Climate Change Adaptation Report

National Grid Electricity Transmission

July 2021

nationalgrid

Contents

Executive Summary

National Grid Electricity Transmission (NGET) has submitted responses to the two previous DEFRA Climate Change Adaptation Reporting Power (ARP) cycles. This report fulfils our commitment to the third-round reporting cycle (ARP3).

Since the publication of our second-round report, our understanding of potential climate change impacts has advanced with the publication by the Met Office of the UKCP18 climate model. In 2020, National Grid committed to reduce its carbon emissions to Net Zero by 2050 and for the fifth year running, we have secured a place on global environmental charity CDP's prestigious 'A List'.

We are also a Principal Partner for COP26, the UN Climate Change Conference being held in the UK in 2021 and since 2019 have been reporting through the Task Force on Climate-Related Financial Disclosures (TCFD).

Since ARP3, the System Operator has been separated from NGET and operates as National Grid Electricity System Operator (ESO) within National Grid Group under its own licence. It is therefore not included in this assessment. Additionally, while Western Power Distribution joined National Grid Group in June 2021, it will be reporting separately. As a result, this report focusses solely on the physical risks to assets under the control and operation of NGET.

This ARP3 report represents a step change in NGET's climate adaption assessments. For the first time, in conjunction with the ENA and DNO partners, we have completed a fully scored climate impact risk assessment. To provide comparison with previous reports we have also retrospectively undertaken the assessment for ARP2 and in line with DEFRA requirements, have taken a view to 2050.

The assessment, in recognition of NGET's commitment to understanding our climate change impacts, has involved a full gap analysis our potential climate risks; collating 86 potential risks and formally assessing 50 in this report.

The ARP3 risk assessment has identified 2 new high risks in Coastal Management Policy and Flooding from Storm Surges. This recognises recent changes in climate, weather systems and sea level, alongside a shift from a defensive to pragmatic coastal management policy.

The high and medium climate risks identified in ARP3, while more specific in nature, are broadly consistent with previous NGET adaptation reports:

- Coastal Change
- Raised Temperatures
- Temperature Cycles
- Erosion, Ground Movement and Scour
- Flooding
- Compound Events and Storms involving high winds
- Lightning
- Drought

The 2050 assessment illustrates the escalating nature of climate change. Twelve risks identified as higher tier medium risks in ARP3 will increase to high risks in the period to 2050. These include high temperatures; erosion, ground movement and scour; flooding; coastal change and compound events. The dependency of other infrastructure and service providers mitigating their climate change risks will also increase during the coming years and decades.

This report therefore determines that it will be necessary for NGET to continually appraise its understanding of climate risk and the potential scale and timing of impacts on its assets. This will be through a range of measures including climate modelling, risk assessment, process development and engagement with external stakeholder and policy makers.

While 2050 is a key date in climate policy, the report demonstrates that action is needed now and consistently during the coming decades. Inaction will only result in a loss of resilience and the

opportunity to implement satisfactory solutions, particularly where risk assessment, investment planning and (where needed) construction might take many years.

The ARP3 and 2050 assessments highlight the real need for continued preparedness and long-term planning by NGET, but also by industry and regulators. As future scenario data becomes more certain, a flexible and adaptive approach will need to be applied when installing new assets to ensure they are resilient to future scenarios. There is a need that longer term resilience planning also be factored into asset design and installation, either now, or through intelligent design to cater for potential increased vulnerabilities over the lifespan of our assets.

Finally, given the likely and significant climate related challenges in the future, it is key that all sectors have the time required to identify emerging risks and the opportunity to adequately plan, finance and implement adaptation measures in a co-ordinated manner.

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Introduction

The Adaptation Reporting Power set out in the Climate Change Act 2008 provides for the Secretary of State to direct reporting organisations (those with functions of a public nature or statutory undertakers) to report on how they are addressing current and future climate impacts. Reports should detail:

- the current and future projected impacts of climate change on their organisation,
- proposals for adapting to climate change,
- an assessment of progress towards implementing the policies and proposals set out in previous reports.

ARP aims to ensure that organisations of a public nature with climate-sensitive responsibilities are taking appropriate action to adapt to the impacts of climate change. It does this both directly, through engaging organisations in reporting, and indirectly, through raising awareness, building capacity in organisations, and making examples of good practice publicly available.

The Government's Adaptation Sub-Committee review the outputs of the ARP process and it supports the Government's National Adaptation Programme and future UK Climate Change Risk Assessments.

This report supports this process by fulfilling the requirements of ARP3 for NGET and covers the period 2016 to 2021.

National Grid Group plc

National Grid Group plc lies at the heart of a transforming energy system, spanning the UK and the US.

Our businesses supply gas and electricity, safely, reliably and efficiently to millions of customers and communities. But we also drive change through engineering innovation and by incubating new ideas with the power to revolutionise our industry.

In the UK, we have a unique position at the heart of Britain's energy system, connecting people to the energy they use, safely and reliably. We keep the lights on and the gas flowing, so people can go about their daily lives. And we're working to build a cleaner, fairer and more affordable energy system that serves everyone.

Facts: National Grid UK

4,481 miles (7,212 kilometres) of overhead electricity lines

1,391 miles (2,239 kilometres) of underground electricity cables

4,740 miles (7,630 kilometres) of high-pressure gas pipes

By 2030, 90% of electricity imported by our electricity interconnectors will be from net zero carbon sources

By 2024, National Grid's electricity interconnectors will import enough energy to power 8 million homes

In 2020, National Grid committed to reduce its carbon emissions to Net Zero by 2050.

With our role at the heart of the UK energy system we are committed to facilitating decarbonisation and helping to deliver a clean energy future.

For the fifth year running, in 2020, we have been recognised for leadership in corporate sustainability, securing a place on global environmental not-for-profit charity CDP's prestigious 'A List'. We are also a Principal Partner for COP26, the UN Climate Change Conference being held in the UK in 2021.

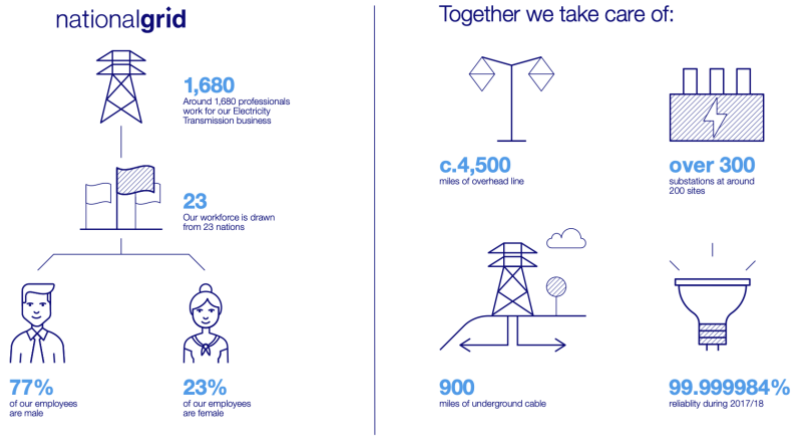
In recognising the importance of our approach to climate change, we also voluntarily undertake financial reporting through the TCFD. In order to understand the future impact of climate change on our business, in 2020, we embarked on an ambitious climate modelling exercise to quantify our climate risks during the rest of the century.

National Grid Electricity Transmission

National Grid Electricity Transmission plc owns and operates approximately 4,500 miles of high voltage overhead lines and underground cables that constitute the electricity transmission system in England and Wales.

NGET itself does not sell electricity. We transmit electricity from the generators to Distribution Network Operators (DNO) who supply and sell to homes or businesses.

Electricity Transmission: Our Network in Numbers

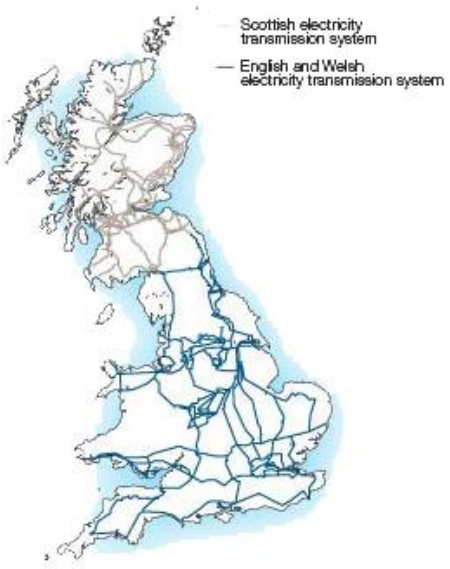


National Grid's ARP1 and ARP2 reports for electricity, covered our operations as Transmission Owner and System Operator.

Since the publication of ARP2, the System Operator has been separated from NGET and now operates as National Grid Electricity System Operator (ESO) within National Grid Group. In addition, Western Power Distribution became a National Grid company in June 2021, however it will publish its own submission.

As a result, this report focusses solely on the physical risks to assets under the control and operation of NGET.

Electricity Transmission: Our Transmission System



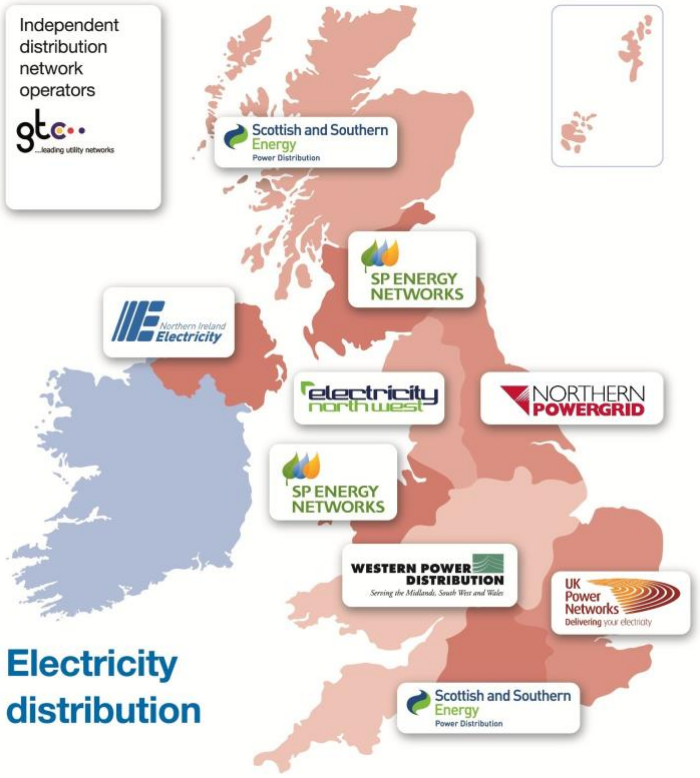
Energy Networks Association

The ENA is the trade association for the energy networks. Its members own and operate the wires and pipes which carry electricity and gas into communities, supporting the economy.

NGET are members of the ENA Climate Change Adaptation Reporting Group alongside partner members including National Grid Gas Transmission and the Electricity Distribution Operators (DNO) and Gas Distribution Network (GDN) businesses.

The electricity companies have worked closely with colleagues in the GDNs and National Grid Gas Transmission to develop an overarching approach to ARP3. The businesses will continue this collaborative approach to progressing climate change adaptation in the newly formed ENA Climate Change Resilience Working Group.

ENA Members: Electricity Distribution Companies



Facts: Energy Networks Association

The gas network in the UK and Ireland comprises around 300,000km of pipes – enough to go round the world seven times

The electricity network in the UK and Ireland comprises around 1,000,000km of cables – enough to go round the world 25 times

Around 30 million homes and businesses are connected to the electricity networks

Around 22 million homes and businesses are connected to the gas networks

ENA and its member companies have contributed to all rounds of climate change adaptation reporting:

- In ARP1, ENA established the response as a collaborative project amongst electricity network operators and identified key risks to network assets and operation posed by climate change impacts.

- In ARP2, ENA built on its understanding of the risks and updated DEFRA on industry mitigation measures being put into place on the networks. It developed the consistent reporting methodology from ARP1 and provided further evidence of actions taken in response to key climate risks.
- In ARP3, the aim has been to provide an update on existing risks, mitigation measures and programmes. It also looks to identify new risks being realised in order to provide a fuller picture of the potential for climate change impacts to affect networks. More importantly, the ARP3 report aims to combine Gas and Electricity network reports to provide a consolidated Energy Industry response.

The ARP3 energy sector response has been prepared by the Climate Change Adaptation Reporting Group and is intended to provide a response to climate change adaptation on behalf of the Energy Industry. This report continues the progress made since the second round of reporting and should be read in conjunction with the Second Round Report.

Adaptation First Round Report

National Grid were approached directly by government and invited to respond to the First Round of Adaptation Reporting in 2011, which was designed to:

- Assess the current and predicted impact of climate change in relation to the companies' functions; and
- Outline the proposals and policies for adapting to climate change in those functions and the timescales for introducing those proposals and policies.

The main categories of weather events and environmental risks were identified as follows:

- Flooding and heavy rain fall (including saturated ground conditions)
- Snow and ice
- Increases in temperature, heat waves and drought conditions
- Coastal erosion from sea level rise
- River erosion
- Storm events and high winds

Using information drawn from United Kingdom Climate Projections 2009 (UKCP09) and working alongside the Meteorological Office Hadley Research Centre, the Environment Agency and the Scottish Environmental Protection Agency, the key risks and opportunities facing the businesses were identified. High emissions projections to 2050 and 2080 were used to determine worst case scenarios and for correlation against the lifetimes of existing assets. Account was taken of the expected increase in number, frequency and intensity of weather events.

Inherent risks to the networks due to change in climate are largely due to the majority of NGET assets being above ground where they are exposed to the elements and subject to the climate change parameters as mentioned above.

In addition, prolonged periods of extreme weather could have a significant impact on the ability of the workforce to access and carry out their roles, particularly field-based engineers. They could also impact on the ability to conduct 'business as usual' activities as a result of the reliance on appropriate adaptation of other major infrastructures, such as telecommunications and transport. Impacts on the operation of supply chain businesses and the continued availability of equipment also need to be considered. The environmental impact of companies' assets could be affected by the mobilisation and migration of land contaminants from flooding and ground saturation.

It was generally highlighted that network assets and processes may be vulnerable to certain aspects of climate change. However, the national and regional infrastructure has a significant degree of resilience to these impacts and none of the identified risks were considered to be high.

Adaptation Second Round Report

The Second Round of Adaptation Reporting in 2016 followed the same methodology as ARP1. It was also recognised that there had been no significant changes in understanding of climate change impact with the exception of limited development of environmental regulators flood mapping.

Again, the overall level of uncertainty for electricity networks was assessed as low as the sector has a high level of inherent resilience due to the level of safety awareness and regulatory overview.

However, the assessment was itself expanded to include a greater number of hazards and identified the following risks:

- Increased solar heat
- Increased heavy rainfall
- Sea level rise
- Increased lightning
- Wind and gale
- Snow, sleet, blizzard and freezing fog
- Increased flooding
- Increased coastal / river erosion
- Increased subsidence / land slip

Key higher-level risks were:

- Increased Solar Heat - Potential impact on equipment ratings at substations.
- Increased Heavy Rainfall – The inability of existing site drainage systems to deal with rainfall and related impacts on safe site access.
- Sea Level Rise – Leading to the flooding of assets.
- Flooding – Resulting in sites becoming non-operational potentially leading to a loss of system resilience or a loss of supply.
- Coastal and River Erosion – Resulting in flooding and asset damage.

The report noted the flooding events of 2007 and 2013 and that NGET was in the process of undertaking flood mitigation work for tidal and fluvial flood risk to reduce the level of risk through a prioritised investment programme. This work was embedded in agreed regulatory business plans (RIIO-T1). Under that regulatory price control, NGET allocated £153m to network resilience, flooding and physical security. Investment focussed on the highest risk priority 1:100-year flood risk sites, with £17m of investment at these sites. Other sites were allocated £136m investment. Current T1 forecast spend was £14.21m on 1 in 100 sites, £63m on 1 in 200 sites and £76.5m on 1 in 1000 risk sites with a target of completion by 31st March 2021. Approximately £4.2 million was also invested in interim mobile flood defences with supporting equipment and bespoke porting facilities. This included surface water risk assessments for sites not previously identified and the assessment of other non-substation sites.

The report also detailed the outputs from the Engineering and Physical Sciences Research Council (EPSRC) - funded Resilient Energy Networks for Great Britain “RESNET” project. The aim of RESNET was to

- Develop and demonstrate a comprehensive approach to analysis at a national level
- Understand climate related changes in the reliability of the UK’s electricity system
- Develop tools for quantifying the value of adaptations that would enhance its resilience.

The report used UKCP09 to assess thermal rating calculations for overhead lines, cables and transformers to determine the impact of changing climate on the ratings of these assets. It showed that there will be a detrimental impact on ratings and that this will increase through the 21st century. In the short to medium term, transmission assets were however seen to be resilient to climate change.

Interdependencies were also assessed, with concerns regarding transport systems to enable access to key sites, and telecommunications for control room systems and voice communications. It was also highlighted that there are interdependencies between improving climate knowledge and the current eight-year regulatory process which could result in a delay between any change in climate knowledge and a corresponding change in investment. However, in view of the long-term nature of climate considerations this is not considered to be a significant concern.

The report concluded that there was a mix of low probability risks based on the present level of understanding, and management through existing business controls was presently sufficient.

Adaptation Third Round Report Introduction

In 2018, National Grid was invited by DEFRA to participate in the Third Round of Adaptation Reporting.

Since the publication of our ARP2 Report, our understanding and response to climate change has evolved, not least our commitment to Net Zero and TCFD.

Additionally, since the publication of ARP2, the Met Office has released its updated climate modelling (UKCP18) which provides the most up-to-date assessment of how the UK climate may change in the future.

As a result, NGET has used this round of reporting to undertake a full reassessment of our climate risks. Our objective for ARP3 has been to:

- Provide an update on existing risks and mitigation measures described in the previous reports;
- Identify new or emerging risks to provide a comprehensive picture of the potential for climate change impacts to affect NGET; and
- Incorporate the latest climate information provided by UKCP18.

NGET has therefore undertaken a full gap analysis of its climate change risks, with consideration given to:

- The outputs of UKCP18;
- Hazards assessed in the ENA Met Office Report;
- Relevant risks identified in previous NGET and National Grid Gas Transmission ARP reports;
- Hazards identified in preparation for the National Grid TCFD Climate Modelling project;
- Interdependencies with external factors, such as telecommunications; and
- Compound climate risks such as heavy rainfall that follows drought conditions.

Previous NGET reports did not include a standardised risk matrix. For ARP3, NGET has been working with ENA partners to develop a framework which is consistent with that used by the DNOs in previous ARP reports. As a result, NGET has undertaken a retrospective risk assessment for ARP2 for comparison, alongside ARP3 and the DEFRA requested position for 2050.

The 2050 assessment is qualitative and based on ‘business as usual’ combined with our understanding of future climate. Wherever possible, this has been undertaken using the ENA Met Office Report and any findings are therefore consistent with impacts seen under a high emission scenario (discussed in the next chapter).

In total, NGET considered 86 potential risks. Following a detailed assessment looking at relevance, significance, duplication and overlap within these risks, 50 were carried forward for consideration in this report.

This is intended to provide a benchmark for future climate work and provide a repository of climate change knowledge while linking to wider climate research and adaptation efforts within NGET.

ENA Met Office Climate Report

In spring/summer 2020, on behalf of its members, the ENA commissioned the Met Office to undertake a review of the UKCP18 data and existing studies in to order to understand the changes in potential impact to energy infrastructure assets from climate change. The report from this research has been used to assess the current risks to NGET and inform future mitigation or management.

Hazards were identified by the ENA Climate Change Adaptation Group which includes National Grid (Gas and Electricity Transmission businesses) and the respective Gas Distribution companies and Electricity Distribution Network Operators. The group requested the highest Representative Concentration Pathway (RCP8.5) was used to provide a worst case scenario and timeframes out towards the end of the century.

Because of the number and diversity of the hazards, it was decided to prioritise those which posed the highest risk to energy network assets. The assessment process was also graded to provide main focus accordingly. A full climate assessment was produced for the highest priority hazards:

- Prolonged rainfall leading to flooding
- Extreme high temperatures
- Heavy rainfall/drought cycles

Since there is currently no strong signal within the climate projections for a change to future storm intensity, the risk of strong winds was assessed in the current climate only.

For the remaining, lower priority, hazards a qualitative approach was undertaken:

- Sea level rise
- Warm and wetter conditions, followed by heavy rainfall and/or wind
- Storm surge and wave height
- Warmer and wetter conditions – longer growing/nesting seasons
- Snow and ice
- Wildfire
- Lightning
- Solar storm
- Diurnal temperature cycles

Many of the hazards identified by ENA members are projected to increase due to future climate change: Increased frequency of high temperature days; prolonged rainfall events; hourly rainfall extremes; sea-level rise; extreme sea level events (storm surges); increased risk of wildfire and increased extreme diurnal cycle events are all expected over the 21st century.

On the other hand, the frequency of snow and ice days are expected to decrease.

Hazards for which there is not currently strong evidence for a change in frequency include strong wind events, high wave heights, wetter conditions coincident with warmer temperatures and/or strong winds, lightning, and to some extent, diurnal temperature cycles. Solar storms are not affected by increased greenhouse gases, so a study of historic occurrence of this hazard has been presented.

The societal response to climate change has also been considered in the context of hazards to the energy network. Impacts of weather hazards on the energy network are likely to come in the form of an altered dependency between weather and both supply and demand. Increases to the prevalence of electrified heating and electric vehicles increases the reliance on the electricity network by consumers. This increases the impact of hazards on the electricity network.

Interconnections between different industry sectors is a major source of risk for the energy network, with failures from one sector frequently causing impacts. Telecommunications and road

transport are thought to be the most important sources of risk. Telecommunications are already important for automated and remotely controlled equipment, and for communication with personnel in the field. Risk from telecommunications failure has the potential to increase in the future with greater reliance on smart systems (dependent on telecommunications). Road transport is often essential for restoration of supply and access to assets for routine maintenance. Societal responses to climate change may also increase the risk from the road network on the electricity network. As electric vehicles become more commonplace these impacts may be amplified.

Risk Narrative

Introduction

This chapter presents the context of the risks identified, their present and future impacts and any relevant case studies.

The risks are presented in groups. For conciseness, some groups are formed from a number of risks where the impact or mitigation is similar. Otherwise, they are dealt with separately.

The codes presented relate to the NGET gap analysis and the ENA Climate Change Adaptation Sub-Group, namely:

- **AR**: ENA Climate Change Adaptation Reporting Group Electricity Risks
- **ARG**: ENA Climate Change Gas Adaptation Sub-Group
- **GT**: Gap Analysis between National Grid Gas Transmission and National Grid Electricity Transmission
- **TCFD**: Risks considered by the TCFD Working Group Climate Modelling, but not considered in previous ARP Reports.
- **MO**: Risks considered by the Met Office Report, but not considered in previous ARP Reports.

1. Policy & Procedure

ARG1: Lack of climate change management procedure

ARG2: Lack of specific policies and procedures governing risk assessment process on climate change

ARG3: Risk and action owners not identified at senior leadership team level

Background

Management risks have been identified where there is a potential that company corporate policy, procedure and strategy may not be adequate to realise and address climate change hazards or where the risk is not directly attributed to damage or reduced operation of an asset.

Discussion

National Grid has a corporate risk for climate change which drives business risk management. It is also driving our commitments under TCFD and its associated climate modelling and risk assessment work. Within NGET, the risk is currently owned by the Head of Engineering and Asset Management.

Work is ongoing to ensure that a robust climate change adaptation strategy is in place. Findings of the ENA Met Office Report demonstrate that while existing risk management frameworks are suitable for the present climate, given the potential impacts, this will not always be the case. Action will therefore be required to ensure the network remains resilient.

The current risk management framework within NGET are a combination of:

- Reactive and proactive mitigation in the form of business resilience.
- Risk identification work in the form of ‘line walking’ and helicopter surveys (to identify erosion, land movement and excessive vegetation growth).
- Proactive measures (including Environmental Impact Assessments (EIA)) for new assets and sites where physical impacts of climate such as flooding are accounted for.

- Local escalation of known issues through existing reporting lines.
- Regular emergency planning exercises.

Long-term planning has the challenge of not being immediately beneficial and makes justification for potential increased investment problematic under relatively short regulatory period. The time required to respond to particular risks is also an important consideration in planning for climate change. Challenges include:

- Time required to undertake more research where needed.
- Refinement of risk assessments across numerous sites or assets.
- Securing suitable investment (which might require inclusion in the next RIIO cycle).
- Undertaking the relevant remedial works or construction activities.

The pace of climate change impacts on the business will therefore be kept under review, particularly the output of the TCFD Climate Modelling project. This is in addition to the prevailing regulatory expectations to determine whether a specific procedure would benefit the business.

2. Raised Temperatures

AR1: Overhead line conductors affected by temperature rise

AR7: Transformers affected by temperature rise

Background

Thermal expansion of conductors in summer is a common consideration for all overhead lines (OHL), and supporting structures are designed to account for sag to ensure the minimum ground to conductor clearances are maintained.

Where these lines are exposed to temperatures considered extreme by UK standards, and where the frequency and duration of these events increases, it is possible that sag will exceed the current OHL design parameters. This could lead to an increasing number of incidents where conductor clearance limits are compromised.

Increasing temperatures also impact on the capacity of the conductors, and consequently, of the network. Conductors are designed to operate at their maximum efficiency up to a maximum core temperature; as air temperature increases it becomes difficult for the heat from the conductor to radiate. As the core temperature increases so does resistance within the conductor, reducing its ability to carry current, thus reducing its capacity.

Discussion

Temperature increases will impact assets in the future with both the ENA Met Office Report and TCFD Climate Modelling project showing that the number of days experiencing temperatures above 30^{o}C will increase. However, there remains a major challenge in developing a strategy to cover the lifespan of existing and newly installed assets. Greater integration of climate change data into asset planning and investment is therefore needed.

Ratings settings are reviewed on an annual basis, which includes a review of long-term temperature forecasts and the network situation. While ratings are the primary concern, other factors around ground movement are also an issue.

For future resilience, the business needs to continue to monitor, seek to understand and make changes to Policy, Procedure and Design Standards as necessary.

Additional funding will therefore be required to facilitate both a greater understanding of temperature impacts and additional investment to adapt sufficiently to these impacts. NGET will

need to work with the ESO to understand which areas of the network that require reinforcement due to the impacts of increased temperatures.

AR4: Underground cable systems affected by increase in ground temperature

Background

As with OHL, increasing temperatures impact on the capacity of cables, and consequently, of the network. Cables are designed to operate at their maximum efficiency up to a maximum core temperature. As the ground temperature increases it becomes difficult for the heat from the cable to radiate, and as the core temperature increases so does resistance within the cable, reducing its ability to carry current and thus reducing its capacity.

Discussion

To an extent, underground cable systems are insulated by the surrounding ground. However, any impacts may be greater in urban areas due to the surface coverings of shallower cables, efficient heat dissipation may be reduced resulting in a potential downrating during prolong periods of extreme heat.

A secondary impact from heat includes ground movement, which accelerates as the surrounding material dries out. Additional potential environmental impacts in these cases include the loss of oil to ground if the asset is a fluid-filled cable.

AR6: Substation and network earthing systems adversely affected by Summer drought conditions

Background

As moisture in the soil reduces the soil resistivity increases, reducing the effectiveness of the earthing system. Where earthing design parameters are exceeded, system and public safety issues can arise with reduced touch potential distances or failure to fully dissipate fault current leaving exposed metal components inside and outside the site boundary live.

Discussion

Impacts on earthing systems may primarily be related to ground movement and the snapping of tape rather than reduced conductivity of the ground.

It is considered that existing robust earthing systems should be effective in mitigating the risk. This is however location specific and dependent on the existing level of robustness, the extent of temperature rise and the specific ground conditions at the substation.

AR8: Transformers affected by urban heat islands and coincident air conditioning demand

TCFD10: Demand growth in Summer due to increased cooling load

Background

Localised build-up of heat, particularly in city environments, will lead to increased demand from air-conditioning and ventilation unit operation; some network operators are now seeing very little difference between summer and winter demand where traditionally summer was always the season of reduced electricity usage. Increased demand can overload transformers causing tripping and loss of supply.

Discussion

This is an emerging risk, particularly given the urban location of many NGET substations. Elevated temperatures can significantly impact the operation of substations and the associated circuits.

Wider network constraints can also be seen as temperatures rise because urban substations are often combined and so resilience may be restricted at a regional level. This may be further impacted as local generation is added to the network, resulting in the network becoming less flexible and more constrained.

Consideration will be required to further understand temperature increases in urban environments. Current available modelling does not consider urban heat in any significant detail and so additional modelling work will be necessary.

Additional planning and investment will also be necessary across the energy sector to increase the robustness of urban networks and the ability to provide supplies via other substations at a regional level.

AR9: Switchgear affected by temperature rise

Background

Increases in temperature may impact switchgear by reducing its capacity, or in extreme cases, by causing the switchgear to trip. This could result in damage to the assets and loss of supply. Prolonged periods of hot weather could potentially increase the temperature inside switch rooms above the maximum optimum operating parameter for the switchgear. This would increase the potential for faults or mal operation.

Although, as with OHL, switchgear is designed to international standards, and there have been days recorded where switch room ambient temperatures have exceeded the operational maximum of the switchgear.

Discussion

Temperature increases will have some impact in the future, however, the continued lack of firm actionable data on which to base long-term planning remains a major challenge in developing a strategy to cover the lifespan of existing and newly installed assets. While ratings are the primary concern other factors around ground movements are also a concern.

3. Low Temperatures

ARG6a: Above and below ground assets affected by lower temperatures

Background

Network assets are manufactured to international standards and designed to operate within particular temperature parameters. Lower temperatures can impact equipment operating performance from both a temperature and (water) freezing perspective. There are also safety concerns for colleagues who are required to free or fix the impacted equipment.

Discussion

Assets are designed to be operated anywhere in the world and so short spells of cold weather in the UK are not a significant issue.

However, on above ground assets, ice loading on OHL can prove a particular problem. Below ground assets, while they are insulated, may be impacted by erosion (caused by the action of freeze-thaw cycles) and other related ground movement.

Given the expected decrease in cold weather periods related to climate change, the business does not expect this to be a significant risk as we look further into the century.

4. Temperature Cycles

TCFD12: Fast cycling between temperature extremes

MO14: Diurnal Temperature Range

Background

Rapid fluctuations in ambient temperatures have the potential to induce material stress in assets. Where this is associated with water, additional stresses may be seen which can impact assets further. This may also induce physical erosion of soil and rock, impacting foundations and asset integrity.

Discussion

Although temperatures are generally rising with climate change, evidence suggests that short term temperature fluctuations are increasing. The range between minimum and maximum temperatures appears to be static (although both are increasing) and as a result, rapid changes in temperature will continue to cause issues.

Rapid freeze – thaw cycles (or the sudden freezing of rain) are also known to result in greater erosion of natural or non-natural surfaces (such as concrete foundations).

Given the range of assets owned by NGET, including a significant number of OHL towers, the risk of adverse impacts remains.

5. Erosion

ET2c: Riverbank Stability and Scour

ET2f: Surface Water Runoff Scour

ET2d Groundwater Geohazards

Background

Foundations of OHL towers and cable routes can be undermined by riverbank erosion, subsurface flow and surface water runoff. More frequent flooding and increased river and watercourse flows will increase this level of risk.

Foundations may be undermined through sub-surface chemical processes (e.g. chalk cysts dissolving) or through physical erosion of soil and rock (e.g. sinkholes). Changes to the water cycle where we get increasing peaks of excessive rainfall may increase surface and subsurface flows which may impact an asset location and the rate of these processes. Resulting surface water discharge may also result in erosion and destabilisation of slopes, river channels and coastal locations.

Discussion

This risk is considered to be increasing its impact on the network, although it has a more transient effect than more permanent changes seen at the coast. Research was undertaken during RIIO-T1 that identified potential risk areas, which may be more vulnerable to these impacts during the coming decade.

Plans are in place to respond to the most credible emergency scenario, e.g., erosion and destabilisation of OHL tower foundations. In this instance, loss of any one double circuit would not normally result in loss of supply. However, in some coastal areas where long-term sea-level rise increases flooding and tidal inundation routes, there may be a risk of prolonged outages.

During flooding events, access to equipment may be constrained in the short term but a prolonged impact on maintenance etc. is unlikely. However, there is an expectation that increased access restrictions and planning, work and costs will be necessary for more vulnerable routes.

For future resilience, a long-term strategy will be required including modelling to understand specific risks across river catchments. We will continue to base our risk assessments on the Environment Agencies data, recognising that their models are periodically updated and therefore we will need to reassess the risk to our assts in response. The business will therefore also need to continue to monitor, seek to understand and make changes to Policy, Procedure and Design Standards, in response.

Additional funding may therefore be necessary to facilitate modelling or additional investment necessary to adapt sufficiently.

6. Ground Movement

AR2: Overhead line structures affected by Summer drought and consequent ground movement

Background

Increasing temperatures will, without precipitation, lead to drying of the ground causing it to shrink and potentially be subject to greater erosion. Any structures built on this ground will be subject to movement which, as well as being amplified by the height of the structure, can lead to instability of the foundations. Overhead line structures are more vulnerable to this movement, but it can also impact on ground mounted structures such as transformer bases and switch house foundations.

Discussion

This is an emerging risk that is closely linked to increased flooding risks from changes to, and fluctuations in the natural water cycle which may be exacerbated by changes to infiltration rates and vegetation die-back.

Plans are in place to respond to the most credible emergency scenarios and in most circumstances the loss of any one double circuit would not normally result in loss of supply. However, as electricity demand and distributed energy sources increase, constraints on the network may also increase.

AR5: Underground cable systems affected by summer drought and consequential ground movement

TCFD10b: Temperature: Increased rate of loss of level in areas with already low depth of cover (e.g. Fenland area)

MO4: Repeated Cycles of drought and rainfall

Background

Ground movement caused by drying and shrinkage will exert tensile forces on cables. Whilst cables have an inherent tensile strength, joints in the network are more vulnerable and may fail

because of flexing, as demonstrated through increased water leaks during dry periods. Extreme wet-dry and freeze-thaw ground movements will have a similar impact.

Discussion

This risk is primarily centred on ground movement. Loss of cover is not a significant risk given the location and construction of underground cables.

As discussed above, the primary mechanism is the drying out of soils (shrink-swell) or fast temperature fluctuations which may result in ground movement which causes stress to the asset. Currently, existing risk management processes are considered to be sufficient to manage this risk.

ET2a: Geohazards

Background

Geohazard risks are generally associated with collapsible deposits, compressible ground, running sand, landslide, shrink-swell, soluble rocks and old mining areas. In these areas, gradual ground deformation may lead to loss of foundation support or deformation of tower infrastructure. More significant or sudden deformation may also be related to events such as landslides, karst and undermining collapse.

Discussion

NGET has recently seen this risk increase, although present risk management processes are mitigating the impacts.

Future changes to the water cycle seen in the ENA Met Office Report, including the location, intensity and duration of rainfall across the UK, will result in a further increase in the occurrence, location and impact of geohazards.

The business will therefore need to continually monitor and refine its understanding of this risk to ensure that an appropriate and timely response is developed. This is likely to require additional funding to enable appropriate studies and investment to be undertaken before a significant impact is seen.

ET2e: Landslips, slope stability, ground creep, avalanche

Background

Physical movement of slopes can undermine foundations, resulting in asset stress and, in some circumstances, the catastrophic failure of an asset.

Discussion

The recent, tragic events at Stonehaven have demonstrated the fragility of some slopes and the resulting impacts.

There is a distinction in the characteristics and management of natural and engineered slopes, although the potential impact of failure can be significant in each case. Work was undertaken in RIIO-T1 with the British Geological Survey (BGS) to understand NGET risks relating to slopes. As a result, we understand which assets are in higher risk areas and where known issues are identified the slopes and assets monitored.

Like many erosion risks, the relationship between the landscape, geology and climate is significant. The ENA Met Office Report has demonstrated that temperature and rainfall patterns will continue to change through the century. This is particularly significant in upland areas where the steepest slopes can be found and the greatest increase in rainfall seen.

As a result, for future resilience, a long-term strategy will be required, including the business continuing to monitor, seek to understand and make changes to Policy, Procedure and Design Standards as necessary. This may be facilitated by detailed studies or work within the business. Additional funding may therefore be necessary to facilitate this or additional investment necessary to adapt sufficiently.

7. Fluvial Flooding

AR10: Substations affected by river flooding due to increased winter rainfall

ET8a: Fluvial river and coastal flooding of NGET sites

ET8c: Shifting flood areas may affect existing sites in the future

Background

Flooding (pluvial or fluvial) is associated with a broad range of impacts including access issues, asset damage and reduced performance. It presents a risk to many ENA business areas including gas distribution, buried assets, above ground sites and overhead assets.

Regardless of the source, the impact of flooding on ground located assets is the same. Plant and equipment may be physically damaged by flood water; water ingress will cause faulting within the assets and the network leading to extensive damage and loss of supply. Consequential repair or replacement of assets is costly and time-consuming, leading to extended periods of restoration. Network operators may often choose to switch out plant and equipment in order to avoid water ingress causing damage and uncontrolled shut down.

Discussion

The floods of 2007 and the significant risk presented to Walham substation demonstrated the power and potential impact of flooding on the network.

Increased heavy rainfall and pluvial flooding is perhaps the biggest flooding challenge faced on our existing sites. The retrofitting of mitigation measures to target standards is in some cases impracticable and sometimes unachievable. The challenge is maintaining an appropriate level of resilience investment within current levels of funding.

The risks include:

- If one or more sites / routes are lost from flooding it may result in a deterioration of resilience and flexibility of operating the system.
- A site may become non-operational or have critical assets damaged due to flooding potentially leading to a loss of supply.
- Access to equipment may be constrained in the short term, although it is considered very unlikely to have a prolonged impact on maintenance and other operations.
- Increased safety risks to colleagues and local stakeholders in the event of an electrical safety issue.

New sites and expansions are managed through NGET's planning policy and flood design standards and are subject to the appropriate level of planning consultation.

At existing locations, it is acknowledged that while significant work on flood defence has been undertaken in RIIO-T1, our understanding of flood risk is continually evolving. This is not just related to increased potential impact at present flood risk areas but also to wider changes to flood

risk patterns, which are likely to be exacerbated by climate change. We may therefore see assets formerly considered to be low risk requiring assessment and action.

The environmental regulators also continue to review and update their flood risk maps based on updated land use and climate information. This, in combination with our wider understanding of climate change, requires that these risks are continually reviewed, and appropriate actions taken.

As a result, for future resilience, a long-term strategy will be required, including the business continuing to monitor, seek to understand and make changes to Policy, Procedure and Design Standards as necessary. This may be facilitated by detailed studies or work within the business. Additional funding may therefore be necessary to facilitate this or additional investment necessary to adapt sufficiently.

ET8b: Fluvial river and coastal flooding – neighbouring sites leaving NGET sites stranded

Background

There is a risk that while asset owners may protect their own sites, the impact of flooding on the surrounding area may leave them stranded. Typical issues may be flooded roads or tunnels and other transport routes.

Discussion

There are two related elements to this risk:

- While NGET adequately protects its sites, connected customers and infrastructure may not protect to a similar level.
- New developments may be permitted in the surrounding area, changing hydraulic flows, impacting the capacity of wider infrastructure and adversely impacting the capacity of neighbouring sites to deal with flood water.

NGET can respond to its own risks but is reliant on those external stakeholders with responsibility for drainage to ensure local facilities are sufficient. Likewise, it is assumed that other stakeholders consider the risk of flooding in a similar way to NGET and have similar risk management frameworks.

8. Pluvial Flooding

AR11: Substations affected by pluvial (flash) flooding due to increased rainstorms in Summer and Winter

MO1: Increased intensity of short duration rainfall leading to flooding

Background

Flooding (pluvial or fluvial) is associated with a broad range of impacts including access issues, asset damage and reduced performance. It presents a risk to many ENA business areas including gas distribution, fixed level assets and overhead assets.

Intense, short duration rainfall events have the potential to overwhelm existing drainage systems and the ground's natural ability to allow percolation. As a result, surface water flooding presents a risk even for assets located away from watercourses or the indicative fluvial flooding zones.

There is a risk that while asset owners may protect their own sites, the impact of flooding on the surrounding area may leave them stranded. Typical issues may be flooded roads or tunnels and other transport routes.

Discussion

Sites at fluvial and tidal flooding risk identified as part of the RIIO-T1 works were also protected against surface water risks. As the Environment Agency did not release the surface water flooding maps until mid-way through RIIO-T1, sites at surface water risk were identified in RIIO-T1 for further investment in RIIO-T2. We are currently seeking funding for these in RIIO-T2.

Some substations have an inbuilt resilience to pluvial flooding to a depth of approximately 300 mm and target resilience levels for defences is 1 in 1000.

The ENA Met Office Report identified an increased signal relating to short duration intense rainfall. While any NGET sites benefit from having open areas of “chippings” where water can infiltrate into the ground, the potential for local incidence of surface water running through or onto a site is high. This is especially true in more urban sites and those which are situated on land lower than the surrounding area. Whilst most surface water issues can be dealt with at a local level (e.g., improvements to, and maintenance of drainage systems) some will require significant investment to mitigate the risks.

The ENA Met Office Report suggests these events will become more frequent in the future. Although there is nothing to escalate to a strategic level at present, examination of the risks posed, particularly in vulnerable locations (such as small or narrow river catchments) will be required in the future.

9. Sea Level Rise & Coastal Change

Introduction

The UK’s coastline is constantly changing and evolving. The risks associated with erosion and sea level rise are managed through Shoreline Management Plans which are developed by Coastal Groups which are mainly local authorities, the Environment Agency and Natural Resources Wales. They identify the most sustainable approach to managing flooding and coastal erosion in the short, medium and long term. Four options are identified; hold the line, managed retreat, advance the line and no active intervention.

A number of NGET sites and assets are in these coastal areas, particularly substations associated with present or former generation sites, for example Dungeness. Evidence from the ENA Met Office Report suggests that sea level rise of c.200mm will have taken place by 2040. By 2100, this may be as much as 700mm. In most cases therefore, in the short-term (0 to 10 years), the suggested impact on our assets will be limited, however as we move to the medium term, 10 to 50 years, several sites and overhead line routes will be at increased risk.

AR12: Substations affected by sea flooding due to increased rainstorms and/or tidal surges

Background

Regardless of the source, the impact of flooding on ground located assets is the same. Plant and equipment is physically damaged by flood water; water ingress will cause faulting within the assets and the network leading to extensive loss of supply. Consequential repair or replacement of assets is costly and time-consuming, leading to extended periods of restoration. Network operators will often choose to switch out plant and equipment in order to avoid water ingress causing a fault and uncontrolled shut down.

Discussion

Throughout the RIIO-T1 price control period, NGET undertook an extensive flood protection programme to provide physical protection to minimise disruption from localised flood events. Flood protection works will continue into RIIO-T2. New substation development and reinforcement

schemes will continue to reference guidance within ENA Engineering Technical Report 138 entitled “Resilience to flooding of grid and primary substations”.

If one or more sites / routes are lost from flooding, it may result in a deterioration of resilience and flexibility of operating the system and how we are able to support network reconfigurations should DNOs also be impacted.

Please also refer to the commentary under the ‘Fluvial Flooding’ and ‘Pluvial Flooding’ risks.

ET2b: Coastal Management Policy

Background

Sea level rise and changes to storm patterns will result in different patterns of erosion. While this will result in physical changes, there are corresponding policy decisions which may impact on infrastructure. The shift in approach from coastal defence to management and in some cases managed retreat may result in impacts to assets.

Discussion

Long term coastal management strategies have changed in recent decades from defence to a more pragmatic approach, in some cases resulting in stretches of the coastline being returned to a natural state. Managed realignment or retreat may be applied where NGET have sites and assets that require moving or additional protection.

Shoreline management plans continue to be assessed against the environmental regulator’s strategy and recent long-term decisions have shown that some sites may/will become untenable with extreme projected sea level rises. The investment of mitigation and development of alternative options under the current funding mechanisms is extremely unlikely given that we operate a 'long term view’ of only 20 years where climate projections consider 80 to 100 years long term.

There are significant benefits in the outputs of Shoreline Management Plans. NGET will need to monitor the development of the plans and work with stakeholders and regulators. It should be recognised that extra investment may be necessary to protect or relocate assets where they are subject to the impact of sea level rise and the development of regional coastal adaptation plans.

ET8e: Flooding from Storm Surges

Background

Storm surges present the potential for greater magnitude flooding in coastal areas. The compound impacts of sea level rise, erosion and tidal influences present the potential for assets to be flooded to a greater extent or in perceived lower risk areas.

Sea level rise is a calculated increase year on year and may accelerate as global temperatures near key tipping points; we may see a ramp up towards the latter half of the century.

Discussion

Storm surges associated with sea level rise pose a significant risk to coastal NGET assets as a direct result of flooding and erosion. An increase in airborne saline pollutants may also lead to increased maintenance or reduce asset life.

The potential for higher sea temperatures suggests there may be increased evaporation which may lead to more storms being generated. When this is considered with sea level rise, what we see as ‘normal’ very low-pressure system now, happening multiple times a year, would be equivalent to an extremely low-pressure storm event happening multiple times a year in the future.

There is uncertainty in calculating the storm surge peak height, especially in estuaries where trapping and funnelling effects can amplify high river discharge rates, and consequently surge height. We are already seeing the impacts of hurricanes and intense storms retaining their strength and crossing the north Atlantic maintaining their surge potential further north than previous norms. This, coupled with the increasing 'chain' like appearance of winter low pressure storms impacting the UK means an increasing likelihood of storm surges coinciding with the highest tidal periods and/or very high river discharge.

NGET has undertaken a review of assets at risk from coastal erosion and identified several sites and asset routes which would either become undefendable and require relocation or experience increased risks from more frequent tidal inundation.

Further work is needed to understand specific risks. It should be recognised that extra investment may be necessary where NGET assets are subject to the impact of sea level rise and the coastal management strategies demonstrate that long-term protection of some coastal assets is not practicable.

Please also refer to the commentary under the ‘Fluvial Flooding’ and ‘Pluvial Flooding’ risks.

ARG21: Saline contamination and increased corrosion rate of above and below ground assets from sea water or atmospheric salt

Background

There is a risk of gradual chemical damage to electricity assets from increased tidal flooding and corrosion from atmospheric salt, which will affect asset integrity and increase maintenance requirements.

Discussion

Sea water ingress and corrosion of NGET below ground assets is not considered to be a significant issue.

Atmospheric salt however can cause corrosion and interfere with the efficient operation of substations. The asset management strategy may also be impacted as those contaminated with salt cannot be used for spares.

The majority of coastal NGET substations are constructed within buildings to help mitigate the effects of weather. However, salt contamination is not a linear issue (i.e., that only impacts a certain distance inland) and is highly influenced by the direction of prevailing winds. Ingress further inland, for example on our major river estuaries, can therefore be an issue.

An increase in storm activity or increasing periods of low cloud and sea mist on salt marshes close to coastal power stations may result in an increase in NO_x, H+, NO_3 and SO_4 all of which lead to increased pollution. Coastal substations tend to be indoor to limit coastal saline pollution, however this indoor environment increases the humidity if not properly controlled may lead to the formation of ozone and nitrogen gases.

10.Lightning

AR14: Overhead lines and transformers affected by increasing lightning activity

Background

Increased storm frequency can lead to increased lightning strike frequency. Where lightning strikes exposed substation plants or, more likely, overhead line assets, the resulting surge will cause

circuits to trip under fault condition. In extreme cases strikes will lead to physical damage to the assets, loss of generation and/or loss of supply.

Discussion

The transmission system is normally resilient to loss of any one double circuit. Any potential increase in lightning strikes will increase the probability of very short duration outages but there is no evidence of an increased risk to date.

Whilst NGET have evidence that lightning strikes around our assets are increasing in some areas, protection and control equipment should continue to manage the risk. It is considered that an increase in storm activity linked to warmer summer temperatures generates the potential for increased storm cell formation which would lead to increased lightning storm frequency.

The ENA Met Office Report also suggests a projected increase, particularly in the spring and summer, driven by deeper and more intense storms. A limited decrease may be seen in the Autumn due to changes in ice fluxes.

Currently, the impacts are managed via system controls. While the business is therefore resilient at present, this may not be the case for the whole end to end network and consideration of the impact of increased lightning will be required in the future.

11.Wildfire

AR15: Wildfires

Background

This risk has been added for the third-round reporting following the Saddleworth Moor wildfires in 2018. Although a consequential risk of increased temperatures and reduced precipitation, wildfire poses a risk to above ground structures and assets when they are in susceptible areas such as open heathland. Operational telecommunication systems could also be considered at risk from this scenario.

Discussion

Wildfire is an emerging risk. Recent examples include the significant Saddleworth moor fires in 2018 and 2020 and that at Waverham Forest in 2020 which resulted in a supply outage and constraint on the local electricity network. In many cases, wildfires demonstrate the significant human factors involved in starting fires in addition to natural influences such as lightning, temperature and vegetation cover.

Wildfires impacting OHL are mitigated to a significant extent due to vegetation management policies. However, the same is not true for substations and sites sitting in wooded areas, which may lead to higher flame potential and more pollution impacting these sites.

Areas where vegetation has burnt off may also be at increased risk of erosion and slope instability during heavy or prolonged rainfall.

Areas of elevated risk were identified in the ENA Met Office Report based on an assessment of future weather conditions and vulnerable geology. However, this was indicative and therefore further work is necessary to fully understand the risk to NGET assets. This will require a combination of understanding local soils, land and vegetation management, climate trends (such as increased temperatures and reduced rainfall) in addition to understanding the influence of human activity on the incidence of wildfires.

12.Wildlife

ARG16: Wildlife Impacts

Background

Changes to breeding patterns, nesting seasons and species distribution as a result of climate change have the potential to impact operations. Asset access issues at locations where protected species are present, and the care and attention required to minimise impacts or implement mitigation, may cause adverse impacts on both standard and emergency operations.

Discussion

Wildlife presents a number of challenges to NGETs operations, both at fixed and non-fixed locations.

Nesting birds are attracted to the open space and security offered by NGET sites and in particular the open lattice structures at substations and OHL towers which make excellent nesting locations. Rabbits and other burrowing species can also impact assets, particularly cables and other ancillary equipment. Burrowing animals can increase the water driven destabilisation of ground surrounding asset foundations.

Non-fixed locations and development sites are subject to significant constraints which include protected species and habitats, which must be carefully assessed and managed.

It is uncertain how, or if, climate change will influence both the type and activity of wildlife that access NGET locations. However, as a responsible business, we always try to work in a sensitive way with wildlife. This includes undertaking significant pre-planning for projects and construction and working with our ecological consultants to implement management plans. As a result, existing processes are considered to be suitable at this stage, however, given significant changes, additional resource and investment may be required.

13.Vegetation Growth

AR3: Overhead lines affected by interference from vegetation due to prolonged growing season

Background

Increases in both temperature and precipitation will lead to increased vegetation growth. This impacts OHL as increased growth of tree branches growing adjacent to the OHL can impact on minimum clearances, potentially leading to faults and physical damage.

Discussion

Vegetation growth presents challenges to NGET, particularly where contact with, or arcing from live assets is possible.

Where NGET assets are surrounded by third party land where vegetation is not maintained, routine and emergency work can be delayed. Maintaining appropriate security at fixed sites, particularly in maintaining cleared areas around fence lines, is also important.

NGET is starting to see increased levels of vegetation clearance as part of its routine work. Existing risk management processes including maintenance, line walking and helicopter surveys are considered to be sufficient. However, in the longer term, additional investment may be needed to ensure the frequency of these activities and the corresponding remedial work keeps pace with changes in the landscape.

While increased vegetation growth and tree planting (as part of offsetting, nature based solutions or wider biodiversity improvements) may be seen as climate change progresses, the overall risk is considered to be minimal in the short term.

NGET will continue to consider the impact of vegetation growth as climate change progresses and continue to review its standards and specifications to ensure the safe operation of the network.

14.Snow & Ice

ET7: Snow & Ice; Severity, intensity and frequency of storms

Background

Extreme and compound weather events have the potential to cause widespread disruption. The combination of high winds, low temperatures and snow, could present significant challenges to networks. These may be particularly compounded when events combine with high demand for electricity.

Discussion

The icing phenomena and snowfall can cause the formation of ice and snow sleeves on the components of the overhead lines. When the amount of ice and snow on the line structures is exceptional, the consequent overload can cause the disruption of conductors, insulators, poles, or towers. Moreover, snowfall can also load trees in proximity of OHL, so that branches or entire trees could fall on the line conductors or poles. Cold spells can also cause an increase in mechanical tension on OHL, leading to asset ageing.

Heavy snowfall would not normally affect the operation of a substation. Emergency procedures allocate a fleet of 4x4 vehicles in order to ensure staff are able to respond to emergencies in extreme snow fall and ice conditions. Mutual aid procedures within the energy sector are also an available option.

The ENA Met Office Report details how snow and ice will generally be confined to elevated and northern areas. However, it has been suggested that as these events reduce, there may be an intervening period or greater incidence of ‘wet snow’ and rapid freezing, which due to its greater mass and potential to freeze may present its own challenges. However, it is anticipated that existing risk management and resilience frameworks should be sufficient to manage any impacts.

15.Solar Weather

MO15: Solar Storms

Background

The impact of solar storms falls into two categories: asset damage, and damage to telecommunications, resulting in health and safety considerations and loss of control of technology. Variations in the geomagnetic field, caused by space weather, induce an electric field in the surface of the Earth. This electric field, in turn, induces electrical currents in the power grid, which can cause power transmission network instabilities and transformer burn out.

Discussion

Although not a climate issue, solar storms are incorporated into NGET risk management frameworks, with an increase in spares holdings of transformers being undertaken in 2012 for such an issue.

Electrical surges are well controlled, and a vulnerability assessment was undertaken on the NGET network in 2012, particularly focussing on OHL (and those vulnerable locations at the end of the

network). As a result, safety measures were installed and additional investment in extra spare transformers undertaken.

Any potential impacts may be amplified if an event coincides with another natural hazard impacting the system.

16.Storms

ET6: Severity, Intensity and Frequency of Storms

Background

Extreme and compound weather events have the potential to cause widespread disruption. Assets are subject to damage from extreme weather events including storms and high winds. Any increase in the frequency and severity of these events will mean a higher risk of infrastructure damage or failure and an impact on support services.

Discussion

Windstorms can disrupt infrastructure systems:

- Directly, by immediately damaging infrastructure assets.
- By adding to long-term stress and failure.
- Indirectly, by toppling trees or blowing other debris around.

Existing NGET design standards account for extreme weather conditions. Substation equipment for example is designed to a relevant wind speed of 34 m/s (76 mph). NGET have seen instances of recent storm activities that have equalled and exceeded these standards, but the network and assets have performed well.

Access to OHLs may be restricted during a wind event but it is considered extremely unlikely to have a severe impact on fault response due to the resilience of the network and relatively short storm duration. There is a risk of falling trees and other vegetation, but these are managed through NGET's standard risk management framework.

There is debate as to how wind will be impacted in future climate scenarios making it difficult to establish a strategy on how we may need to deal with any changes. Multiple hazards occurring at the same time or closely following another and amplifying the impacts is not something which has traditionally been investigated. We are endeavouring to include some elements of 'multi hazards' in our assessments.

MO11: Warm, wetter conditions combined with rainfall and / or wind

Background

Assets are subject to damage from extreme weather events including storms and high winds. Any increase in the frequency and severity of these events will mean a higher risk of infrastructure damage or failure, and an impact on support services.

Discussion

The impact of wind is considered to be the greatest driver of this risk. Wind not only causes immediate impacts (either directly or indirectly through debris) at 'peak' speeds, but also causes long-term damage. This is a particular challenge as the slow, long-term build-up of stress is difficult to model. Resilience also drops with each wind event and the final critical damage may be caused by lighter winds. Remedial measures may also require significant investment of resources.

A number of substations are constructed within buildings, with many located on the coast. These can be vulnerable to wind impacts due to their size and generally flat roofs. Once the roof is damaged, secondary impacts such as the ingress of rain impacting substation equipment can then occur.

17.Compound Events

TCFD7: Extreme weather events including a combination of wind, rainfall, temperature or snow

Background

Extreme and compound weather events have the potential to cause widespread disruption. The combination of high winds, low temperatures and snow, could present significant challenges to networks. These may be particularly compounded when events combine with high demand for gas.

Discussion

The risk associated with this compound event is driven by the combination of wet snow, low temperatures and wind. A combination of the three can result in ice accretion on OHL, causing significant issues.

Issues relating to site access are only a concern in emergency or alarm situations. In normal operation, most sites may be unmanned and can, to an extent, be remotely operated. Operations are also supplied with 4x4 vehicles.

Please also refer to the commentary under ‘Snow & Ice’.

TCFD8: Perfect Storm of a cold winter, high electricity demand and heavy persistent rain

Background

The compound risk of high demand and persistent rainfall could lead to pinch points on the network being challenged at a time of greatest loading while resilience and redundancy in the system may be constrained.

Discussion

This is considered to be primarily an ESO risk. Whilst the NGET network is resilient to cold weather and persistent rain, the impact of electricity demand sits with the system operator.

18.Contaminated Ground

ET4: Polluted ground fires, Old Mine workings

ARG11: Ground contamination and transport of materials from flooding of contaminated sites

Background

Legacy contaminated ground and former industrial areas pose not only environmental but also safety challenges. These might be from the substances contained within them, but also the

potential fire risk from hydrocarbons, ground gases and highly organic made ground. As a result of climate change, contaminants might become increasingly mobile and more readily combustible.

Increased flooding of contaminated sites will lead to faster and greater transportation of materials in ground water, especially for sites located within flood plains. This will lead to increased inspection and remediation costs to mitigate any damage. There is also a risk of resulting regulatory and enforcement action.

Discussion

Legacy, third-party owned land can present challenges to NGET assets, particularly OHL towers. Brownfield land can be unstable due to its historic use and fires can either directly impact assets or undermine them, creating instability. Old mine workings can also present fire risks, in addition to subsidence and flooding.

The majority of NGET substations are however located away from former industrial areas, although some are located in urban areas and alongside former power stations or areas which have been in industrial use for decades.

The management of potential land contamination is undertaken by National Grid Land & Property (UKL&P) who have a programme to investigate and assess the risk at NGET substations. Where any historic contamination is discovered, UKL&P prioritise NGET sites for additional investigation and potential remediation. They also offer specialist support in the event of unknown contamination issues impacting NGET where needed.

19.Groundwater

ARG22: Groundwater flooding of below ground assets leading to water ingress to assets

Background

Changes to groundwater characteristics may result in direct damage by impacting the asset or affecting the underlying and surrounding ground. Areas previously unsaturated may become so and patterns of erosion and ground movement may accelerate or increase their geographical spread.

Discussion

The greatest risk considered from groundwater is the impact on erosion and ground movement discussed in other sections of this report.

Changes to rainfall patterns suggested in the ENA Met Office Report may influence groundwater levels and subsequently affect erosion and ground movement. This may be through greater flows, particularly at surface interactions, or the corresponding lack of flows resulting in the shrinking of soils, making them more prone to erosion.

It is possible that with changes to rainfall patterns we may see the emergence of previously unrecorded springs and surface flows.

The UK is perhaps one of the most heavily mined country's having had centuries of industrial and preindustrial mining of resources. This has resulted in an extensive networks of subsurface flow paths for groundwater. This has been demonstrated recently when the village of Skewen in South Wales when an old mineshaft ‘blew out’ inundating the area. While many newer mine shafts are recorded information on older mines is limited. As with the other inter-dependencies detailed below, NGET is partly reliant on the resilience work of other infrastructure owners such as the Coal Authority to mitigate their risks.

The uncertainties of how water is flowing through, the stability issues associated with this coupled with the changing characteristics of the water cycle through climate change means a likely increase in similar flooding and ground stability issues.

Current risk management processes are considered to be sufficient in the present environment. However, the changes to rainfall patterns requires this risk to be kept under review alongside those of erosion, ground movement and scour.

20.Business Continuity

ARG18: BCM plans affected due to severe travel difficulties resulting from extreme weather events

Background

Severe weather has the potential to disrupt service to customers and business operations. Critical locations and systems may be impacted alongside a number of safety and logistical challenges in operatives gaining direct access to assets. The potential to compound emergency situations or slow the mitigation of their impacts may be an issue.

Discussion

National Grid has a robust resilience framework. The plans are focussed on disruption of service, for example as a result of severe weather, rather than specific climate risks. The risk posed by climate change is discussed in response to the risk 'Lack of climate change management procedure".

In addition, NGET have also recently undertaken a review of its resilience across a wide range of factors including climate change adaptation. This review will support the business' approach to resilience during the RIIO-T2 period.

As demonstrated through the Covid-19 lockdowns, National Grid has been able to safely maintain its operations.

21.Interdependencies

As a transmission business, NGET connects electricity generators with customers. We are therefore aware that business resilience is reliant on the resilience of partners in the supply chain and other infrastructure providers.

This may be related to:

- Transport infrastructure - by impacting the ability of our teams to reach critical assets.
- Communication systems - by impacting the flow of information and response.
- Asset management - by failing to sufficiently mitigate or control climate risks that subsequently impact of assets.
- Policy decisions – by impacting or affecting the use and operation of assets.

Four such examples have been discussed in previous sections, namely:

- The management of third-party land contamination and old mine-workings
- Environmental regulator coastal management policy
- Pluvial flooding which may be caused or exacerbated by external drainage systems, such as those in the highway or within adjacent sites
- Groundwater flooding of assets related to old mine-workings.

There are, however, a number which can be addressed as individual risks.

ARG13: Vulnerability of critical IT systems managed by third parties from extreme weather events

Background

This represents an interdependency with other service suppliers and there is a risk of the loss of critical IT systems and functionality, especially if there is insufficient flood protection or cooling of third-party data centres and/or these cannot be relocated.

Discussion

To a large extent, NGET is reliant on telecommunications and IT service providers to ensure they too are resilient to the potential impacts of climate change. Other interconnections, particularly with infrastructure partners are significant in ensuring that assets can be accessed as necessary.

NGET IT systems are considered to be resilient. The systems are isolated and secure, and the business has design rules for systems which includes in-built redundancy and the ability to operate substations in isolation.

ARG17: Supply chain

Background

Supply chains could be affected due to travel difficulties resulting from extreme weather events. This can result in an impact on the continued operation and maintenance of the networks and on emergency response during and after a significant event. Business Continuity Management plans must consider the impact of climate change.

ARP3

Disruption to our global supply chain (continuity of supply) is recognised as a key risk within our global procurement division's risk register. Work is underway to understand particular risks from climate change within the supply chain. National Grid, as part of its framework, works with responsible businesses who themselves consider climate and extreme weather vulnerability as part of their procurement and risk management frameworks.

AR13: Substations affected by water flood wave from dam burst

ET8d: Reservoir / Canal Failure

Background

Engineered structures such as canals and dams can hold significant amounts of water. Potential structural failure, in combination with water volume and stored energy presents a risk of widespread flooding in downstream areas. Less significant structural failures, requiring the release of water to alleviate stresses, may also lead to localised flooding.

Discussion

The 2019 Whaley Bridge Dam collapse highlighted the potential risks and impact of reservoir failure. The NGET Bredbury substation was within the potential impact zone of a catastrophic collapse.

Where substations are located far enough away from dams, the impact of water inundation from a dam burst may not be different from "standard" pluvial, fluvial or tidal flooding and flooding impacts

may be considered similar. However, there are a number of sites which are not at any normal flooding risk but potentially vulnerable to reservoir or canal failure.

Where substations are close enough to dams to be impacted by the full force of a breach, the damage to a substation may be substantial. Plant and equipment may not only be impacted by water ingress but would likely be physically damaged or even washed away by the force of water. Where a substation site has been impacted by the full force of a dam breach, it would not be possible to re-establish supply without full reconstruction and recommissioning of the site which would take months.

Following the introduction of the Flood and Water Management Act 2010, National Grid undertook a review of all of its substations considered to lie in a reservoir inundation zone. This work was in preparation for the anticipated production of local authority emergency plans. This highlighted which sites or multiple sites may be impacted by a single or multiple reservoirs such as in the case of a cascade failure. Sites which have flood mitigation measures in place may have some resilience to a failure some sites may not be at any other flooding risk other than reservoir failure.

NGET would look to the application of the existing legislation to manage the risks from larger reservoirs and dams. However, smaller structures which may fall below the current legislation in some cases may not be maintained or monitored adequately and have the potential to impact some of our assets.

Raised canal embankments are not covered under the current legislation and may pose a risk where they are in proximity to our sites and assets. The risk is not only from the water directly but also from scouring out as water flows around our assets. Due to the nature of canals and the large variability on the location of any breach it is difficult to establish an exact risk to our sites.

In all cases, NGET would seek assurance from environmental regulators, the relevant local authority and the asset owner to ensure their responsibilities laid out in the legislation are discharged appropriately.

Risk Assessment

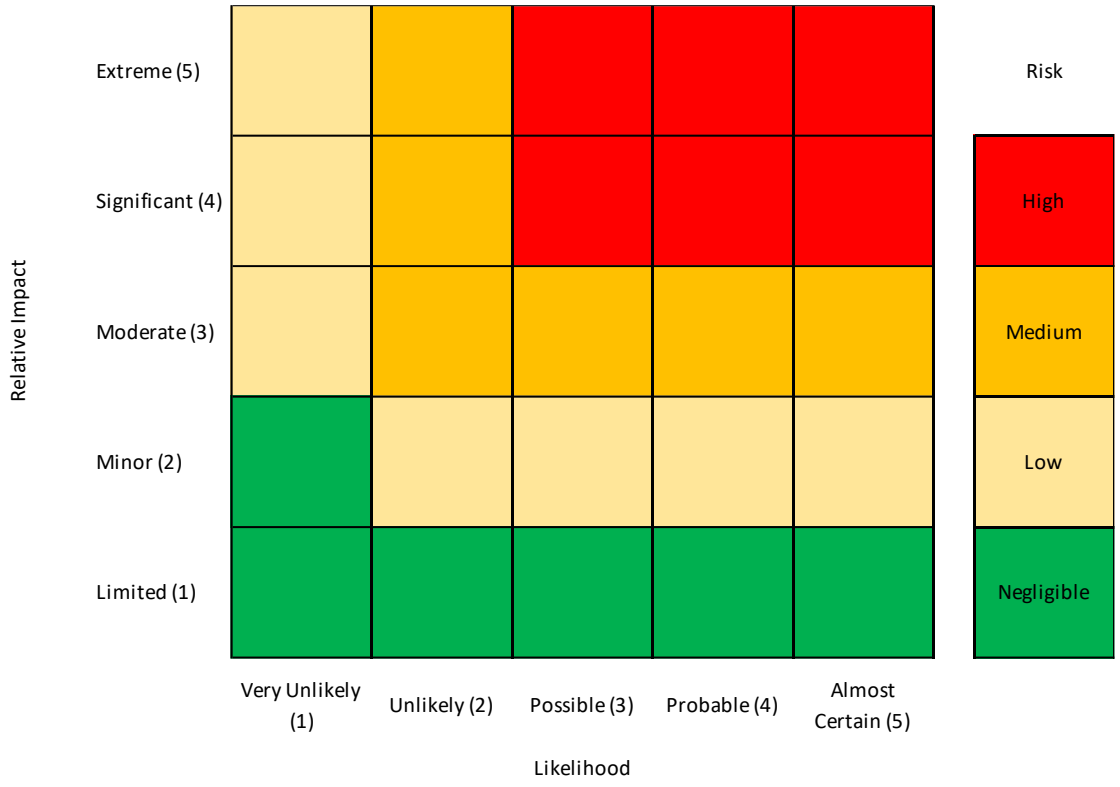
Introduction

This is the first electricity adaptation report to include a formal risk assessment which is consistent with the ENA Climate Adaptation Group approach. To ensure consistency across members and within the ENA sector response, the ENA Adaptation Group members have developed the following risk matrix.

The matrix has been developed by the Group and builds upon that used for ARP2 and 3 by the DNOs.

The full risk ratings are presented as Appendix 1 and are presented as likelihood vs impact.

Risk Matrix Template



Risk Matrix Impact Definitions

Rating	Definition
Extreme	Regional area affected with people off supply for a month or more OR asset de-rating exceeds ability to reinforce network leading to rota disconnections on peak demand.
Significant	County or city area affected with people off supply for a week or more OR asset de-rating requires a significant re-prioritisation of network reinforcement and deferment of new connection activities.
Moderate	Large town or conurbation off supply for up to a week OR significant increase in cost of network strengthening
Minor	Small town off supply for a 24-hour period OR significant increase in cost of network maintenance requirements.
Limited	Limited impact - can be managed within “business as usual” processes.

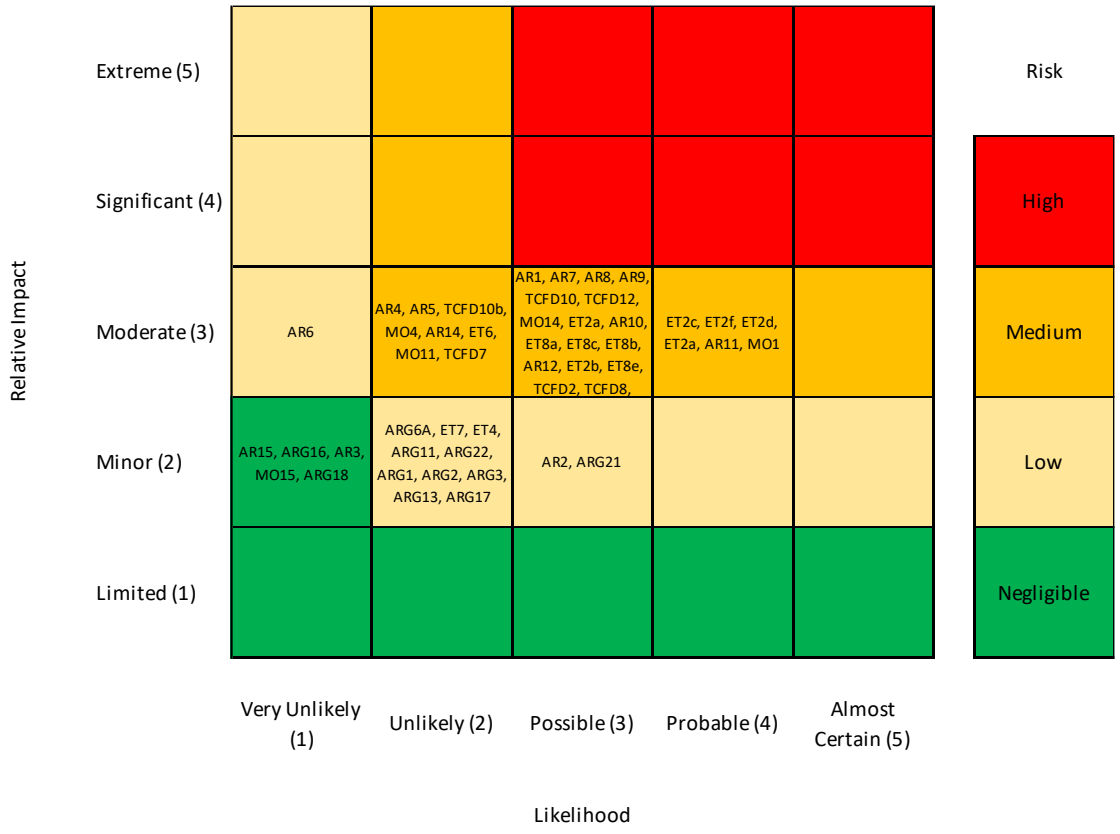
Risk Matrix Likelihood Definitions

Rating	Definition
Almost Certain	The risk is expected to be realised and may already be under active management as an event.
Likely	Past events have not been fully resolved, effective mitigations not yet identified, control weakness are known and are being managed.
Possible	Past events satisfactorily resolved, mitigations are in place or are on track to be in place, control improvements are under active management
Unlikely	Events are rare, required mitigations in place, controls are effective
Very Unlikely	No known event or if known extremely rare, extreme industry-wide scenarios

2.ARP2 Risk Matrix

ARP2 covered the period of 2011 to 2016. As stated above, to aid comparison with ARP3 and the 2050 assessment, NGET has undertaken a retrospective assessment of its ARP3 risks for the timeframe of ARP2.

ARP2 Risk Matrix



ARP 2 High and Medium Climate Adaptation Risks

Code	Risk	ARP2 Score
ET2c	Riverbank Stability and Scour	4x3
ET2f	Surface Water Runoff Scour	4x3
ET2d	Groundwater & Geohazards	4x3
ET2a	Geohazards	4x3
AR11	Substations affected by pluvial (flash) flooding due to increased rainstorms in Summer and Winter	4x3
MO 1	Increased intensity of short duration rainfall leading to flooding	4x3
AR1	Overhead line conductors affected by temperature rise.	3x3
AR7	Transformers affected by temperature rise	3x3
AR8	Transformers affected by urban heat islands and coincident air conditioning demand	3x3
AR9	Switchgear affected by temperature rise	3x3
TCFD10	Demand growth in Summer due to increased cooling load	3x3
TCFD12	Fast Freeze-thaw cycles	3x3
MO14	Diurnal Temperature Range	3x3
ET2e	Landslips, slope stability, ground creep, avalanche	3x3
AR10	Substations affected by river flooding due to increased winter rainfall	3x3
ET8a	Fluvial river and coastal flooding of NGET sites	3x3
ET8c	Shifting flood areas may affect existing sites in the future	3x3
ET8b	Fluvial river and coastal flooding – neighbouring sites leaving NGET sites stranded	3x3
AR12	Substations affected by sea flooding due to increased rainstorms and/or tidal surges	3x3
ET2b	Coastal Management Policy	3x3
ET8e	Flooding from Storm Surges	3x3
TCFD8	Perfect Storm of a cold winter, high electricity demand and heavy persistent rain	3x3
AR13	Substations affected by water flood wave from dam burst	3x3
ET8d	Reservoir / Canal Failure	3x3
AR4	Underground cable systems affected by increase in ground temperature,	2x3
AR5	Underground cable systems affected by Summer drought and consequential ground movement,	2x3
TCFD10b	Increased rate of loss of level in areas with already low depth of cover (e.g. Fenland area)	2x3

MO 4	Repeated Cycles of drought and rainfall	2x3
AR14	Overhead lines and transformers affected by increasing lightning activity	2x3
ET6	Severity, Intensity and Frequency of Storms	2x3
MO11	Warm, wetter conditions combined with rainfall and / or wind	2x3
TCFD7	Extreme weather events including a combination of wind, rainfall, temperature or snow	2x3

The retrospective assessment for the period of ARP2 identified no high risks.

Thirty-two medium risks were identified. Six of these are rated in the higher tier of having a 'likely' likelihood and 'moderate' impact (4x3); eighteen were identified as having a 'possible' likelihood and 'moderate' impact (3x3); while eight were identified in the lower tier of 'unlikely' likelihood and 'moderate' impact (2x3).

The highest risks identified can be split into three groups, namely erosion & scour, ground movement and flooding:

- **Riverbank Stability and Scour**: Erosion by rivers and the potential for impact of local assets.
- **Surface Water Runoff and Scour**: Erosion driven by surface water runoff (overland flow) resulting in damage to assets and foundations.
- **Groundwater Geohazards**: Undermining by sub-surface chemical processes (e.g., sink holes) or through physical erosion of soil and rock.
- **Geohazards**: Associated with compressible ground and shrink-swell areas resulting in the loss of foundation support or deformation of tower infrastructure.
- **Substations affected by pluvial (flash) flooding due to increased rainstorms in Summer and Winter**: The sudden increase in surface water flow resulting in flooding.
- **Increased intensity of short duration rainfall leading to flooding**: Isolated, intense and localised rainfall resulting in flooding.

The eighteen risks identified in the second tier of medium risks can be categorised into seven broad areas. These are:

- **Raised Temperatures**:
    - Overhead line conductors affected by temperature rise.
    - Transformers affected by temperature rise.
    - Transformers affected by urban heat islands and coincident air conditioning demand.
    - Switchgear affected by temperature rise.
    - Demand growth in Summer due to increased cooling load.
- **Temperature Cycles**:
    - Fast Freeze-thaw cycles.
    - Diurnal Temperature Range.
- **Erosion**: Landslips, slope stability, ground creep, avalanche.
- **Flooding**:
    - Substations affected by river flooding due to increased winter rainfall.

- Fluvial river and coastal flooding of NGET sites.
- Shifting flood areas may affect existing sites in the future.
- Fluvial river and coastal flooding – neighbouring sites leaving NGET sites stranded.

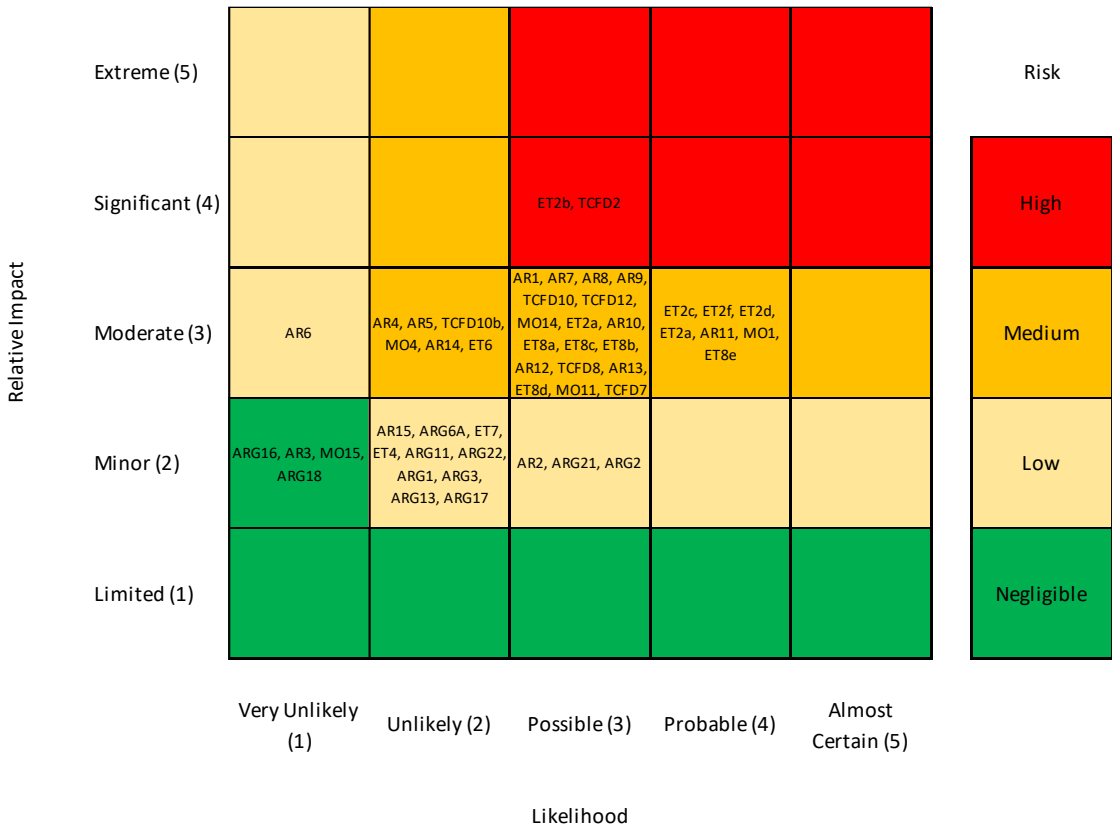
- **Coastal Change**:
  - Substations affected by sea flooding due to increased rainstorms and/or tidal surges.
  - Coastal Management Policy.
  - Flooding from Storm Surges.
- **Compound Event**: Perfect storm of a cold winter, high electricity demand and heavy persistent rain
- **Interdependencies:**
  - Substations affected by water flood wave from dam burst.
  - Reservoir / Canal Failure.

The lower, third tier of medium risks cover a number of risk areas including temperature, drought, erosion, lightning, storms and two compound events combining rainfall and wind.

3.ARP3 Risks

ARP3 covers the period 2016 to 2021.

ARP 3 Risk Matrix



ARP 3 High and Medium Climate Adaptation Risks

Code	Risk	ARP3 Score
ET2b	Coastal Management Policy	3x4
ET8e	Flooding from Storm Surges	3x4
ET2c	Riverbank Stability and Scour	4x3
ET2f	Surface Water Runoff Scour	4x3
ET2d	Groundwater & Geohazards	4x3
ET2a	Geohazards	4x3
AR11	Substations affected by pluvial (flash) flooding due to increased rainstorms in Summer and Winter	4x3
MO 1	Increased intensity of short duration rainfall leading to flooding	4x3
AR1	Overhead line conductors affected by temperature rise.	3x3
AR7	Transformers affected by temperature rise	3x3
AR8	Transformers affected by urban heat islands and coincident air conditioning demand	3x3
AR9	Switchgear affected by temperature rise	3x3
TCFD10	Demand growth in Summer due to increased cooling load	3x3
TCFD12	Fast Freeze-thaw cycles	3x3
MO14	Diurnal Temperature Range	3x3
ET2e	Landslips, slope stability, ground creep, avalanche	3x3
AR10	Substations affected by river flooding due to increased winter rainfall	3x3
ET8a	Fluvial river and coastal flooding of NGET sites	3x3
ET8c	Shifting flood areas may affect existing sites in the future	3x3
ET8b	Fluvial river and coastal flooding – neighbouring sites leaving NGET sites stranded	3x3
AR12	Substations affected by sea flooding due to increased rainstorms and/or tidal surges	3x3
MO11	Warm, wetter conditions combined with rainfall and / or wind	3x3
TCFD7	Extreme weather events including a combination of wind, rainfall, temperature or snow	3x3
TCFD8	Perfect Storm of a cold winter, high electricity demand and heavy persistent rain	3x3
AR13	Substations affected by water flood wave from dam burst	3x3
ET8d	Reservoir / Canal Failure	3x3
AR4	Underground cable systems affected by increase in ground temperature,	2x3

AR5	Underground cable systems affected by Summer drought and consequential ground movement,	2x3
TCFD10b	Increased rate of loss of level in areas with already low depth of cover (e.g. Fenland area)	2x3
MO 4	Repeated Cycles of drought and rainfall	2x3
AR14	Overhead lines and transformers affected by increasing lightning activity	2x3
ET6	Severity, Intensity and Frequency of Storms	2x3

ARP3 has identified two high risk issues and eighteen medium risks.

The highest risks identified are related to impacts at the coast, one due to the impact of nature processes and the second, linking with coastal management policy. These increased their risk rating from the middle tier of medium risk in ARP2 ('possible' likelihood and 'moderate' impact (3x3)) to high risk (a 'possible' likelihood and 'significant' impact (3x4)) in ARP3:

- **Coastal Management Policy**: The potential impact of policy on asset and asset management from changes in coastal management.
- **Flooding from Storm Surges**: The impact of coastal flooding compounded by sea level rise, erosion and tidal influences.

The highest tier medium risks identified in ARP3, having a 'likely' likelihood and 'moderate' impact (4x3) rating remained unchanged from ARP2. These are:

- **Riverbank Stability and Scour**
- **Surface Water Runoff and Scour**
- **Groundwater Geohazards**
- **Geohazards**
- **Substations affected by pluvial (flash) flooding due to increased rainstorms in Summer and Winter**
- **Increased intensity of short duration rainfall leading to flooding**

There was also little change in those risks classed in the second tier of medium risks, having a 'possible' likelihood and 'moderate' impact (3x3). The two risks that have increased during this period were:

- **Warm, wetter conditions combined with rainfall and / or wind**: In this case, the limiting factor is considered to be wind strength.
- **Extreme weather events including a combination of wind, rainfall, temperature or snow**: Where the risk of icing is considerable, particularly where there is 'wet snow' or cold rain, low temperatures and wind impacts on assets.

The remaining low-level medium risks in the lower category of 'unlikely' likelihood and 'moderate' impact (2x3) remain unchanged.

4.2050 Risks

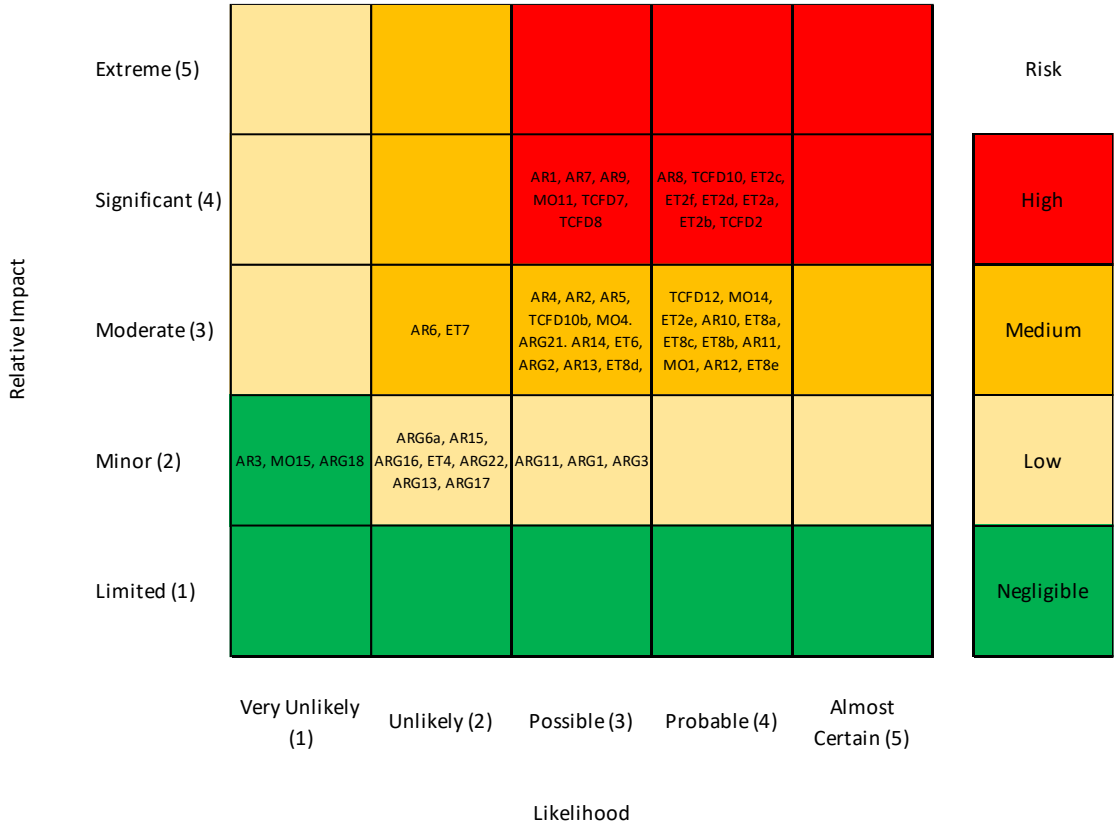
DEFRA has requested an assessment of the position in 2050 based on business as usual.

This assessment has therefore been undertaken from the perspective that the NGET network and working practices remain the same.

The ENA Climate Change Adaptation Reporting Group agreed that the assessment should be based on a high emission (worst case) scenario and is therefore consistent with the ENA Met Office Report.

The results should therefore be treated as a worst-case assessment rather than an indication of future performance.

2050 Risk Matrix



2050 High and Medium Climate Adaptation Risks

Code	Risk	2050 BAU Score
AR8	Transformers affected by urban heat islands and coincident air conditioning demand	4x4
TCFD10	Demand growth in Summer due to increased cooling load	4x4
ET2c	Riverbank Stability and Scour	4x4
ET2f	Surface Water Runoff Scour	4x4
ET2d	Groundwater & Geohazards	4x4
ET2a	Geohazards	4x4

ET2b	Coastal Management Policy	4x4
ET8e	Flooding from Storm Surges	4x4
AR1	Overhead line conductors affected by temperature rise.	3x4
AR7	Transformers affected by temperature rise	3x4
AR9	Switchgear affected by temperature rise	3x4
MO11	Warm, wetter conditions combined with rainfall and / or wind	3x4
TCFD7	Extreme weather events including a combination of wind, rainfall, temperature or snow	3x4
TCFD8	Perfect Storm of a cold winter, high electricity demand and heavy persistent rain	3x4
TCFD12	Fast Freeze-thaw cycles	4x3
MO14	Diurnal Temperature Range	4x3
ET2e	Landslips, slope stability, ground creep, avalanche	4x3
AR10	Substations affected by river flooding due to increased winter rainfall	4x3
ET8a	Fluvial river and coastal flooding of NGET sites	4x3
ET8c	Shifting flood areas may affect existing sites in the future	4x3
ET8b	Fluvial river and coastal flooding – neighbouring sites leaving NGET sites stranded	4x3
AR11	Substations affected by pluvial (flash) flooding due to increased rainstorms in Summer and Winter	4x3
MO 1	Increased intensity of short duration rainfall leading to flooding	4x3
AR12	Substations affected by sea flooding due to increased rainstorms and/or tidal surges	4x3
AR4	Underground cable systems affected by increase in ground temperature	3x3
AR2	Overhead line structures affected by Summer drought and consequent ground movement	3x3
AR5	Underground cable systems affected by Summer drought and consequential ground movement,	3x3
TCFD10b	Increased rate of loss of level in areas with already low depth of cover (e.g. Fenland area)	3x3
MO 4	Repeated Cycles of drought and rainfall	3x3
ARG21	Saline contamination and increased corrosion rate of above and below ground assets from sea water or atmospheric salt	3x3
AR14	Overhead lines and transformers affected by increasing lightning activity	3x3
ET6	Severity, Intensity and Frequency of Storms	3x3
ARG2	Lack of specific policies and procedures governing risk assessment process on climate change	3x3
AR13	Substations affected by water flood wave from dam burst	3x3

ET8d	Reservoir / Canal Failure	3x3
AR6	Substation and network earthing systems adversely affected by Summer drought conditions	2x3
ET7	Snow & Ice; Severity, intensity and frequency of storms	2x3

2050 Discussion

Fourteen high-level risks have been identified in the 2050 assessment. Eight of these are classified in the higher tier as having a 'likely' likelihood and 'significant' impact (4x4). These include the two high-level coastal risks described in ARP3. These are:

- **Coastal Management Policy**
- **Flooding from Storm Surges**
- **Geohazards**
- **Groundwater & Geohazards**
- **Surface Water Runoff Scour**
- **Riverbank Stability and Scour**
- **Demand growth in Summer due to increased cooling load**
- **Transformers affected by urban heat islands and coincident air conditioning demand**

The six high-level risks in the lower tier, having a 'possible' likelihood and 'significant' impact (3x4) can be split into two distinct groups. The emergence of temperature related impacts in this and the high-risk category is consistent with the ENA Met Office Report:

- **Temperature**:
    - Overhead line conductors affected by temperature rise
    - Transformers affected by temperature rise
    - Switchgear affected by temperature rise
- **Compound Events**:
    - Warm, wetter conditions combined with rainfall and / or wind
    - Extreme weather events including a combination of wind, rainfall, temperature or snow
    - Perfect Storm of a cold winter, high electricity demand and heavy persistent rain

Of the ten highest medium risks, having a 'likely' likelihood and 'moderate' impact (4x3), all but one (**Substations affected by pluvial (flash) flooding due to increased rainstorms in Summer and Winter**) have increased from their position in ARP3. Of these, six are related to the risk of **increased flooding**:

- **Fast Freeze-thaw cycles**
- **Diurnal Temperature Range**
- **Landslips, slope stability, ground creep, avalanche**
- **Substations affected by river flooding due to increased winter rainfall**
- **Fluvial river and coastal flooding of NGET sites**
- **Shifting flood areas may affect existing sites in the future**
- **Fluvial river and coastal flooding – neighbouring sites leaving NGET sites stranded**

- **Increased intensity of short duration rainfall leading to flooding**
- **Substations affected by sea flooding due to increased rainstorms and/or tidal surges**

ARP3 Risk Narrative

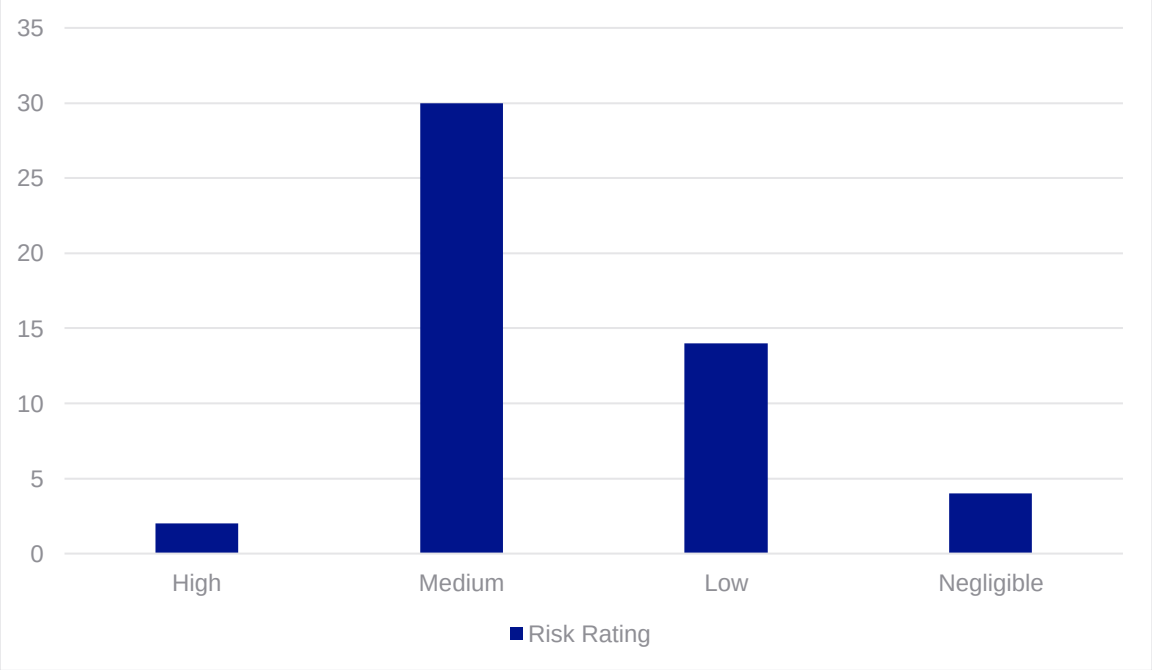
Introduction

This chapter discusses the findings of the NGET risk assessment. Although scoring has been undertaken above, the ARP2 risk assessment is used here only as a basis to discuss ARP3 and 2050 risk assessments. Detailed discussion of the risks for ARP2 can be found in the report referenced above.

As discussed, NGET undertook a detailed gap analysis of its risks associated with climate change. A total of 86 risks were initially identified by NGET as part of the screening assessment for ARP3. These came from previous and present ENA risk assessments, the ENA Met Office Report, National Grid Gas Climate Risk and TCFD assessment work. Of these, 50 were carried through for detailed assessment.

The high and medium risks are discussed below, and the overall scores and risk ratings can be found in Appendix 1. A summary chart of the risk ratings for ARP3 are shown in the following table.

ARP3: Number of Risks by Category



High Risks

Coastal Change

The greatest risk for ARP3 is considered to be in relation to the coast where storm surges can present a significant risk. In combination with sea level rise, erosion and tidal influences, they can cause coastal flooding on a much greater scale than any of the individual risks. Furthermore, particularly in areas such as the large river estuaries where funnelling occurs, the magnitude of their impact can be further increased to affect those sites not normally considered to be at risk from coastal flooding.

NGET is aware of the sensible and pragmatic shift in coastal policy during recent decades, from defend and construct to a more nuanced assessment of intervention that is stakeholder driven.

Medium Risks

The medium NGET climate change risks can be split into five areas and are reflective of the ENA Met Office climate study. They are also broadly consistent with the findings of ARP2, therefore demonstrating little change in risk between the two periods.

The risks relating to canal and dam burst are discussed in the following section on interdependencies and so only four areas are discussed here.

The context of these risks should also be noted. Given the inherent resilience of the NGET network, these risks are not at present significant. The commentary and actions should therefore be considered in that context.

Erosion, Ground Movement and Scour

Erosion and ground movement poses a risk to NGET assets. Overhead line towers, given their number, distribution and need to traverse many challenging landscapes are vulnerable to impacts that affect their stability.

Causes identified include, river and surface water scour, groundwater erosion, shrink-swell, freeze-thaw cycles and slope instability.

It is considered that impacts are already being experienced across the NGET network. Line walking, aerial surveillance and studies such as those undertaken with the British Geological Survey on NGET behalf have identified assets at current and increased risks.

Flooding

Flooding, whether from rivers, surface runoff or sea level rise, presents a number of challenges which were highlighted in the assessment. It has the potential to inundate sites, isolate them from access, impact erosion/deposition and in worst case scenarios cause a loss of electricity supply.

Seven flood risks have been assessed as medium. They reflect how flooding is an ephemeral and shifting issue across our landscape, with the potential to impact a wide range of NGET assets. This is highlighted in the identified risk of ‘shifting flood areas may affect existing sites in the future’ which is a recognition that the nature of flooding rarely stays stable and that it should be kept under review.

Raised Temperatures

Higher temperatures have the ability to impact a number of NGET assets in addition to driving extra demand, particularly in the summer (e.g., from the uptake of air conditioning). Highlighted impacts were related to overhead line conductors, transformers and switchgear.

Of note is the increased the additional generation of heat islands in urban areas which can result in focussed areas of impact. While not common in the present climate they do have the potential to constrain NGETs urban networks and supplies.

Compound Events

Three compound events were identified as medium risks. While formed from a combination of risks, they primarily have underlying primary causes. While rainfall may cause increased erosion or localised flooding, the impact from these compound events was assessed as being due to the over-riding impact of the wind and cold, resulting in damage and ice loading respectively.

Interdependencies

Eight interdependencies have been considered in the risk assessment namely:

- AR15: Wildfires
- ET2b: Coastal Management Policy

- ET8b: Pluvial flooding resulting in NGET sites being stranded
- ARG13**:** Vulnerability of critical IT systems managed by third parties from extreme weather events
- AR17: Supply chain impacts
- ET8d: Reservoir / canal failure
- AR13: Substations affected by water flood wave from dam burst
- AR3: Overhead lines affected by interference from vegetation due to prolonged growing season

With the exception of **reservoir/ canal failure** and **substations affected by water flood wave from dam burst**, these risks were all considered to be low or negligible.

While large reservoir and dam structures are subject to significant regulation, the assessment considered smaller structures that are currently not subject to the same level of control. These structures have the potential to impact NGET assets should they fail, whether that be locally in a significant loss of supply or pluvial flooding in the wider influence area.

Conclusion

The ARP3 assessment has demonstrated that NGET remains resilient to the observed impacts of climate change. There is limited change from the period of ARP2 in the majority of risks. However, while the level of change is limited and risk management frameworks are presently suitable, the emergence of high risks demonstrates that change is occurring. NGET therefore recognises the need to continually reappraise its climate risks to ensure it remains resilient in the future.

2050 Risk Narrative

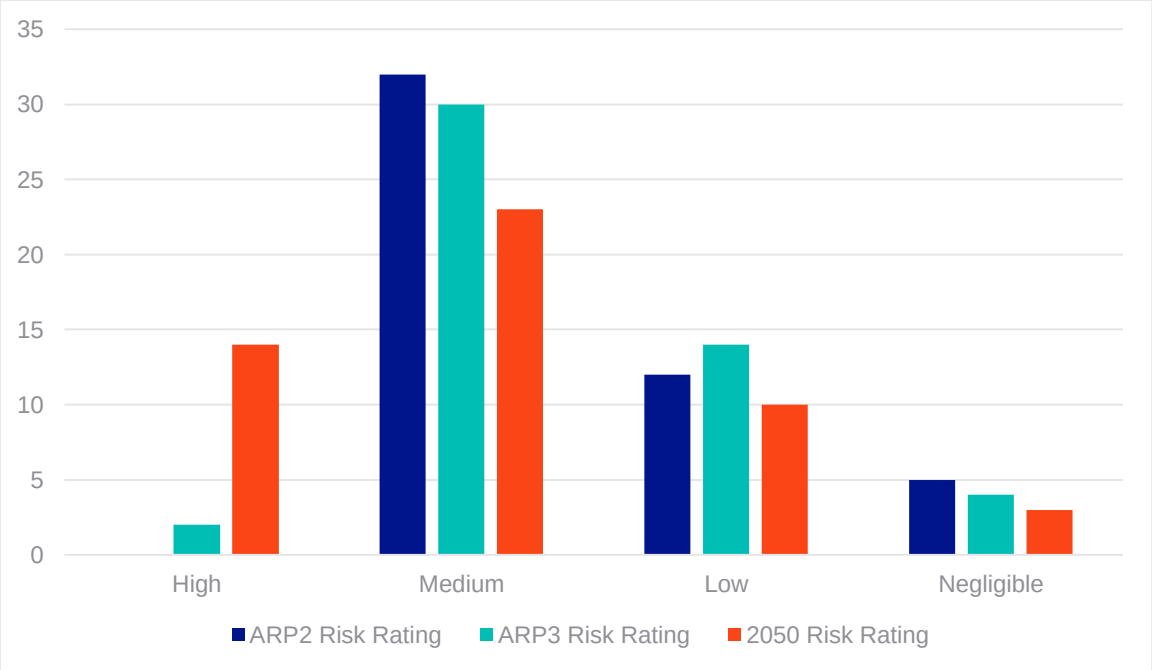
Introduction

For the ARP3 report, DEFRA requested the risk assessment look to the potential business impacts in 2050 should a business-as-usual approach be taken.

NGET therefore took the same approach as the main ARP3 assessment, utilising information from UKCP18 and the ENA Met Office Report. It is however important to recognise that the assessment is qualitative and reliant on a wide range of assumptions.

Next steps are not discussed in this chapter as any relevant actions are presented above. It is also important with such a long-term view that other work streams, such as the TCFD Climate Modelling project feed into the business' long-term planning.

2050: Number of Risks by Category and comparison with ARP2 and ARP3



As would be expected, there is a level of risk escalation from ARP2 and 3, with a greater number of high and medium risks identified in 2050. Based on business as usual, NGET would have fourteen high risks and twenty-three in the medium category.

High Risks

The fourteen high-risk areas can be grouped into five broad categories.

Temperature

This risk carries over from ARP3. Evidence from UKCP18 and the ENA Met Office Report demonstrates that average and peak temperatures will rise through the century and so the potential impact on both demand and asset will increase. The potential increase in demand for summer cooling is seen as the primary driver alongside the generation of heat islands in urban settings.

It is considered that impacts will be seen across the network in areas including overhead line conductors, and substation transformers and switchgear.

Erosion, Ground Movement and Scour

The ENA Met Office Report identified changes to rainfall during coming decades. They outlined increased rainfall in the west and north of the UK; an increase in intense, short-duration rainfall and a signal towards wetter autumns. This may also be combined with hot and dry summers that make soils less able to allow infiltration, thus resulting in greater volumes of water retained at the surface.

The assessment considered these changes will result in an increase in riverbank, surface and subsurface water runoff issues, increasing the vulnerability of structures including overhead line towers.

Changes to the water cycle, resulting from the changes to rainfall patterns described in the ENA Met Office Report suggest climate change will produce an increase in the occurrence and impact of Geohazards.

Flooding

As discussed above, there will be significant changes to rainfall patterns across the UK in coming decades. Alongside erosion, changes to the location, frequency and duration of rainfall will present challenges from both fluvial, pluvial and coastal flooding.

The assessment considered that this change in rainfall patterns presents a challenge to existing flood mitigation work as the focus shifts across catchments and the landscape in general. This will also be impacted by human driven changes to the landscape (e.g., new buildings and roads) which will themselves drive a change in runoff patterns and potentially impact flood characteristics.

It is therefore key that flood risk assessments are continually updated to reflect changes in land use, rainfall patterns and our understanding to ensure that appropriate levels of flood protection (whether natural or physical in nature) are implemented to protect NGET assets.

Coastal Change

Both physical risks at the coast (in the form of sea level rise and storm surges) and the influence of shoreline management policy were considered in the assessment.

The ENA Met Office report was clear in outlining the likely extent of sea-level rise through the century. As a result, the assessment considered the associated impact of flooding from storm surges to be an escalating risk to NGET assets at the coast.

The impacts from projected sea level rise and increase in storm activity may lead to an increase in associated impacts such as flooding. These impacts may be amplified in particularly vulnerable areas.

Policy driven response to coastal change was also considered, particularly long-term coastal management strategies that are focussed on managed realignment or retreat where we have sites and assets. It is considered this may mean NGET being required to either move assets or seek to protect them which could require significant investment.

Compound Events

As discussed above, these events were identified due to the over-riding potential for wind and cold weather impacts on assets rather than as a combination. The assessment considered that while the likelihood of such events might not increase, the potential impacts on the network have the potential to. Understanding of and actionable data on how the impacts of a single event may amplify, raise or extend the vulnerabilities from a connected or unconnected climate hazard is very low.

Medium Risks

Twenty-three medium risks were identified within the 2050 assessment. Many are those identified in ARP3 that haven't escalated to a high-level risk in the intervening period. Of note is flooding, which has remained in the higher tier of medium risks throughout the ARP process.

The medium risks represent flooding, temperature variations, ground movement, lightning, depth of cover, storms, lightning and reservoir / canal / dam failure.

Three of the risks relate to increased dryer conditions, particularly in the south and east of the UK, thus representing an emerging risk during coming decades:

- AR2: Overhead line structures affected by summer drought and consequent ground movement
- MO4: Repeated cycles of drought and rainfall
- AR6: Substation and network earthing systems adversely affected by summer drought conditions

The remaining additions to the medium risk category saw a slight increase in saline contamination (due to sea level rise), the intensity of snow and ice storms and the risk of not having specific climate change related policies.

Interdependencies

Of the eight interdependencies discussed in ARP3, there was no change in the risk category for each. The risks were seen to have increased but only within their ARP3 category.

Conclusion

The 2050 assessment demonstrates the potential scale and escalating impact of climate change. The range of risks highlighted indicate that long term planning will be necessary to adapt and maintain the level of resilience our customers and regulators demand. Addressing these risks at a high level may include regular reviews or risk assessments of:

- Flood risk
- Temperature levels, including continuous high temperatures and heat island
- Coastal management policy, including stakeholder engagement in the development of Shoreline Management Plans
- Erosion, ground movement and scour
- The impact of drought
- Ratings and rating assessments

The time required to assess these issues and undertake appropriate investment makes long-term planning essential. However, it must be recognised that long term guidance and frameworks are also needed from our regulators to ensure that a co-ordinated and effective approach can be taken that ensures consistency across industry to climate change adaptation.

Conclusion

The NGET ARP3 report considers the physical risk to our transmission assets. Unlike previous reports when the system operator was part of NGET, it does not consider system risks, which now sit with National Grid Electricity System Operator. Furthermore, while Wester Power Distribution joined National Grid in June 2021 prior to the publication of this report, they will be reporting separately.

This ARP3 report represents a step change in NGET's climate adaption assessments. For the first time, in conjunction with the ENA and DNO partners, we have completed a fully scored climate impact risk assessment. To provide comparison with previous reports we have also retrospectively undertaken the assessment for ARP2 and in line with DEFRA requirements, have taken a view to 2050.

The assessment, in recognition of NGET's commitment to understanding our climate change impacts, has involved a full gap analysis our potential climate risks; collating 86 potential risks and formally assessing 50 in this report.

The ARP3 risk assessment has identified 2 new high risks in Coastal Management Policy and Flooding from Storm Surges. This recognises recent changes in climate, weather systems and sea level, alongside a shift from a defensive to pragmatic coastal management policy.

The high and medium climate risks identified in ARP3, while more specific in nature, are broadly consistent with previous NGET adaptation reports:

- Coastal Change
- Raised Temperatures
- Temperature Cycles
- Erosion, Ground Movement and Scour
- Flooding
- Compound Events and Storms involving high winds
- Lightning
- Drought

The 2050 assessment illustrates the escalating nature of climate change. Twelve risks identified as higher tier medium risks in ARP3 will increase to high risks in the period to 2050. These include high temperatures; erosion, ground movement and scour; flooding; coastal change and compound events. The dependency of other infrastructure and service providers mitigating their climate change risks will also increase during the coming years and decades.

This report therefore determines that it will be necessary for NGET to continually appraise its understanding of climate risk and the potential scale and timing of impacts on its assets. This will be through a range of measures including climate modelling, risk assessment, process development and engagement with external stakeholder and policy makers.

While 2050 is a key date in climate policy, the report demonstrates that action is needed now and consistently during the coming decades. Inaction will only result in a loss of resilience and the opportunity to implement satisfactory solutions, particularly where risk assessment, investment planning and (where needed) construction might take many years.

The ARP3 and 2050 assessments highlight the real need for continued preparedness and long-term planning by NGET, but also by industry and regulators. As future scenario data becomes more certain, a flexible and adaptive approach will need to be applied when installing new assets to ensure they are resilient to future scenarios. There is a need that longer term resilience planning be factored into asset design and installation either now or cater for potential increased vulnerabilities over the lifespan of our long-life assets.

Finally, given the likely and significant climate related challenges in the future, it is key that all sectors have the time required to identify emerging risks and the opportunity to adequately plan, finance and implement adaptation measures in a co-ordinated manner.

Appendix 1: NGET ARP Scoring Matrices

ARP2 Risk Ratings

Code	Risk	ARP2 Score
ET2c	Riverbank Stability and Scour	4x3
ET2f	Surface Water Runoff Scour	4x3
ET2d	Groundwater & Geohazards	4x3
ET2a	Geohazards	4x3
AR11	Substations affected by pluvial (flash) flooding due to increased rainstorms in Summer and Winter	4x3
MO 1	Increased intensity of short duration rainfall leading to flooding	4x3
AR1	Overhead line conductors affected by temperature rise.	3x3
AR7	Transformers affected by temperature rise	3x3
AR8	Transformers affected by urban heat islands and coincident air conditioning demand	3x3
AR9	Switchgear affected by temperature rise	3x3
TCFD10	Demand growth in Summer due to increased cooling load	3x3
TCFD12	Fast Freeze-thaw cycles	3x3
MO14	Diurnal Temperature Range	3x3
ET2e	Landslips, slope stability, ground creep, avalanche	3x3
AR10	Substations affected by river flooding due to increased winter rainfall	3x3
ET8a	Fluvial river and coastal flooding of NGET sites	3x3
ET8c	Shifting flood areas may affect existing sites in the future	3x3
ET8b	Fluvial river and coastal flooding – neighbouring sites leaving NGET sites stranded	3x3
AR12	Substations affected by sea flooding due to increased rainstorms and/or tidal surges	3x3
ET2b	Coastal Management Policy	3x3
ET8e	Flooding from Storm Surges	3x3
TCFD8	Perfect Storm of a cold winter, high electricity demand and heavy persistent rain	3x3
AR13	Substations affected by water flood wave from dam burst	3x3
ET8d	Reservoir / Canal Failure	3x3
AR4	Underground cable systems affected by increase in ground temperature,	2x3
AR5	Underground cable systems affected by Summer drought and consequential ground movement,	2x3

TCFD10b	Increased rate of loss of level in areas with already low depth of cover (e.g. Fenland area)	2x3
MO 4	Repeated Cycles of drought and rainfall	2x3
AR14	Overhead lines and transformers affected by increasing lightning activity	2x3
ET6	Severity, Intensity and Frequency of Storms	2x3
MO11	Warm, wetter conditions combined with rainfall and / or wind	2x3
TCFD7	Extreme weather events including a combination of wind, rainfall, temperature or snow	2x3
AR2	Overhead line structures affected by Summer drought and consequent ground movement	3x2
ARG21	Saline contamination and increased corrosion rate of above and below ground assets from sea water or atmospheric salt	3x2
ARG6a	Above and below ground assets affected by lower temperatures	2x2
ET7	Snow & Ice; Severity, intensity and frequency of storms	2x2
ET4	Polluted ground fires, Old Mine workings	2x2
ARG11	Ground contamination and transport of materials from flooding of contaminated sites	2x2
ARG22	Groundwater flooding of below ground assets leading to water ingress to pipes	2x2
ARG1	Lack of climate change management procedure	2x2
ARG2	Lack of specific policies and procedures governing risk assessment process on climate change	2x2
ARG3	Risk and action owners not identified at senior leadership team level	2x2
ARG13	Vulnerability of critical IT systems managed by third parties from extreme weather events	2x2
ARG17	Supply chain impacts	2x2
AR6	Substation and network earthing systems adversely affected by Summer drought conditions	1x3
AR15	Wildfires	1X2
ARG16	Wildlife impacts	1x2
AR3	Overhead lines affected by interference from vegetation due to prolonged growing season	1x2
MO15	Solar Storm	1x2
ARG18	BCM plans affected due to severe travel difficulties resulting from extreme weather events	1x2

ARP3 Risk Ratings

Code	Risk	ARP3 Score
ET2b	Coastal Management Policy	3x4
ET8e	Flooding from Storm Surges	3x4
ET2c	Riverbank Stability and Scour	4x3
ET2f	Surface Water Runoff Scour	4x3
ET2d	Groundwater & Geohazards	4x3
ET2a	Geohazards	4x3
AR11	Substations affected by pluvial (flash) flooding due to increased rainstorms in Summer and Winter	4x3
MO 1	Increased intensity of short duration rainfall leading to flooding	4x3
AR1	Overhead line conductors affected by temperature rise.	3x3
AR7	Transformers affected by temperature rise	3x3
AR8	Transformers affected by urban heat islands and coincident air conditioning demand	3x3
AR9	Switchgear affected by temperature rise	3x3
TCFD10	Demand growth in Summer due to increased cooling load	3x3
TCFD12	Fast Freeze-thaw cycles	3x3
MO14	Diurnal Temperature Range	3x3
ET2e	Landslips, slope stability, ground creep, avalanche	3x3
AR10	Substations affected by river flooding due to increased winter rainfall	3x3
ET8a	Fluvial river and coastal flooding of NGET sites	3x3
ET8c	Shifting flood areas may affect existing sites in the future	3x3
ET8b	Fluvial river and coastal flooding – neighbouring sites leaving NGET sites stranded	3x3
AR12	Substations affected by sea flooding due to increased rainstorms and/or tidal surges	3x3
MO11	Warm, wetter conditions combined with rainfall and / or wind	3x3
TCFD7	Extreme weather events including a combination of wind, rainfall, temperature or snow	3x3
TCFD8	Perfect Storm of a cold winter, high electricity demand and heavy persistent rain	3x3
AR13	Substations affected by water flood wave from dam burst	3x3
ET8d	Reservoir / Canal Failure	3x3
AR4	Underground cable systems affected by increase in ground temperature,	2x3

AR5	Underground cable systems affected by Summer drought and consequential ground movement,	2x3
TCFD10b	Increased rate of loss of level in areas with already low depth of cover (e.g. Fenland area)	2x3
MO 4	Repeated Cycles of drought and rainfall	2x3
AR14	Overhead lines and transformers affected by increasing lightning activity	2x3
ET6	Severity, Intensity and Frequency of Storms	2x3
AR2	Overhead line structures affected by Summer drought and consequent ground movement	3x2
ARG21	Saline contamination and increased corrosion rate of above and below ground assets from sea water or atmospheric salt	3x2
ARG2	Lack of specific policies and procedures governing risk assessment process on climate change	3x2
ARG6a	Above and below ground assets affected by lower temperatures	2x2
AR15	Wildfires	2X2
ET7	Snow & Ice; Severity, intensity and frequency of storms	2x2
ET4	Polluted ground fires, Old Mine workings	2x2
ARG11	Ground contamination and transport of materials from flooding of contaminated sites	2x2
ARG22	Groundwater flooding of below ground assets leading to water ingress to pipes	2x2
ARG1	Lack of climate change management procedure	2x2
ARG3	Risk and action owners not identified at senior leadership team level	2x2
ARG13	Vulnerability of critical IT systems managed by third parties from extreme weather events	2x2
ARG17	Supply chain impacts	2x2
AR6	Substation and network earthing systems adversely affected by Summer drought conditions	1x3
ARG16	Wildlife impacts	1x2
AR3	Overhead lines affected by interference from vegetation due to prolonged growing season	1x2
MO15	Solar Storm	1x2
ARG18	BCM plans affected due to severe travel difficulties resulting from extreme weather events	1x2

ARP3 2050 Risk Ratings

Code	Risk	2050 BAU Score
AR8	Transformers affected by urban heat islands and coincident air conditioning demand	4x4
TCFD10	Demand growth in Summer due to increased cooling load	4x4
ET2c	Riverbank Stability and Scour	4x4
ET2f	Surface Water Runoff Scour	4x4
ET2d	Groundwater & Geohazards	4x4
ET2a	Geohazards	4x4
ET2b	Coastal Management Policy	4x4
ET8e	Flooding from Storm Surges	4x4
AR1	Overhead line conductors affected by temperature rise.	3x4
AR7	Transformers affected by temperature rise	3x4
AR9	Switchgear affected by temperature rise	3x4
MO11	Warm, wetter conditions combined with rainfall and / or wind	3x4
TCFD7	Extreme weather events including a combination of wind, rainfall, temperature or snow	3x4
TCFD8	Perfect Storm of a cold winter, high electricity demand and heavy persistent rain	3x4
TCFD12	Fast Freeze-thaw cycles	4x3
MO14	Diurnal Temperature Range	4x3
ET2e	Landslips, slope stability, ground creep, avalanche	4x3
AR10	Substations affected by river flooding due to increased winter rainfall	4x3
ET8a	Fluvial river and coastal flooding of NGET sites	4x3
ET8c	Shifting flood areas may affect existing sites in the future	4x3
ET8b	Fluvial river and coastal flooding – neighbouring sites leaving NGET sites stranded	4x3
AR11	Substations affected by pluvial (flash) flooding due to increased rain storms in Summer and Winter	4x3
MO 1	Increased intensity of short duration rainfall leading to flooding	4x3
AR12	Substations affected by sea flooding due to increased rainstorms and/or tidal surges	4x3
AR4	Underground cable systems affected by increase in ground temperature,	3x3
AR2	Overhead line structures affected by Summer drought and consequent ground movement	3x3

AR5	Underground cable systems affected by Summer drought and consequential ground movement,	3x3
TCFD10b	Increased rate of loss of level in areas with already low depth of cover (e.g. Fenland area)	3x3
MO 4	Repeated Cycles of drought and rainfall	3x3
ARG21	Saline contamination and increased corrosion rate of above and below ground assets from sea water or atmospheric salt	3x3
AR14	Overhead lines and transformers affected by increasing lightning activity	3x3
ET6	Severity, Intensity and Frequency of Storms	3x3
ARG2	Lack of specific policies and procedures governing risk assessment process on climate change	3x3
AR13	Substations affected by water flood wave from dam burst	3x3
ET8d	Reservoir / Canal Failure	3x3
AR6	Substation and network earthing systems adversely affected by Summer drought conditions	2x3
ET7	Snow & Ice; Severity, intensity and frequency of storms	2x3
ARG6a	Above and below ground assets affected by lower temperatures	2x2
AR15	Wildfires	2X2
ARG16	Wildlife impacts	2x2
ET4	Polluted ground fires, Old Mine workings	2x2
ARG11	Ground contamination and transport of materials from flooding of contaminated sites	3x2
ARG22	Groundwater flooding of below ground assets leading to water ingress to pipes	2x2
ARG1	Lack of climate change management procedure	3x2
ARG3	Risk and action owners not identified at senior leadership team level	3x2
ARG13	Vulnerability of critical IT systems managed by third parties from extreme weather events	2x2
ARG17	Supply chain impacts	2x2
AR3	Overhead lines affected by interference from vegetation due to prolonged growing season	1x2
MO15	Solar Storm	1x2
ARG18	BCM plans affected due to severe travel difficulties resulting from extreme weather events	1x2

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