Adaptation to Climate Change Task Group

Gas & Electricity Transmission and Distribution Network Companies

3rd Round Climate Change Adaptation Report

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1. Introduction

Method of producing the report and background information

Energy Networks Association (ENA) is the trade association for the energy networks. Our members own and operate the wires and pipes which carry electricity and gas into your community, supporting our economy. This assessment report has been developed in response to the requirements placed on reporting authorities by the Climate Change Act under the 3rd Round of Adaptation Reporting.

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

- In ARP1 we 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. The key messages for the gas network businesses similarly revolved around the resilience of the gas networks and any climate vulnerabilities.
- In ARP2 we built on our understanding of the risks and updated DEFRA on industry mitigation measures being put into place on the networks. We developed the consistent reporting methodology from ARP1 and provided further evidence of actions taken in response to key climate risks.
- In ARP3 we aim to provide an update on existing risks, mitigation measures and programmes, but will also look 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 this ARP3 report aims to consolidate Gas and Electricity network reports to provide an Energy Networks response.

This report has been prepared by a task group of gas and electricity distribution and transmission network operator members of ENA and is intended to provide a response to climate change adaptation on behalf of the Energy Networks. This report continues the progress made since the second round of reporting and should be read in conjunction with the 2nd Round Reports.

It is intended that companies can use this report as the basis for their individual reports which will also include company specific information. This report intentionally provides information at an industry level as details of how risk is specifically managed within member companies will be dealt with within their individual reports.

Transmission and distribution companies in Great Britain are regulated businesses and operate under licences issued by the Office of Gas and Electricity Markets (Ofgem), and are also subject to common statutory requirements which are overseen by the Department for Business, Energy and Industrial Strategy (BEIS), the Health and Safety Executive (HSE), the Environment Agency (EA), the Scottish Environment Protection Agency (SEPA), and Natural Resources Wales (NRW). Allowed revenues for the industry are currently set by Ofgem in periodic price reviews and therefore any costs associated with adaptation to climate change need to be agreed with Ofgem.

Transmission and distribution companies are responsible for transporting gas and electrical power from generating plants to customers over their networks. Overall levels of supply security are agreed with Ofgem and these standards specify the requirements for the availability of alternative supplies at various levels of customer load. Although these standards allow for the loss of multiple electrical circuits, they do not provide for certain low probability events including multiple failures or the total failure of the network. Particular attention must therefore be given to key sites when considering network resilience.

Whilst every effort is made to ensure network resilience, companies have well developed business continuity and emergency plans to ensure an effective response to a range of events that can affect both transmission and distribution networks. Under the terms of the Civil Contingencies Act, network operators are Category Two responders and work closely with other utilities, the emergency services and local authorities. They are also active participants in the BEIS Energy Emergencies Executive Committee (E3C).

Headline climate change impacts

The main impacts on gas and electricity networks from the latest independent Met Office UKCP18 climate change projections remain:

- Temperature—predicted increase.

- Precipitation—predicted increase in winter rainfall and summer droughts.
- Sea level rise—predicted increase.
- Storm surge—predicted increase.
- Increasing wet – dry cycles.
- Increasing windstorm frequency (particularly when following high intensity precipitation).
- Significant cold spells – predicted decrease but more severe.
- Wildfire.

2. Climate Change Research

In considering adaptation to climate change, electricity and gas network companies use the Met Office UK Climate Projection (UKCP18) tool, and take into account projections to the end of this century as much of the network infrastructure generally has an operational life expectancy of 30-80 years.

In spring/summer 2020, on behalf of its members, ENA commissioned the Met Office to undertake a review of the UKCP18 data and existing studies in 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 the energy network, and to guide future mitigation or management actions. In addition, other tools, for example the Landmark flood mapping tool, have been used by Energy network organisations in research and risk assessment independent to the ENA Met Office research.

Because of the diversity of the hazards it was decided to prioritise those which pose the highest risk to energy network assets, and the assessment process was accordingly graded to provide an appropriate focus.

- 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

3. Met Office Report Outputs

The final version of the commissioned report was provided by the Met Office in November 2020.

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, 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 the 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 and emergency restoration. Societal responses to climate change may also increase the risk on the road network *from* the electricity network, as electric vehicles become more commonplace.

4. Climate Change Adaptation Risks

This section details the Adaptation Risks referenced in the first and second round reports and highlighted in the third-round reporting template. The climate variables and their impact on the transmission and distribution networks have been identified. The mitigation measures being undertaken by networks are outlined in Section 5.

4.1 Electricity Network Risks

AR1 Temperature - Overhead line conductors affected by temperature rise

Thermal expansion of conductors in Summer is a common consideration for all overhead lines, 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 overhead line 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 of the network as a consequence. Conductors are designed to operate at their maximum efficiency up to a maximum core temperature, and 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.

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

Increasing temperatures will, without precipitation, lead to drying of the ground causing it to shrink. 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.

AR3 Temperature / precipitation - Overhead lines affected by interference from vegetation due to prolonged growing season

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

AR4 Temperature - Underground cable systems affected by increase in ground temperature

As with overhead lines, increasing temperatures impact on the capacity of cables and of the network as a consequence. Cables are designed to operate at their maximum efficiency up to a maximum core temperature, and as the ground 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 and thus reducing its capacity.

AR5 Temperature - Underground cable systems affected by Summer drought and consequential ground movement

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 can fail by being effectively pulled apart. Extreme wet-dry and freeze-thaw ground movements will have a similar impact.

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

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.

AR7 Temperature - Transformers affected by temperature rise

As with cables and overhead conductors, transformers are designed to operate within particular temperature parameters. As air temperature increases it becomes more difficult to expel the heat created by the

transformation process, consequently transformers can begin to overheat reducing capacity and life expectancy and, in extreme cases, causing catastrophic failure of the unit.

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

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.

AR9 Temperature - Switchgear affected by temperature rise

Increasing temperature impacts all plant and equipment and increases will impact on switchgear by reducing its capacity, or in extreme cases lead to the switchgear tripping resulting in loss of supply or operating incorrectly and damaging the network. Prolonged periods of hot weather will increase the temperature inside switch rooms above the maximum optimum operating parameter for the switchgear increasing the potential for faults or mal-operation.

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

AR10 Precipitation - Substations affected by river (fluvial) flooding due to increased winter rainfall

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

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

Regardless of the source the impact of flooding on ground located assets is the same. Plant and equipment is physically damaged by flood water, but water ingress will also 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 extending restoration of supply to local areas. Network operators will often choose to switch out plant and equipment in order to avoid water ingress causing a fault and uncontrolled shut down.

AR13 Precipitation - Substations affected by water flood wave from dam burst

Where substations are located far enough away from dams the impact of water inundation from a dam burst is no different from “standard” pluvial, fluvial, or tidal flooding and flooding impacts can be considered similar.

Where substations are close enough to dams to be impacted by the full force of a breach, the damage to a substation would be substantial. Plant and equipment would not only be impacted by water ingress but are likely to 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 fully reconstructing and recommissioning the site.

AR 14 Overhead lines and transformers affected by increasing lightning activity

Increased storm frequency can lead to an increased lightning strike frequency. Where lightning strikes exposed substation plant 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 or a loss of generation, leading to other network protection systems operating and leading to loss of supply.

AR15 Wildfire - Overhead lines and underground cables affected by extreme heat and fire smoke damage

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 significant risk to overhead line structures and conductors where they are located in susceptible areas such as open heathland.

Operational telecommunication systems should also be considered at risk from this scenario, and without operational telecoms it is impossible to control the network and loss of supply could occur following an unrectified fault.

4.2 Gas Network Risks

ARG4 Precipitation - Flood risk of above ground assets (governors and pressure reducing equipment)

There is a risk of physical damage to assets located in flood plains (fluvial) or to other assets from extreme and extended rainfall (pluvial) with ancillary instrumentation and communication equipment being the most vulnerable, although governors and pressure reducing equipment are resilient and capable of operating when submerged in water. This will be exacerbated if flood defences are ineffective and/or plant relocation is not possible.

ARG5 Precipitation- Flood risk of above ground assets (governors and pressure reducing equipment) from catastrophic dam failure

Extreme precipitation can lead to dam overload and failure. Where assets are located far enough away from dams the impact of water inundation from a dam burst is no different from “standard” pluvial, fluvial or tidal flooding, and flooding impacts can be considered similar.

Where assets are close enough to dams to be impacted by the full force of a breach, the damage would be substantial. Plant and equipment would not only be impacted by water ingress but are likely to be physically damaged or washed away by the force of water.

ARG6 Temperature - Above ground assets affected by raised temperatures

Gas network assets are manufactured to international standards and designed to operate within particular temperature parameters. Increasing temperature impacts all plant and equipment and increases could affect rating and asset performance. However, gas equipment is inherently resilient and designed to operate at high temperatures in excess of any expected average increase and there should be minimal impact on the gas network controls.

ARG7 Wind - Damage to above ground assets from storm events

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 and failure and an impact on support services. Again, communication equipment will be the most vulnerable assets.

ARG8 Temperature - Extreme weather impacts from lightning

Increased storm frequency can lead to an increased lightning strike frequency. Where lightning strikes exposed assets, this could cause physical damage and failure. This may lead to operational failure, loss of telecommunications equipment, and a fire risk to gas venting stacks.

ARG9 Precipitation - Asset impact from snow/ice falls and accumulation

The risk to above ground assets is expected to gradually decrease due to less frequent snow events. However, a risk remains of physical damage from excessive snow or ice falls, for example increased loading on building roofs.

ARG10 Precipitation - Risk to underground pipelines from river erosion

Pipelines can be exposed and are then susceptible to physical damage from external impact or from being unsupported, with the main risk being the scouring and erosion of pipeline coatings. More frequent flooding and increased river and watercourse flows will increase this level of risk.

ARG11 Precipitation - Ground contamination and transport of materials from flooding of contaminated sites

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.

AR12 Temperature - Ground movement due to drought conditions and dry ground

Ground movement caused by drying and shrinkage will exert tensile forces on underground assets, especially to more vulnerable joints and connections, with cast iron mains presenting the highest risk. This could lead to mechanical damage and the potential fracture of pipelines leading to a serious risk of gas release or explosion. Any loss of ground cover above pipes could also increase the risk of third-party strikes.

ARG13 Temperature & precipitation - Vulnerability of critical IT systems managed by third parties from extreme weather events

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. Any loss of capacity could lead to the need for manual intervention and reduced network control.

ARG14 Wildfire - Asset damage if no wildfire risk assessment or remediation measures

Wildfire is a consequential risk of increased temperatures and reduced precipitation and, whilst difficult to forecast, pose a significant risk to above ground assets where they are located in susceptible areas. These include open heathland, grassland or forested areas and may be in remote locations. The risk of underground pipeline damage is increased in the absence of vegetation clearance within 3m of site boundaries. There is an interdependent risk from any impact on other utility assets such as electricity lines and substations and telecommunication lines.

ARG15 Temperature & precipitation - Vegetation growth

Increases in both temperature and precipitation will lead to increased vegetation growth. Above ground assets will be impacted by any increased growth of trees adjacent to operational equipment. This will lead to increased levels of maintenance and reduced access issues. Similar issues may be encountered with the accelerated growth of plants or invasive species. Any change in the numbers or seasons of nesting birds and protected species will need to be registered on habitat surveys and could potentially restrict work activities.

ARG 20 Sea level rise - Tidal Flooding of above ground assets

Regardless of the source the impact of flooding on above ground assets is the same. There is a risk of physical damage to assets, although governors and pressure reducing equipment are resilient and capable of operating when submerged in water. This will be exacerbated if flood defences are ineffective and/or plant relocation is not possible.

ARG 21 Sea level rise - Saline contamination and increased corrosion rate of above and below ground assets from sea water

There is a risk of gradual chemical damage to pipelines from increased tidal flooding, which will affect asset integrity and could lead to water ingress and gas release. Ingress of saline groundwater may also impact the buoyancy of pipes and cause structural issues.

ARG 22 Precipitation - Ground water flooding of below ground assets leading to water ingress to pipes

Despite the inherent resilience of pipelines, more frequent and prolonged flooding will increase the risk of physical damage and the likelihood of water ingress leading to operational and supply issues.

Management Risks

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 attributable to the damage or reduced operation of an asset.

ARG1 All - Lack of climate change management procedure

The requirements for climate change management need to be specified to ensure the necessary procedures and actions are integrated into the organisation's environmental management system. This leads to a greater understanding of the potential impact of climate change and improves the overall environmental culture within the business.

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

A robust climate risk assessment process is required for all major network investment decisions. Climate change needs to be considered at the planning stage prior to the installation of new/replacement gas and electricity infrastructure. This will result in a greater level of asset data and information and increased asset integrity.

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

Asset climate risks need to be afforded the same status as other risks to assets including security, safety, and other environmental impacts. Accountability is then required at senior management level and responsibilities included within existing business risk processes.

ARG16 All - Wildlife impacts

The effects of climate change could lead to impacts on wildlife due to changes in environments, habitats, and behaviours. This could lead to restricted access to assets from changed nesting habits, prolonged nesting seasons, changes to species migration, subsidence from digging etc.

ARG17 All - Supply chain impacts

Business Continuity Management (BCM) plans could be affected due to severe travel difficulties resulting from extreme weather events. This can result in reduced capability and support from supply chain businesses and impact on the continued operation and maintenance of the networks. The adoption of new technology and equipment will assist in the ability of the workforce to work remotely and continue to manage network assets.

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

Business Continuity Management plans could be affected due to extreme weather events. There l may be an impact on organisational capability and staff resources and the continued operation and maintenance of the networks. The recent COVID pandemic has tested the current arrangements and systems in place which have proved to be effective The adoption of new technology and equipment will also assist in the ability of the workforce to work remotely and continue to manage network assets.

ARG19 All - Knock on effect on GDN operations from variable electricity supply due to impact on DNOs

One of the potential interdependencies within the sector is the knock-on effect on gas network operations from a variable electricity supply. Any initial climate impact on the electricity networks, as set out in the electricity network risks, may result in electricity supply interruptions leading to an impact on asset operations and gas supplies to customers.

5. Risk Mitigation and Management

Electricity Networks

AR1, AR2, AR4, AR5, AR6, AR7, AR8

While the likelihood of global temperature rise is accepted, the impacts on UK distribution and transmission network operators have not yet begun to be realised. Because of this, networks do not currently see any drivers to invest ahead of need to offset risks. Network and asset performance will continue to be monitored and developed and will be modified once climate change impacts begin to have a direct and longer-term effect.

Where low ground to conductor clearance has been identified, and air temperature sagging is considered to be a contributing or additional factor, some DNO companies have installed taller poles during pole replacement programmes in order to counteract the loss of clearance through thermal sagging.

It should be noted that all DNOs use cables and overhead conductors designed and manufactured to international standards, and consequently these assets are designed to operate safely in much greater maximum and minimum temperature ranges than those found in the UK.

AR3

Currently DNOs treat vegetation growth as a business-as-usual activity and manage it as part of their ongoing overhead line maintenance and clearance programmes. No information from overhead line patrols has indicated a requirement for an enhanced or more frequent tree cutting programme.

ENA document ETR132, “Improving resilience of overhead networks under abnormal weather conditions using a risk-based methodology”, provides industry guidance on the management of vegetation below and to the side of overhead line routes. This document is reviewed on a regular basis and would incorporate a suggestion of increased frequency of tree cutting and vegetation management if the BaU programmes were not managing to maintain minimum clearances or in the light of increasing storm frequency.

AR9

Many DNO switch rooms and plant enclosures are designed to maximise the use of natural ventilation to keep internal temperatures within plant and equipment operating within their optimum parameters. Where heat build-up is perceived to be an issue forced ventilation is used and, in extreme cases or where the path to an external air inlet is problematic, air conditioning is considered.

AR10, 11 & 12

Throughout the DPCR5, RIIO ED1 and T1 price control periods, network operators have undertaken an extensive flood protection programme to provide physical protection and network reconfiguration to minimise disruption from localised flood events. Dependent on the outcome of the next regulatory settlement, the flood protection programmes will continue into RIIO ED2 and T2 to accommodate recommendations raised in the 2016 Government National Flood Risk Review. New substation development and substation reinforcement schemes will continue to reference guidance from the ENA ETR 138 document, “Resilience to flooding of grid and primary substations”.

AR13

It is understood that dams are now designed to a 1:10,000 risk of failure, far exceeding the 1:1000 design risk utilised for assessing and developing flood protection measures for substations with more than 10,000 connected customers. While DNOs will try and avoid constructing a new substation within the breach zone of a dam, there is currently no programme to relocate existing substations.

AR14

Storm and lightning frequency are not expected to increase, and technical controls and tripping are currently employed to earth lightning strikes and protect network equipment. More earthing, surge arresters on plant, and other equipment and automated procedures will be considered if strike frequency increases.

AR15

The impact of increasingly dry and warm Summers on the frequency of wildfires has yet to be established. Once established the frequency would need to be ratified against a potential increase of risk to overhead line and operational telecommunications assets.

DNOs acknowledge the possibility of this emerging wildfire risk and are maintaining a watching brief on events and event frequency.

Gas Networks

ARG4 Precipitation - Flood risk of above ground assets (governors and pressure reducing equipment)

Above ground assets, such as Pressure Reducing Stations (PRS) and buildings, will be subject to risk of flooding, particularly those located within flood plains. Company risk assessment processes and the use of available tools, such as Environment Agency Flood Maps, will assist in the development of asset registers and determine vulnerabilities. Assets can be protected by the use of physical flood barriers and there may be opportunities to install more resilient equipment on replacement. Companies should also work with environmental regulators and agencies to establish catchment area flood mitigation practices.

Asset replacement programmes should include consideration of current and future expected climate change, and in some cases the risk assessment could incorporate flood modelling prior to design and installation. There may be limited opportunity to relocate assets and so robust emergency response plans and equipment should be in place, such as the use of breathers on pipes and procedures for shutting off the network in extreme circumstances.

ARG5 Precipitation - Flood risk of above ground assets (governors and pressure reducing equipment) from catastrophic dam failure

Existing flood protection practices and equipment will form the basis of risk management controls for flooding from dam failure. Dam locations and assets

in proximity to dams should be identified, and the potential impact on the business and customers assessed in the event of catastrophic failure. There will be limited opportunities to relocate new or replacement assets outside of the flood risk area, and so emergency incident plans will need to consider the likelihood of asset loss and appropriate response procedures.

ARG6 Temperature - Above ground assets affected by raised temperatures

Gas network assets are manufactured to international standards and are designed to operate at significantly elevated temperatures to those experienced in the UK, including any expected average increase over the course of the century. There could be some minor impact on performance in the event of extended, elevated temperatures during heatwaves, but the most vulnerable assets are considered to be IT equipment and instrumentation which may need to be housed or supported by cooling (air conditioning) to avoid any overheating. The performance of all assets are monitored and maintained as part of routine asset management practices.

ARG7 Wind - Damage to above ground assets from storm events

Gas network assets are mainly located underground, and above ground equipment is designed and constructed to be resilient to storms, although a level of risk remains from extreme weather events. Larger transmission assets will be less vulnerable than local or regional distribution equipment, but the latter represent a lower level of business and customer supply risk. Electrical and instrumentation control equipment are the most vulnerable assets and may need to be protected or housed if located in exposed areas.

Offices and buildings are subject to wind damage or damage from trees so effective vegetation management practices and building maintenance procedures assist in reducing any risk.

ARG8 Temperature - Extreme weather impacts from lightning

The risk from lightning strikes is currently assumed to remain at the same low level of risk, and the Met Office report forecasts no notable change in frequency or intensity. Any impact on operational activity is addressed through risk assessment of buildings and assets, and existing earthing arrangements are deemed sufficient to manage any impact from lightning. The risk assessment should also address any likelihood of gas ignition.

ARG9 Precipitation - Asset impact from snow/ice falls and accumulation

The risk from snow and ice falls is forecast to decrease over time as average temperatures correspondingly increase. The possibility remains for localised, extreme events with heavy snowfalls leading to excessive loading on buildings, and secondary risks from icing of equipment and roads. Both can lead to access issues and disruption to operational activities. Building integrity and the risk to assets (control equipment, water pipes) will need to be determined, and there may be a need to insulate equipment and revise operational procedures.

ARG10 Precipitation - Risk to underground pipelines from river erosion

Assets that cross or are located near river courses are vulnerable to the effects of river erosion, and a register of such assets should be maintained to assess the level of risk. Similarly, any subsidence or increased frequency in flooding should be recorded to establish whether this risk has increased. The main concerns are the exposure of buried pipes from ground erosion, and the impact and damage to pipes from flood water and any debris contained within it.

It is unlikely that new or replacement pipelines can be relocated away from areas of flood risk and is likely to be cost prohibitive, but this may be an option or it may be possible to utilise directional drilling techniques and change the depth of pipes underneath waterways. Ongoing maintenance and proactive checks of pipeline condition are other mitigation practices in place, and this provides early warning of any increase in the risk of exposure.

ARG11 Precipitation - Ground contamination and transport of materials from flooding of contaminated sites

Contaminated land sites have been identified and recorded within site risk registers. This has led to proactive programmes of remediation, which is steadily reducing the level of business risk exposure. Site surveys and sampling provides a good understanding of the contaminants present and determines the appropriate remediation processes to employ to remove any hazardous material.

Short term impacts from flooding presents less of a risk than long term leaching of contaminants from sites with elevated groundwater levels, but both risks are being reduced through the robust, established decontamination programmes in place.

ARG12 Temperature - Ground movement due to drought conditions and dry ground

Any ground movement or subsidence presents a risk of damage or fracture to gas pipes including joints and connections. This risk is higher for older, less ductile iron gas mains pipes. The risk is gradually being reduced through the established network gas mains replacement programme and the introduction of less vulnerable polyethylene pipe. Other proactive mitigation includes pipeline walking surveys, and the monitoring and recording of instances of ground subsidence/movement to determine any vulnerable areas or increased frequency of events.

ARG13 Temperature & precipitation - Vulnerability of critical IT systems managed by third parties from extreme weather events

IT equipment and electrical instrumentation have been identified as assets that are vulnerable to extreme weather events, such as prolonged elevated temperatures. Such equipment may need to be housed in temperature monitored buildings and cooled by air conditioning equipment to avoid overheating. Such housing may need flood protection barriers and systems in place if located in flood plains or vulnerable areas. If the equipment is owned and managed by third parties on behalf of the network businesses then this

represents a reduced level of control, and suitable service provision agreements should be in place.

ARG14 Wildfire Asset damage if no wildfire risk assessment or remediation measures

This is an emerging issue, but currently represents a low risk to the gas networks as pipeline depths should normally be sufficient to prevent any impact from wildfires. As heat rises any such events would pose more of a risk to electricity and telecommunications assets, although this does represent an interdependency risk to gas network operations.

Vegetation management and clearance practices should be reviewed in any sensitive areas, such as peat land, where above ground assets are located. Other mitigation is provided through emergency and fire response procedures.

ARG15 Temperature & precipitation - Vegetation growth

Increased growth rates and growing seasons arising from raised temperatures and precipitation levels may lead to the need for enhanced vegetation clearance and tree cutting schedules to maintain separation from assets/buildings. This will be ascertained by monitoring vegetation growth rates and any spread of fast-growing invasive species. Existing controls include habitat surveys and environmental risk assessments for new installations/projects. Any protected trees, species or wildlife should be identified and recorded within this process.

ARG 20 Sea level rise - Tidal Flooding of above ground assets

This represents a lower overall risk than pluvial and fluvial flooding, but any events are likely to be more significant, extreme events. Registers of the type and location of vulnerable above ground assets (such as Pressure Reducing Stations) should be maintained and risk assessed to determine whether additional protection measures are required; these could include flood

barriers, emergency response equipment etc. This assessment should consider the risk from both current and future climate impacts.

A number of sources of supporting information on coastal erosion and flood risk are available for use, including shoreline management plans and guidance from DEFRA and environmental regulatory bodies (EA, SEPA, NRW, NIEA). These can be referenced for both existing sites and any new asset investment plans.

ARG 21 Sea level rise - Saline contamination and increased corrosion rate of above and below ground assets from sea water

Above and below ground assets located in coastal flood plains carry a low risk associated with saline contamination and increased rates of corrosion. Asset registers will assist in routine monitoring and inspection programmes, and these could also record any differences in risk levels from the resistance of different pipeline construction materials. Monitoring of the cathodic protection coatings help ensure the continued integrity of gas pipes is maintained or indicate whether repair or earlier replacement is needed.

ARG 22 Precipitation - Ground water flooding of below ground assets leading to water ingress to pipes

There is a risk of water ingress into low pressure gas pipelines, and this risk could increase in line with more severe and higher rates of flooding. Water ingress can also result from burst and struck water mains. Historic water ingress events will provide a benchmark to monitor any increase in the level of risk, but this is being reduced by the ongoing gas mains replacement programme and the removal of other, older assets, and the installation of polyethylene pipes. Improved operational practices and response procedures will also reduce any impact on gas supplies to customers from such events.

Management Risks

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 attributable to the damage or reduced operation of an asset.

The requirements for climate change management need to be specified to ensure the necessary procedures and actions are integrated into the organisation's environmental management system and considered for all major network investment decisions.

Asset climate risks need to be afforded the same status as other risks to assets including security, safety, and other environmental impacts. Accountability is then required at senior management level and responsibilities included within existing business risk processes.

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 therefore consider and address the impact of climate change.

6. Risk Assessment

As part of the ARP and ARP2 responses the risks AR1-14 were assessed and quantified in the Risk Matrix as set out in **Figure 1** below.

In order to provide comparison, the assessment has been repeated for ARP3 in **Figure 2** for Electricity, and a new Risk Matrix has been developed for the Gas networks**, Figure 3**. Both are based on industry progression in mitigating or managing climate change impacts, utilising the information and predictions set out in the Met Office Report provided for the Energy Networks in November 2020.

Risk Code (Score)	Climate Variable	Impact	ARP3 Risk Considerations
AR1 (9)	Temperature	Overhead line conductors affected by temperature rise	Localised increase in pole heights and age-related replacement maintains line clearances. No significant changes in UKCP18 predictions over UKCP09
AR2 (6)	Temperature	Overhead line structures affected by Summer drought and consequent ground movement	Emerging risk. Impact dependent on geology and topology
AR3 (8)	Temperature / precipitation	Overhead lines affected by interference from vegetation due to prolonged growing season	Increase in growth offset by increase in cutting at each visit.
AR4 (9)	Temperature	Underground cable systems affected by increase in ground temperature	Limited data on impact on cable ratings
AR5 (6)	Temperature	Underground cable systems affected by Summer drought and consequential ground movement	Emerging risk. Impact dependent on geology and topology
AR6 (6)	Temperature	Substation and network earthing systems adversely affected by Summer drought conditions	Limited test data available, but anecdotally Grid and Primary substations are buried deep enough to only experience minor impact in performance.
AR7 (6)	Temperature	Transformers affected by temperature rise	Temperature rise accommodated in design

Risk Code (Score)	Climate Variable	Impact	ARP3 Risk Considerations
AR8 (9)	Temperature	Transformers affected by urban heat islands and coincident air conditioning demand	Managed through load planning although extended high load my reduce the life expectancy of the transformer.
AR9 (4)	Temperature	Switchgear affected by temperature rise	Temperature rise accommodated in design
AR10 (9)	Precipitation	Grid and Primary Substations affected by river flooding due to increased winter rainfall	While risk of flooding has increased the asset protection measures employed have offset and reduced the risk.
AR11 (6)	Precipitation	Grid and Primary Substations affected by pluvial (flash) flooding due to increased rainstorms in Summer and Winter	While risk of flooding has increased the asset protection measures employed have offset and reduced the risk.
AR12 (8)	Precipitation	Grid and Primary Substations affected by sea flooding due to increased rainstorms and/or tidal surges	While risk of flooding has increased the asset protection measures employed have offset and reduced the risk.
AR13 (5)	Precipitation	Grid and Primary Substations affected by water flood wave from dam burst	Considered unviable to protect against.
AR14 (6)	Lightning	Overhead lines and transformers affected by increasing lightning activity	Existing mitigation measures adequate.
AR15 (6)	Wildfire	Overhead lines and underground cables affected by extreme heat and fire smoke damage	Based on Saddleworth Moor incidents and increased frequency of California wildfires

Risk Code (Score)	Climate Variable	Impact	ARP3 Risk Considerations
ARG1 (8)	All	Lack of climate change management procedure	Climate risks are considered alongside other business risks and incorporated within company business plans and asset management policies.
ARG2 (8)	All	Lack of specific policies and procedures governing risk assessment process on climate change	Adaptation issues integrated within environmental management system to provide the necessary governance of long-term risks.
ARG3 (9)	All	Risk and action owners not identified at senior leadership team level	Leadership and accountability ensure that Adaptation Action Plans are monitored and reviewed, and corrective actions taken.
ARG4 (9)	Precipitation	Flood risk of above ground assets (governors and pressure reducing equipment)	Above ground assets are less resilient than gas pipes and may need flood protection barriers and emergency response plans to be in place
ARG5 (4)	Precipitation	Flood risk of above ground assets (governors and pressure reducing equipment) from catastrophic dam failure	Vulnerable assets identified, but flood protection systems will be insufficient to prevent loss.
ARG6 (8)	Temperature	Above ground assets affected by raised temperatures	Gas assets inherently resilient to temperature changes, but IT equipment and instrumentation may need additional protection.
ARG7 (6)	Wind	Damage to above ground assets from storm events	Risk of damage to buildings and control equipment from extreme weather remains, but this represents a low business and customer supply risk.
ARG8 (3)	Temperature	Extreme weather impacts from lightning	Risk to remain at low level, and existing risk assessment

Risk Code (Score)	Climate Variable	Impact	ARP3 Risk Considerations
			and earthing arrangements deemed sufficient.
ARG9 (6)	Precipitation	Asset impact from snow/ice falls and accumulation	Despite a general increase in overall temperatures, there will be an ongoing need to manage extreme snow/ice events and any impact on buildings and roads/access.
ARG10 (12)	Precipitation	Risk to underground pipelines from river erosion	Increased levels of flooding will result in more incidents of pipeline exposure and asset damage.
ARG11 (6)	Precipitation	Ground contamination and transport of materials from flooding of contaminated sites	Flooding will exacerbate leaching of materials from contaminated land, but short and long-term risks managed by established monitoring and remediation programmes.
ARG12 (6)	Temperature	Ground movement due to drought conditions and dry ground	The gas mains replacement programme and growth in PE pipe installation are reducing risks from ground movement arising from drought conditions.
ARG13 (8)	Temperature & precipitation	Vulnerability of critical IT systems managed by third parties from extreme weather events	IT and electrical instrumentation equipment are the most vulnerable to extreme weather events but are critical to management of the networks requiring protection from flooding and increased temperatures.
ARG14 (6)	Wildfire	Asset damage if no wildfire risk assessment or remediation measures	Emerging but low risk to gas networks; potential interdependency risk from wildfire impacts on electricity and telecommunications assets.
ARG15 (4)	Temperature & precipitation	Vegetation growth	Any increased vegetation growth can be managed

Risk Code (Score)	Climate Variable	Impact	ARP3 Risk Considerations
			through enhanced clearance and tree cutting schedules, and environmental assessments for new installations.
ARG16 (3)	All	Wildlife impacts	Any change in wildlife activity may result in access issues but are managed by ecological surveys as required.
ARG17 (6)	All	Supply chain impacts	Risk to supply chain provision for both equipment and services in the event of extreme weather events, addressed within Business Continuity Plans.
ARG18 (4)	Precipitation	BCM plans affected due to severe travel difficulties resulting from extreme weather events	Extreme weather events and flooding may affect travel and operational activities, but current systems have proved to be effective. Suitable technology and equipment will support self-sufficiency and remote working.
ARG19 (6)	All	Knock-on effect on GDN operations from variable electricity supply due to impact on DNOs	Increasing risk from the dependency on electricity supplies for gas network operation; for example, the risk of substation flooding, but this is mitigated by asset protection measures.
ARG20 (9)	Sea level rise	Tidal Flooding of above ground assets	Flood risk to above ground assets; vulnerable areas to be identified and additional flood protection and emergency response equipment employed.
ARG21 (4)	Sea level rise	Saline contamination	Low risk of corrosion in coastal flood plain areas; vulnerable assets are identified, and pipeline

Risk Code (Score)	Climate Variable	Impact	ARP3 Risk Considerations
			cathodic protection is monitored or assets are repaired/replaced.
ARG22 (8)	Precipitation	Ground water flooding of below ground assets leading to water ingress to pipes	Increased flooding increases the risk of water ingress, but mitigated by the gas mains replacement programme and the installation of PE pipe and improved operational practices

ARP Risk Matrix (Electricity)

The following risk explanations and matrices have been developed as a means of measuring climate adaptation risk based on the definition and assessment of both the level of impact and likelihood of the identified risks being realised.

The ARP3 Risk matrix shows a general reduction in risk over ARP2 when considering the measures and mitigation put in place over the DPCR5 and RIIO ED1 regulatory periods to manage the risk.

Horizons: 2025, 2050, 2080		Impact				
		Limited	Minor	Moderate	Significant	Extreme
Likelihood	Almost Certain	5 / moderate	10 / major	15 / major	20 / severe	25 / severe
	Likely	4 / moderate	8 / moderate	12 / major	16 / major	20 / severe
	Possible	3 / minor	6 / moderate	9 / moderate	12 / major	15 / major
	Unlikely	2 / minor	4 / moderate	6 / moderate	8 / moderate	10 / major
	Very Unlikely	1 / minor	2 / minor	3 / minor	4 / moderate	5 / moderate

Impact (Electricity)

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.

Likelihood (Electricity)

Rating	Definition
Almost certain	The risk in the process of materialising 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

ARP2 Risk Matrix (Electricity)

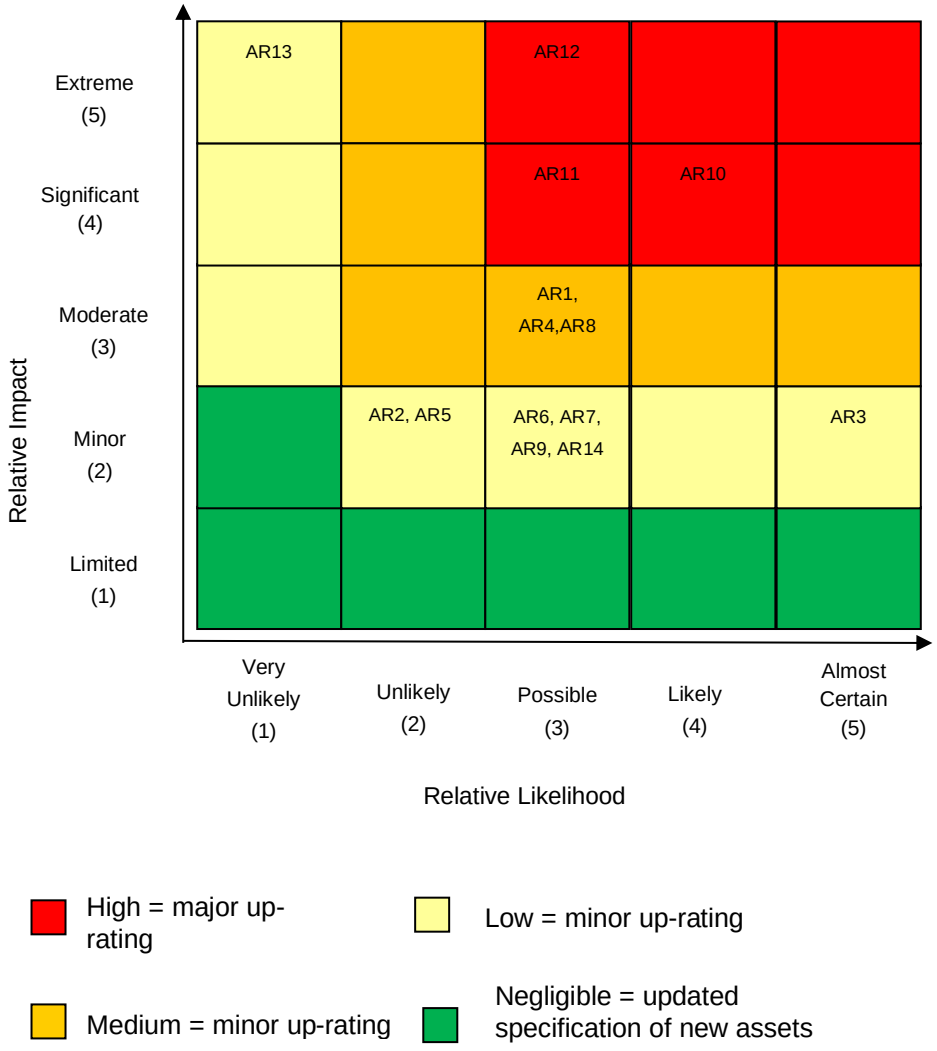

Figure 1

ARP3 Risk Matrix (Electricity)

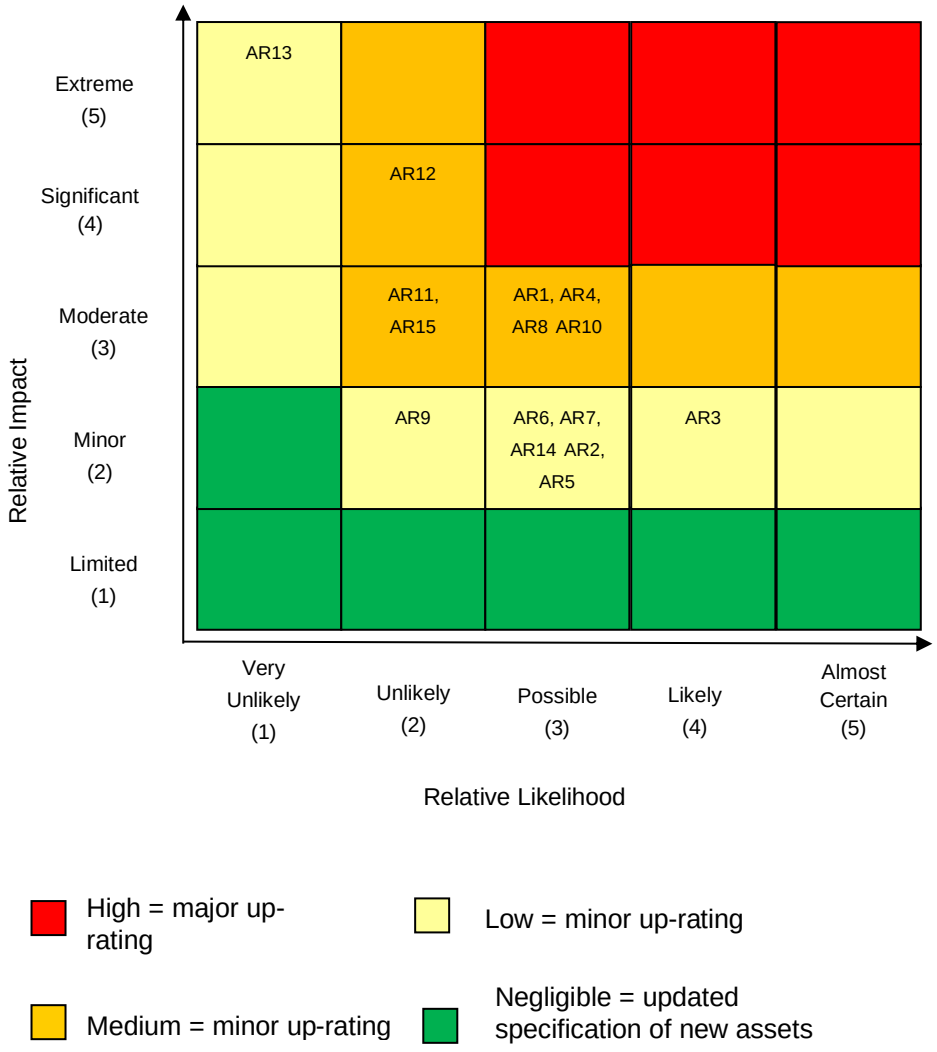

Figure 2

Please note, the above matrix is the consolidated view of the risks from climate change to the electricity distribution and transmission networks. There may be minor differences between networks arising from their specific function

and regional location, and the individual network reports should be referred to for individual network risk scoring and accompanying narrative.

ARP3 Risk Matrix (Gas)

ARP3 is the first time Gas networks have collectively assessed their risks so no previous industry risk matrices are available.

Companies have developed a means of measuring climate adaptation risk based on the definition and assessment of both the level of impact and likelihood of the identified risks being realised. These are then scored to provide a comparative rating which can be used for future benchmarking of progress.

Measurement of risk

Horizons: 2025, 2050, 2080		Impact				
		Limited (1)	Minor (2)	Moderate (3)	Significant (4)	Extreme (5)
Likelihood	Almost Certain (5)	5 / moderate	10 / major	15 / major	20 / severe	25 / severe
	Likely (4)	4 / moderate	8 / moderate	12 / major	16 / major	20 / severe
	Possible (3)	3 / minor	6 / moderate	9 / moderate	12 / major	15 / major
	Unlikely (2)	2 / minor	4 / moderate	6 / moderate	8 / moderate	10 / major
	Very Unlikely (1)	1 / minor	2 / minor	3 / minor	4 / moderate	5 / moderate

Impact (Gas)

Rating	Definition
Extreme/Catastrophic	Regional area affected with people off supply or significant asset failure which exceeds ability for network intervention or reinforcement. Financial: Cost dependent on GT/GDN impact (>£50M, typically >£20M) Safety: Multiple fatality/HSE Enforcement Notice Reputation: External impact on international stakeholders, company accused of poor practice or negligence, direct blame to company leading to extensive media coverage, significant business and company value impact, loss of licence Environment: Reportable incident, serious and lasting environmental damage or loss (>10 years recovery), enforcement action and fine certain Asset/Security of Supply: Total loss of asset, major conurbation and high customer numbers off supply for lengthy period of time (major conurbation off supply >24 hours), national transmission system disruption
Significant/Major	County or city area affected with people off supply or significant asset failure which requires significant network intervention or reinforcement. Financial: Cost dependent on GT/GDN impact (≤ £50M, typically £10-20M) Safety: Fatality/Life changing injury/HSE Enforcement Notice Reputation: External impact on national stakeholders, extensive media coverage, business and company value impact, repeated regulatory intervention, potential loss of licence Environment: Reportable incident, significant environmental damage or loss (5-10 year recovery), enforcement action expected Asset/Security of Supply: Significant asset damage or failure, geographical area off supply, major outage on distribution networks
Moderate	Significant increase in costs of response and network strengthening

	Financial: Cost dependent on GT/GDN impact (≤ £30M, typically £1-10M) Safety: Major injury e.g. RIDDOR reportable Reputation: External impact on stakeholders, adverse media coverage, negative customer impact, regulatory intervention, minor company value impact Environment: Reportable environmental incident resulting from breach of consent or permit, medium damage and loss to environment (up to 5 years recovery), potential enforcement action/letter of concern Asset/Security of Supply: Asset damage of failure, significant numbers of tariff customers off supply for considerable time
Minor	Cost of network maintenance requirements and impact on business now of concern Financial: Cost dependent on GT/GDN impact (≤ £10M, typically £500K - £1M) Safety: Lost time injury/HSE Letter of Concern Reputation: Internal impact within business and stakeholders, industry press and local media interest supported by regulator, some business criticism Environment: Minor, potentially reportable incident affecting local environment (< one year), quick resolution Asset/Security of Supply issues: Minor asset damage or failure leading to localised loss of supply for a short period of time, firm contract customer supply affected
Insignificant/Minimal	Limited impact - can be managed within “business as usual” processes Financial: Cost dependent on GT/GDN impact (≤ £5M, typically < £500K) Safety: Minor injury/medical treatment/near miss/negligible Reputation: Internal issue from local event, negligible inconvenience, minimal local media coverage Environment: Non-reportable incident with negligible environmental impact or damage, immediately resolved Asset/Security of Supply: Limited impact on assets and supplies, limited disruption to interruptible supplies

Likelihood (Gas)

Rating	definition
Almost certain	The risk is expected to be realised and may already be under active management as an event. No controls in place to reduce likelihood of risk being realised. Guideline: >90% or at least once a year frequency.
Likely	More likely and probably will occur, mitigations not fully effective, control weaknesses are known but being managed. Guideline: 60-90% or 1 in 5 years frequency.
Possible	Equally likely as unlikely, mitigations are in place, control measures are under active management. Guideline: 30-60% or 1 in 10 years frequency.
Unlikely	Events are rare and unlikely but could occur, required mitigations in place, controls are effective. Guideline: 10-30% or 1 in 15 years frequency.
Very Unlikely	No known event or extremely rare or remote chance of occurring, controls are fully effective to reduce likelihood of risk being realised. Guideline: <10% or 1 in 20 years or greater frequency.

ARP3 Risk Matrix (Gas)

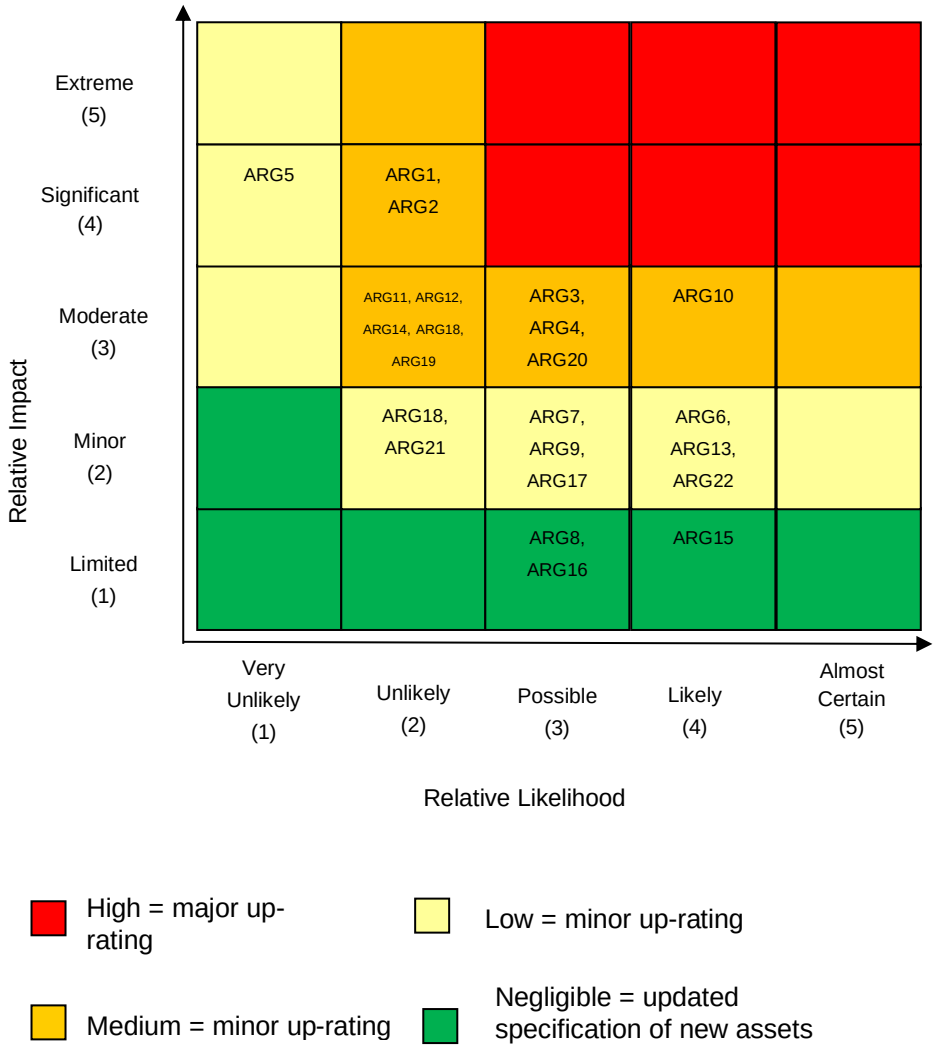

Figure 3

Please note, the above matrix is the consolidated view of the risks from climate change to the gas distribution and transmission networks. There may be minor differences between networks arising from their specific function and regional location, and the individual network reports should be referred to for individual network risk scoring and accompanying narrative.

7. Interdependencies

One of the potential interdependencies within the energy sector is the knock-on effect on gas network operations from increased electricity demand. Increasing temperatures will lead to increased use of air-conditioning systems in both commercial and domestic environments, particularly in urban areas. This in turn will lead to an increase electricity demand, which is often supported by gas fired generation, resulting in a drawdown of gas reserves which could impact domestic supplies as pressures are reduced to meet generation demand.

The electricity networks are also aware that other infrastructure operators and society in general are reliant on having a reliable and resilient supply. DNOs and the National Grid Electricity System Operator (NGESO) continue to work to ensure that the UK electricity network remains one of the most reliable networks in the world, and climate change is one of the impacts considered when developing and reinforcing those networks.

8. 2050 Risk Score Narrative

Energy networks have not been able to provide a risk score for 2050 as there are too many variables that could affect the magnitude of climate change impacts. Networks will, however, continue to monitor the impacts of Net Zero strategies, review climate change impacts and develop and implement mitigation and management strategies for as long as they are supported by the regulatory mechanism and as they become Business as Usual activities.

9. Assumptions (including on data, operational, regulatory changes, etc)

Energy networks expect that future regulatory settlements will support the continuance of specific work programmes and schemes designed to respond to and manage the impacts of climate change.

UKCP18 data has not indicated any significant changes in risk nor has it suggested that there are any new hazards likely to impact energy network operations. This provides network operators with the assurance that measures and approaches used in adaptation and protection will continue to support network operation as climate change impacts are realised.