SSEN DISTRIBUTION RIIO-ED2

A SAFE AND RESILIENT NETWORK

RIIO-ED2 Business Plan Annex 7.1

Scottish & Southern Electricity Networks

Contents

EXECUTIVE SUMMARY

Maintaining the safety and resilience of our network through responsible asset management is a critical outcome of our RIIO-ED2 plans for everyone who interacts with our network, especially in the context of our growing reliance on electricity as we progress towards net zero.

Safety is part of our DNA: if it's not safe we don't do it. Safety is a key driver of investment for us, and it is vital we maintain compliance with our safety obligations to protect the public and our colleagues from the risks posed by electricity.

Our RIIO-ED2 business plan will therefore continue to build on our excellent safety record, and we are proposing to spend £408m on key safety and compliance priorities such as tree-cutting and overhead line clearances. We will also build on our successful programme of safety engagement, working with our local communities to keep them safe.

We know that customers highly value the resilience of our services. The COVID-19 pandemic has only increased our communities' reliance on electricity, and the electrification of heat and transport will mean electricity will play a greater role in our daily lives.

We are therefore proposing to spend over £1.1bn on a wide range of activities that support strategic resilience, enabling us to replace those assets on our network that are at highest risk of failure. Our plan is focused on delivering value for customers today and tomorrow, striking the right balance between improving reliability to our network and longer-term resilience, while taking into account affordability considerations.

We are always looking for ways to drive efficiency. We know that there are opportunities to improve our asset replacement unit costs. We have therefore built in a 5% and 2.5% efficiency improvement in SEPD and SHEPD respectively, saving customers £25m over RIIO-ED2. We have identified and implemented a further £32m in efficiencies in other unit rates across a number of areas including LV cables, HV poles and diversions. These savings are mainly attributed to our commercial strategy (outlined in more detail in our ***Cost Efficiency (Chapter 15)*** and ***Deliverability Strategy (Annex 16.1)*** and our ability to drive better value for money for our customers as a result of increased volumes. We have identified £24m of efficiency savings through our tree cutting (targeted efficiencies to improve our benchmarking performance) and repair and maintenance programmes (through economies of scale). We have also embedded over £5m of savings into our plan through our optimisation across different investment drivers.

1. ENHANCED ENGAGEMENT

Our Safe and Resilient Network strategy has been informed by our ***Enhanced Engagement Strategy (Annex 3.1).*** Our draft plan was underpinned by three phases of stakeholder and customer engagement (illustrated in the diagram above). The details of this engagement and insights are set out in Appendix C to this Annex and provide a clear line of sight between what stakeholders told us and our Safe and Resilient Network strategy and outputs.

FINAL SAFE AND RESILIENT NETWORK STRATEGY TESTING AND ACCEPTANCE

We have refined our final Safe and Resilient Network strategy and outputs based on Phase 4 of our Enhanced Engagement, which involved direct testing of the strategy, outputs and costs with 1,501 stakeholders through eight events. The table below sets out the clear line of sight of the changes between our draft and final Safe and Resilient Network strategy and outputs based on this engagement.

ENGAGEMENT EVIDENCE TRIANGULATION AND CHANGES BETWEEN DRAFT AND FINAL PLAN

The table below summarises the clear line of sight between stakeholder and consumer insights and our Safe and Resilient Network strategy and outputs. For our **draft Safe and Resilient Network strategy** and outputs, based on phases 1 to 3 of our enhanced engagement program, we demonstrated how engagement insights had informed our outputs using these keys:

Findings converge to support proposals.

Findings generate new insights that lead to further refinement of proposal.

The proposed approach diverges from the findings.

To demonstrate the line of sight between the scope of **change between draft and final**, based on testing our draft proposals with stakeholders and consumers, we use theses keys:

NEW – a new output for the final plan **ENHANCED** – the draft output has increased in ambition for final plan
REFINED – more clarity is provided in final plan

Strategy/Output	Phase 1-3 Enhanced Engagement	Phase 4 Outputs and Cost Testing	Acceptability
REFINED **Safe and Resilient Network strategy**	**Stakeholders said** Stakeholders across both of our regions strongly supported our proposed resilience strategy **Our response** Our strategy will target assets with the highest probability of failure. Our resilience objectives are informed by stakeholder engagement and cost benefit analysis (CBA), and demonstrate that selected investment options both efficiently meet their stakeholder-driven objectives and efficiently deliver sufficient net benefit for existing and future consumers	**Stakeholders and Consumers said** Stakeholders urged ambition on resilience because of its importance to consumers and businesses with some questions over whether it was value for money. **Our response** We have refined our resilience plans for our final plan reflecting Stakeholder's feedback on ambition and their priorities around value for money. Our ambitious automation plans are detailed in our ***Reliability Annex (Annex 7.2)*** highlighting how we plan to mitigate the impact to Customers through reducing the number and duration of interruptions to their electricity supplies. We will continue to engage with Stakeholders across both of these areas of our plan going forward.	79% for *A Safe, Resilient and Responsive Network* strategic outcome

Strategy/Output	Phase 1-3 Enhanced Engagement	Phase 4 Outputs and Cost Testing	Acceptability
REFINED **Output:** Intervene in our network assets with the highest probability of failure, reducing longer-term risk by just over 14%, relative to a future without intervention	**Stakeholders said** Targeted investments to areas with higher failure rates and/or where the impact of a fault is high is critical. Undergrounding overhead lines was suggested to mitigate asset failures caused by storms and bird strikes. **Our response** Our Business Plan includes undergrounding of overhead lined driven by visual amenity and stakeholder support. We have a robust approach to mitigating asset failures which can included undergrounding but only where this is economic.	**Stakeholders said** Stakeholders urged ambition to make the network resilient as possible and suggested initiatives including further automation of assets and working with Local Resilience Forums. **Our response** We have refined our resilience plans for our final plan reflecting Stakeholder's feedback on ambition and their priorities around value for money. Our ambitious automation plans are detailed in our ***Reliability Annex (Annex 7.2)*** highlighting how we plan to mitigate the impact to Customers through reducing the number and duration of interruptions to their electricity supplies. We will continue to engage with Stakeholders across both of these areas of our plan going forward.	Not tested
UNCHANGED **Output:** Extend our engagement on safety around our assets, reaching 50,000 partners and members of our communities by 2028	-	**Stakeholders and customers said** Most customers ranked this output as a high and medium priority **Our response** We will implement our proposed extension of our safety engagement.	74%

Strategy/Output	Phase 1-3 Enhanced Engagement	Phase 4 Outputs and Cost Testing	Acceptability
UNCHANGED **Output:** Aim to remove redundant equipment from our unoccupied sites within 3 months to prevent risk to the public from the start of ED2	-	**Stakeholders and consumers said** Fuel poor and Future Consumers urged SSEN to be more ambitious and remove redundant equipment immediately or sooner than 3 months. **Our response** We consider 3 months to be a pragmatic solution for removal, given the nature of our assets noting that all redundant assets are made secure against public access. We will consider in the future whether we can shorten the timeframe for removing redundant equipment.	80%

2. INTRODUCTION

This Annex describes what we're proposing to do in RIIO-ED2 that will ensure we continue to deliver a safe, resilient network for all of our customers and employees in an affordable way

The Annex supports the content of ***Safety and Compliance*** (***Chapter 6)*** and ***Maintain a resilient Network*** (***Chapter 7)*** in our main submission document with the underlying detail behind our proposals. It does so by summarising the content contained within the Investment Decision Packs (IDPs), which contain our Engineering Justification Papers (EJPs) and Cost Benefit Analysis (CBAs) and explaining how these align with our submissions in the Business Plan Data Tables (BPDTs), and our key regulatory outputs. The document is structured to methodically explain what our proposals are and why.

- Section 3 of this Annex explains what our proposed investments will deliver for consumers and employees in terms of safety and resilience outcomes.
- Section 4 then details what activities we're proposing to undertake in RIIO-ED2 to support these outcomes.
- Section 5 explains how we built our plan through stakeholder engagement, the principles we applied, and our option development and decision-making processes.
- Section 6 gives further critical insights on our plan through comparisons of RIIO-ED2 key proposals to our RIIO-ED1 activities, highlighting and explaining material differences.
- Finally, section 7 discusses the proposed Uncertainty Mechanisms (UMs) associated with our safety and resilience activities, which have been designed to allow us to flexibly respond to activities where the investment requirement during RIIO-ED2 is uncertain in terms of scope and/or timing.

This Annex is supported by five appendices that detail critical parts of our approach to RIIO-ED2:

- Appendix A sets out our strategy for managing Asset Data, a key enabler of our plan.
- Appendix B explains our application of the Common Network Asset Indices Methodology (CNAIM), which lets us generate the Network Assets Risk Metrics (NARMs) which support decision-making.
- Appendix C explains our enhanced engagement approach and outcomes for this area of the plan.
- Appendix D is a report by consultants ADAS related to our tree cutting requirements
- Appendix E lists the EJPs and CBAs linked to this annex

This annex gives a complete overview of our approach to planning a safe and resilient network during ED2, and justifies our spending plans. Further detail for each area of spend is contained within the relevant EJPs; this annex synthesises the key messages from these critical documents. The relevant EJPs and CBAs that exist are detailed in Appendix E.

Between the draft submission and this final submission, we have taken on board feedback from our stakeholders and worked hard to maximise the efficiency of the expenditure in our baseline plans resulting in a reduction in our funding ask.

The challenge of maintaining a safe and resilient network is not new for the RIIO-ED2 period; but our investments reflect evolving stakeholder needs and network utilisation due to the changing climate position in terms of resilience, changing asset conditions and updated policy requirements. They ensure we can deliver on our RIIO-ED2 strategic outcomes of being a trusted and valued service to our customers and communities; a safe and resilient network; and a provider of a smart, flexible and sustainable energy system enabling the transition to net zero.

3. WHAT WILL CONSUMERS GET FROM OUR PROPOSALS?

Our plan for maintaining a safe and resilient network through the RIIO-ED2 period is a core element of our overall proposal. The expenditure justified within this plan covers a wide range of diverse activities, which are united by their output of managing the long-term risk in our network, meaning customers, employees and contractors will benefit from a safe, resilient network.

Our primary approach has been to manage and mitigate the safety risk to members of the public, our contract partners and our staff when in proximity to our network. We have used the latest most accurate information to determine the activity of work required and then risk assessed these activity volumes down to those that drive the highest value and need addressed in ED2 to remain compliant to safety standards. For achieving a resilient network to meet our customers' needs, we have proposed to invest in network assets that are truly "end of life" where any deferment in replacement or refurbishment would result in a higher risk of failure for customers which is not acceptable.

In selecting our intervention options, we have chosen approaches that provide the greatest long-term value at the most efficient cost. By adopting these approaches to our activities, we are mitigating the bill impact to consumers whilst ensuring everyone's safety on or near our networks, and managing the occurrence of faults.

Activities relevant to these critical goals fall across 16 of the Cost and Volume (CV) reporting categories within the BPDTs and have been grouped by their primary contribution, safety or resilience, as shown in Table 1. This categorisation is a simplification; the nature of power networks means that a single category of activity can be driven by a variety of different drivers and contribute to multiple outputs. These drivers include areas such as safety, resilience, responsiveness, sustainability, and Low Carbon Technology (LCT) facilitation. However, within this Annex we describe those activities dominated by the safety and resilience drivers.

Table 1 - CV tables relevant to delivering long-term risk reduction

Table name	Description	Primary Contribution
CV7 (a-c)	Asset replacement	Resilience
CV8&9	Refurbishment	Resilience
CV10	Civil works condition driven	Resilience
CV26	Faults	Resilience
CV28	Occurrences Not Incentivised (ONIs)	Resilience
CV29	Tree cutting	Safety
CV27	Severe weather 1-20	Resilience
CV30	Inspections	Resilience
CV31	Repair & maintenance	Resilience
CV5&6	Wayleaves & Land Rights	Safety*
CV14	Legal and safety	Safety
CV17	Rising Lateral Mains (RLMs)	Safety
CV18	OH Clearances	Safety
CV32	Dismantlement	Safety

*though Wayleaves are not a safety issue, due to the 3rd party nature of these costs they are grouped with Safety for reporting purposes

KEY SAFETY BENEFITS FROM OUR PLAN

Safety is part of our DNA: if it's not safe we don't do it. Our vision is to continuously deliver safe outcomes for the public, our people and the environment. Safety is driven in large part through our processes, leadership and behaviours and the underpinning safety culture in our organisation, and through investment in a range of critical activities on our assets that deliver long-term risk reductions to anyone interacting with our network.

Our RIIO-ED2 plan will remove specific risks prioritised by the Health and Safety Executive (HSE), such as issues associated with Rising Lateral Mains (RLMs) and link boxes. These legal and compliance issues do not always have a quantified monetary benefit associated, but the unquantified benefit is a clear reduction in particular known risks.

Our asset Condition Based Risk Management (CBRM) also factors in safety risks through the Network Asset Risk Metrics (NARMs) methodology (as detailed in section 5.2. The methodology combines financial, safety, environmental and network performance factors), meaning that safety benefits of our asset replacement programme for resilience are understood and a key factor in the definition of that plan. For example, safety issues will increase the criticality rating of plant which will drive investment decisions earlier for higher risk asset categories.

Other works that directly drive safety outcomes include smarter tree cutting, fitting of safety blankets to link boxes, enhanced site security and dismantlement as shown in Figure 1.

TREE CUTTING ~1000KM OF OHL MADE SAFER

Our smarter approach to tree cutting in ED2 will remove risk from 1000km of our network more efficiently than before

LINK BOXES RISK MITIGATED FOR ~4000 UNITS

Amongst actions on other identified risks, we will intervene on 4097 link boxes across our LV networks

SITE SECURITY 92 ADDITIONAL SITES PROTECTED

To align to our Site Security Risk Index (SSRI) score, we will enhance security measures at 92 sites to ensure the continued safety of the public and deter unwanted access and potential theft

DISMANTLEMENT 200 SITES DERISKED

We will mitigate the risk at more than 200 sites without impacting network performance to minimise risk to the public

Figure 1 - A selection of key safety benefits unlocked by our RIIO-ED2 plan

KEY RESILIENCE BENEFITS FROM OUR PLAN

Resilience is the ability of assets and networks to anticipate, absorb, adapt to and recover from external disruption. This ability delivers clear benefits to customers in the form of improved network reliability, discussed in ***Reliability Strategy (Annex 7.2)*** but also more generally in the reduction of long-term financial, environmental, safety and network performance risks. The CNAIM approach identifies a consistent means of calculating the Risk Index presented by each of our assets in terms of the long-term risk improvement our interventions could alleviate on our network. This approach is discussed in Section 5 of this document, and further explained in Appendix B. Figure 2 below summarises the benefit delivered by our plan as quantified through our application of CNAIM.

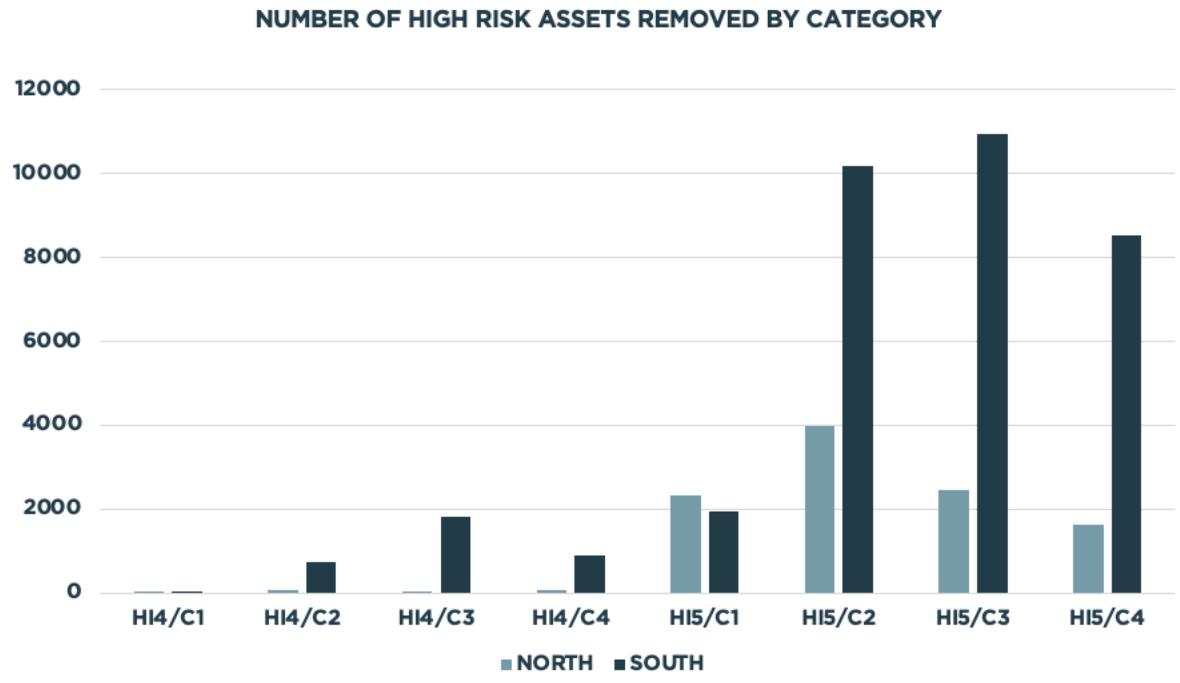

Figure 2 - Reduction in number of high risk assets into better health banding driven by RIIO-ED2 works

The proposed program of works doesn't materially alter the criticality ratings in most cases- this is because criticality is driven by factors such as functional location and asset type, so like-for-like replacements do not influence this. However, interventions utilising alternative solution types may potentially also impact criticality, or network reconfiguration to address other drivers such as load- this is also captured by our methodology. Changes which improve the Health Index (HI) of an asset drive a reduction in the Probability of Failure (PoF), which in turn will lead to less risk in our network.

A measure of the impact of this change is Monetised Risk. The industry standard CNAIM allows for the quantification of long-term risk associated with specific asset classifications in a standardised way. This determines the Consequence of Failure (CoF) to be formed from the aggregated safety, financial, environmental and network performance impacts an asset failure would have, as a monetised value. When the assets CoF and PoF are combined, they form a Risk Index quantified as Monetised Risk.

This Monetised Risk value accounts for the Probability of Failure multiplied by the financial impact associated with the Consequence of Failure, as shown below:

Monetised Risk per asset = Consequence of Failure * Probability of Failure

The value of intervention on network assets can then be measured and the benefit evaluated by comparing the Monetised Risk reduction an activity is expected to achieve relative to if no action was taken. This does not cover our entire portfolio of asset interventions; at this time, the agreed industry standard covers the most material assets in terms of expenditure and impact. We hence use slightly different methodologies for decision making between NARMs and non-NARMs assets.

The forecast evolution of Monetised Risk for our NARMs assets is shown in Figure 3. It shows that our interventions remove ~£900m of risk from arising across our networks. The most effective area of our plan in terms of the Monetised Risk is High Voltage (HV) Overhead Line (OHL) supports; Low Voltage (LV) OHL Supports and Extra High Voltage (EHV) poles, and transformers across all voltage levels also drive substantial reductions meaning our work in these areas demonstrably prevents unacceptable risks impacting on both safety and reliability. Note that another critical NARMs asset type is submarine cable- the associated risk and decision making is described in ***Supporting the Scottish Islands (Chapter 8)*** and ***Scottish Islands Strategy (Annex 8.1)***.

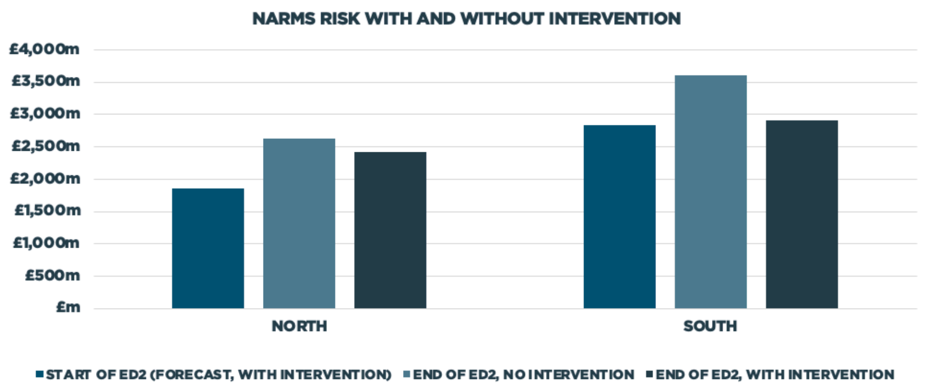

Figure 3 - Monetised Risk impact of all RIIO-ED2 interventions on NARMs assets

It is important to note that absolute total Monetised Risk on the network still increases through RIIO-ED2 highlighting a key nuance of Monetised Risk; as age is a key factor of the Health Index calculation for our assets, risk constantly rises across our installed asset base even when it is still in relatively good condition. This change in Monetised Risk is driven by age related migrations from HI1 to HI2 and HI2 to HI3 classifications. This effect across all health categories would generate £1,481m of extra risk in the network without our targeted interventions to manage this. To deliver an economic plan whilst delivering our long-term risk objectives and strategy, we do not consider it beneficial intervening to reverse all of these risk increases through proactive replacement within RIIO-ED2. This is because the Probability of Failure up to HI3 is relatively low compared to the worse health categories, making proactive replacement drive excessive costs, whereas the assets we have targeted will create long term benefits by significantly reducing probability of failure, for years to come, for high criticality assets. Assets with a health index below HI4 may still need additional inspections, repair and maintenance which is more cost effective at this point in their risk profile.

REGULATORY OUTPUTS OUR PLAN WILL DELIVER

In delivering a safe, resilient and responsive network, we propose a number of regulatory outputs, which we have tested with our customers and stakeholders, and which represent tangible measures of what we will deliver in RIIO-ED2. This is shown in Table 2.

Table 2 - Regulatory outputs associated with investments for safety and resilience

Output	Type	Level of ambition	Cost in baseline plan	Consumer benefits
Safety				
Meet our safety obligations	LO	Continue to meet all safety-related legal requirements	£294.0m	A safe and compliant network for our colleagues, partners and the wider public
Safety engagement	SSEN Aim	Extend our engagement on safety around our assets, reaching 50,000 partners and members of our communities by 2028	£1.2m	Increased awareness and reduced accidents
Keeping the public safe around our assets	SSEN Aim	Aim to remove redundant equipment from our unoccupied sites within 3 months to prevent risk to the public from the start of ED2	£2.2m	Reduced accidents and increased network safety
Resilience				
Network Asset Risk Metrics	PCD/ ODI-F	Intervene in those assets with highest probability of failure, reducing longer-term risk by just over 14% relative to a future without intervention	£338.0m	Improved resilience in the longer term, and improvements to shorter-term reliability. Greater ability of our assets to withstand climate shocks and support the transition to net zero.

LO – licence obligation; PCD – price control deliverable; ODI – output delivery incentive (F – Financial, R – Reputational), SSEN Aim – company goal

The resultant proposed overall cost of our RIIO-ED2 asset plan to meet our strategic commitments and deliver the related outputs is set out in Table 3, for each of our two License regions i.e. our Scottish Hydro Electric Power Distribution (SHEPD) region, and Southern Electric Power Distribution (SEPD) region.

Table 3 - Overall expenditure in safety and resilience

Overall Expenditure	RIIO-ED1 (Final 5 yrs) £m	RIIO-ED2 £m
SHEPD	360	450
SEPD	873	1083
Total	1232	1534

4. WHAT ACTIONS WILL BE TAKEN TO DELIVER ON THESE PROPOSALS?

Our focus over RIIO-ED1 has been on building the strong foundations required to deliver a safe, resilient, and responsive network. The expenditure required to deliver our RIIO-ED2 proposals covers a wide range of diverse activities, which are united by their output of delivering a reduction to long-term risk in our network, meaning the public and our employees will benefit from a safer, more resilient network, and will reduce impact from consumers such as upfront statements in terms of bill impacts. Safety is a key driver of investment for us. We are required to comply with Health and Safety Executive (HSE) requirements such as the Electricity Safety, Quality and Continuity Regulations (ESQCR).

This section of the Annex describes those activities dominated by safety and resilience drivers. Where applicable, we have co-ordinated with other activities such as load and environment to ensure we have not double counted within the RIIO-ED2 proposals. We have created over 1,180MVA of additional capacity through our non-load investments, where this supports our load forecasts (see our ***Load Related Plan build & strategy (Annex 10.1)*** for further details).

BPDT Name	BPDT Name	BPDT Total Cost (£m)	BPDT Total Volume
CV7a	Asset Replacement - NARM	319.8	45,958

We propose a £319.8m investment during RIIO-ED2 for CV7a and implemented a CBRM system at the start of ED1 to inform the Monetised Risk associated with each asset category. The CBRM system utilises the CNAIM which is consistent across all DNOs. This is used to calculate a long-term risk value for each NARM asset which considers both the Health and Criticality index. This information informs the replacement strategy for each asset category and helps us to prioritise investment into assets based upon both the PoF and CoF for what is best for both the network and consumers interest. The information provided by CBRM data is key to the CV7a (Asset Replacement) strategies for each asset category.

BPDT Name	BPDT Name	BPDT Total Cost (£m)	BPDT Total Volume
CV7b	Asset Replacement – Non-NARM	191.0	31,141

We propose to spend £191m during RIIO-ED2 for the replacement of non-NARM assets. Non-NARM assets are not currently tracked within our CBRM models and as such do not have a calculated future projected Health or Criticality score to inform future intervention volumes. For example, there is currently no CBRM modelling providing output data for predicting asset risk on LV and HV underground cable systems. The primary factor for these categories is customer impact (i.e., CI/CML) and fault history. Due to us not being able to inspect these assets due to them being underground and unable to collate data like NARMS related assets, we need to obtain other types of data not previously considered to allow us to make better investment decisions in the future.

A programme of works has been initiated to improve the data collection and record keeping of NARM assets or those that are moving towards NARM, which will continue over the coming few years to ensure that improved data is available in the future. This improvement plan is collectively covered under the Information Gathering Plan (IGP) work contained in TG-NET-ENG-023.

BPDT Name	BPDT Name	BPDT Total Cost (£m)	BPDT Total Volume
CV7c	Civils work due to Asset Replacement	20.5	No volumes required in BPDT

During the replacement of electrical plant, it is sometimes necessary to replace or refurbish the civil asset(s) in order to support the long-term health of the installation. Civils works are normally required when switchgear and transformers are replaced at Grid and Primary sites. This may involve the modification of an existing bund or plinth or complete replacement if the new asset differs significantly from the replaced item or if the civils asset is in poor condition. For asset replacement at Secondary sites, we often have to remove the existing base, carry out excavation works for jointing and reform a new base. Using a similar forecast and approach to RIIO-ED1, we propose to spend £20.5m on civils works relating to Asset Replacement over the RIIO-ED2 period.

BPDT Name	BPDT Name	BPDT Total Cost (£m)	BPDT Total Volume
CV8&9	Refurbishment	74.8	62,251

We propose to spend £74.8m during RIIO-ED2 on Asset Refurbishment. £56.4m will be requested to refurbish Non-NARM assets which need to be intervened upon during RIIO-ED2 due to asset condition and £18.3m will be requested to refurbish NARM assets. This includes corresponding increases in service transfers due to LV cable overlays. In some instances it is more cost effective to refurbish some assets compared to replacement as in CV7. It is critical that we maintain the condition of this asset investment category in order to do what is best for both the network and consumers interest by avoiding expensive reactive works when more efficient proactive intervention can be taken.

BPDT Name	BPDT Name	BPDT Total Cost (£m)	BPDT Total Volume
CV10	Civils Work Condition Driven	28.5	5,920

SSEN continually strive to ensure that the assets utilised have longevity, are fit for purpose and have an optimal asset life. The assets targeted for intervention are deemed end of life and no longer fit for their required purpose. The biggest contributor to the proposed RIIO-ED2 civil costs includes the replacement of substation fences, doors and roofs. A combination of condition-based assessment and trends in historic volumes has been used to forecast the volumes and expenditure of substation building components and surrounds. The main risks in respect to these civils assets have been identified and considered and remain unchanged from RIIO-ED1.

Furthermore, a mixture of risk assessment, site surveys and historic volumes of interventions has been used to forecast volumes and expenditures for specific programmes of work. The combined total proposed for civil works condition driven during RIIO-ED2 is £28.5m.

BPDT Name	BPDT Name	BPDT Total Cost (£m)	BPDT Total Volume
CV26	Faults	269.7	137,224

A key factor in our RIIO-ED2 plan is setting that right balance of proactive asset replacement and repairs/maintenance activities and the anticipated resultant level of faults which will still require reactive response. We propose to invest £269.7m during RIIO-ED2 to manage faults on the network and to obtain the optimum balance of proactive and reactive interventions.

This is a key balancing act we strive to achieve in creating a plan which most cost-effectively meets the safety, resilience and reliability expectations of our customers and our associated reliability ambitions to reduce the number and duration of customer interruptions.

Our fault prediction drives a modelled trend analysis using numerous data inputs from historic data, forecasted volumes for the remainder of ED1 and data from the Master BPDTs for ED2. Using six years' worth of NaFIRS (i.e., National Fault and Interruption Reporting System) data, the faults were grouped into three categories i.e., 'within gift' (SSEN could have prevented by early intervention), 'trees' and 'external' (i.e., faulted assets due to third party damage, malicious damage, unforeseen and force major) and further separated based on the asset classes recorded within CV26. Six years of RIIO-ED1 fault performance data has been used to provide a start point for the trend analysis against interventions on the network and a linear trend is used to forecast the fault rate between 2021 and 2028. This approach was sanity checked by looking at alternative parameters. The total faults across the three categories were then combined and filtered into the 28 categories required for CV26 and the split was derived using RIIO-ED1 ratios.

BPDT Name	BPDT Name	BPDT Total Cost (£m)	BPDT Total Volume
CV28	ONIs	47.6	268,769

We propose to invest £47.6m during RIIO-ED2 to manage Troublecall Occurrences Not Incentivised (ONI) on our network (i.e. non-urgent street lighting faults and reactive work that has to be addressed quickly such as Category A defects requiring urgent action and Category B defects preventing work, which need resolving within a short timescale). A combination of external factors and minimal material change in trends during RIIO-ED1 has led us to believe the numbers will continue at the same rate in RIIO-ED2 as we've seen in the current control period.

BPDT Name	BPDT Name	BPDT Total Cost (£m)	BPDT Total Volume
CV29	Tree Cutting	189.7	941,220

We propose to spend £189.7m on Tree Cutting during RIIO-ED2 to maintain the safety and integrity of the OHL network and to avoid the public coming into contact with our electrical assets. This includes all costs associated with the inspection and cut of the overhead line network including the ENA TS 43/8 compliance cut, the ETR 132 compliance cut, LiDAR surveys, and a dedicated Ash Dieback survey. Unmanaged tree and vegetation growth can cause serious physical damage to the OHL network resulting in faults and outages for network customers. In extreme cases, during storms trees can fall onto the OHL network resulting in significant damage and a serious safety risk to the public and our employees. Tree and vegetation growth represent a real risk to the reliability and safety of the electricity distribution network and must be managed effectively within both of our license areas. Further details are discussed in depth in Section 6.

BPDT Name	BPDT Name	BPDT Total Cost (£m)	BPDT Total Volume
CV27	Severe weather 1-20	19.2	1,792

Severe weather events cause significant damage to the distribution network through high winds in excess of normal operating conditions, lightning strikes, snowstorms and ice loading. The resultant damage can be catastrophic with large numbers of wooden poles broken due to the sheer weight of line ice loading, overhead line feeders with broken conductor and faulty plant having been struck by lightning. The SHEPD licence area has seen two of these events in the last 10 years. Although we haven't seen any events for the past two price control periods in SEPD, we see this as a risk to the network.

We are experiencing continuing emerging patterns of high temperature and rainfall extremes and with global temperatures rising, the UK's weather is likely to become even more extreme. We have therefore used the same cost projection for both networks and uplifted the cost to reflect 20/21 prices. Further information on the impacts of weather on our network can be found in ***Climate Resilience Strategy (Annex 7.3)***

BPDT Name	BPDT Name	BPDT Total Cost (£m)	BPDT Total Volume
CV30	Inspections	41.6	869,794

We are proposing to spend £41.6m during the RIIO-ED2 period to ensure plant and equipment is inspected and to confirm it is operating correctly and safely. In order to ensure good quality data is captured and recorded in the asset register in a timely manner, key condition and defect information is collected during routine inspections. To ensure the quality of the data being captured correctly, SSEN inspectors are provided with the required training on condition assessments and the benefits of good data quality. This has led to more accurate information being collated and has provided a better understanding of the overall condition of our electrical assets which feeds into our decision-making tools such as CBRM. This approach has also enabled the prioritisation of high-risk defects allowing SSEN to more effectively plan activities resulting in appropriate rectification and a more efficient use of resources. Please see Appendix A: Asset data strategy for further details on Asset Data Quality.

Approximately 800k of our inspection costs are tied to South Subsea cables; note that Northern Subsea cables are discussed in depth in the ***Scottish Islands Annex (8.1***.)

BPDT Name	BPDT Name	BPDT Total Cost (£m)	BPDT Total Volume
CV31	Repair and Maintenance	112.7	499,534

The scheduling of maintenance has a critical impact on the utilisation and effectiveness of an asset. Maintenance activities help to ensure an asset will reliably perform its function throughout its time in service and to ensure the safety of our staff and the public. We propose to spend £112.7m carrying out repair and maintenance activities on our assets. This is usually carried out at regular intervals during RIIO-ED2 in accordance with our maintenance policies and recommendations from equipment suppliers. Maintenance activities can be time based or duty based, and this depends on the asset requirements (i.e., switchgear that has operated under fault conditions may need to be maintained prior to its planned maintenance to ensure it will function in a safe and timely manner). Maintenance forms part of the asset life requirements and by not doing this we will reduce the life span of the equipment.

Approximately 300k of our Repair and Maintenance costs are tied to South Subsea cables; note that Northern Subsea cables are discussed in depth in the ***Scottish Islands*** (***Annex 8.1***.)

BPDT Name	BPDT Name	BPDT Total Cost (£m)	BPDT Total Volume
CV5&6	Diversions	112.0	18,014

During RIIO-ED1 we have seen a sharp upturn in the size and scale of Injurious Affection claims. This increase is in part due to urban expansion which brings developments into contention with our assets, but also as a result of landowners, occupiers and their representatives are more willing to test their rights and ours. For example, we have seen claiming agents develop business plans which focus on the pursuit of claims on behalf of property owners on a high-volume low return basis, flooding the industry with a huge portfolio of claims to manage.

However, we are proposing to limit the baseline spend in the plan for Injurious Affections to align to the last 5 years in ED1 (i.e. £64.7m during the RIIO-ED2 period). This is due to the uncertainty of the volume of claims submitted to SEPD and SHEPD. We also want to engage with government, devolved administrations, other DNO's and other stakeholders through the ENA Estates and Wayleaves forum (EWF) to look at legislative reform.

In addition, there is uncertainty around the nature and quantum of termination and diversion costs. The costs of reconfiguring the network can vary significantly, and this in turn drives cost uncertainty at the aggregate level.

Whilst not strictly a wayleave termination, SSEN has with Network Rail, a Master Wayleave Agreement covering our overhead lines and underground cables crossing Network Rail property. Under the terms of the agreement Network Rail can serve a notice requesting us to remove or relocate our assets crossing its property. We are currently engaging with Network Rail and other parties regarding plans for a rail electrification programme in the North of Scotland. Whilst we have an indication of the routes being considered for electrification, we have not yet received the detailed information required to define the extent of diversion works required. We are also yet to receive detailed information on either the proposed phasing of the works, or on the distribution of funding across customer bases (with a potential for financial contribution from rail customers). As a result, we cannot currently forecast the potential costs associated with this programme. In relation to the SEPD license area, we are not aware of any planned rail electrification programmes over ED2.

We consider that the re-opener should be made available in case a need for diversion works emerges in the future. We will continue to work proactively with Network rail on their proposed programme but at this time we simply do not have any level of certainty of what will be required from us and when.

BPDT Name	BPDT Name	BPDT Total Cost (£m)	BPDT Total Volume
CV14	Legal & Safety	14.5	22,012

Safety and statutory compliance are two of our main drivers for investment. Our decisions are driven by the HSE, ESQCR commitments and our safety culture. The key areas of the £14.5m investment for RIIO-ED2 Legal and Safety BPDT covers a variety of categories including site security, asbestos management and operational restrictions. To ensure compliance with the Control of Asbestos Regulations (CAR) 2012 and the safety of SSEN assets, staff and members of the public, we propose to spend £3.2m managing Asbestos Containing Material during RIIO-ED2. To adhere to the National ENA standard, ENA Engineering Report 2; Guidance on Security of Substations, Cable Bridges and Cable Tunnels, we plan to spend £4.5m on security enhancements at our sites to ensure the continued safety of the public and deter unwanted access and potential theft. In line with PR-NET-ENG-028, the National Equipment Defect Reporting Scheme and Association with Operational Restrictions, we propose to invest £3.7m during RIIO-ED2 to manage Operational Restrictions across our network.

BPDT Name	BPDT Name	BPDT Total Cost (£m)	BPDT Total Volume
CV17	RLM	29.4	627,884

In response to the Grenfell tower block fire in London in 2017, the HSE are reviewing the arrangements for all utility services to manage such buildings. This is partly in response to the tower block fire in London in 2017 but ultimately to ensure that no buildings are at risk due to faulty or poor condition assets. We are proposing to spend £29.4m to manage RLM during the RIIO-ED2 period.

Due to a high population of RLM on the network, we have taken an efficient approach and recently inspected a statistically significant sample size of multi occupancy buildings across SEPD and SHEPD and extrapolated the condition data to help understand the condition of SSEN's asset base. The results from the recently completed inspection programme have been used to determine the final volumes and associated costs for RLMs in ED2. The final volumes for both RLMs related inspections and interventions reflect the increased focus on the safety of high-rise multi-occupancy dwellings. The large increase from ED1 is due to a combination of the increased focus on safety related concerns in multi-storey buildings and the ageing RLM asset base and associated non-compliant RLM assets.

BPDT Name	BPDT Name	BPDT Total Cost (£m)	BPDT Total Volume
CV18	OH Clearances	60.5	35,522

The deployment of Light Detection and Ranging (LiDAR) technology has highlighted that our OHL network, especially at low voltage, requires additional work to ensure safe clearance to ground and buildings. This is to ensure that we maintain the required levels of public safety. The introduction of LiDAR technology has been key to developing a more accurate and in-depth understanding of our assets. Acting on new and enriched data and information means we can keep the public and our colleagues safe. We are proposing to spend £60.5m across both our networks on OHL clearances.

BPDT Name	BPDT Name	BPDT Total Cost (£m)	BPDT Total Volume
CV32	Dismantlement	2.2	672

The £2.2m RIIO-ED2 investment for Dismantlement targets redundant sites that pose a significant safety risk as often they are left on abandoned industrial sites and it is not always practical or efficient to check the location is continuously secure. These sites run the risk of trespass, vandalism, increased probability of metal theft and unauthorised interference. Although dismantlement is generally associated with HV ground or pole mounted secondary sites, there may be instances where redundant underground cable and overhead line needs to be removed. We carry out a risk assessment to determine the reason for disuse and the likelihood of return to service and propose which sites are more effective to remove and the optimum time to remove them.

The safety of the distribution network for both the public and our employees is of the utmost priority and substations must be secure to trespass and potential theft which can result in serious harm to members of the public. It is important that appropriate measures are put in place when assets are no longer supplying customers. This can include additional signage, de-energisation or complete dismantlement.

Delivering efficiencies and value to consumers

We are proposing an increase in our spend relating to tree-cutting and OHL clearances when compared to RIIO-ED1. There are a number of factors for this. The introduction of LiDAR technology has been key to developing a more in-depth understanding of our assets. Acting on new and enriched data and information means we can keep the public and our colleagues safe, and we have reviewed our RIIO-ED1 activities to understand the impact of this new information on our RIIO-ED2 programme of works.

We will continue to rollout innovations developed in RIIO-ED1 to deliver our services in the most efficient way possible. The live line harvester method for example has allowed tree cutting to be carried out without planned interruptions. We have also been using forestry mulchers, specialised machines designed to clear small trees and shrubs underneath overhead lines. Both technologies have been deployed in our SHEPD network, as they are limited by site access restrictions and tackle very specific vegetation issues, with savings of over £7.5m to date in RIIO-ED1.

Wayleaves and diversions continue to be a growing problem across our industry. We will continue to protect our customers from unnecessary cost increases, both through our management of individual claims and the use of an uncertainty mechanism.

We are also making wider changes to our commercial and supply chain strategy to meet the step-change in performance required to deliver RIIO-ED2. Collectively these investments and strategic changes will allow us to deliver ongoing efficiencies throughout RIIO-ED2 (our stretch ongoing efficiency target of 0.7% per annum, as set out in ***Costs and efficiency (Chapter 15)***.

Deliverability of our plan

Our ***Ensuring Deliverability and a Resilient Workforce*** (***Chapter 16)*** document describes our approach to evidencing the deliverability of our overall plan both as a package and its individual components, to ensure that we can demonstrate a credible plan to move from our RIIO-ED1 performance to our target RIIO-ED2 scale of delivery and efficiency.

Our deliverability strategy describes our approach to evidencing the deliverability of our overall RIIO-ED2 plan as a package, and its individual components. Testing of our plan has prioritised assessment of efficiency and capacity, and this has ensured that we can demonstrate a credible plan to move from our RIIO-ED1 performance to our target RIIO-ED2 efficiency. We have also demonstrated that our in-house and contractor options can, or will through investment or managed change, provide the capacity and skills at the right time, in the right locations. This assessment has been part of the regular assessment of our engineering justification papers, and business plan data tables, which has continued through to our final plan submission. Our deliverability testing has identified major strategic opportunities which is relevant across our plan:

1. In RIIO-ED2 we will change the way capital expenditure is delivered, maximising synergies within the network to minimise disruptions for our customers. This is particularly relevant for a price control period where volumes of work are increasing across all work types.

2. The principle is to develop and deliver programmes of work, manage risk and complexity at programme level and to develop strategic relationships with our suppliers and partners to enable efficiency realisation.

3. The commercial strategy will explore the creation of work banks and identify key constraints. The load work will be the primary driver for a work bank, supplemented by non-load work at a given primary substation.

This approach will capitalise on synergies between the load and non-load work, whereby the associated downstream work from a primary substation will maximise outage utilisation, enabling the programme to touch the network in a controlled manner with the objective of touching the network-once.

4. Transparency with the supplier in terms of constraints, challenges, outage planning and engineering standards will capitalise on efficiencies, supported by a robust contracting strategy.

5. WHY DID WE CHOOSE THESE INVESTMENT PROPOSALS OVER ALTERNATIVES?

As demonstrated in the preceding sections of this Annex, maintaining a safe and resilient network through RIIO-ED2 requires a significant diversity of activities on all our different asset types. To develop our understanding of what activities were required on what assets, and importantly how combinations of solutions could deliver the outcomes consumers want economically and efficiently, we undertook a range of engineering analyses, followed by robust options development, decision making, justification, and Cost Benefit Analysis (CBA) activities.

As shown in Figure 4, this section will describe how we understood our requirements with stakeholders, our guiding principles in designing potential interventions, our interventions that are determined by the legal and regulatory environment through our work with the HSE, and our options development, analysis and CBA processes for ensuring economic solutions were chosen where there was optionality.

Figure 4 - Section 4 structure

This Annex summarises the choices we have made across our full portfolio of assets and related activities; however detailed justification for each particular expenditure class can be found in the relevant EJPs, which provide the detail of each item of spend.

These are, where appropriate, supported by CBAs; these are provided wherever there is material optionality in how we can address the networks requirements, and it is credible that multiple options could be optimal.

5.1 DEVELOPING REQUIREMENTS WITH STAKEHOLDERS

Our approach to Enhanced Engagement is detailed in Section 1.

5.2 PRINCIPLES OF ROBUST DECISION-MAKING

This subsection addresses the principles, data practices and methodologies we have used in developing our plan. This consists of 4 topics:

1. A discussion of our approach to best practice asset management
2. A summary of our asset data approach, the full detail of which is in Appendix A
3. A summary of our CBRM approach, which is supported by Appendix B; this describes the methodology for assets within the scope of CNAIM
4. A discussion of our methodologies for assets which fall outside the scope of CNAIM

GETTING THE RIGHT BALANCE- DECISION-MAKING FOR OPTIMAL RISK, COST AND PERFORMANCE

Asset management for long-term resilience of the network requires navigating a trade-off between accepting increased risks, incurring costs on activities to reduce risks, and maintaining the capability to respond when risks manifest. In the risk mitigation space, there are then different levels of mitigation and cost to select from to achieve an aggregated impact that gives consumers the network performance they seek at the right cost. This trade off and our potential responses to it are characterised in Figure 5.

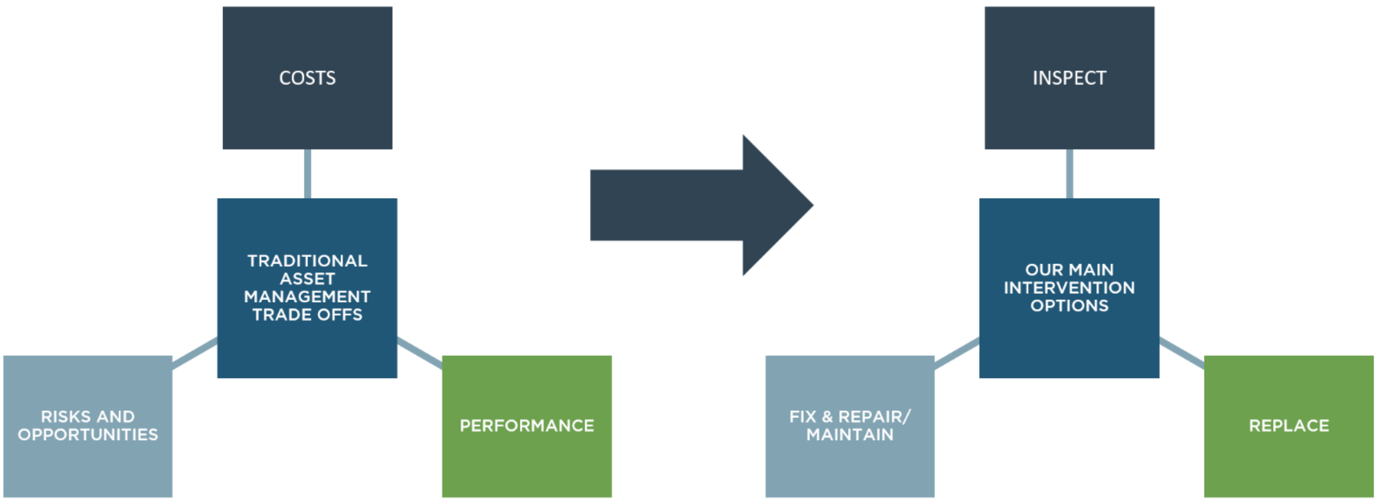

Figure 5 - Trade-offs in asset management and our interventions

Asset management is an integral part of everything we do. An effective Asset Management System (AMS) will ensure that our network continues to provide a safe and reliable supply to all customers. We are certificated to BS ISO 55001:2014 Asset Management. Implementing this standard enables us to achieve our objectives through effective control and governance of our network assets enabling us to realise value through managing risk and opportunity in order to achieve the desired balance of cost, risk and performance.

We recognise the importance of our networks' infrastructure in the context of the wellbeing of all who use it. A defined and integrated risk-based asset management system provides an efficient, cost-effective solution which will ensure that we meet our Asset Management objectives. The application of an AMS provides assurance that those objectives can be achieved consistently and sustainably over time. Our AMS enables us to translate the company's objectives into asset-related decisions, plans and activities, using a risk-based approach. Good stewardship of the whole lifecycle of our asset base delivers long-term value for our customers.

ENABLING ROBUST DECISIONS: THE ASSET DATA STRATEGY

Data is a core component of our plan and will act as enabler as set out in the strategic outcome of this document. The biggest required change is in the cultural acceptance of a clear strategic approach to managing data and obtaining value from data.

We have continued to refine our current strategies and build on the availability of further enriched data as we proceed in to ED2. Some areas of continued work to allow better investment decisions to take place are:

- Ensure our data remains trusted and valued for our customers now and in the future.
- Establish Data as an Asset.
- To meet the minimum requirements for the provision of Open data and Digitalisation.
- To provide the systems and capabilities to enable the delivery of our ED2 commitments.

Our position on asset data will continue to be updated as we work with Ofgem and other DNOs as part of the various working groups, consultations and methodologies for RIIO-ED2. Our approach will be aligned with the UK Government, Ofgem, and SSEN's ***Digitalisation Investment Plan (Annex 5.2.)*** This includes industry forums and best practice principles such as those produced by the Energy Data Catapult.

To deliver the preceding outcomes, we will focus our efforts in 5 key areas:

1. **Expand NARMs commitment across all common asset categories modelled in CBRM utilising CNAIM to cover 61 RRP categories – 78% of our non-load related expenditure**
2. **Accelerate Information Gathering Plan (IGP) commitments**
3. **LiDAR utilisation and GIS integration**
4. **Data Governance culture and awareness**
5. **Data Quality (DQ) rules, policies & scorecards**

Further detail and commentary on our progress towards our strategic outcomes for Asset Data is available in Appendix A of this document, and our Digitalisation strategy, which describes investments that will enable our data related capabilities, is available in ***Digitalisation Investment Plan (Annex 5.1.)***

CONDITION BASED RISK MANAGEMENT TO MANAGE SAFETY AND RESILIENCE

Utilising the information gathered on our assets and sites from inspections along with other key information collected during installation, commissioning and configuration we utilise our industry standard approach of CNAIM and CBRM system to prioritise our investment in assets.

The approach is based on a standard risk approach assessing the Probability of Failure (Health Index) and the Consequences of Failure (Criticality Index) to calculate an overall risk score (Monetised Risk) for each applicable asset type and this can provide a cumulative total figure for each of our license network areas (SHEPD and SEPD).

The Health Index is a framework for collecting information relating to asset health and Probability of Failure. The Health Index consists of five bandings, HI1 to HI5. The HI1 banding represents assets with the lowest Probability of Failure and HI5 the highest.

The Criticality Index is a framework for collecting information relating to Consequences of Failure. The Criticality Index consists of four bandings, C1 to C4. Assets are currently allocated to a Criticality Index Band according to the relative magnitude of the Consequences of Failure for the individual asset compared to the Average Overall Consequences of Failure for the relevant Health Index Asset Category. The C1 banding represents assets with lower-than-average consequences of failure, whereas the C4 banding is used for those with significantly higher than average consequences of failure. In CNAIM, Consequences of Failure are assessed by considering four separate consequence categories: -

- Financial;
- Safety;
- Environmental; and
- Network Performance.

The Criticality Index banding is based on consideration of the overall Consequences of Failure, considering all four consequence categories.

For existing regulatory reporting, Network Asset Indices are reported using 5 x 4 matrices of Health Index against Criticality Index, such as the one shown in Table 4. These are known as Risk Index matrices. Each reported asset is positioned in the Risk Index matrix based upon its own HI and CI. Each position in the matrix is indicative of a different level of relative risk denoted by the green/amber/red in the table below. HI5/C4 being the highest overall risk.

Table 4 - Health/Criticality Risk Index matrix

		Health Index				
Criticality		HI1	HI2	HI3	HI4	HI5
	C1					
	C2					
	C3					
	C4					

Based on the above we have developed an investment criterion against the outputs of CBRM to identify the volumes of assets that need to be intervened upon within RIIO-ED2 based on the risk of condition related failures (Probability of Failure). This approach maximises the useful life of our network assets whilst keeping the risk of failure within a tolerable level for our customers.

As detailed above the total risk for customers (Monetised Risk) is a combination of the asset health and criticality. As such, for high-criticality assets a lower health score is acceptable to keep the total risk of failure to an acceptable level.

This approach ensures that we only invest in network assets that are truly "end of life" where any deferment in replacement or refurbishment would result in a higher risk of failure for customers which is not acceptable. As such, where the only driver for intervention is condition, we will only invest in Health Index 5 (HI5) assets during RIIO-ED2 i.e. Assets that our CBRM has modelled will be HI5 assets by the end of RIIO-ED2.

Figure 6 illustrates how the PoF increases exponentially as assets reach the HI5 banding.

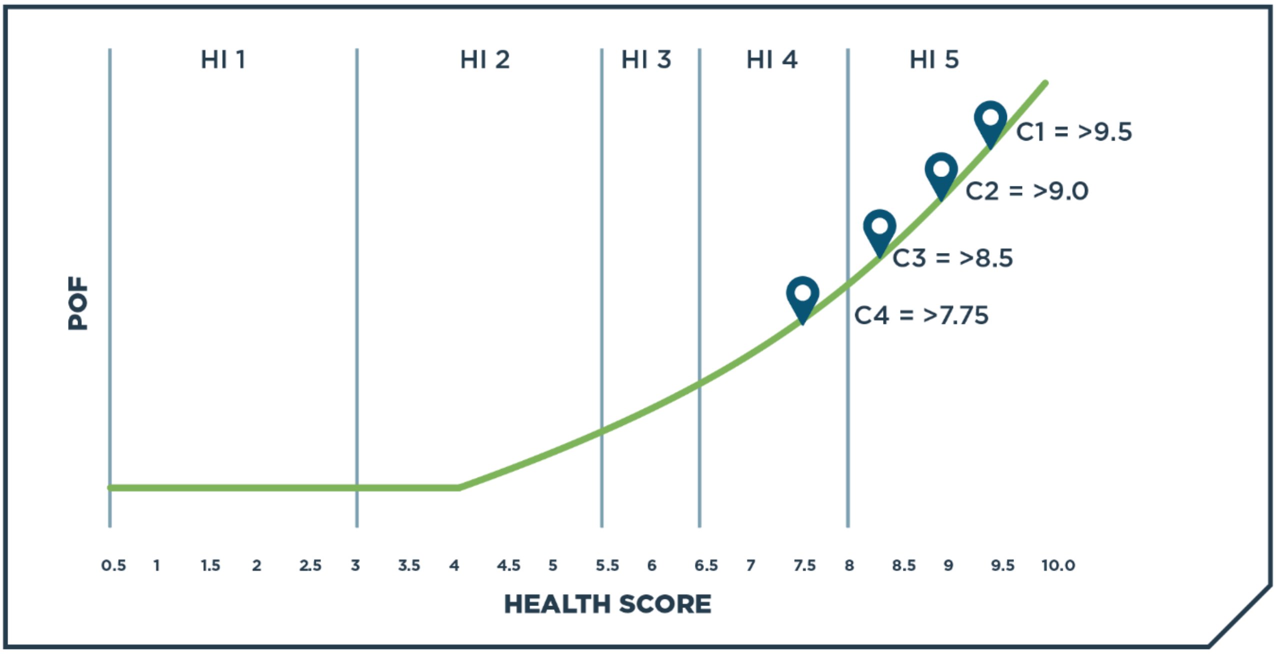

Figure 6 - CNAIM Health Score by Probability of Failure (POF)

However, we recognise that within the HI5 Banding there is a need to be cognisant of the criticality of each asset under consideration to ensure the total risk of failure remains acceptable for our customers.

A HI5 asset does not necessarily need to be intervened upon the moment it reaches the HI5 banding (score >=8.0). These assets still have useful life that should be maximised until the health and criticality gives a total risk of failure that can no longer be accepted.

As such, it is not appropriate to shortlist all assets that are expected to become HI5 in RIIO-ED2 for intervention without consideration of both the health score and criticality.

A health score investment criteria has been developed which defines the minimum Health Score required to justify the need to invest in an asset by the Criticality Index (C1-C4) of each asset. Table 5 below lists all assets that have been subject to this approach and sets out the health score investment which triggers the need to invest in each asset category.

Table 5 - Intervention criteria by asset class

Intervention Criteria				
Asset Category	**C1**	**C2**	**C3**	**C4**
6.6/11kV Transformer (GM)	>=10.0	>=9.0	>=8.5	>=7.75
33kV Transformer	>=9.5	>=9.0	>=8.5	>=7.75
66kV Transformer	>=9.5	>=9.0	>=8.5	>=7.75
132kV Transformer	>=9.5	>=9.0	>=8.5	>=7.75
6.6/11kV CB (GM) Primary	>=9.5	>=9.0	>=8.5	>=7.75
33kV CB (Air Insulated Busbars) (ID) (GM)	>=9.5	>=9.0	>=8.5	>=7.75
33kV CB (Air Insulated Busbars) (OD) (GM)	>=9.5	>=9.0	>=8.5	>=7.75
33kV CB (Gas Insulated Busbars) (ID)(GM)	>=9.5	>=9.0	>=8.5	>=7.75
33kV CB (Gas Insulated Busbars) (OD)(GM)	>=9.5	>=9.0	>=8.5	>=7.75
132kV CB (Air Insulated Busbars) (OD) (GM)	>=9.5	>=9.0	>=8.5	>=7.75
132kV CB (Gas Insulated Busbars) (ID)(GM)	>=9.5	>=9.0	>=8.5	>=7.75
132kV CB (Gas Insulated Busbars) (OD)(GM)	>=9.5	>=9.0	>=8.5	>=7.75
33kV Switch (GM)	>=9.5	>=9.0	>=8.5	>=7.75
33kV RMU	>=9.5	>=9.0	>=8.5	>=7.75
LV Circuit Breaker	>=9.5	>=9.0	>=8.5	>=7.75
LV Pillar (ID)	>=9.5	>=9.0	>=8.5	>=7.75
LV Pillar (OD at Substation)	>=9.5	>=9.0	>=8.5	>=7.75
LV Pillar (OD not at a Substation)	>=9.5	>=9.0	>=8.5	>=7.75
LV Board (WM)	>=9.5	>=9.0	>=8.5	>=7.75
LV UGB	>=9.5	>=9.0	>=8.5	>=7.75
6.6/11kV CB (GM) Secondary	>=9.5	>=9.0	>=8.5	>=7.75
6.6/11kV Switch (GM)	>=9.5	>=9.0	>=8.5	>=7.75
6.6/11kV RMU	>=9.5	>=9.0	>=8.5	>=7.75
6.6/11kV X-type RMU	>=9.5	>=9.0	>=8.5	>=7.75
LV Poles	>=8.0	>=8.0	>=8.0	>=8.0
6.6/11kV Poles	>=9.5	>=9.0	>=8.5	>=7.75
33kV Pole	>=9.5	>=9.0	>=8.5	>=7.75
66kV Pole	>=9.5	>=9.0	>=8.5	>=7.75
132kV Pole	>=9.5	>=9.0	>=8.5	>=7.75
33kV Fittings	>=7.25	>=7.25	>=7.25	>=7.25
66kV Fittings	>=7.25	>=7.25	>=7.25	>=7.25
132kV Fittings	>=7.25	>=7.25	>=7.25	>=7.25
Tower Line Conductor (33kV and 132kV)	>=9.5	>=9.0	>=8.5	>=7.75

Deriving RIIO-ED2 workload volumes

To calculate the volumes of refurbishment and replacement for NARMs assets, we extracted the relevant data from our asset systems and then applied our intervention methodology as described above. We forecast expected intervention volumes for the remainder of RIIO-ED1, either by individual asset or workload for high volume asset categories. Using this we then set the total expected volumes of interventions required during RIIO-ED2.

In a dynamic programme of work we will respond to new network information. Our plans for NARMS interventions in the remainder of RIIO-ED1 have been updated based on actual progress to date, with further updates to asset health scores resulting from recently completed inspections, and prioritising investment for the remaining two years of the price control period. We have adjusted our closing RIIO-ED1 NARMS position to be consistent with this forecast workload and the RRP submission in July 2021. These changes in the closing NARMS risk matrices for RIIO-ED1 therefore feed through into the RIIO-ED2 period. To illustrate, an increase in RIIO-ED1 intervention volumes on higher risk assets reduces the population in those categories at the end of RIIO-ED2.

NON-CBRM ASSETS: HISTORIC FAULT ANALYSIS & RISK CATEGORISATION APPROACHES

The condition-based asset management approach outlined in the preceding section gives us a useful view of our asset's conditions that provides a strong foundation for decision making for RIIO-ED2. However, this approach does not yet apply to all of our assets due to the scope of CNAIM to date. Where CNAIM does not apply, the key analysis approaches we have taken include historic fault analysis, customer impact and bespoke risk categorisation. Below is a description of how historic fault analysis underpins our understanding of our likely fault management costs, and how we have used it in the context of underground cables; this is followed by a description of how risk categorisation works in the OHL clearance space. These three methodologies do not cover our entire portfolio, however these are three of the most material areas in terms of RIIO-ED2 spend, and give a good indication of the types of analysis that can be found throughout the EJPs.

Historic fault analysis for prediction of RIIO-ED2 fault management costs

Asset management in networks requires a trade-off between investment to mitigate risk and accept certain levels of risk by targeting the most efficient intervention. In the context of resilience, this means we accept that to manage our costs incurred through asset replacements, we accept a level of risk that will result in a particular level of faults occurring. The more we invest, the lower this level of fault management will need to be- however it may be more economic to invest slightly less in replacements and accept this will have a corresponding increase in costs in the fault management space.

To predict how the rest of our plan will influence fault management requirements, using six years' worth of NaFIRS data, the faults were grouped into three categories: Within Gift (faults that could have been prevented by early intervention), External (faulted assets due to third party damage, malicious damage, unforeseen and force majeure) and Tree Related Faults. Faults were then further separated based on the asset classes recorded within CV26. Additionally, six years of RIIO-ED1 fault performance data has been used to provide a start point for the trend analysis against interventions (additions/disposals of assets following a fault) on the network. A linear trend is used to forecast the fault rate between 2021 and 2028.

The methodology for the Within Gifts (Any fault that could have been mitigated through intervention i.e. deterioration, corrosion, weather, flooding, fault rating etc) and Tree Related faults categories used fault data that is directly related to our network interventions and can be impacted by increased or reduced investment on the network. Actuals were taken from the Quality of Supply (QoS) Calculator that has extracted the specific faults codes that relate to Tree Faults and Within Gift faults. The interventions from the past 5 years were used to determine the change in fault volumes per intervention. The interventions were taken from CV1, CV2, CV3, CV7, CV22 and the historical performance and actual spend in RIIO-ED1 was used. For Tree Faults we used the spans cut over the past 5 years using CV29 data.

As external faults cannot be controlled or managed through asset intervention, a linear trend or RIIO-ED1 average was applied to future forecast. Actuals were taken from the QoS Calculator that extracts the specific faults codes that relate to external factors. When using the linear trend it can produce spurious results for some asset categories so the results were analysed for each asset category to determine whether a Linear Trend or RIIO-ED1 Average should be used to forecast performance in RIIO-ED2.

The total faults across the three categories were then combined and filtered into the 28 categories required for CV26. The split was derived using RIIO-ED1 ratios.

Historic fault analysis for identifying priority cable routes for intervention

The fault database was filtered for faults attributed to LV cables, and to causes identified as primary and secondary drivers related to cable condition. Primary drivers are fault causes that are directly related to the condition of the cable (e.g. deterioration due to age and wear) whereas secondary drivers encompass fault causes that are likely to decrease the condition of the cable long-term e.g. through damage to the cable or the need to joint the cable; multiple joints on a cable decreases the condition and can lead to an increase in faults. Primary faults were focused on, and the fault data was processed to determine the average annual fault level experienced on individual LV underground cables between 2015-2019.

The circuit level fault data was used to create a summary of the number of circuits that have average fault rates at specific increments, for example by applying fault rate 'data bins' at every 0.2 increment of an average annual fault rate. A typical length of cable per circuit was applied to determine indicative cable volumes associated with each fault rate data bin. Typical costs associated with intervening to rectify a fault on an UG Cable circuit were determined from annual intervention records, and were then applied to each circuit, incorporating the specific fault rate on each circuit. The CBA options are used to test various fault data criteria for replacement, under a range of fault trend scenarios, that will provide the best 45-year NPV. The optimum year for investment, in order to provide best value for the customer, is identified. Where the optimum investment year lies within RIIO-ED2 then the fault level and associated fault intervention and IIS costs are recorded and used to identify the number of actual circuits that meet these criteria.

This approach thus generated a volume of cables where intervention is proven to drive customer value through valuing the likely reduction in faults from historic levels that could be achieved.

A very similar approach was also applied to our HV cables, which is omitted here for brevity- the full detail and outcomes of both HV and LV cable fault analysis can be found in their respective EJPs.

Risk categorisation: applying the ESQCR to Overhead Line clearances

In other cases, our assets historic performance is not the critical factor in defining where intervention can be prioritised. OHL clearances are a good example- as a safety issue, it is critical that we're proactive rather than reactive, and historic issues may not influence present risk (for instance if new 3rd party structures are erected that breach safety clearances). Therefore, other approaches, such as inspections combined with risk categorisations, are deployed to best manage these risks and remain compliant.

As part of the ESQCR, we are mandated to ensure that the network is safe and meets specific safety standards. As part of ESQCR there are specific safety requirements for OHL conductors that relate to the lowest point between the OHL conductor and ground / vegetation / infrastructure etc and the minimum height requirements differ depending on the location of the OHL. As well as stipulating the minimum conductor height, we also record the associated risk of the OHL which is dependent on location. Table 6 below shows the different land codes and associated risk.

Table 6- Risk categorisation for OHL clearance versus land use

Location Reference	Location Code	Risk
RIVER	A	Medium
SCHOOLS	B	Very High
DENSEHOUSING	C	Very High
CAMPING AND CARAVAN SITES	D	Very High
RECREATION GROUND / PLAYAREA	E	Very High
DERELICTSITE	G	Medium
QUARRY	H	High
INDUSTRIAL / COMMERCIAL AREAS	J	Very High
ROAD / FOOTPATH / ADJACENT ROAD VERGE / ADJACENT	K	Very High
FARMYARD	L	High
BEACH	M	Medium
ARABLECROPS	N	High
PRIVATEGARDEN	O	High
AIRFIELD	P	Medium
HEATHLAND	Q	Medium
FOREST	R	Medium
PASTURE	S	High
WASTELAND	T	Medium
MOTORWAY CROSSING	V	High
RAILWAY CROSSING	W	High

Throughout RIIO-ED1 we have undertaken OHL inspections that record the location code, associated risk and the height of the lowest point the conductor to ground / object across the network. However, these clearances do continuously change due to factors such as developers changing the topography of the land, or soil storage underneath lines reducing clearance- hence requiring ongoing inspection programs. To drive efficiencies and improve overall accuracy of OHL conductor clearances we have deployed airborne LiDAR systems to assess the entire OHL network all at once (rather than covering parts of the network each year). LiDAR provide data on horizontal distance to objects, such as tree and buildings, and also the vertical distance from the conductor to ground or other objects to identify the lowest point. The accuracy of the technology is down to a few millimetres and the methodology is applied consistently across the entire network; this reduces the chance of error from different inspectors recording things differently. Using LiDAR to determine the lowest conductor height and correlating it to the land code allows us to derive the volume of OHL Clearances that need to be addressed.

5.3 MANAGING ASSETS TO IMPROVE SAFETY- HSE COMMITMENTS

Safety and statutory compliance is one of our main drivers for investment. Our decisions are driven by the HSE and ESQCR commitments, our safety culture, operational restrictions, as well as factoring safety into our overall assessment of risk through CBRM as safety is a key component of criticality.

This section deals with a specific type of intervention we are proposing for RIIO-ED2, that where our work with the HSE has identified compulsory works.

The HSE are completing a review in all DNOs of public safety/asset management issues and a specific concern regarding the robustness of training and assessment. The HSE have concerns about management of asset risks, particularly assets which are in public areas and on customer premises. The areas of key interest which impact our spending plans are listed below. These costs are captured in various BPDTs, primarily CV14 and CV17.

LV SYSTEM

The HSE have a view that the importance surrounding the integrity of the LV system is growing and therefore we should ensure they are comfortable with our approach to the management of the LV system; ultimately the focus is on ensuring the integrity of the LV system in the public domain. We treat the LV system with equal importance to the HV and EHV system and ensure our asset management processes are complete and robust.

SERVICES TO HIGH RISE BUILDINGS (RISING MAINS) AND MULTI-OCCUPANCY SITES

In response to the Grenfell tower block fire in London in 2017, the HSE are reviewing the arrangements for all utility services to manage such buildings. This is partly in response to the tower block fire in London in 2017 but ultimately to ensure that no buildings are at risk due to faulty or poor condition assets. We are proposing to spend £29.3m to manage RLM during the RIIO-ED2 period. The final volumes for both RLMs related inspections and interventions reflect the increased focus on the safety of high-rise multi-occupancy dwellings.

LV UNDERGROUND LINK BOXES

Our approach to LV underground link boxes (LV UGB) takes into account the conclusions made in the Energy Networks Association (ENA) position paper 08, “Management of Link Boxes and Cable Pits on LV Distribution Network.” It considers the mitigations for the risks of LV UGB’s having a disruptive failure. This paper was produced following a rise in the number of incidents reported via the Electricity Safety, Quality and Continuity Regulations (ESQCR) 2002 Regulation 31 and an increase in public awareness of disruptive failures of cable pits and LV UGB’s.

Evidence indicates (through the conclusions in the ENA Position Paper 08 and Link box Working 7.4 Group investigations) that only a very small proportion of failures result in a disruptive failure. Examples of a disruptive failure of a link box are when the cover is lifted (from pressure created by an explosion) and flames are expelled into the ground above the LV UGB or when soot or a flashover is evident). In most cases failures are contained within the LV UGB pit and as such pose minimal risk to the general public. The likelihood of the link boxes failing and causing injury to individuals or staff on our network is low; however, the consequences of failure can be extremely high.

In view of the risks described above, the ENA commissioned a detailed Cost Benefit Analysis (CBA), (ENA Position Paper 08) to determine if there is an economic benefit to the public and electricity company workforces in making changes to member companies’ current link box strategies. The CBA highlighted committed expenditure has to be targeted to areas where the risk is identified as being highest. We identify our high-risk link box locations through risk assessment. This is done primarily by assessing pedestrian footfall near our LV UGB. High risk LV UGB’s are those situated in areas with high pedestrian traffic such as shopping high streets or adjacent to public buildings. Further detail of how these findings have been incorporated to our plan can be found in “315_SSEPD_NLR_LINKBOXES.”

5.4 ENSURING SOLUTIONS ARE ECONOMIC THROUGH OPTIONS DEVELOPMENT & ANALYSIS

To ensure our plan delivers what consumers value in an economic and efficient way, we follow options development and CBA processes that minimise costs for customers whilst appropriately valuing any relevant benefits that candidate options could bring.

This section discusses firstly how we generate a range of options to address our safety and resilience requirements, and then how we select from those using engineering analysis as presented in the EJPs, and where required the Ofgem CBA template. The following section, “Credible transition from RIIO-ED1 to RIIO-ED2”, then gives further detail on the outputs of this process discussing material changes by asset & activity type.

DEVELOPING OPTIONS FOR ADDRESSING REQUIREMENTS

A critical prerequisite to producing an efficient plan is considering sufficient breadth of options for addressing requirements. The options we consider must include innovative options, whole systems solutions, and smart solutions which vary how we operate our assets to maximise outcomes at efficient cost. Moreover, the optimal approach in our portfolio wide decisions is most likely to be a hybrid of these solutions; we can have a very high volume of assets within a given class with varying conditions and situations, and we have had to apply a generic approach as we can’t assess every location individually. In these cases, the relevant EJPs outline our best current view.

The options considered are described under the following categorisation:

1. Innovation
2. Flexibility solutions
3. Inspection, Maintenance and refurbishment solutions
4. Asset replacement solutions

RIIO-ED2 Innovation: OLTCs

Previous innovation projects undertaken by GB DNO’s have indicated significant customer benefits can be secured by the deployment of LV On-Load Tap Changer (LV OLTC). These devices replace the conventional fixed tap changer built into conventional 6.6kV/11kV Transformers (GM).

These fixed tap changers cannot actively regulate the voltage on the LV network to maximise efficiency and improve power quality to network customers. However, LV OLTCs can respond automatically in real time to changes in demand and generation across the 11kV and LV network. This allows DNOs to implement a technique known as Conservation Voltage Reduction (CVR) to reduce the energy consumed by the customers fed by each HV transformer.

Previous GB DNO innovation projects have proven that CVR has the potential to reduce the consumption of network customers by up to 7.5% each year by keeping the LV supply voltage as close to the lower statutory limits as possible. Keeping the voltage low allows various households devices and loads to operate more efficiently and pull less energy from the network.

When combined with LV network monitoring, LV OLTCs can provide significant savings for network customers and consumers which more than justifies the additional capital costs associated with this technology. This has been demonstrated within the CBA that complements the OLTC EJP.

As per the CBA the financial value for network customers associated with the Conservation Voltage Reduction (CVR) and reduction in energy consumption is significant. The incremental cost of the LV OLTC compared to a standard HV transformer varies from 1-2 years.

The LV OLTC can also add additional capacity to the network by alleviating voltage constraints caused by the adoption of photovoltaics and electric vehicles. This additional benefit will protect the network against future load growth and allow distribution network to accommodate a higher penetration of low carbon technologies before wider and costly network reinforcement is required.

Given the benefits described above and the results of the CBA we are proposing a phased roll out of this technology over the course of RIIO-ED2 where the volume of units deployed are steadily increased over the 5 years of RIIO-ED2. The purpose of this is to allow time for our staff to gain more experience with the technology and to identify the most efficient deployment strategy for the technology. This is further explained in Section 7 of the HV Transformer EJP.

Deploying RIIO-ED1 Innovation: LiDAR and growth models for tree cutting optimization

Historically, manual foot patrols of the overhead line network have been used to identify which spans are affected by tree and vegetation growth. To cover the entire overhead line network these manual inspections are very time consuming and costly. For this reason, moving forward we will undertake LiDAR surveys of the overhead line network as an alternative to manual tree cutting inspections.

Once every 4 years we carry out aerial surveys of the overhead line network using LiDAR technology. This technology allows us to efficiently identify the number of spans at each voltage level that are affected by trees without the need to carry out separate and costly foot patrols for tree cutting inspections of the network.

In recent years, LiDAR technology and data processing has advanced significantly allowing us to build up a detailed view of the entire overhead line network, including the distance of each individual tree to the overhead line network. The data can be used to identify high risk spans that are not compliant with standards and to prioritise the tree cutting programme to address overhead spans that are most at risk of significantly impacting both network reliability, affordability for customers and most importantly the safety of our network for the public and our staff.

Figure 7 shows how the LiDAR data can be represented in a 3D model of the overhead line network. The data provides tree cutting teams which a risk grading for each span which includes the distance between the crown of each tree and the overhead line conductor. The image shows a densely populated LV network. The rest of the vegetation colour coded (RAG) based on clearance distance. The RAG coloured shapes on the floor represent a ‘Canopy’ i.e. tree crown size including its RAG status.

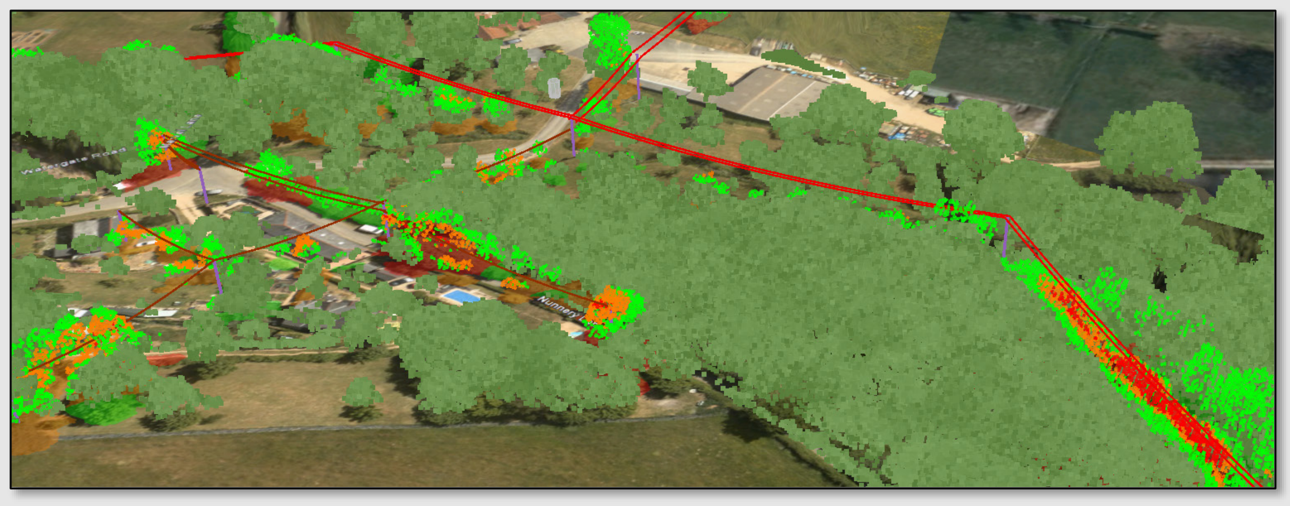

Figure 7 - 3D LIDAR model of OHL network

Furthermore, the LiDAR survey data has also allowed us to make significant changes to the overhead line inspection cycle and maximise the efficiency of overhead line inspections by moving to an eight-year frequency from the previous four-year cycle.

For these reasons, during RIIO-ED2 LiDAR will be an integral part of our overhead line strategy and has replaced the need to undertake manual foot inspections for affected spans going forward.

During RIIO-ED2, we will explore the development of growth models which can take the data provided by the LiDAR surveys and predict future growth rates across the entire overhead line network to better inform the tree cutting programme. This would ensure tree cutting crews are only sent to intervene on spans that truly require intervention and avoid late visit to spans which tree growth has already caused damage or faults.

A growth model that can identify tree species will also support our management of diseased ash trees. This enhancement will help us understand ash and the progression of the disease. (See ***Innovation Strategy*** (***Annex 14.1)***). The UM will look to remove ash tree's outside of a normal 43-8 cut.

Flexibility Options

In line with the flexibility first principle across our whole plan, flexibility solutions have been considered wherever credible we have considered the procurement of the Constraint Management Zone (CMZ) flexibility products to help manage the risk associated with network assets in poor condition and those assets approaching end of life. However, there are many areas under safety and resilience where flexibility cannot provide the necessary risk reduction. Although flexibility is well suited to reduce loading which is one factor of asset risk, key asset condition factors such as age, location and specific type related issues are not ameliorated by influencing network flow.

Given the current lack of evidence it is unclear if the procurement of flexibility would deliver value as an effective tool to manage ageing transformers or improve network reliability and resilience of the network, whether that’s through extending the lifetime of primary assets or helping to minimise Probability of Failure until these assets can be replaced or refurbished at a later date. As such, flexibility has not been considered for implementation in the RIIO-ED2 baseline plan. We will continue to seek evidence which demonstrates additional use cases where it can provide value for money in the context of resilience and safety, to complement its extensive proposed usage in other parts of our plan; primarily load and connections.

However, we have considered the use of flexibility in terms on managing planned interruptions and minimising disruption to customers, further details can be found in our ***Deliverability Strategy (Annex 16.1)*** and our ***Reliability Strategy (Annex 7.2***.)

Monitoring maintenance and refurbishment-based solutions

A range of effective solutions exist in the asset management space for changing operating practices rather than physical assets. These practices are designed to get the most out of the asset while minimising risk or mitigating risk through adequately preparing to quickly and effectively manage the consequences of failure. This approach also has the benefit of preserving optionality- if monitoring of ongoing performance confirms that replacement is required, monitoring does not preclude investment. By contrast, an immediate investment decision does exclude the possibility of maximising the asset's operational life if there is any uncertainty about its capability to maintain network performance. These solutions tend to work well in the short-term, however we have also been mindful of the cost of additional inspection and maintenance strategies which are balanced against the additional lifetime that can be attributed to this increased OPEX investment and the deferment in the future replacement of the asset.

Throughout our EJPs, we have included a range of potential inspection and monitoring programs, as shown in 7. These areas have scope for more innovative and advanced techniques, such as the innovative deployment of LiDAR coupled with modelling of tree growth to get a detailed understanding of OHL risk, as described above.

Maintenance and refurbishment solutions are often economic where components are limiting the performance of a whole unit. Key examples include transformers, where replacement of components drive health index improvement for only a fraction of the cost of replacement of the whole unit; taking targeted action on the gaskets, bushings, tap changer, oil, cooler or conservator could suffice to reduce risk.

Equally, steel towers can be very costly to replace in their entirety, so we give full consideration to works such as steelwork painting, conductor replacement, foundations work, insulators and fittings replacement, targeted span replacements, partial steelwork replacement, or full rebuilds to manage risk at an efficient cost.

These maintenance approaches have key synergies with inspection strategies; targeting maintenance activities effectively depends on having an accurate understanding of asset and component condition.

Table 7 - Key types of inspection, maintenance and refurbishment activity considered in EJPs

Visual inspections
Leak detection (Capenhurst, hydraulic tests, PFT method)
Switchgear monitoring (i.e. partial discharge measurement installed)
Transformer oil sampling
Critical component inspection and intervention
Tower painting
Tower steelwork (partial) replacement
Refurbishment of the operating mechanism, enclosure or contacts for switchgear

Asset replacement solutions

Asset replacement is one of the most common solution types, however this captures a broad space of solutions. When replacing an asset due to its condition, like for like is the most straightforward approach- we understand the performance outcome, as it will achieve similar network outcomes to those the previous asset did (when it was in better condition earlier in its life). Even this has two important variations: proactive and reactive replacement.

Although we do not plan to run assets to failure, assets do fail for a variety of foreseeable and unforeseeable reasons. It would not be economic to try and decrease asset failures to zero; the best way to achieve this goal would be to replace every asset on our network, which would drive exorbitant costs. This is why criticality is an important metric- it tells us which assets we are prepared to accept an increased risk of failure on, in return for more economic operation of the network, striking the balance between managing faults, investing in assets, and managing risks. The necessity for reactive replacement following failure requires us to consider what volume of spares and workforce capability to maintain, as well as knowing in advance our policy on what replacement type to pursue in these cases; for instance, like-for-like, a newer design of the same asset type, or a larger asset.

Proactive replacements are economic where the risk (i.e. likelihood x consequence) of failure is less acceptable, having more severe potential consequences for our customers and employees. Here again we consider the different variations of replacement as listed in Table 8 noting that for each, they may be deployed proactively or following the failure of an asset.

Table 8 - Key variations of replacement solutions considered in EJPs

Like for like replacement
Replacement with new model
Replacement with different asset type
Sectional vs complete replacement
Replace an existing cable with same size
Replace an existing cable with a larger cable
Replacement with advanced functionality
Replacement of steelwork (rather than tower)
Proactive replacement with low-loss transformer
Proactive replacement with LV On-Load Tap Changer (OLTC) transformer

MAKING THE OPTIMAL SELECTION-ENGINEERING JUSTIFICATION AND THE CBA

The many different solution types detailed in the previous section then feed into an engineering and economic analysis to determine the best option for delivering the outcomes our stakeholders want. The logic of each of our decisions is explained in the corresponding EJP, and in some cases further justified with an accompanying set of CBAs.

In many cases, the logic and engineering analysis within the EJP is sufficient to demonstrate that the option we've selected is clearly the most economic; for example, defined shifts in Monetised Risk derived from CBRM, coupled with a lack of optionality, may provide sufficient evidence to give confidence in our decision as per Ofgem's CBA guidance.

Our selections, where CBAs are not necessary, are primarily driven by technical feasibility- we consider a wide range of options, and detailed analysis reveals which will work in supporting safety and/or resilience- and by respective costs of options. CBAs work well where multiple benefit streams and costs can be identified and quantified for options which all satisfy compliance criteria.

Ofgem CBA template

In developing our resilience and safety expenditure proposal we have used the CBA model published by Ofgem. Supporting documentation that defines how the model should be used, is also published[1]. We have supported industry development of the final model and guidance and have followed this in the CBAs required throughout our business plan.

Our CBA results

Where needed, we have justified our selection through the use of Ofgem's CBA tool. Here we have demonstrated several key benefits that our selections can access, and used these to ensure our plan maximises consumer benefit through the consideration of:

- CI/CML reductions
- Safety improvements- reduced probability of serious injury and fatality
- Environmental benefits including CO2 emissions and oil leakages
- Reduction in losses and energy consumption reductions through OLTC deployment

These CBAs each demonstrate the best decision for particular cohorts of assets; those not just of the same type, but with similar conditions and situations. The definition of these cohorts is a key part of the overall analysis and can be found in the relevant EJP. These will be supplemented by additional CBAs that will further evidence our costs and volumes in our final submission.

Such CBAs are available for the investments shown in Table 9:

Table 9 - Safety and resilience related CBAs and outcomes

Class of asset considered	Option demonstrated as most economic
HV Transformers reaching end of life (SEPD & SHEPD)	The proactive replacement of end of life HV transformers with transformers equipped with an LV OLTC which is also compliant with latest EU regulation on losses. LV OLTC brings energy consumption savings through CVR.
EHV Transformers where refurbishment delivers significant lifetime extension (SEPD & SHEPD)	Refurbishment of "end-of-life" EHV Transformers to extend lifetime by 15 years before future replacement
EHV Transformers where refurbishment does not deliver significant lifetime extension (SEPD & SHEPD)	Proactive replacement of "end-of-life" transformers with a unit compliant with the latest EU regulation of tolerable network losses.
132kV Transformers where refurbishment delivers significant lifetime extension (SEPD & SHEPD)	The refurbishment of 132kV Transformers to extend lifetime before future replacement
132kV Transformers where refurbishment does not deliver significant lifetime extension (SEPD & SHEPD)	The proactive replacement of end-of-life 132kV Transformers before failure. Unit will be compliant with latest EU regulation on transformer losses

[1] https://www.ofgem.gov.uk/system/files/docs/2021/04/riio-ed2_cba_guidance.pdf

Class of asset considered	Option demonstrated as most economic
LV Underground Mains (SEPD & SHEPD)	The CBA demonstrates lengths of LV cable for which there is a case to replace during RIIO-ED2, based on the fault rate, average cost of fault intervention, and IIS impact. The types of intervention that will be deployed, and in what specific situations, are detailed in the EJP.
6.6/11kV Underground Cables (SEPD & SHEPD)	The CBA demonstrates the optimal year of intervention for different architypes of HV cable as determined by specific sets of fault characteristics including fault rate, average cost of fault intervention, and IIS impact. The types of intervention that will be deployed, and in what specific situations, are detailed in the EJP.
Investment associated with tree cutting (SEPD & SHEPD)	For spans that have been identified as requiring intervention due to their conductor type and the insulation present, optimal approach is Insuline deployed on all circuits where this is technically possible as the most cost-effective option. ABC chosen for all other LV open wire circuits.

6. A CREDIBLE TRANSITION FROM RIIO-ED1 TO RIIO-ED2

Our focus over RIIO-ED1 has been on building the strong foundations required to deliver a safe, resilient, and responsive network. Our RIIO-ED2 strategy in both our network areas has and will continue to focus on making better use of our intervention data to efficiently target activities that will deliver maximum benefits to our customers. This section of the Annex gives further critical insights on our plan through comparisons of RIIO-ED2 key proposals to our RIIO-ED1 activities, highlighting and explaining core material differences.

Network Asset Risk Management activity

Expenditure Category	RIIO-ED1 (Final 5yrs) £m		RIIO-ED2 £m	
	SEPD	SHEPD	SEPD	SHEPD
Network Asset Risk Management	280.3	150.1	208.9	129.1

A large portfolio of our network assets are managed with a specific focus on balancing the trade-off of the reliability benefits of proactive replacement of assets before failure versus the affordability considerations of early replacement of assets which might, if left in service, continue to operate reliably for a further period of time. As we set out earlier in this Annex, we have a systematic approach based on industry best practice to strike that balance and to identify which assets we should replace before failure based on the consideration of the likelihood of failure (or Asset Health) and the Criticality of Failure (i.e. impact on our customers).

In a typical population of assets, what is known as the Monetised Risk[2] will go up and down over time, depending on how the network has developed over preceding years. For example, taking age as a rough proxy for condition, a population of relatively young assets would be expected to increase in Monetised Risk over several price control periods, before intervention became necessary or justified. As such, pursuing reductions in Monetised Risk is not always appropriate as it would drive unnecessarily high costs for customers for no material benefit to the reliability of supply they experience.

Overall, we have determined for RIIO-ED2 based on the right trade-off between costs and service reliability risks to our customers, it is appropriate for us to allow the overall level of Monetised Risk for our portfolio of assets in both of our regions to increase in RIIO-ED2 from the level we see in RIIO-ED1. We don't believe intervening is effective or efficient and we are managing the risk to mitigate the impact to the public whilst mitigating the bill impact.

As an example, a large change in SHEPD’s Monetised Risk is for HV poles, with a 30% increase over the RIIO-ED2 period. Figure 8 compares the health profile of assets as of now with the end of RIIO-ED2, after our proposed intervention – which is addressing more HV poles than we will in RIIO-ED1. This reveals a significant natural age migration of younger assets, which is the main driver for the increase in Monetised Risk. However, the overall profile of HV poles by end of RIIO-ED2 after our proposed intervention remains relatively low risk and still relatively healthy.

[2] This is the measure Ofgem use to define the level of risk a portfolio of assets represents based on asset value, health and criticality

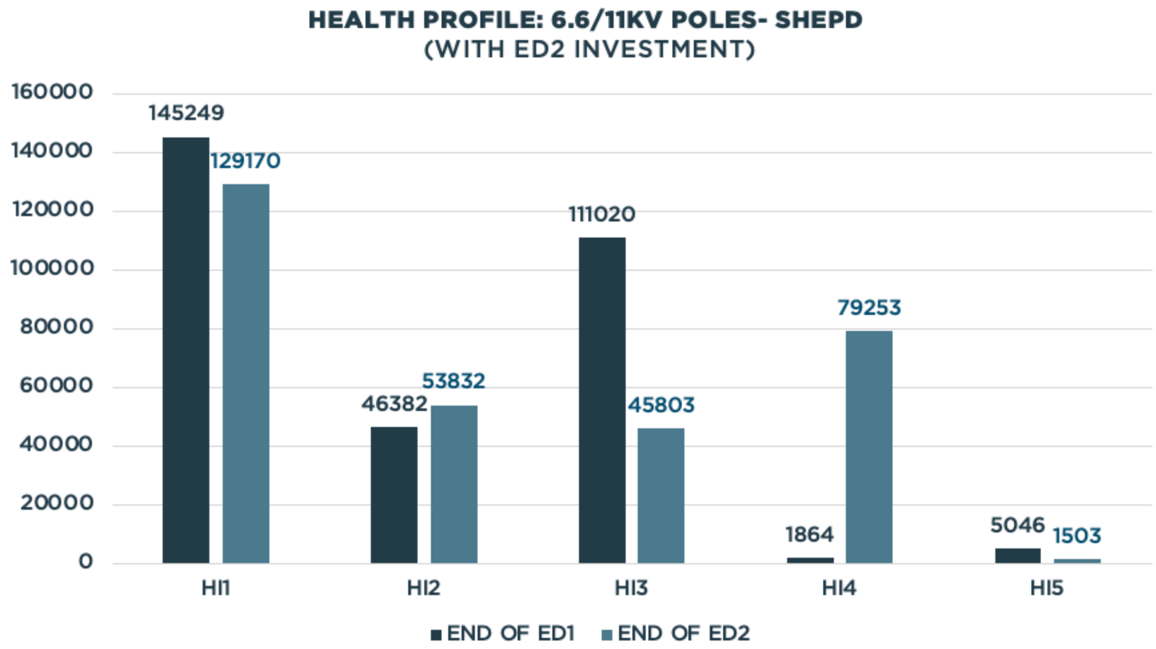

Figure 8 - Health Profile: 6.6/11kV Poles – SHEPD (with RIIO-ED2 Investment)

When we further consider that the majority of these assets have low-criticality of impact on customers if they fail and will have several years of useful life remaining, then further intervention on HV poles is not recommended so that maximum value can be delivered for customers.

Consequently, our proposed expenditure in RIIO-ED2 on managing network asset risk is £208.9m and £129.1m respectively for our SEPD and SHEPD regions. This compares to an expenditure of £280.3m and £150.1m respectively in RIIO-ED1 so represents a decrease from RIIO-ED1, rather than to a more aggressive early replacement we could adopt if, for example we were to seek to maintain the overall level of Monetised Risk in RIIO-ED1. We believe this is the right overall outcome for our customers setting the right balance of reliability and affordability for our customers.

LV cables

Expenditure Category	RIIO-ED1 (Final 5yrs) £m		RIIO-ED2 £m	
	SEPD	SHEPD	SEPD	SHEPD
LV Cables replacement	10.1	2.8	38.5	16.3
LV Service replacement	2.6	0.4	7.5	6.2
LV Service refurbishment	2.8	0.0	13.0	5.1

These are the cables on our network which are ultimately directly connected to our customers. It is difficult to define and agree industry guidelines for the normal expected lifetime for LV Cables. This is partly due to the range of cable construction types and the limited availability of condition data given they are buried underground. However, a clear driver of need for replacement is natural deterioration of the cables over time and the observed performance of those cables in terms of faults and the number of customers impacted.

Our ageing fleet of LV cables in both regions presents increasing challenges to our customers in the number of faults and the impact on customer service in the form of interruptions to supply. As an example, Figure 9 shows the systematic increase in faults we are seeing across our LV cables in our SEPD region.

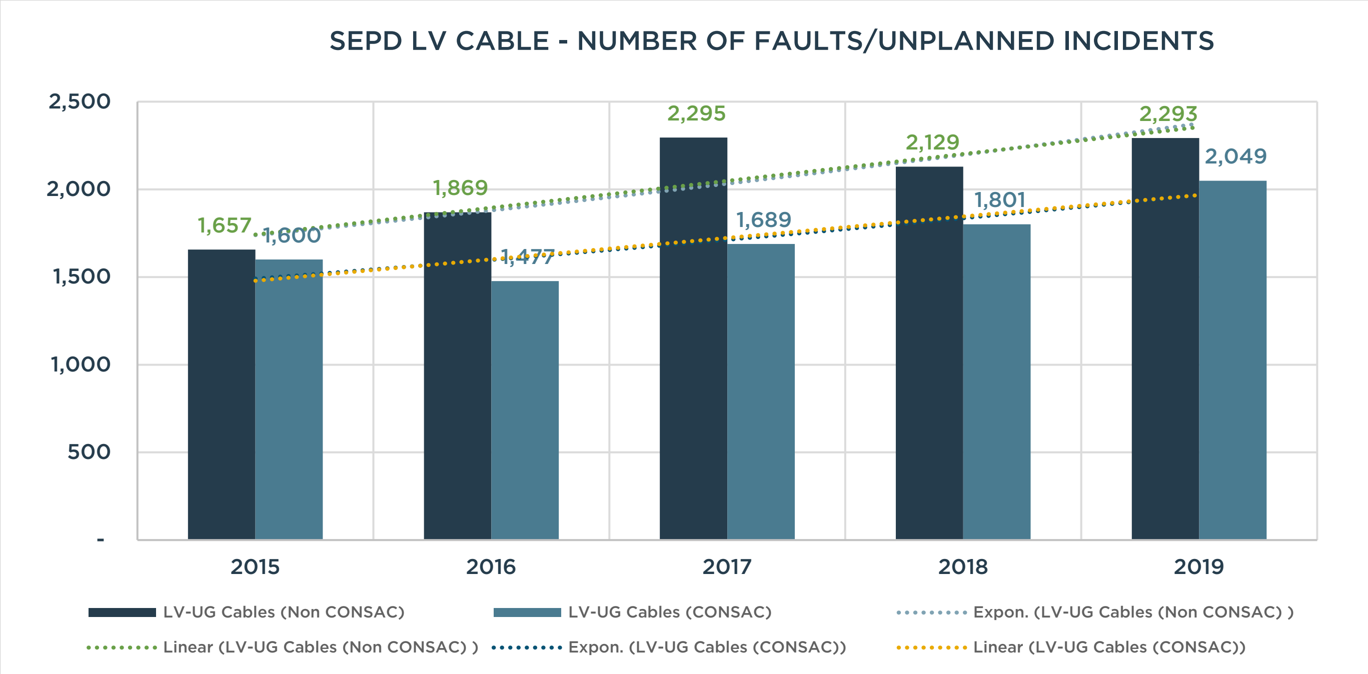

Figure 9 - SEPD LV Cable Faults/Unplanned Incidents

As part of our commitment to deliver enhanced reliability to our customers, we must begin to undertake a substantial programme of LV cable replacement and the necessary associated service cable refurbishment in RIIO-ED2 which we expect to continue to build into ED3 reflecting the age profile and fault performance of our LV cables. We will also – as part of our overall Workforce Resilience Strategy[3] - need to build and sustain an efficient delivery capability to execute this significant increase in work on our LV cables which is well beyond what we have previously undertaken.

Therefore, we propose to spend £38.5m on the replacement of 350km of LV cable in SEPD and £16.3m on the replacement of 164km of LV cable in our SHEPD region. This compares to a combined replacement expenditure of £15.9m and expected refurbishment expenditure of £2.8m in RIIO-ED1.

HV cables

Expenditure Category	RIIO-ED1 (Final 5yrs) £m		RIIO-ED2 £m	
	SEPD	SHEPD	SEPD	SHEPD
HV Cables replacement	16.5	4.9	34.7	10.3

These are the cables which are further away from our customers on our network but where a fault or failure can have a bigger customer impact than for LV cables. Similarly to LV cables, the performance profile of our HV cables is also driving a need for us to ramp up the volume of replacement we need to undertake. Without intervention on our HV cables in RIIO-ED2 we expect an increase in costly cable failures, which will significantly impact both network reliability and affordability for customers.

We are proposing to replace 200km and 95km of HV cables in our SEPD and SHEPD regions respectively in RIIO-ED2 to deliver the safety and improved reliability we have committed we will deliver to our employees and customers.

[3] See Section 4.5 in this Chapter and Annex 12 – Workforce Resilience Strategy for details of our overall capability and capacity building within our internal workforce

This will cost £34.7m and £10.3m respectively, reflecting the different operating environments between our two regions and compares to an expected comparative spend in RIIO-ED1 of £16.5m and £4.9m. We have co-ordinated with Load activities to ensure we have not double counted.

Tree cutting

Expenditure Category	RIIO-ED1 (Final 5yrs) £m		RIIO-ED2 £m	
	SEPD	SHEPD	SEPD	SHEPD
Tree cutting	96.2	40.0	140.3	49.4
Low Voltage ABC[4]	2.2	N/A	13.4	N/A
Low Voltage Insuline	0	N/A	2.8	N/A

Tree Cutting is a critical activity undertaken to maintain the safety and integrity of our overhead line network. Tree and vegetation growth represent a real risk to the safety, reliability and resilience of our network and must be managed effectively. Tree cutting is necessary to ensure that the overhead line networks remain compliant with statutory safety clearance requirements to ensure physical contact with our overhead lines from members of the public is avoided whilst embracing industry best practice when undertaking vegetation management.

Unmanaged tree and vegetation growth can cause serious physical damage to the OHL network. Tree branches can grow into the conductor, fittings, insulators and cause damage. In extreme cases, during storms entire trees can fall onto the OHL network resulting in significant damage and a serious safety risk to the public and our employees as demonstrated in Figure 10.

Figure 10 - Example of tree related damage to an overhead pole

There is over 58,000km of overhead line network across both our regions. This represents a challenge for us to ensure the length of the network remains compliant with minimum standards. However, as an activity that is critical to the safety and reliability of the network, we are committed to undertaking the work require to manage vegetation and tree growth.

[4] Low Voltage Aerial Bunched Conductor (insulated conductor type)

We undertake the works efficiently to minimise cost and maximise benefit in terms of safety and quality of supply. Hence, we have undertaken extensive assessment of our network in both our regions using a sophisticated industry best practice technique known as LiDAR5. LiDAR is a key tool in particular in our SEPD region, where tree cutting costs are higher as a result of vegetation density and growth rates. We therefore flew LiDAR in SEPD 2020/21 as a priority and we are updating our SHEPD LiDAR data from 2017/18 now with the results being available in March / April 2022. This has revealed in our SEPD region an emergent need for a very substantial programme of tree cutting to maintain both the public safety and to improve both the resilience and the reliability of our overhead line assets. This is especially important given the increased experience of weather events such as storms which present increased risks to customer service.

To comply with formal obligations under the industry's ESQCR we are required to resolve where possible all conductors below statutory limits. Our LiDAR assessment, independently verified by Airbus for our SEPD region, has confirmed a significant state of tree intrusion on our SEPD region's LV to 132kV overhead lines. Also, from the recent LiDAR assessment, it has been identified that we have significant vegetation growth around LV bare-wire conductor. To manage vegetation near our overhead electrical equipment, in addition to addressing an unprecedentedly high volume of tree-cutting activity (as indicated above) we are proposing to replace over 1,000km (equivalent to 25,000 spans) with ABC insulated conductor, tree-guards and another insulated conductor solution (Insuline). Our assessment indicates that the investment will remove the requirement to cut trees on a three-year cycle and instead revert to every 14 years when the tree-guard will itself require replacement, providing a saving of approximately £10m over a period of 45 years. The cost of this for RIIO-ED2 will be £16.2m compared to £3.5m in RIIO-ED1.

An independent assessment undertaken by ADAS, has confirmed our SEPD region exhibits one of the fastest rates of tree growth and highest levels of tree density in the UK. The report from this assessment is appended to this report as Appendix D. We also face the challenge of managing "Ash Dieback". As described in the ADAS report, Ash Dieback is a chronic disease of Ash trees that has spread across Europe. It is affecting all areas of the UK and is now classed as an epidemic in which some predictions estimate that 94% of the UK's Ash trees could be lost. As per the ADAS report, our SEPD region has the second highest prevalence of Ash trees in the UK and so we are particularly exposed to this risk. Managing Ash Dieback will be an important but uncertain part of our tree cutting strategy. A £6.5m two year survey is proposed to identify exactly where Ash affects our network and to inform an UM (further details can be found in Section 7) that has been designed to account for the incremental costs associated with the management of diseased Ash. This will ensure customers are protected from any unnecessary increase in costs in this space to minimise the unavoidable costs to our customers.

Consequently overall, as a result of this extensive LiDAR assessment we have undertaken, and the need to address Ash Dieback in the South, the required expenditure for RIIO-ED2 is £140.3m and £49.4m respectively in our SEPD and SHEPD regions compared to an expected expenditure of £96.2m and £40.0m to meet industry obligations and standards[6], but reflects the increase in work we must do in RIIO-ED2 to deliver our safety obligations and our resilience and reliability commitments to our customers. This will deliver an estimated tree clearance for nearly half a million spans[7] for our LV and HV networks across both regions.

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[5] LiDAR stands for Light Detection and Ranging, is a remote sensing method that uses light in the form of a pulsed laser to measure ranges between objects and is conducted through use of aerial inspection of our overhead assets.
[6] The UK electricity industry's Electricity Safety, Quality and Continuity Regulations (known as ESQCR).
[7] A "span" is the term used for the section of overhead line between two overhead poles or towers

Overhead Line clearance work

Expenditure Category	RIIO-ED1 (Final 5yrs) £m		RIIO-ED2 £m	
	SEPD	SHEPD	SEPD	SHEPD
OHL clearance	5.8	0.8	34.3	26.2

As part of the Electricity Safety, Quality and Continuity Regulations (ESQCR), SSEN are mandated to ensure that the network is fit for purpose and meets specific safety standards. As part of ESQCR there are specific safety requirements for overhead line (OHL) conductors that relate to the lowest/shortest point between the OHL conductor and ground / vegetation / infrastructure etc. The minimum height requirements differ depending on the location of the OHL, for example if the OHL is over a road the minimum height requirement is 5.8m for High Voltage (HV) OHL, however, if the conductor is over a field the minimum height can be 5.2m for an HV OHL. As well as stipulating the minimum conductor height, SSEN also record the associated risk of the OHL which is dependent on location, as per ESQCR land use codes.

Using LiDAR to determine the conductor clearance infringements and correlating the span to a land use code allows SSEN to drive a risk-based strategy to derive the volume of OHL clearance infringements that need to be addressed in RIIO-ED2. Based on the LiDAR data and through a risk-based approach, we propose to address all very high and high risk sites where conductor clearance infringements have been identified across our entire network. For all clearance infringements that are deemed to be medium or low risk, as per our risk assessment on land use codes, we will continually monitor and risk assess the clearance. If circumstances change, resulting in a higher risk or the conductor continues to become a concern, then targeted investment will be undertaken to mitigate the clearance.

LiDAR provides a view of the entire network in a single year, whereas we were only aware of clearance infringements as and when inspectors walked each OHL circuit. As a result, we have identified every clearance infringement in a single inspection; hence the increase in volumes and associated costs compared to RIIO-ED1. We therefore propose to spend £34.3m and £26.2m respectively in our SEPD and SHEPD regions.

Repairs & Maintenance

Expenditure Category	RIIO-ED1 (Final 5yrs) £m		RIIO-ED2 £m	
	SEPD	SHEPD	SEPD	SHEPD
Repair & Maintenance	48.9	15.8	84.6	28.1

It would not be cost-effective or affordable for our customers if we simply replaced every asset before failure. This becomes especially so the earlier we intervene to do so as discussed above as the benefits of the reduced risks to overall reliability of supply to our customers would be massively outweighed by the costs they would bear for this relatively small overall benefit. Consequently, as good Asset Stewards we seek to identify those assets where a strong Repair and Maintenance regime is the most cost-effective approach to manage those assets before the need for replacement becomes compelling, in the case of level of risk, or forced i.e. in the case of failure.

Consequently, in lieu of simply replacing at much higher cost during RIIO-ED2 but equally to suitably extend asset life and manage the likelihood of failure we have identified a substantially increased cost in our Repair and Maintenance for RIIO-ED2, including resolving defects and repairs identified from our inspections which wouldn't be cost beneficial at this stage to move to replacement/refurbishment. We propose to spend £84.6m and £28.1m respectively in our SEPD and SHEPD regions. This compares to £48.9m and £15.8m we expect to spend in RIIO-ED1 – and reflects the uplift in Repairs and Maintenance we believe is cost-effective to do to avoid or defer much more expensive asset replacement.

Excluding mandatory safety and diversion spend, and the discretionary cable expenditure, we are spending less on core CAPEX in RIIO-ED2 compared with RIIO-ED1 with increased expenditure proposed in our OPEX expenditure.

Faults Management

Expenditure Category	RIIO-ED1 (Final 5yrs) £m		RIIO-ED2 £m	
	SEPD	SHEPD	SEPD	SHEPD
Faults Management	203.4	78.2	208.9	60.8

Faults on assets increase as they age, their health deteriorates and as their cumulative usage increases. Our fundamental role as Asset Stewards is to sufficiently invest in our assets such that we avoid faults going up too much in the short-term and creating a longer-term problem for maintaining a safe and resilient network. At the same time as responsible Asset Stewards we need to avoid spending excessive money on our assets where the resulting benefits for our current and future customers in the form of reliability for example do not justify this on a cost benefit basis.

Consequently, in our RIIO-ED2 plan a key factor is setting that right balance of proactive asset replacement and Repairs & Maintenance activity as described in the previous sections and the anticipated resultant level of faults which will still require a reactive response. This is a key balancing act we strive to achieve in creating a plan which most cost-effectively meets the safety, resilience and reliability expectations of our customers and our associated reliability ambitions to reduce the number and duration of customer interruptions.

As a result of this balancing act for RIIO-ED2 – we predict we will need to spend £208.9m and £60.8m respectively for our SEPD and SHEPD regions to address the level of faults which we will see even given the level of expenditure we have set for the rest of our asset plan for RIIO-ED2. This compares to 5-year RIIO-ED1 costs of £203.4m and £78.2m, respectively for our SEPD and SHEPD regions.

Wayleaves and Land Rights

Expenditure Category	RIIO-ED1 (Final 5yrs) £m		RIIO-ED2 £m	
	SEPD	SHEPD	SEPD	SHEPD
Wayleaves & Land Rights	65.9	13.0	96.7	15.3

Wayleaves are the payments we make to land-owners for allowing us to use their land to "host" our assets, typically these being overhead line assets. Compensation covers the payments we make where land-owners can evidence that the presence of our assets has a negative financial impact on them in terms of the value of their property/land. Whilst we will see an increase in Wayleaves costs as we increase the scale of our asset base in RIIO-ED2, the primary driver of the substantial increase on costs we expect in RIIO-ED2 relate to the growth in compensation claims we have begun to see in RIIO-ED1 and expect to continue to grow in RIIO-ED2, as discussed below.

Our approach to managing wayleaves is designed to achieve the best outcome for consumers. The two primary forms of land access agreements used are wayleave agreements and easements (also known as deeds of servitude in Scotland). Wayleave agreements are personal agreements between the network operator and the grantor, in return for an annual rental or one-off commuted payment to the grantor. Wayleaves are a terminable agreement and grantors can seek removal of assets or a diversion of apparatus. By contrast, easement (or servitude) agreements are permanent rights that form a burden on the property title, and they therefore run with the property and are binding on successors in title. As a result, these are a non-terminable agreement. Gaining an agreement for a Wayleave is cheaper and quicker and more likely to get an agreement with the landowner. By contrast, an Easement takes more time and is more difficult to obtain.

As a general rule, we do not automatically pay out compensation for such claims. This may result in disputes being taken to court but protects customers from unnecessary payments. Where possible, we also seek to secure easements (or servitudes) over wayleaves, to ensure efficient and sustainable land access.

The Electricity Act 1989 enables land-owners and occupiers to claim compensation for demonstrable losses as a result of having our assets on or over their land. This gives rise to claims for Injurious Affection[8] or requests to remove our assets from their land. During RIIO-ED1 we have has seen a sharp upturn in the size and scale of these types of claims which we collectively call Wayleaves and Land Rights. This increase is in part due to urban expansion which brings developments into contention with our assets, but also as a result of land-owners, occupiers and their representatives are more willing to test their rights and ours. For example, we have seen claiming agents develop business plans which focus on the pursuit of claims on behalf of property owners on a high-volume low return basis, flooding the industry with a huge portfolio of claims to manage.

SSEN is represented at the ENA Estates and Wayleaves forum (EWF) by the Policy Manager. Matters relating to all aspects of consenting are addressed at this forum with particular focus recently around delivery of net zero through legislative reform and changes to planning. Subgroups of the EWF are currently being formed to drive forward lobbying of Government and devolved administrations to bring about required legislative change for electricity industry consenting policy.

During RIIO-ED1 we have has seen a sharp upturn in the size and scale of Injurious Affection claims. However, we are proposing to limit the baseline spend in the plan for Injurious Affections to the total of the last 5 years in ED1 (i.e. £64.7m during the RIIO-ED2 period), as shown in Figure 11. This is due to the uncertainty of the volume of claims submitted to SEPD and SHEPD. We also that we want to engage with government, devolved administrations, other DNOs and other stakeholders through the ENA Estates and Wayleaves forum (EWF) to look at legislative reform.

[8] Injurious Affection is the term used for compensation claims largely related to the reduction in the value of land and property as a result of the presence of our network assets.

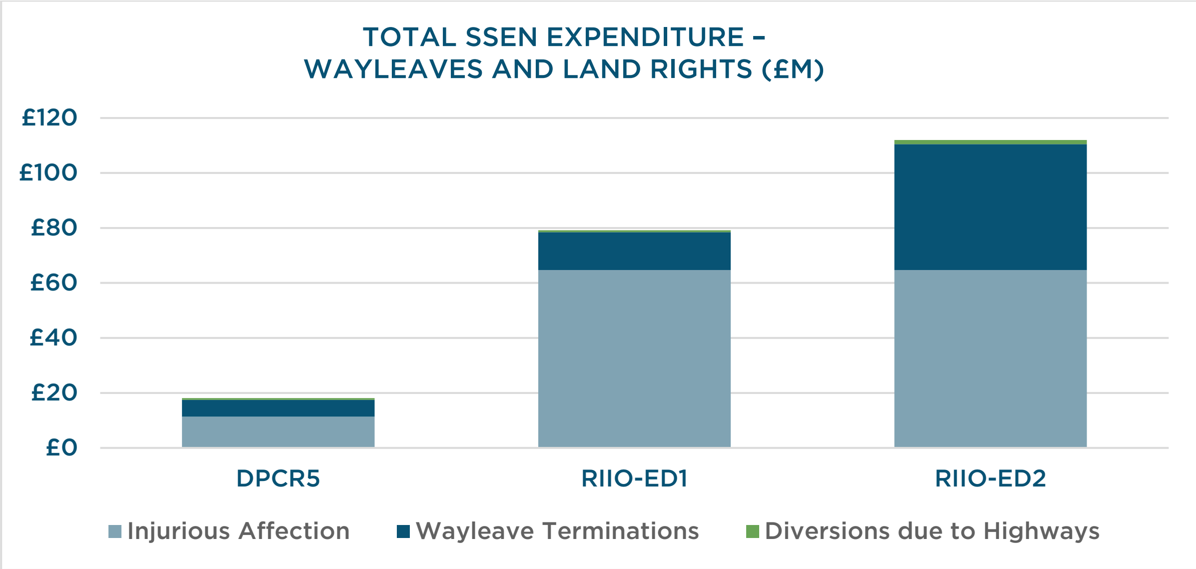


Figure 11 - Total Expenditure Wayleaves and Land Rights

The bulk of the claims are dealt with by our Land Consents Managers but some of the larger, or more complex, claims are managed by expertise within the business, including in some cases, our expert in-house and external legal and professional advisors. The quantum of some of the claims can run into millions of pounds, and therefore there is a real need to protect, both the integrity of the network but also the interests of bill payers.

In addition, there is uncertainty around the nature and quantum of termination and diversion costs (i.e. where the landowner wants our assets removed from their land and we incur costs to remove/divert these). The costs of reconfiguring the network can vary significantly, and this in turn drives cost uncertainty at the aggregate level.

In RIIO-ED2 we believe we will need to spend £96.7m and £15.3m in our SEPD and SHEPD regions respectively to address this area of Wayleaves and Compensation compared to £65.9m and £13.0m respectively in RIIO-ED1. However, given the scale of potential increase, we are proposing a baseline allowance for our current view of the costs combined with an uncertainty mechanism to allow for us either to recover any additional efficient costs or for the return of unspent allowances to consumers.

7. WHAT IF THE FUTURE IS NOT AS PREDICTED?

We have been working directly with Ofgem and other stakeholders over the course of the last 18 months to consider the need case and principles of operation for new forms of uncertainty mechanism, applicable to all DNOs. Our plans around safety and resilience are for the large part stable to the different energy scenarios that could arise during RIIO-ED2, as the core drivers- primarily asset condition- are unlikely to change significantly with variation in load growth. There are a limited number of areas that are subject to uncertainty driven by external factors out of our control; these areas are summarised in Table 10. A description of each proposed UM follows. For further detail, in ***Uncertainty Mechanisms (Annex 17.1)*** we set out proposals for uncertainty mechanisms with a full justification against minimum requirements.

Table 10 - UMs relevant to maintaining safe and resilient network

UM name	Type of UM	Applicable to:	Issues addressed	Cost uncertainty range relative to RIIO-ED2 baseline
Our proposed UMs				
Wayleaves and Diversions	Re-opener	ED companies	Costs associated with uncertain diversions costs following wayleave terminations.	SEPD -£9m to +£35m SHEPD -£1m to +£1m
Ash Dieback removal	Re-opener	ED companies	Costs associated with removing Ash Dieback diseased trees in proximity of contact with our network.	SEPD £0 to +£38m SHEPD £0 to +£10m
Street Works	Re-opener	ED companies	Uncertainty around costs related to performing works on public streets.	Unquantifiable

WAYLEAVES AND DIVERSIONS

a. Issues and risks that the proposed mechanism addresses

To operate and maintain our network apparatus, including overhead lines and underground cables, we require access rights to privately owned land which our apparatus crosses. To secure access rights, we negotiate land access agreements with property owners (known as ‘Grantors’). Negotiation surrounds rental and/or compensation where appropriate for the grant of the land right.

The two primary forms of land access agreements used are Wayleave agreements and Easements (also known as Deeds of Servitude in Scotland). These agreement types differ significantly in their permanence. Wayleave agreements are personal agreements between the network operator and the Grantor, in return for an annual rental or one-off commuted payment to the Grantor. By contrast, Easement (Servitude) agreements are permanent rights that form a burden on the property title, and they therefore run with the property and are binding on successors in title. As a result, Easements (Servitudes) are a non-terminable agreement. We seek to secure Easements (Servitudes) over Wayleaves where possible, to ensure efficient and sustainable land access.

As discussed above, Wayleaves are a terminable agreement. Grantors can seek removal of assets or a diversion of apparatus. When this happens, Network operators are time constrained to three months to either negotiate a mutually acceptable solution or lodge an application for Necessary Wayleave. Network system planning, valuation principles, compensation principles and planning principles all have to be understood in order that an appropriate strategy can be defined to best protect the UK bill payer. It might be that a mutually acceptable arrangement can be reached between Grantor and us or it might be that a retention of assets in their existing location is required and a Necessary Wayleave is pursued. A Necessary Wayleave is no guarantee of success and will likely give rise to a compensation claim which could be heard at a tribunal hearing.

There is uncertainty around the nature and quantum of termination and diversion costs. These challenges can range from individual householder led notices to remove to large scale housing developer claims running into millions of pounds. There are costs associated with initial strategic and planning work as well as the potential costs of reconfiguring the network when required. The costs of reconfiguring the network can vary significantly, and this in turn drives cost uncertainty at the aggregate level.

Throughout ED1, we have found that the annual cost of diversions has fluctuated significantly, due to volatility in the volume and average cost of works. This makes it challenging for us to accurately forecast diversions costs at RIIO-ED2, with the potential for costs to be significantly higher than our central projection should the volume and/or average cost of diversions differ materially from this projection. This is an issue that affects all distribution licence areas to some extent, although as we explain further below, this is a more critical issue on our Southern network given that many of our largest diversion works involve the 132kV network.

Our RIIO-ED2 business plan includes baseline funding proposals for diversion works, which have been calculated based on historic data and expert insight.

We are additionally proposing a re-opener UM which will adjust our allowances based on the realised cost of delivering diversion works. This will allow us to recover efficient additional costs as required to complete diversion works in a timely manner.

It is important to emphasise that diversion works are not the only potential outcome from a land access challenge. One of the alternative outcomes is that we may reach a compensation settlement with the Grantor to ensure continued land access, reflecting a loss of land value caused by the network apparatus. These settlements are known as Injurious Affection (IA) claims, and they may be initiated by Grantors even when they are not pursuing a Wayleave termination. Whilst the volume of IA claims has risen over ED1, reflecting the broader evolution of the claims market, the RIIO-ED2 costs of these claims are easier to predict than diversions costs due to relatively large sample sizes and stable average settlement costs.

As a result, we are not proposing a re-opener for IA compensation costs. We are instead proposing that Ofgem applies an RIIO-ED2 close-out adjustment for IA compensation costs, to reflect the efficient costs incurred. This would match the approach towards IA compensation costs adopted at T2 by Ofgem and SHET. We propose to strengthen the reporting of the costs arising from IA compensation cost within the annual regulatory reporting cycle. This will provide Ofgem and DNOs with greater visibility as costs are incurred and can therefore better prepare for the close out.

Our proposed approach recognises that whilst IA compensation costs are easier to predict than diversions costs, they are largely outside of our control and dependent on the future trajectory of IA claims initiated by Grantors (who are generally supported by claiming agencies). In keeping with the T2 approach, we consider that we should not benefit or be penalised through the TIM in relation to IA compensation costs, as any over or under-performance is not likely to be due to efficiency or inefficiency, but rather due to the nature of how the costs arise.

b. The design of the proposed mechanism

Our proposed mechanism is a re-opener, with the standard materiality threshold (1% of annual allowed base revenue). The re-opener will allow for either upward or downward adjustment of cost allowances, depending on outturn costs. We consider that there should be regular application windows available for this re-opener to provide the required flexibility to adjust allowances during RIIO-ED2. However, we also recognise the value to both DNOs and Ofgem of limiting the quantum of re-opener applications (especially where there is potential for both upward and downward adjustment of allowances). We therefore propose that the first re-opener application window should fall in January 2025, with annual application windows available thereafter.

The scope of the re-opener will include all costs relating to physical diversion works in the CV5 Business Plan Data Table, incorporating diversions due to wayleave terminations and diversions for highways.

Further we propose that Ofgem applies an RIIO-ED2 close-out adjustment for IA compensation costs, to reflect the efficient costs incurred. This would match the approach towards IA compensation costs adopted at T2 by Ofgem and SHET.

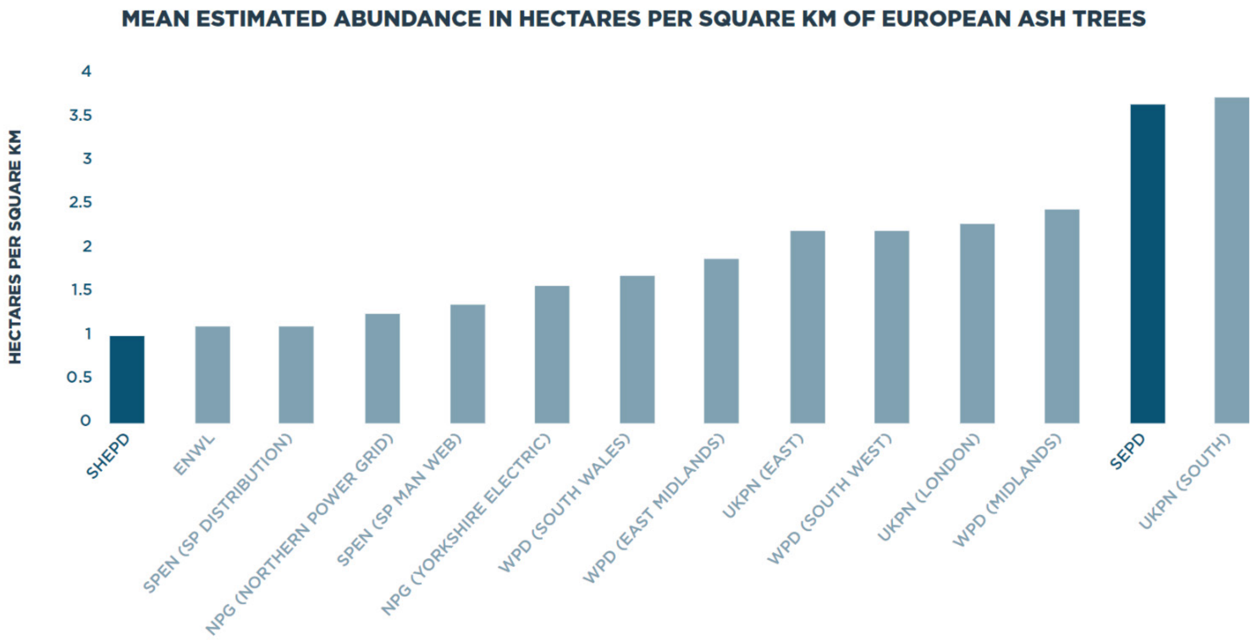
ASH DIEBACK REMOVAL

a. Issues and risks that the proposed mechanism addresses

We have a legal duty to maintain overhead line networks free of interruptions, Electricity Safety, Quality and Continuity Regulations (ESQCR 43-8) and resilience standard Engineering Technical Report (ETR 132). Trees are one of the principal causes of unplanned service interruptions on lines and we are required to make networks 'resilient' to tree and vegetation damage, including during abnormal weather conditions. We undertake targeted vegetation management programmes to help achieve this, which will continue into RIIO-ED2.

Since its first identification in the UK in 2012, Ash Dieback, which is caused by a fungal pathogen – *Hymenoscyphus fraxineus*, has been detected in over 60% of $10km^2$ in the UK. Research has shown that less than 20% of the UK's Ash population is tolerant to the disease. The rate of progress of the disease within individual trees can be unpredictable and can take up to 18 months for symptoms to show after first infection; as it is dependent upon environmental factors and the presence of other pathogens which may take advantage of weakness caused by the disease and hasten the trees' decline. SEPD has the second highest abundance of Ash trees of all DNOs, see Figure 12. Whilst SHEPD has the lowest abundance of Ash trees this does not exempt the area from the issues caused by Ash dieback. Whilst we have high level estimates of Ash abundance and a clear need to remove impacting diseased trees, we do not have complete data on proximity of diseased Ash trees to our assets. This issue is not regional specific, but rather industry wide, affecting all electricity distribution companies, as well as other utilities and infrastructure sectors with above ground assets, such as highway and rail agencies.

Figure 12 - Mean estimated abundance of European Ash trees by DNO license area (Source: ADAS Report)



Many trees will ultimately die from the disease, but they will become gradually more dangerous as they decline towards death. The main risk posed by trees which are affected by Ash dieback is that weakened or damaged limbs, or the whole tree, may fall and cause injury or contact with our assets. Diseased trees create a particular challenge for us; and due to the reduced strength conventional means (manual access, climbing with chainsaws etc.) of tree removal are not always suitable and mechanical harvesting equipment with the operator in a protective cab is often required. Our experience form ED1 suggests this could be up to five times more expensive than conventional tree removal means. The cost of removal is directly linked to the state of disease within the tree. For trees at an earlier stage of decay the cost for removal can be lower as the structural integrity of the tree is better suited to conventional removal; the state of the disease can only be found following visual expert inspection. **This creates a cost uncertainty** with the exact means and effort for removal varying by site, and heavily influenced by the required safety measures.

The cost uncertainty is **compounded by volume uncertainty** with exact numbers and rates of death and decline of Ash trees in proximity to our assets difficult to predict. Research, and the experience of those managing tree populations, demonstrates that most Ash trees in the UK which are close to property or infrastructure will need to be felled over the next few years. Additionally, Ash trees grow widely and very vigorously from seed, so, although a significant proportion of mature trees are expected to die over the next few years, the size of the overall Ash population is likely to take longer to decline. Death rates of mature trees will also vary depending on pressures on the population from other environmental and biological factors.

We have responsibility for Ash dieback management in proximity to our assets, where a tree is considered at risk of contact. The need case to remove these trees is clear and is a requirement ESQCR. Consideration for stakeholders, and budgetary implications, mean that removing all Ash trees within the vicinity of the overhead line network as part of a mass felling exercise funded through the ex-ante baseline plan would not be feasible, and would not gain the desired permanent network resilience due to the expected regeneration of new trees. It will therefore be necessary to plan an ongoing monitoring and cutting schedule which is flexible and responsive to manage the evolving threat to the network throughout our licence areas.

In the current price control period, ED1, we have managed the prevalence of diseased trees through our ongoing tree cutting budget, although the growing rate of diseased trees, since first being detected in 2012 and their high costs for removal have created significant strain on this allowance and is one of the reasons for overspend. Given the increasing cost and volume uncertainty associated with Ash removal relative to our networks we are proposing a re-opener UM in RIIO-ED2 which will allow us to trigger additional funding upon receipt of updated information from ongoing manual[9] survey work for removal during the RIIO-ED2 period. We propose the costs of manual surveying to detect Ash dieback threats in proximity to our network is covered through the baseline. We propose the total costs of diseased tree removal is only borne by consumers after a cost materiality threshold has been exceeded, consistent with the approach adopted in most other UMs.

Ash dieback will be an ongoing issue into the ED3 period and beyond. Whilst our efforts in RIIO-ED2 will remove most known diseased trees at risk of contact with our assets this will not preclude further spread into healthy trees or regeneration of new trees which subsequently become infected. It is more than likely we will require to update our tree removal strategy in preparation for ED3.

b. The design of the proposed mechanism

The proposed UM is a re-opener, with the standard materiality threshold (1% of annual allowed base revenue). We propose that we should have the flexibility to trigger this re-opener once after the standard materiality threshold has been exceeded. To trigger the re-opener, we propose to present updated Ofgem survey data showing the extent of diseased trees in proximity to our assets and costs for removal based on disease intrusion. This data will evidence a refined cost allowances ask to cover the ongoing management of the risk to the end of the RIIO-ED2 period. We propose to complete the survey within the first two years of RIIO-ED2 on both our networks; meaning the timing of our re-opener submission is likely to be 2025, depending on costs incurred to date relative to the materiality threshold. The cost of the survey is included with our baseline proposal. We propose the scope of the re-opener request be narrow and focused only on the increased costs of removing diseased trees in proximity of contact with our assets. For the avoidance of doubt the re-opener would not cover costs or volumes associated with other drivers for vegetation management.

We do not consider that Ofgem should be able to trigger this mechanism, as there is no potential for downward allowance adjustment (*only upward adjustment on a zero baseline for diseased tree felling costs*) and the triggering of the ask to use the mechanisms is not conditional on Ofgem or other stakeholder decisions. We consider that it is our sole responsibility to apply for funding adjustments where required, ensuring that we provide sufficient justification for the re-opener to be used after we have exceeded the cost materiality threshold.

Streetworks (Ofgem proposal)

Description of Ofgem proposal: This mechanism has been carried over from ED1, and Ofgem is not currently proposing to make changes for RIIO-ED2. The existing mechanism covers additional costs associated with permitting schemes and other street works legislation not included as part of the ex-ante allowance. The existing mechanism also covers the volumes of activity associated specifically with load-related expenditure and new connections expenditure.

[9] “Manual” survey, as we need to not only ensure we have the specific species of tree, but we must also check if an Ash tree is healthy or not. We cannot remove a healthy Ash tree ‘just in case’.

Our proposed amendment: This re-opener should be amended to allow us to recover additional costs if we are mandated to handle hazardous types of spoil differently, as guided by the Environment Agency.[10] We propose the re-opener should be triggered twice:

1. After a protocol comes into force (this could be as early as 2023) – provision of the amendment to the re-opener will allow us to apply for allowances to cover one-off costs of delivering the protocol (e.g. staff up-skilling to identify waste, laboratory and establishing quarantine storage sites)

2. At the end of ED2 – this will allow us to apply for allowances to cover spend we've incurred associated with disposing of the waste aligned with the protocol

Our estimate of materiality over RIIO-ED2: We cannot calculate the materiality of spend associated with amending the re-opener today. The volume of waste classified as hazardous remains unknown and is dependent on mandates from the Environment Agency; and the cost of disposing the waste is dependent on the mandate as well. Therefore we will only apply at the end of the period if costs are greater than the standard UM materiality threshold and Ofgem would have the right to review costs and volumes associated with our application at the end of ED2.

[10] Environment Agency Guidance RPS 211 - Excavated waste form utilities installation and repair

APPENDIX A: ASSET DATA STRATEGY

1. Executive Summary

This supporting document covers SSEN's strategic approach to asset data within the RIIO-ED2 Business Plan. Our goal is to build on the platform of RIIO-ED1 with strategic targeted improvements in our asset data which drive value for our asset management decision making and business performance.

We have invested significantly in our business and IT transformation during RIIO-ED1 which has improved our systems, processes and associated asset data. The approach set out in this Appendix will allow us to quantify our current position and deliver a successful RIIO-ED2 plan including the need for greater governance driven by the changing landscape in RIIO-ED2.

Our aims for asset data been designed to deliver the following key outputs for customers and consumers, in the lead up to and throughout RIIO-ED2:

- Ensure our data remains trusted and valued for our customers now and in the future.
- Establish Data as an Asset.
- To meet the minimum requirements for the provision of Open Data and Digitalisation.
- To provide the systems and capabilities to enable the delivery of our RIIO-ED2 commitments.

Our position on asset data will continue to be updated as we work through the development of our business plan and work with Ofgem and other DNOs as part of the various working groups, consultations, and methodologies for RIIO-ED2. Our approach will be aligned with the UK Government, Ofgem, and SSEN's strategy on Digitalisation. This includes industry forums and best practice principles such as those produced by the Energy Data Catapult.

Our approach is to focus and prioritise our preparation for RIIO-ED2 and our activities within RIIO-ED2 based on the value they drive from the verification, assurance and improvements in asset data. Our main areas of consideration so far have been asset data quality, particularly accuracy, completeness and timeliness.

We completed two data quality projects in regard to the above, in which we developed a statistical methodology to generate a significant and random sample size of SSEN's asset data. We shared this information with Ofgem and received positive feedback on our approach. This enabled us to verify the quality of asset data (95% confidence +/- 5% precision) across both DNO areas.

The projects produced a strong set of results regarding the quality of asset data in these areas. Moreover, targeted areas for improvement have been identified for follow up from these projects and learnings have been incorporated into the improvement works. The results of the data quality project are below:

Table 11 – Asset Data Quality Matrix

Asset Data Quality Matrix						
Company	Sub-Asset Type Grading			Accuracy	Completeness	Timeliness
SSEN	Secondary Deliverable Ground Mounted Plant	4	Score	81%	92%	77%
			Grading	4	3	4
	Wooden Poles	3	Score	91%	99%	91%
			Grading	3	1	3
SEPD	Secondary Deliverable Ground Mounted Plant	4	Score	84%	96%	80%
			Grading	4	2	4
	Wooden Poles	4	Score	86%	99%	94%
			Grading	4	1	3
SHEPD	Secondary Deliverable Ground Mounted Plant	5	Score	78%	87%	74%
			Grading	4	4	5
	Wooden Poles	4	Score	97%	99%	87%
			Grading	2	1	4

Grading						
	1	2	3	4	5	6
Score	>=99%	>=95%	>=90%	>=75%	>=50%	<50%

2. Introduction

Data is an important modern asset. SSEN are committed to progressing beyond the treatment of data as an asset and ensuring that our data can be put to best use with coordinated services.

Improving asset data quality will ensure investment decisions are more robust and that we operate our network more efficiently. Asset data quality is recognised and included in the SSEN Digital Strategy, ensuring the business recognises the importance of asset data and its interactions across the business in working towards our strategic goals. With the link between asset data and the digital strategy in place we can ensure that stakeholders will be better able to make decisions and we can invest in our assets at the right time with improved decision making.

Asset data is not a new theme for the RIIO-ED2 period; but our investments reflect evolving stakeholder needs, changing asset conditions and updated policy requirements. They ensure we can deliver on our RIIO-ED2 strategic outcomes of being a trusted and valued service to our customers and communities; a safe and resilient network; and a provider of a smart, flexible and sustainable energy system enabling the transition to net zero in Scotland.

In this document, we will step through:

- What our asset data strategy has been designed to achieve.
- What its key constituent activities are.
- Justification that the described activities are the optimal way to deliver the strategic outcomes.

3. Our Strategic Outcomes for asset data

Our asset plan has been designed to deliver the following key outputs for customers and consumers, in the lead up to and throughout RIIO-ED2:

Our aims for asset data

- Ensure our data remains trusted and valued for our customers now and in the future.
- Establish Data as an Asset.
- To meet the minimum requirements for the provision of Open Data and Digitalisation. You can read more about this in our ***Digital Investment Plan Strategic Annex (Annex 5.2)***[11].
- To provide the systems and capabilities to enable the delivery of our RIIO-ED2 commitments.

We believe that through the principle of establishing data as an asset, we can maximise the value of our asset data to the business and ensure we are making the right decisions at the right time. Applying lifecycle management and a proper governance framework to our data will provide rigor and assurance in line with any other asset we own.

Through making our data open, discoverable and searchable, we will enable third parties to see how to get the best from our network. Utilising the automated data pipelines, resources and toolsets currently being implemented we will provide data quality metrics on a regular basis to ensure our asset data is reliable and trusted.

The changing data landscape and associated requirements needs to be identified and given a level of focus for improvement. Allowing for more detailed load flows and network calculations to be undertaken with confidence to meet the challenges the DSO environment will demand. These data demand opportunities need to be focused to those with the greatest need and benefits.

These changes to the way we work will ultimately have widespread impacts across our business - though these are challenging to quantify at this time, we are confident that ultimately, they will enable us to deliver a better performing, lower cost network by streamlining processes throughout the business, and providing greater visibility to parties external to the business.

[11] Digital Investment Plan Strategic Annex (Annex 5.2)

4. What actions will be taken to deliver these outcomes?

To deliver the preceding outcomes, we will focus our efforts in 4 key areas:

- **Expand NARMs across all common asset categories modelled in CBRM utilising CNAIM to cover 61 RRP categories – 78% of our non-load related expenditure.** The ability to have all 61 RRP categories included in the CNAIM allows greater flexibility in Risk Value trading between categories to maximise the risk reduction benefit to the customers from our network whilst providing the flexibility to modify our delivery to target the areas required without incurring any non-delivery in volumes as long as the risk reduction trading are justified and considerate.
- **Deliver against our Information Gathering Plan (IGP).** To support expanding the NARMs, we need to complete our data collection and quality improvements associated with our commitments in the IGP for all observed and inspected data points. We will deliver against our IGP to support expanding the NARMs across all common asset categories modelled in CBRM.
- **Data Governance culture and awareness.** We will implement and maintain a Master Data Management platform for SSEN through utilising the Informatica Axon Data Governance tool. This will provide a glossary of definitions and business terminology along with data classifications and hierarchies, naming & coding conventions.
- **Data Quality (DQ) rules, policies and scorecards.** We will implement a team and associated system to provide data quality metrics on a regular basis which will show month-on-month improvements in Asset Data Quality. This will be built from the learnings obtained through our Asset Data projects in 2020.

5. Asset Data Governance

To deliver on the above and develop a robust asset data governance process. We therefore implemented the following:

- Set up a Data Governance Board to provide necessary oversight.
- Set a long-term roadmap reflecting business requirements for asset data.
- Implement simple but effective data quality tooling providing rigor, governance and functionality.
- Measure data quality to allow it to be managed.
- Allocate dedicated resources to data quality to drive improvements.
- Pull on central resources available within SSE Group to ensure industry best practice is applied.

The above points were highlighted by our external assurance partners when they reviewed our approach to asset data governance.

6. How are we influenced by stakeholders and consumers in developing and delivering this strategy?

Our approach is the right thing to do for our consumers because it allows us to focus on gathering and maintaining the quality of asset data that allows SSEN to make valuable asset management decisions for our customers and our networks and to be able to justify these decisions.

Our focus areas for RIIO-ED2 will be aligned with Consumer and Stakeholder feedback to ensure that we are meeting our consumers' expectations to improve our asset management decision making and drive value in our investments on our networks.

Our approach will be aligned with the UK Government, Ofgem, and SSEN's strategy on Digitalisation. This includes industry forums and best practice principles such as those produced by the Energy Data Catapult.

During our more detailed work on data quality assessment, we collaborated extensively with external parties to assure our approach and present our results to Ofgem.

7. Why did we choose these actions over alternatives?

SSEN's Health Index/Criticality doesn't cover all asset types/expenditure and was never intended to during ED1. However, SSEN will be reporting on far more asset categories covered with in the common methodology in RIIO-ED2 which requires good quality data to substantiate and justify our proposed investment portfolio or to demonstrate why investment is not required through asset data.

Our approach is to focus and prioritise our preparation for RIIO-ED2 and our activities within RIIO-ED2 based on the value they drive from the verification, assurance and improvements in asset data. Our main areas of consideration are asset data quality, particularly accuracy, completeness and timeliness. Areas of a lower value or materiality within our business plan and associated activities will receive less attention and updates as the impact does not warrant the investment. The materiality assessment has considered financial and societal/reputational factors.

The below paragraphs outline the options we have considered, and the approach taken:

Prioritise - Materiality Assessment - Our first activity was to prioritise the importance of the asset data we utilise based on materiality. We have defined materiality as Costs/Volumes and Reputational impact (Safety, Environment, Customer/Stakeholder, IIS).

Assess - Asset Data Quality - Our next step is to assess the asset data quality of the prioritised/material items from above. We have prioritised the dimensions of accuracy, completeness and timeliness for assessing data quality. However, other key items of asset data quality should not be ignored such as conformity, consistency and duplicates as these will be important for BAU and Digitalisation particularly the sharing of data with external Stakeholders. Similarly, Data Relevance is used to describe data which is required to fulfil a business need. This should be clear for the asset data required to complete the RIIO-ED2 business plan. Relevance may not be clear for all the data we currently gather, nor is there a clear understanding of what data (which may or may not be collected currently) is truly relevant to the business moving forward. This is a different parameter to those outlined for data quality and will require further work going forward.

There are two elements to our assessment: Qualitative and Quantitative. Combining this with our materiality assessment gives us an overall data assessment of risk and opportunity. We need to consider how we assure our assessment of quality and whether this requires internal, independent or external input. Our proposal is to now develop a plan to quantify and assure the asset data quality for the high risk/opportunity categories and then repeat this assessment to determine the next group of asset data to be assessed/assured and quantify the data quality.

Data Quality Improvement Plan - Following on from the steps above we can then quantify the data quality and assess whether this is at an acceptable level for justification for the business plan and/or for business-as-usual activities and decision making. We can then develop a plan to collect missing data and or correct/validate existing data.

A statistical approach has been followed to generate a significant and random sample size of SSEN's asset data to verify the quality of asset data (95% confidence +/- 5% precision) across both DNO areas.

The approach chosen was the statistical method – Attribute Sampling (stratified) using the Cochran formula and random selection of the required samples.

- **Attribute Sampling -** As the purpose is to evaluate the accuracy of the observed conditions per asset, all observed conditions per inspection of a single asset must be accurate for the asset data in scope to be considered "correct".

- **Population -** Distribution is comprised of two companies with a different asset profile therefore the dataset has been treated as two distinct populations – Scottish Hydro Electric Power Distribution (SHEPD) assets and Southern Electric Power Distribution (SEPD) assets.

- **Stratified by Region -** Within the Distribution, there are seven regions that manage the inspections of assets across the two companies (three regions in SHEPD and four regions in SEPD). In order to ensure that these subgroups were reflective, the samples per company have been selected in a proportion to the relevant assets per region.

- **Number of Samples -** The Cochrane formula was applied in order to calculate the number of samples that would be required to be tested.

- **Random Selection -** In order to select the samples, the asset data was split by region and using the RAND() function to create a random number per asset which was then sorted, the relevant number of samples per region were selected.

The statistical approach was externally assured, and we utilised it in our two data quality assessments of our non-load assets: the first of our secondary deliverable ground mounted plant[12] and the second of our wooden pole assets[13]. We submitted the reports to Ofgem as assurance of our data quality pertaining to completeness, timeliness and accuracy.

[12] SSEN Observed Condition Assurance Report_Secondary Deliverable Plant Assets
[13] SSEN Observed Condition Assurance Report_Wooden Poles

The projects produced a strong set of results regarding the quality of asset data in these areas. Moreover, targeted areas for improvement have been identified for follow up from these projects and learnings have been incorporated into the improvement works. The results of the data quality project are below:

Table 12 – Asset Data Quality Matrix

Asset Data Quality Matrix						
Company	**Sub-Asset Type Grading**			**Accuracy**	**Completeness**	**Timeliness**
SSEN	**Secondary Deliverable Ground Mounted Plant**	4	Score	81%	92%	77%
			Grading	4	3	4
	Wooden Poles	3	Score	91%	99%	91%
			Grading	3	1	3
SEPD	**Secondary Deliverable Ground Mounted Plant**	4	Score	84%	96%	80%
			Grading	4	2	4
	Wooden Poles	4	Score	86%	99%	94%
			Grading	4	1	3
SHEPD	**Secondary Deliverable Ground Mounted Plant**	5	Score	78%	87%	74%
			Grading	4	4	5
	Wooden Poles	4	Score	97%	99%	87%
			Grading	2	1	4

Grading						
	1	2	3	4	5	6
Score	>=99%	>=95%	>=90%	>=75%	>=50%	<50%

We have also undertaken similar statistically significant sample projects as part of our data quality assessments. In response to the Grenfell tower block fire in London in 2017, the HSE are reviewing the arrangements for all utility services to manage such buildings. We are proposing to invest £29.3m to manage Rising and Lateral Mains (RLM) during RIIO-ED2. We have inspected a statistically significant sample size of multi-occupancy buildings across both our networks to help better understand the condition of our asset base. This has helped further inform and refine our programme of work for RIIO-ED2[14].

8. How this asset data strategy supports our broader RIIO-ED2 plan

Asset Data has links to many of our positions and areas within the business plan. This Appendix aims to summarise the material areas of focus and provide clarity on our activities to maximise the benefit from asset data and how these responsibilities will be delivered.

[14] 322/SSEPD/NLR/RLM

APPENDIX B: NARMS

1. References

The documents detailed in

Table 13.1 - Scottish and Southern Electricity Documents

Table 13.2 - External Documents,

Table 13.3 - Miscellaneous Documents, should be used in conjunction with this appendix.

Table 13.1 Scottish and Southern Electricity Documents

Reference	Title
TG-NET-ENG-023	Information Gathering Plan 2 (IGP2) for data in RIIO-ED2
TG-NET-ENG-026	Network Asset Intervention Methodology (NAIM)

Table 13.2 - External Documents

Reference	Title
CNAIM v2.1	Common Network Asset Indices Methodology (CNAIM) v2.1
CNAIM v1.1	Common Network Asset Indices Methodology (CNAIM) v1.1

Table 13.3 - Miscellaneous Documents

Title
Network Assets Workbook (NAW)
RIIO-ED1 Electricity Distribution Price Control - Regulatory Instructions and Guidance (RIGs)

2. Introduction

2.1 Our risk-based approach to Asset Management is underpinned by our commitment to maintain the highest industry standards through our certification to the BS ISO 55001 standard. There are two main types of investment undertaken by SSEN on our Networks – Load & Non-Load related. Load related investments are usually initiated by a customer-driven need to connect to the electricity network or are associated with reinforcement of the network to allow increased flows of electricity. This appendix focusses on our Non-Load related investments. These investments ensure our existing assets perform to the standards required by undertaking the appropriate intervention at the right time whether that be repair, refurbishment, or full replacement. In order to identify exactly when Non-Load related investment is required, we continually monitor and assess the condition of our assets to maintain the reliable and resilient network that is expected by our stakeholders.

2.2 Deterioration of asset condition is normal and expected. This occurs due to the operational conditions and stresses that the assets are subjected to during their working life and include:

- Electrical stress – experienced by assets like circuit breakers during the clearance of fault currents

- Thermal stress – experienced by transformers, reactors & cables, due to the heating effect of carrying loads close to their design limits for short or sustained periods to meet network demands
- Mechanical stress – experienced by all assets during fault conditions, but most often seen on overhead line assets as wind-induced vibration
- Environmental factors – these can include landslides, sea salt spray, industrial pollution, as well as excessive wind, snow & ice

2.3 If unchecked, the deterioration associated with our asset base can have a significant detrimental effect on the electricity network and the customers connected to it. To ensure our understanding of current asset condition is accurate, we undertake periodic inspections and testing of our assets to assess and measure their condition. Our asset condition information, current and historical, is held within our Maximo asset database and a number of other specialised data-management platforms. This data is a key component in the decision-making processes used to manage our asset base and to identify and select the appropriate interventions to meet our asset management strategy.

2.4 This appendix outlines the impact and considerations of our intervention strategy, whether that be replacement or refurbishment, and the risk this poses to our networks, including safety considerations of our assets. This is commonly referenced as the Monetised Risk under a recognised and approved Common Network Asset Indices Methodology (CNAIM) utilised by all the Distribution Network Operators (DNOs) operating the electricity distribution networks within Great Britain. As part of the understanding of this methodology it is important to establish and understand some fundamental concepts at a high level before exploring the detailed calculations within the mechanism deployed.

2.5 If you take all the main asset types which form the basis of this methodology (CNAIM), currently 61 different types of assets from steel towers, large transformers to underground link boxes in the public footpaths, each one can be considered to have its own part to play in the overall network risk it places on our electricity system. The individual risk of each of these assets can be combined to identify the overall risk per asset category. If you then apply standard weightings and cost implications associated with the risk, then the methodology can be used to produce a total risk for the assets on the network and this, when considered with cost, is used to produce the Monetised Risk.

2.6 This risk can be calculated at any point in time with the modelling tools we have available. Therefore, SSEN can quickly assess the impact of any intervention strategy on the overall network risk by the types of intervention chosen, from the complete replacement of an asset in poor overall health to earlier refurbishment activity to improve its health and increase the time before a replacement is required. Most of the assessment of determining the intervention strategy is covered by Cost Benefit Analysis (CBA) however the benefit to the overall network can be expressed in terms of the reduction in Monetised Risk.

2.7 Within the methodology there is the ability to consider several different approaches on how to manage the network with regard to the overall Monetised Risk. These approaches can vary significantly depending on the options under consideration but are always measured as the benefit in the reduction of the overall Monetised Risk when compared to the effect which no intervention would have on the network. This would be an option where the assets are allowed to deteriorate without any intervention until end-of-life failure occurred. The graph shown in Figure 13 below is used to illustrate the differences which can be delivered with the different approaches with differing intervention strategies shown as Option 1, 2, 3 & 4 and in some case extreme results in the short and longer term.

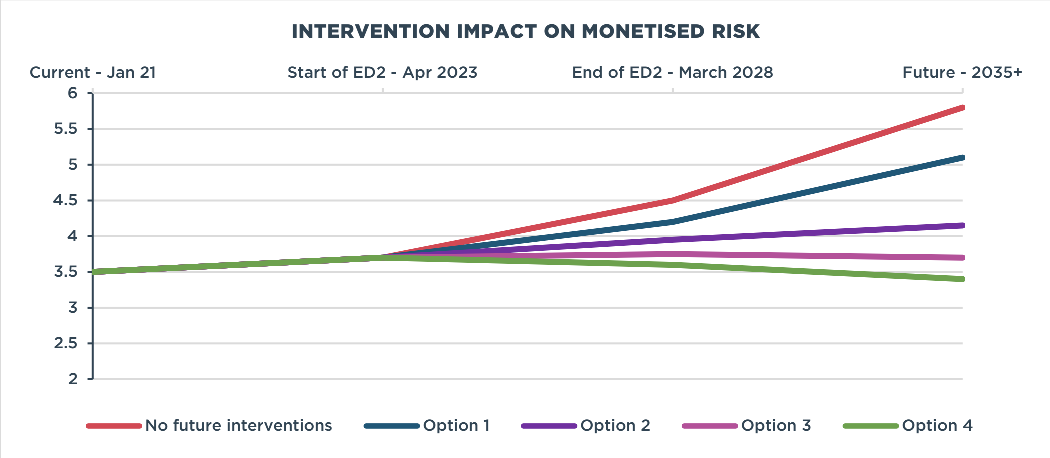


Figure 13 - Intervention impact on Monetised Risk for illustration only

2.8 It is important to note however that with the volume of aging assets on the system that the general trend in the majority of cases will always result in an increase in the overall Monetised Risk on the network unless you can intervene on more assets at a rate greater than normal deterioration. This is highly unlikely as it will not be justifiable, nor would it be efficient to replace assets which within a very short period of time simply to offset the Monetised Risk increase they present to the network.

2.9 This appendix provides an overview of our Network Asset Intervention Methodology (NAIM), TG-NET-ENG-026, which has been developed for RIIO-ED2 to explain how the output from the Common Network Asset Indices Methodology (CNAIM) is used to determine accurately when individual network asset should be intervened upon based upon both the Health and Criticality information that is calculated for each asset. This intervention methodology ensures only assets that truly require intervention are targeted for investment during RIIO-ED2 by balancing both Probability of Failure (PoF) with the Consequence of Failure (CoF) of each asset. This is covered in Section 8 of this appendix.

3. Definition – Network Resilience

3.1 Monetised Risk is a key component in relation to the overall measure of Network Resilience. This appendix is focused on the impact of the Network Asset Risk Metric (NARM) where Ofgem stated the purpose as 'If a network company does not appropriately manage their assets, the risk of those assets failing will generally increase over time. To keep the network asset risk i.e. the consequence of asset failure and the likelihood of a failure occurring, within reasonable bounds, network companies are funded to carry out asset management activities such as replacement and refurbishment.'

3.2 Similarly, the agreed approach 'To build on developments in RIIO-ED1, set outputs that reflect the long-term benefit of the work the licensees are funded to deliver and that improve coverage and alignment of the NARM methodology across the sector.'

3.3 The NARM forms an overarching core component of the overall Network Resilience. However other considerations, not covered in this appendix, also have an impact on the overall Network Resilience as illustrated in the relationship diagram shown in Figure 14 below:

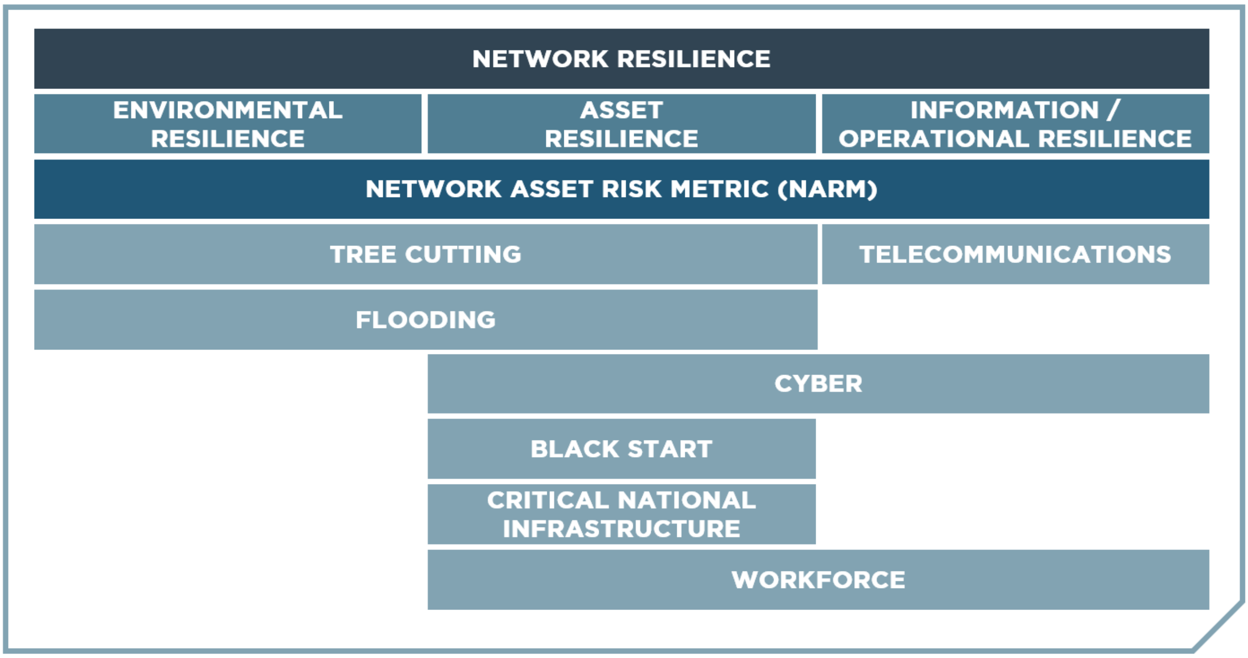


Figure 14 - Ofgem Network Resilience categories

4. Background behind methodology

4.1 As part of their regulatory submissions to Ofgem, Distribution Network Operators (DNOs) provide information relating to the risk of condition-based failure for certain categories of distribution asset.

4.2 For each asset, this is expressed using three elements:

- The Health Index: this provides information about the health of the asset and can be related to its probability of failure;
- The Criticality Index: this provides information about the consequences of an asset failure. These are quantified in terms of the impact upon the environment, network performance, safety, and financial implications (e.g. repair costs);
- The Risk Index: this is a monetised measure of the overall condition-based risk for the asset, which is derived using the combination of both the Health Index and Criticality Index.

These three elements are collectively known in the RIIO-ED1 regulatory period as Network Asset Indices.

4.3 Requirements for reporting of Network Asset Indices were introduced within Standard Licence Condition 51 for RIIO-ED1. This licence condition required DNOs to jointly develop a Common Network Asset Indices Methodology, so that DNOs use a common approach to the derivation and reporting of Network Asset Indices. This resulted in the DNO Common Network Asset Indices Methodology (CNAIM) v1.1, which was approved by Ofgem in May 2017.

4.4 For RIIO-ED1, DNOs have agreed Network Asset Secondary Deliverables for delivery of a reduction in condition-based failure risk through their asset replacement and refurbishment activities. These are part of the RIIO-ED1 Network Output Measures (NOMs) and provide a measure of the effectiveness of DNO's replacement and refurbishment activities in managing the risk associated with condition-based asset failures. The DNOs individual targets for their Network Asset Secondary Deliverables (NASDs), and measure of delivery performance, are expressed using the Network Asset Indices.

4.5 The RIIO-ED1 period ends on 31 March 2023 and the price control process for the following period, RIIO-ED2, will commence in 2021 with the submission of each DNO's Business Plans. The RIIO-ED2 price control period will operate between 1 April 2023 and 31 March 2028. Ofgem have already held initial working groups to develop their views on the role that Network Asset Indices shall play in RIIO-ED2. These working groups have helped inform Ofgem's views on the RIIO-ED2 methodology, which were the subject to a consultation (Ofgem's RIIO-ED2 Methodology Consultation) that ran between 28 July 2020 and 1 October 2020.

4.6 From discussions at Ofgem's RIIO-ED2 Safety, Resilience and Reliability Working Group (SRRWG) meetings, it is anticipated that Network Asset Indices shall continue to perform a similar function in the RIIO-ED2 framework, as part of the Network Asset Risk Metric (NARMs). However, as outlined in Ofgem's RIIO-ED2 Methodology Consultation and their subsequent Decision, Ofgem have confirmed that NARMs should consider long term risk within the measure of condition-based risk, whereas during RIIO-ED1 the Risk Index measure evaluated only 'in year' risk. Consideration of long term risk in RIIO-ED2 has required modifications to be made to CNAIM.

4.7 Ofgem has also confirmed that there shall be greater commonality between DNOs over the asset categories that are included within NARMs and that NARMs shall be specified using a more disaggregated level of asset category than used for RIIO-ED1. These proposals have also facilitated further changes to the existing CNAIM.

4.8 CNAIM, therefore, needed to be modified to meet the changes in regulatory requirements that will be introduced for RIIO-ED2 and hence the introduction of CNAIM version 2 for use in RIIO-ED2. In addition, the DNOs have identified several enhancements to the methodology which have also been included.

4.9 Since approval of CNAIM for RIIO-ED1, DNOs have gained significant experience in implementing and reporting against the existing CNAIM. DNOs have collectively monitored and reviewed the suitability of the existing methodology throughout RIIO-ED1 through meetings of the ENA[15] NOMs Electricity Distribution Working Group. This working group has used the DNOs collective experience of implementing CNAIM to identify areas where improvements to the methodology can be made. This has resulted in the additional changes for introduction within CNAIM v2.1 for use in RIIO-ED2.

4.10 DNOs RIIO-ED2 Business Plan submissions will include provision of Network Asset Indices information for NARMs. This will enable a consistent methodology to be implemented in the Business Plan submissions, definition of NARMs targets and reporting throughout RIIO-ED2. This will ensure that a clear and transparent linkage between allowances and the NARMs deliverable is maintained throughout the whole of the RIIO-ED2 period.

4.11 The approved version of CNAIM v2.1 is designed to be applied in the creation of RIIO-ED2 business plans and reporting against these during the RIIO-ED2 period only. DNOs will continue to use CNAIM v1.1 for the reporting of delivery against the RIIO-ED1 Network Asset Secondary Deliverables (NASD) to avoid destabilising the output measure at a late stage in the regulatory period, by changing the view of delivery achieved to date.

4.12 The approved version of CNAIM v2.1 used for the RIIO-ED2 process states all financial values used in the derivation of consequences of failure are in 2020/21 prices, which is the price base now being used. CNAIM v1.1 retains the original price base of 2012/13 that was used in the

[15] ENA is the Energy Networks Association, the Trade body for the Energy sector. All DNOs are members of this organisation.

RIIO-ED1 Business Plans. Ofgem's originally indicated during the RIIO-ED2 Methodology Consultation indicates that this would be 2019/20 prices, but this has been further updated.

4.13 Several key cost parameters that are used in the derivation of the reference costs for determination of consequences of failure have now been updated in the approved version of CNAIM v2.1 following agreement with Ofgem over the appropriate values for usage in RIIO-ED2 cost assessment. Once new industry average unit costs are established during the cost assessment process, following the review of the RIIO-ED2 Business plans, the DNOs intend to update these unit cost parameters within CNAIM v2.1 if directed to do so by Ofgem for use in RIIO-ED2 reporting period if they are material in the calculations of Consequences of Failure.

5. Existing Approach to Evaluating the Risk Index using Network Asset Indices

5.1 CNAIM determines a Health Index and Criticality Index for each individual asset where Network Asset Indices are reported.

5.2 The Health Index is a framework for collecting information relating to asset health and probability of failure. The Health Index consists of five bandings, HI1 to HI5. The HI1 banding represents assets with the lowest probability of failure and HI5 the highest.

5.3 The Criticality Index is a framework for collecting information relating to consequences of failure.

The Criticality Index consists of four bandings, C1 to C4. Assets are currently allocated to a Criticality Index Band according to the relative magnitude of the consequences of failure for the individual asset compared to the Average Overall Consequences of Failure for the relevant Health Index Asset Category.

The C1 banding represents assets with lower-than-average consequences of failure, whereas the C4 banding is used for those with significantly higher than average consequences of failure.

In CNAIM, consequences of failure are assessed by considering four separate Consequence Categories:

- Financial;
- Safety;
- Environmental; and
- Network Performance.

5.4 The Criticality Index banding is based on consideration of the overall consequences of failure, considering all four Consequence Categories.

5.5 For existing regulatory reporting, Network Asset Indices are reported using 5 x 4 matrices of Health Index against Criticality Index, such as the one shown in Table 14 below. These are known as Risk Index matrices. Each reported asset is positioned in the Risk Index matrix based upon its own Health Index and Criticality Index. Each position in the Risk Index matrix is indicative of a different level of relative risk expressed in £'s representative of Monetised Risk.

Table 14 - Risk Index Matrix

		Health Index				
Criticality		HI1	HI2	HI3	HI4	HI5
	C1					
	C2					
	C3					
	C4					

5.6 An annual submission of Network Asset Indices information to Ofgem is made using the Secondary Deliverable Reporting Pack (described within Ofgem's RIIO-ED1 Regulatory Instructions and Guidance Annex D). This includes separate Risk Index matrices to show:

- The distribution of assets across the Health Index Bands and Criticality Index Bands for the asset population.
- Movements in the position of assets within the Health Index Bands and Criticality Bands due to changes in asset data (for example due to changes in age, new assessments of condition etc.).
- Movements in the asset population arising from different DNO activities (for example separate Risk Index matrices are used to show movements due to asset replacement activities, fault related activity etc.)
- Movements in the position of assets within the Health Index Bands and Criticality Bands due to certain refurbishment activities that are included within the Network Asset Secondary Deliverable.

5.7 These enable the condition-based risk within the population of each asset type to be derived, changes in this risk to be identified and are related to the relevant driver for change (such as areas of DNO investment).

5.8 Where a Risk Index matrix is used to show the distribution of a population of assets across the Health Index Bands and Criticality Index Bands, each portion of the matrix is populated to show the volume of assets that have the associated Health Index/ Criticality Index.

5.9 Where a Risk Index matrix is used to show asset movements, the resulting change in volume of assets in each portion of the matrix is shown.

5.10 Within the RIIO-ED1 Secondary Deliverable Reporting Pack, separate sets of matrices are populated for each Regulatory Reporting Pack (RRP) Asset Register Category that is included within the DNOs own Network Asset Secondary Deliverables. These are the asset categories that are used in the annual regulatory Cost & Volume reporting (as specified within described within Ofgem's RIIO-ED1 Regulatory Instructions and Guidance Annex B).

5.11 The agreed Network Asset Secondary Deliverables for RIIO-ED1 have been specified using Health Index Asset Categories. For RIIO-ED1, DNOs could elect which Health Index Asset Categories would be included within their own Network Asset Secondary Deliverables. Consequently, there are some differences between DNOs with regards to the categories considered. This will now be standardised to the complete 61 asset categories for all DNOs in the submission of the RIIO-ED2 Business Plan and all subsequent reporting during the RIIO-ED2 period.

5.12 The RIIO-ED1 Health Index Asset Categories are often an aggregation of several RRP Asset Register Categories that are used for Cost & Volume reporting. A Health Index Asset Category may include many RRP Asset Register Categories. For example, the HV Switchgear (GM) – Distribution Health Index Asset Category is used for reporting of Network Asset Indices relating to the following RRP Asset Register Categories:

- 6.6/11kV CB (GM) Secondary;
- 6.6/11kV RMU;
- 6.6/11kV X-type RMU;
- 6.6/11kV Switch (GM);
- 20kV CB (GM) Secondary;
- 20kV RMU; and
- 20kV Switch (GM).

5.13 The Health Index and Criticality Index Banding is performed in a way that enables the matrices for all the RRP Asset Register Categories within an individual Health Index Asset Category to be summated. This enables them to be compared with the agreed Network Asset Secondary Deliverable target for the Health Index Asset Category and is achieved by using consistent banding criteria within CNAIM v1.1 and similarly in CNAIM v2.1 for all assets within a Health Index Asset Category.

5.14 To derive the Health Index for an asset, CNAIM evaluates the asset health by firstly determining a Health Score for the asset, using information about the asset such as age, location, duty, condition etc. Health Scores are assigned to assets using a continuous scale from 0.5 to 10 (which is extended to 15 when forecasting the future health of an asset). These scores are numerical representations of the condition of each asset in terms of the proximity to the end of the asset life. Higher values of Health Score represent assets that are closer to the end of life. The use of a continuous scale facilitates the modelling of degradation of asset health with time. Assets are assigned a Health Index Band based upon the value of Health Score associated with the asset.

5.15 The following table illustrates the banding criteria used within CNAIM v1.1 compared to the revised values in CNAIM v2.1:

Table 15 - Health Banding Criteria changes v1.1 against v2.1

Health Index Band	Health Index Banding Criteria CNAIM v1.1		Health Index Banding Criteria CNAIM v2.1	
	Lower Limit of Health Score	Upper Limit of Health Score	Lower Limit of Health Score	Upper Limit of Health Score
HI1	≥0.5	<4	≥0.5	<3
HI2	≥4	<5.5	≥3	<5.5
HI3	≥5.5	<6.5	≥5.5	<6.5
HI4	≥6.5	<8	≥6.5	<8
HI5	≥8	≤15	≥8	≤15

5.16 CNAIM also defines a relationship that enables the probability of condition-based failure (i.e. the likely number of conditions based failures per annum) to be derived from the Health Score. This is illustrated below:

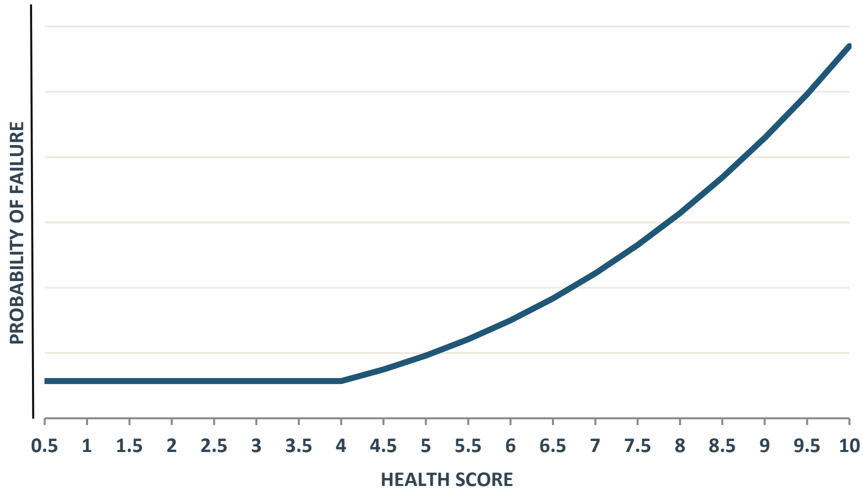


Figure 15 - Typical Probability of Failure (PoF) curve

5.17 This relationship can be used to determine a probability of failure value for each individual asset.

5.18 Within the Risk Index matrix representation used for regulatory reporting of Network Asset Indices in RIIO-ED1, many assets may be represented within each Health Index Band, each with individual values of probability of failure. Typical values of probability of failure are assigned to each Health Index Band, so that a value of risk can be approximated for an asset based upon its position within the Risk Index matrix and used within the evaluation of Network Asset Secondary Deliverables.

5.19 The assignment of typical values of probability of failure to a Health Index Band uses the relationship between probability of failure and Health Score that is defined within CNAIM. Through this relationship, a typical value of probability of failure is assigned to a particular Health Index Band that is defined as the probability of failure that would be determined if a typical value of Health Score within the Health Index Band is considered. The typical values of Health Score used for this purpose are defined within CNAIM. The table below illustrates how these are specified in CNAIM v1.1 compared to the revised values in CNAIM v2.1:

Table 16 – Health Score derived Average v1.1 against v2.1

Health Index Band	Health Score to be used to derive Average PoF (v1.1)	Health Score to be used to derive Average PoF (v2.1)
HI1	4.0	1.23
HI2	4.75	4.25
HI3	6.00	6.00
HI4	7.25	7.25
HI5	10	9.00

5.20 Different values for some of the factors deriving the probability of failure are used for different asset categories. Where Health Index Asset Categories contain multiple RRP Asset Register Categories, it is possible in some cases for the relationship between probability of failure and Health Score to be different for the different RRP Asset Register Categories.

Where this occurs, DNOs determine typical value of probability of failures for each Health Index Band, for use with all assets within the same Health Index Asset Category, based upon a weighted average that takes into consideration the population mix of the various RRP Asset Register Categories and their associated probabilities of failure. In such cases, the typical values of probability of failure assigned to the Health Index Bands are, by their nature, DNO specific.

5.21 For regulatory reporting of Network Asset Indices, typical values of consequence of failure for the relevant Health Index Asset Category are assigned to each Criticality Index Band in the Risk Index matrices. These represent the impact of failure expressed in monetary terms (i.e. £). These are combined with the typical values of probability of failure for the Health Index Bands to determine the risk associated for each Health Index Band/ Criticality Index Band combination within the Risk Index matrix.

5.22 The Criticality Index Bands are defined in terms of relative magnitude to the Average Overall Consequences of Failure associated with the Health Index Asset Category, as shown in the table below:

Table 17 - Criticality Index Banding Criteria

Criticality Index Band	Criticality Index Banding Criteria	
	Lower Limit of Overall Consequence of Failure (as % of Average Overall Consequence of Failure for the Asset Category)	Upper Limit of Overall Consequence of Failure (as % of Average Overall Consequence of Failure for the Asset Category)
C1	-	< 75%
C2	≥ 75%	< 125%
C3	≥ 125%	< 200%
C4	≥ 200%	-

5.23 The Average Overall Consequences of Failure is determined, for each Health Index Asset Category, from the consequences of failure associated with the asset population that exists at a given point in time (e.g. for RIIO-ED1 this is the average for the population at the start of the period) within the DNO. This is then frozen as a reference point for the banding of asset criticality throughout the period. This ensures that Risk Index matrices reported in each year are directly comparable with those reported in other years and comparable with the Network Asset Secondary Deliverable targets.

5.24 The Average Overall Consequences of Failure for each Health Index Asset Category are DNO specific values, recognising that differences exist in the typical level of impact of failure between DNOs. In part, these differences are driven by factors such as differences in usage, utilisation, or location of assets. For example, the size of the impact of asset failure on network performance will be dependent on factors such as load / customer density and network topology, which will differ between each DNO. However, in some of the Health Index Asset Categories, the range and mix of different types of RRP Asset Register Category within the Health Index Asset Category is a significant driver for differences in the Average Overall Consequences of Failure between DNOs.

5.25 The typical values of consequences of failure that are assigned to each Criticality Index Band are defined within CNAIM as a specified proportion of the Average Overall Consequences of Failure. This is shown in the table below:

Table 18 - Consequence of Failure (CoF) Banding

Criticality Index Band	% of Average Overall Consequences of Failure to be used to determine typical value of Consequences of Failure for the Criticality Band
C1	70%
C2	100%
C3	150%
C4	250%

5.26 The Risk Index for each Health Index/ Criticality Index combination within the Risk Index matrices is the determined from the product of:

- the typical value of probability of failure associated with the Health Index Band; and
- the typical value of consequence of failure associated with the Criticality Index Band.

5.27 This produces a monetised value of risk (£) for each of the Health Index/ Criticality Index combinations.

5.28 An overall value of Monetised Risk for an asset population can be derived by multiplying the asset volumes in each Health Index/ Criticality Index combination by the appropriate Risk Index value for the relevant portion of the matrix and summating for the whole of the matrix. In a similar way, the change in Monetised Risk caused by movements in the Risk Index matrices, for example due to DNO investment, can be evaluated by multiplying the movement volumes by the appropriate Risk Index value for the relevant portion of the matrix. In this way, each DNO's RIIO-ED1 Network Asset Secondary Deliverable target has been derived and expressed as a Monetised Risk value.

5.29 The Network Asset Secondary Deliverable relates to the benefit in risk reduction that is delivered through the DNO's asset replacement activity and some refurbishment activities.

5.30 Asset replacement is the activity of whole replacement of an asset (or for linear assets, such as underground cables, a length of asset) predominantly driven by asset condition, obsolescence, or safety. Within Ofgem's Regulatory Instructions and Guidance (RIG), refurbishment is a one-off activity undertaken on an asset that is deemed to be close to end of life or is otherwise not fit for purpose that extends the life of that asset or restores its functionality. Refurbishment may involve replacement of a subcomponent of an asset, but does not include replacement of the whole asset, itself.

5.31 For RIIO-ED1 regulatory reporting, refurbishment is classified into two types. This requirement is extended for use in RIIO-ED2 by inclusion of some additional options in each category:

- Refurbishment (SDI) activities – these are refurbishment activities where any change in Risk Index delivered through these activities can be considered in the delivery against the Network Asset Secondary Deliverables target; and
- Refurbishment (No SDI) activities – these are refurbishment activities that, if undertaken, are not considered in the delivery of the Network Asset Secondary Deliverables.

5.32 Ofgem's Regulatory Instructions and Guidance Annex A allocates whether a specified refurbishment activity should be considered as Refurbishment (SDI) or Refurbishment (No SDI) activities. For example, within the guidance for a LV Pole:

- 'Complete replacement of pole top steelwork (including associated insulators and fittings)' is classified as a Refurbishment (No SDI) activity; whereas

- ‘Pole Strengthening (e.g. clamping a steelwork supporting bracket to an existing pole)’ is classified as a Refurbishment (SDI) activity.

5.33 In allocating refurbishment activities between the two categories, consideration has been given to whether the activity delivers asset health benefits and whether any benefits delivered by the activity are measurable and capable of being reflected within the inputs provided to the calculation of Network Asset Indices. As Refurbishment (SDI) activities are included within the Network Asset Secondary Deliverable measure, it is important that CNAIM enables the risk improvement benefits associated with the activity to be quantified within the Network Asset Indices.

6. Incorporating Long Term Risk into the Risk Index

Summary of changes in risk for RIIO-ED2

6.1 A Monetised Risk Index measure that quantifies the condition-based asset risk associated with the risk held in a single year is produced by CNAIM v1.1.

6.2 For RIIO-ED2, Ofgem require that the Network Asset Risk Metric should consider a longer-term view of risk, considering the value of the future risk associated with an asset.

6.3 The proposal is to change the basis for the weightings that are applied to the Health Index Bands, when deriving the Risk Index from the Risk Index matrices so that the weighting factors produce a representation of the cumulative risk in the current year and future years, when combined with the typical values of consequences of failure for each Criticality Index Band.

Driver for change

6.4 Within the Risk Index matrices used for the regulatory reporting of Network Asset Indices, asset volumes are populated into the Health Index and Criticality Index portion of the matrix that represents the Health Index and Criticality Index that the asset has reached at a given point in time.

6.5 In CNAIM v1.1, a value of Monetised Risk (Risk Index) is derived from the position of an asset within the Risk Index matrices by assigning:

- a typical value of probability of failure (per annum) to all assets within the same Health Index Band (for a given Health Index Asset Category); and
- a typical value of Consequence of Failure to all assets within the same Criticality Index Band (for a given Health Index Asset Category).

6.6 The Risk Index produced from these typical values represents a typical value of risk of failure (per annum) for an asset that has reached the relevant Health Index / Criticality Index at the point in time represented by the Risk Index matrix. This is the measure of Monetised Risk used in RIIO-ED1 Network Asset Secondary Deliverables. This represents the value of risk in a single year.

6.7 The Network Asset Secondary Deliverable relates to the risk reduction benefit that is delivered through asset replacement and certain refurbishment interventions. Where the risk reduction is assessed using the RIIO-ED1 Risk Index measure, this evaluates a Monetised Risk value representative of the risk reduction (in £ per annum) in the year represented by the relevant Risk Index matrix. This produces a measure of risk reduction in a single year. The following diagram provides an illustration of what this measure is evaluating. The diagram shows a measure of risk reduction in a single year for an asset removed from the network in year n, based on a continuous time/ probability of failure curve:

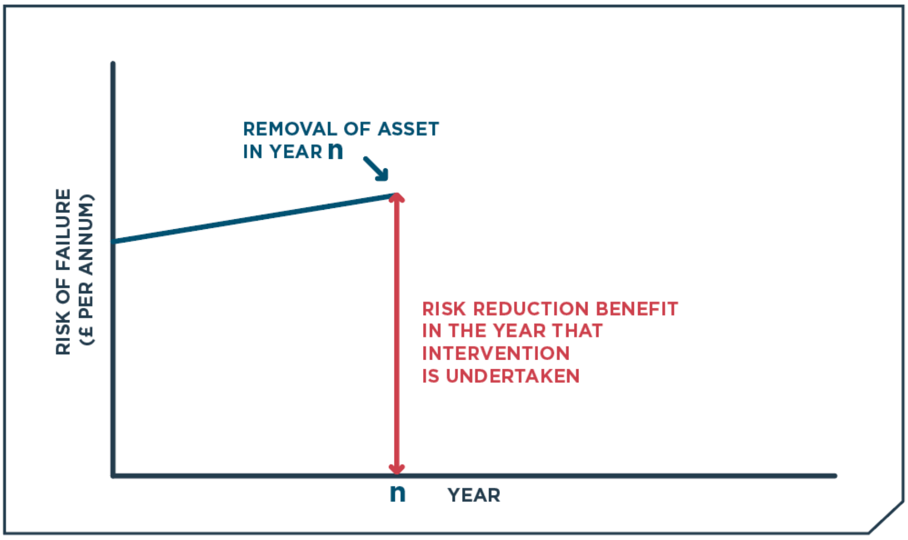


Figure 16 - Risk in 'n' year

6.8 A measure that considers the risk in a single year does not consider the longer term risk associated with an asset. When an intervention is performed that reduces risk, this intervention does not only reduce the risk in the year that the intervention is undertaken, but also addresses the risk that would be held in future years if the intervention were not undertaken. This is illustrated in the diagram below, which again considers the risk reduction benefit associated with removal of an asset in year n.

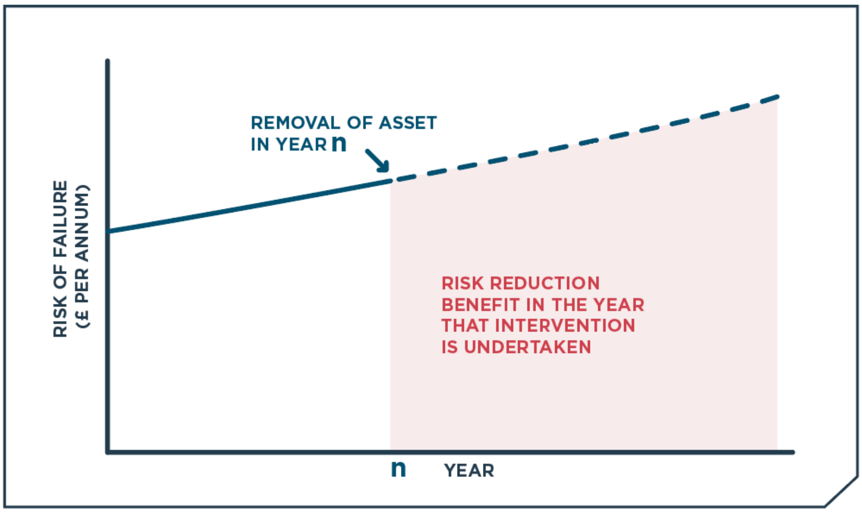


Figure 17 - Risk in future period

6.9 The CNAIM v1.1 Risk Index provides an acceptable measure for use in assessing delivery against the Network Asset Secondary Deliverables targets, despite quantifying the risk reduction in terms of the risk reduction in a single year. This is because both the target and the delivery are evaluated on a consistent basis and can therefore be directly compared to assess whether the target has been delivered.

6.10 The monetisation of risk within the CNAIM v1.1 Risk Index does not quantify the reduction in future risk delivered by interventions and so it does not produce a measure of risk reduction benefit that enables comparison of the true value of the benefit delivered by an activity with the activity's associated cost. This means that it does not quantify risk in a way that facilitates evaluation of whether the expenditure on the activity is commensurate with the benefits that it delivers.

6.11 Ofgem has confirmed that the Monetised Risk measure used in the RIIO-ED2 Network Asset Risk Metric (NARM) must consider the long-term condition-based risk associated with assets. Long Term Risk provides a measure that that facilitates clearer visibility of the cost-benefit justification associated with interventions.

6.12 The requirement to consider Long Term Risk in the RIIO-ED2 NARMs required changes to be introduced to CNAIM v2.1 to reflect this requirement within the Risk Index.

Details of the approved changes

6.13 The Risk Index matrix representation used in RIIO-ED1 regulatory reporting enables clear and transparent communication to all stakeholders about the health and criticality of high-volume asset populations. Such populations are typical within the ED sector. Risk Index matrices permit movements and changes (such as impact of investment, deterioration, material changes) to be clearly represented and understood, using terminology and presentation that has become well established and understood throughout the industry. The Risk Index matrix representation is now part of an established and mature regulatory reporting and assessment process for the ED sector.

6.14 It is agreed that a Risk Index measure reflective of long-term future risk is introduced in CNAIM v2.1 that is an evolution of the existing Risk Index matrix approach. This enables the benefits of the existing Risk Index matrix approach and the established regulatory processes to be retained.

6.15 In CNAIM v2.1, it is agreed that the existing methodology for derivation and assignment of assets to Health Indices and Criticality Indices within the Risk Index matrix is not changed. Long Term Risk will be recognised in CNAIM v2.1 by changes to the weighting that is applied to each Health Index Band when determining the value of the Risk Index. This weighting shall be changed so that it:

- reflects the cumulative probabilities of failure in the current year and future years; and
- considers financial discounting so that the resulting Risk Index represents a monetisation of future risk that represents it in present value terms.

6.16 These weightings represent the 'cumulative discounted probability of failure' that is typical for each Health Index Band.

6.17 When the Health Index Band weightings are combined with the typical values of consequences of failure that are assigned to the Criticality Bands, the resulting Risk Index represents a quantification of the long-term risk in the current and future years that is expressed in present value terms. This enables any risk benefits delivered by interventions to be directly compared with the cost of intervention.

6.18 The weightings determined for each Health Index Band are derived based upon:

- a typical value of current year Health Score for an asset within the Health Index Band;
- typical degradation forecasts for future asset health (based upon the existing principles used in determining future year deterioration in asset health for the derivation of Future Health Score within CNAIM);
- and financial discount rates consistent with **HM Treasury Green Book guidance** (2018).

6.19 To derive the weightings:

- the forecast Health Score for each future year (starting with the typical value of current year Health Score) is determined using typical degradation assumptions based upon the calculations for Future Health Score within CNAIM; then
- a probability of failure for each of the years is derived from the forecast Health Score for the relevant year, using the relationship between Health Score and probability of failure that is defined in CNAIM; then
- a discounting factor, appropriate to the relevant year, is applied to the probability of failure for each year to create a 'discounted probability of failure' for each year; and finally
- the 'cumulative discounted probability of failure' weighting is determined by summating the 'discounted probability of failure' for each year.

6.20 Further information relating to the evaluation of Long Term Risk using the Risk Index matrices can be found in section 5.5 of the approved CNAIM v2.1[16] document should further information or detail be required.

[16] Common Network Asset Indices Methodology v2.1 approved by Ofgem

7. Revision of Health Index HI1 Banding Criteria

Summary change in CNAIM v2.1

7.1 Assets are allocated to a Health Index band based upon the Health Score of the asset.

7.2 The Risk Index is determined by allocating typical weightings to each Health Index Band and typical values of consequences of failure to each Criticality Band. The Risk Index is derived from the product of these typical values.

7.3 For RIIO-ED2 the Risk Index shall represent the Long Term Risk associated with assets, reflecting the cumulative current and future risk associated with assets. This is achieved by allocating typical weighting factors to each Health Index Band that represent the cumulative discounted probability of failure that is typical for each Health Index Band.

7.4 It is has been agreed to change the upper limit banding criteria for the HI1 band, in CNAIM v2.1, to better facilitate the use of a weighting factor for application to the HI1 Health Index Band that is reflective of the range of assets within the band, when Long Term Risk is considered.

Driver for Change

7.5 Assets are assigned a Health Index Band based upon their Health Score. The figure below shows the bandings that are specified in CNAIM v1.1 and illustrates how they relate to the probability of failure curve that is generated from the Health Score.

7.6 When the Health Index (HI) banding criteria was developed for CNAIM v1.1, the HI1 band was defined as being applicable to all assets where the Health Score is less than 4. This was appropriate because the same value of probability of failure (per annum) is given to all assets, within the same asset category, that have a Health Score of 4 or below. This also enabled the Risk Index for the HI1 band to be derived using a typical probability of failure that would be the same as the probability of failure that would be calculated individually for all assets included within the band.

7.7 Based upon the age-based curve that underpins CNAIM's Initial Health Score calculation, assets would be expected to normally be in the HI1 band for a significant proportion of the lives. The HI1 band covers approximately 85% of the Expected Life of an asset, which is the point in an asset's life when the first significant signs of deterioration would be expected.

Figure 18 - Health Index Banding v1.1

7.8 CNAIM is calibrated so that a Health Score of 5.5 represents the point that the first significant signs of deterioration would be expected. The HI2 band was defined so that it includes all remaining assets that have a Health Score below the calibration point of 5.5.

7.9 The calculations for Health Score use an exponential function and so assets normally transition more quickly along the ‘tail’ of the probability of failure curve. The remaining Health Index Bands were defined so that they provided a suitably granular view of an assets’ transition towards the end of its life, taking into account that this is the portion of the curve that is normally examined when determining the timing of any condition-based interventions.

7.10 CNAIM v2.1 introduces a Risk Index measure that reflects Long Term Risk. This takes account of the cumulative risk in the current and future years and expresses this in present value terms. This is achieved by applying weightings to the Health Index Bands that represent the ‘cumulative discounted probability of failure’ that is typical for each Health Index Band. These weighting factors are derived by considering the typical Health Score for an asset within each Health Index Band and the typical deterioration that would be expected in future years.

7.11 Due to the length of time that an asset takes to pass through the HI1 band (as defined in CNAIM v1.1), there would be considerable differences in the values of future risk that are associated with an asset at the beginning of the HI1 band compared to those for an asset that starts at the end of the HI1 band (i.e. Health Score 4), when considering future risk over a fixed period and taking account of financial discounting of the value of future risk. The differences arise because assets that start in the current year at the beginning of the HI1 band are at the start of the ‘flat’ portion of the probability of failure curve. Consequently, the probability of failure associated with such assets will not be forecast to rise until many years into the future have elapsed. However, the probability of failure for assets that start at the end of the HI1 band will increase in each forecast future year.

7.12 The scale of difference varies for each asset type, but typically the cumulative future risk, in present value terms, associated with assets that start from the end of the HI1 band could be 5 or 6 times greater than for assets that start from the beginning of the band. This range means that any value selected for a weighting factor for the HI1 Health Index Band, to be used in the derivation of a Risk Index that considers Long Term Risk, may not be representative of assets at one or other end of the range of Health Scores within the band. For this reason, there is a need to revise the Health Index banding criteria for the HI1 band in CNAIM v2.1.

Details of the changes for RIIO-ED2

7.13 It has been agreed by Ofgem to change the banding criteria for the HI1/ HI2 boundary in CNAIM v2.1 to a Health Score of 3. This is a reduction of the upper limit of the HI1 band, which was set at a Health Score of 4 in CNAIM v1.1.

7.14 The revised banding criteria is shown in the table below:

Table 19 - Health Index banding criteria

Health index band	Health index banding criteria	
	Lower limit of health score	Upper limit of health score
HI1	≥0.5	<3
HI2	≥3	<5.5
HI3	≥5.5	<6.5
HI4	≥6.5	<8
HI5	≥8	≤15

7.15 With the revised upper limit to the HI1 band, the range of cumulative future risk between assets at either end of the banding criteria is approximately half the size of the range where an upper limit of a Health Score of 4 is used. This enables a more suitable weighting factor to be applied to the HI1 band in CNAIM v2.1 that can be used in the derivation of the Risk Index to produce a value of Long Term Risk more typical for the range of assets within the Health Index band.

7.16 The figure below illustrates the revised banding criteria for CNAIM v2.1:

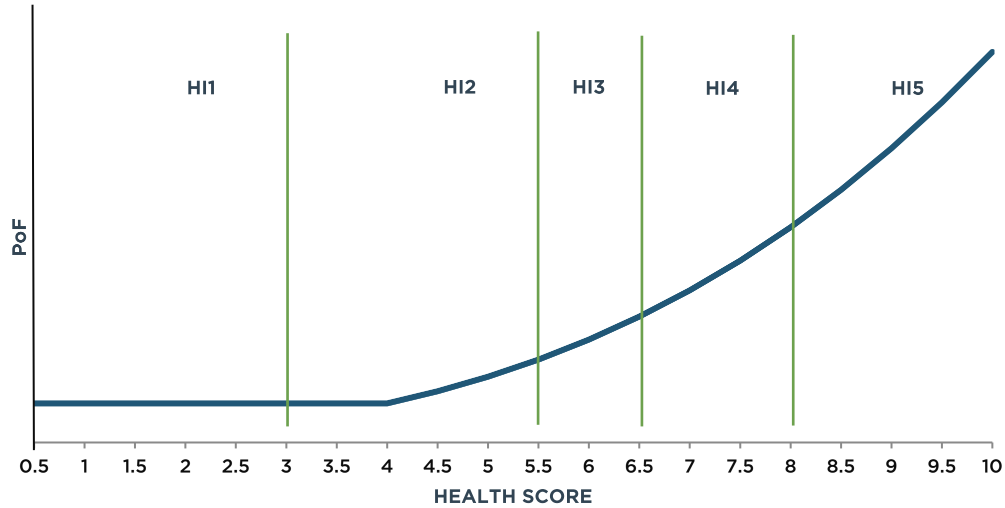


Figure 19 - Health Index Banding v2.1

8. Network Asset Intervention Methodology (NAIM)

8.1 This section describes the additional considerations and approach which was undertaken for the RIIO-ED2 Business Plan submission utilising the outputs from our CBRM system from the CNAIM models available for all asset classifications.

8.2 The complete methodology for each of the 61 different asset classifications covered by NARMs are documented in our Network Asset Intervention Methodology (NAIM), TG-NET-ENG-026. This section outlines the principles applied as a typical example without necessarily being asset specific – the high-level overview of the methodology.

8.3 This methodology defines how we identify network assets that require condition related intervention within the RIIO-ED2 price control period, and the selection of the most cost-effective intervention option e.g. refurbishment vs replacement. The Health and Criticality calculations for each asset produced, using CNAIM v2.1 for final RIIO-ED2 Business plan submission, are key inputs to the NAIM and help to determine when it is appropriate to intervene upon our assets.

8.4 As outlined in Section 7 above, the Health Index banding covers a range of different calculated Health Scores and where a general intervention approach, for example, could be applied as a blanket selection to invest in all HI5 classified assets at either the current or future point in time there are other more granular options to consider.

8.5 Similarly, they could be further prioritised by means of their associated Criticality, and therefore this could be combined with the Health Index banding and classified as a Monetised Risk approach to intervention selection. An example would be to consider all HI5/C4 classified assets for replacement as this will drive the greatest Monetised Risk reduction from your Network. By considering each of the cells in the normal CNAIM 5 x4 reporting matrix then a priority could be used to set an order based on the next highest order Monetised Risk, etc. in sequence This would continue through until all the cells in the 5 x 4 matrix has a priority from ranging from P1 to P20 as illustrated below:

Table 20 – Risk Index matrix illustrating a simple Monetised Risk priority approach

		Health Index				
		HI1	HI2	HI3	HI4	HI5
Criticality	C1	P20	P16	P13	P10	P7
	C2	P19	P15	P12	P8	P4
	C3	P18	P14	P9	P5	P3
	C4	P17	P11	P6	P2	P1

8.6 However, as referenced, it is then possible to consider the Monetised Risk reduction as a financial benefit (£) and to compare it to the unit cost value of the replacement and carry out a simple calculation on the difference being considered as the Net Present Value (NPV).

Where this investment returns greater Monetised Risk reduction than the amount of the investment for the intervention option then it could be considered to be a 'positive' result and therefore justifiable as a positive NPV. This is illustrated in the table below where if the unit cost is £13,722 then there is positive return benefit in the cells coloured green and negative benefit in those shown pink:

Table 21 - Cost Benefit Analysis on Monetised Risk

		Cost Benefit: Monetised Risk (Long Term Risk) Benefit of Like for Like Replacement - Cost of Replacement (£)				
		HI1	**HI2**	**HI3**	**HI4**	**HI5**
6.6/11kV Transformer (GM)	**C1**	-13722	-11964	-9327	-6085	-1733
	C2	-13722	-11210	-7444	-2811	3405
	C3	-13722	-9954	-4305	2644	11968
	C4	-13722	-7442	1973	13555	29094
		Forecast Unit Cost: Ofgem Expert View (ED1 Cost Assessment) £k (inflated to 20/21 price base)				
6.6/11kV Transformer (GM)		13.722				

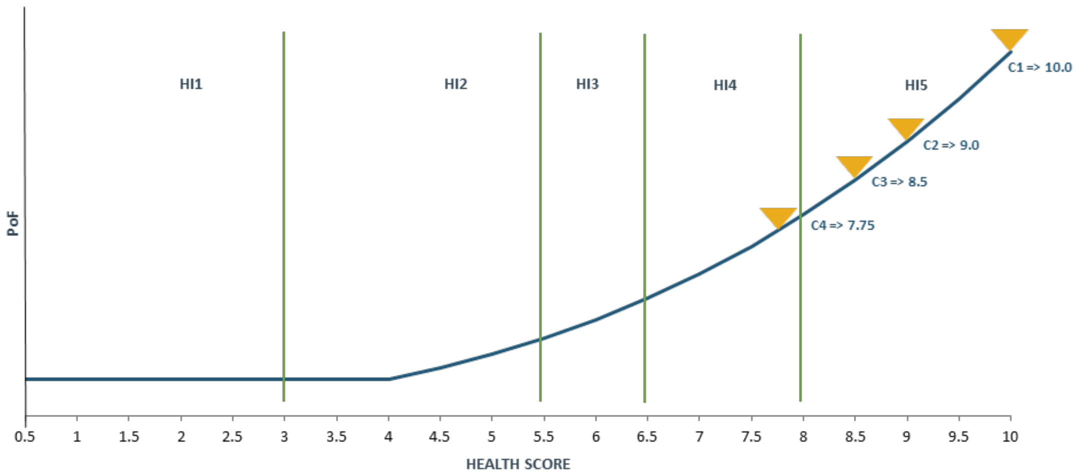
8.7 This is a very simple and pragmatic approach however it can also be challenged where the asset has only just reached the HI5 Health Score of 8.0 or greater at this future point in time. In this situation it is still considered to have sufficient remaining useful life that immediate replacement is not always in the best interest of the customers nor the Distribution Network Operator.

8.8 The normal assessment of any HI5 asset is considered as 'End of Life', the intervention is normally then considered as a very binary decision to replace once it has reached this Health Index, and its replacement retains the same identified Criticality to merit its position in the prioritisation matrix order.

8.9 Our Network Asset Intervention Methodology (NAIM) instead utilises a Health Score Investment criterion which is specific to each asset category and considers both the Health and Criticality of each network asset to determine if intervention is required. This is a risk based methodology where lower Criticality (C1) assets are shortlisted for intervention at a higher Future Health Score (e.g. a Health Score of 10.0) than high Criticality (C4) assets where a lower Probability of Failure is required (e.g. a Health Score of 7.75) to manage the overall risk of failure.

8.10 An example of the asset specific Health Score investment criteria developed for RIIO-ED2 is shown in Figure 20 below, where the starred Future Health Score values on the graph indicate the trigger points for intervention by asset Criticality. This specific example is for SHEPD's 6.6kV/11kV Transformers (GM). As seen, to manage the total risk of failure, a lower Probability of Failure (PoF) is allowed for high criticality assets (C4s) which have a higher Consequence of Failure (CoF). This approach allows us to manage the risk across the network whilst maximising the lifetime of our network assets.

Figure 20 - Health Score Intervention Criteria



8.11 It is worth remembering that the Health Score calculation in CNAIM for a future asset failure is on a range of 0.5 to 15.0, whereas the current asset Health Score is on a range of 0.5 to 10. This is not indicating a significant increase in the risk on the network nor the risk to customers, just the point when the intervention is initiated is not immediate when the Health Score is 8.0 or greater as already mentioned. This additional Health Score range helps SSEN tune its intervention investments whilst managing the 'appetite to risk' within a considered tolerance for each asset category proportionately.

8.12 Again from this example, the difference in intervention volumes is illustrated in Table 22 below on the top row the number of HI5 assets classified in Criticality Index (C1 to C4) for these 6.6kV/11kV Transformers (GM) in SHEPD.

8.13 It then shows the volumes of transformers shortlisted for intervention once the Health Score intervention criteria is applied to the CNAIM data. By applying our NAIM criteria only 456 of the 811 HI5 transformers have met the granular assessment criteria based on the Health Score values which then justifies intervention within RIIO-ED2 period. All the deselected HI5 transformers are likely to further deteriorate and we can set a future date to verify this to understand a further assessment of those which will meet this criteria in RIIO-ED3 or beyond.

Table 22 - Volume of 6.6kV/11kV Transformers shortlisted for intervention – SHEPD

	C1	C2	C3	C4	Total
Number of HI5 Transformers within each Criticality	118	607	38	48	**811**
Health Score Investment Criteria by Criticality	>=10	>=9.0	>=8.5	>=7.75	-
No. of Transformers within Health Score Investment Criteria	55	312	30	59	**456**

8.14 This allows us to defer investment until the asset is closer to 'end of life', providing a greater efficiency in the use of the asset and the value to the customer without unduly presenting additional risk to the network.

8.15 This is an example of the general principles of our NAIM with a similar approach applied to all the NARM asset classifications rather than a straightforward Monetised Risk only approach. The output of this process is still recorded as Monetised Risk benefit it is just not solely based on that criteria as the intervention decision driver.

8.16 It should also be noted in this example we are only showing the HI5 asset volumes and in this specific asset classification there are other factors for consideration including the type of asset and its configuration with other associated assets.

An example is where the 6.6/11kV Transformer is part of a composite unit i.e. a combined unit made up of a transformer, HV Switchgear and LV feeder pillar where the entire composite unit may be the economical and efficient replacement solution even when the other aspects of this unit are not HI5 and indicating intervention required. In these instances, the combined unit may be replaced resulting in lower risk assets being replaced at the same time earlier in their life cycle.

8.17 The threshold values set within the matrix cells, i.e. the Health Score trigger points, are under continuous review and any updates can be made through an internal approval process with all the associated documentation and modelling information updated for our NAIM as required.

8.18 A key objective of the NAIM is to optimise the TOTEX investment required across the distribution network during RIIO-ED2. In principle, to maximise value for money for network customers, it is preferable to extend an assets lifetime for as long as possible before CAPEX intensive intervention is undertaken.

8.19 However, this must be balanced against an increasing risk of failure which can lead to an increase in fault and repair related OPEX spend. The NAIM intends to optimise both CAPEX and OPEX spend (TOTEX) by identifying the assets that truly require intervention, where the risk associated with deferring this intervention any further is not considered tolerable or cost effective for network customers.

8.20 Utilising our NAIM, when compared to a straight HI5 basic intervention approach, the benefit to our customers from the above methodology we are able to demonstrate an illustrative intervention savings for NARM asset categories across our licence areas of around £104.5m. This is based on £32.8m for SHEPD and £71.7m for SEPD, whilst only increasing the risk on the network by 1.86% for SHEPD (SSEH) and 4.35% for SEPD (SSES) which delivers cost efficiencies to the customer with little increased risk to them.

APPENDIX C: ENHANCED ENGAGEMENT

- Overview: **We will invest in our assets to reduce the probability of failure to maximise reliability to our customers**
- Total cost: **£338.0m (Network Asset Risk output), £299.6m (Safety outputs)**
- Contribution to annual customer bills: **Network Asset Risk – £7.52 (South), £13.30 (North), Safety – £7.62 (South), £8.57 (North)**

RIIO-1 context

During ED1 we have continued to invest in our network to maintain, replace or refurbish assets which may have defects that require attention, or are at the end of their service life due to their condition.

Throughout ED1, we have developed and used a risk management approach when driving investment decisions as part of our asset management strategy. This allows informed investment decisions to be made on the basis of balancing risks, opportunities, costs and performance, ensuring effective management of our risks and improving our identification of emerging risks, opportunities and threats.

ENGAGEMENT SYNTHESIS

Stakeholder engagement	
Engagement details	**Insights derived**
Consultants We engaged EA Technology to evaluate and comment on our Network Asset Intervention Methodology (NAIM) for asset replacement	• Broad agreement that our NAIM approach supplemented by EJPs and Net Present Value analysis to justify investments is appropriate to prioritise asset investments for the RIIO-ED2. [E179] Challenges with data or shortcomings of CNAIM support evaluation of different approaches for replacement of different asset classes. [E179]
Next generation bill payers, fuel-poor customers, customers in vulnerable situations and medium business customers We tested our **safety and resilience strategy, outputs and costs** through qualitative focus groups to get insights into the acceptability and affordability of our Draft Business Plan	• Network resilience was a key priority for all customer segments and they felt this part of the plan represented good value for money. Business customers noted that secure electricity supply was essential for their businesses [E156] • **Future customers** and **Fuel poor customers** felt 3 months was too long to remove redundant equipment from sites and lacked ambition and questioned why this could not be done immediately or in a shorter timeframe. [E156] • Some **fuel poor customers** in England wanted to see more explicit emphasis on and funding for safety of staff. [E156] • Those customers who found the safety and resilience part of the plan unacceptable pointed to a lack of ambition or the fact that it was funded through customer bills, not “shareholders’ dividend”. [E156]

Non-consumer stakeholders We tested our **safety and resilience strategy, outputs and costs** with a broad range of non-consumer stakeholders to understand their views on the **acceptability and bill impacts** of our Draft Business Plan via an online consultation event and surveys	• There was broad consensus from Stakeholders that SSEN should intervene in assets with the highest probability of failure and commit to replacing assets to enable more automation. • A government representative noted that there may be a balance between maintaining resilience and the context of net zero in the next 40 years. [E151] • A government representative wanted to understand to what extent supply chain issues have been taken into account when selecting and costing proactive asset replacement projects. Also the extent to which offshore wind has been considered in the procurement and delivery of these projects. [E151]
Academics We engaged academics on our Draft Business Plan via an academic panel round table	• It was noted that asset write-off period for some assets do not have the same expiry dates of robust assets like transformers. For example, storage and distributed generation assets don't last as long and so may require a different approach. [E152] • Potential to improve the life cycle analysis on new types of assets and infrastructure which go beyond the traditional short-term economic models. [E152]
Domestic customers We tested our **resilience and safety outputs** with consumers via an on-line survey	• 'Intervening in our network assets with the highest probability of failure, reducing longer-term risk by 21.8%, relative to a future without intervention' was a medium priority for the majority of customers (52% in both licence areas); 31% in the south and 30% in the north said it was a high priority, and 17% in both licence areas and said it was a low priority. [E170] • 'We will continue to meet all safety-related legal requirements', was a high priority for the majority of customers (59% in both licence areas); 35% in the south and 31% in the north said it was a medium priority, and only 5% in the south and 10% in the north said it was a low priority. [E170] • 'We will extend our engagement on safety around our assets, reaching 50,000 partners and members of our communities' was a high priority for 44% of customers in the south and 38% in the north; 45% in the south and 50% in the north said it was a medium priority, and 11% in the south and 12% in the north said it was a low priority. [E170] • 'We will remove redundant equipment from our unoccupied sites within 3 months to prevent risk to the public whilst also preventing vandalism and theft across 100% of sites' was a high priority for 51% of customers in the south and 45% in the north; 37% in the south and 48% in the north said it was a medium priority, and 12% in the south and 7% in the north said it was a low priority. [E170]

Current and future employees We conducted audience research on our safety and resilience outputs with colleagues via a survey	• Condition-based risk management (CBRM) modelling was queried as to whether it effectively showed where the investment is most needed. Also, it was observed that some Unit Rates are lower than current Unit Rates. [E153]
Vulnerable customer representatives Citizens Advice provided their views on all DNOs draft Business plans via a published report	• Citizens Advice felt expected outcomes from SROI and engagement with 50,000 partners and members of its communities on safety around assets should be drawn out in the plan. [E159]
Supply chain, Local Authorities, Consumer groups, Community energy schemes, Contractors, Landowners/farmers We engaged stakeholders separately in both Licence Areas separately via online workshops to co-create how we should replace and repair assets on our networks to meet stakeholder and consumer expectations for a safe and reliable network	**Network reliability** • All stakeholders strongly supported our proposed asset intervention approach. However, stakeholders in the South wanted to see more synergy between load and non-load assets when intervening in order to ensure that any measures taken are as effective as possible [E122]. • Stakeholders in the North wanted greater clarification about the types of data involved in asset monitoring for determining whether intervention should take place. Stakeholders in the South stressed that there should be investment in enhanced asset-monitoring technology (such as AI) [E122]. • Stakeholders generally felt that it was better to spend more now on both underground cables and overhead lines in order to avoid reliability issues and increased customer charges later. There was more enthusiastic support among stakeholders in the North to actively invest in underground cables than in overhead lines [E122]. • Both sets of stakeholders were generally of the view that we should be investing in replacing assets, but we should be careful and balanced in how we spend customer money [E122]. **Monetised risk** • Stakeholders strongly supported our proposed approach of prioritising assets with a higher likelihood of failure. However, they also advocated ensuring that the data used for monitoring was high quality and up-to-date. It was stressed that this would be crucial to ensuring that the monetised-risk strategy is a success [E122]. • Stakeholders strongly urged us to strike a balance between maintain a reliable network by simply fixing older assets now, and replacing assets (at a higher cost now) so that the network is ready for future use [E122]

	• There was widespread support at both events for costs to be included on customer bills now in order to protect future bill payers. SHEPD stakeholders suggested educating customers on why this approach is important [E122].
Major connections customers We co-created our connections strategy via audience research, during which we gained insight on asset management aspects of this area	• One stakeholder encouraged us to analyse the additional demand that will be placed on transformers as a result of the electrification of heating and transport [E020]. • One stakeholder suggested our connections admin team should send 'as-laid' records to developers for mains or service connection works so everyone knows what works has been done, and aware of what still needs to be done. As a developer, he could then keep our site agents **safe** onsite and ensure the integrity of our assets [E020].
Domestic and SME customers We conducted audience research via a survey to understand consumers' high-level priorities for ED2	• We should be open about how consumer data is used, publication of worst affected areas, and repair times [E118].
Landowners/farmers We conducted audience research via bilaterals	• The most commonly used pieces of machinery were to the user second nature. They were on autopilot when they got into them, not really thinking about operating them, they just do it [E121] • Some of the common tasks which were machinery were used for comprised cutting trees, feeding livestock, fencing, harvesting, loading bales, spraying etc [E121] • Qualifications in the use of farm machinery were a pre-requisite when applying for a job in farming and they were generally acquired during time spent at agricultural college. Two examining bodies mentioned were NTPC (National Proficiency Tests Council) and LANTRA (National Training Organisation for the Land Based Industries). The NPTC qualification was a lifetime one, the LANTRA required a refresher course every five years - body varies by college. One stakeholder mentioned "Grandfather rights" - if you were born before the requirement to have the test was made compulsory then you were not obliged to take it [E121] • There is no legal requirement to have a "ticket" for the use of tractors as long as you held a regular driver's licence and was working on your own private land [E121] • It is common on family farms to learn to drive and operate machinery from parents/grandparents since they were small so second nature - possible to come across farmers with little or no official training in the use of machinery [E121] • If a new piece of machinery was bought then, on delivery, there would be induction training given by the person delivering the machine, however, this sometimes did not happen or done in a rush.

	However, it was a service that was part of the purchase process and would doubtless cover the safe use of the machine [E121] • There could be a possible opportunity for SSEN to engage with dealers to make sure that this briefing covered the safe use of the machine around electricity. This could be accompanied by a safety pack from SSEN which could be left along with the manual for the new machine [E121] • College lecturers agreed that safety on the farm and in the operating of machinery was very high up on the agenda in colleges and in their teaching and this had become more so over time. One even felt that it had become too onerous and excessive nowadays to the point where students could lose interest [E121] • Another felt it was for the good as it was now a tested part of the course. In the past safety was taught but students were not examined on it [E121] • Stakeholders mentioned risk assessment of activities before being undertaken was a new aspect of many agricultural courses [E121] • SYNOPTIC was mentioned as one means of conducting assessments, whereby students were required to write up a risk assessment before activity started - the purpose of this was to make the student aware of all the potential hazards they could be faced with and to check their surroundings, their vehicle, the weather conditions etc. so that they were sure the activity was safe to begin. They were being taught to THINK AHEAD, even if they had done the same task 100 times before each occasion was unique and this had to be taken into account [E121]. • One stakeholder gave an example where a friend of his who was a surgeon who delivered a talk on the effect of an electric shock on the body. This was done as a favour. These talks were felt to be very effective, and the lecturers would all welcome more of these as students enjoyed hearing from experts. They were also popular as they were a change from the norm, a break from the routine of lectures [E121] • All interviewees claimed to take safety seriously, however, it was clear attention paid on a day-to-day basis was affected by the size of the farm/business - one-man farms had no safety briefings, smaller farms had a more informal approach whereas larger farms had a more formal structured approach to safety [E121] • The larger the enterprise the more staff and therefore a more structured approach to how the farm functions and, importantly, how safety is managed - on larger farms there will be formal training and safety briefings to comply with the law. On smaller, family farms this will be unlikely to take place [E121] • An example at a larger farm (10k acres) held formal briefings which included safety protocol at harvest time with all their seasonal workers, whereas a smaller farm (2k acres) held Toolbox Talks occasionally to talk about new equipment or processes and this would include a reminder of safety advice [E121]

	• It was suggested that we could engage with farms and farmers when meetings like this took place with perhaps posters, presentations and “take-away” safety packs for farm workers [E121]
	• Some of the younger respondents (late teens/early 20s) expressed concerns over their personal safety - recognised that they were at the beginning of their careers and their adult lives and were aware that a serious accident could put an end to or seriously affect that [E121]
	• There is an opportunity for us to tap into this insight and impress upon young farmers how much they would have to lose if they were involved in a serious accident on the farm. That a lapse in concentration or attention to hazards could cost them their life or livelihood [E121]
	• When asked to discuss what hazards they were aware of and thought about when operating farm machinery, electricity was mentioned but not always first [E121]:
	• Awareness of dangers posed by operating machinery around electricity was good and related to working at height - the machine could touch the lines or get close enough to cause arcing. However, wasn't commonly known how close one could be without causing arcing [E121]
	• Farmers themselves were very aware, especially those who used very large machinery on their farms, that the sheer height of some of these machines nowadays meant that this danger was getting more and more prevalent [E121]
	• One school of thought on advice if machinery came into contact with electricity was 'stay in cab' - jumping out of the cab causes the electricity to earth through you, and some security in the rubber tyres of the tractor which stopped the electricity earthing. The other school of thought on advice if machinery came into contact with electricity was 'jump out of cab' [E121]
	• All farmers thought it would be good to be reminded of dangers and to be provided with official advice should difficulties arise at the point of impact eg messages/stickers etc in cabs, around the farmyard and on poles. This would benefit contractors and seasonal labour landowner would already know where the lines are [E121]
	• Farmers thought it was important for them to know both the heights of their machine and the height of powerlines [E121]
	• When asked what messages they would pass on to other farmers in relation to farm machinery and electricity, farmers responded [E121]:
	    o Keep away, don’t touch
	    o Check where powerlines are
	    o Always check your surroundings
	    o Do not operate under powerlines unless really no choice
	    o Do not jump out unless really have to
	    o If in doubt, don’t jump out
	• Farmers would welcome training and/or seminars on the topic by our staff, either formally or informally. One suggested that our

engineers on callouts to farms for general maintenance could be coached with a short (10 minutes) safety briefing on the farm during the visit where an engineer could talk through the official advice as well as leave materials (including stickers) for the farm workers [E121]

- On a more formal footing, farmers would welcome SSEN talks at various functions/meetings held by farmers (once Covid restriction are eased) so that they could show the films they have, give advice, and do Q&As [E121]
- Farmers called for stickers with the 'Look out, Look up' advice (for those who knew of it) and the 105 number. To be stuck on the windscreen and around the farm to act as a reminder of the advice [E121]
- Our engineers could offer a safety briefing tour of a farm, highlighting to the farmer the danger points and perhaps even putting signage on equipment, gates, and poles so that it acts as a constant reminder. Having a sign on EACH pole with the EXACT height of the pole would also assist the farmer in knowing where to act with care [E121]
- The advice/training to students was in essence [E121]:
    - To avoid overhead cables at all costs
    - Do not need to be in CONTACT with cables, electricity can arc if close enough
    - Reduce booms etc. when passing underneath lines
    - Do not stack bales under overhead cables
    - What to you if in contact with electricity when using machinery
    - If the cab not on fire, stay in the cab and call for help (not always spontaneously mentioning 105)
- Arable farmers felt that they were particularly frantic at planting time and during the harvest, so they were best addressed in early spring before they started planting and pre-harvest [E121]
- In Scotland, planting happened mid-March to mid-May and harvesting from August to the end of October [E121]
- Social media accounts followed by farmers often included [E121]:
    - Agricultural companies
    - AHDB (Agriculture & Horticulture Development Board)
    - Colleges
    - Dorset Smallholders (private Facebook group – 1300 members)
    - Farmers Weekly
    - Farming UK
    - Graindex
    - Mole Valley Farmers
    - NFU
    - Royal Highland Educational Trust
    - Sell my Livestock (90,000 members)
- Other websites that framers were likely to mention were [E121]:
    - Aberdeen Press & Journal
    - Daily Mail
    - Dundee Courier

	o Farmers Guardian o Farmers Weekly o Farming Forum o HSE o Machinery Ring o Red Tractor Assurance o Ringlink
Police and Fire & Rescue Service We conducted audience research via bilaterals with emergency response providers	• Stakeholder advised that electricity is at the top of National Security Risk Assessment rankings ahead of water and gas [E129] • Stakeholder advised that connecting with their rural crime team and their bobby van could be leveraged [E129] • Stakeholder advised us to reach out to the WPC Corps comms team if interested in knowing more about how the police communicated through social media channels [E129] • Communications channels should be established within incident command at both SSEN and Wiltshire Police to be able to share information in a timely fashion and not duplicate efforts [E129] • Stakeholders advocated education as an important part of their messaging - younger secondary school students are at a prime age to understand the importance of safety and potential impacts when safety is compromised. They will also likely share information with family and friends [E130] • Fire and rescue service stakeholders indicated that they would be willing to work in partnership, sharing networks and information - shared work they are doing understanding communities' needs to inform strategic planning [E130] • Fire and rescue service stakeholders suggested we work with their community liaison officers to help build partnerships with other fire and rescue groups in Perth and Kinross to facilitate working at the community level in those local authority areas [E130] • Stakeholders advocated a grassroots approach to education through home visits, where they can encounter households in fuel poverty. The approach is now more risk-based eg where they got notified through social workers etc that a household would benefit from a visit - stakeholders would like to share this information with us. [E130]

ENGAGEMENT STATISTICS

ED2 ENGAGEMENT EVENTS	SOURCES OF INSIGHT	NUMBER OF STAKEHOLDERS
17	318	2,684

STAKEHOLDER SEGMENTS ENGAGED

CONSUMERS	Domestic customers	Customers in vulnerable situations	Transient customers	Next generation bill payers	SMEs	Major energy users	
CUSTOMERS	Distributed generation customers	Builders and developers	Community energy schemes	Landowners/ farmers			
POLICY MAKERS AND INFLUENCERS	Government	Research bodies, policy forums and think tanks	Media	Consumer groups	Regulators		
COMMUNITIES AND LOCAL DECISION MAKERS	Local authorities	Charities	Academic institutions	Housing associations			
	Vulnerable customer representatives	LEPs	Emergency response	Healthcare	Community interest bodies		
WIDER INDUSTRY AND VALUE CHAIN	DNOs	Transmission	GDNs	Water	Telecoms	IDNOs	
	ICPs	Consultants	Energy suppliers	EV charging	Other supply chain	Storage and renewable providers/ installers	Transport and highways agencies
PARTNERS AND ENABLERS	Current and future employees	Contractors	Service partners	Shareholders	Investors	Business advisers	Trade unions

EVIDENCE ASSESSMENT

ENGAGEMENT SCORING KEY

The engagement score assigns a weight to each source accounting for the robustness of the engagement event and the relevance of the feedback to the topic.

Score	Description
1-1.66	Limited evidence of good event planning, methodology or data collection. Feedback provided is high level with tangential relevance to the topic.
1.67-2.33	Good evidence of engagement planning and discussion of data collection methods, but limited depth of feedback and range of opinions. Feedback not necessarily fully aligned to the topic and only provides a limited insight and thus moderately useful.
2.34-3	Well-conducted, trustworthy event with highly relevant feedback. Specific, clear and relevant information with clear link to the topic discussed and high value added.

Phase	Date	Event ID	Event name	Key stakeholder groups	Number of stakeholders engaged	Engagement score
Phase 4: Testing and Acceptance	Oct-21	E179	NAIM Investment Methodology Review	Consultant	1	3.0
	Oct-21	E153	Employee Consultation Document Engagement on Draft Plan	Current and future employees	3	1.8
	Oct-21	E155	Stakeholder Consultation Document Engagement on Draft Plan	Community interest groups, storage and renewables suppliers, emergency response, healthcare and highways agencies	19	2.3
	Sep-21	E151	Consolidated Outputs and Costings Event	Contractors, Consultants, Local Authorities, National Government, Storage and Renewables suppliers, Supply Chain	106	3.0
	Sep-21	E152	Academic Panel	Academic Institutions	7	3.0
	Sep-21	E156	Draft Plan Qualitative Acceptability Testing Event	Domestic Customers	46	3.0

Phase	Date	Event ID	Event name	Key stakeholder groups	Number of stakeholders engaged	Engagement score
	Sep-21	E170	Microsite survey on Costed outputs	Domestic Customers, Vulnerable Customers and Future Customers	1,298	2.7
	Aug-21	E159	Customer Service and Consumer Vulnerability Bilateral and Survey on Draft Outputs	Consumer groups, Local Authorities, Research Bodies, Vulnerable Customer representatives, Charities, Water and Energy Suppliers	21	2.0
Phase 3: Business Plan Refinement	May-21	E122	Monetised Risk/Non load (North and South)	Other supply chain, local authorities	35	3.0
	May-21	E129	SHE bilateral Wiltshire Police	Emergency Services	1	1.8
	May-21	E130	SHE bilateral Scottish Fire & Rescue	Emergency Services	1	1.8
	May-21	E131	SHE bilateral Thakenham Homes	Builders and Developers	1	1.8
	May-21	E147	ED2 microsite survey: main phase	Domestic customers, community interest groups, SMEs	1,072	2.2
	Feb-21	E121	Farm Safety Research Report	Landowners/farmers, academic institutions	14	2.5
Phase 2: Co-creation	Jan-21	E020	Connections ICE Engagement - BAU & ED2 Survey	Distributed generation customers, builders and developers, local authorities, ICPs and IDNOs	16	2.3
	Dec-20	E025	Connections engagement - ED2 focus groups - Commercial/Industrial/Consultants	Consultants	4	1.3
	Oct-20	E118	ED2 Customer Priorities Survey	Domestic customers, customers in vulnerable situations, next generation bill payers, SMEs	39	2.0

MEASUREMENT OF SUCCESS

The table below sets out the benefits that our Safe and Resilient Network strategy and the outputs within it will deliver to customers.

Output	Northern target	Southern target	Comparison to RIIO-1	Cost in baseline plan	Consumer benefits
Intervene in our network assets with the highest probability of failure, reducing longer-term risk by just over 14%, relative to a future without intervention	Longer-term risk reduced by just over 14% relative to no intervention across both Licence Areas	Longer-term risk reduced by just over 14%relative to no intervention across both Licence Areas	£430.4m (last 5 years)	£338.0m	Improved resilience in the longer term, and improvements to shorter-term reliability. Greater ability of our assets to withstand climate shocks and support the transition to net zero.
Continue to meet all safety-related legal requirements	All legal requirements met	All legal requirements met	£164.9m	£294.0m	A safe and compliant network for our colleagues, partners and the wider public
Extend our engagement on safety around our assets, reaching 50,000 partners and members of our communities by 2028	50,000 across both Licence Areas	50,000 across both Licence Areas	Not measured	£1.2m	Increased awareness and reduced accidents
Aim to remove redundant equipment from our unoccupied sites within 3 months to prevent risk to the public from the start of ED2	3 months	3 months	New for ED2	£2.2m	Reduced accidents and increased network safety

APPENDIX D: ADAS REPORT

The ADAS report commences from the following page

Scottish & Southern Electricity Networks

A review of predicted tree growth rates and projected climate change threat to trees linked to vegetation management in the SSE (Southern) region

16th June 2021

ADAS

ADAS GENERAL NOTES

Project No.: 1021532

Title: A review of predicted tree growth rates and projected climate change threat to trees linked to vegetation management in the SSE (Southern) region

Client: Scottish & Southern Electricity Networks

Date: 16th June 2021

Status: Final

Authors	Ben Hockridge, George Holmes & Ruth Tothill
Date:	16th June 2021
Technical reviewer	Lucy Wilson & Ian Braddock
Date:	16th June 2021

EXECUTIVE SUMMARY

In Britain, electric utility companies are under a legal duty to maintain their overhead power line (OHPL) networks free of interruptions where reasonably practicable. Trees are one of the principal causes of unplanned service interruptions on the OHPL networks and electric utilities are required to make their networks 'resilient' to tree and vegetation damage, including during 'abnormal weather conditions'. Targeted vegetation management programmes can help achieve this whilst keeping costs under control.

The purpose of this report is to investigate and present the evidence for a requirement for more frequent vegetation management in SSE's Southern region compared to other Distribution Network Operator regions.

Utility Space Degradation (USD) and climate change impacts

The importance of knowing the growth rates of the most common tree species on the OHPL networks has been demonstrated. It is also important to know how these growth rates might change in response to projected change in climate as set out in the UK Climate Impact Projections (UKCIP), in order to plan and implement proactive tree clearance programmes with sufficient reliability and budget. A research project previously carried out by ADAS between 2008 and 2011 measured utility space degradation (USD) over 1700 experimental sites across the country. The measurements were interpolated using bioclimatic zones to give a continuous dataset of USD across the UK. This was used alongside climate scenarios from the UK Climates Impact Programme (UKCP09) to project the likely impact of a changing climate on the magnitude and spatial distribution of USD.

The UK Climate Projections 2018 project (UKCP18) provides a new set of probabilistic projections for climate change that supersede those under UKCP09. These new projections were used in this project to update the USD estimates for future climate scenarios out to the 2080s on the basis of expected changes to bioclimatic zones. Average USDs per electricity Distribution Network Operator (DNO) region for baseline and future climates were calculated and used as comparators to the Southern region of SSE.

Rates of growth measured by USD varied greatly across the country and therefore across DNO regions. At baseline (1981-2010) the region with the greatest average USD was SSE (Southern) with an average growth rate of 1.33 m. The DNO region with the lowest average USD at baseline was the SSEH (SSE's Scottish licensed area) region with an average USD of 0.47 m. The mean USD across all DNO regions at baseline was 0.93 m.

For future climates, the smallest USD change is predicted in the South of England, [redacted] SSE (Southern), where USD is predicted to increase very little over the next decade and may even be limiting in the 2080s and decreasing. It should be noted, however, that there may be significant errors associated with projected USD under the more extreme climate change scenarios in 2050 and 2080. USD rates for these projections are based on estimated changes in bioclimatic zones which in themselves have potential uncertainties. Alongside this there were a decreasing number of measured zones being used to represent the country.

<u>Key Finding 1.</u> The SSE (Southern) region experiences the highest average USD at baseline. This will likely also continue to be the case into the next decade according to UKCP18 climate projections.

Comparisons of woodland coverage and species composition

National datasets exist that enable us to compare tree or woodland coverage and species compositions within the different DNO regions. These additional data were queried to determine spatial variation in some of those metrics that affect risk to overhead powerlines.

National Forest Inventory (Forestry Commission, 2018) data were used to calculate the total area of woodland and area of different types of woodland for each DNO area. It has also been possible to illustrate the potential impacts of ash dieback by using the tree species estimated abundance maps from Hill et al. (2017) to produce a map of European Ash abundance (*Fraxinus excelsior*) and a table showing mean estimated abundance of each tree species for which data was obtained for each DNO region.

The DNO region with the greatest woodland percentage coverage is [redacted] at 20.5%. The SSEH & SSE (Southern) regions have 15.4% and 14.3% woodland coverage respectively. In the SSE (Southern) region, 67% of the woodland area is made up of broadleaved woodland, with 15.8% being conifer. This is compared to 14.1% broadleaved and 47% conifer in the SSEH region.

In terms of total area of woodland, the SSEH region has the greatest with 988,588 ha. The SSE (Southern) region has the third highest area of woodland with 246,394 ha. The SSE (Southern) region also has the highest area of broadleaved woodland at 165,692 ha. The area with the highest mean ash abundance is [redacted] with [redacted], followed by SSE (Southern) Region with 3.58 ha per km^2.

USD has been demonstrated to be more dependent on lateral growth rates than vertical ones. Broadleaves will produce lateral shoots that grow rapidly after cutting, whereas conifers usually show rapid vertical rather than lateral growth. The SSEH region, which has proportionally more conifers than broadleaves, will therefore require less intensive monitoring and management than the SSE (Southern) region.

Key Finding 2. Having the highest proportion of broadleaved woodland coverage, along with the second highest proportion of ash coverage of all the DNOs means that the challenges of vegetation management for system resilience will also be greater in the SSE (Southern) region in comparison with the other DNOs.

Impact on the health of trees from pests, diseases and storms

The main predicted effects of climate change could have numerous impacts on trees, including changes to growth rates, more susceptibility to frost damage, pests & diseases, increased waterlogging, and more invasive species. This complex combination of factors makes it difficult for those managing trees to predict future requirements for tree pruning and felling in order to protect people, property, and in this case utility infrastructure, from the consequences of increased tree and limb failures.

The SSE (Southern) region has one of the highest proportions of sweet chestnut (*Castanea sativa*) and oak (*Quercus spp.*) of all the DNOs. Sweet chestnut blight (*Cryphonectria parasitica*) and chronic oak decline, which is caused by the interaction of several damaging agents working sequentially or simultaneously, are likely to affect more of these trees throughout the region as the effects of climate change continue to weaken the trees and strengthen the influence of the pathogens.

The abundance estimations of tree populations by Hill et al. (2017) suggest that the SSE (Southern) region has the second highest abundance of ash trees of all DNOs, meaning that they will have a larger responsibility for ash dieback management than the majority of other regions. However, consideration for stakeholders, and budgetary implications, mean that removing all ash trees within the vicinity of SSE (Southern) OHL network as part of a mass felling exercise would not be feasible and would not gain the desired permanent network resilience due to the expected regeneration of new trees. It will therefore be necessary to plan an ongoing monitoring and cutting schedule which is flexible and responsive enough to manage the evolving threat to the network presented by the anticipated impact of ash dieback throughout the region.

The strongest wind gusts are currently seen throughout the winter months in the southern regions of the UK. When these strong gusts in the winter months are paired with the fact that trees are likely to be weakened by the other aspects of climate change, in addition to the increased likelihood of soil waterlogging which leads to poor anchorage, it can be anticipated that limb and tree failures are more likely to happen in what could be considered 'normal' storm events.

The general trend expected in the SSE (Southern) region over the next few decades is for weather to become hotter and drier. This will lead to an increase in trees suffering from drought stress.

Key Finding 3: Overall the burden of managing the potential risk to the OHL network from trees in the SSE (Southern) region can be expected to become more complex, time consuming and costly as climate change continues to cause the region to experience warmer and drier conditions. The relatively high number of trees across the region, particularly of those species which are already being affected by known pests and pathogens, represents a larger responsibility for the DNO in terms of monitoring and cutting of trees when compared with the other DNOs in the UK.

CONTENTS

Tables

Figures

1 BACKGROUND

In Britain, electric utility companies are under a legal duty to maintain their overhead power line (OHPL) networks free of interruptions where reasonably practicable. Trees are one of the principal causes of unplanned service interruptions on the OHPL networks and electric utilities are required to make their networks 'resilient' to tree and vegetation damage, including during 'abnormal weather conditions'. Targeted vegetation management programmes can help achieve this whilst keeping costs under control.

The importance of knowing the growth rates of the most common tree species on the OHPL networks has been demonstrated. It is also important to know how these growth rates might change in response to projected change in climate as set out in the UK Climate Impact Projections (UKCIP), in order to plan and implement proactive tree clearance programmes with sufficient reliability and budget.

In a research project carried out by ADAS between 2008 and 2011 (Humphries, 2012), over 1700 experimental sites were established across the country. At each site, trees under and adjacent to the OHLPs were cut and measurements taken over the following three years to determine the annual re-growth rates and the rate at which utility space was degraded by tree growth (utility space degradation or USD). USD differs from average growth rates in that it focuses on the key aspect which is the fastest growing vegetation relative to the infrastructure.

The baseline measurements were analysed to see if there was significant variation due to the land use, exposure, shading or regional location. The measurements were also interpolated using bioclimatic zones (used to divide the country into areas with a similar capacity to support growth), to give a continuous dataset of USD across the UK based on the meteorological conditions observed during the experimental period. This dataset was used in conjunction with climate forecast data from UKCIP (UKCP09) to project the likely impact of the high and low climate impact projections of UKCIP on the magnitude and spatial distribution of USD at 2020 and 2050. When comparisons were made using the climate change projections, the results suggested that there were likely to be substantial changes in growth and variation to 2020 and beyond.

ADAS produced a bespoke set of USD data and accompanying report for Scottish and Southern Energy (SSE) in 2013 by extrapolating the results from the research project described above to the Southern and Scottish Hydro licence areas based on baseline bioclimatic zones and those projected for future climates in the 2020s to the 2080s. The Southern region of SSE was estimated to have the highest USD at baseline than all the other electricity Distribution Network Operators (DNOs). Little change was expected in the Southern region for the future climate projections, suggesting that the USD rates in this region were already optimal for the species found here. However, even if growth rates in the Southern region are currently at their maximum possible levels, there is a real possibility that additional threats of pests and diseases will occur under climate change scenarios.

2 UPDATE OF FUTURE CLIMATE USD ESTIMATES

The UK Climate Projections 2018 project (UKCP18) provides a new set of probabilistic projections for climate change that supersede those produced under UKCP09. These new projections combine information from computer models with observations using advanced statistical methodologies. These estimates of the ranges of future climate are available for several alternative future scenarios of emissions.

2.1 Method

2.1.1 Data

Variable	Dataset
Baseline data	HadUK-Grid Gridded Climate Observations on a 25km grid over the UK HadUK-Grid Gridded Climate Observations on a 5km grid over the UK
Future climate data	UKCP18 Probabilistic Projections on a 25km grid over the UK for 1961-2100
Soil	European Soil Database v2.0

Baseline 1980 – 2010

Meteorological records covering the UK for the period 1981 to 2000 were obtained from the UK Met Office. The data have been interpolated from meteorological station data onto a uniform grid to provide complete and consistent coverage across the UK. These data provide the long-term annual averages for precipitation and temperature.

Projected climate data

These data represent the probabilistic climate projections component of future climate scenario projections data, produced as part of the UK Climate Projections 2018 (UKCP18) project. The climate projection data is provided at a 25 x 25 km grid for the UK and represents modelled anomalies with respect to the 1981-2010 baseline period. The temperature and precipitation anomaly data were obtained for each of the following different criteria:

- Representative Concentration Pathway (RCP): 4.5, 6.0, 8.5
- Years: 2020, 2030, 2040, 2050, 2080
- Probability: 10%, 50%, 90%

In order to improve the resolution of these data, the deviations of the averages for the 5 km climate observations from the 25km average were calculated. This was done by calculating the fraction of the observed climate value for each 5 km cell relative to the total value for the 25 km cell within which it fell (for both rainfall and temperature). This process is outlined in Figure 1.

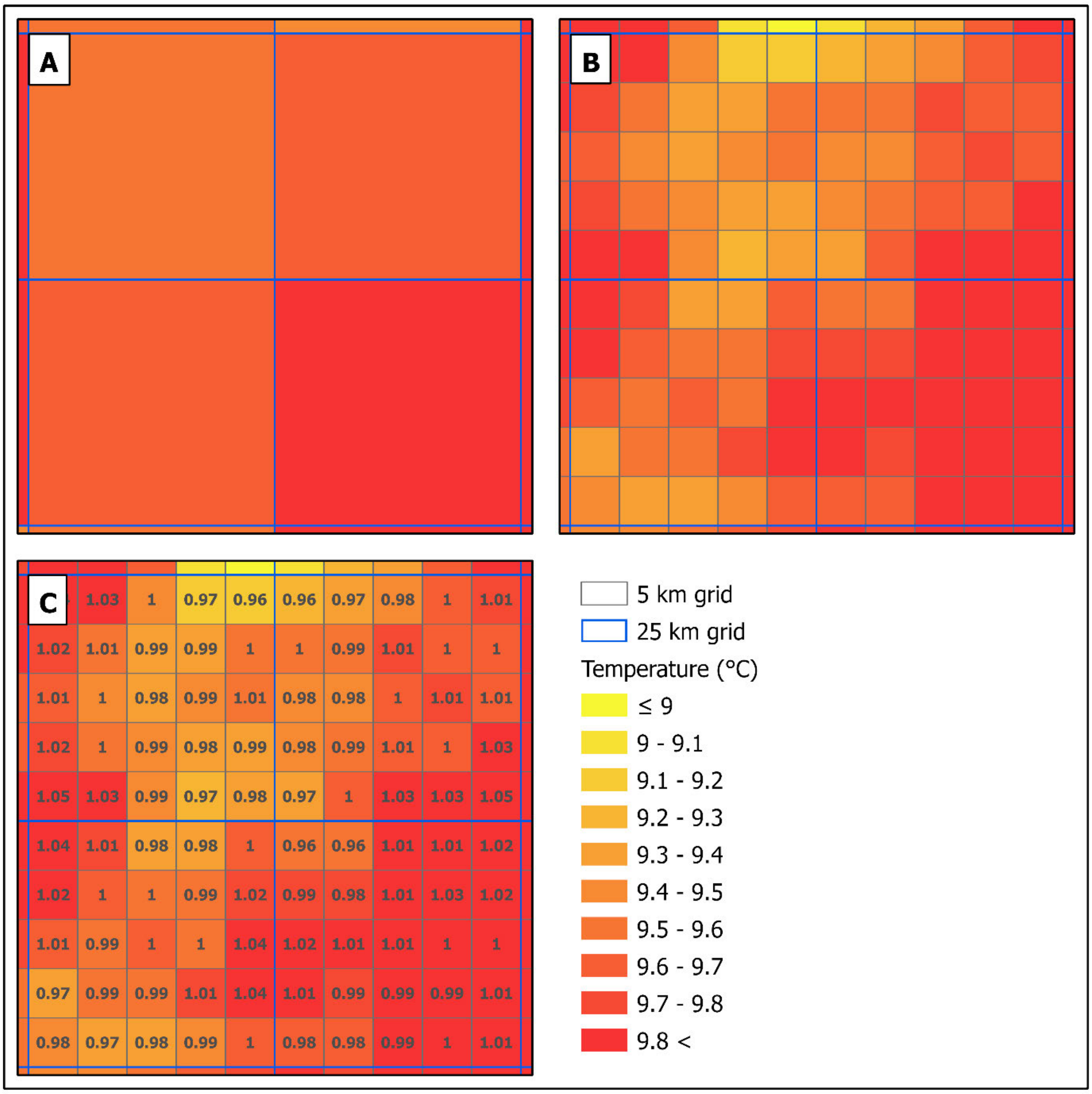


Figure 1 Example calculation of the fraction of the average climate observation at a 25 km grid cell scale for each 5 km cell within the 25 km grid. These fractions were used to improve the resolution of the 25 km projected climate data.

Figure 1 shows the mean temperature on a 25 km grid (A) compared to a 5 km grid (B). The fraction of the 25 km average was calculated for each 5 km cell (C). These fractions calculated for the baseline climate data were then applied to the 25 km projected climate data to provide a 5 km projected climate grid for each scenario.

2.1.2 Analysis

Bioclimatic Zones

The bioclimatic zone maps were calculated based on 3 key criteria – average air temperature, accumulated rainfall and soil texture. Spatial Analyst (ESRI, UK) was used to build maps from the meteorological data, using an inverse distance weighting interpolation method (using the default settings) to map the climate data at a resolution of 150 m resolution.

The temperature and rainfall maps were classified according to Table 1 and Table 2. Soil texture information was extracted from the European Soil Database (ESDB v2) available from the European Soil Data Centre. This was reclassified into 6 classes and converted into a raster map covering the UK at the same resolution as the climate data (Table 3).

A raster calculator was used to add the reclassified values for each of the 3 layers - temperature, rainfall and soil texture - to produce a final layer in which the coldest temperature with the least precipitation and coarsest soil had a value of 1101 and so on. These calculations were made for the climatic baseline and all 45 future climate scenarios, with each having its bespoke bioclimatic zones.

Table 1 Thermal region categories used in construction of bioclimatic zones

Description	Annual average temperature (°C)	Value
Moderately cold	0.0 to 4.5	1000
Slightly cold	4.5 to 7.5	2000
Moderately cool	7.5 to 8.75	3000
Slightly cool	8.75 to 10	4000
Moderately warm	10 to 13	5000
Slightly warm	13 to 15	6000
Moderately hot	15 to 17	7000
Slightly hot	>17	8000

Table 2 Rainfall region categories used in construction of bioclimatic zones

Description	Accumulated rainfall (Average mm $year^{-1}$)	Value
Slightly dry	0-800	100
Slightly moist	800-1200	200
Moderately moist	1200-1600	300
Slightly wet	1600-2200	400
Moderately wet	2200-5000	500

Table 3 Soil texture categories

Description	Value
Coarse	1
Medium	2
Medium fine	3
Fine	4
Very fine	5

Utility Space Degradation

In a previous study, Utility Space Degradation (USD) measurements were made across the UK, covering a range of bioclimatic zones (Humphries, 2012). Zonal average USD measurements based on bioclimatic zones were then mapped across the UK to provide expected rates of USD for each bioclimatic zone.

These previous data were used to map USD values to the baseline 1981-2010 data, and to the 45 future climate scenarios.

Results

The baseline bioclimatic zones map for the UK is shown in Figure 3 and the baseline USD map in Figure 4. Figures 4 – 8 show the predicted bioclimatic zones for future climate scenarios. Figures 9 – 13 show the predicted USD averages for these zones for future climate scenarios. These predicted USD averages were then used to estimate a mean USD for each DNO region. A map showing the DNO regions used in this study and their names is shown in Figure 2. This was created from the GB DNO License Areas Boundary shapefile from the National Grid website (National Grid, 2020).

Figure 2. Map showing the DNO regions used in this study and their names.

2.1.3 Baseline Bioclimatic Zones

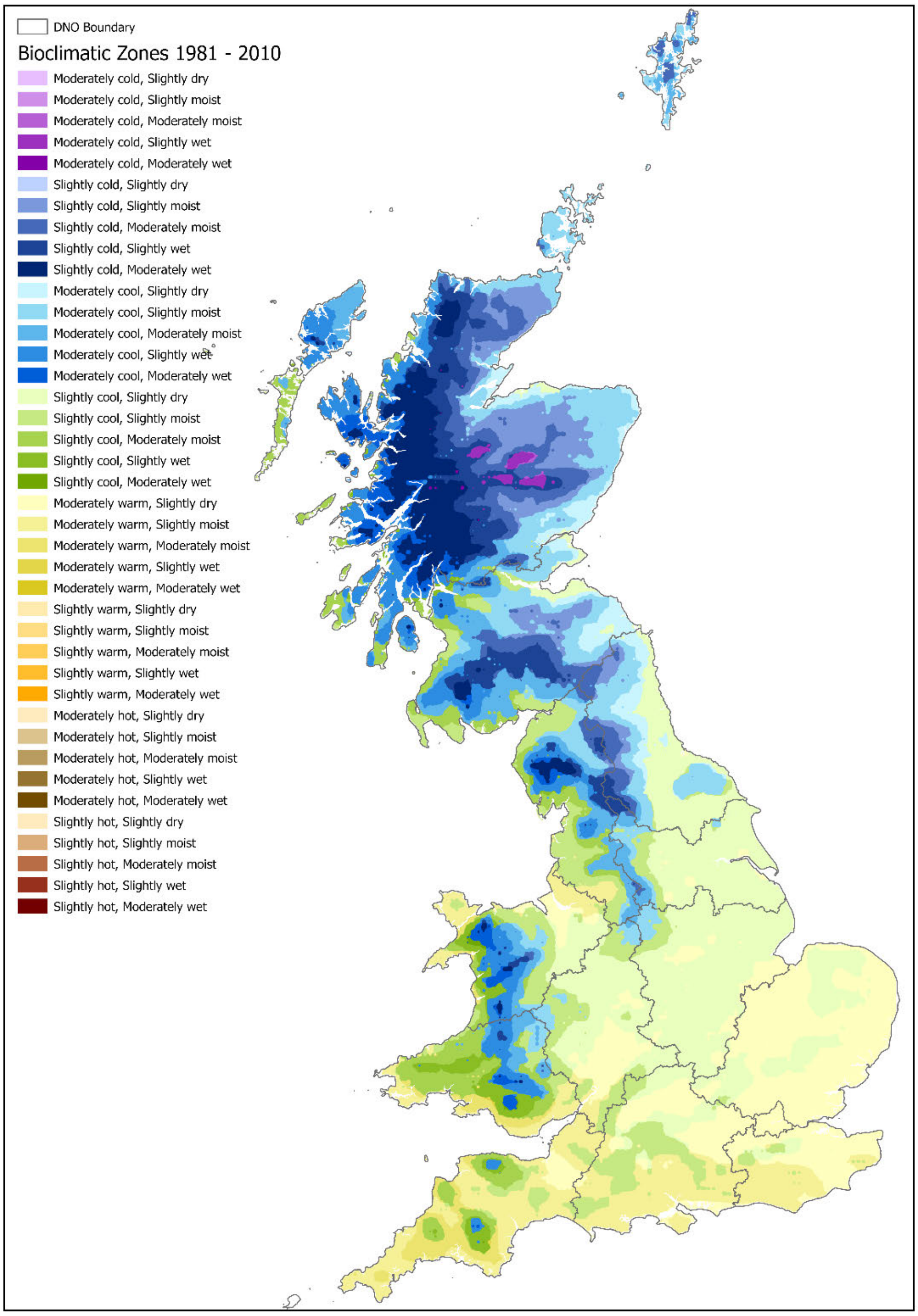


Figure 3. Distribution of bioclimatic zones in the UK based on baseline/current (1981- 2010) meteorological data

2.1.4 Baseline USD

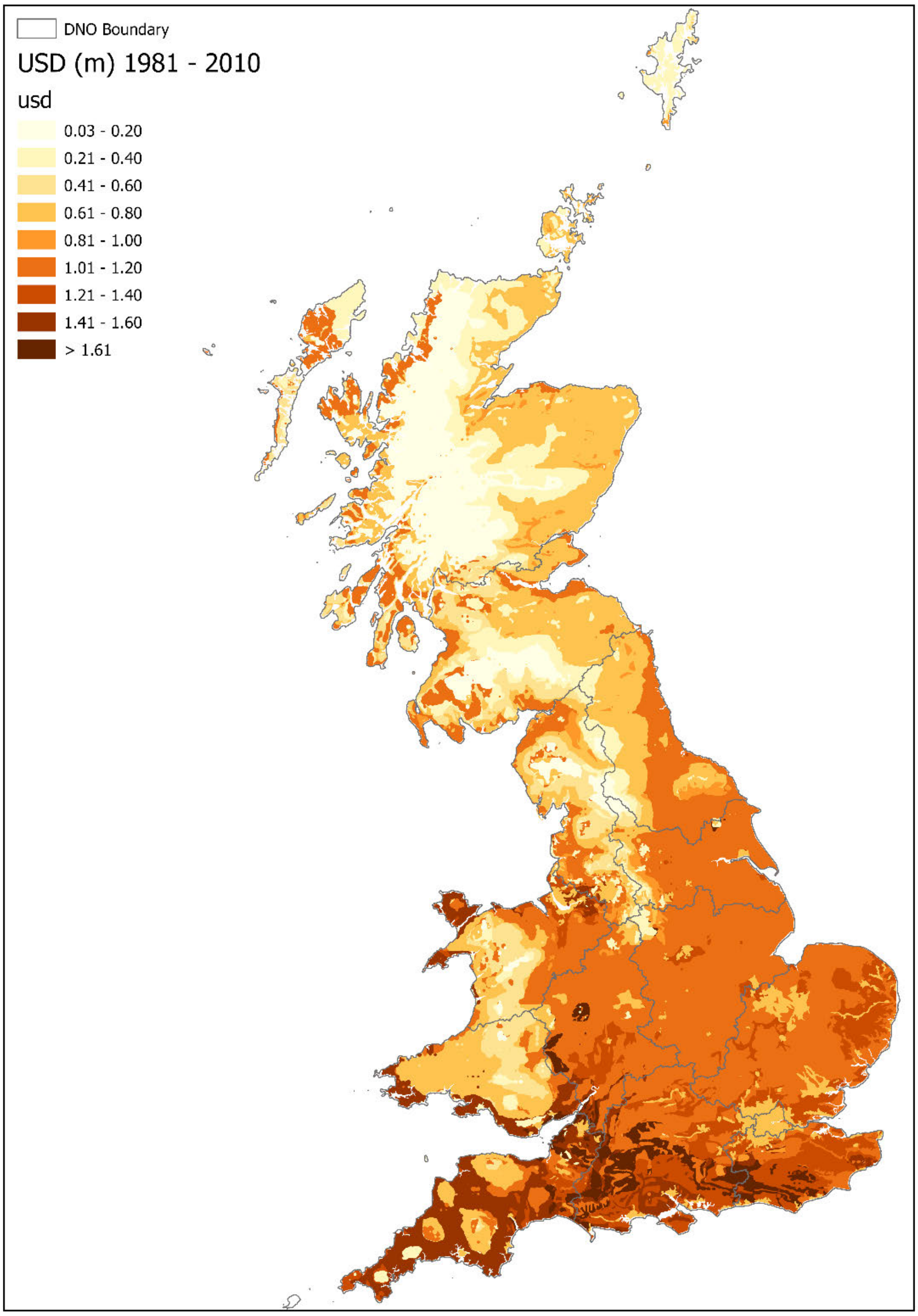


Figure 4. Distribution of vegetation growth in the form of USD (m) in the UK based on baseline/current (1981-2010) bioclimatic zones

2.1.5 Future Bioclimatic Zones

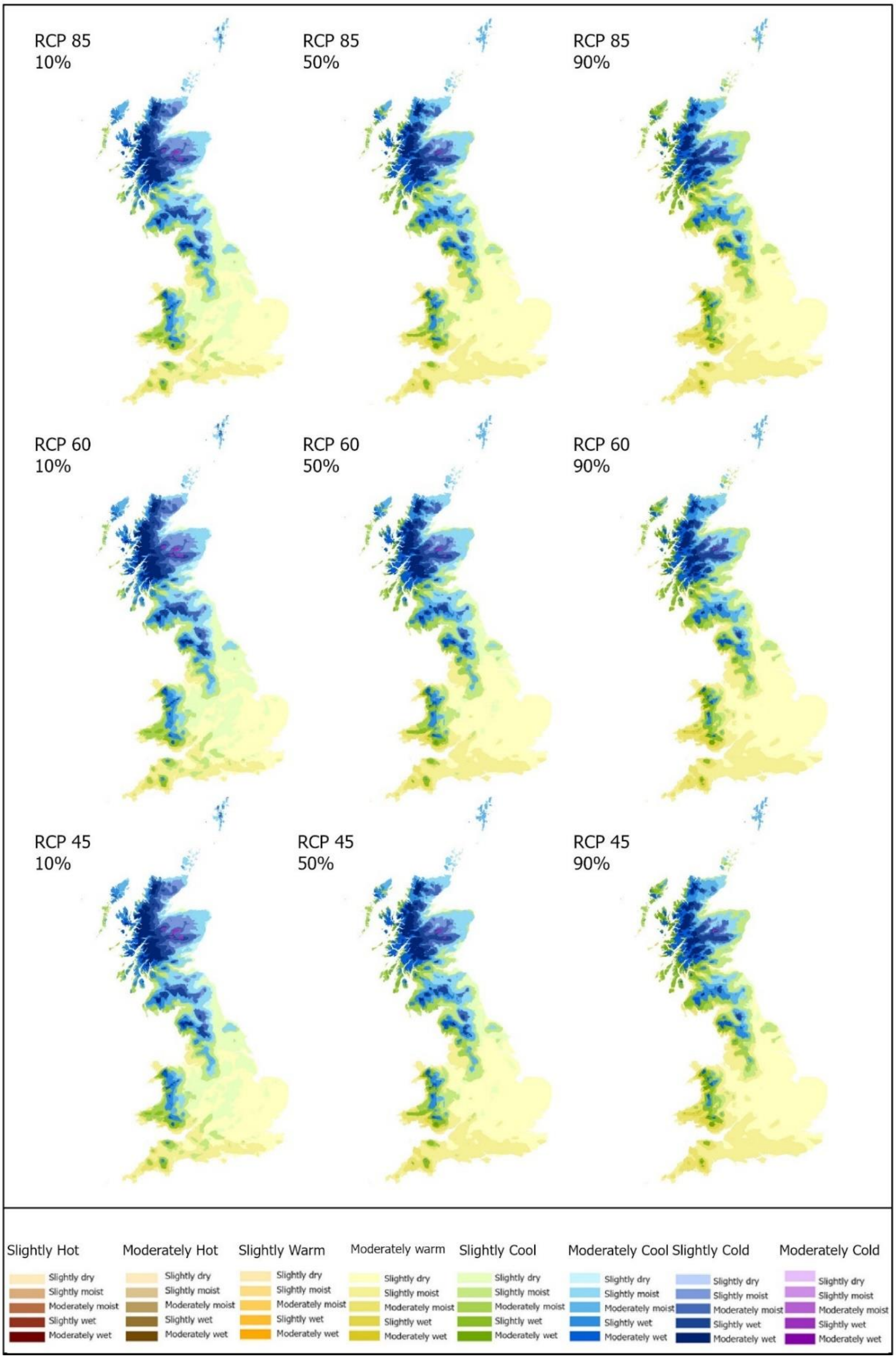


Figure 5. Predicted distribution of Bioclimatic zones in the 2020s

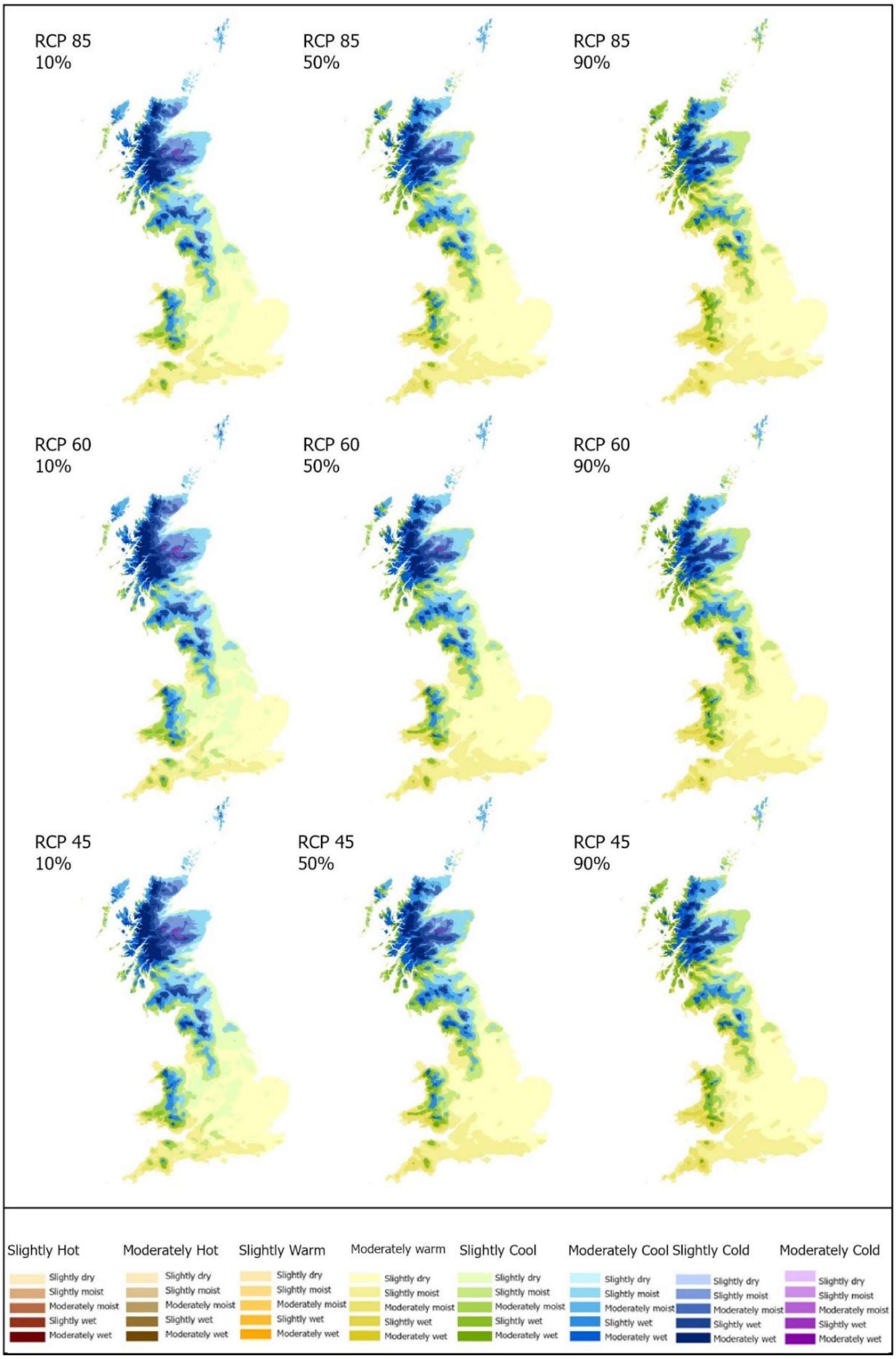


Figure 6. Predicted distribution of Bioclimatic zones in the 2030s

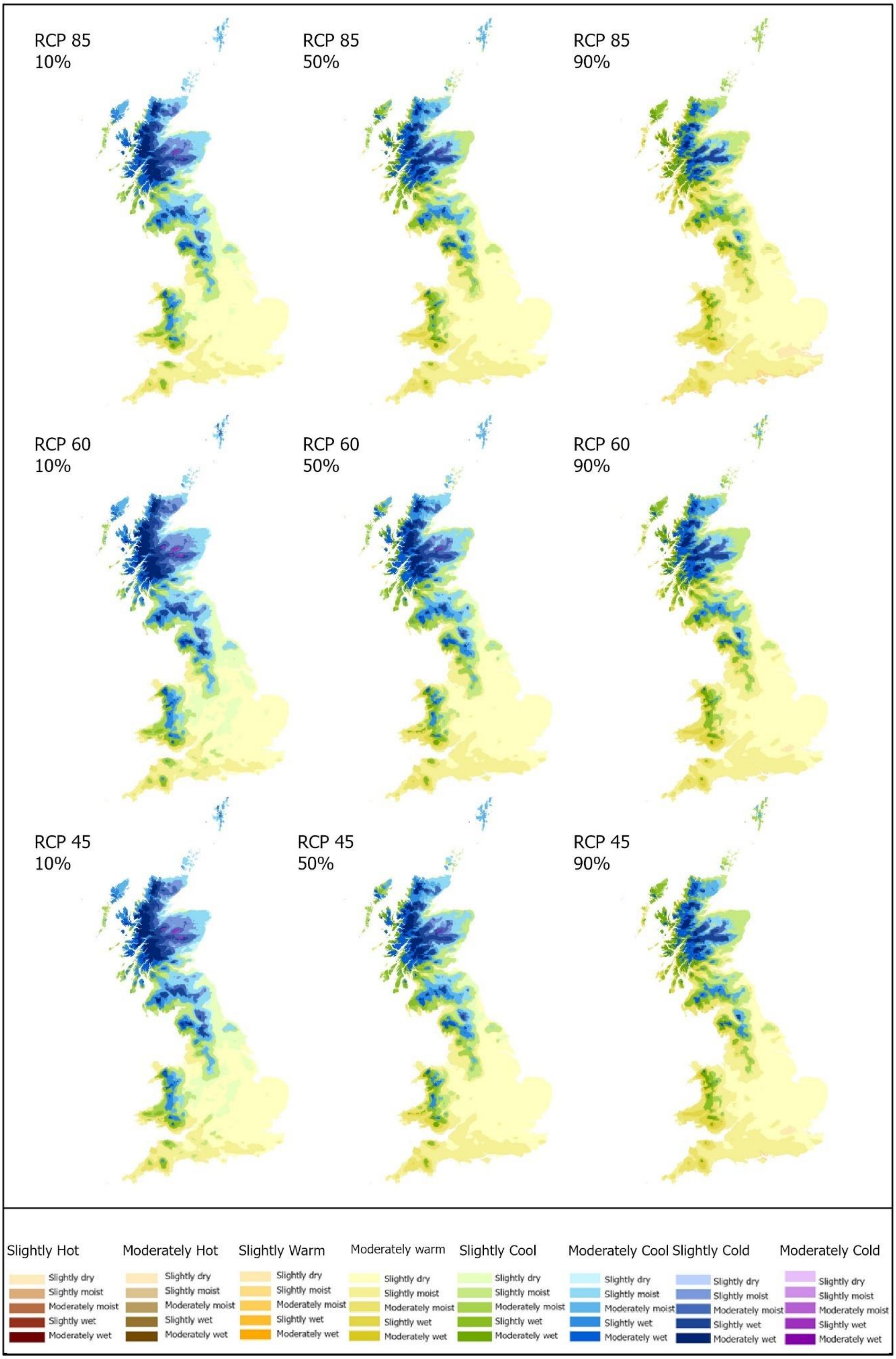


Figure 7. Predicted distribution of Bioclimatic zones in the 2040s

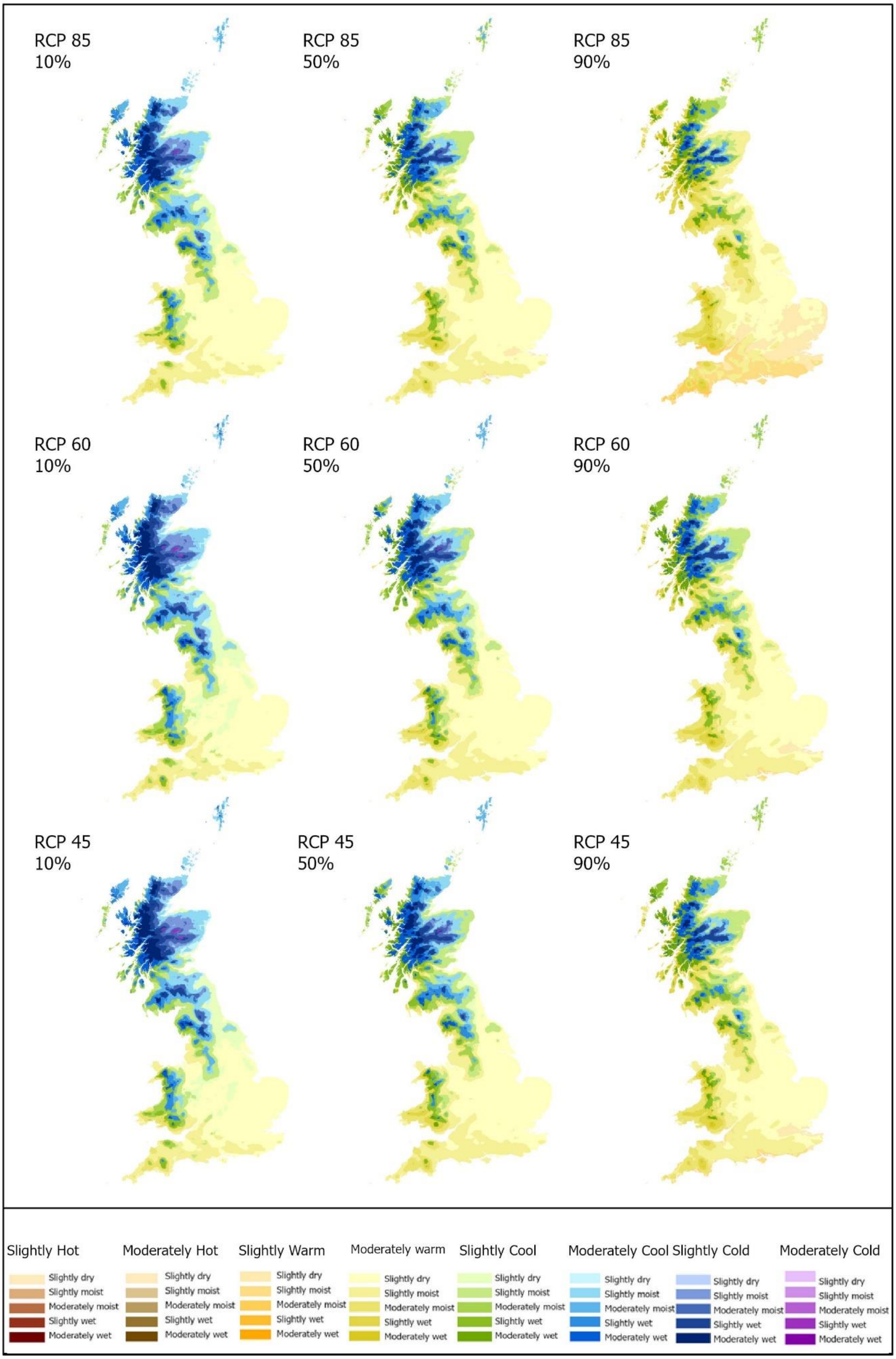


Figure 8. Predicted distribution of Bioclimatic zones in the 2050s

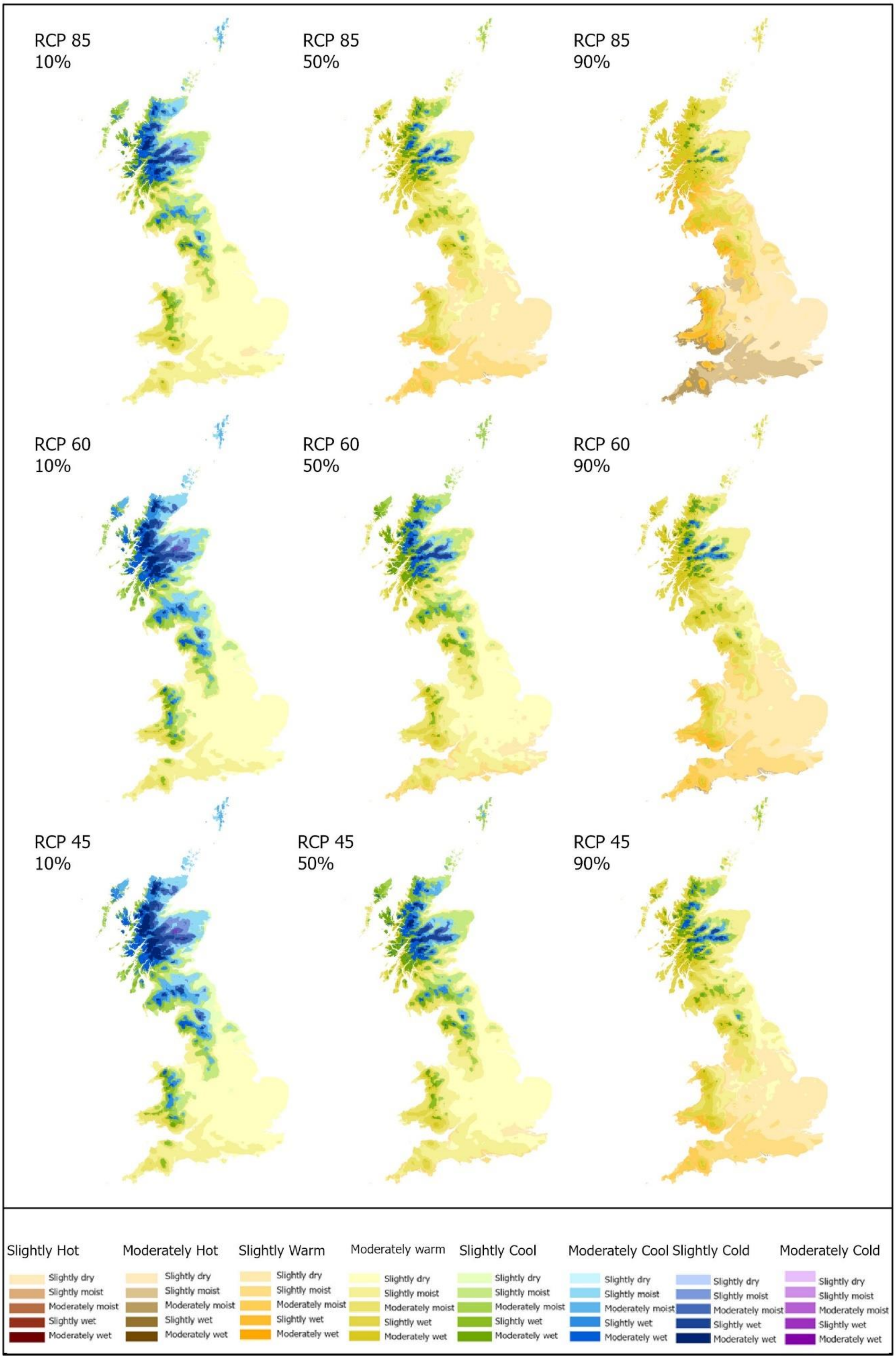


Figure 9. Predicted distribution of Bioclimatic zones in the 2080s

2.1.6 Future USD

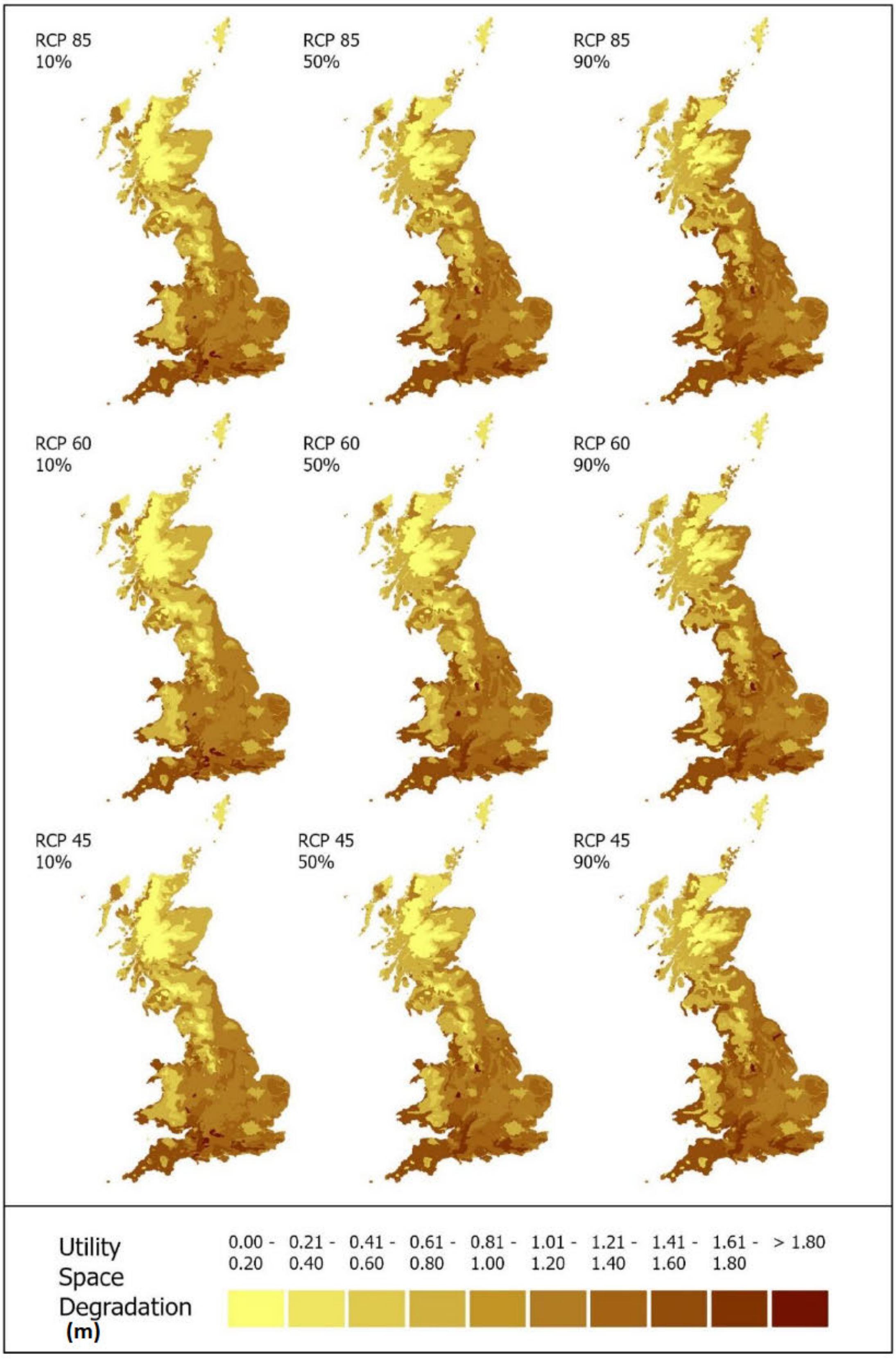


Figure 10. Predicted USD (metres) for the 2020s

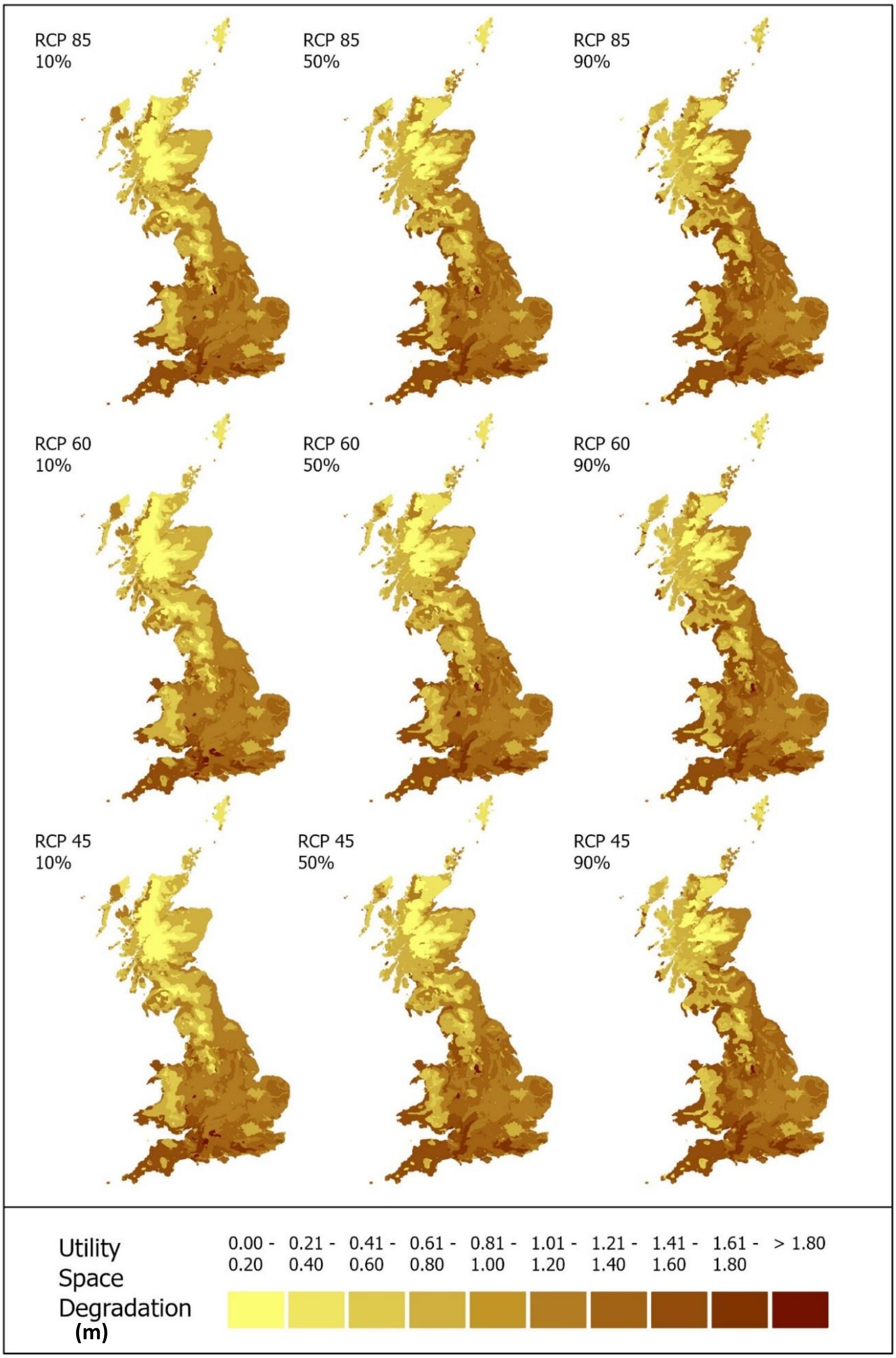


Figure 11. Predicted USD (metres) for the 2030s

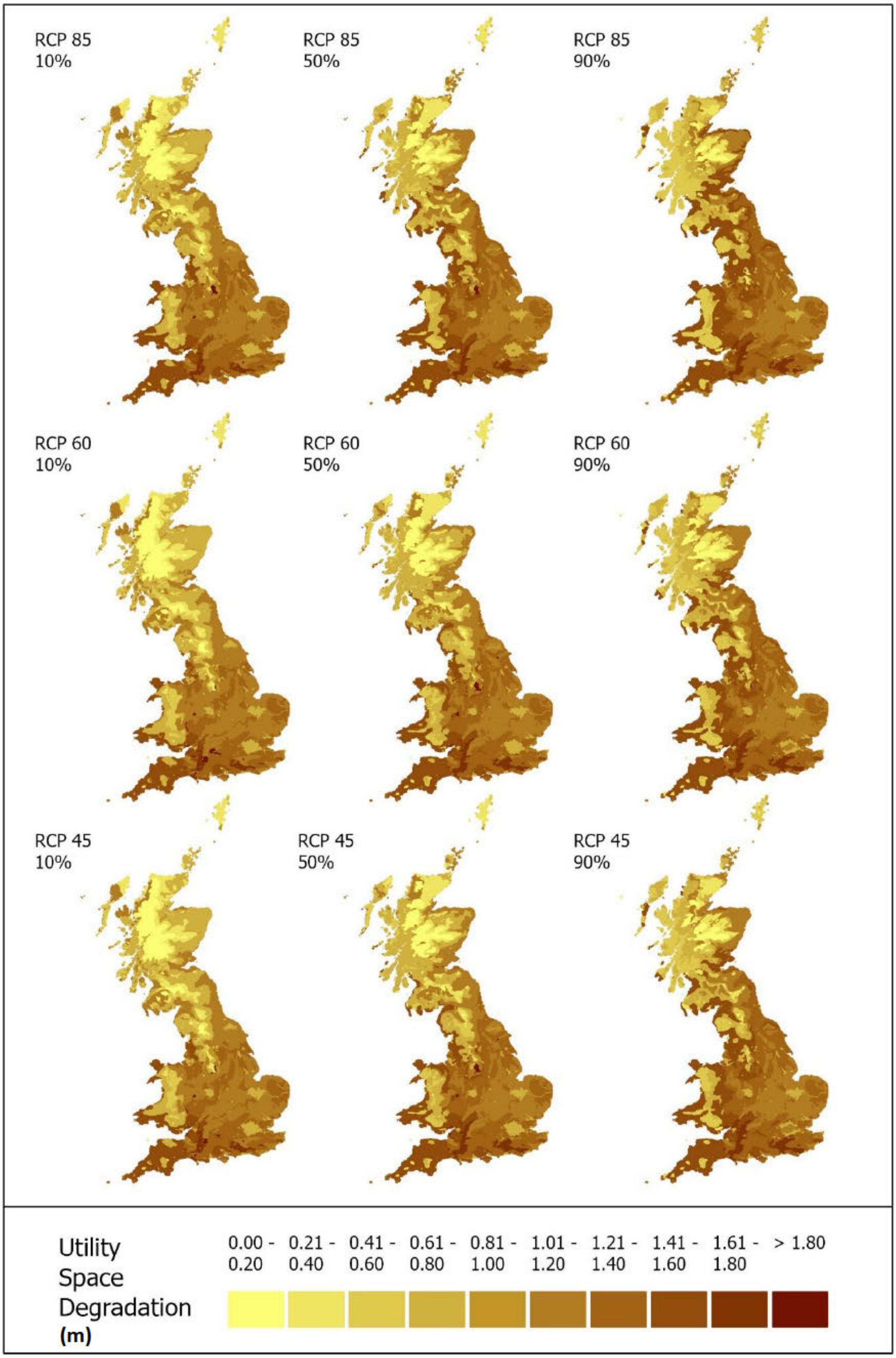


Figure 12. Predicted USD (metres) for the 2040s

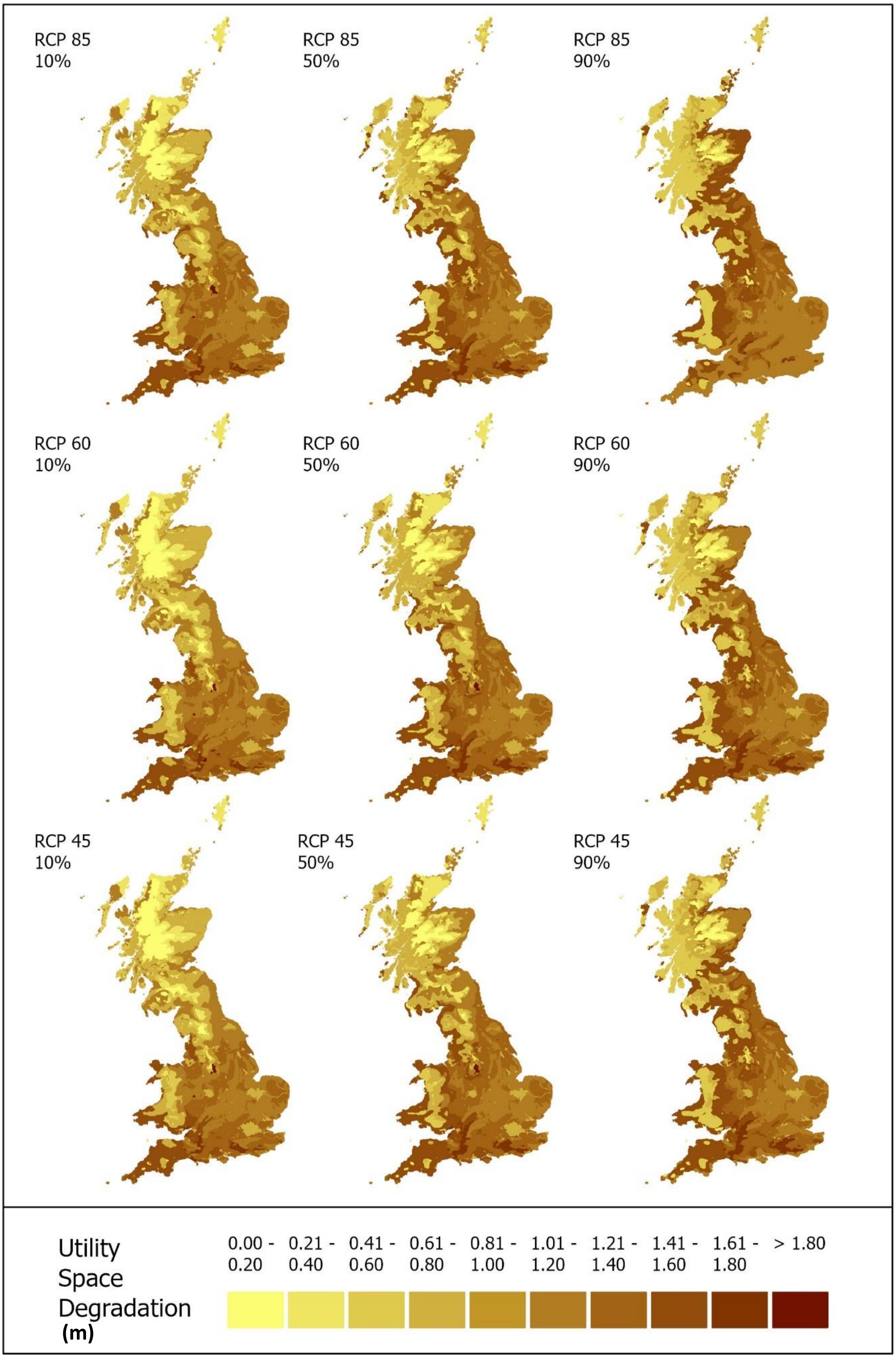


Figure 13. Predicted USD (metres) for the 2050s

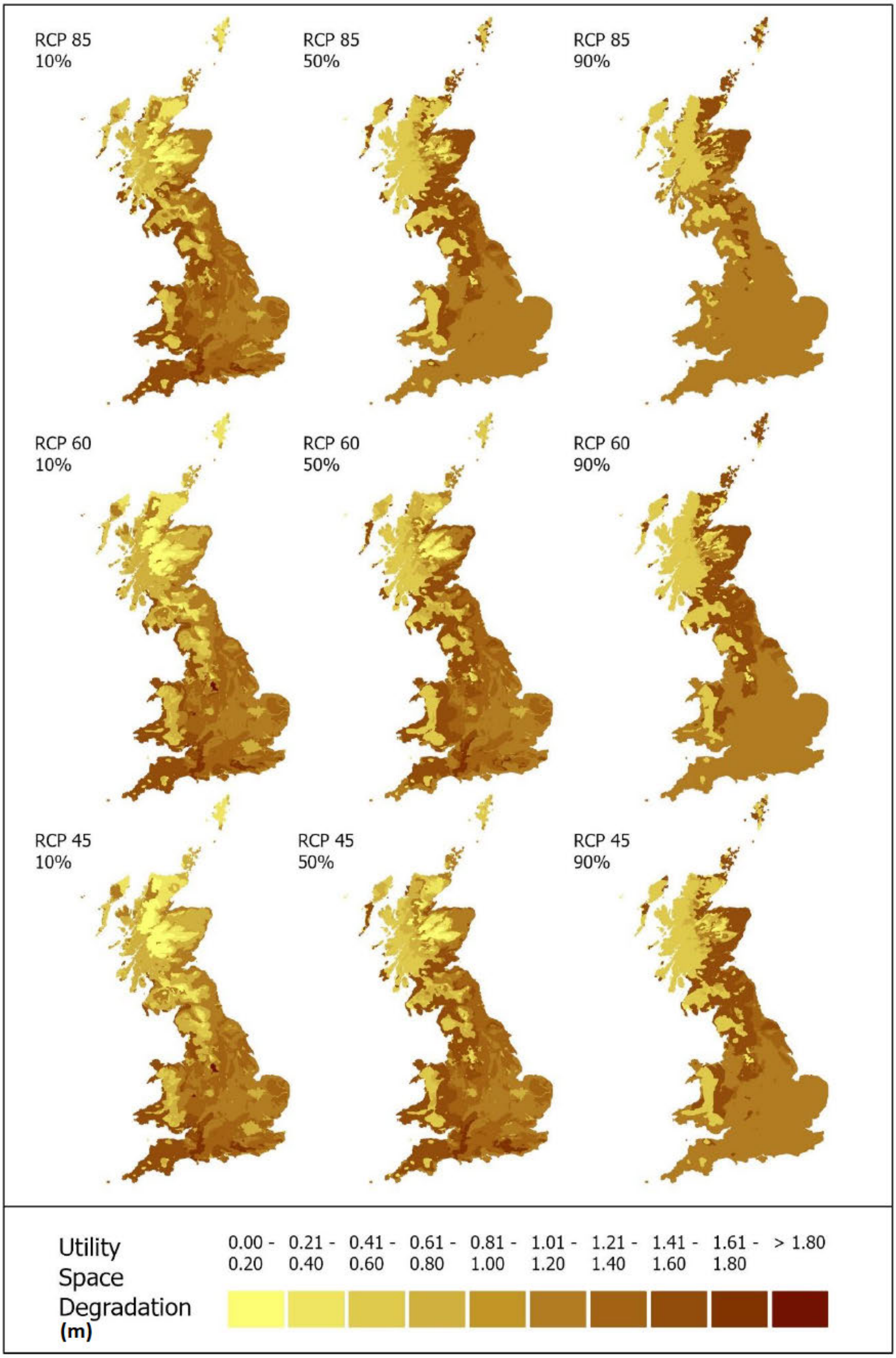


Figure 14. Predicted USD (metres) for the 2080s

2.2 Comparison of Electricity Distribution Network Operators

Table 4 to Table 17 show utility space degradation (m) for the climatic baseline (1981-2010) and RPC 45, RPC 60 and RPC 85 scenarios at 10, 50 and 90% probabilities for the decades 2020s to 2080s for each electricity Distribution Network Operators (DNO) region. . Mean USD rates per DNO region were calculated using zonal analysis of USD rates mapped according to bioclimatic zones. Note that the baseline values shown are based on measured meteorological data and the associated growth rates are assumed constant irrespective of scenario and probability as these don't apply.

Table 4. Mean USD growth rates for the SSE (Southern) region under baseline and climate forecast scenarios

SSE (Southern)	USD (m)								
	rcp45			**rcp60**			**rcp85**		
Year	10%	50%	90%	10%	50%	90%	10%	50%	90%
Baseline (1981-2010)	1.33	1.33	1.33	1.33	1.33	1.33	1.33	1.33	1.33
2020	1.30	1.33	1.35	1.30	1.33	1.35	1.31	1.33	1.35
2030	1.31	1.33	1.35	1.30	1.33	1.35	1.31	1.33	1.35
2040	1.29	1.33	1.35	1.29	1.33	1.35	1.30	1.33	1.34
2050	1.29	1.33	1.34	1.29	1.33	1.34	1.29	1.33	1.20
2080	1.30	1.32	1.11	1.30	1.29	1.10	1.30	1.11	1.10

Table 5. Mean USD growth rates for the [redacted] region under baseline and climate forecast scenarios

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Table 6. Mean USD growth rates for the [redacted]) region under baseline and climate forecast scenarios

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Table 7. Mean USD growth rates for the [redacted] region under baseline and climate forecast scenarios

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Table 8. Mean USD growth rates for the [redacted] region under baseline and climate forecast scenarios

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Table 9. Mean USD growth rates for the [redacted] region under baseline and climate forecast scenarios

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Table 10. Mean USD growth rates for the [redacted] region under baseline and climate forecast scenarios

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Table 11. Mean USD growth rates for the [redacted] region under baseline and climate forecast scenarios

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Table 12. Mean USD growth rates for the SSEH region under baseline and climate forecast scenarios

SSEH	USD (m)								
	rcp45			**rcp60**			**rcp85**		
Year	10%	50%	90%	10%	50%	90%	10%	50%	90%
Baseline (1981-2010)	0.47	0.47	0.47	0.47	0.47	0.47	0.47	0.47	0.47
2020	0.49	0.50	0.55	0.49	0.50	0.55	0.49	0.51	0.57
2030	0.49	0.52	0.59	0.49	0.51	0.58	0.50	0.54	0.61
2040	0.50	0.54	0.62	0.50	0.54	0.61	0.52	0.58	0.66
2050	0.51	0.57	0.65	0.50	0.56	0.64	0.53	0.63	0.72
2080	0.54	0.67	0.77	0.56	0.70	0.81	0.65	0.78	0.87

Table 13. Mean USD growth rates for the [redacted]) region under baseline and climate forecast scenarios

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Table 14. Mean USD growth rates for the [redacted] region under baseline and climate forecast scenarios

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[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]

Table 15. Mean USD growth rates for the [redacted] region under baseline and climate forecast scenarios

[redacted]									
[redacted]	[redacted]								
	[redacted]			[redacted]			[redacted]		
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]

Table 16. Mean USD growth rates for the [redacted] region under baseline and climate forecast scenarios

[redacted]	[redacted]								
	[redacted]			[redacted]			[redacted]		
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]

Table 17. Mean USD growth rates for the [redacted] region under baseline and climate forecast scenarios

[redacted]	[redacted]								
	[redacted]			[redacted]			[redacted]		
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]

Table 18 to Table 31 show the percentage change in USD (m) rate for the utility regions for the low, medium and high climate change scenarios with 10, 50 and 90% probabilities relative to the baseline (1981-2010). These figures were calculated using zonal analysis of USD rates mapped according to bioclimatic zones.

Table 18. Mean percentage change in USD growth rates from baseline for climate change scenarios for the SSE (Southern) region

SSE (Southern)	% Change in USD								
	rcp45			**rcp60**			**rcp85**		
Year	10%	50%	90%	10%	50%	90%	10%	50%	90%
Baseline (1981-2010)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2020	-1.94	0.32	1.88	-2.22	0.27	1.89	-1.62	0.43	1.88
2030	-1.68	0.50	1.83	-1.87	0.46	1.82	-1.49	0.51	1.86
2040	-2.53	0.30	1.77	-2.55	0.27	1.80	-2.42	0.26	0.66
2050	-3.14	0.17	0.95	-3.02	0.12	1.26	-2.97	0.02	-9.26
2080	-1.97	-0.59	-16.51	-1.99	-2.66	-17.13	-2.32	-16.75	-17.14

Table 19. Mean percentage change in USD growth rates from baseline for climate change scenarios for the [redacted] region

[redacted]	[redacted]								
	[redacted]			[redacted]			[redacted]		
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]

Table 20. Mean percentage change in USD growth rates from baseline for climate change scenarios for the [redacted]

[redacted]	[redacted]								
	[redacted]			[redacted]			[redacted]		
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]

Table 21. Mean percentage change in USD growth rates from baseline for climate change scenarios for the [redacted]n) region

[redacted]	[redacted]								
	[redacted]			[redacted]			[redacted]		
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]

Table 22. Mean percentage change in USD growth rates from baseline for climate change scenarios for the [redacted] region

[redacted]									
[redacted]	[redacted]								
	[redacted]			[redacted]			[redacted]		
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]

Table 23. Mean percentage change in USD growth rates from baseline for climate change scenarios for the [redacted] region

[redacted]	[redacted]								
	[redacted]			[redacted]			[redacted]		
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]

Table 24. Mean percentage change in USD growth rates from baseline for climate change scenarios for the [redacted] region

[redacted]									
[redacted]	[redacted]								
	[redacted]			[redacted]			[redacted]		
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]

Table 25. Mean percentage change in USD growth rates from baseline for climate change scenarios for the [redacted] region

[redacted]

Table 26. Mean percentage change in USD growth rates from baseline for climate change scenarios for the SSEH region

SSEH	% Change in USD								
	rcp45			**rcp60**			**rcp85**		
Year	10%	50%	90%	10%	50%	90%	10%	50%	90%
Baseline (1981-2010)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2020	4.10	6.39	17.34	3.67	6.17	16.52	4.94	8.77	20.51
2030	4.84	9.76	24.05	4.28	8.68	22.01	6.84	15.11	29.24
2040	6.51	15.16	31.51	5.73	13.44	28.82	9.78	23.86	40.89
2050	7.50	20.40	37.99	6.98	18.49	35.78	13.13	33.10	51.78
2080	14.22	41.06	63.15	19.30	47.96	71.90	38.12	65.96	84.89

Table 27. Mean percentage change in USD growth rates from baseline for climate change scenarios for the [redacted] region

[redacted]

Table 28. Mean percentage change in USD growth rates from baseline for climate change scenarios for the [redacted] region

[redacted]	[redacted]								
	[redacted]			[redacted]			[redacted]		
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]

Table 29. Mean percentage change in USD growth rates from baseline for climate change scenarios for the [redacted] region

[redacted]	[redacted]								
	[redacted]			[redacted]			[redacted]		
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]

Table 30. Mean percentage change in USD growth rates from baseline for climate change scenarios for the [redacted] region

[redacted]	[redacted]								
	[redacted]			[redacted]			[redacted]		
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]

Table 31. Mean percentage change in USD growth rates from baseline for climate change scenarios for the [redacted] region

[redacted]									
[redacted]	[redacted]								
	[redacted]			[redacted]			[redacted]		
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]

Figure 15 to Figure 28 show a comparison of the bioclimatic zones for the baseline meteorological dataset (1981-2010) and 2020 RCP60 scenario 50% probability meteorological forecast. They also show a comparison of USD (m) for the current baseline growth and the forecast for 2020 assuming a RCP60 climate change scenario and the ‘as likely as not’ 50% probability level. This is shown for each DNO region.

[redacted]

Figure 15. Comparison of bioclimatic zones and USD for the baseline meteorological dataset (1981-2010) and 2020 RCP60 scenario 50% probability meteorological forecast for the [redacted] region.

[redacted]

Figure 16. Comparison of bioclimatic zones and USD for the baseline meteorological dataset (1981-2010) and 2020 RCP60 scenario 50% probability meteorological forecast for the [redacted] region.

[redacted]

Figure 17. Comparison of bioclimatic zones and USD for the baseline meteorological dataset (1981-2010) and 2020 RCP60 scenario 50% probability meteorological forecast for the [redacted] region.

[redacted]

Figure 18. Comparison of bioclimatic zones and USD for the baseline meteorological dataset (1981-2010) and 2020 RCP60 scenario 50% probability meteorological forecast for the [redacted] region.

[redacted]

Figure 19. Comparison of bioclimatic zones and USD for the baseline meteorological dataset (1981-2010) and 2020 RCP60 scenario 50% probability meteorological forecast for the [redacted] region.

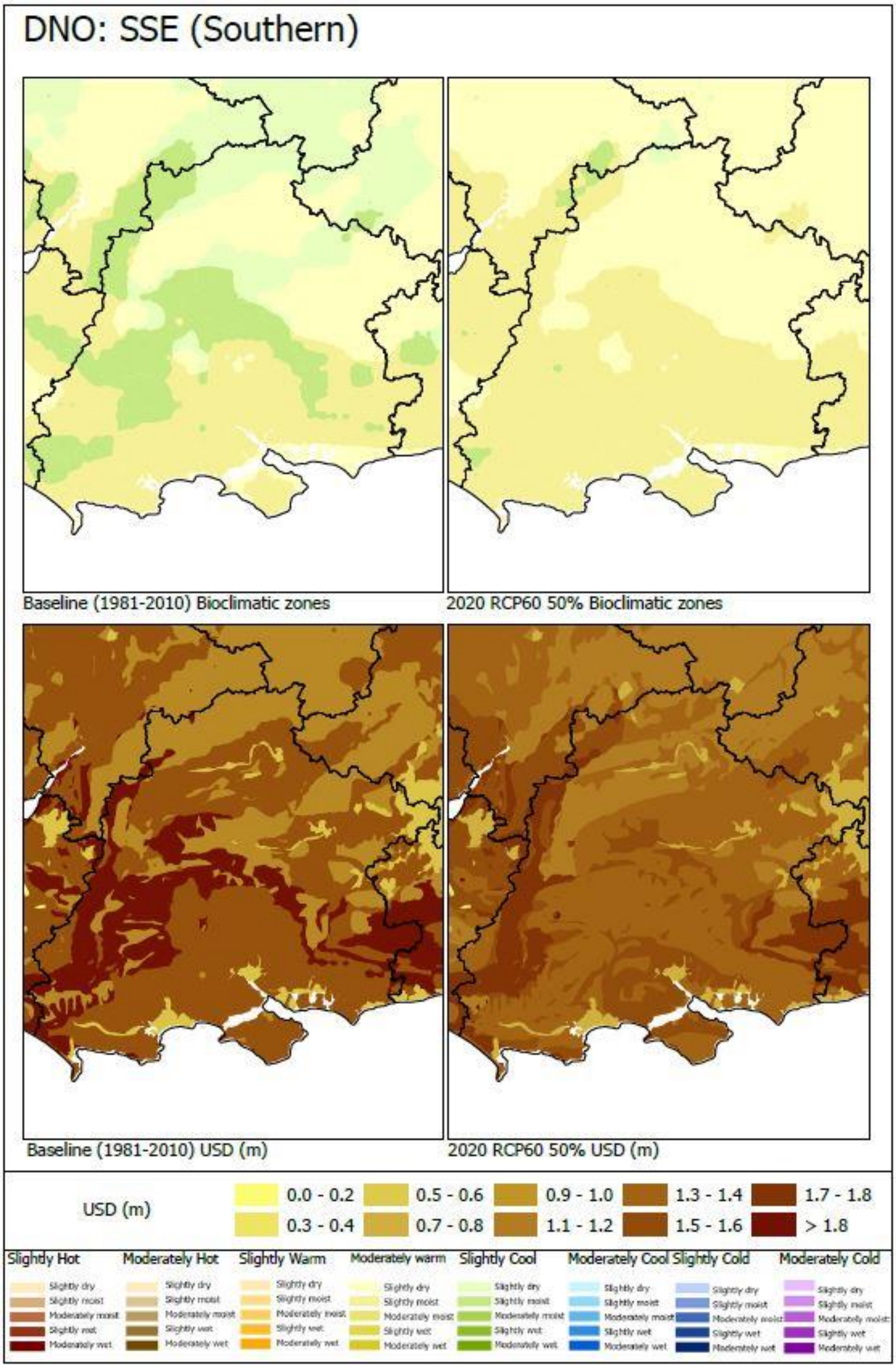

Figure 20. **Comparison of bioclimatic zones and USD for the baseline meteorological dataset (1981-2010) and 2020 RCP60 scenario 50% probability meteorological forecast for the SSE (Southern) region.**

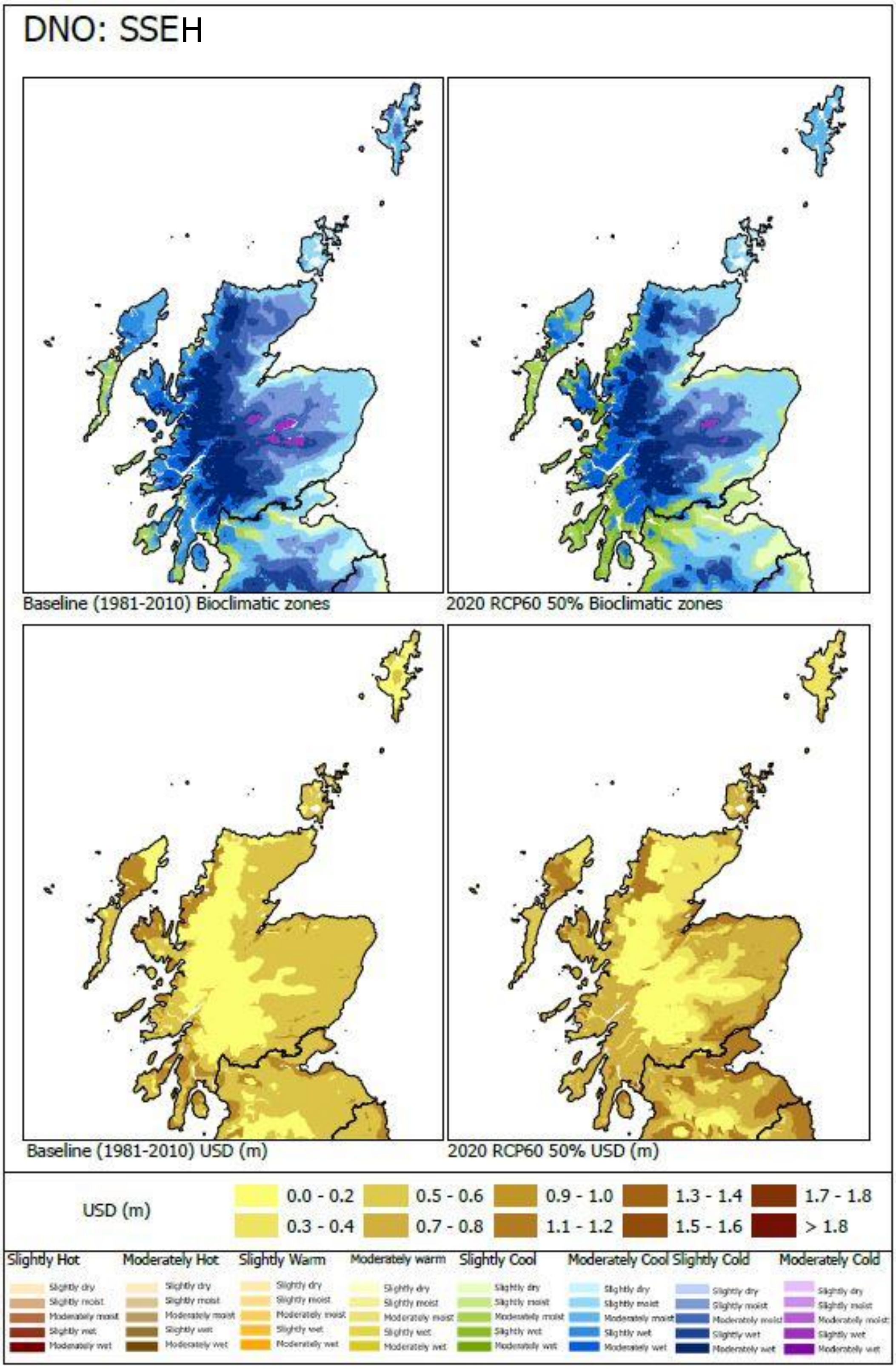

Figure 21. **Comparison of bioclimatic zones and USD for the baseline meteorological dataset (1981-2010) and 2020 RCP60 scenario 50% probability meteorological forecast for the SSEH region.**

[redacted]

Figure 22. **Comparison of bioclimatic zones and USD for the baseline meteorological dataset (1981-2010) and 2020 RCP60 scenario 50% probability meteorological forecast for the [redacted] region.**

[redacted]

Figure 23. Comparison of bioclimatic zones and USD for the baseline meteorological dataset (1981-2010) and 2020 RCP60 scenario 50% probability meteorological forecast for the [redacted] region.

[redacted]

Figure 24. Comparison of bioclimatic zones and USD for the baseline meteorological dataset (1981-2010) and 2020 RCP60 scenario 50% probability meteorological forecast for the [redacted] region.

[redacted]

Figure 25. Comparison of bioclimatic zones and USD for the baseline meteorological dataset (1981-2010) and 2020 RCP60 scenario 50% probability meteorological forecast for the [redacted] region.

[redacted]

Figure 26. Comparison of bioclimatic zones and USD for the baseline meteorological dataset (1981-2010) and 2020 RCP60 scenario 50% probability meteorological forecast for the [redacted] region.

[redacted]

Figure 27. **Comparison of bioclimatic zones and USD for the baseline meteorological dataset (1981-2010) and 2020 RCP60 scenario 50% probability meteorological forecast for the** [redacted] **region.**

[redacted]

Figure 28. Comparison of bioclimatic zones and USD for the baseline meteorological dataset (1981-2010) and 2020 RCP60 scenario 50% probability meteorological forecast for the [redacted] region.

2.3 Discussion

The baseline or current bioclimatic zone map shown in Figure 3 was produced by processing meteorological records for the period 1981-2010. Considerable variation in meteorological conditions was seen across the UK along temperature and rainfall gradients and localised soil texture patterns. Bioclimatic zones ranged from; moderately cold & moderately moist, to moderately warm & slightly wet. USD rates were averaged according to bioclimatic zone and mapped to produce the map of current USD rate shown in Figure 4. This map echoes the spatial variation seen in measured USD and the variation in bioclimatic zones.

Rates of growth measured by USD varied greatly across the country and therefore across DNO regions. At baseline (1981-2010) the region with the greatest average USD was SSE (Southern) with an average growth rate of 1.33 m. The DNO region with the lowest average USD at baseline was the SSEH region with an average USD of 0.47 m. Across all other DNO regions the highest average USD at baseline was seen also in the Southern part of England [redacted] with an average of [redacted] The lowest average USD at baseline across all other DNO regions was [redacted] in Scotland, [redacted] with an average of [redacted] The mean USD across all DNO regions at baseline was 0.93 m.

The greatest absolute change in USD predicted across all climate change scenarios and DNO regions was in [redacted] region, with average USD across this region rising from the baseline value of [redacted] to [redacted] in 2080 assuming a RCP85 scenario with 50% likelihood. The smallest USD change is predicted in the South of England, [redacted] SSE (Southern), where USD is predicted to increase very little over the next decade and may even be limiting in the 2080s and decreasing. It should be noted, however, that there may be significant errors associated with projected USD under the more extreme climate change scenarios in 2050 and 2080. USD rates for these projections are based on estimated changes in bioclimatic zones which in themselves have potential uncertainties. Alongside this there were a decreasing number of measured zones being used to represent the country.

As the composition of bioclimatic zones moves to hotter temperatures the area of the UK under current conditions in which measurements could be made becomes smaller and therefore the estimates of USD under these conditions less reliable. It is therefore uncertain whether growth rates will continue to increase in already currently warm areas if further warming occurs in the future. The approach taken here is best suited to studying the less extreme climate change scenarios occurring in the near future (10-30 years) rather than more extreme (high scenario and probability) situations in 2050 or 2080 as a result of the inability to track growth patterns in much warmer conditions which are more likely to come about in the 2050s and 2080s.

For the 2020s, under a RCP60 climate change scenario, with 50% likelihood the SSE region sees an increase in USD of 6.17% (0.03 m). SSE (Southern) region sees almost no change in average USD under this scenario, rising 0.27%. The largest changes across all DNO regions under this scenario were seen in [redacted] with average USD increasing [redacted] over the next decade. The largest percentage change was seen in [redacted] region which saw average USD increase [redacted]

Change in average USD for the 2020s assuming an RCP60 50% climate change scenario is compared for all DNO regions in Table 32.

Table 32. Table comparing change in average USD for next decade (2020s) compared to the baseline (1981-2010) for all DNO regions assuming an RCP60 50% climate change scenario. Table is in order of % change.

DNO region	USD (m) (baseline 1981-2010)	USD (m) (rcp60 50%)	change in USD (m)	% change in USD
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
SSEH	0.47	0.50	0.03	6.17
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
SSE (Southern)	1.33	1.33	0.00	0.27
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]

Overall, the SSEH region sees the lowest average USD at baseline compared to all other DNO regions, and this is likely to still be the case into the next decade. The SSE (Southern) region however sees the highest average USD at baseline. This will likely also continue to be the case into the next decade, however it is likely that other DNO regions will see their average USD increase to similar levels to that seen in SSE (Southern) in following decades.

3 COMPARISON OF WOODLAND COVERAGE AND SPECIES COMPOSITION

National datasets exist that enable us to compare tree or woodland coverage and species compositions within the different DNO regions. These additional data were queried to determine spatial variation in some of those metrics that affect risk to overhead powerlines.

3.1 Method

3.1.1 Data

National Forest Inventory (NFI) Data were downloaded from the Forestry Commission data portal (National Forest Inventory Woodland GB, 2018) covering the whole of Great Britain. The most recent version, from 2018, was chosen. This analysis also used the GB DNO License Areas Boundary shapefile from the National Grid website (National Grid, 2020).

Data on the estimated abundance of different tree species across Great Britain was also obtained from Hill et al. (2017).

3.1.2 Analysis

Woodland areas were selected out from the NFI data and intersected with the DNO boundaries. The total area of woodland and area of different types of woodland were calculated for each DNO area. The different types of woodland include: broadleaved, conifer, mixed (mainly broadleaved), mixed (mainly conifer), and 'other'. The 'other' group includes all other type of woodland listed In the NFI and includes: Coppice, Failed & Felled woodland, low density woodland, shrub, windblown trees, and young trees. The area of each of these groups was then used to calculate the percentage of each DNO area that is covered by the different types of woodland.

Maps were created showing the percentage of each DNO that is covered by woodland, and the percentage of the woodland area that is broadleaved, conifer, mixed (mainly broadleaved), mixed (mainly conifer). These are shown in section 3.2. accompanied by tables comparing the values for each DNO.

It has also been possible to illustrate the potential impacts of ash dieback, by using the tree species estimated abundance maps from Hill et al. (2017) to produce a map of European Ash abundance (*Fraxinus excelsior*) and a table showing mean estimated abundance of each tree species for which data was obtained for each DNO region.

3.2 Results

A map showing the percentage of the total area of each DNO region that is covered by woodland is shown in Figure 29. Maps showing the percentage of woodland area that are broadleaved, conifer or mixed is shown in Figure 30.

Tables showing the area of each DNO region covered by different types of woodland and the percentage of the total area of woodland of each different type are shown in Table 33 & Table 34. The fraction of the total woodland area made up by each type of woodland is mapped for each DNO area in Figure 31.

The DNO region with the greatest woodland percentage coverage is [redacted] with [redacted] of its area covered by woodland. The SSEH & SSE (Southern) regions have 15.4%

and 14.3% woodland coverage respectively. In the SSE (Southern) region 67% of the woodland area is made up of broadleaved woodland, with 15.8% being conifer. This is compared to 14.1% broadleaved woodland and 47% conifer in the SSEH region.

In terms of total area of woodland, the region with the greatest area of woodland is the SSEH region with 988,588 ha. This is almost double the region with second most woodland area – [redacted] with 459,850 ha. The SSE (Southern) region has the third highest area of woodland with 246,394 ha. The SSE (Southern) region also has the highest area of broadleaved woodland at 165,692 ha.

A map showing the estimated abundance of European Ash (Fraxinus excelsior) is shown in Figure 32. This map demonstrates a greater abundance of Ash in the South and South east of England. Table 36 shows mean estimated abundance of each tree species for which data were obtained for each DNO region. The area with the highest mean ash abundance is [redacted] with [redacted], followed by SSE (Southern) with 3.58 ha per km^2.

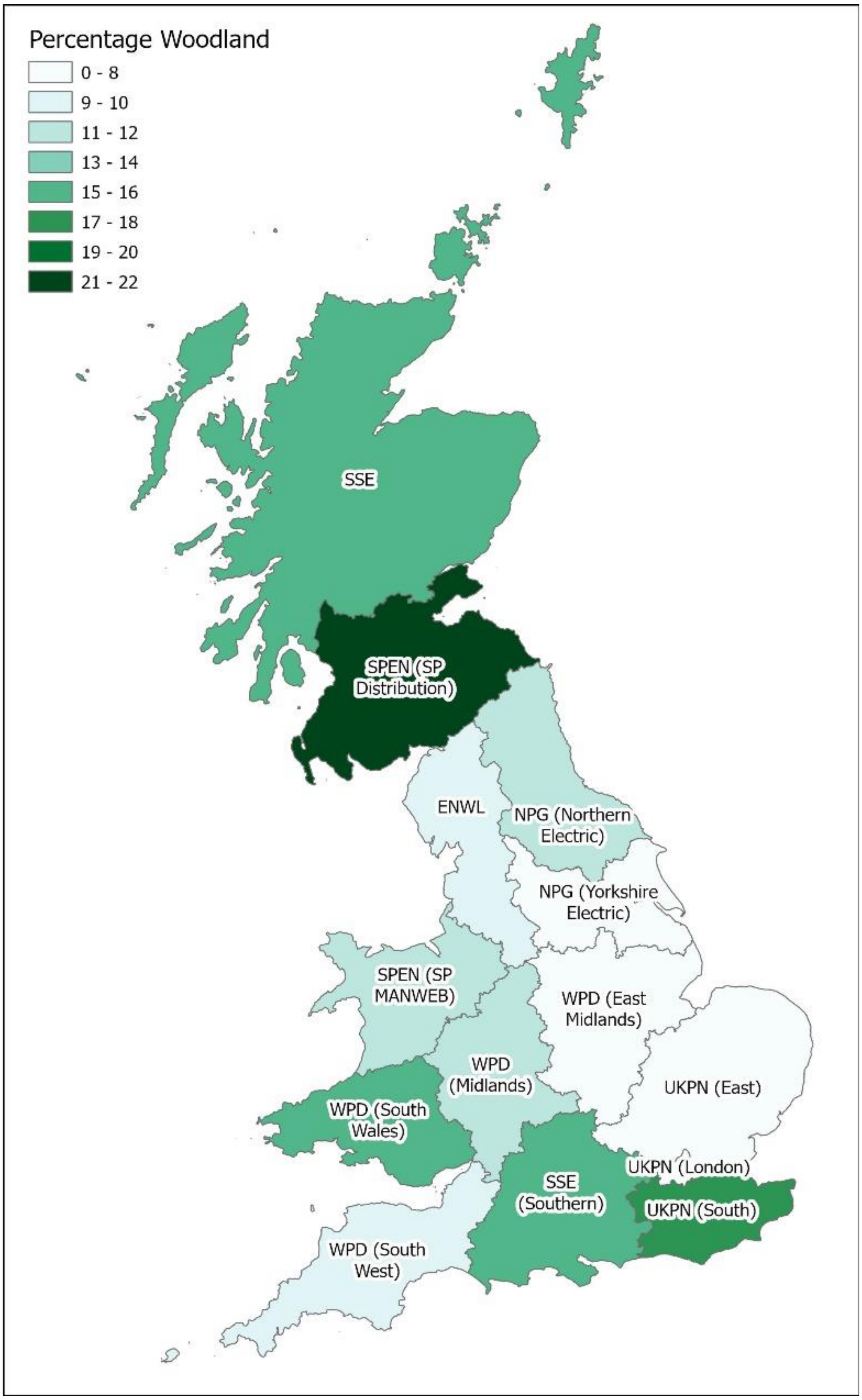

Figure 29. Map showing percentage of the total area of each DNO that is covered by woodland. Source – (National Forest Inventory Woodland GB, 2018).

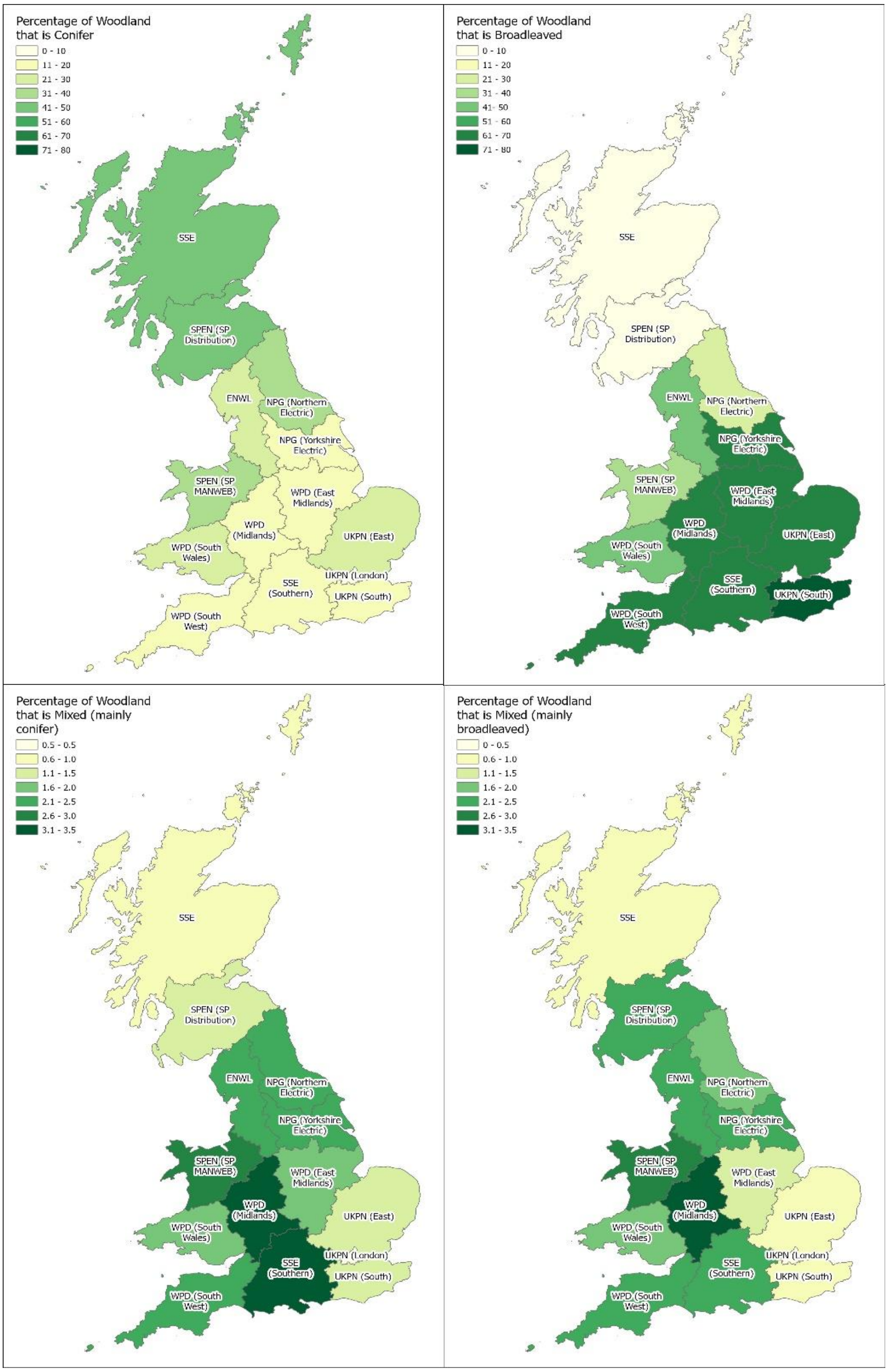

Figure 30. Maps showing the percentage of woodland area within each DNO that is Conifer, Broadleaved, Mixed (mainly Conifer) or Mixed (mainly Broadleaved). Source – (National Forest Inventory Woodland GB, 2018).

Table 33. Table showing the area of each DNO region that is covered by woodland and the areas that are Broadleaved, Conifer, Mixed or Other woodland. Source – (National Forest Inventory Woodland GB, 2018)

	[redacted]	SSE (Southern)	[redacted]	SSEH	[redacted]
Broadleaved Area (ha)	[redacted]	165,692	[redacted]	138,917	[redacted]
Conifer Area (ha)	[redacted]	43,664	[redacted]	464,421	[redacted]
Mixed (mainly broadleaved) Area (ha)	[redacted]	5,299	[redacted]	9,623	[redacted]
Mixed (mainly conifer) Area (ha)	[redacted]	7,430	[redacted]	8,790	[redacted]
Other Area (ha)	[redacted]	24,307	[redacted]	366,837	[redacted]
Total Woodland Area (ha)	[redacted]	246,394	[redacted]	988,588	[redacted]
Total Area of DNO (ha)	[redacted]	1,723,356	[redacted]	6,434,451	[redacted]

Table 34. Table showing percentage area of each DNO region that is covered by woodland and percentage of the woodland area that is Broadleaved, Conifer, Mixed or Other woodland. Source – (National Forest Inventory Woodland GB, 2018)

	[redacted]	SSE (Southern)	[redacted]	SSEH	[redacted]
Percentage of Woodland that is Broadleaved	[redacted]	67.2	[redacted]	14.1	[redacted]
Percentage of Woodland that is Conifer	[redacted]	17.7	[redacted]	47.0	[redacted]
Percentage of Woodland that is Mixed (mainly broadleaved)	[redacted]	2.2	[redacted]	1.0	[redacted]
Percentage of Woodland that is Mixed (mainly conifer)	[redacted]	3.0	[redacted]	0.9	[redacted]
Percentage of Woodland that is Other Woodland	[redacted]	9.9	[redacted]	37.1	[redacted]
Percentage of total area that is woodland	[redacted]	14.3	[redacted]	15.4	[redacted]

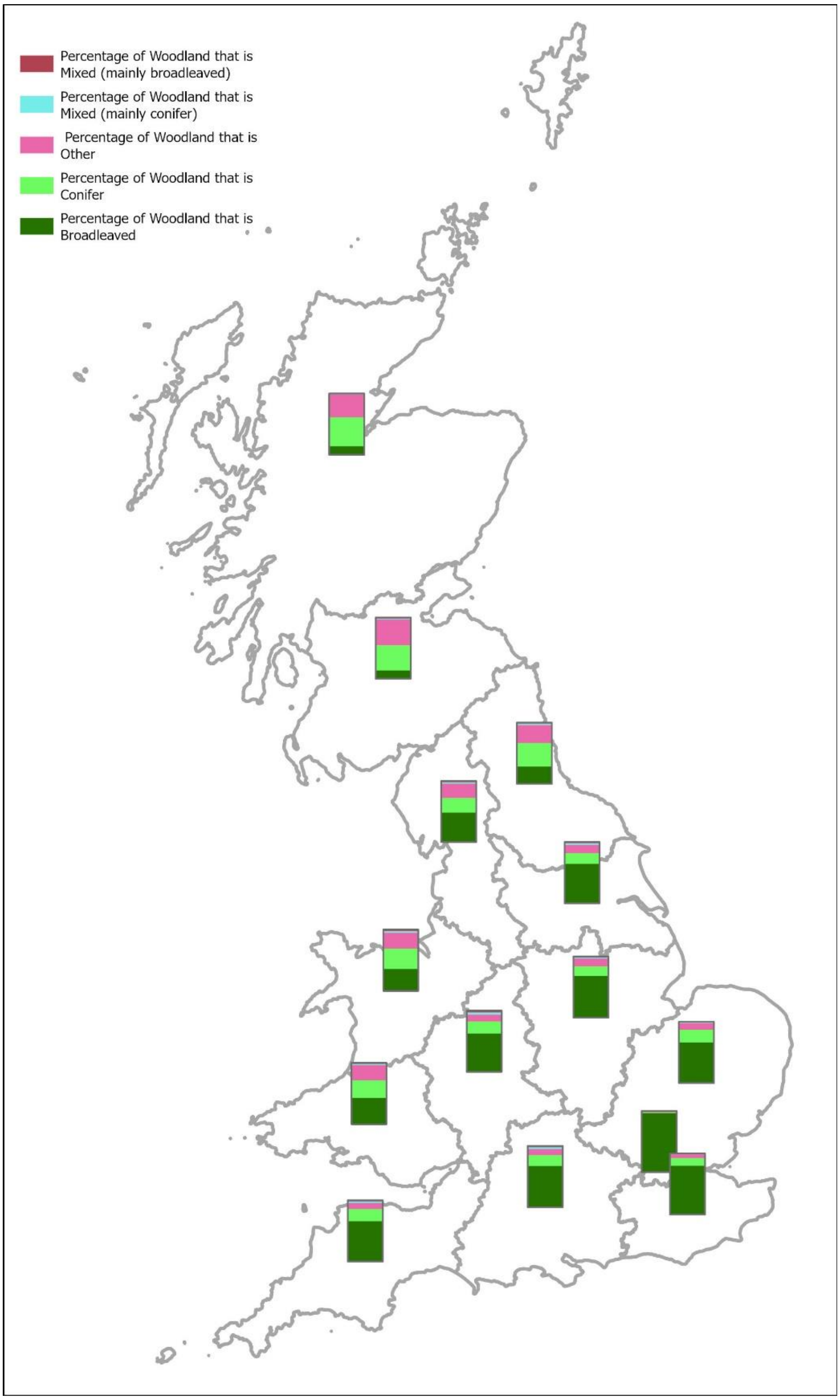

Figure 31. Map showing fraction of woodland area in each DNO that is Broadleaved, Conifer, Mixed or Other woodland. From (National Forest Inventory Woodland GB, 2018).

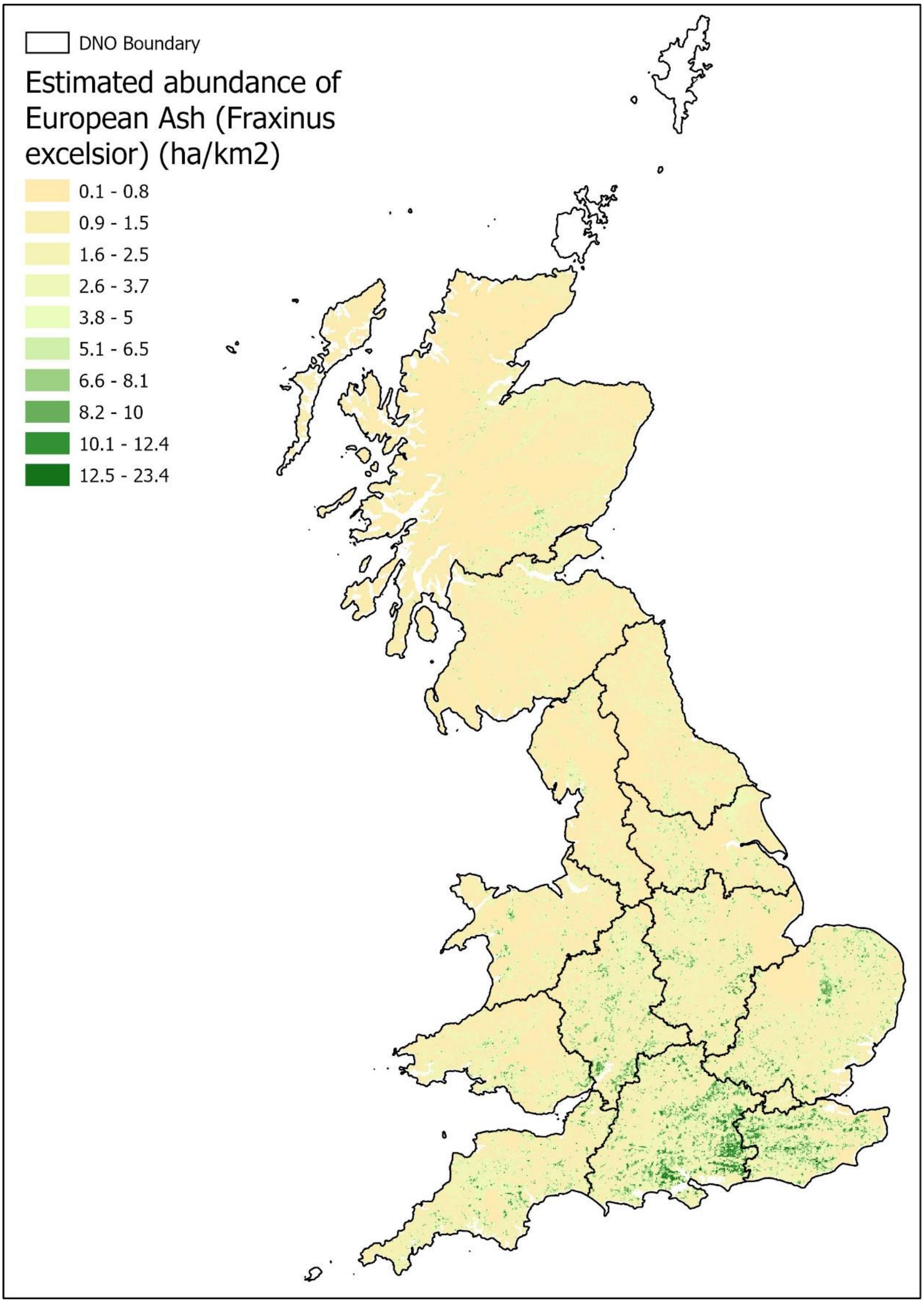

Figure 32. Map showing estimated abundance of European Ash (*Fraxinus excelsior*) (ha/km2). From (Hill et al., 2017).

Table 35. Lookup table showing species name for each tree species code used in subsequent Table 36. Source - (Hill et al., 2017).

Tree Species Code	Species Name	Common Name	Growth Rate Ranking (from Humpries, 2012)
Aca	Acer campestre.	Field maple	10
Apl	Acer platanoides.	Norway maple	10
Aps	Acer pseudoplatanus.	Sycamore maple	10
Agl	Alnus glutinosa.	Black alder	15
Bpe	Betula pendula.	Silver birch	4
Bpu	Betula pubescens.	downy birch	4
Cbe	Carpinus betulus.	European hornbeam	
Csa	Castanea sativa.	Sweet chestnut	3
Cav	Corylus avellana.	common hazel	6
Cmo	Crataegus monogyna.	common hawthorn	12
Fsy	Fagus sylvatica.	European beech	13
Fex	Fraxinus excelsior.	European ash	9
Ptr	Populus tremula.	European aspen	1
Pav	Prunus avium.	Sweet Cherry	14
Ppa	Prunus padus.	Prunus padus	14
Pme	Pseudotsuga menziesii.	Douglas fir	5
Qpe	Quercus petraea.	Sessile Oak	7
Qro	Quercus robur.	English oak	7
Sca	Salix caprea.	goat willow	8
Sci	Salix cinerea.	Grey willow	8
Sar	Sorbus aria.	common whitebeam	
Tba	Taxus baccata.	English Yew	
Tco	Tilia cordata.	small-leaved linden	2
Ugl	Ulmus glabra.	Scots elm	11
Upr	Ulmus procera.	English elm	11

Tree Species Code	[redacted]	SSEH	[redacted]	SSE (Southern)
Aca		0.13		1.08
Agl		1.49		2.68
Apl		0.14		0.59
Aps		1.49		2.68
Bpe		1.51		2.99
Bpu		1.83		1.52
Cav		0.86		3.08
Cbe		0.16		1.94
Cmo		0.57		0.82
Csa		0.76		4.55
Fex		**0.95**		**3.58**
Fsy		1.20		4.44
Pav		0.23		1.22
Pme		2.68		3.96
Ppa		0.00		0.00
Ptr		0.03		0.22
Qpe		0.87		2.81
Qro		1.20		4.35
Sar		0.00		0.00
Sca		0.21		0.65
Sci		0.10		0.04
Tba		0.11		0.87
Tco		0.04		0.64
Ugl		0.02		0.10
Upr		0.01		0.14

Table 36. Table showing mean estimated abundance in hectares per square km of different tree species across each DNO region. See Table 35 for species names. Also showing the three fastest growing species highlighted. From (Hill et al., 2017).

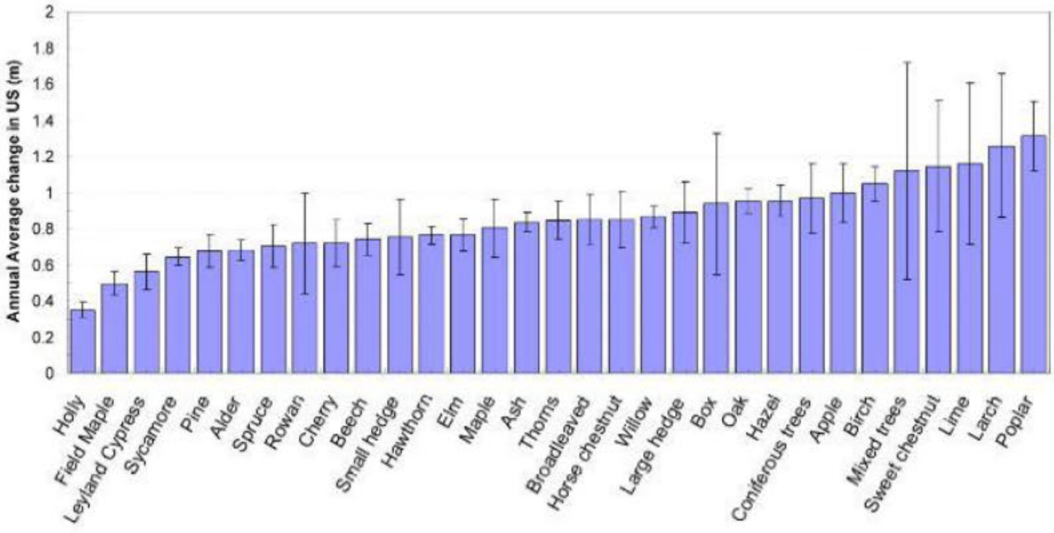

Figure 33. Summary chart of national average change in utility space (m) by vegetation type with standard error bars shown. From (Humphries, 2012).

3.3 Discussion

Table 36 shows that SSE (Southern) has one of the highest proportions of the fastest growing tree species of all DNOs , meaning they will have to consider more frequent cutting cycles or consider more intensive tree management by removing these species from the proximity of their network.

ADAS' original USD measurement project (Humphries, 2012) demonstrated that trees showed accelerated growth for the first year after cutting and that overall USD was higher for broadleaves[1]. This was thought to be due to the fact that USD is more dependent on lateral growth rates than vertical ones, and that, while broadleaves will produce epicormics shoots which grow rapidly after cutting, conifers usually show rapid vertical growth, but are slower to achieve lateral growth, especially after cutting because they do not produce epicormic shoots, so lateral regrowth depends on shoot growth from pre-existing branches. Therefore, the SSEH region, which has proportionally more conifers than broadleaves, will require less intensive monitoring and management than the SSE (Southern) region. Figure 33 shows a summary of national average change in US (m) by tree species from ADAS' original USD measurement project (Humphries, 2012).

Having the highest proportion of broadleaved woodland coverage, along with the second highest proportion of ash coverage, of all the DNOs, mean that the challenges of vegetation

[1] "Substantial variation in rates of US [utility space] closure was also noted between species within a region with highest rates of growth associated with poplar (*Populus*, 1.31m±0.19 s.e.), larch (*Larix* 1.25m±0.4 s.e.), lime (*Tilia* 1.16m±0.45 s.e.) and sweet chestnut (*Castanea* 1.15m±0.4 s.e.)." (Humphries, 2012)

management for system resilience will be greater in the SSE (Southern) region in comparison with the other DNOs.

SSE (Southern) will need to undertake additional surveys aimed at specifically identifying existing ash trees already affected by ash die-back which currently threaten the network. They will also need to identify and record those which may pose a threat in the future and need to be monitored. This will enable the DNO to plan its regime of vegetation management and whether additional cycles of cutting will be necessary in areas where clearing the area around the OHL network is not possible due to stakeholder considerations.

4 THE IMPACT ON THE HEALTH OF TREES FROM PESTS AND DISEASES AND STORMS

4.1 Introduction

The main predicted effects of climate change, and their anticipated impacts on trees, are listed below.

- Longer growing season – this will result in earlier bud burst, later bud set and more lammas growth (second flush of leaves in July/August).
- Warmer growing season with increased CO_2 concentration – will lead to increased growth rates.
- Fewer frost days / milder winters – resulting in reduced hardening of saplings and later dormancy which will increase the risk of autumn frost damage.
- Reduced summer rainfall – drier summers will lead to reduced growth, increased drought stress which will increase susceptibility to secondary pest / disease outbreaks, and increased likelihood of fires.
- Increased winter rainfall – this will lead to increased waterlogging which causes trees to suffer stress and can kill roots. Waterlogging also decreases trees' stability, affecting their anchorage in wetter soil, which increases the likelihood of windthrow, soil erosion and slope failure. Waterborne pathogens such as *Phytophthora* and *Hymenoscyphus* will increase.
- Longer growing season – will lead to more generations of insect and mammal pests per year.
- Milder winters in combination with warmer growing season and increased CO_2 concentration – increase in mammal populations, insect pests and tree diseases, conditions will become suitable for more alien invasive species.
- Increased high winds – this increases the incidence of wind damage which provides opportunity for access for pests and diseases.

(Ray et al., 2010)

Tree populations are resilient – the fact that forest lifespans are measured in geological time attests to this – and, as existing tree populations decline through climate change pressures, tree species which are adapted to the new conditions (and, in many cases, are already present in small numbers in suitable environments) will begin to thrive and succeed the failing populations. Clearly this complex combination of factors makes it difficult for those managing trees to predict future requirements for tree pruning and felling in order to protect people, property, and in this case utility infrastructure, from the consequences of increased tree and limb failures.

4.2 The effect of climate change on the range and severity of attacks to trees from pests and diseases

Current research demonstrates that the predicted warmer, wetter winters will cause nutrient deficiencies and root death due to waterlogging of soil, and hotter, drier summers will cause water stress and also possible root death due to desiccation of the soil. These environmental stressors can have a severe detrimental impact on trees' natural defence mechanisms which would usually protect them from attacks by pests and pathogens. A simulation of the effects of climate change on the range and activity of forest pathogens by Desprez-Loustau et al. (2007) concluded that "The predicted warming would be favourable to most of the studied species, especially those for which winter survival is a limiting factor linked to low temperatures (e.g. *Phytophthora cinnamomi* and *Melampsora medusae*)."

The combined effects of climate change and other factors associated with human activity, such as the increase in global trade, have led to an increase in the rate of introduction and establishment of new pests and diseases which affect trees in the UK. Insect pests which are introduced to new environments are able to flourish due to the absence of their natural predators, and pathogens are able to increase their geographical range as temperatures, which are often a limiting factor to their spread, increase. The increased frequency of extreme weather events such as drought, flood and high winds means that storm damaged trees tend to have more exposed broken timber or torn roots which offer an entry point for disease. (Potter and Urquhart, 2017)

A review, by Jactel et al. (2019), of studies into the expected response of forest pests to climate change concluded that "The main identified mechanisms of positive forest insect responses (i.e. more damage) to climate change are (i) higher number of generations per year and higher survival under warmer temperatures, (ii) lower tree resistance to insect attack under more severe droughts, (iii) higher amount of breeding substrate for bark beetles following storms, and (iv) changes in substrate quality for defoliators due to elevated CO_2 (Figure 32)."

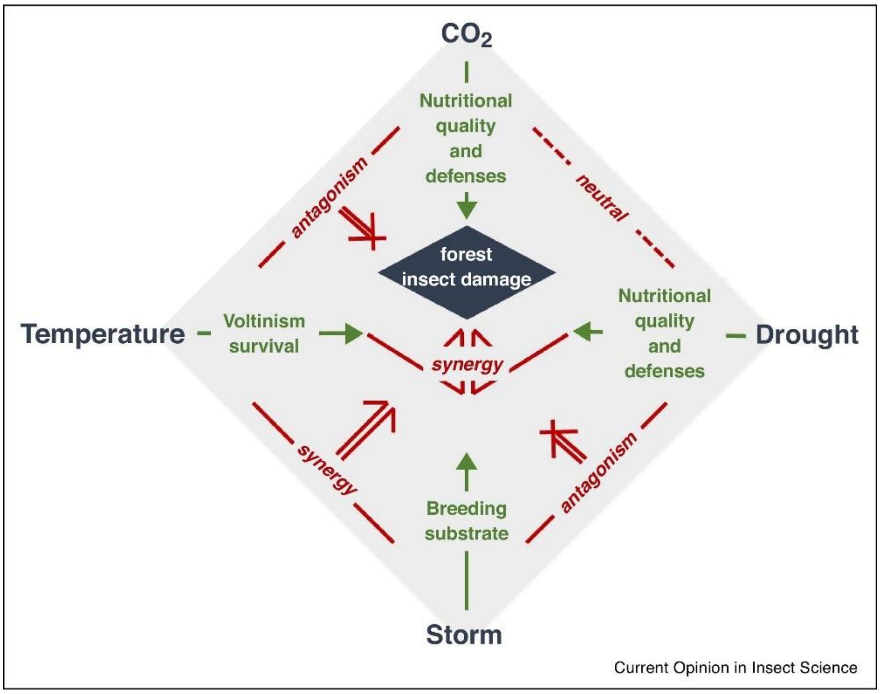

Figure 32. Conceptual diagram showing the relationships between main components of climate change and the mechanisms explaining their effects on forest insect damage. (Jactel et al., 2019)

Similarly to insect pests, many of the pathogens which pose a threat to UK trees now are ascomycete fungus type organisms such as *Pseudomonas syringae* whose various pathovars colonise trees and add to the weakening effects of environmental stresses. Bacterial wetwood, which is caused by various different bacterial agents, causes unsightly slime-flux and affects the resilience of trees to the impacts of other pests and diseases. The warmer and wetter winters which are predicted to affect the UK over the next few decades will favour the increase and spread of these types of pathogens.

The SSE (Southern) region also has one of the highest proportions of sweet chestnut (*Castanea sativa*) and oak (*Quercus spp.*) of all the DNOs. Sweet chestnut blight (*Cryphonectria parasitica*) and chronic oak decline, which is caused by the interaction of several damaging agents working sequentially or simultaneously, are likely to affect more of these trees throughout the region as the effects of climate change continue to weaken the trees and strengthen the influence of the pathogens.

There are many other known pests and pathogens, such as anthracnose of plane (*Apiognomonia veneta*), *Xylella fastidiosa* and the Asian Longhorn Beetle (*Anoplophora glabripennis*), which have been identified in various parts of Europe, that would thrive in the more temperate conditions which are predicted to become the norm in the UK.

Therefore, although it is not possible to be definitive about what species will arrive and become established in the UK, it is possible to predict that the pressures on UK trees from pests and diseases will increase as a result of climate change, which will in turn increase the pressures on those responsible for vegetation management to take action to prevent the risks to the OHL network from diseased and declining trees becoming too great.

4.3 Current and future extent of Ash Dieback and the increasing threat to SEPD's OHL network

Since its first identification in the UK in 2012, Ash Dieback, which is caused by a fungal pathogen – *Hymenoscyphus fraxineus*, has been detected in over 60% of 10km squares in the UK. Research has shown that less than 20% of the UK's ash population is tolerant to the disease. The rate of progress of the disease within individual trees can be unpredictable, as it is dependent upon environmental factors and the presence of other pathogens which may take advantage of weakness caused by the disease and hasten the trees' decline.

Many trees will ultimately die from the disease, but they will become gradually more dangerous as they decline towards death. The main risk posed by trees which are affected by Ash Dieback is that weakened or damaged limbs, or the whole tree, may fall and cause injury or property damage.

Exact numbers and rates of death and decline of Ash trees due to this disease are difficult to predict, but research, and the experience of those managing tree populations, demonstrates that the majority of Ash trees in the UK which are close to property or infrastructure will need to be felled over the next few years.

A study by Hietala et al. (2018) found that infection pressure was strongly influenced by summer temperatures (higher temperatures favour population growth) and that *H. fraxineus* populations grew exponentially during years with favourable local conditions.

Ash trees grow widely and very vigorously from seed, so, although a significant proportion of mature trees are expected to die over the next few years, the size of the overall ash population is likely to take longer to decline. Death rates of mature trees will also vary depending on pressures on the population from other environmental and biological factors.

The abundance estimations of tree populations by Hill et al. (2017) suggest that the SSE (Southern) region has the second highest abundance of ash trees of all DNOs, meaning that they will have a larger responsibility for ash dieback management than the majority of other regions. However, consideration for stakeholders, and budgetary implications, mean that removing all ash trees within the vicinity of SSE (Southern) OHL network as part of a mass felling exercise would not be feasible and would not gain the desired permanent network resilience due to the expected regeneration of new trees. It will therefore be necessary to plan an ongoing monitoring and cutting schedule which is flexible and responsive enough to manage the evolving threat to the network presented by the anticipated impact of ash dieback throughout the region.

4.4 The severity and frequency of storms and the effect that this will have on the level of tree clearance needed to maintain power supplies to SEPD's customers

The latest 'State of the UK Climate Report' (Kendon et al. 2019) states that there are no compelling trends in storminess when considering maximum gust speeds over the last four decades. However, the reality for DNOs is that the negative effects of storm events on damage by trees to infrastructure and property are becoming more frequent and significant (Ofgem, 2014). For example, a study in Connecticut, USA, found that 90% of storm outages in the region were tree related (Wanik et al. 2017)

According to the UK Meteorological Office, "since 1998, the UK has seen seven of the ten wettest years on record". Over the next decade or so they predict that rainy winters, which keep the soil wet into spring, and dry summers of infrequent rainfall will become the norm.

The lengthening of the growing season, which leads to broadleaf trees coming into leaf earlier in the spring and losing their leaves later in the autumn, is likely to affect the number of tree failures due to high winds. This is due to the fact that the canopy of a broadleaf tree when it is in leaf presents a much larger resistance to the wind, referred to as sail-factor, than a leafless tree or a conifer.

The strongest wind gusts are currently seen throughout the winter months in the southern regions of the UK. When these strong gusts in the winter months are paired with the fact that trees are likely to be weakened by the other aspects of climate change, in addition to the increased likelihood of soil waterlogging which leads to poor anchorage, it can be anticipated that limb and tree failures are more likely to happen in what could be considered 'normal' storm events.

Figure 33: Showing trees which have fallen due to waterlogging of soil reducing its mechanical integrity (ADAS).

The general trend expected in the SSE (Southern) region over the next few decades is for weather to become hotter and drier. This will lead to an increase in trees suffering from drought stress. Drought stress directly affects a tree's growth and biological functions, often leading to loss of some, or all, foliage and in some cases to the sudden failure of branches. Indirect effects of drought stress include changes to the tree's chemical defence mechanisms which, after prolonged drought, are likely to decrease which will make the tree more vulnerable to attack by pests and pathogens (Gely et al. 2019)

Trees which are under stress, particularly if their roots are being compromised by drought and waterlogging, undergo a natural process of retrenchment, where the outer parts of the crown will die back and eventually drop off leaving a reduced crown which requires less water, nutrients and physical support. These dead and weakened limbs are more likely to break and be carried by gusts into powerlines. Fallen trees and wind-blown debris caused the majority of damage to infrastructure that was experienced during the 2013 storms (Ofgem, 2014). Management of retrenching trees, in cases where their removal is undesirable, involves complicated and time consuming pruning work and ongoing monitoring, therefore an increase in the number of trees with these issues will create a greater workload for those responsible for the OHL security.

Even where trees appear otherwise healthy, with full crowns of leaves, it has been demonstrated that long term drought and waterlogging stress, or other types of environmental stress, lead to the trees remobilising sugars from their heartwood, weakening the timber, reducing their structural strength and their ability to withstand strong gusts.

These timber weakening effects are then compounded by the activity of pests and pathogens which continue the processes of degradation of the timber leading to increased failure risk. It is also difficult to determine from a visual check whether this internal weakening is taking place, so it may be necessary for SSE to undertake more regular surveys than some of the other DNOs, who have less tree coverage, to monitor the trees near their network.

Overall the burden of managing the potential risk to the OHL network from trees in the SSE (Southern) region can be expected to become more complex, time consuming and costly as climate change continues to cause the region to experience warmer and drier conditions. The relatively high number of trees across the region, particularly of those species which are already being affected by known pests and pathogens, represents a larger responsibility for the DNO in terms of monitoring and cutting of trees when compared with the other DNOs in the UK.

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APPENDIX E: EJPS AND CBAS

EJP reference	EJP	Driver
305/SSEPD/NLR/11kV_SWGR	6.6/11kV Primary Switchgear (Ground Mounted)	Non-Load – Asset Condition
306/SSEPD/NLR/33kV_SWGR	EHV Switchgear	Non-Load - Reliability
307/SSEPD/NLR/132kV_SWGR	132 kV Circuit Breakers	Non-Load - Reliability
308/SSEPD/NLR/HV_TRANSF	6.6kV/11kV Transformers (GM) CAPEX intervention	Non Load - Condition
309/SSEPD/NLR/EHV_TRANSF	EHV Transformers (GM) CAPEX intervention	Non Load - Asset Condition
310/SSEPD/NLR/132kV_TRANSF	132kV Transformers (GM) CAPEX intervention	Non Load - Asset Condition
311/SSEPD/NLR/LV_UG	LV Underground Mains and Service	Non-load – Reliability
312/SSEPD/NLR/HV_UG	6.6/11kV Underground Cables	Non-load – Reliability
313/SSEPD/NLR/HV_132kV_UG	EHV and 132kV Underground Cables	Non-load – Reliability
314/SSEPD/NLR/LV_SWGR	LV Switchgear	Non-Load – Asset Health Replacement
315/SSEPD/NLR/LINKBOXES	LV UGB	Non Load – Safety and Resilience
316/SSEPD/NLR/LV_POLES	LV Poles, LV Services (OHL) and LV Conductor (OHL)	Non Load – Reliability
317/SSEPD/NLR/HV_POLES	6.6/11 kV OHL Poles	Non Load – Reliability
318/SSEPD/NLR/EHV_POLES	33 kV Overhead Line Poles & Conductor CAPEX Intervention	Non Load – Reliability
320/SSEPD/NLR/LEGAL	Site Security	Non Load – Safety and Resilience
321/SSEPD/NLR/DIVERSIONS	Asset Diversions	Non Load – Safety and Resilience
322/SSEPD/NLR/RLM	Rising and Lateral Mains Driven By Condition & Asset Replacement	Non-load – Safety and Resilience/Reliability
323/SSEPD/NLR/CIVILS	Civil Works Driven By Civils Condition & Asset Replacement	Non Load – Safety and Resilience
324/SSEPD/NLR/TREES	Tree Cutting	Non-Load: Network Reliability
325/SSEPD/NLR/DISMANTLEMENT	Dismantlement	Non Load – Safety and Resilience
327/SSEPD/NLR/ASBESTOS	Asbestos	Non Load – Safety and Resilience
418/SSEPD/NLR/OHL_Clearances	OHL Clearances	ESQCR Compliance and Safety
425/SSEPD/NLR/TOWERS	33kV & 132kV Overhead Line Towers, Conductor & Fittings CAPEX Intervention	Non-Load - Condition

CBA reference	CBA name
308	SEPD_NLR_HV_TRANSF
308	SHEPD_NLR_HV_TRANSF
309	SEPD_NLR_EHV_REFURB
309	SEPD_NLR_EHV_REPLACE
309	SHEPD_NLR_EHV_REFURB
309	SHEPD_NLR_EHV_REPLACE
310	SEPD_NLR_132kV_TRANSF_REFURB
310	SEPD_NLR_132kV_TRANSF_REPLACE
324	SSEPD_NLR_TREES
308	SEPD_NLR_HV_TRANSF
308	SHEPD_NLR_HV_TRANSF

309	SEPD_NLR_EHV_REFURB
309	SEPD_NLR_EHV_REPLACE
309	SHEPD_NLR_EHV_REFURB
309	SHEPD_NLR_EHV_REPLACE
310	SEPD_NLR_132kV_TRANSF_REFURB
310	SEPD_NLR_132kV_TRANSF_REPLACE
324	SSEPD_NLR_TREES
308	SEPD_NLR_HV_TRANSF
308	SHEPD_NLR_HV_TRANSF
309	SEPD_NLR_EHV_REFURB
309	SEPD_NLR_EHV_REPLACE
309	SHEPD_NLR_EHV_REFURB
309	SHEPD_NLR_EHV_REPLACE
310	SEPD_NLR_132kV_TRANSF_REFURB
310	SEPD_NLR_132kV_TRANSF_REPLACE
311	SEPD_NLR_LV_UG_1
311	SEPD_NLR_LV_UG_2
311	SHEPD_NLR_LV_UG_1
311	SHEPD_NLR_LV_UG_2
312	SEPD_NLR_HV_UG_1
312	SEPD_NLR_HV_UG_2
312	SHEPD_NLR_HV_UG_1
312	SHEPD_NLR_HV_UG_2
324	SSEPD_NLR_TREES

APPENDIX F: OFGEM'S MINIMUM REQUIREMENTS

	Ofgem minium requirement	Where and how this is addressed in narrative
3.15	As a minimum requirement under Stage 1 of the BPI, Business Plans must set out the company's views on asset health, criticality and replacement priorities at each of:	
(a)	the start of the price control period, effectively reflecting their view on the asset health, criticality and risk of assets on the network.	See Section 3 and our NARMS sheets within the BPDTs. For subsea cables see ***Scottish Islands Strategy (Annex 8.1)*** Section 3.1 along with the NARMS sheets within the BPDTs.
(b)	the end of the price control period with no intervention, effectively reflecting their view on asset degradation over the period	
(c)	the end of the price control period with intervention.	
3.16	We also expect companies to explain their long-term risk objectives and strategy, as well as the long-term benefits delivered by their proposed interventions.	See Section 5 for details. For subsea cables see ***Scottish Islands Strategy (Annex 8.1)*** Section 4.
3.17	Monetised Risk objectives must be informed by stakeholder engagement and costbenefit analysis (CBA), and demonstrate that selected investment options both efficiently meet their stakeholder-driven objectives and efficiently deliver sufficient net benefit for existing and future consumers.	See Section 5 and Enhanced Engagement Appendix C. For subsea cables see ***Scottish Islands Strategy (Annex 8.1)*** Section 4.