventilation and cooling. This will also include adapting our current design policy documents for future substation designs	Soft Measure
Monitoring & Inspections	Increased transformer and switchgear monitoring (online/offline) and inspection of assets displaying signs of decreased performance during high temperature. This would also include consideration of latest technology when installing transformer and switchgear monitoring and benefit of retrofitting where already fitted.	Soft Measure
Uprating transformers	Assess options and specifications when decision point is reached for uprating transformers based on maximum demand and increased load during summer months but also taking in to account any embedded generation and battery storage.	Soft Measure
Increase drainage	Drainage/SuDS solutions at vulnerable substation sites.	Hard Measure
Monitoring solutions	Maintain network management and maintenance activities across all assets. Develop monitoring solutions, to help identify damage to assets following extreme weather events e.g. detect underground cables becoming exposed following river erosion.	Soft Measure
Cooling measures	Forced air ventilation/water cooling for deep bore cable tunnels.	Hard Measure
Alternative fill	Use of alternative sand/soil backfill to enhance thermal conductivity of underground cables.	Hard Measure
Cable spacing	Addressing cable spacing when replacing assets underground.	Hard Measure
Leaky barriers	Create leaky barriers to slow water flow in streams and ditches; or divert high water flows and create areas to store water (i.e. Swales and SUDS)	Nature-based solution
Creating (/restoring) coastal wetlands	Creating (/restoring) coastal wetlands and/or salt marshes and/or, mudflats to reduce damage on assets and linear facilities, reduce maintenance costs, reduce erosion surrounding coastal infrastructure, as well as providing carbon sequestration services. Biodiversity benefit of supporting the recovery of degraded, damaged or destroyed ecosystems	Nature-based solution
Restoring river channels	Restoring river channels and meanders can be used to slow the flow, reducing the volume of water in downstream areas, reducing the risk of flooding.	Nature-based solution

Appendix D - Comparison of Costs and Actions in a Climate Event affecting the Transmission Network

1. Reactive Action to loss of 132kV Tower

For this example, we are using **V Route from Hawick 132kV Substation to Gretna 132kV Substation.**

Main sequence of events:

- Loss of 1x132kV Tower.
- Customers impacted approximately 17,000.
- All customers can be restored in less than 1 hour via transmission circuit from Gala or via 33kV distribution interconnection.
- Transmission Operations Resources deployed to make equipment safe and prepare for erection of Emergency Response System to bypass failed tower.
- Specialist contractors mobilized to erect the Emergency Response System.
- Landowners contacted to allow access for works.
- Estimate to carry out work to erect Emergency Response System is 5 days.
- Longer term work required will be to clear failed tower and debris from site, prepare foundations for a new 132kV tower, design, and construction of new 132kV tower, conductor re-stringing.

Breakdown of Main Costs below:

- Cost of contractors and erection of Emergency Response System - **£300k.**
- Transmission Operations Costs for 5 days - **£20k.**
- ENS Penalty for initial customer loss on day 1 - **£205k.**
- Costs of clearing old tower and preparing foundations for new tower - **£500k**
- Costs of the new tower, design, and re-stringing - **£1.3m**

Total Cost – £2.325m

2. Proactively protecting 132kV OHL Route at High-Risk Sections

Main actions:

- Detailed survey of route showing areas of high landslip risk.
- Solution devised to protect route at these locations.
- Produce Costings.
- Initiate project to implement protection.

Business plan guide

See below for high level costs to protect 1 tower 20m square:

- Crib Walls for 1 tower = £350p/m, allowed for 20m per tower materials and £5k labour p/week = £1200/m

Cost for 20m square tower – £0.24m.

Why is so important to proactively protect our assets from Climate Change?
The costs for proactivity protecting 1 Transmission Tower are substantially lower than the reactive costs which reduces customer disruption and interruption to our day-to-day business activity.