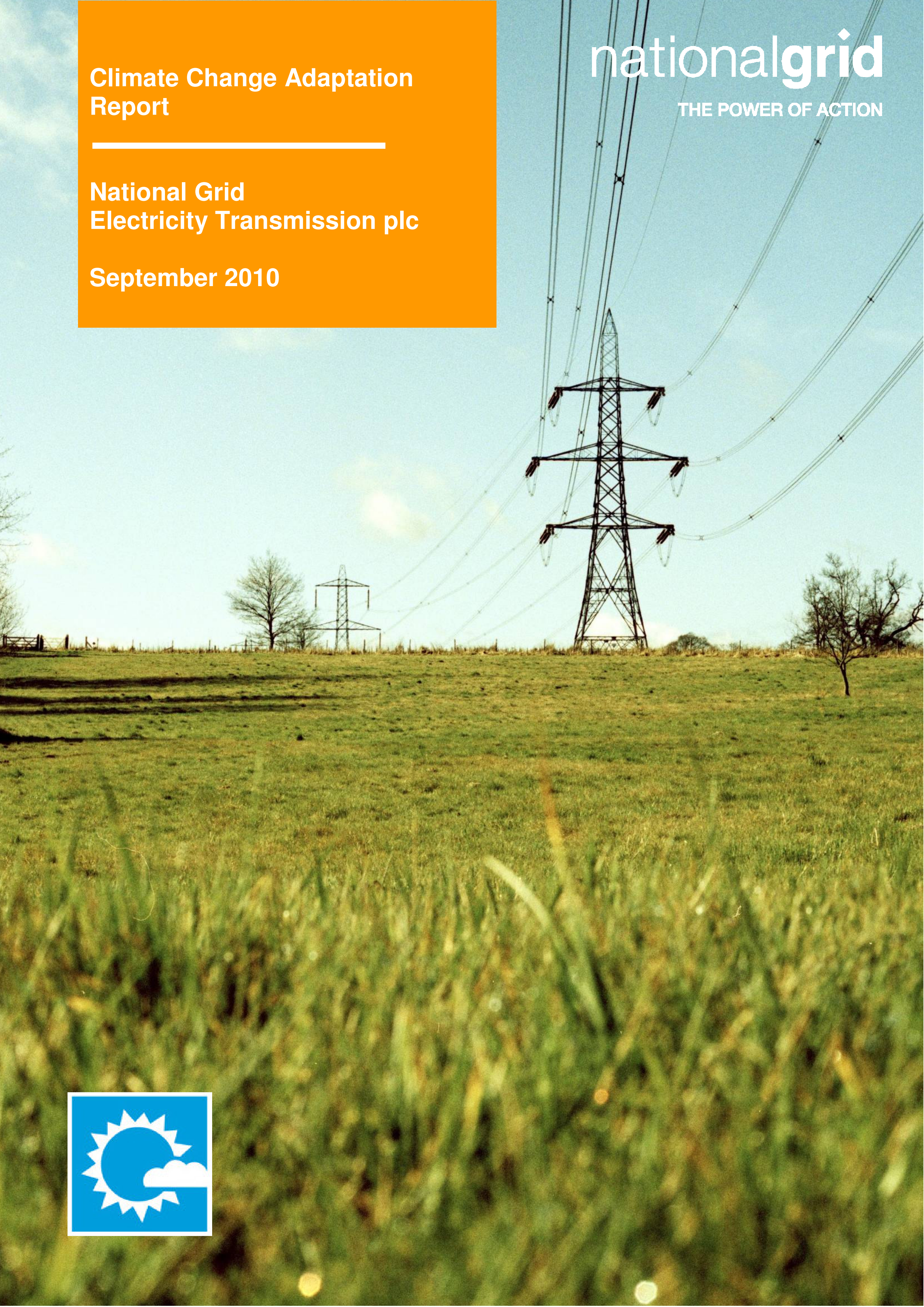
# Climate Change Adaptation Report

## National Grid
## Electricity Transmission plc

**September 2010**



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# 1. EXECUTIVE SUMMARY

Following a direction to report issued in March 2010 by Defra under the Climate Change Act 2008, National Grid is part of the first phase of adaptation reporting. Separate directions were issued to National Grid's two licensed businesses: **National Grid Electricity Transmission plc** and **National Grid Gas plc**.

National Grid supports the views of Climate Change science and believes that mankind contributes to a level of climatic change. National Grid also recognises that meeting the challenges of climate change is not only about reducing greenhouse gas emissions and developing a low-carbon economy but also ensuring that National Grid adapts to climate change such as; incremental hotter drier summers, warmer and wetter winters, coastal and river bed erosion and increasingly frequent extreme weather events such as floods.

National Grid owns National Grid Electricity Transmission plc and National Grid Gas plc. The former owns and operates the high voltage electricity transmission system in England and Wales it is also the National Electricity Transmission System Operator (NETSO) which operates the Scottish high voltage transmission system and the offshore transmission system. The latter owns and operates the UK Gas Transmission system and the low pressure gas distribution in the heart of England distributing to approximately eleven million homes, offices and schools.

National Grid is at a very advanced stage of embedding its Climate Change policy for both mitigation and adaptation within the organisation, with climate change risks firmly embedded into National Grid's Risk Management Procedure which is constantly reviewed and updated with appropriate actions and targets.

National Grid has risk assessed climate change adaptation against information drawn from UKCP09, and has chosen to assess its assets and processes against the high level scenario which is based on the least likely to occur prediction of climate change as of 2080. This was on the basis that should National Grid's assets and processes demonstrate resilience against this scenario it would inevitably be adapted against less significant and more likely climate change.

Analysis and experience has shown that energy infrastructure may be vulnerable to certain aspects of climate change; however the infrastructure has a significant degree of resilience to change, and therefore adaptation. In addition, technically it will be feasible to deal with adaptation issues over short, medium and long-term periods.

This risk assessment has indicated that overall National Grid Electricity Transmission plc's assets and processes are resilient to climate change that is predicted to occur. Within this assessment there are some assets which require further assessment using more refined data. This is an ongoing process which is incorporated in to National Grid's risk management process.

It is important to note that even where an asset is at a potential risk in this worst case scenario model, the risk is localised to the asset and the process it supports and is unlikely to lead to a loss of supply. None of the risks considered are likely to result in a risk to the system as a whole.

National Grid Electricity Transmission plc is committed to continued investment in the electricity transmission system and indeed is compelled to do so by the Electricity Safety Quality and Continuity Regulations 2002 (ESQCR). Assuming continued support from key stakeholders, over the coming decades and long before it is envisaged that the worst case scenario could materialise there will be substantial levels of investment to upgrade the system. This investment, much of which will be driven by predicted increasing demand and the development of Smart Networks, will provide an opportunity to accommodate adaptation to climate change.

In order to ensure National Grid Electricity Transmission plc is prepared for the affects of climate change, it is engaged, in conjunction with other energy companies and the scientific community focussing on mitigation and adaptation to climate change. Using data from UKCIP02 and UKCP09 several detailed reports have been commissioned.

The identified Specific Physical Characteristics which National Grid have risk assessed its assets against are the UKCP09 High Emissions Scenarios, refer to Section 4.3 and Appendix C, in order to asses the impacts under extreme conditions.

Some risks have been identified and National Grid Electricity Transmission plc has already commenced management of these risks and in some cases completed research to enable a better understanding of the issues considered to be of greatest impact through climatic change. National Grid intends to monitor those ongoing climate change scenarios to assess whether the risks identified against the "worst case" are increasing, and warrant further mitigating action, or reducing enabling existing processes to mange an extreme event.

A parallel challenge for electricity network companies over the coming decades concerns the change to "Smart Networks". This initiative is planned to support the requirement that Renewable Distributed Generation and Low Carbon Loads can be connected to Networks in large numbers, as part of the programme to meet the 2020 / 2050 Carbon Reduction targets, whilst still maintaining supplies to customers in a cost effective and reliable manner.

National Grid Electricity Transmission plc acknowledges that climate adaptation is an evolving science and it is envisaged that the flexible approach that has been adopted will allow for risks to be reassessed as further information becomes available. National Grid Electricity Transmission plc found the UKCP09 information invaluable in completing its analysis, but has highlighted areas where additional information would be useful in future particularly around the following Specific Physical Characteristics: Increased lightning, wind and gale, snow, sleet, blizzard, ice and freezing fog and increased subsidence. It would also be helpful for future data to include absolute values or ranges as well as any incremental values from historic trends.

Although these characteristics may be caused as a result of climate change, further work will be required in the next update of the UKCP09 data to assess any expected increases in magnitude and the associated probabilities.

Energy infrastructure is designed to international standards and the same standards allow infrastructure to operate around the world in varying climatic conditions, including projected climate conditions for the UK.

In addition to National Grid Electricity Transmission plc statutory duties, climate adaptation reports such as this report, EP2, ETR 138 and National Grid's risk process has found that there is currently no justification to support adjusting network or asset design standards save for the areas of flooding, and potentially the thermal ratings of equipment and apparatus. The risks posed by fluvial (river) and tidal are well understood and managed on an ongoing basis. The issue of thermal rating needs further investigation. However it is important to view any potential de-ratings against the response to growth of electricity demand on the transmission network, anticipated to be 0.2% p.a. (1.4% p.a. High Growth Scenario) until 2016/17[1]. Also the scale of the change to "Smart Networks" is likely to be very large, and the resultant upgrade to the network may be far larger than that required to accommodate potential adaptation.

In conclusion, the analysis and results have demonstrated that National Grid Electricity Transmission plc has a good understanding of the risks of climate adaptation. The management of these risks is already at an advanced stage of being embedded into the normal day to day business risk processes, with appropriate actions being developed and delivered. As a consequence National Grid Electricity Transmission plc is well placed and in a good state of preparedness as assessed against future anticipated climate change scenarios.

[1] National Grid seven year statement 2010

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## 2. INTRODUCTION AND BACKGROUND TO REPORT

This report was produced following a direction to report issued by The Department for Environment, Food and Rural Affairs (Defra) as a result of the Climate Change Act (2008). The UK is the first country in the world to have a legally binding, long-term framework to cut carbon emissions. The Climate Change Act also creates a framework for building the UK's ability to adapt to climate change. Part of the Act requires the Secretary of State to lay before Parliament assessments of the risks posed to the UK by climate change. This is National Grid's response to the direction.

This work is being undertaken within the Adapting to Climate Change (ACC) cross government programme, based in Defra. The first assessments will be laid before Parliament in January 2012 and then an update every 5 years.

The ACC programme identified National Grid as being of particular importance in adapting the country to the impacts of climate change, and it is therefore considered within the strategy as a priority reporting authority. In March 2010 National Grid Electricity Transmission plc and National Grid Gas plc were issued with a Direction to report which as a legal instrument placed a deadline for companies to report in September 2010.

National Grid has produced two separate reports and this is the report for National Grid Electricity Transmission plc and has been prepared following the Statutory Guidance issued by Defra to reporting authorities in 2009.

The first phase of adaptation reporting will lead to the first full round of mandatory reporting by a wide range of industry and agencies in 2011. Other organisations participating in the first phase of reporting are: The Environment Agency, Highways Agency, Network Rail, Natural England, and Trinity House (Lighthouse Authority).

The purpose of this report is to provide details as to how National Grid Electricity Transmission plc has assessed the specific business risks associated with climate change and demonstrated the steps being taken in adapting to the challenges posed by climatic change.

Section 4.1 of the report provides an overview of how Britain's electricity market operates the key assets and the role of National Grid Electricity Transmission plc and other stakeholders to set the context for the nature and impact of climatic risks to National Grid Electricity Transmission plc.

Section 4.2 describes the level of adaptation preparedness already in place by National Grid Electricity Transmission plc and outlines National Grid's approach to risk management.

Section 4.3 defines the methodology applied in assessing the climatic risk to National Grid Electricity Transmission plc and describes the process employed of adopting a worst case scenario basis to identify the specific assets and processes that require further review.

Section 4.4 provides a summary of the results from the initial assessment and Sections 4.5 and 4.6 discuss the uncertainties, assumptions and actions identified through this review.

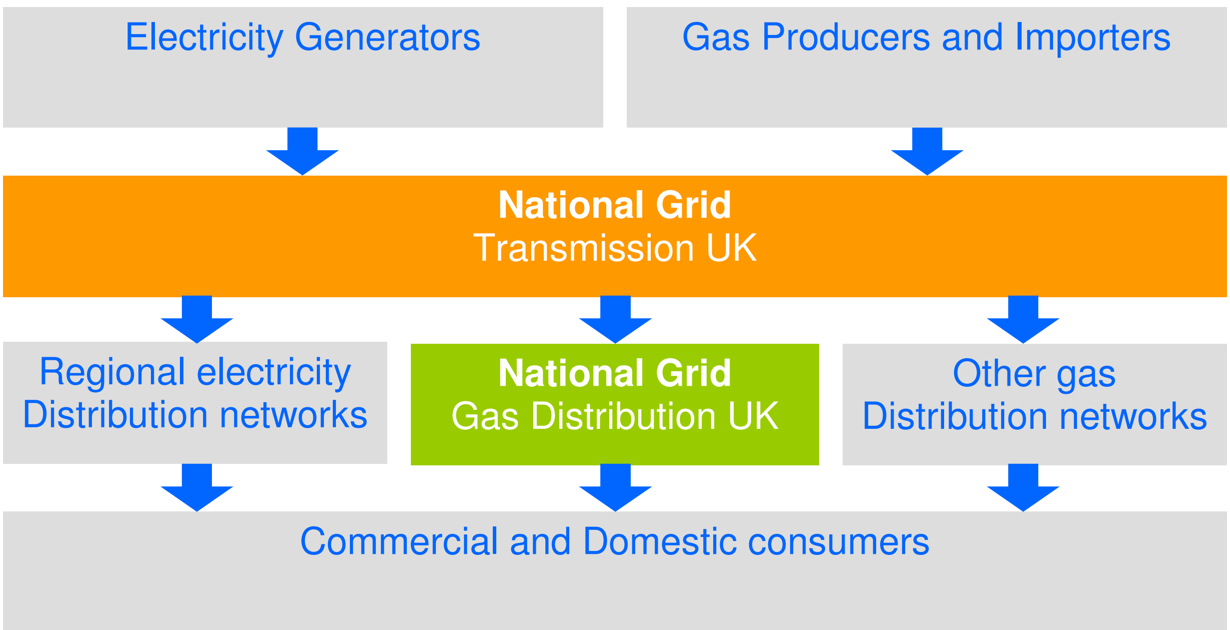
The subsequent sections provide an appraisal of the process, opportunities identified through the assessment, recommendations and conclusions to this study.

## 3. OVERVIEW OF NATIONAL GRID

National Grid originated from the restructurings of the UK gas industry in 1986 and the UK electricity industry in 1990. The principal markets in which National Grid operates in the UK are the electricity and gas markets, National Grid owns and operates the high voltage electricity transmission system in England and Wales and the UK Gas Transmission system. As National Electricity Transmission System Operator (NETSO), National Grid also operates the Scottish high voltage transmission system and the offshore transmission system. National Grid owns low pressure gas distribution in the heart of England distributing to approximately eleven million homes, offices and schools. In addition National Grid owns and operates significant electricity and gas assets in New England and New York in the United States.

National Grid as an international electricity and gas company is one of the largest investor-owned energy companies in the world. National Grid plays a vital role in delivering gas and electricity to many millions of people across Great Britain and north-eastern US in an efficient, reliable and safe manner.

*Figure 3.1 Energy Transportation in the UK*



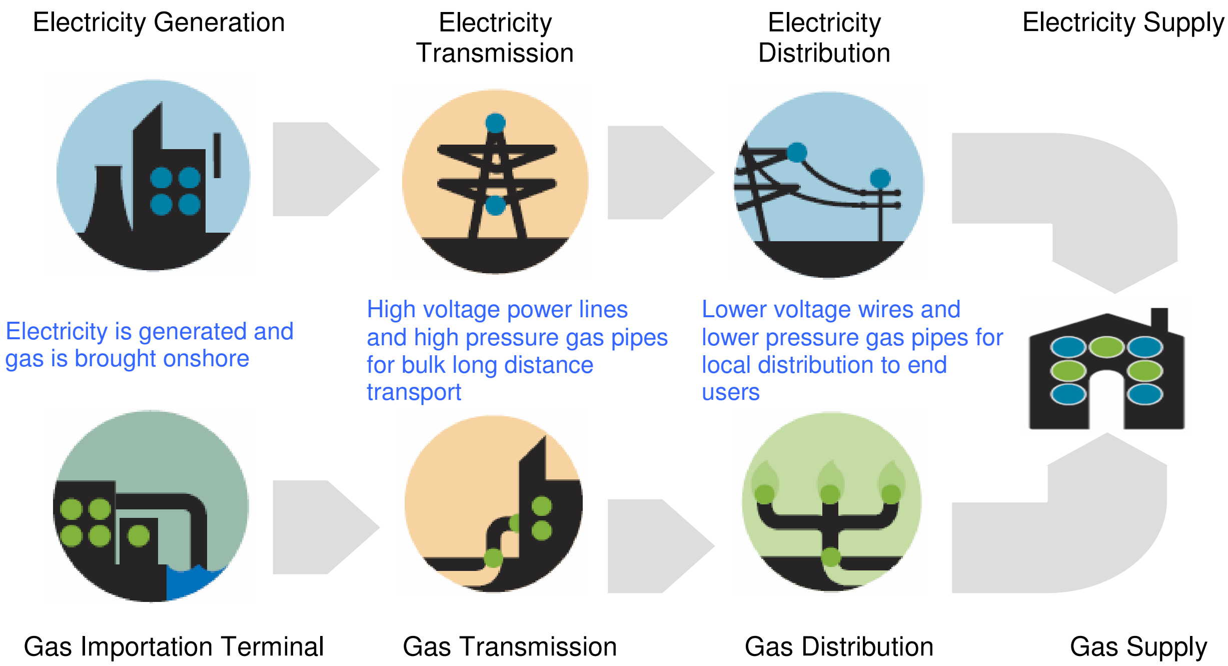

The key roles in the provision of gas and electricity in the UK are shown in Figure 3.1. The supply of electricity and gas in the UK is competitive in that consumers can choose their energy supplier. Those suppliers are then responsible for sourcing the energy from electricity generators or from gas extractors or importers as appropriate, as well as arranging for that energy to be delivered through physical delivery networks. These networks, including the ones National Grid operates, are natural monopolies in their local areas because, for the majority of consumers, there are no alternative methods of transporting electricity or gas.

## Energy Delivery in the UK

In general in the UK, energy is transported through electricity or gas transmission networks to regional electricity or gas distribution networks that then deliver energy to consumers on behalf of suppliers. This is shown in Figure 3.2. Certain end users, primarily large industrial consumers, receive electricity or gas directly from the relevant transmission network, rather than through a distribution network (not shown in diagram).

National Grid Electricity Transmission plc is the owner and operator of the high voltage electricity transmission network in England and Wales; operator, but not owner, of the two electricity transmission networks in Scotland; and owner and operator of the national gas transmission system and of four of the eight regional gas distribution networks in Great Britain. National Grid charges electricity and gas suppliers, electricity generators and gas shippers for its services. There are 14 electricity distribution networks in the UK, owned by 7 different companies.

*Figure 3.2 How the Energy Industry Operates*



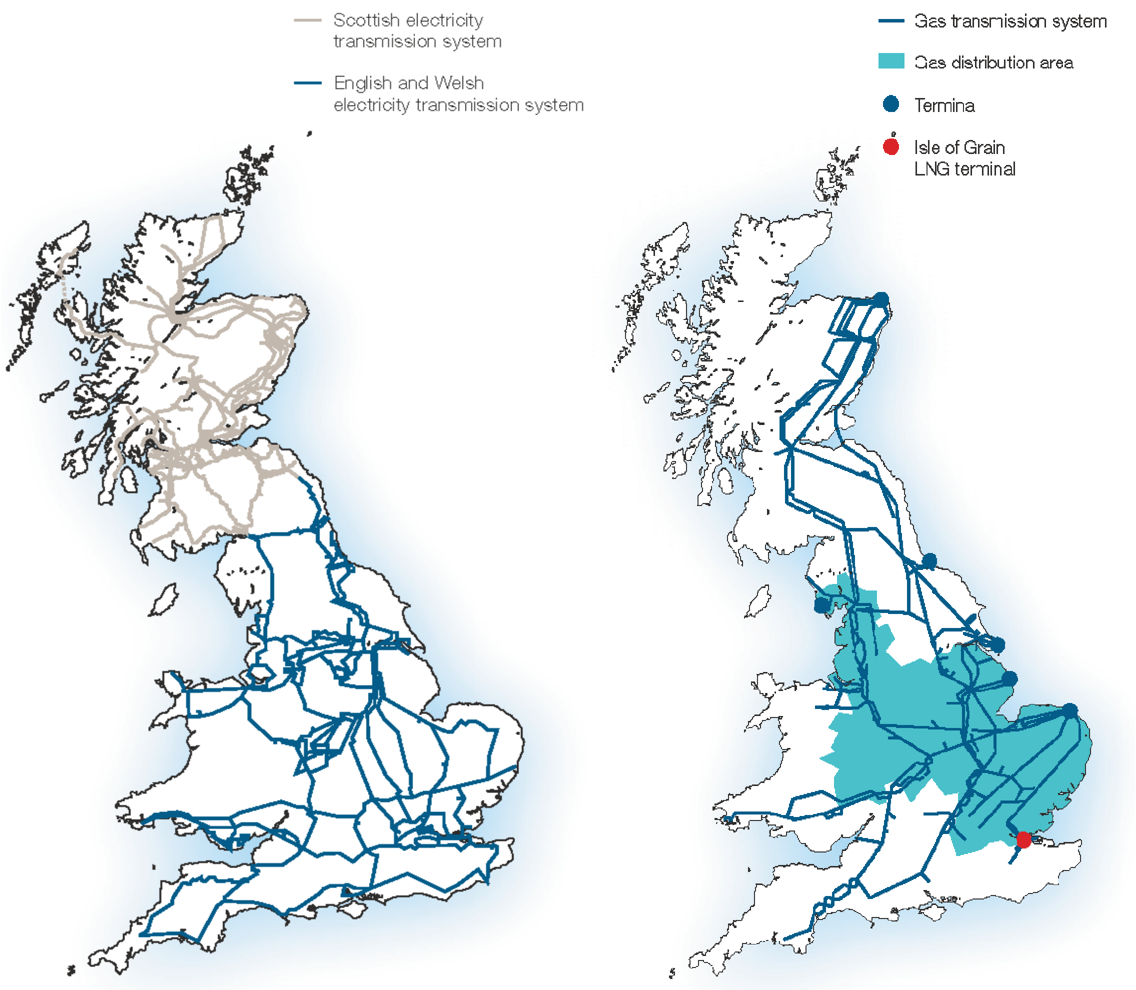

Key Facts

- Over 90% of Britain's gas demand, ~1200Wh/a, flows through National Grid's Gas Transmission System and this figure rises further, closer to 95%, if gas producers own use gas (offshore) is excluded. This is approximately 40% of Great Britain's primary energy demand (including transport).
- Great Britain is covered by 8 gas distribution networks that deliver over 60% of residual energy demand to over 22m consumers (80% of Great Britain's total properties). National Grid owns and operates 4 of the 8 networks covering the North West, Midlands, East Anglia and London and approximately half of the gas consumers nationwide.
- Approximately 90% of electricity demand is transmitted across National Grid's Electricity Transmission system. The equivalent of 13% of the UK's primary energy demand (including transport) is transmitted across National Grid's Electricity Transmission System.

In the UK, National Grid's businesses primary duties under the Electricity and Gas Acts are to develop and maintain efficient and reliable networks and facilitate competition.

Through National Grid's subsidiaries, National Grid also owns and maintains around 18 million domestic and commercial gas meters, the electricity inter-connector between England and France, and Liquid Natural Gas importation terminal at the Isle of Grain. Figure 3.3 shows the key elements of the gas and electricity networks in the UK.

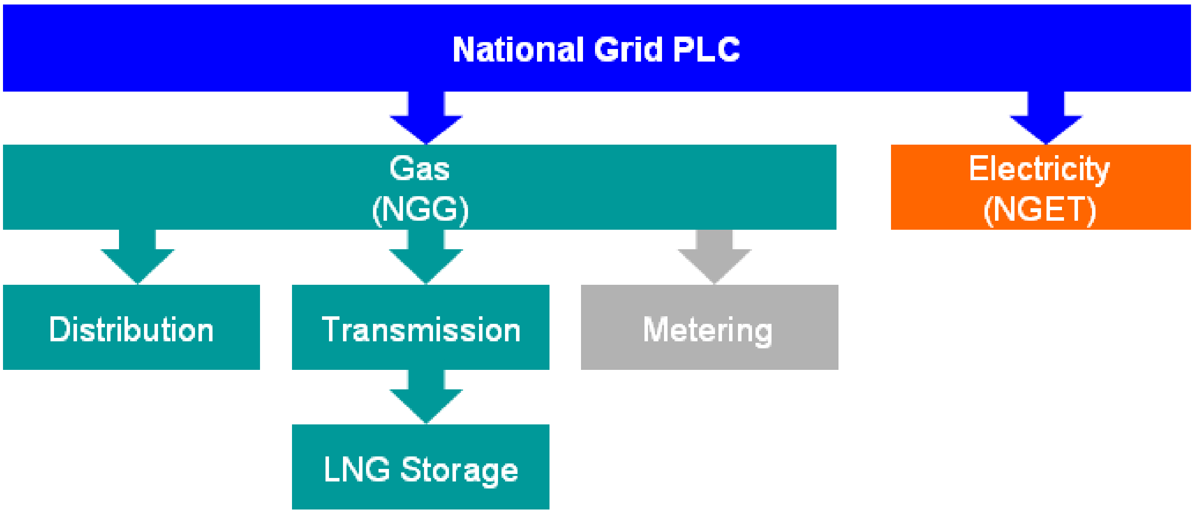
*Figure 3.3 Electricity and Gas Networks*




National Grid's core activities are natural monopolies and accordingly are regulated businesses. Regulated utilities operate under a Licence that governs the service levels.

Figure 3.4 illustrates National Grid's business units and identifies those business units by UK Licence covered within the National Grid Electricity Transmission plc's (NGET) Licence and the National Grid Gas plc's (NGG) Licence.

*Figure 3.4 National Grid Structure and Adaptation Assessment Coverage*




It is noted that certain business units within National Grid have been excluded, either because they are not covered by the regulatory Licence or have been excluded due to the negligible level of impact expected as a result of climate change (e.g. National Grid Metering, where National Grid's assets are located within customer's homes / properties and Isle of Grain as an unregulated storage business).

## National Grid's Vision

> ***"We, at National Grid, will be the foremost international Electricity and Gas Company, delivering unparalleled safety, reliability and efficiency, vital to the wellbeing of our customers and communities.***
>
> ***We are committed to being an innovative leader in energy management and to safeguarding our global environment for future generations."***

From the National Grid vision "delivering unparalleled reliability to the wellbeing of National Grid's customers and communities" effectively means that National Grid's networks are designed, maintained and operated to ensure efficient and resilient performance for the UK consumer, considering the effects of climate change and other factors.

This report details the adaptation assessment for National Grid Electricity Transmission plc.

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# 4. RESPONSE TO STATUTORY GUIDANCE

## 4.1. INFORMATION ON ORGANISATION

### National Grid Electricity Transmission plc

**Transmission UK - Electricity Transmission Owner -** National Grid Electricity Transmission plc owns the electricity transmission system in England and Wales. National Grid Electricity Transmission plc's assets comprise a route length of over 7,200 kilometres of overhead line, mainly consisting of double circuits, about 700 kilometres of underground cable and 338 substations at 242 sites.

As electricity transmission owner, National Grid Electricity Transmission plc owns and maintains the physical assets, develop the networks to accommodate new connections and disconnections, and manage a programme of asset replacement and investment to ensure the long-term reliability of the respective networks.

**Transmission UK - Electricity System Operator –** National Grid Electricity Transmission plc is the national electricity transmission system operator, responsible for managing the operation of both the England and Wales transmission system that National Grid Electricity Transmission plc own and also the two high voltage electricity transmission networks in Scotland, which National Grid do not own. Day-to-day operation of the Great Britain electricity transmission system involves the continuous real-time matching of demand and generation output, ensuring the stability and security of the power system and the maintenance of satisfactory voltage and frequency. National Grid Electricity Transmission plc is also designated as system operator for the new offshore electricity transmission regime.

As electricity transmission system operator, National Grid Electricity Transmission plc undertakes a range of activities necessary for the successful, efficient delivery of secure and reliable energy. In the case of electricity, this involves the management of balancing services that include commercial arrangements with market participants that enable electricity demand or generation output to be varied.

### Regulation

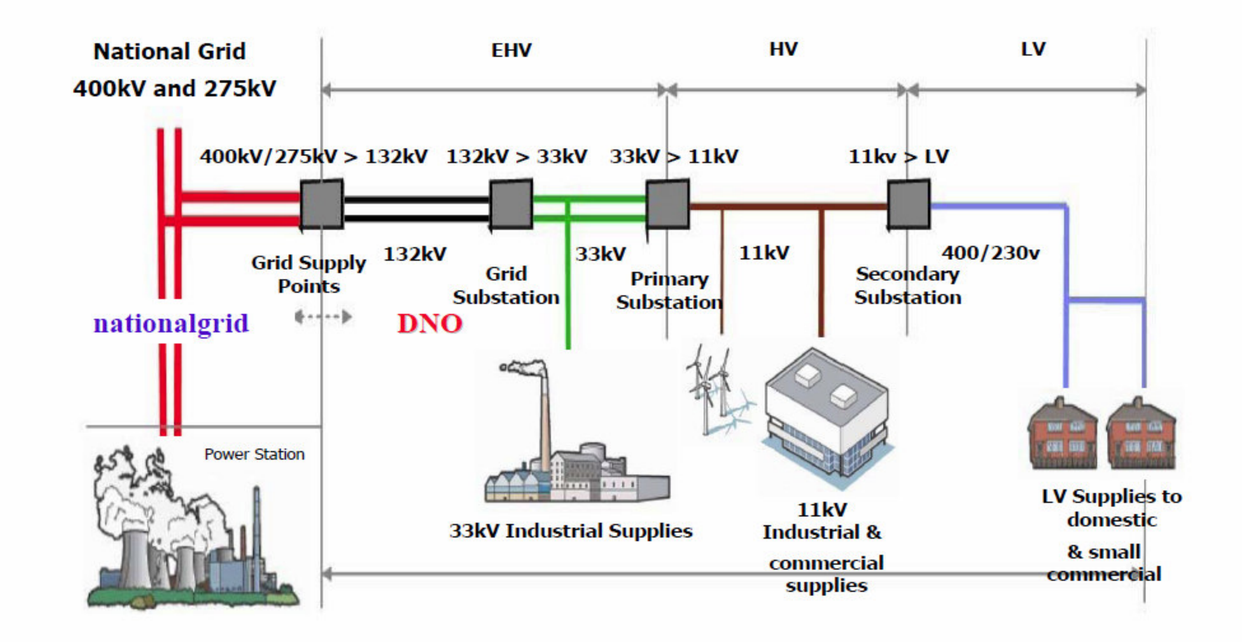
National Grid Electricity Transmission plc is the sole holder of an electricity transmission licence for England and Wales. This licence also covers National Grid Electricity Transmission plc's role as system operator for the transmission networks in Great Britain. Under the Electricity Act 1989, National Grid Electricity Transmission plc has a duty to develop and maintain an efficient, coordinated and economical system of electricity transmission and to facilitate competition in the supply and generation of electricity.

National Grid Electricity Transmission plc price controls are typically reviewed every five years and the current price control for both electricity and gas transmission activities as network owners covers the period 1 April 2007 to 31 March 2012. In December 2009, Ofgem announced that they intend to delay the implementation of the next control by one year to 2013; as a result the current control will need to be extended.

## Details of the Electricity Network

The Electricity Network comprises a mixture of overhead lines and underground cables. In addition there are points on the system; called substations, where voltage transformation takes place and switching and control equipment are located. The interface between Electricity Transmission and the Distribution Network Operators (DNOs) takes place within these grid substations normally at 132 kV.

*Figure 4.1.1 Electricity transportation process and voltage transformation*

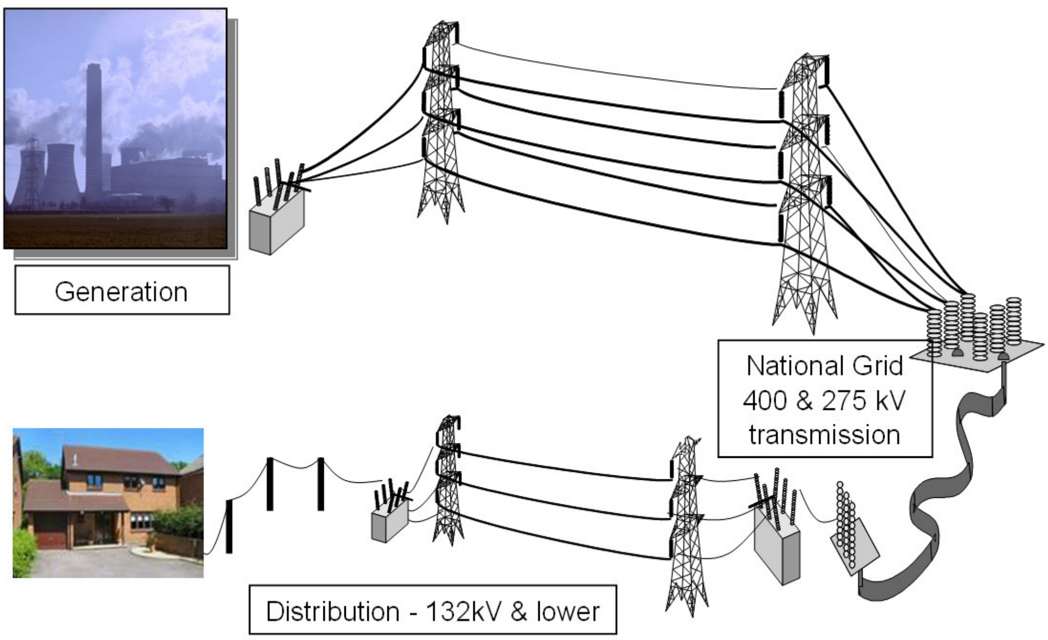



These networks are designed to provide an excellent level of service within a regulatory framework. Network design also takes account of normal load growth which has historically been around 1.5 to 2% per annum.

National Grid Electricity Transmission plc's transmission system covering England and Wales is linked by an interconnector to the transmission system of France and will also shortly be connected to the Netherlands transmission system which is due to be operational in late 2010. Although there is sufficient generation in the British transmission system (which includes the Scottish transmission network operated under licence by the Scottish transmission owners) to meet demand, by linking to another country's transmission system, National Grid Electricity Transmission plc can facilitate competition in the wholesale electricity market covering England, Scotland and Wales.

**Overhead lines** (OHL) in the UK Transmission networks are constructed using steel towers to support the conductors; these are often referred to as ("pylons"). The OHL support insulators that carry conductors that carry electrical current. The conductors are usually copper or aluminium based and of different sizes to provide different current carrying capabilities. These OHL normally connect one large substation to another, with no intermediate connections, and are referred to as "routes" and these routes connect the network together from generators at grid supply points to the grid supply substations then to the electricity distribution networks which in turn, at lower voltage, radiate out feeding individual customers or small communities / businesses along the route.

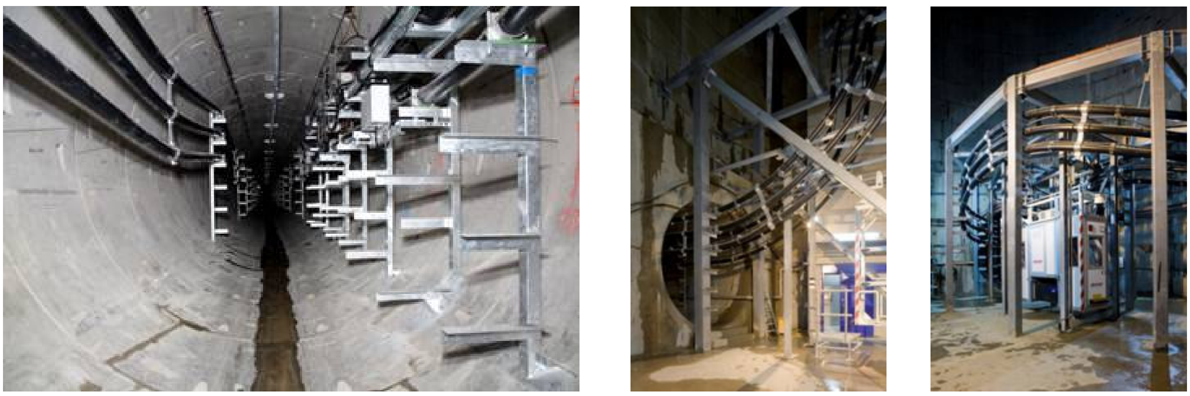
*Figure 4.1.2 Transportation methods*




**Cables** In the UK electricity cables are installed and operated at all the common voltages used on the electricity network from Low Voltage (400 / 230 volts) to 400 kV. Lower voltage cables may be installed 0.45m below the surface whilst higher voltage cables may be buried at depths of 1m or more.

The length of cables operated at the highest transmission voltages is limited due to the substantial costs involved, however as cable voltages reduce, the cost premium compared to an equivalent overhead line falls.

*Figure 4.1.3 High Voltage Cable Circuit from West Ham to Hackney, via New Cable Tunnel*



**Substations** A transmission substation connects two or more transmission lines. The simplest case is where all transmission lines have the same voltage. In such cases, the substation contains high-voltage switches that allow lines to be connected or isolated for fault clearance or maintenance. A transmission substation may have transformers to convert between two transmission voltages, voltage control devices such as capacitors, reactors and equipment such as phase transformers to control power flow. Transmission substations can range from simple to complex. Grid transmission substations can cover a large area (several acres / hectares) with multiple voltage levels, many circuit breakers (high voltage switches) and a large amount of protection and control equipment.

*Figure 4.1.4 – 400 kV Air Insulated Substation*

**Transformers** Used to transform voltage from one level to another. Within the transmission systems the most common transformation steps are 400 kV to 275 kV, to 132 kV which supplies the distribution networks which in turn further reduce the voltage to end user requirements.

Transformers basically comprise an iron core with copper or aluminium insulated wire coils wrapped around that, further insulated with a mineral oil and housed in a steel tank, with external connection points to the system. The passage of current through the wire coils ("windings") causes heating, since no wire is a perfect conductor, the insulating oil plays a major part in conducting that heat away.

The load carrying capability of the transformer is primarily dictated by the maximum temperature at which the windings and insulation can be operated without causing damage and fault. The greater the external ambient temperature the less heating can be permitted from the windings and consequently the rating is reduced. The pattern of demand loading during the day also has an impact.

*Figure 4.1.5 - 1000 MVA 400 / 275 kV Auto Transformer*

## 4.2. BUSINESS PREPAREDNESS

### Business Preparedness before the Direction to Report was Issued

National Grid has put climate change at the heart of its business. Alongside adapting National Grid's networks to climate change, National Grid is committed to both reducing its impact and helping the wider move to a low carbon economy. For example:

1. Embedding a **target of 80% greenhouse gas reduction** across National Grid's businesses by at least 2050 with a mid term reduction target of 45% by 2020
2. Investing **in its infrastructure** over the next five years to connect new low carbon energy sources
3. **Encouraging businesses, organisations and individuals** to meet the climate change challenge and embrace energy efficiency

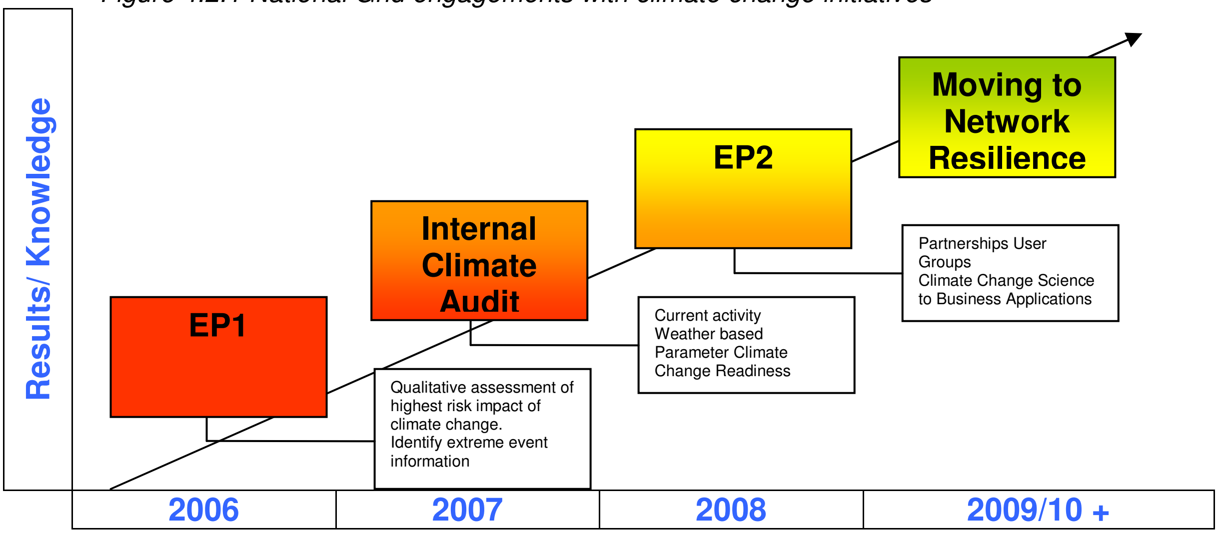
Asset management principles are embedded into all of National Grid's businesses including Electricity Transmission, Gas Transmission and Gas Distribution. This is demonstrated through its PAS55 certification which is a publicly available specification for the optimised management of physical assets. As part of National Grid's day-to-day business it regularly assesses risks to its assets including the risk from climate change.

National Grid has worked alongside the Climate Scientists at the Met Office, Hadley Research Centre and other energy companies over the last 3-4 years on research to better understand and prepare for the wider impacts of climate change on its electricity and gas assets and business operations.

Since 2006, National Grid Electricity Transmission plc has worked closely with the Environment Agency on addressing flood risks and sharing National Grid Electricity Transmission plc's work on the risk to substation sites currently within flood zones as indicated on the Environment Agency flood maps. This process is under continuous review as more data becomes available.

National Grid Electricity Transmission plc has been engaged in a number of initiatives related to climate change impacts and the journey so far has been summarised in Figure 4.2.1.

*Figure 4.2.1 National Grid engagements with climate change initiatives*



## Regulation and Levels of Service

Three key documents address important areas of regulation and levels of service for the electricity transmission system:

- **Grid Code**. This covers all material technical aspects relating to connections to, and the operation and use of, Great Britain's electricity transmission system. It is approved by Ofgem.

- **National Electricity Transmission System Security and Quality of Supply Standard**. Addressing overall levels of supply security, the standard specifies the conditions under which various levels of load should be maintained or re-connected in the event of an interruption. Although this standard allows for the loss of multiple circuits they do not provide for the loss of certain single points of failure, in particular, substations. Therefore, these sites must be given particular attention in terms of resilience planning. The standard is approved by Ofgem.

- **Electricity Safety Quality and Continuity Regulations 2002 (ESQCR)**. The regulations are set by the Department of Energy and Climate Change (DECC). Section 3, General adequacy of electrical equipment (1) (b), states that:

  "*Generators, distributors and meter operators shall ensure that their equipment is so constructed, installed, protected (both electrically and mechanically), used and maintained as to prevent danger, interference with or interruption of supply, so far as is reasonably practicable.*"

## Design Standards

National Grid Electricity Transmission plc's network infrastructure is designed to national and international industry standards. As these international standards apply within Europe and across the world in countries where existing conditions are similar to those projected due to climate change conditions for the UK by 2080, it demonstrates a degree of existing resilience to the expected climate changes.

Therefore there is some existing resilience to climate change impacts within existing UK design standards.

Equipment in the UK is based on industry standards that have been developed and enhanced over many years to ensure that UK networks are built from high specification, safe equipment that is fully interchangeable and can be installed and operated in a similar manner across the UK.

These industry standards and engineering practices have been established over the years through the Energy Networks Association (ENA) and predecessor organisations and therefore, because UK networks are designed and built on a common basis, they will all experience similar impacts from similar changes in climate. This underlines the reason for a common approach to national issues in adaptation.

The production of new ENA documents and the updating of existing documents are covered by an agreed process involving all ENA transmission and distribution network operators.

Some ENA document are annexed or are appendices to the Grid or Distribution codes and therefore any modifications are subject to governance by the Grid or Distribution Code Review Panel.

The development and review of National and International Standards is subject to well established procedures and UK electricity network operators have a long tradition of leading and influencing this work through BSI, European and International standards organisations.

Further details on these standards can be found in Appendix A.

## Embedding Climate Change Risk Assessment into the Organisation

The assessment of climate change risk is embedded into the National Grid organisation via the risk and compliance process, as detailed in Section 4.3 and ultimately results in actions or changes in policies and procedures where required. National Grid has processes in place to monitor legislation changes and changes to industry policy and procedures such that the policies and procedures within National Grid are reviewed and updated as necessary to remain current with regard to published information.

National Grid's attitude to risk management helps focus attention on business critical activities to bring increased consistency to all operations. In this way where a risk is common to all National Grid's operations, such as climate change, the corporate centre sets out the strategy to respond to the risk while the business units tailor the guidance to meet their operational requirements.

National Grid's group procedure on risk management was approved in 2003 where the key statutory and best practice outcomes include:

- Combined code 2003, in particular the related Turnbull Guidance on Internal Control
- US Corporate and Criminal Fraud and Accountability Act of 2002 (the Sarbanes-Oxley Act)
- Risk Management Standard produced in 2002 by UK professional bodies, e.g. Institute of Risk Management

The group procedure is aimed at ensuring a consistent 'best practice' approach is adopted across National Grid to identify and manage risks to ensure that:

- Risks are considered in the context of their ability to impact the business objectives
- Clear allocation of responsibilities for managing risk
- Proactive review of risks (on management and executive agendas)
- Supporting systems are in place to assist in the effective management of risks

## National Grid's Risk and Compliance Process

National Grid has a robust risk compliance process which has already identified climate adaptation risks. Best practice business risk assessment should:

- Focus on those risks that would impact upon your business objectives
- Rely on professional judgement and common-sense
- Be relevant to business area
- Focus on significant current and future events
- Consider historical information and experience where available
- Identify the causes and consequences of each risk
- Highlight the impact of the risk (both financial and reputation) and the likelihood (probability or frequency) of its occurrence
- Identify the controls in place or that are needed, to remove or reduce risks to a target level

The Risk Management Control Procedure sets out that, as minimum, key risks are reviewed at National Grid Executive level on a half-yearly basis.

**Key Risks** are reviewed by the National Grid's Directorate Management Teams on at least a quarterly basis and in line with Group procedure requirements. This review focuses on changes in risk profile throughout the period and progress to date against actions.

If the risk(s) is not mitigated to the target level assessed for the risk, actions are required to be completed in order to manage the risk to an acceptable target level. In this instance, the review should focus on improvement actions needed to achieve the target rating.

An example of this process in practice is the risk of sites flooding which brought about an action to assess the location of sites against the probability and impact of a flood occurrence. Further information on National Grid's Risk and Compliance Process can be found in Section 4.3.

## Investigative Studies on the Impacts of Climate Change

National Grid Electricity Transmission plc, together with other energy companies and the trade body, the ENA has commissioned several studies into the affects of climate change. Some of this work has been delivered or is in progress and is funded by the by Investment Funding Initiative (IFI) or traditional investment schemes. Table 4.2.1 details the high level output or continuing work of these studies.

*Table 4.2.1 – Projects with climate change considerations*

| Projects with Climate Change Considerations | | |
|---|---|---|
| **Project Title** | **External Body** | **Energy Participants** |
| Vegetation Management | ADAS | National Grid, EDF, SP, ENW, CN |
| Pluvial Flood Risk Modelling | ADAS | CN |
| Future Network Resilience | Met Office | ENA |
| Dynamic Ratings Project | Met Office | CN |
| EP1/2 Impact of Climate Change on the UK Energy Industry | Met Office | ENA |
| Urban Heat Island Study | Birmingham University | CN |
| Earthing Information Systems | BGS and NSA | EDF, CN |
| Flooding Risk Reduction | Mott McDonald | National Grid |
| Investigation to Network Resilience to Weather Events | EA, Met Office | ENA |
| Re-appraisal of seasons and temperature thresholds for the power rating of electrical plant – a pilot study considering transformers only 2006 | Met Office / Southampton Dielectric Consultants Ltd | National Grid |
| Re-appraisal of seasons and temperature thresholds for the power rating of electrical plant – a pilot study considering transformers only 2007 | Met Office / Southampton Dielectric Consultants Ltd | National Grid |
| Re-appraisal of seasons and temperature thresholds for the power rating of electrical plant – a pilot study additional work 2008 | Met Office / Southampton Dielectric Consultants Ltd | National Grid |
| Flooding Risk and Severe Weather Mitigation Demountable Flood Barrier Facilitating work | N/A | National Grid |
| Flood Risk Assessment | N/A | National Grid |
| Flood Risk Mitigation works 1:100 risk sites | N/A | National Grid |
| Flood Risk Mitigation studies 1:200 risk sites | N/A | National Grid |
| Flood Risk Mitigation studies 1:1000 risk sites | N/A | National Grid |
| Flood Risk Mitigation, Towers and Erosion studies | N/A | National Grid |

## ENA – ETR 138 – Resilience to Flooding for Grid and Primary Substations – Issue 1 October 2009

The serious incidents of flooding in the South Midlands and South Yorkshire during the summer of 2007 and the incident at Carlisle in 2005 highlighted the potential vulnerability of electricity substations to major flood incidents from current levels of flooding.

In the absence of any specific guidance on the level of acceptable flood risk or regulatory impact assessment, it was recognised that the extent of the duty has been unclear. Since the introduction of the Electricity Safety, Quality and Continuity Regulations, far greater information on flood levels has become available to assess flood risk to substations and the respective mitigation options and costs. This facilitated the development of an industry Engineering Technical Report, ETR 138, setting out a common approach to the assessment of flood risk (inclusive of allowances for climate change and sea level rise) and the development of target mitigation levels that are subject to cost benefit assessment.

The Task Group that produced ETR 138 comprised representatives from Networks Companies, DECC, OFGEM, EA, SEPA, Met Office and the Pitt Review Team. The report was accepted by the Energy Emergencies Executive Committee and companies have begun a circa ten year programme of work to improve substation resilience to flooding. Distribution companies agreed their first five year programme, with Ofgem at the end of 2009. Transmission companies have already started their resilience work and expect to formally agree a programme with Ofgem at their next Price Review in 2013.

As a general principle Network Owners will target the completion of agreed protection to grid and primary substations as follows:-

- Transmission Sites - finishing in 2022 (subject to Price Control Review Periods)

However, these timescales may be extended if additional substations are identified to be at risk due, for example, increased climate change allowances and/or visibility of risks associated with surface or ground water flooding. National Grid Electricity Transmission plc will prioritise their investment programmes to ensure that risk is appropriately managed during the implementation period consistent with available funding for these programmes.

## National Grid Electricity Transmission plc's Work on Flood Resilience

In line with ETR 138, National Grid Electricity Transmission plc has undertaken a review of the impact of fluvial (river) and tidal (sea) flooding at all substation sites. Substation sites were checked against the Environmental Agency (EA) fluvial and tidal flood risk data. Where sites were identified at risk National Grid Electricity Transmission plc contacted the EA to validate the flood height data. In order to evaluate the risk to the site this data was then checked against the substation Above Ordnance Datum (AOD).

National Grid Electricity Transmission plc is preparing a scheme to undertake flood mitigation work at all sites at risk of a 1:100 year fluvial and tidal flood event and undertake the next phase of detailed site surveys for sites indicated at risk from a 1:200 year flood event inclusive of climate change and data inaccuracies.

National Grid Electricity Transmission plc is also undertaking assessments to understand the risks posed to substations from other sources of flooding e.g. pluvial (extreme rainfall), and erosion risks.

Until work to defend sites is complete National Grid Electricity Transmission plc has emergency deployment plans to utilise a 1.2 km mobile flood defence system, which can be deployed at short notice.

47 sites were originally identified at risk of flooding from a 1:100 year flood event. After more detailed site surveys in 2009/10, which also confirmed the AOD, and included costs to defend the sites against flooding, of the original 47 sites only 13 were actually at risk from a 1:100 year flood event.

ETR 138 defines the target resilience of 1:1000 year flood event with suitable allowances for climate change and errors in data. Where this is not achievable it should be reduced until practical (e.g. 1:900, 1:600, 1:300 etc.) with a minimum standard of 1:200 with suitable allowances for climate change and errors in data in all cases.

Where the target standard is not practical an appropriate cost benefit analysis will be carried out considering societal risk, refer to Table 4.2.2 for details of typical customers supplied by National Grid Electricity Transmission plc sites.

*Table 4.2.2 – Typical voltage levels and customers supplied*

| Typical Voltage Transformation Levels | Approximate Number of National Grid Sites | Typical Size | Typical Number of Customers Supplied |
|---|---|---|---|
| 400 kV to 132 kV | 242 | 250m by 250m | 500,000 / 200,000 |

As well as societal risk the following factors are considered;

- The projected lifespan of the site (< 10 years)
- Engineering constraints on site
- Any wall defence not exceeding 2.4m high due to safety and engineering constraints
- Cost of the target resilience not exceeding 50% or £1m of the minimum defence option which ever is the greater

Coastal erosion risks to substations are also being monitored as the Environmental Agency continues to update their shoreline management plans (SMP). Following an initial assessment carried out in 2009, a total of 57 substation sites have been identified as being in these zones. It is anticipated that the Environment Agency's preferred policy will be to hold the line in the majority of cases i.e. maintain the existing level of defence. Confirmation and further studies will be carried out when the SMP review is completed in 2011.

## Met Office EP1 / EP2 Project – The Impact of Climate Change on the UK Energy Industry - 2008

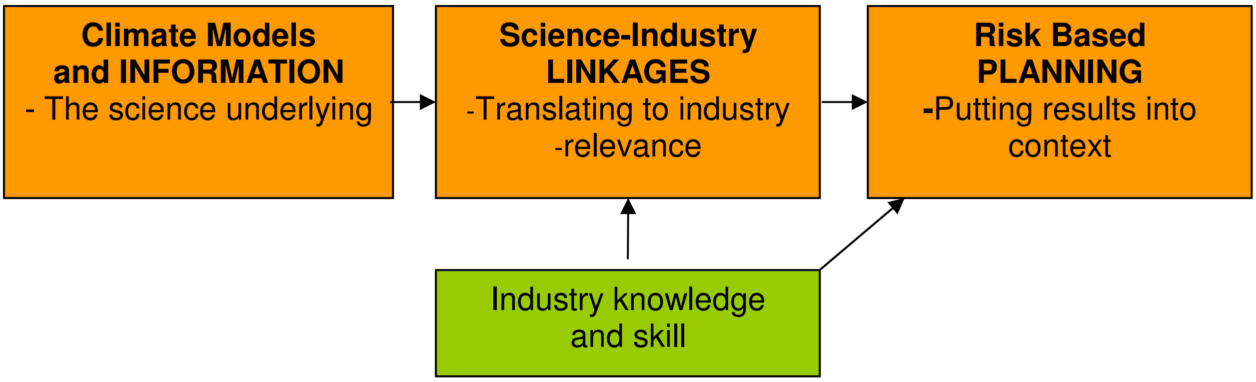
A number of UK energy companies including National Grid Electricity Transmission plc commissioned the Met Office to carry out a project to investigate the potential impact of climate change. The project was split into EP1 customer requirements and scoping which was completed in 2006 which facilitated the EP2 project which assessed the risk of climate change on the UK's energy industry. This report was published in 2008.

### Met Office Project EP2

In 2008, alongside other energy companies and the Met Office, National Grid Electricity Transmission plc completed a groundbreaking study to consider the effects of climate change on the energy industry.

The 14-month project called 'Energy Project 2 (EP2) set out to establish what effect climate change will have on the industry's infrastructure and business. EP2 project was carried out with industry experts (working in partnership, see Figure 4.2.2) with the view to bring the science very close to practical business application for planning purposes.

*Figure 4.2.2 Partnership approach*




EP2 was vital for the industry because of the need to be able to forecast 15 to 40 years ahead for any current asset investment. The EP2 project has given the Energy Industry some of the tools National Grid Electricity Transmission plc need for future planning. Energy infrastructure is costly and can have a lifespan of 40 or more years, therefore the Energy Industry took the expert advice of the Met Office Hadley Centre. This will help anticipate the potential impacts of climate change and allow the industry to future proof what it builds in the coming years.

EP2 investigated a number of issues including soil conditions and their impact on cables; how urban heat islands might change so the distribution industry can plan city infrastructure; the relationship between electricity network resilience and weather; a tool to predict sea surges at sites of interest, and climate models and wind projections.

Potential changes in demand are another key factor as higher temperatures could increase electricity requirements during the summer, as air conditioning units become more widely used. However, this is balanced by expected lower demand in the winter. The findings of the next 10 years climate data is being considered by Energy Companies to use in their future Energy supply / demand planning process.

## The project covered the following areas:

- Developed innovative new techniques that apply climate models to energy applications so that the industry is better placed to adapt to climate change
- Investigated future wind resource, enabling the industry to understand the continued uncertainty of future wind power. This will assist risk management and investment decisions
- Modelled future soil conditions and their impact on cables so that Companies can understand the cost and benefits of installing cables for a more resilient future network
- Built a tool to enable UK and marine sites of interest to be screened to assess if sea level rise should be considered in more detail
- Investigated how the urban heat island effect may change in the future so that Networks can develop plans for their infrastructure in cities
- Produced guidance to help make best use of public domain information on climate change such as the United Kingdom Climate Impacts Programme new scenarios of climate change (UKCP09)
- Delivered new site specific climatologies of temperature, wind speed and solar radiation that account for climate change so that decisions can be based on realistic climate expectations
- Examined the relationship between historic weather patterns and network fault performance with a view to developing a tool to predict future network resilience

## EP2 - Estimation of the Impact and Likelihood of Risks Occurring at Various Points in the Future

The EP2 Project found that because of climate change:

- With a few exceptions, such as the thermal ratings of equipment and apparatus, there is currently no evidence to support adjusting network design standards. For example existing design standards for overhead line conductors do not require change.
- The risk profile for distribution transformers will be affected. Design thresholds of temperature will be exceeded more often and there will be more hot nights in cities.
- Soil conditions will change; higher temperatures and seasonal differences in soil moisture are expected. Future conditions could be included in cable rating studies by increasing average summer soil temperatures in the models by approximately 0.5°C per decade.
- Wind resource is uncertain and understanding future resource represents a significant challenge. Although National Grid Electricity Transmission plc doesn't yet have the answers, this project has highlighted possible strategies for improving National Grid Electricity Transmission plc's knowledge.

## Met Office – Base Line Climate Risk Assessment for the Electricity Network – June 2010

This document is a report on the progress in Component 2 of the Met Office "Climate risk assessment of future network resilience" project see below.

The current (baseline) risk experienced by the electricity network from weather-related faults has been investigated by analysing the historical record and assessing the relationships between faults and weather, and the relative contributions of different types of weather related fault, both in terms of numbers of faults and numbers of customer interruptions that have been caused by these faults.

England and Wales transmission: key conclusions:

- The transmission network is much more resilient to weather related faults than the distribution network
- The dominant cause of weather related faults on the England and Wales transmission network is lightning (62% of weather related faults)
- Wind and gale, and snow storms / blizzards and ice cause a further 22% and 12% of weather related faults respectively
- Rain accounts for the remaining weather related faults (~3%), with almost no freezing fog and frost faults (~0.1%) or flooding faults (~0.3%) being recorded. No solar heat faults have been noted in the historical record

A UK wide hazard analysis has been undertaken for the transmission network in terms of wind and gale, lightning, and snow storms / blizzards and ice faults.

## Met Office - Climate Risk Assessment on Future Network Resilience – Due to Complete end 2010

The electricity transmission and distribution networks are susceptible to localised faults caused by weather such as lightning, snow and high winds. The objective of this project is to investigate whether the network risk to weather related faults may change in the future as a result of climate change. The work in this project has been split into the following four components:

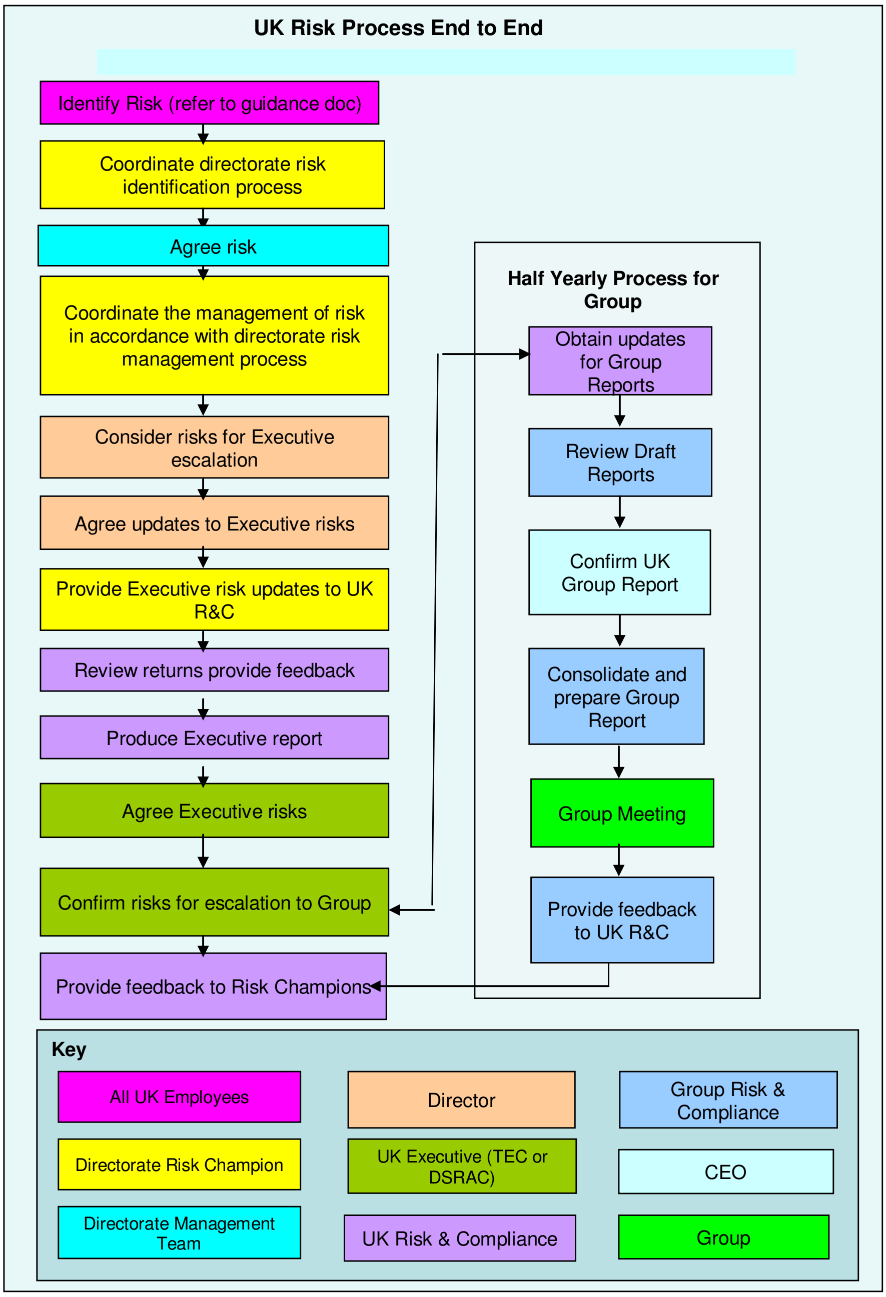
- Component 1: - Downscaling the UK Climate Projections (UKCP09) to energy license boundary areas from 25 km
- Component 2: - Model development
- Component 3: - Impacts assessment
- Component 4: - Tool development

# 4.3. IDENTIFYING THE RISKS DUE TO CLIMATE CHANGE

## Risk Assessment Methodology

National Grid's approach to assessing the risks has been consistent across both Electricity and Gas and the details of this process can be found in Figure 4.3.1. As part of ongoing risk process, climate change issues have been captured and followed through to the annual report and the corporate responsibility report.

*Figure 4.3.1 National Grid's Risk and Compliance Process*



## Climate Change Risk Assessment Methodology

*Figure 4.3.2 Climate Change Risk Assessment Methodology*


At present, the best available published information on climate predictions is contained in the UK Climate Projections 2009 (UKCP09) published in July 2009. Figure 4.3.2 shows National Grid's climate change risk assessment methodology.

UKCP09 provides historic and projected climate information for the UK up to the end of this century. Projections of future changes to the UK's climate are provided, based on simulations from climate models.

The Projections show three different scenarios representing high, medium and low greenhouse gas levels. The types of climate information provided are:

- Observed climate data (20th and 21st century historical information about temperature, precipitation, storms, sea surface temperatures and sea level)
- Future climate projections (for temperature, precipitation, air pressure, cloud and humidity)
- Future marine and coastal projections (for sea level rise, storm surge, sea surface and sub-surface temperature, salinity, currents and waves)

Key vulnerabilities in the energy sector are those associated with higher temperatures and an increased intensity of precipitation and therefore flooding. Other possible vulnerabilities may include changes in wind, increased frequency of lightning etc. To date there is no published data in UKCP09 to support any increases in these areas.

In summary, using the UKCP09 work, three scenarios were developed for 2020, 2050 and 2080. National Grid has chosen to risk assess its assets and processes against the high level scenario which is based on the least likely to occur prediction of climate change as of 2080. This was on the basis that should National Grid Electricity Transmission plc's assets and process demonstrate resilience against this scenario it would inevitably be adapted against lower and more likely climate change. This is also consistent with general planning assumptions within the businesses.

To better understand the potential impacts and associated risks that these Climate Change Scenarios pose on National Grid Electricity Transmission plc's assets they have been converted into key 'Specific Physical Characteristics'. To help do this additional information has been taken from the Met Office's work on climate risk assessment on future network resilience and combined with National Grid Electricity Transmission plc's engineering judgement.

The result has been to identify Specific Physical Characteristics that are likely to be caused by these scenarios, and it is the impact of these characteristics to National Grid Electricity Transmission plc's key assets and processes that is risk assessed. The Physical Characteristics can be broken down into three groups that provide a total of nine Specific Physical Characteristics:

1. **UKCP09 Characteristics** are directly correlated to the UKCP09 work and so have greater definition and probabilities around them

2. **Met Office Characteristics** are taken from the Met Office work on "Risk Assessment on future Network Resilience"

3. **National Grid Characteristics** added by National Grid to ensure that the main key risk areas are covered

For the final two groups, although these characteristics may be caused as a result of climate change, further work will be required in the next update of the UKCP09 data to assess any expected increases in magnitude and the associated probabilities.

The Specific Physical Characteristics can be summarised as follows:

**UKCP09 Characteristics**

- Summer mean temperature rise of up to 8$^{o}$C
- Increased heavy rainfall (by a factor of up to 3.5)
- Sea level rises of up to 43 cm

**Met Office Characteristics**

- Increased lightning
- Increased wind and gale
- Increased snow, sleet, blizzard, ice and freezing fog
- Increased flooding

**National Grid Characteristics**

- Increased coastal / river erosion
- Increased subsidence

Further information and the methodology used in developing the scenario characteristics can be found in Appendix C.

Having identified the Specific Physical Characteristics, the key asset types and processes to assess these against were identified.

**Electricity Transmission Assets**

- Substation Sites – including all plant and equipment e.g. switchgear, transformers and earthing
- Expansion of existing substation sites (outside of existing boundary)
- Existing Tunnels and Underground Cable Route
- Existing Cable Bridges
- Existing Overhead Lines (OHL) and Towers
- New Sites(Substations, Overhead lines, Tunnel Heads, Cable Sealing Ends)

**Electricity Processes**

- Emergency
- Maintenance, Construction & Fault Repairs
- Control Centre Operations
- Office staff

The Adaptation Risk Assessment process applies the Specific Physical Characteristic, one at a time, to each of the Key Assets and Processes. It then assesses if the result may have an impact on the public from a security of supply perspective, albeit there may still be other impacts.

This analysis has four potential outcomes that are identified using the following approach:

**Green** No material risk to assets or processes from the Specific Physical Characteristic. This is either because no risk has been identified or the existing assets or processes are robust and no further action is required in terms of adaptation measures.

**Yellow** A level of risk has been identified through the risk assessment. Action plans have or are being developed and progress is being monitored via the risk process, it may be that additional investment will be required to manage these risks. These risks have been further assessed using National Grid's risk management process.

**Amber** Insufficient information is currently available on the affects of the Specific Physical Characteristic to calculate the level of risk. Further monitoring or assessment will be carried out to better understand this risk.

**Red** Highly likely or significant, material risk in the future. Current business processes and action plans do not adequately address this specific risk. Full risk assessment and action plan to be developed.

Further details of the risk assessment process can be found in Appendix C, the outcome of this process can be seen in Section 4.4.

National Grid has embedded in its processes the costs of adaptation, for example flooding is on the risk register, and the associated schemes to mitigate this issue are produced and sanctioned within existing processes. A cost benefit analysis for each individual scheme is required as part of National Grid Electricity Transmission plc's scheme sanction process.

## 4.4. ASSESSING RISKS

### Adaptation Risk Assessment Results

Whilst it is apparent that energy infrastructure may be vulnerable to certain aspects of climate change, the infrastructure has a significant degree of resilience, to change and therefore adaptation. In addition, technically it will be feasible to deal with adaptation issues over short, medium and long-term periods. Energy infrastructure is designed to international standards and the same standards allow infrastructure to operate around the world in varying climatic conditions, including projected climate conditions for the UK.

The identified Specific Physical Characteristics which National Grid Electricity Transmission plc have risk assessed its main assets and processes against are:

- Summer Mean temperature rise of up to 8°C
- Increased heavy rainfall (by a factor of up to 3.5)
- Sea Level rises of up to 43cm
- Increased lightning
- Increased wind and gale
- Increased snow, sleet, blizzard, ice and freezing fog
- Increased flooding
- Increased coastal/river erosion
- Increased subsidence

### Temperature Effects – Summer Mean Temperature Rise 8°C

Electrical current passing through a conductor causes the conductor to heat up. The current rating of electrical plant is generally governed by the equipment's maximum permissible operating temperature i.e. the amount of power the equipment can transmit without exceeding maximum design temperature. The current rating is dependent on the ambient temperature the equipment is operating within and enhanced equipment ratings can be achieved for lower ambient temperatures.

Maximum operating temperature is determined by international standards. National Grid Electricity Transmission plc then determines the seasonal ambient temperature which is published in a Technical Guidance Document. The ambient temperature is then used to determine the maximum current rating of the electrical plant.

If the ambient temperature increases the maximum current rating of overhead lines, cables, transformers, switchgear is reduced. EP2 project has highlighted ratings as potentially impacted by climate change, refer to Table 4.4.1.

*Table 4.4.1 Typical reduction in asset capacity for high emissions at 90% probability level*

| **EP2 - Typical Reduction in asset capacity for high emissions at 90% Probability Level** | |
|---|---|
| Equipment | UKCP09 Period 2070-2099 |
| Overhead Lines | 3% |
| Underground Cables | 5% |
| Transformers | 5% |

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Additional work is needed to study the potential impact of reduced ratings in order to ascertain any potential effect on the system and associated costs.

A reduction in capacity can be seen as equivalent to an increase in load and these are relatively small capacity reductions compared with recent historical load growth. In addition, networks will also be undergoing major upgrading over the next ten to twenty years to accommodate a low carbon energy future, refer to Section 4.7.

**Seasonal Demand Curve**

Milder winters are expected to reduce winter peak demand and air conditioning load is expected to increase summer demand, resulting in a flattening of the seasonal demand profile. At present, networks are designed with a level of security that ensures that circuits can be taken out of service at more lightly loaded times in the summer to allow maintenance or construction activities. With a flatter demand curve, this will be more difficult to achieve.

However this has to be seen in the context of accommodating a low carbon energy future and a change to “Smart Networks”. This initiative is planned to support the requirement that Renewable Distributed Generation and Low Carbon Loads can be connected to Networks in large numbers; the adaptation work connected with this is likely to offset any flattening of the demand curve.

Transformers, cables and overhead lines, used in electrical power transmission, all generate heat when in use and have maximum safe operating temperatures. The temperature of this equipment increases with ambient temperature and current. As ambient temperature increases, the maximum current for safe operation is reduced; therefore, in order to aid network planning, each type of equipment is allocated a maximum power rating which varies with temperature. Furthermore, each season is allocated a maximum ‘operating temperature’ for each type of equipment. This is the maximum temperature likely to be exceeded for a sufficient duration to affect the equipment.

For transformers, the maximum current load is determined by assuming that the highest temperature sustained for a period of 3-6 consecutive hours is 10ºC in winter, 20ºC in spring and autumn and 30ºC in summer. The period of 3-6 hours allows for the slow thermal response of transformers. ‘Winter’ is defined as December-February, ‘spring/autumn’ as March, April and September-November and summer as May-August. Different operating temperatures and seasons are defined for other types of electrical plant.

The decision making process for equipment rating begins about a year ahead, when plans are made to shut down equipment for maintenance. Computer models of the transmission system are used to ensure that there is an "N-2" level of resilience. This means that supply to domestic consumers must be uninterrupted even if two circuits fail in addition to planned maintenance outages. Exceeding maximum operating temperature reduces the operational life-time of the equipment and may cause it to fail. Conversely, if the maximum ambient temperature is overestimated, then the current may be reduced, or investment in extra infrastructure made, unnecessarily. Hence, there is value in re-appraising the operating temperature guidelines from time to time.

Studies carried out on National Grid Electricity Transmission plc’s behalf have shown that cumulative temperature distributions have been presented for the hot summers of 2003 and 2006 which in London at least; are shown to be ~5$^{o}$C warmer than the standard curve currently used by National Grid Electricity Transmission plc. The curves for Manchester, representing a more northerly location, were also warmer but less so. It is also found from a meteorological viewpoint, the months of May and September could sensibly be combined to form a separate ‘low summer’ season, leaving a warmer ‘high summer’ season, June-August. Given that September is also shown to be warmer than May, it is furthermore concluded that, if May is retained in the existing definition of summer (May-August), it would be sensible to also include September.

Further investigations are ongoing to fully understand any potential ramifications of adopting this and the affects of Adaptation into National Grid Electricity Transmission plc’s procedures.

**Substation Earthing - Impact of Climate Change on Earth Resistance**

Earthing is essential to enable faults, to be detected quickly and automatically made safe. When an earth fault occurs on the electricity network:

- A large current will flow along the cable and OHLs and return to the source via the cable sheath and the general mass of earth
- The current will flow until the source protection disconnects the power supply
- The current flowing through the ground will cause a considerable rise in voltage - known as rise of earth potential (ROEP) or earth potential rise (EPR) - on the ground and any metalwork connected to earth near the fault - creating a possible danger (touch and step potential) to anyone in the vicinity if this exceeds tolerable voltage levels
- This rise in voltage may be transferred onto adjacent power and metallic service cables creating possible danger to anyone who might be in contact with them – this may be some distance from the actual fault

An earth system is designed to alleviate the above dangers and not transfer but allow protective systems to operate correctly. The design at transmission substations requires measurements and complex calculations to be carried out prior to construction.

The impedance of an earthing system is mainly determined by the soil / geology in contact with the earthing system and the soil / geology in the immediate vicinity of the earthing installation. Different soil / geology types exhibit different values of resistivity.

Earthing impedance changes with time as the resistivity of the ground varies in response to changes in water content and for shallow installations, temperature extremes. If the variations in moisture and temperature caused by climate change adversely affect the soil resistivity the earth impedance could increase and the earthing installations would no longer satisfy the requirements of the original earthing design. Major maintenance is carried out every 12 years and impedance measurement tests are carried out in order to validate that the protection design is still to National Grid Electricity Transmission plc standards. Subsequently any changes required to the earth system design would be captured under National Grid Electricity Transmission plc's normal process.

## Lightning

Lightning storms have the potential to cause damage, latent damage, flashovers and transient interruptions to the electricity transmission network, for example damage to insulators, bushings and cables. The effects of lightning can be minimised by including both shielding measures and suppression devices into electricity networks.

The existing design standards of overhead lines and substations takes account of the frequency of lightning storms i.e. 1 event / 100 km / annum. At present there is no data published in UKCP09 to indicate an increase in the severity or frequency of lightning storms.

Therefore unless a future update of UKCP09 indicates an increase in intensity or frequency there is no potential climate change impact to National Grid Electricity Transmission plc's assets from lightning storms and hence adaptation measures are not necessary at this stage.

## Wind Data

Overhead electricity lines form a key asset group for electricity transmission and the primary climate interactions for ratings involve temperature and low wind speeds (of the order of < 0.5m/s), whilst those for resilience involve high wind speeds and their return periods. Whilst UKCP09 has a good level of detail down to 25 km level on ambient temperatures, it does not have correspondingly detailed data on wind speeds.

**Wind Storms -** Work undertaken by Met Office Hadley Centre has indicated that they do not forecast an increase in severity of high wind events (say > 25m/s), but there might be an (un-quantified) increase in frequency of such events. This gap in detailed knowledge will affect National Grid Electricity Transmission plc's ability to undertake an equivalently detailed assessment in relation to high wind speed events.

Site equipment is designed for effective wind speeds of 34m/s (76mph) and the most vulnerable assets to wind events, OHLs are designed for:

- Mean wind speed of 33.28m/s to 37.81m/s (74mph to 85mph)
- Gusts of 51.91m/s to 58.99m/s (116mph to 131mph)

**Wind Loading -** The original wind map for the British Standard for tower design (BS 8100) was produced from an analysis of Met Office wind records by Cook and Prior. The map was published in 1986, based on the analysis of the 11 years of wind data from 1970 to 1980. Cook recently updated the wind map for the British Standards Institution, making use of the 30 years of wind data that were now available since 1970. The main findings from this new and more extensive analysis were published in 2001. It was concluded that, from an analysis of successive ten-year periods, overlapped by 5 years, there is a slight trend of decreasing 50-year return wind speed. The revised wind map is essentially similar to the existing version in BS 8100, but there is a reduction in wind speeds across the Midlands and East Anglia. Hence, this study found no evidence for climate change causing an increase in extreme wind speeds in the UK.

Therefore unless a future update of UKCP09 indicates mean or gust speeds in excess of those values stated above there is no potential climate change impact to National Grid Electricity Transmission plc's assets from wind storms and hence adaptation measures are not necessary at this stage.

## Snow, Ice Accretion

Overhead line mechanical design takes account of the combination of wind + snow / ice accretion loading. At present there is no data published in UKCP09 to indicate an increase in the severity of snow or ice accretion.

Following the storms in France in December 1999 and ice storms in Canada 1998 National Grid Electricity Transmission plc has worked with the Met office to answer the question below:

*"Specifically what changes will there be to the sizes of the structural elements of towers to take account of climate change / more violent weather?"*

The project found that a reduction in the intensity of the most frequent extreme meteorological conditions likely to cause conductor damage is a possibility. However, the ability of climate models to simulate changes in extreme winds is not high. It is recognised that, at this stage, a marked increase in the intensity of the most extreme cases cannot be ruled out. However, in the absence of robust evidence to the contrary, the project recommended that the industry should continue to use design criteria based on present day risk.

**Ice loading -** The Met Office was also asked to review the icing climate in England and Wales based on historical weather data: this was to investigate the suitability of the icing map in BS 8100.

The Met Office does not record atmospheric icing, and the existence of icing conditions had to be inferred from historical records of temperature, humidity, precipitation and, in some cases, observations of present weather conditions. The icing was divided into four categories: freezing rain and drizzle, freezing fog, freezing cloud and wet snow. The review concluded that the BS 8100 icing map is principally based on rime ice caused by freezing cloud but it is not clear exactly how the design ice thickness was derived. It is considered that BS 8100 tends to overestimate icing from freezing rain and freezing cloud, at low altitude, but to ignore icing due to wet snow. To get a more precise picture of the icing climate would require very significant long-term measurements and research. National Grid Electricity Transmission plc's experience suggests that the overestimate of freezing rain and freezing cloud balance out the lack of allowance for wet snow. It should be noted that National Grid adopts a minimum design ice thickness of 40 mm without wind and 7 mm with wind, even where BS 8100 would predict smaller values. In summary, the Met Office observed no trend of increased likelihood of icing events, and National Grid Electricity Transmission plc's operational experience suggests that icing events are becoming less frequent.

Therefore unless a future update of UKCP09 indicates an increase in ice accretion there is no potential climate change impact to National Grid Electricity Transmission plc's assets from snow / ice accretion and hence adaptation measures are not necessary at this stage.

## Precipitation – Increased Rainfall, Flooding, Sea Level Rise, Coastal Erosion, Subsidence due to Flooding

In line with ETR 138, National Grid has undertaken a review of the impact of fluvial (river) and tidal (sea) flooding at all substation sites. In order to evaluate the risk to the site the EA data was then checked against the substation ordnance survey Above Ordinance Datum (AOD).

National Grid Electricity Transmission plc is preparing a scheme to undertake flood mitigation work at all sites at risk of a 1:100 year fluvial and tidal flood events and undertake the next phase of detailed site surveys for sites indicated at risk from a 1:200 year flood event inclusive of climate change and data inaccuracies.

National Grid Electricity Transmission plc is also undertaking assessments to understand the risks posed to substations from other sources of flooding e.g. pluvial (surface water flooding).

Until work to defend sites is complete National Grid Electricity Transmission plc has emergency deployment plans to utilise a 1.2 km mobile flood defence system, which can be deployed at short notice.

Coastal erosion risks to substations are also being monitored as the Environmental Agency updates their shoreline management plans.

Works are also being undertaken to understand the risks posed from flooding and erosion to other electricity sites and routes.

**Flood Depth Data for Flooding Causes other than Fluvial and Tidal** - There is no wide scale publicly accessible data of similar style to EA fluvial and tidal flood data on flood probability / depth for other causes of flooding such as pluvial (surface water), dam reservoir inundation.

The EA have indicated that information will start becoming available for other source of flooding in 2010.

**EA Shoreline Management Plans -** Whilst it is National Grid Electricity Transmission plc's understanding that Defra requires periodic updating of shoreline management plans (SMPs) which span out to + 100 years and that recently initiated work will incorporate UKCP09 data, it is inevitable that it will be some time before EA completes the process to update full "UKCP09" based coverage of the entire coastline. Consequently, although it is possible to obtain from EA the height of existing coastal defences and their preferred policy for each area, there is currently limited information on what decisions have been made on SMPs for future levels of defence, meaning there is some short term uncertainty whether specific assets would be flood mitigated at the shoreline or whether alternative solutions would be needed.

**River Erosion and Subsidence -** Ground movement and subsidence is presently managed through National Grid Electricity Transmission plc's existing processes and procedures by inspection, monitoring and remedial action.

Table 4.4.1 shows a summary of the process described in Section 4.3 for National Grid Electricity Transmission plc, refer to Table B.1 in Appendix B for a detailed version of this assessment.

*Table 4.4.1 – Specific Physical Characteristics of Climate Adaptation Scenarios*

| | Specific Physical Characteristics of Climate Adaptation Scenarios | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | UKCP09 Characteristics | | | Met Office Characteristics | | | | NG Characteristics | |
| **Key Assets and Processes** | **Solar Heat - Temperature rise of up to 8C** | **Increased Heavy Rainfall (by a factor of 3.5)** | **Sea Level Rises of up to 43cm** | **Increased Lightning** | **Increased Wind and Gale** | **Increased Snow, Sleet, Blizzard, Ice and freezing fog** | **Increased Flooding** | **Increased Coastal / River erosion** | **Increased Subsidence** |
| Included in National Grid Risk Management Process | **Yes** | **Yes** | **Yes** | **Yes** | **Yes** | **Yes** | **Yes** | **Yes** | **Yes** |
| **Assets** | | | | | | | | | |
| Substation Sites (Incl. switchgear, transformers, earthing) | | | | | | | | | |
| Expansion of Existing Substation Sites (outside of existing boundary) | | | | | | | | | |
| Existing Tunnels and Underground Cable Routes | | | | | | | | | |
| Existing Cable Bridges | | | | | | | | | |
| Existing Overhead Lines (OHL) and Towers | | | | | | | | | |
| New Sites - (Substations, OHL, Tunnel Heads, Cable Sealing Ends) | | | | | | | | | |
| **Processes** | | | | | | | | | |
| Emergency | | | | | | | | | |
| Maintenance, Construction & Fault Repairs | | | | | | | | | |
| Control Centre Operations | | | | | | | | | |
| Office Staff | | | | | | | | | |

## 4.5. UNCERTANTIES & ASSUMPTIONS

### Uncertainties in the Adaptation Programme

National Grid Electricity Transmission plc's adaptation plans are based on the evidence provided by UKCP09 and this information covers three scenarios for future climate change which are projections.

As the current data from the UKCP09 work is specific to temperature, rainfall and sea level rises, National Grid Electricity Transmission plc developed additional characteristics using data from work that it had completed with the Met Office and engineering judgement to give a wider range of scenarios.

As there is less detail available for these new characteristics they were treated more generically and so were not assessed to the same level as the UKCP09 Characteristics which were very specific. However, it was felt valuable to make broad assumptions around the potential impact on National Grid Electricity Transmission plc's assets if these characteristics materialise.

Climate change thresholds that start to trigger extreme weather events such as flooding or storms could be critical for National Grid, experience indicates these events may cause disruption to society, whilst repairs are undertaken.

At present UKCP09 does not provide any specific guidance on the potential effects of climate change on the Met Office and National Grid's additional characteristics, refer to Section 4.3. National Grid will continue to maintain close contact with the Met Office and other agencies to ensure that the most up to date information is available regarding these potential threats.

### Information Gap Analysis / Recommendations

National Grid welcomes any further information or assistance from the Met Office or other such agencies to enable better assessments of the risks going forward. Specifically the following limitations have been identified in available information within UKCP09 data:

- There is no information on future changes in frequency / intensity of wind / gales, including the combined probability of low wind speed (dead calm) events with high ambient temperatures
- There is no information on future changes in the frequency / intensity of lightning
- There is no information on future changes in frequency / intensity of snow, sleet, blizzard, ice and freezing fog
- EA shoreline management plan reviews (Coastal erosion) are not expected to be published until 2011

Although these characteristics may be caused as a result of climate change, further work will be required in the next update of the UKCP09 data to assess any expected increases in magnitude and the associated probabilities.

## Assumptions

There are a number of fundamental assumptions that underpin National Grid Electricity Transmission plc's risk assessment. These are detailed below:

1. UKCP09 and data from the Met Office is an accurate representation of climate change which will occur
2. National Grid Electricity Transmission plc's current business plans are assumed to be acceptable to the regulators and attract appropriate funding with government regulation continuing to operate without major change
3. Energy infrastructure continues to operate fundamentally in the same way as it does today
4. Third party organisations whose business affects energy infrastructure resilience, continue to operate fundamentally in the same way as they do today
5. Customers and suppliers will continue to have similar requirements for electricity which will continue to grow at historic rates
6. There will be no extreme changes to population numbers or distribution profile across the country
7. There will be no fundamental changes to industry standards or asset knowledge

## 4.6. ADDRESSING CURRENT AND FUTURE RISKS DUE TO CLIMATE CHANGE

Assessing the results that can be seen in Table 4.4.1 it can be seen that there are already a significant number of green cells showing that there are areas where no material risks have been identified. Crucially, there are no red cells, meaning that there are no instances where if the risk were to materialise, there would be an impact to the process in terms of loss of supply, safety or the environment. There are a number of yellows and ambers showing that there are gaps in knowledge and understanding and that further work is required.

*Table 4.6.1: Summary of yellow and amber risks from Risk Assessment Matrix*

| Business Function | Climate variable (e.g. increase in temperature) | Primary impact of climate change variable (e.g. health) | Threshold(s) above which this will affect your organisation | Likelihood of threshold(s) being exceeded in the future and confidence in the assessment | Potential impacts on organisation and stakeholders | Proposed action to mitigate impact | Timescale over which risks are expected to materialise and action is planned |
|---|---|---|---|---|---|---|---|
| Substation sites (including Switchgear, transformers and earthing) | Increased Temperature | Ratings | Temperature increases may have a marginal impact on equipment ratings<br><br>More work is required to better understand the potential impact | More work is required to better understand the potential impact and the likelihood of threshold being exceeded | Possible reduction in the flexibility of the network<br><br>More work is required to better understand the constraints which this may bring, also studies are required to understand if normal system growth would offset any loss in resilience | Studies to better understand the constraints which this may bring, and identify possible weaknesses in the system<br><br>Also studies are required to understand if normal system growth would offset any loss in resilience | It is not anticipated for risks to materialise within the next 20 - 40 years<br><br>Initial studies to confirm the risks are anticipated to be completed by 2012 |
| Substation sites (including Switchgear, transformers and earthing) | Increased Flooding and Heavy Rainfall | Pluvial and Fluvial flooding<br><br>There is a risk that due to extreme flooding a site may be lost or unable to function leading to reduced system security of supply | Most sites have a resilience to flooding to an approximate depth of 300mm<br><br>Each site has been assessed to better understand the projected flood frequency and possible impact of flooding on each site | In line with ETR 138 National Grid Electricity Transmission plc has assessed the flood risk of all substations in line with EA and AOD data<br><br>13 sites have been identified as being at risk from a 1 in 100 flooding event | A site may become non-operational due to sea inundation potentially leading to a loss of system resilience or a loss of supply<br><br>A non-operational site may not lead to a loss in supply | National Grid Electricity Transmission plc has embarked on a prioritised investment plan to defend sites to 1 in 200 or 1 in 1000 year flooding event dependant on cost benefit analysis and societal risk<br><br>In the interim National Grid has invested in a demountable mobile defence system of 1.2km | Investment is targeted for completion on all sites by 2022 beginning with the 1 in 100 risk sites |

| Business Function | Climate variable (e.g. increase in temperature) | Primary impact of climate change variable<br><br>(e.g. health) | Threshold(s) above which this will affect your organisation | Likelihood of threshold(s) being exceeded in the future and confidence in the assessment | Potential impacts on organisation and stakeholders | Proposed action to mitigate impact | Timescale over which risks are expected to materialise and action is planned |
|---|---|---|---|---|---|---|---|
| Substation sites (including Switchgear, transformers and earthing) | Increased Sea Level Rise | Flooding - sea inundation<br><br>There is a risk that due to extreme flooding a site may be lost or unable to function leading to reduced system security of supply | Most sites have a resilience to flooding to an approximate depth of 300mm<br><br>Each site has been assessed to better understand the projected flood frequency and possible impact of flooding on each site | Sea level rise is proven however the rate of increase is open to debate<br><br>Early assessments suggest a number of sites are in the EA study areas with a very small number potentially at an increased risk if the level of current protection is not maintained or improved | A site may become non-operational due to sea inundation potentially leading to a loss of system resilience or a loss of supply<br><br>A non-operational site may not lead to a loss in supply | Mitigation options will be subject to the outcome of the EA's shoreline management plan (SMP) review and any change in current level of protection<br><br>In the interim National Grid has invested in a demountable mobile defence system of 1.2km | Initial assessments of the EA's preferred options highlight some potential issues which will be further assessed following the final SMP release<br><br>The shoreline management plans are scheduled to be announced in 2011 |
| Substation sites (including Switchgear, transformers and earthing) | Increased Erosion | Coastal erosion | Shoreline management plans currently being reassessed by the EA indicate that a number of sites may be at risk from sea level rise<br><br>The level of risk will be subject to what mitigation, ongoing defence options are adopted, improved or maintained by the EA | Early assessments suggest a number of sites are in the EA study areas with a very small number potentially at an increased risk if the level of current protection is not maintained or improved | Due to the slow nature of coastal erosion any site that is identified at risk will be either protected or relocated prior to any system impacts<br><br>However mitigation costs may be significant | Mitigation options will be subject to the outcome of the EA's shoreline management plan (SMP) review and any change in current level of protection | Initial assessments of the EA's preferred options highlight some potential issues which will be further assessed following the final SMP release<br><br>The shoreline management plans are scheduled to be announced in 2011 |
| Expansion of existing substation sites (including Switchgear, transformers and earthing) | Increased Temperature | Ratings | Temperature increases may have a marginal impact on equipment ratings<br><br>More work is required to better understand the potential impact | More work is required to better understand the potential impact and the likelihood of threshold being exceeded | Possible reduction in the flexibility of the network<br><br>More work is required to better understand the constraints which this may bring, also studies are required to understand if normal system growth would offset any loss in resilience | Studies to better understand the constraints which this may bring, and identify possible weaknesses in the system<br><br>Also studies are required to understand if normal system growth would offset any loss in resilience | It is not anticipated for risks to materialise within the next 20 - 40 years<br><br>Initial studies to confirm the risks are anticipated to be completed by 2012 |

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| Business Function | Climate variable (e.g. increase in temperature) | Primary impact of climate change variable<br><br>(e.g. health) | Threshold(s) above which this will affect your organisation | Likelihood of threshold(s) being exceeded in the future and confidence in the assessment | Potential impacts on organisation and stakeholders | Proposed action to mitigate impact | Timescale over which risks are expected to materialise and action is planned |
|---|---|---|---|---|---|---|---|
| Expansion of existing substation sites (including Switchgear, transformers and earthing) | Increased Sea Level Rise | Flooding - sea inundation<br><br>There is a risk that due to extreme flooding a site may be lost or unable to function leading to reduced system security of supply | Most sites have a resilience to flooding to an approximate depth of 300mm<br><br>Each site has been assessed to better understand the projected flood frequency and possible impact of flooding on each site | Sea level rise is proven however the rate of increase is open to debate<br><br>Early assessments suggest a number of sites are in the EA study areas with a very small number potentially at an increased risk if the level of current protection is not maintained or improved | A site may become non-operational due to sea inundation potentially leading to a loss of system resilience or a loss of supply<br><br>A non-operational site may not lead to a loss in supply | Mitigation options will be subject to the outcome of the EA's shoreline management plan (SMP) review and any change in current level of protection<br><br>In the interim National Grid has invested in a demountable mobile defence system of 1.2km | Initial assessments of the EA's preferred options highlight some potential issues which will be further assessed following the final SMP release<br><br>The shoreline management plans are scheduled to be announced in 2011 |
| Expansion of existing substation sites (including Switchgear, transformers and earthing) | Increased Erosion | Coastal erosion | Shoreline management plans currently being reassessed by the EA indicate that a number of sites may be at risk from sea level rise<br><br>The level of risk will be subject to what mitigation, ongoing defence options are adopted, improved or maintained by the EA | Early assessments suggest a number of sites are in the EA study areas with a very small number potentially at an increased risk if the level of current protection is not maintained or improved | Due to the slow nature of coastal erosion any site that is identified at risk will be either protected or relocated prior to any system impacts<br><br>However mitigation costs may be significant | Mitigation options will be subject to the outcome of the EA's shoreline management plan (SMP) review and any change in current level of protection<br><br>As part of PPS25 a requirement to undertake an erosion report will be required to be submitted with a planning application | Initial assessments of the EA's preferred options highlight some potential issues which will be further assessed following the final SMP release<br><br>The shoreline management plans are scheduled to be announced in 2011 |
| Existing tunnels and underground cable routes | Increased Temperature | Ratings | Temperature increases may have a marginal impact on equipment ratings<br><br>More work is required to better understand the potential impact | More work is required to better understand the potential impact and the likelihood of threshold being exceeded | Possible reduction in the flexibility of the network<br><br>More work is required to better understand the constraints which this may bring, also studies are required to understand if normal system growth would offset any loss in resilience | Studies to better understand the constraints which this may bring, and identify possible weaknesses in the system<br><br>Also studies are required to understand if normal system growth would offset any loss in resilience | It is not anticipated for risks to materialise within the next 20 - 40 years<br><br>Initial studies to confirm the risks are anticipated to be completed by 2012 |

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| Business Function | Climate variable (e.g. increase in temperature) | Primary impact of climate change variable (e.g. health) | Threshold(s) above which this will affect your organisation | Likelihood of threshold(s) being exceeded in the future and confidence in the assessment | Potential impacts on organisation and stakeholders | Proposed action to mitigate impact | Timescale over which risks are expected to materialise and action is planned |
|---|---|---|---|---|---|---|---|
| Existing tunnels and underground cable routes | Increased Sea Level Rise | Flooding - sea inundation | Each site has been assessed to better understand the projected flood frequency and possible impact of flooding | Sea level rise is proven however the rate of increase is open to debate<br><br>Early assessments suggest a number of sites are in the EA study areas with a very small number potentially at an increased risk if the level of current protection is not maintained or improved | Due to the slow nature of sea level rise any tunnel or cable route that is identified at risk will be either protected or relocated prior to any system impacts<br><br>However mitigation costs may be significant | Mitigation options will be subject to the outcome of the EA's shoreline management plan (SMP) review and any change in current level of protection<br><br>In the interim National Grid has invested in a demountable mobile defence system of 1.2km | Initial assessments of the EA's preferred options highlight some potential issues which will be further assessed following the final SMP release<br><br>The shoreline management plans are scheduled to be announced in 2011 |
| Existing tunnels and underground cable routes | Increased Erosion | Coastal erosion | Shoreline management plans currently being reassessed by the EA indicate that a number of sites may be at risk from sea level rise<br><br>The level of risk will be subject to what mitigation, ongoing defence options are adopted, improved or maintained by the EA | Early assessments suggest a number of sites are in the EA study areas with a very small number potentially at an increased risk if the level of current protection is not maintained or improved | Due to the slow nature of coastal erosion any site that is identified at risk will be either protected or relocated prior to any system impacts<br><br>However mitigation costs may be significant | Mitigation options will be subject to the outcome of the EA's shoreline management plan (SMP) review and any change in current level of protection | Initial assessments of the EA's preferred options highlight some potential issues which will be further assessed following the final SMP release<br><br>The shoreline management plans are scheduled to be announced in 2011 |
| Existing cable bridges | Increased Rainfall and Extreme Events | Flooding | This will be subject to the projected height of flooding and river clearances (to avoid debris) | As extreme flooding can occur anywhere and at any time of the year it is likely that a crossing point will be subjected to a potential flood | A cable route may become non-operational due to sea inundation potentially leading to a loss of system resilience or a loss of supply<br><br>A non-operational cable route may not lead to a loss in supply | Risk assessments will be undertaken on bridging points to better understand the potential risk | This is unlikely to be a risk to supply and detailed risk assessment will be carried out in the next 3 to 5 years |

| Business Function | Climate variable (e.g. increase in temperature) | Primary impact of climate change variable (e.g. health) | Threshold(s) above which this will affect your organisation | Likelihood of threshold(s) being exceeded in the future and confidence in the assessment | Potential impacts on organisation and stakeholders | Proposed action to mitigate impact | Timescale over which risks are expected to materialise and action is planned |
|---|---|---|---|---|---|---|---|
| Existing cable bridges | Increased Temperature | Ratings | Temperature increases may have a marginal impact on equipment ratings<br><br>More work is required to better understand the potential impact | More work is required to better understand the potential impact and the likelihood of threshold being exceeded | Possible reduction in the flexibility of the network<br><br>More work is required to better understand the constraints which this may bring, also studies are required to understand if normal system growth would offset any loss in resilience | Studies to better understand the constraints which this may bring, and identify possible weaknesses in the system<br><br>Also studies are required to understand if normal system growth would offset any loss in resilience | It is not anticipated for risks to materialise within the next 20 - 40 years<br><br>Initial studies to confirm the risks are anticipated to be completed by 2012 |
| Existing cable bridges | Increased Sea Level Rise | Flooding - sea inundation | Shoreline management plans currently being reassessed by the EA indicate that a number of sites may be at risk from sea level rise<br><br>The level of risk will be subject to what mitigation, ongoing defence options are adopted, improved or maintained by the EA | Sea level rise is proven however the rate of increase is open to debate<br><br>Early assessments suggest a number of sites are in the EA study areas with a very small number potentially at an increased risk if the level of current protection is not maintained or improved | A cable route may become non-operational due to sea inundation potentially leading to a loss of system resilience or a loss of supply<br><br>A non-operational cable route not lead to a loss in supply | Mitigation options will be subject to the outcome of the EA's shoreline management plan (SMP) review and any change in current level of protection<br><br>In the interim National Grid has invested in a demountable mobile defence system of 1.2km | Initial assessments of the EA's preferred options highlight some potential issues which will be further assessed following the final SMP release<br><br>The shoreline management plans are scheduled to be announced in 2011 |
| Existing overhead lines and towers | Increased Temperature | Ratings | Temperature increases may have a marginal impact on equipment ratings<br><br>More work is required to better understand the potential impact | More work is required to better understand the potential impact and the likelihood of threshold being exceeded | Possible reduction in the flexibility of the network<br><br>More work is required to better understand the constraints which this may bring, also studies are required to understand if normal system growth would offset any loss in resilience | Studies to better understand the constraints which this may bring, and identify possible weaknesses in the system<br><br>Also studies are required to understand if normal system growth would offset any loss in resilience | It is not anticipated for risks to materialise within the next 20 - 40 years<br><br>Initial studies to confirm the risks are anticipated to be completed by 2012 |

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| Business Function | Climate variable (e.g. increase in temperature) | Primary impact of climate change variable (e.g. health) | Threshold(s) above which this will affect your organisation | Likelihood of threshold(s) being exceeded in the future and confidence in the assessment | Potential impacts on organisation and stakeholders | Proposed action to mitigate impact | Timescale over which risks are expected to materialise and action is planned |
|---|---|---|---|---|---|---|---|
| Existing overhead lines and towers | Increased Sea Level Rise | Flooding | Shoreline management plans currently being reassessed by the EA indicate that a number of sites may be at risk from sea level rise<br><br>The level of risk will be subject to what mitigation, ongoing defence options are adopted, improved or maintained by the EA | Sea level rise is proven however the rate of increase is open to debate<br><br>Early assessments suggest a number of sites are in the EA study areas with a very small number potentially at an increased risk if the level of current protection is not maintained or improved | A tower or route may become non-operational due to sea inundation potentially leading to a loss of system resilience or a loss of supply<br><br>A non-operational tower or route may not lead to a loss in supply | Mitigation options will be subject to the outcome of the EA's shoreline management plan (SMP) review and any change in current level of protection<br><br>In the interim National Grid has invested in a demountable mobile defence system of 1.2km | Initial assessments of the EA's preferred options highlight some potential issues which will be further assessed following the final SMP release<br><br>The shoreline management plans are scheduled to be announced in 2011 |
| Existing overhead lines and towers<br><br>Existing cable bridges | Increased Coastal Erosion | Coastal erosion | Shoreline management plans currently being reassessed by the EA indicate that a number of sites may be at risk from sea level rise<br><br>The level of risk will be subject to what mitigation, ongoing defence options are adopted, improved or maintained by the EA | Early assessments suggest a number of sites are in the EA study areas with a very small number potentially at an increased risk if the level of current protection is not maintained or improved | Due to the slow nature of erosion any site that is identified at risk will be either protected or relocated prior to any system impacts<br><br>However mitigation costs may be significant | Mitigation options will be subject to the outcome of the EA's shoreline management plan (SMP) review and any change in current level of protection | Initial assessments of the EA's preferred options highlight some potential issues which will be further assessed following the final SMP release<br><br>The shoreline management plans are scheduled to be announced in 2011 |
| Existing overhead lines and towers<br><br>Existing cable bridges | Increased River Erosion | River erosion | If foundations are exposed, weakened or the soil stability is reduced a tower or bridge may fail | As flooding can occur anywhere and at any time of the year it is likely that towers will be subjected to a potential flood and an increased erosion rate | A tower or cable route may become non-operational due to erosion potentially leading to a loss of system resilience or a loss of supply<br><br>A non-operational tower or cable route may not lead to a loss in supply | Risk assessments will be undertaken on routes and individual towers to better understand the potential risk | As this is a low risk to supply as opposed to the loss of a substation detailed risk assessment will be carried out in the next 3 to 5 years |

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| Business Function | Climate variable (e.g. increase in temperature) | Primary impact of climate change variable<br><br>(e.g. health) | Threshold(s) above which this will affect your organisation | Likelihood of threshold(s) being exceeded in the future and confidence in the assessment | Potential impacts on organisation and stakeholders | Proposed action to mitigate impact | Timescale over which risks are expected to materialise and action is planned |
|---|---|---|---|---|---|---|---|
| New sites – Substations, overhead lines Tunnel heads, Cable sealing ends (including Switchgear, transformers and earthing) | Increased Temperature | Ratings | Temperature increases may have a marginal impact on equipment ratings<br><br>More work is required to better understand the potential impact | More work is required to better understand the potential impact and the likelihood of threshold being exceeded | Possible reduction in the flexibility of the network<br><br>More work is required to better understand the constraints which this may bring, also studies are required to understand if normal system growth would offset any loss in resilience | Studies to better understand the constraints which this may bring, and identify possible weaknesses in the system<br><br>Also studies are required to understand if normal system growth would offset any loss in resilience | It is not anticipated for risks to materialise within the next 20 - 40 years<br><br>Initial studies to confirm the risks are anticipated to be completed by 2012 |
| Maintenance construction and fault repairs | Increase Temperature | Maintenance programme summer outages | Temperature increases may have a marginal impact on equipment ratings which impact on these activities<br><br>More work is required to better understand the potential impact | More work is required to better understand the potential impact and the likelihood of threshold being exceeded | Possible reduction in the flexibility of the network<br><br>More work is required to better understand the constraints which this may bring, also studies are required to understand if normal system growth would offset any loss in resilience | Studies to better understand the constraints which this may bring, and identify possible weaknesses in the system<br><br>Also studies are required to understand if normal system growth would offset any loss in resilience | It is not anticipated for risks to materialise within the next 20 - 40 years<br><br>Initial studies to confirm the risks are anticipated to be completed by 2012 |
| Emergency response | Increased Rainfall/ Flooding<br><br>Sea Level Rise | Safe access | Each site has been assessed to better understand the projected flood frequency and possible impact of flooding on each site | In line with ETR 138 National Grid Electricity Transmission plc has assessed the flood risk of all substations in line with EA and AOD data<br><br>13 sites have being identified as being at risk from a 1 in 100 flooding event | An extreme rainfall event may prevent safe immediate access to an asset requiring emergency repair<br><br>The loss of a site may not lead to a loss in supply | National Grid Electricity Transmission plc has embarked on a prioritised investment plan to defend sites to 1 in 200 or 1 in 1000 year flooding event dependant on cost benefit analysis and societal risk<br><br>This includes emergency access to a site for personnel | Investment is targeted for completion on all sites by 2022 beginning with the 1 in 100 year risk sites |

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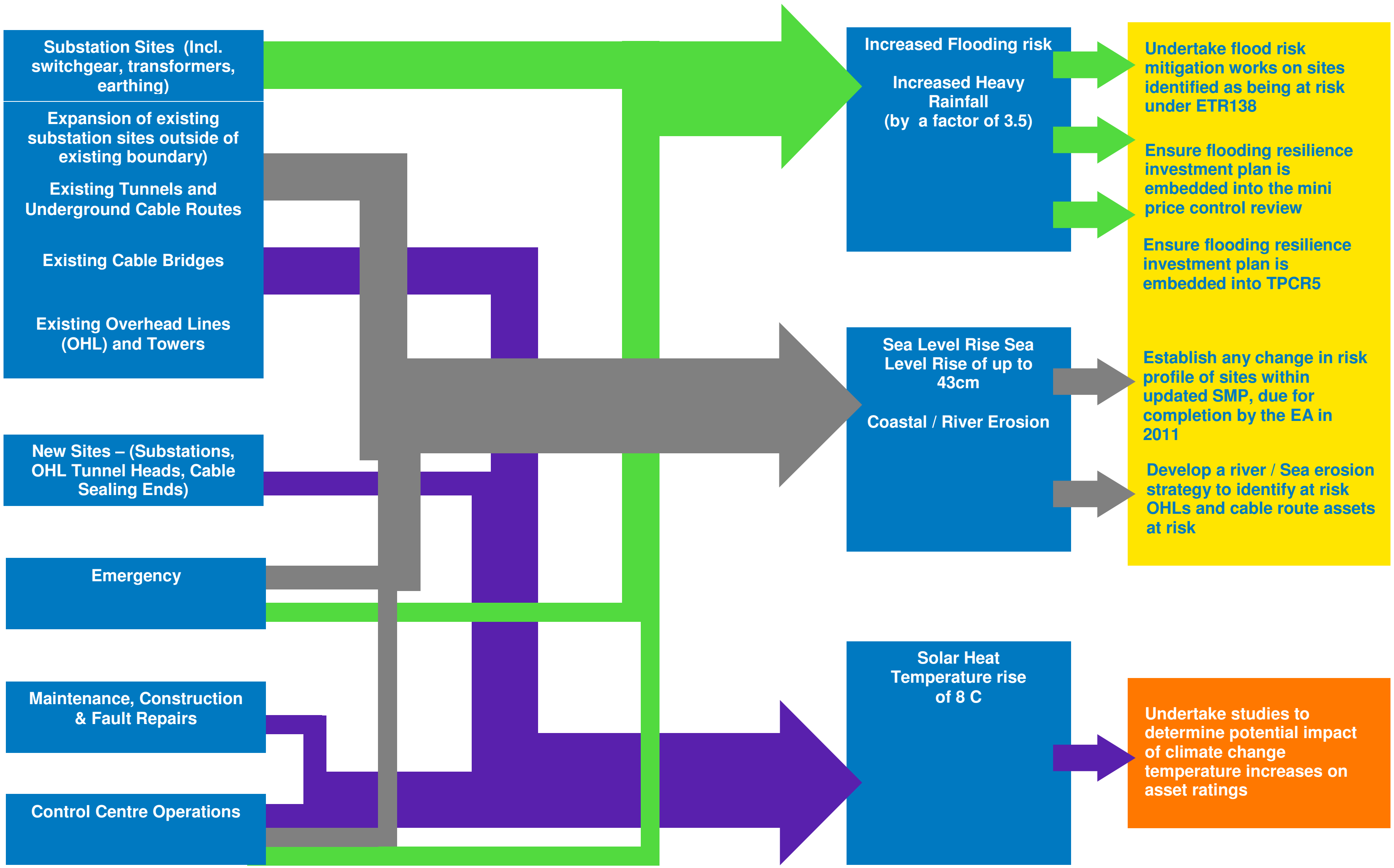
| Business Function | Climate variable (e.g. increase in temperature) | Primary impact of climate change variable (e.g. health) | Threshold(s) above which this will affect your organisation | Likelihood of threshold(s) being exceeded in the future and confidence in the assessment | Potential impacts on organisation and stakeholders | Proposed action to mitigate impact | Timescale over which risks are expected to materialise and action is planned |
|---|---|---|---|---|---|---|---|
| Control Centre System Operations | Increased Temperature | Ratings | Temperature increases may have a marginal impact on equipment ratings which impact on these activities<br><br>More work is required to better understand the potential impact | More work is required to better understand the potential impact and the likelihood of threshold being exceeded | Possible reduction in the flexibility of the network<br><br>More work is required to better understand the constraints which this may bring, also studies are required to understand if normal system growth would offset any loss in resilience | Studies to better understand the constraints which this may bring, and identify possible weaknesses in the system<br><br>Also studies are required to understand if normal system growth would offset any loss in resilience | It is not anticipated for risks to materialise within the next 20 - 40 years<br><br>Initial studies to confirm the risks are anticipated to be completed by 2012 |
| Control Centre System Operations | Increased Rainfall / Flooding<br><br>Increased Sea Level Rise | Pluvial and Fluvial flooding<br><br>Whilst the control centres are secure there is a risk that due to flooding an operational site may be lost or unable to function leading to reduced system security of supply | Most sites have a resilience to flooding to an approximate depth of 300mm<br><br>Each site has been assessed to better understand the projected flood frequency and possible impact of flooding on each site | In line with ETR 138 National Grid Electricity Transmission plc has assessed the flood risk of all substations in line with EA and AOD data<br><br>13 sites have been identified as being at risk from a 1 in 100 flooding event | A site may become non-operational due to flooding potentially leading to a loss of system resilience or a loss of supply<br><br>A non-operational site may not lead to a loss in supply | National Grid Electricity Transmission plc has embarked on a prioritised investment plan to defend sites to 1 in 200 or 1 in 1000 year flooding event dependant on cost benefit analysis and societal risk<br><br>In the interim National Grid has invested in a demountable mobile defence system of 1.2km | Investment is targeted for completion on all sites by 2022 beginning with the 1 in 100 risk sites |

In order to address the current risks identified in Section 4.6 the following risk have been created on National Grid's risk register and actions tracked to completion.

| Detailed Risk Actions Climate Adaptation | | | |
|---|---|---|---|
| **Climate Adaptation Risk** | | **Flooding risk** | |
| *There is a risk that...We may fail to recognise the impact of climate change (adaptation) on network resilience and ratings resulting in potential future de-rating of circuits and failure of equipment during future severe weather.* | | *There is a risk that...We may fail to manage the consequences of flooding, either through the loss of demand or perception that demand may be lost, to both gas and electricity net* | |
| **Undertake research and Development to understand the impact on future weather patterns** | **Complete EP1 & EP2 Projects** | **Undertake review of risk of flooding/ validation of date via EA** | **Complete 2008** |
| Met Office "Climate risk assessment on future network resilience | Due for completion December 2010 | **Ensure end to end processes are fully supported and documented** | **Complete 2009** |
| **Review existing designs to determine environmental parameters used in design** | **Complete 2008** | **Agree investment strategy for existing sites with Regulation / Ofgem** | **Complete 2009 (ETR 138)** |
| **Develop demand / generation scenarios that reflect climate change** | **Complete 2008** | Ensure consistent investment criteria applied to all future sites in accordance with PPS25 | Due for completion 2010 |
| **Develop transmission 20/30 networks to understand implications** | **Complete 2009** | **Develop / document capability of installing mobile flood barrier** | **Complete 2009** |
| **Review Electricity Safety, Quality and Continuity Regulations 2002 and determine impact on security due to increased failure arising from events of extreme weather** | **Complete 2009** | Develop a river erosion strategy to identify at risk OHLs and cable route assets at risk | Due for completion end 2012 |
| Issue Adaptation Report and add furthers actions identified | Due for completion September 2010 | **Identify sites within coastal erosion Shoreline Management Areas (SMP)** | **Complete 2009** |
| Undertake studies to determine potential impact of climate change temperature increases on asset ratings | Due for completion late 2012 | Establish any change in risk profile of sites within updated SMP, due for completion by the EA in 2011 | Due for completion end 2011 |
| Revisit work on spring summer ratings | Due for completion late 2012 | Undertake flood risk mitigation works on sites identified as being at risk under ETR138 | Due for completion 2022 |
| | | To ensure flooding resilience investment plan is embedded into the mini price control review | Due for completion October 2010 |
| | | To ensure flooding resilience investment plan is embedded into TPCR5 | Due for completion July 2011 |

## Actions to address identified risks

*Figure 4.5.1: Detailed risk actions to address climate changer*



## 4.7. BARRIERS TO IMPLEMENTING THE ADAPTATION PROGRAMME

### During the work the following potential barriers have been identified:

**Acceptance from stakeholders**

There is still a lot of uncertainty around climate change and how quickly or severe it may be. National Grid is fully committed to ensuring that appropriate actions are taken to ensure that its assets and processes are well placed to withstand changes in the climate. However some of those actions may require major investments and these investments have to be justified as necessary and efficient in advance of climate change. There is a requirement for wide acceptance of the likely scenarios that need to be planned and invested for. The current data provided by government through the UKCP09 climate projections contributes towards this acceptance.

In order to ensure that the right investments are made, consideration should be given in the future, to expand the UKCP09 climate projections to cover a wider range of physical characteristics. These can then be used by industry for their assessments and in developing their robust business cases to ensure that the right investments are made.

**Interdependencies including stakeholders**

The energy infrastructure system is highly interconnected. There are also interconnections between the infrastructure components both within and between the Gas, Electric and Water sectors. Where these interconnections are associated with the supply or receipt of a service on which the receiving sector is reliant an impact on this supply could be critical.

However National Grid Electricity Transmission plc substations are for the most part independent of external services as follows:

- All sites have 6 hour DC battery back up supplies to operate main equipment and essential services
- Major sites have a diesel generator in case of the loss of LVAC supplies with fuel for 52 hours or 168 hours for strategically important sites
- Sites without diesel generators have an emergency diesel generator contract where a portable generator will be delivered within 4 hours
- Electrical Substation sites are not dependant upon water supplies
- Although National Grid Electricity Transmission plc protective systems use global positioning systems (GPS), these devices are designed to operate independently should the GPS signal cease
- National Grid Electricity Transmission plc operates an independent communications system for remote substation control and protection

Two specific types of interdependencies could have greater impact on infrastructure functionality than individual failures:

**Cascade failures** - Referring to a series of linked impacts or failures e.g. loss of a 400 kV Substation may impact supplies to a Distribution Network Operator (DNO) 132 kV substation.

If a substation is at risk, National Grid in liaison with the Distribution Network Owners will be able to assess the likely impact of its loss. This will vary from site to site to site and depend upon many factors such as network configuration, outages, demand and generation profiles, which *can only be assessed in real time* by the Electricity Network Control Centres. Loss of supply may affect areas not impacted by the weather event. In some cases, electricity may be re-routed to minimise disruption to supplies and to optimise network security. This requires complex planning and assessment which can only be done by the electricity companies at their respective control centres. In some cases, phased or partial restoration may be possible and electricity can be shared by making rota disconnections.

**Regional convergences** - Regional concentrations of infrastructure, which, if impacted by an extreme weather event, could have consequences on functionality at a national scale in one or more of the three sectors (Energy, Transport and Water). National Grid Electricity Transmission plc recognises the need for local / regional area mutual defence strategies but clear guidance on funding of these projects needs to be developed.

**Skilled Resources**

Skilled resource, particularly technical, is an ongoing concern for many companies. National Grid Electricity Transmission plc actively seeks to recruit and develop both strategically and tactically. In addition to its normal recruiting programmes, National Grid Electricity Transmission plc seeks talent through its Internship, Year in Industry, Industrial Placement, Sponsored Student, Graduate and Foundation Engineer programmes. The resource from these programmes also assists to satisfy current business requirements.

**External Agencies**

A number of National Grid Electricity Transmission plc's assets rely on the flood defences or shoreline management plans owned and maintained by external agencies, the Environmental Agency (EA) or the Scottish Environmental Protection Agency (SEPA). To ensure that adaptation is successful, dialogue between these agencies and National Grid are required to ensure these layers of protection are maintained.

National Grid Electricity transmission plc's duties are to develop and maintain efficient, coordinated and economical networks and facilitate competition in energy supply. While National Grid Electricity transmission plc has discretion concerning the investments that it undertakes in these network businesses to achieve these duties, the revenues that will fund these investments depend on the regulator accepting that such investments are in the interest of present and future consumers.

To progress investments which improve the resilience of infrastructure National Grid must establish that future revenues to fund such investments can be secured. In line with the regulatory approach taken by Ofgem to set price controls for a future period, National Grid presents future investment plans for scrutiny by Ofgem in the price control review process in order to secure future funding.

In summary, regulation has a strong influence on capital investment programmes and operational expenditures that National Grid's licensed network businesses can undertake. National Grid will work with Ofgem to achieve a shared view of the potential requirements for adaptation and the associated expenditure that are in the interests of present and future consumers. National Grid's plans for adaptation may depend on obtaining suitable agreement with Ofgem on the associated financial investment plans presented by National Grid. National Grid believes that the current regulatory framework will provide suitable levels of investment.

To improve the long term resilience of new and existing infrastructure a number of barriers and challenges will need to be overcome, these include:

- Maintaining and developing policies, standards and designs for new and existing infrastructure ensuring that the long term impacts of climate change are considered and incorporated
- Incorporating the issue of resilience against climate change into operational business decisions so that monitoring and planning for the impacts become part of core business operations
- Ensuring that the climate change projections, science and impacts are better understood by those in the planning, investment and asset management for infrastructure so that appropriate measures are incorporated into the decision making process

National Grid's network businesses are capital intensive activities and, due to their natural monopoly nature, are subject to price controls and efficiency incentives set by the gas and electricity sector regulator Ofgem and its decision making body the Gas and Electricity Markets Authority.

**Potential Impacts of Climate Change on Key Stakeholders**

For the purposes of the Adaptation Programme, the following sectors / organisations have been identified as National Grid's key stakeholders:-

- Cabinet Office
- Welsh Assembly
- Scottish Parliament
- Department of Energy Climate Change (DECC)
- Office of the Gas and Electricity Markets (Ofgem)
- Health and Safety Executive (HSE)
- Civil Contingencies Secretariat
- Large Connected Customers
- Department for Environment, Food and Rural Affairs (Defra)
- Environment Agency (EA)
- Met Office
- Regional and Local Resilience Forums
- Distribution Network Operators (DNOs)
- Scottish Environmental Protection Agency (SEPA)
- Local Authorities
- Land Owners

In developing adaptation it is important, where appropriate, that plans are co-ordinated with key stakeholders to ensure a consistent and effective approach. For example, it is essential that company plans and Ofgem's plans are in harmony and that supplier's plans will enable companies to deliver any reinforcement or replacement projects that may be required to safeguard the electricity system.

National Grid Electricity Transmission plc continues to consult with key stakeholders as demonstrated by the Task Group that produced ETR 138 which comprised representatives from DNOs, DECC, Ofgem, EA, SEPA, Met Office and the Pitt Review Team.

National Grid Electricity Transmission plc is also working with Generators (Large Connected Customers) on local flood defence schemes, consulted with Defra on the requirements of the direction to report on adaptation to climate change and engaged with the Met Office on climate change projects such as EP1 & EP2.

**Market Mitigation**

A parallel challenge for electricity network companies over the coming decades concerns the change to “Smart Networks”. This initiative is planned to support the requirement that Renewable Distributed Generation and Low Carbon Loads can be connected to Networks in large numbers, as part of the programme to meet the 2020/2050 Carbon Reduction targets, whilst still maintaining supplies to customers in a cost effective and reliable manner. This will mean that Networks are likely to undergo considerable change at the same time that work may need to be carried out to improve resilience to climate change impacts.

The scale of the change to “Smart Networks” is likely to be very large, the resultant upgrade may be far larger than required to accommodate potential adaptation requirements and it will be necessary to understand these two requirements fully before companies submit their financial plans to Ofgem.

Therefore, although it is essential to research fully the potential effects of climate change in order to understand the potential impacts and mitigations, it is probable that the scale of any network upgrades will be dictated by the drive to Low Carbon Networks.

National Grid Electricity Transmission plc has been instrumental in developing electricity generation and demand scenarios consistent with the EU targets for 15% of UK energy to be produced from renewable sources by 2020 and greenhouse emissions targets for 2020 and beyond. These scenarios have been used to help identify the first round of potential electricity transmission network solutions.

For more information see the Electricity Network Strategy Report (ENSG) report on the DECC website.

http://www.ensg.gov.uk/index.php?article=126

**Local / Regional Area Mutual Defence Strategies**

National Grid recognises the need for local / regional area mutual defence strategies, for example a number of utilities contributing to a coordinated mutual defence scheme rather than defending their own assets in isolation.

However, whilst in most cases this is the correct approach, it is unclear as to how this can be accommodated under the present regulatory frameworks of different utilities, local governments, public and private sectors. Thus there is a need for clear centralised guidance on how these projects should be managed and funded.

**Data Changes**

National Grid has assessed its assets against current data, but as this data develops and refines the risk to sites can change. National Grid would like to continue to work with stakeholders in developing a method by which changes to data are cascaded to key infrastructure owners.

**Addressing the Barriers Identified**

National Grid Electricity Transmission plc will continue to actively engage with its key stakeholders on climate change adaptation and seek to ensure any potential barriers are identified and resolved.

Adaptation risks are assessed through National Grid’s risk processes and work in addressing these risks will where appropriate lead to policy’s or standards being revised e.g. National Grid Electricity Transmission plc has incorporated PPS 25 and flood risk assessment into National Grid Electricity Transmission plc’s investment procedure.

National Grid Electricity Transmission plc will highlight the importance of resilience enhancing investments and operational measures in National Grid Electricity Transmission plc’s business plans to its regulator and thereby seek to secure suitable financing revenues.

## 4.8. REPORT AND REVIEW

### Monitoring the Adaptation Programme

The risk assessment process has been useful in enabling a central view of the risks identified in the process. How these risks are managed will depend on the result of the initial assessment.

The individual risks are managed through the National Grid risk process and the timescales are managed through the risk review process. National Grid's overall adaptation strategy is kept under continuous review by the central Climate Change team. Updates are given annually to the Executive and also the Risk Responsibility Committees.

Where the risk was identified as being green, it is deemed that at this stage no further action is required and the risks will be refreshed at the next reporting period with the latest available climate data.

Where the risk was identified as yellow, it has been fully written up as part of National Grid's on going corporate risk reporting process. This means that the risk is fully assessed, has mitigation actions with delivery deadlines as well as risk owners. Part of the corporate reporting process means that the risk is reviewed every quarter ensuring that there is the appropriate management focus to ensure that actions are progressed and completed in a timely fashion.

Where the risk was identified as being Amber, actions will have or are being identified during the current reporting period to quantify the actual risk and develop an action plan if required.

For some of the amber risks, the actions will require ongoing monitoring until sufficient information is available to understand the risk. This may not be immediately available and mean they remain amber into the next reporting period.

If the risk was identified as being Red, there is a high probability of a significant material risk in the future. Current business processes and action plans do not adequately address this specific risk and require a further full risk assessment and action plan to be developed commensurate with the risk.

The benefits of the programme are focused around National Grid ensuring that it is prepared for climate adaptation and making the appropriate preparatory investments to safely manage any increased risks to climate adaptation. The quarterly risk review process will ensure that the appropriate actions are being taken forward and as part of the next reporting cycle National Grid will review the effectiveness of the process that it has outlined and implemented as a result of this direction.

The approach has been designed to ensure flexibility has been maintained in the programme by categorising the risks as green, yellow, amber and red. This has allowed the response and actions to a risk to be proportionate to the evidence and certainty that is available at any moment in time. As new information becomes available it will be possible to quickly reassess the risks and update the response as appropriate. It is anticipated that this approach will ensure that essential investments are made in a timely manner but also enable close management of investment in areas of greater uncertainty.

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## Monitoring the Thresholds above Which Climate Change Impacts will Pose a Risk to the Company and Incorporation into Future Risk Assessments

National Grid Electricity Transmission plc in conjunction with energy companies has commissioned work with the Met Office via the EP2 and "Climate risk assessment on future network resilience" which use published UKCIP02 and then UKCP09 data. These projects assess if the current published climate change thresholds pose a risk to the company.

National Grid Electricity Transmission plc has embedded this work into this Adaptation Report which is legally required to be updated every 5 years. Therefore when new climate change data is published or the Adaptation Report is due for renewal any changes in published climate change data will be reviewed and any thresholds which increase and thus potentially cause a risk will be added to the National Grid's risk register.

## Monitoring the Residual Risks of Impacts from Climate Change in the Company

The assessment of climate change risk is embedded into the National Grid risk process and ultimately results in changes in policies and procedures where required. National Grid has processes in place to monitor legislation changes and changes to industry policy and procedures such that the policy and procedures within National Grid Electricity Transmission plc can be reviewed and updated.

## Operational Risk Management

The operational processes ensuring secure operation of the system and adequate dispatch of plant all depend on an accurate assessment of severe weather impacts, the effect these impacts would have upon real and reactive power demands and the likelihood of particular contingencies arising.

In this respect, the requirements for operating the transmission system under severe weather on a day-to-day basis are facilitated by:

- Availability of accurate and reliable information on the time of arrival of a particular type of weather or a step change in weather
- Geographic location of the event impact and its path / speed of travel
- An accurate assessment of the likely dimensions of impact on system demand, voltage and frequency
- An accurate assessment of the dimensions of system contingencies likely to arise as a result of the event e.g. loss of generation, loss of demand, repeated protection operations, transmission equipment tripping etc.
- Knowledge of operational actions to manage specific contingencies e.g. a set of well rehearsed operational instructions and / or procedures

All the above measures together with a working arrangement with all UK Energy companies are currently being used to mitigate and manage the risks.

## 4.9. RECOGNISING OPPORTUNITIES

This process has reinforced the requirement to coordinate risk assessment processes with relevant third party stakeholders and has identified the requirement for further research and collaborative work between government agencies and industries to better understand potential climate change related scenarios and their impacts.

Climate change has resulted in National Grid Electricity Transmission plc being instrumental in developing electricity generation and demand scenarios consistent with the EU targets for 15% of UK energy to be produced from renewable sources by 2020 and greenhouse emissions targets for 2020 and beyond. These scenarios have been used to help identify the first round of potential electricity transmission network solutions.

Adaptation reporting has provided the opportunity for National Grid to assess and demonstrate the resilience of National Grid Electricity Transmission plc's network that may otherwise cause concern to our stakeholders on current and future issues. It also provides a documented foundation on which to have a more informed and focused debate of the risks of climate change.

## 4.10. FURTHER COMMENTS / INFORMATION

The climate change assessment would be more effective and robust if peak values rather than increments were given as part of the UKCP09 characteristics, e.g. a statement such as "the peak temperature will reach 50°C" rather than "the peak temperature will increase by 8 C".

National Grid Electricity Transmission plc is concerned that adaptation reporting may duplicate some of the current guidance that companies already have for internal reporting (e.g. carbon budgets), country level regulatory reporting (e.g. EU ETS, CRC).

National Grid welcomes the work undertaken by the Met Office at Hadley Centre and has been active in supporting some of this work as part of an Innovation Funding Incentive supported project, managed by the Energy Networks Association. This was an industry funded project working to understand precise requirements and develop practical applications and business strategies for a changing world. An understanding of the potential effects of climate change and network resilience will inform long term infrastructure decisions.

National Grid is also very supportive of Ofgem's Low Carbon Network Funding initiative and would welcome involvement in this and related projects.

In addition National Grid's research and development (R&D) strategy is to develop knowledge and technology focussed on reducing our environmental and climate change impacts. National Grid has funded over £1m of research on weather and climate change related projects through the Innovation Funding Incentive since April 2007, both directly and in collaboration with other utilities and manufacturers (Combined funding over £10m).

## 4.11. OVERALL SUMMARY & CONCLUSIONS

National Grid Electricity Transmission plc is at a very advanced stage of embedding Climate Change policy for both mitigation and adaptation within the organisation, with climate change risks firmly embedded into National Grid's Risk Management Procedure which is constantly reviewed and updated with appropriate actions and targets.

National Grid Electricity Transmission plc has risk assessed climate change adaptation against information drawn from UKCP09, and chosen to assess its assets and processes against the high level scenario which is based on the least likely to occur prediction of climate change as of 2080. This was on the basis that should National Grid's assets and process demonstrate resilience against this scenario it would inevitably be adapted against lower and more likely climate change.

Whilst it is apparent that energy infrastructure may be vulnerable to certain aspects of climate change, the infrastructure has a significant degree of resilience to change and hence adaptation. In addition, technically it will be feasible to deal with adaptation issues over short, medium and long-term periods.

This risk assessment has indicated that overall National Grid Electricity Transmission plc's assets and processes are resilient to climate change that is predicted to occur by 2080. Within this assessment there are some assets which require further assessment using more refined data. This is an ongoing process which is incorporated in to National Grid's risk management process.

It is important to note that even where an asset is at a potential risk in this worst case scenario model the risk is localised to the asset and the process it supports and is unlikely to lead to a loss of supply. None of the risks considered are likely to result in a risk to the system as a whole.

National Grid Electricity Transmission plc is committed to continued investment in the electricity transmission system and indeed is compelled to do so by the Electricity Safety Quality and Continuity Regulations 2002 (ESQCR). Assuming continued support from key stakeholders, over the coming decades and long before it is envisaged that the worst case scenario could materialise there will be substantial levels of investment to upgrade the system. This investment, much of which will be driven by predicted increasing demand and the development of Smart Networks, will provide an opportunity to accommodate adaptation to climate change.

In order to ensure National Grid Electricity Transmission plc is prepared for the affects of climate change, National Grid Electricity Transmission plc are engaged, in conjunction with other energy companies and the scientific community focussing on mitigation and adaptation to climate change. Using data from UKCIP02 and UKCP09 several detailed reports have been commissioned:

- ETR 138 — Engineering Technical Report<br>Resilience to Flooding of Grid and Primary Substations
- EP1 — The Impact of Climate Change on the UK Energy Industry
- EP2 — The Impact of Climate Change on the UK Energy Industry
- Met Office — Climate risk assessment on future network resilience

The identified Specific Physical Characteristics which National Grid Electricity Transmission plc have risk assessed its assets against are the UKCP09 High Emissions Scenarios, refer to Appendix C, in order to asses the impacts under extreme conditions:

- Summer Mean temperature rise of up to 8$^{o}$C
- Increased heavy rainfall (by a factor of up to 3.5)
- Sea Level rises of up to 43cm
- Increased lightning
- Increased wind and Gale
- Increased snow, Sleet, Blizzard, Ice and freezing fog
- Increased flooding
- Increased coastal / river erosion
- Increased subsidence

Each of these characteristics was assessed against the key assets and processes for National Grid Electricity Transmission plc. The initial risk assessment had four outputs: green – no material risk, yellow – a currently controlled risk, amber – a risk requiring further information, red – a significant and not currently controlled risk.

Some risks have been identified and National Grid Electricity Transmission plc has already commenced management of these risks and in some cases completed research to enable a better understanding of the issues considered to be of greatest impact through climatic change. National Grid intends to monitor those ongoing climate change scenarios to assess whether the risks identified against the "worst case" are increasing, and warrant further mitigating action, or reducing enabling existing processes to mange an extreme event.

A parallel challenge for electricity network companies over the coming decades concerns the change to "Smart Networks". This initiative is planned to support the requirement that Renewable Distributed Generation and Low Carbon Loads can be connected to Networks in large numbers, as part of the programme to meet the 2020 / 2050 Carbon Reduction targets, whilst still maintaining supplies to customers in a cost effective and reliable manner.

Whilst assessing the impacts of climate change the following limitations have been identified in the available information within UKCP09 data:

- There is no information on future changes in frequency / intensity of wind / gales, including the combined probability of low wind speed (dead calm) events with high ambient temperatures
- There is no information on future changes in the frequency / intensity of lightning
- There is no information on future changes in frequency / intensity of snow, sleet, blizzard, ice and freezing fog
- EA shoreline management plan reviews (Coastal erosion) are not expected to be published until 2011

Although these characteristics may be caused as a result of climate change, further work will be required in the next update of the UKCP09 data to assess any expected increases in magnitude and the associated probabilities.

Energy infrastructure is designed to international standards and the same standards allow infrastructure to operate around the world in varying climatic conditions, including projected climate conditions for the UK.

In addition National Grid Electricity Transmission plc is also legally bound to design and maintain electricity supplies, so far as reasonably practicable, as per: The Electricity Safety Quality and Continuity Regulations 2002 (ESQCR). Section 3 General adequacy of electrical equipment (1) (b) states that:

> "*Generators, distributors and meter operators shall ensure that their equipment is so constructed, installed, protected (both electrically and mechanically), used and maintained as to prevent danger, interference with or interruption of supply, so far as is reasonably practicable."*

In addition to National Grid Electricity Transmission plc statutory duties, climate adaptation reports such as EP2, ETR 138 and National Grid's risk process has found that there is currently no evidence to support adjusting network or asset design standards save for the areas of flooding, and potentially the thermal ratings of equipment and apparatus. The risks posed by flooding are well understood and managed on an ongoing basis. The issue of thermal rating needs further investigation. However it is important to view any potential de-ratings against the response to growth of electricity demand on the transmission network, anticipated to be 0.2% p.a. (1.4% p.a. High Growth Scenario) until 2016/17. Also the scale of the change to "Smart Networks" is likely to be very large, and the resultant upgrade may be far larger than that required to accommodate potential adaptation.

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# 5. APPENDICES

## APPENDIX

## A. ELECTRICITY INDUSTRY DESIGN STANDARDS

Electricity transmission and distribution systems are made up of many different types of equipment including overhead lines, cables and transformers. Current equipment complies with appropriate International and British Standards.

These international standards apply within Europe and across the world where existing conditions can be similar to those predicted in the UK as a result of Climate Change. Therefore there is likely to be existing resilience to climate change impacts within existing UK design standards.

Equipment in the UK also normally complies with industry standards that have been developed and enhanced over many years to ensure that UK networks are built from high specification, safe equipment that is fully interchangeable and can be installed and operated in a similar manner across the UK.

These industry standards and engineering practices have been established over the years through the ENA and predecessor organisations and therefore, because UK networks are built on a common basis, they will all experience similar impacts from similar changes in climate. This underlines the reason for a common approach to national issues in adaptation.

The development and review of National and International Standards is subject to well established procedures and UK electricity network operators have a long tradition of leading and influencing this work through BSI and European and International standards organisations.

### National Grid Electricity Transmission plc Key Design Standards

This appendix provides some background on the most relevant applicable design standards.

Whilst present day standards are dominated by those issued by the International Electrotechnical Commission (IEC) and European Norms (EN), it should be recognised that electricity network infrastructure still in use was designed according to British Standards issued many decades ago. It is thus appropriate to briefly describe the climatic conditions used as the basis for equipment ratings in those old Standards.

The UK was a major manufacturing base of electricity network equipment from the 1920s, supplying a global market dominated by a British sphere of influence. Consequently both British Standards and equipment designs were arranged to meet climatic demands ranging to the Middle East, India, Malaysia, South Africa and Australasia, as evidenced by obsolete design standards referencing peak ambient temperature requirements of 40°C as far back as 1923.

*Table A.1 – Key National grid Electricity Transmission plc Design Standards*

| | Standard | Transformers | Circuit Breakers | Overhead Lines | Cables |
|---|---|---|---|---|---|
| **Temperature** | | | | | |
| Max. Ambient Temp. Outdoor | NG TS 1<br>IEC 61936-1 | $40^{o}$ C | $40^{o}$ C | $40^{o}$ C | $40^{o}$ C |
| Max. Ambient Temp. Indoor | NG TS 1<br>IEC 61936-1 | $40^{o}$ C | $40^{o}$ C | $40^{o}$ C | $40^{o}$ C |
| Min.Ambient Temp. Indoor | NG TS 1 | $-5^{o}$ C | $-5^{o}$ C | $-5^{o}$ C | $-5^{o}$ C |
| Min. Ambient Temp. Outdoor | NG TS 1 | $-25^{o}$ C | $-25^{o}$ C | $-25^{o}$ C | $-25^{o}$ C |
| Overload Ratings Ambient Temp. | TGN 26, 67 68, 29 | $10^{0}$ C / $20^{0}$ C / $30^{0}$ C $^{\#}$ | $10^{0}$ C / $20^{0}$ C / $30^{0}$ C $^{\#}$ | $2^{0}$ C / $9^{0}$ C / $20^{0}$ C $^{\#}$ | See Table A.2 |
| **Wind** | | | | | |
| Wind Speed | NG TS 3.1.04<br>BS 6399 pt.2 | 34 m/s (76mph) | 34 m/s (76mph) | N/A | 34 m/s (76mph) |
| Wind Loading* | TS 2.04<br>BS EN 50341 & 43<br>BS EN 1993-3-1 | N/A | N/A | Gust – 51.91m/s – 58.99 m/s<br>(116mph – 131mph)<br>Mean – 33.28m/s – 37.81m/s<br>(74mph – 85mph) | N/A |
| **Ice Loading** | | | | | |
| Ice Loading Class | NG TS 1 | Class 10 (10mm) | Class 10 (10mm) | Class 10 (10mm) | Class 10 (10mm) |
| Ice Loading | BS EN 50341 & 43 | | | Not < 40mm or min. 7mm (wind & ICE) | |
| **Solar Radiation** | | | | | |
| Solar Radiation | NG TS 1<br>IEC 61936-1 | 1000 W / $m^2$ | 1000 W / $m^2$ | 1000 W / $m^2$ | 1000 W / $m^2$ |
| **Lightning** | | | | | |
| Shielding Angle | NG TS 2.27 | | | Min. $35^{o}$ | |
| Protection Level | | | | 1 event/100km/annum | |
| Lightning Impulse | NG TS 1<br>BS EN 60071 | 400 kV 1425 kV pk<br>275 kV 1050 kV pk. | 400 kV 1425 kV pk<br>275 kV 1050 kV pk | 400 kV 1425 kV pk<br>275 kV 1050 kV pk | 400 kV 1425 kV pk<br>275 kV 1050 kV pk |
| **Flooding** | | Substation Sites | | | |
| New Build | PPS 25 | 1:1000 Flood Event | | | |
| Existing Sites | ETR 138 | Target resilience of 1:1000 unless cost benefit analysis states 1:100 / 1:200 sea is appropriate | | | |

Notes:

# Winter / Spring, Autumn / Summer ambient temperature used for equipment ratings.
* Design of wind loadings are dependant upon the area of the country, geography and height of the overhead line. Typical design values are within the range shown.

1. Rating Seasons
   Winter - December / January / February
   Spring / Autumn - March / April / September / October / November
   Summer - May / June / July August

2. IEC International Standard (International Electrotechnical Commission)
   NG TS National Grid - Technical Specification
   TGN National Grid – Technical Guidance Note
   PPS Planning Policy Statement
   ETR Energy Networks Association - Engineering Technical Report
   BS EN British European Standard Specification

*Table A.2 – Cable Rating Season Design Parameters*

| **Season Designation within NG Months** | **CC** Dec/Jan/Feb | **NC** Mar/Apr/Nov | **NH** Sep/Oct | **HH** May/Aug |
|---|---|---|---|---|
| **Cable environment thermal resistivity (Km/W)** | | | | |
| Outside $50^0$C isotherm | 1.05 | 1.05 | 1.20 | 1.20 |
| Inside $50^0$C isotherm | | | | |
| Cement-bound sand | 1.05 | 1.05 | 1.20 | 1.20 |
| Selected sand | 1.05 | 1.05 | 2.70 | 2.70 |
| Unspecified | 1.05 | 1.05 | 3.00 | 3.00 |
| **Cable ambient temperature ($^0$ C )** | | | | |
| Directly buried | 10 | 10 | 15 | 15 |
| Filled surface trough | 10 | 15 | 25 | 35 |
| Free air | 10 | 20 | 20 | 30 |
| External ambient air for unfilled surface trough | 10 | 20 | 20 | 30 |
| Mean inlet air for long tunnel forced ventilation | 5 | 10 | 10 | 20 |
| Air maximum for subway with other services* | 20 | 25 | 30 | 35 |
| Air maximum for naturally ventilated tunnel* | 20 | 25 | 30 | 35 |
| Water coolant turn round temperature** | 30 | 30 | 30 | 30 |
| (Coolant heat transfer coefficient = 1 kW/m²) | | | | |

*For guidance only – actual values to be agreed with National Grid for each contract
**Not included in NGTS 2.5

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## APPENDIX

## B. ADAPTATION RISK ASSESMENT RESULTS FURTHER DETAIL

*Table B.1 Detailed Risk Assessment for National Grid Electricity Transmission plc*

| National Grid Electricity Transmission plc Climate Change Adaptation Risk Assessment | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| **Key Assets and Processes** | **Specific Physical Characteristics of Climate Adaptation Scenarios** | | | | | | | | |
| | **UKCP09 Characteristics** | | | **Met Office Characteristics** | | | | **NG Characteristics** | |
| **Electricity Transmission Assets** | **Solar Heat - Temperature rise of up to 8$^{o}$C** | **Increased Heavy Rainfall (by a factor of 3.5)** | **Sea Level Rises of up to 43cm** | **Increased Lightning** | **Increased Wind and Gale** | **Increased Snow, Sleet, Blizzard, Ice and freezing fog** | **Increased Flooding** | **Increased Coastal / River Erosion** | **Increased Subsidence** |
| On National Grid Risk Register | **Yes** | **Yes** | **Yes** | **Yes** | **Yes** | **Yes** | **Yes** | **Yes** | **Yes** |
| Substation Sites<br><br>(Incl. switchgear, transformers, earthing) | Temperature increases may have a marginal impact on equipment ratings.<br><br>More work is required to better understand any potential impact | Site drainage may not cope with a sustained extreme rainfall event<br><br>Work is required to understand the level of an event to impact a site<br><br>Sites have resilience to Pluvial (flash flooding) to a depth of approximately 300 mm | Shore line management plans currently being reassessed by the EA indicate that a number of sites may be at an increased risk from sea level rise.<br><br>The level of risk will be subject to what mitigation, ongoing defence options are adopted, improved maintained by the EA announced in 2011 | Electrical equipment is designed to withstand lightning impulse levels e.g. a lightning strike<br><br>Refer to Overhead Line section of this table | Existing design standards account for extreme weather conditions<br><br>Substation equipment is designed to an relevant wind speed of:<br><br>34 m/s<br>(76 mph) | Heavy snowfalls would not normally affect the operation of a substation but ice loading is an issue for which there are existing design standards:<br><br>Ice Loading:<br>Class 10 (10mm) | A site may become non-operational due to flooding potentially leading to a loss of system resilience or a loss of supply<br><br>A non-operational site may not lead to a loss in supply | Shore line management plans currently being reassessed by the EA indicate that a number of sites may be at an increased risk from erosion<br><br>The level of risk will be subject to what mitigation, ongoing defence options are adopted, improved maintained by the EA announced in 2011 | Substation sites are normally built on level land so land slip is not generally an issue<br><br>Substation subsidence issues are being managed via current regulatory allowances and extremely unlikely to impact customer supplies |
| Expansion of Existing Substation Sites (outside of existing boundary) | Temperature increases may have a marginal impact on equipment ratings<br><br>More work is required to better understand any potential impact | Managed by planning policy | Shore line management plans currently being reassessed by the EA indicate that a number of sites may be at an increased risk from sea level rise<br><br>The level of risk will be subject to what mitigation, ongoing defence options are adopted, improved maintained by the EA announced in 2011 | Electrical equipment is designed to withstand lightning impulse levels e.g. a lightning strike<br><br>Refer to Overhead Line section of this table | Existing design standards account for extreme weather conditions<br><br>Substation equipment is designed to an relevant wind speed of:<br><br>34 m/s<br>(76 mph) | Heavy snowfalls would not normally affect the operation of a substation but ice loading is an issue for which there are existing design standards:<br><br>Ice Loading:<br>Class 10 (10mm) | Design standards (PPS 25 and ETR 138) of assets and sites account for extreme weather conditions | Shore line management plans currently being reassessed by the EA indicate that a number of sites may be at an increased risk from erosion<br><br>The level of risk will be subject to what mitigation, ongoing defence options are adopted, improved maintained by the EA announced in 2011 | Substation sites are normally built on level land so land slip is not generally an issue<br><br>Substation subsidence issues are being managed via current regulatory allowances and extremely unlikely to impact customer supplies |

| Key Assets and Processes | Specific Physical Characteristics of Climate Adaptation Scenarios | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | **UKCP09 Characteristics** | | | **Met Office Characteristics** | | | | **NG Characteristics** | |
| **Electricity Transmission Assets** | **Solar Heat - Temperature rise of up to 8°C** | **Increased Heavy Rainfall (by a factor of 3.5)** | **Sea Level Rises of up to 43cm** | **Increased Lightning** | **Increased Wind and Gale** | **Increased Snow, Sleet, Blizzard, Ice and freezing fog** | **Increased Flooding** | **Increased Coastal / River Erosion** | **Increased Subsidence** |
| Existing Tunnels and Underground Cable Routes | Temperature increases may have a marginal impact on equipment ratings<br><br>More work is required to better understand the potential impact. | Cables are either buried in the ground or located in a tunnel<br><br>Therefore flooding would not normally cause a loss of supply; and thus these assets are resilient to rainfall events | Shore line management plans currently being reassessed by the EA indicate that a number of sites may be at an increased risk from sea level rise<br><br>The level of risk will be subject to what mitigation, ongoing defence options are adopted, improved maintained by the EA announced in 2011 | Assets are underground and so are protected from lightning | Assets are underground so are protected from wind and gales | Assets are underground so are protected from snow, ice, frosts | Cables are either buried in the ground or located in a tunnel<br><br>Therefore flooding would not normally cause a loss of supply; and thus these assets are resilient to flooding events | Shore line management plans currently being reassessed by the EA indicate that a number of sites may be at an increased risk from erosion<br><br>The level of risk will be subject to what mitigation, ongoing defence options are adopted, improved maintained by the EA announced in 2011 | Cable and tower routes are regularly patrolled and any issues are highlighted and dealt with through normal business processes |
| Existing Cable Bridges | Temperature increases may have a marginal impact on equipment ratings<br><br>More work is required to better understand the potential impact. | Increased rainfall is unlikely to impact this type of asset however the secondary effects e.g. damage due to debris will require assessing<br><br>Work is needed to be undertaken to identify the risks posed by flash flooding and any potential increase in flooding height | Shore line management plans currently being reassessed by the EA indicate that a number of sites may be at an increased risk from sea level rise<br><br>The level of risk will be subject to what mitigation, ongoing defence options are adopted, improved maintained by the EA announced in 2011 | Cable assets are protected by the structure of the bridge and therefore any loss of supply is extremely unlikely | Design standards of assets and sites account for extreme weather conditions | Snow, ice, fog will not affect cables located within a cable bridge | Work is required to be to identify the risks posed by flash flooding and any potential increase in flooding height | Shore line management plans currently being reassessed by the EA indicate that a number of sites may be at an increased risk from erosion<br><br>The level of risk will be subject to what mitigation, ongoing defence options are adopted, improved maintained by the EA announced in 2011. | Cable and tower routes are regularly patrolled and any issues are highlighted and dealt with through normal business processes |
| Existing Overhead Lines (OHL) and Towers | Temperature increases may have a marginal impact on equipment ratings<br><br>More work is required to better understand the potential impact. | The design height of overhead line conductors provides resilience to increased rain events | Shore line management plans currently being reassessed by the EA indicate that a number of sites may be at an increased risk from sea level rise<br><br>The level of risk will be subject to what mitigation, ongoing defence options are adopted, improved maintained by the EA announced in 2011 | OHLs are designed to withstand lightning impulse levels e.g. a lightning strike<br><br>OHLs are designed to:<br><br>1 event / 100 km / annum | Existing design standards account for extreme weather conditions<br><br>OHLs are designed to:<br><br>Gust – 116mph – 131mph<br>Mean – 74mph – 85mph | Heavy snowfalls would not normally affect the operation of an OHL but ice loading is an issue for which there are existing design standards:<br><br>Not < 40mm or min. 7mm (wind & ICE) | There is a risk of assets "floating" in flooded ground<br><br>Although this may present a long term risk and work is underway to assess this risk, it is extremely unlikely that any one asset located in flooded ground would result in a loss of supply event | Shore line management plans are currently being reassessed by the EA indicate that a number of routes may be at an increased risk from erosion<br><br>The level of risk will be subject to what mitigation, ongoing defence options are adopted, improved maintained by the EA announced in 2011 | Cable and tower routes are regularly patrolled and any issues are highlighted and dealt with through normal business processes |

| Key Assets and Processes | | Specific Physical Characteristics of Climate Adaptation Scenarios | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | UKCP09 Characteristics | | | | Met Office Characteristics | | | | | NG Characteristics | |
| **Electricity Transmission Assets** | | **Solar Heat - Temperature rise of up to 8°C** | **Increased Heavy Rainfall (by a factor of 3.5)** | **Sea Level Rises of up to 43cm** | | **Increased Lightning** | **Increased Wind and Gale** | **Increased Snow, Sleet, Blizzard, Ice and freezing fog** | **Increased Flooding** | | **Increased Coastal / River Erosion** | **Increased Subsidence** |
| New Sites<br><br>(Substations, Overhead lines, Tunnel Heads, Cable Sealing Ends) | | Temperature increases may have a marginal impact on equipment ratings<br><br>More work is required to better understand the potential impact. | Planning design standards in PPS25 will provide resilience against rainfall events | An update to PPS 25 will require all new planning applications within a shoreline management area to have coastal erosion assessment | | Electrical equipment is designed to withstand lightning impulse levels e.g. a lightning strike<br><br>Refer to Overhead Line section of this table | Existing design standards account for extreme weather conditions<br><br>Substation equipment is designed to an average wind speed of:<br><br>34 m/s<br>(76 mph) | Heavy snowfalls would not normally affect the operation of a substation but ice loading is an issue for which there are existing design standards:<br><br>Ice Loading:<br>Class 10 (10mm) | Planning design standards in PPS25 will provide resilience against flooding events | | An update to PPS 25 will require all new planning applications within a shoreline management area to have coastal erosion assessment | Any potential subsidence issues would be taken into account during the design phase of the project |
| **Processes** | | | | | | | | | | | | |
| Emergency | | The process of responding to an emergency will be extremely unlikely to be impacted by working in high temperatures | An extreme rainfall event may prevent safe access to the asset requiring emergency repair<br><br>Work is required to understand the level of event to impact a site | Refer to increased flooding | | Access during the event may be restricted to OHLs but extremely unlikely to have a severe impact on fault response | Access during the event may be restricted to OHLs but extremely unlikely to have a severe impact on fault response | Emergency procedures allocate a fleet of 4x4 vehicles in order to ensure staff are able to respond to emergencies in extreme snow fall, ice conditions | Severe or prolonged flooding may make it impossible to reach sites or assets<br><br>However site plans are being developed for flood defence improvements and allow for road access into the site during flooding events but this does not include the wider road network | | Emergency plans are in place to respond to the most credible emergency scenario, e.g. erosion of OHL tower foundations<br><br>In this instance loss of any one double circuit would not normally result in loss of supply | Emergency plans are in place to respond to the most likely emergency scenario, e.g. erosion of OHL tower foundations<br><br>In this instance loss of any one double circuit would not normally result in loss of supply |

| Key Assets and Processes | Specific Physical Characteristics of Climate Adaptation Scenarios | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | **UKCP09 Characteristics** | | | **Met Office Characteristics** | | | | **NG Characteristics** | |
| **Process** | **Solar Heat - Temperature rise of up to 8°C** | **Increased Heavy Rainfall (by a factor of 3.5)** | **Sea Level Rises of up to 43cm** | **Increased Lightning** | **Increased Wind and Gale** | **Increased Snow, Sleet, Blizzard, Ice and freezing fog** | **Increased Flooding** | **Increased Coastal / River Erosion** | **Increased Subsidence** |
| Maintenance, Construction & Fault Repairs | Milder winters are expected to reduce peak demand and air conditioning load increase summer demand, resulting in a flatter demand curve resulting in difficulty in releasing circuits for maintenance | An extreme rainfall event may prevent safe access to the asset requiring maintenance etc.<br><br>However delays in these activities would be extremely unlikely to result in a loss of supply event | Refer to increased flooding | Access in the short term may be constrained to equipment but very unlikely to have a prolonged impact on maintenance etc. | Access in the short term may be constrained to equipment but very unlikely to have a prolonged impact on maintenance etc. | Access in the short term may be constrained to equipment but very unlikely to have a prolonged impact on maintenance etc. | Access in the short / medium term may be constrained to equipment but very unlikely to have a prolonged impact on maintenance etc. | This is managed over a long time period therefore access for maintenance and fault repairs expected in normal timescales would not be significantly effected | This is managed over a long time period therefore access for maintenance and fault repairs expected in normal timescales would not be significantly effected |
| Control Centre Operations | Temperature increases may impact ratings and place greater restraints on the system<br><br>This could affect the split between winter / summer/ autumn / spring ratings<br><br>More work is required to better understand the potential impact | If one or more site / route are lost from flooding it may result in a deterioration of resilience and flexibility of operating the system | If one or more site / route are lost from flooding it may result in a deterioration of resilience and flexibility of operating the system | The transmission system is normally resilient to loss of any one double circuit<br><br>Any potential increase in lightning strikes will increase the probability of short duration outages (normally 15-20s) but there is no evidence of an increased risk to date | The transmission system is normally resilient to loss of any one double circuit<br><br>Any potential increase in faults due to wind will increase the probability of short duration outages (normally 15-20s) but there is no evidence of an increased risk to date | The transmission system is normally resilient to loss of any one double circuit<br><br>Any potential increase in faults due to ice loading will increase the probability of short duration outages (normally 15-20s) but there is no evidence of an increased risk to date | If one or more site / route are lost from flooding it may result in a deterioration of resilience and flexibility of operating the system | Any potential impact would be alleviated in normal regulatory timescales<br><br>The transmission system is normally resilient to the most credible emergency scenario, e.g. erosion of OHL tower foundations<br><br>In this instance loss of any one double circuit would not normally result in loss of supply | Any potential impact would be alleviated in normal regulatory timescales<br><br>The transmission system is normally resilient to the most credible emergency scenario, e.g. erosion of OHL tower foundations<br><br>In this instance loss of anyone double circuit would not normally result in loss of supply |
| Office Staff | Increased temperatures should not adversely impact National Grid's office based operations | Business Continuity Plans identify alternative office locations for business critical operations | Business Continuity Plans identify alternative office locations for business critical operations | Business Continuity Plans identify alternative office locations for business critical operations | Business Continuity Plans identify alternative office locations for business critical operations | Business Continuity Plans identify alternative office locations for business critical operations | Business Continuity Plans identify alternative office locations for business critical operations | Business Continuity Plans identify alternative office locations for business critical operations | Business Continuity Plans identify alternative office locations for business critical operations |

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# APPENDIX

## C. CLIMATE CHANGE SCENARIOS

### Climate Condition Scenarios

Scenarios are based on the UKCP09 work and build on the work done with the UKCIP02. A scenario has been chosen for 2020, 2050 and 2080 timeframes. All of these timeframes are relevant due to the long asset lives of the infrastructure that National Grid invests in (15 to 80 years for equipment). Further details on the scenarios can be found at:

http://ukclimateprojections.defra.gov.uk/

For each data point the greatest or lowest regional value has been taken to represent the UK. The range of results in the scenarios has been included in square brackets to give a perspective on the variance.

Three proposed High Emissions Scenarios in order to asses the impacts under extreme conditions are:

| | Scenario 1 | Scenario 2 | Scenario 3 |
|---|---|---|---|
| **Scenario Characteristic** | **1: 2020 Scenario 90th percentage [wider range]** | **2: 2050 Scenario 90th percentage [wider range]** | **3: 2080 Scenario 90th percentage [wider range]** |
| **Change in mean winter temperature (ºC)** | +2.2°C [+0.1 to 2.2 °C] | +3.8°C [+0.6 to 3.8 °C] | **+5.7°C [+0.9 to 5.7%]** |
| **Change in mean summer temperature (ºC)** | +2.7°C [+0.4 to 2.8 °C] | +5.2°C [+0.8 to 5.2 °C] | **+8.1°C [+1 to 8.1 °C]** |
| **Change in mean winter precipitation (%)** | +20% [-5% to +20%] | +41% [-2% to+41%] | **+73% [-4% to +73%]** |
| **Change in mean summer precipitation (%)** | +22% [-31% to +22%] | +11% [-50% to +20%] | **+6% [-65% to +15%]** |
| **Relative sea-level changes (cm) with respect to 1990 levels** | +11.5cm [+4.6 to 11.5cm] | +25.9cm [+11.1 to 25.9cm] | **+43.3cm [+18.6 to 43.3cm]** |
| Number of days with heavy rain (>25 mm) - Central estimates are for heavy rain days (rainfall greater than 25 mm) over most of the lowland UK to increase by a factor of between 2 and 3.5 in winter, and 1 to 2 in summer by the 2080s under the medium emissions scenario. | | | |

National Grid has chosen to assess its assets and processes against the high level scenario which is based on the least likely to occur prediction of climate change as of 2080. This was on the basis that should National Grid's assets and process demonstrate resilience against this scenario it would inevitably be adapted against lower and more likely climate change.

To better understand the potential impacts and associated risks that these Climate Change Scenarios pose on National Grid Electricity Transmission plc's assets they have been converted into key Specific Physical Characteristics.

To aid the process additional information from the Met Office "Climate risk assessment on future network resilience" funded by energy companies has been combined with National Grid Electricity Transmission plc's own engineering judgement.

The result has been to identify Specific Physical Characteristics that are likely to be caused by these scenarios, and it is the impact of these characteristics to National Grid Electricity Transmission plc's key assets and processes that is risk assessed. The Physical Characteristics can be broken down into three groups:

1. Directly correlated to the UKCP09 work and so have greater definition and probabilities around them and are known as the UKCP09 Characteristics
2. Taken from the Met Office work on "Risk Assessment on future Network Resilience" and are known as MO Characteristics
3. Additional characteristics added by National Grid to ensure that the main key risk areas are covered, these are known as NG Characteristics

For the final two groups, although these characteristics may be caused as a result of climate change, further work will be required in the next update of the UKCP09 data to assess any expected increases in magnitude and the associated probabilities.

The identified Specific Physical Characteristics are as follows:

## UKCP09 Characteristics

- **Summer Mean Temperature rise of up to 8°C** – This corresponds to the mean summer temperature rise of 8.1°C by 2080 in the scenario. This effect is likely to be geographically specific and the greatest effects would be seen in urban heat islands.
- **Increased Heavy Rainfall (by a factor of up to 3.5)** – Based on the analysis in the UKCP09 projections that heavy rain days (>25mm/day) were likely to increase by up to a factor of 3.5 by 2080.
- **Sea Level Rises of up to 43cm** – Based on the analysis in the UKCP09 projections sea levels may rise by 43.3cm by 2080.

## Met Office Characteristics

- **Increased Lightning –** Increased intensity, frequency and geography of cloud to ground lightning strikes. Although no published UKCP09 data exists to support increases in intensity, frequency etc. National Grid has undertaken an initial adaptation risk assessment against assets and processes.
- **Increased Wind and Gale** – Increased wind and gusts expected, including potential changes in direction. Although no published UKCP09 data exists to support increases in intensity, frequency etc. National Grid has undertaken an initial adaptation risk assessment against assets and processes.
- **Increased Snow, Sleet, Blizzard, Ice and Freezing Fog –** Increased snow fall, ice, frost and freezing fog. Although no published UKCP09 data exists to support increases in intensity, frequency etc. National Grid has undertaken an initial adaptation risk assessment against assets and processes.
- **Increased Flooding** – Due to increased rainfall intensity, frequency and geography of flooding is expected to increase.

## National Grid Characteristics

- **Increased Coastal / River Erosion –** Due to increased rainfall and storms it is anticipated that there will be increased erosion of coastal defences and river banks.
- **Increased Subsidence** – Due to increases in rainfall and greater anticipated seasonal swings it is anticipated that land subsidence may become an issue.

Having identified the Specific Physical Characteristics, the key asset types and processes to assess these against were identified.

**Electricity Transmission Assets**

- Substation Sites – including all plant and equipment e.g. switchgear, transformers and earthing
- Expansion of existing substation sites (outside of existing boundary)
- Existing Tunnels and Underground Cable Route
- Existing Cable Bridges
- Existing Overhead Lines (OHL) and Towers
- New Sites (Substations, Overhead lines, Tunnel Heads, Cable Sealing Ends)

**Electricity Processes**

- Existing Cable Bridges
- Emergency
- Maintenance, Construction & Fault Repairs
- Control Centre Operations
- Office staff

The Adaptation Risk Assessment process applies the Specific Physical Characteristic, one at a time, to each of the Key Assets and Processes. It then assesses if the result may have an impact on the public from a security of supply perspective, albeit there may still be other impacts.

This analysis has four potential outcomes that are identified using the following approach:

**Green** No material risk to assets or processes from the Specific Physical Characteristic. This is either because no risk has been identified or the existing assets or processes are robust and no further action is required in terms of adaptation measures.

**Yellow** A level of risk has been identified through the risk assessment. Action plans have or are being developed and progress is being monitored via the risk process, it may be that additional investment will be required to manage these risks. These risks have been further assessed using National Grid's risk management process.

**Amber** Insufficient information is currently available on the affects of the Specific Physical Characteristic to calculate the level of risk. Further monitoring or assessment will be carried out to better understand this risk.

**Red** Highly likely or significant, material risk in the future. Current business processes and action plans do not adequately address this specific risk. Full risk assessment and action plan to be developed.

Further details of the risk assessment process and the outcome of this process can be seen in Section 4.4.

## Detailed risk assessment and action plan / mitigation actions for red, amber and yellow risk areas

An analysis of the red, amber and yellow boxes from the high level risk assessment is undertaken, with the aim of better quantifying the risk using the National Grid risk framework and applying a consistent approach between National Grid businesses.

As part of this National Grid Electricity Transmission plc would highlight:

- Work that has already been done or is in progress
- Short term actions that need to be completed to better understand the risk
- Longer term research that might need to be conducted if the funding can be secured
- Long term impacts on the business that National Grid Electricity Transmission plc want to sign post to the regulator
- Long term investments that National Grid Electricity Transmission plc would like to make – subject to the appropriate funding

The red, amber and yellow risks have been aligned into National Grid's risk framework.

The individual risks are managed through the National Grid risk register and the timescales are managed through the risk review process. National Grid Electricity Transmission plc's overall adaptation strategy is kept under continuous review by the central climate change team. Updates are given to the executive and also the risk responsibility committees.

Where the risk was identified as being green, it is deemed that at this stage no further action is required and the risks will be refreshed at the next reporting period with the latest available climate data.

Where the risk was identified as yellow, it has been fully written up as part of National Grid's on going corporate risk reporting process. This means that the risk is assessed in great detail, has mitigation actions with delivery deadlines as well as risk owners. Part of the corporate reporting process means that the risk is reviewed every quarter ensuring that there is the appropriate management focus to ensure that actions are progressed and completed in a timely fashion.

Where the risk was identified as being Amber, actions will have or are being identified during the current reporting period to quantify the actual risk and develop an action plan if required.

Where the risk was identified as being Red, it has been identified that there is a high probability of a definite significant material risk in the future. Current business processes and action plans do not adequately address this specific risk to electricity supplies and require a further full risk assessment and action plan to be developed.

# APPENDIX

## D. OVERHEAD LINE RATINGS

The basic equations governing the derivation of overhead line current ratings have been well known for almost a century and used globally. Typical international examples are set out in IEEE Standard 738 and Cigre Technical Brochure 207.

UK electricity Network Operator Members of the Energy Networks Association (ENA) commissioned collaborative research undertaken by UK Met Office Hadley Centre to assess climate change impacts on various asset types, including overhead lines. The above IEEE Standard was used to determine the impacts of changes in climate ratings as part of the EP2 research.

From a ratings perspective, the most challenging conditions prevail in high ambient temperatures, when there is minimum "leeway" between that and the rated conductor design temperature to allow for conductor heating due to the passage of current. 275 kV and 400 kV higher voltage steel tower OHL lines normally have a design operating temperature of between 50℃ - 75℃.

The UKCP09 data and Met Office research has not currently identified a change in the prevalence of very low wind speeds (< 0.5 m/s) or in levels of solar radiation used in the present basis of UK design, but has identified a range of changes in ambient temperature across the UK in each decade, and for each emission scenario. Previous experience has shown that the limiting condition is the highest daily average ambient temperatures that have the greatest correlation with the highest electrical demands. Further research will be required in future years to check the ongoing validity of this, having regard, for example the uptake of air conditioning etc.

Figure D.1 shows, from UKCP09, the spread of changes in average daily maximum temperature for the 2010-2039 medium emission scenario (there is little difference between H,M,L scenarios), and for each of the H,M,L scenarios for the periods 2040-2069 and 2070 – 2099.

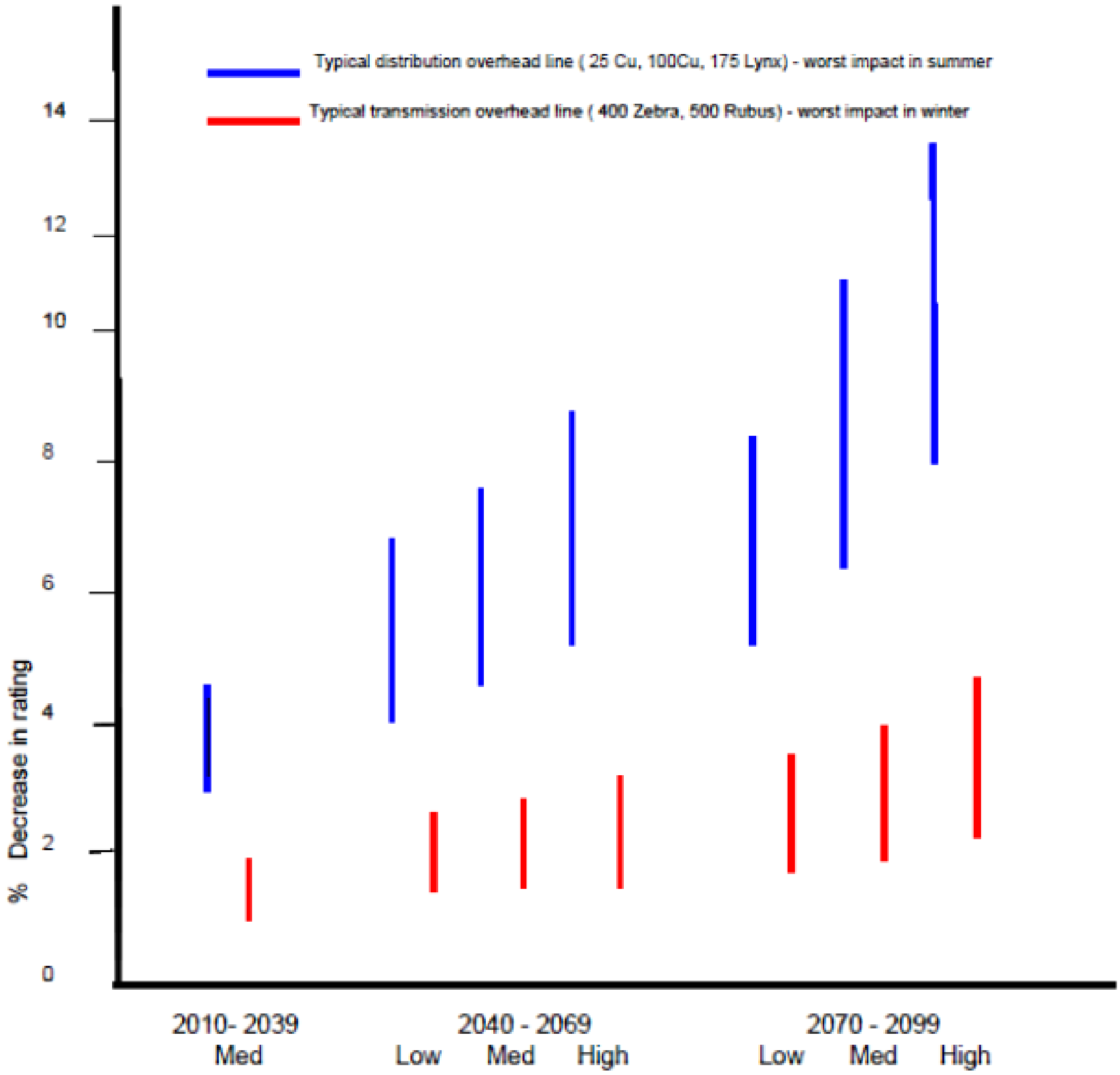
The effects of any of the individual temperatures on a representative range of typical OHL conductor types is established by multiplying the deg C value, by the % rating reduction per deg °C figures derived from the Met Office research and is shown in Table D.1.

Conductor sizes on standard overhead lines range from 16mm² hard-drawn copper to 850mm² aluminium alloy, with rated temperatures varying from 50℃ to 90℃ and even up to 170℃. It would clearly be impractical to look at all these cases for the purposes of this assessment, so the following have been selected as being representative of the most common types of overhead line in the UK, along with the typical limiting rating season:

*Table D.1 Common types of overhead line*

| Conductor & Operating Temperature | Rating | Existing Value | Reduction % |
|---|---|---|---|
| 25mm² Copper @50℃ | Summer | 126 Amps | 1.6% [1.59] /℃ |
| 100mm² Copper @50℃ | Summer | 316 Amps | 1.6% [1.58]/℃ |
| 175mm² Lynx ACSR @50℃ | Summer | 432 Amps | 1.6% [1.62]/℃ |
| 400mm² Zebra ACSR @75℃ | Winter | 1230 Amps | 0.81%/℃ |
| 500mm² Rubus AAAC @90℃ | Winter | 1600 Amps | 0.63%/℃ |

*Figure D.1 Ranges of % de-ratings across UK from UKCP09*




It is important to view the above % de-ratings against past network operator experience in response to growth of electricity demand on their networks; effectively the same challenge. Figure D.1 indicates a range of de-ratings of distribution and Transmission overhead lines of up to 3% over the period having a centre point in 2055. That equates to a ratings impact of some 0.06% per annum, whereas recent demand growth has impacted these same networks at some 1.5% per annum.

The impacts of such reductions in ratings will vary from one circuit to another depending on how close the maximum demand on a particular circuit is to the circuit rating. In the case of 33 kV and higher voltage circuits, when that limit is reached, the entire length of the circuit would have to be assessed to determine which locations required action to increase line height by changing supports (towers) or by other action such as re-conductoring with higher operating temperature conductor and any consequential impacts on supports.

## APPENDIX

## E. CABLE RATINGS

In the UK electricity cables are installed and operated at all the common voltages used on the electricity network from Low Voltage (400 / 230 volts) to 400 kV. Lower voltage cables may be installed just 0.45m below the surface whilst higher voltage cables may be buried at depths of 1m or more.

The length of cable operated at the highest transmission voltages is limited due to the substantial costs involved, however as cable voltages reduce, the cost premium compared to an equivalent overhead line falls.

Cable construction typically comprises a central conductor or conductors of copper or aluminium which is immediately surrounded by insulation (the dielectric) with an outer electrical earthed metallic screen. Older and lower voltage cables are typically of 3, or at LV 4, core construction whilst higher voltage, more recently installed cables are more likely to comprise 3 single core cables laid close together.

As with other electrical equipment, the rating of cables is typically limited by the maximum operating temperature of the insulation surrounding the conductors. Older oil impregnated paper insulated cables have a design maximum conductor temperature of 85℃ with newer oil filled cables post late 1990's rated at 90℃. MIND (Mass Impregnated Non Draining) cable has a maximum temperature range of 55 to 65℃ whilst modern plastic insulated (XLPE) cables have a design maximum conductor temperature of 90℃. Exceeding the maximum operating temperature can have a significant impact on the expected life of the cable. In the case of cables the temperature of the cable is determined by:

Three sources of heat generation:

- Electrical current passing through the electrical resistance of the conductor(s)
- Direct heating of the electrical insulation caused by the alternating voltage, this is only significant in higher voltage cables
- Other external sources of heat in the ground such as other adjacent cables

The ability to conduct heat away from a buried cable

- The way cables are laid is a factor, cables laid in ducts are usually less able to dissipate the heat than those buried directly in the ground
- The thermal resistivity of the ground surrounding the cable or duct. Thermal resistivity itself is affected by the type of soil and the level of moisture it contains
- The temperature of the surrounding soil, which is itself affected by ambient air temperature

The basic equations governing the derivation of cable ratings have been understood for many years and, within the UK, have been incorporated into a comprehensive cable rating tool called GLOIN which can be used to model a range of scenarios in relation to soil temperature and resistivity, for ventilated tunnels MORDEN is used.

Currently cable ratings in the UK are based on assumptions of temperature (air and soil) and thermal resistivity (soil) made more than 50 years ago.

Global warming is predicted to result in hotter, drier summers and milder, wetter winters in the UK. These changes may impact directly upon cable ratings due to the increase in ground temperature and the potential for increased soil thermal resistivity if soils become dry.

The main findings under EP2 in relation to cable assets are that air and soil conditions are expected to change, resulting in higher temperatures and in seasonal differences in soil moisture content. This report recommended that:

- For every 1°C rise in air temperature, soil temperatures at depths of 0.45-1.2m can be expected to increase by 0.75°C
- Reduced precipitation levels may only impact ground resistivity values in extreme, prolonged drought conditions otherwise the effect is small at 1.2m depth
- The effects are similar for different soil types; sand-rich soils offer slightly more resilience to temperature change than types rich in clay or silt, but the variations are small when compared to the effects of changes in the air temperature
- Because of the small effect of soil type, climate change driven changes in air temperatures should be considered independent of soil type when calculating ratings

UKCP09 has produced detailed future climate predictions for the UK, based on low, medium or high emissions, and also on a regional basis and for 2020, 2050 and 2080. The spread of changes in average daily maximum temperature for the 2010-2039 medium emission scenario (there is little difference in the H, M & L scenarios) and the 2040-2069 and 2070- 2099 H, M, L scenarios are shown in Table E.2.

These predictions will apply to the majority of cables installed in the UK however it is important to note that the predicted reduction in ratings may be exceeded in specific situations such as areas affected by Urban Heat Island effects, or localised dry, sandy soil conditions which may be more prone to drying out as temperatures increase.

Table E.1 considers a range of commonly used cable types and installation methods and shows the percentage reduction in rating per °C of air temperature change calculated.

*Table E.1 Typical cable rating reduction per deg C*

| Description | Max °C | Time | Installation | Existing Rating (Amps) | Rating Reduction %/°C Air Temp |
|---|---|---|---|---|---|
| LV 185 Cu Waveform | 80 | Summer | Direct Lay | 339 | 0.590% |
| LV 185 AL PILC-STA | 80 | Summer | Direct Lay | 335 | 0.597% |
| 11kV – 185 Al XLPE 1C | 90 | Summer | Direct Lay | 370 | 0.507% |
| 11kV – 185 Al XLPE 1C | 90 | Summer | Ducted | 360 | 0.521% |
| 11kV – 185 Al PICAS 3C | 65 | Summer | Direct Lay | 270 | 0.787% |
| 33kV – 185 Al XLPE 1C | 90 | Summer | Direct Lay | 457 | 0.492% |
| 33kV – 185 Al XLPE 1C | 90 | Summer | Ducted | 430 | 0.494% |
| 33kV – 185 CU PILC 'H' | 65 | Summer | Direct Lay | 355 | 0.775% |
| 132kV – 630 XLPE 1C | 90 | Summer | Direct Lay | 881 | 0.511% |
| 132kV – 630 XLPE 1C | 90 | Summer | Ducted | 879 | 0.512% |
| 132kV – 630 Cu Lead Sheath | 85 | Summer | Direct Lay | 755 | 0.579% |
| 132kV – 630 Cu Lead Sheath | 85 | Winter | Direct Lay | 827 | 0.544% |
| 400kV – 2000 XLPE 1C | 90 | Summer | Direct Lay | 1429 | 0.560% |
| 400kV – 2000 XLPE 1C | 90 | Summer | Ducted | 1448 | 0.570% |
| 400kV – 2000 XLPE 1C | 90 | Winter | Direct Lay | 1569 | 0.518% |
| 400kV – 2000 Cu Lead Sheath | 85 | Summer | Direct Lay | 1052 | 0.986% |

*Table E.2 R*ange of de-ratings for the 7 climate change scenarios extracted from UKCP09

| Cable Type | | 2010 - 2039 | | 2040 - 2069 | | 2040 - 2069 | | 2040 - 2069 | | 2070 - 2089 | | 2070 - 2089 | | 2070 - 2089 | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Emission Scenario | M | | L | | M | | H | | L | | M | | H | |
| | Range | Min | Max | Min | Max | Min | Max | Min | Max | Min | Max | Min | Max | Min | Max |
| | Air Temp Increase Range ℃ | 1.8 | 2.0 | 2.6 | 4.5 | 2.8 | 4.9 | 3.3 | 5.4 | 3.2 | 5.3 | 4.1 | 6.8 | 5.0 | 8.4 |
| | Soil Temp Increase Range ℃ | 1.3 | 2.2 | 2.0 | 3.4 | 2.1 | 3.6 | 2.4 | 4.1 | 2.4 | 4.0 | 3.1 | 5.1 | 3.8 | 6.3 |
| LV 185 Cu Waveform | Summer - Direct Lay | 1.0% | 1.7% | 1.5% | 2.7% | 1.7% | 2.9% | 1.9% | 3.2% | 1.9% | 3.1% | 2.4% | 4.0% | 3.0% | 5.0% |
| LV 185 AL PILC-STA | Summer - Direct Lay | 1.1% | 1.7% | 1.6% | 2.7% | 1.7% | 2.9% | 1.9% | 3.3% | 1.9% | 3.2% | 2.4% | 4.1% | 3.0% | 5.0% |
| 11kV – 185 Al XLPE 1C | Summer - Direct Lay | 0.9% | 1.5% | 1.3% | 2.3% | 1.4% | 2.5% | 1.7% | 2.8% | 1.6% | 2.7% | 2.1% | 3.4% | 2.5% | 4.3% |
| 11kV – 185 Al XLPE 1C | Summer - Ducted | 0.9% | 1.5% | 1.4% | 2.3% | 1.5% | 2.5% | 1.7% | 2.8% | 1.7% | 2.8% | 2.1% | 3.5% | 2.6% | 4.4% |
| 11kV – 185 Al PICAS 3C | Summer - Direct Lay | 1.4% | 2.3% | 2.1% | 3.5% | 2.2% | 3.8% | 2.6% | 4.3% | 2.5% | 4.2% | 3.2% | 5.3% | 3.9% | 6.6% |
| 33kV – 185 Al XLPE 1C | Summer - Direct Lay | 0.9% | 1.4% | 1.3% | 2.2% | 1.4% | 2.4% | 1.6% | 2.7% | 1.6% | 2.6% | 2.0% | 3.3% | 2.5% | 4.1% |
| 33kV – 185 Al XLPE 1C | Summer - Ducted | 0.9% | 1.4% | 1.3% | 2.2% | 1.4% | 2.4% | 1.6% | 2.7% | 1.6% | 2.6% | 2.0% | 3.4% | 2.5% | 4.2% |
| 33kV – 185 CU PILC 'H' | Summer - Direct Lay | 1.4% | 2.2% | 2.0% | 3.5% | 2.2% | 3.8% | 2.5% | 4.2% | 2.5% | 4.1% | 3.2% | 5.3% | 3.9% | 6.5% |
| 132kV – 630 XLPE 1C | Summer - Direct Lay | 0.9% | 1.5% | 1.3% | 2.3% | 1.4% | 2.5% | 1.7% | 2.8% | 1.6% | 2.7% | 2.1% | 3.5% | 2.6% | 4.3% |
| 132kV – 630 XLPE 1C | Summer - Ducted | 0.9% | 1.5% | 1.3% | 2.3% | 1.4% | 2.5% | 1.7% | 2.8% | 1.6% | 2.7% | 2.1% | 3.5% | 2.6% | 4.3% |
| 132kV – 630 Cu Lead Sheath | Summer - Direct Lay | 1.0% | 1.7% | 1.5% | 2.6% | 1.6% | 2.8% | 1.9% | 3.2% | 1.9% | 3.1% | 2.4% | 3.9% | 2.9% | 4.9% |
| 400kV – 2000 XLPE 1C | Summer - Direct Lay | 1.0% | 1.6% | 1.5% | 2.5% | 1.6% | 2.7% | 1.8% | 3.0% | 1.8% | 3.0% | 2.3% | 3.8% | 2.8% | 4.7% |
| 400kV – 2000 XLPE 1C | Summer - Ducted | 1.0% | 1.6% | 1.5% | 2.6% | 1.6% | 2.8% | 1.9% | 3.1% | 1.8% | 3.0% | 2.3% | 3.9% | 2.9% | 4.8% |
| 400kV – 2000 Cu Lead Sheath | Summer - Direct Lay | 1.7% | 2.9% | 2.6% | 4.4% | 2.8% | 4.8% | 3.2% | 5.4% | 3.2% | 5.2% | 4.0% | 6.7% | 4.9% | 8.3% |

## APPENDIX

## F. TRANSFORMER RATINGS

Transformers are used to transform voltage from one level to another. Within the transmission systems the most common transformation steps are 400 kV volts to 275 kV, to 132 kV which supplies the distribution networks which in turn further reduce the voltage to end user requirements.

Transformers basically comprise an iron core with copper or aluminium insulated wire coils wrapped around that, further insulated with a mineral oil and housed in a steel tank, with external connection points to the system. The passage of current through the wire coils (“windings”) causes heating, since no wire is a perfect conductor, and the insulating oil plays a major part in conducting that heat away.

The load carrying capability of the transformer is primarily dictated by the maximum temperature at which the windings and insulation can be operated without causing damage and fault. The greater the external ambient temperature the less heating can be permitted from the windings and consequently the rating is reduced. The pattern of demand loading during the day also has an impact.

Transformers, cables and overhead lines, used in electrical power transmission, all generate heat when in use and have maximum safe operating temperatures. The temperature of this equipment increases with ambient temperature and current. As ambient temperature increases, the maximum current for safe operation is reduced; therefore, in order to aid network planning, each type of equipment is allocated a maximum power rating which varies with temperature. Furthermore, each season is allocated a maximum ‘operating temperature’ for each type of equipment. This is the maximum temperature likely to be exceeded for a sufficient duration to affect the equipment.

For transformers, the maximum current load is determined by assuming that the highest temperature sustained for a period of 3-6 consecutive hours is 10ºC in winter, 20ºC in spring and autumn and 30ºC in summer. The period of 3-6 hours allows for the slow thermal response of transformers. ‘Winter’ is defined as December-February, ‘spring/autumn’ as March, April and September-November and summer as May-August. Different operating temperatures and seasons are defined for other types of electrical plant.

The decision-making process for equipment rating begins about a year ahead, when plans are made to shut down equipment for maintenance. Computer models of the grid are used to ensure that there is an "N-2" level of resilience. This means that supply to domestic consumers must be uninterrupted even if two circuits fail in addition to planned maintenance outages. Exceeding maximum operating temperature reduces the life-time of the equipment and may cause it to fail. Conversely, if the maximum ambient temperature is overestimated, then the current may be reduced, or investment in extra infrastructure made, unnecessarily. Hence, there is value in re-appraising the operating temperature guidelines from time to time.

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# APPENDIX

## G. DEFINITIONS AND GLOSSARY OF TERMS

National Grid Electricity Transmission plc's aim is to use plain English in this report. However, where necessary, National Grid Electricity Transmission plc does use a number of terms and or abbreviations and have summarised the principal ones below, together with an explanation of their meanings. The definitions are not formal legal definitions.

### A - D

**Above Ordnance Datum (AOD)**
Used by an ordnance survey as a basis for deriving altitude on maps usually mean sea level (MSL) is used for the datum

**British European Standard Specification (BS EN)**
British Standards are the standards produced by BSI Group.

**British Standards Institution (BSI)**
Services provider whose principal activity is the production of standards and the supply of standards-related services.

**Civil Contingencies Secretariat**
Department of the British Cabinet Office responsible for emergency planning in the UK.

**Customer**
A person to whom electrical power is provided (whether or not he / she is the same person as the person who provides the electrical power).

**Department of Energy Climate Change (DECC)**
Government department which brings together energy policy and climate change mitigation policy.

### E – H

**Electricity Network Strategy Report (ENSG)**
Forum which brings together key stakeholders in electricity networks that work together to support government in meeting the long-term energy challenges of tackling climate change.

**Electricity Act 1989**
This Act provides the core legislation for planning consents for the construction and operation of generating stations within England and Wales.

**Energy Networks Association (ENA)**
Represents the interests of its member companies who operate the national and regional networks for energy to transport gas and electricity into UK homes and businesses.

**EP1 / EP2**
ENA initiated Met Office study to investigate the potential impact of climate change. The project was split into EP1 customer requirements and scoping which was completed in 2006 which facilitated the EP2 project which assessed the risk of climate change on the UK's energy industry this report was published in 2008.

**Electricity Safety Quality and Continuity Regulations ESQCR**
Statutory instruments which support the Electricity Act 1989.

**Engineering Technical Report ETR138**
ENA technical report which provides guidance on flood risk assessments.

**Gas and Electricity Markets Authority**
Ofgem decision making body.

**Generator**
A person who generates electricity under license or exemption under the Electricity Act acting in its capacity as a generator in Great Britain.

**Grid Code**
The Grid Code is an interface document setting out the planning and operating procedures and principles governing National Grid Electricity Transmission plc's relationship with all Users of the National Electricity Transmission System, be they Generators, DC Converter owners, Suppliers or Non-Embedded Customers. The Grid Code specifies the day to day procedures for both planning and operational purposes and covers both normal and exceptional circumstances. The Grid Code is drawn up pursuant to the Transmission license, and from time to time revised in accordance with the Transmission License.

**Health and Safety Executive (HSE)**
HSE is the national independent watchdog for work-related health, safety and illness. An independent regulator and act in the public interest to reduce work-related death and serious injury across Great Britain's workplaces.

## I – L

**International Electrotechnical Commission (IEC)**
An organization that prepares and publishes international standards for all electrical, electronic and related technologies.

**Institute of Electrical and Electronics Engineers (IEEE)**
The world's largest professional association dedicated to advancing technological innovation and excellence for the benefit of humanity. IEEE and its members inspire a global community through IEEE's highly cited publications, conferences, technology standards, and professional and educational activities.

**Licence Standard**
The Standard (the National Electricity Transmission System "Security and Quality of Supply Standard" (SQSS), Version 1.0, 22 September 2004) referred to in condition C17 of National Grid's Transmission Licence and/or Condition D3 of a relevant Transmission Licensee's Transmission Licence.

## M – P

**Main Interconnected Transmission System (MITS)**
This comprises all the 400 kV and 275 kV elements of the National Electricity Transmission System and, in Scotland, the 132 kV elements of the National Electricity Transmission System operated in parallel with the Supergrid, but excludes Generation Circuits, transformer connections to lower voltage systems and External Interconnections between the GB Transmission System and External Systems.

**Met Office**
The UK's National Weather Service.

**Network Operator**
A person with a User System directly connected to the National Electricity Transmission System to which Customers and/or Power Stations (not forming part of that system) are connected, acting in its capacity as an operator of the User System, but shall not include a person who operates an External System.

**Office of the Gas and Electricity Markets Ofgem**
Protecting consumers by promoting competition, wherever appropriate, and regulating the monopoly companies which run the gas and electricity networks.

**Pitt Review**
An independent review of the flooding emergency that took place in June and July 2007.

**Plant**
Fixed and movable items used in the generation and/or supply and/or transmission of electricity, other than Apparatus.

**PASS55**
PAS 55 is the British Standards Institution's (BSI) Publicly Available Specification for the optimised management of physical assets.

**Power Station**
An installation comprising one or more Generating Units (even where sited separately) owned and/or controlled by the same Generator, which may reasonably be considered as being managed as one Power Station.

**Planning Policy Statement 25 (PPS25)**
Sets out the Government's spatial planning policy on development and flood risk.

## Q – T

**Rating**
The continuous rating of a Circuit is the maximum power flow that can be passed through the Circuit, without damaging equipment, or infringing statutory clearances on overhead lines. This will normally be for a period within 24 hours. This rating varies for each season of the year, because of the effect of differing climatic conditions on equipment performance.

**Regional and Local Resilience Forums**
Deals with emergency preparedness, response and recovery as directed by government implemented at a regional and local level.

**Supergrid**
That part of the National Electricity Transmission System operated at a nominal voltage of 275 kV or above.

**Scottish Environmental Protection Agency SEPA**
Scotland's environmental regulator similar to the Environment Agency in England and Wales.

**Shoreline Management Plans**
A large-scale assessment of the risks associated with coastal processes coordinated by the Environment Agency.

**Supergrid Transformer (SGT)**
Power transformers which interconnect the 400 kV and 275 kV transmission system with the distribution systems (typically 132 kV or 66 kV).

**Transmission System Operator**
An operator that transmits electrical power from generation plants to regional or local electricity Distribution Network Operators.

**Transmission Area**
Has the meaning set out in the Transmission Licence of a Transmission Licensee.

**Transmission License**
The License granted under Section 6(1)(b) of the Electricity Act 1989 (as amended by the Utilities Act 2000 and the Energy Act 2004).

**Transmission Licensee**
This means the holder, for the time being, of a Transmission License. For the purpose of this NETS SYS, this means National Grid Electricity Transmission plc or Scottish Power Transmission Ltd or Scottish Hydro-Electric Transmission Limited.

**Transmission Price Control Review (TPCR)**
Ofgem sets price controls for the four electricity and gas transmission companies which own Britain's high-voltage national networks and the national gas pipeline.

## U - Z

**UK Climate Impacts Programme 2002 (UKIP02)**
Climate change scenarios derived from a series of climate modelling experiments commissioned and funded by Defra, undertaken by the Hadley Centre and analysed by the Tyndall Centre.

**UKCP09**
Provides future climate projections for land and marine regions, and observed climate data.

## APPENDIX

## H. REFERENCES AND LINKS

**National grid 7 year statement**
http://www.nationalgrid.com/uk/Electricity/SYS/

**National Grid Annual Report 2010**
http://www.nationalgrid.com/corporate/Investor+Relations/Reports/

**Institute of Electrical and Electronics Engineers (IEEE)**
http://www.ieee.org/index.html

**UKCP09**
http://ukclimateprojections.defra.gov.uk/content/view/12/689/

**British Standards Institution (BSI)**
http://www.bsigroup.com/

**Office of the Gas and Electricity Markets Ofgem**
http://www.ofgem.gov.uk/Pages/OfgemHome.aspx

**Department for Environment, Food and Rural Affairs (Defra)**
http://ww2.defra.gov.uk/

**International Electrotechnical Commission (IEC)**
http://www.iec.ch/