Infrastructure Climate Change Impacts

Report Card 2015

This LWEC Report Card is aimed at anyone who works with, or has an interest in, infrastructure in the UK. Infrastructure provides services important for our safety, our health and our economic development. Climate change may affect it in a number of ways. Failure to consider and plan for these changes could lead to increased disruption of a whole range of services that we rely on, such as heating, lighting, sanitation and transportation.

Focusing on the possible physical impacts of climate change, this card sets out to aid understanding of the nature and scale of those impacts on UK infrastructure and so inform decisions about infrastructure's management and further development. The card provides a high-level summary of the main findings from 12 detailed technical reports prepared by leading experts in their fields using the best available science from academic literature. (See the table on page 16) All of these reports are available at www.lwec.org.uk

This card complements other Report Cards that look at climate change impacts in the following spheres: Marine; Terrestrial Biodiversity; Water; and Health. Collectively, the five publications are beginning to build up a picture of both historical and future changes caused by climate change. In time, we expect the current suite of Report Cards to be supplemented by others that complete the picture of how climate change is affecting and may further affect the UK.

The report card covers the following topics:

- Rail transport
- Road transport
- Inland waterway, port and marine transport
- Potable water
- Waste water and sanitation
- Flood and coastal erosion management
- Information and communication technology
- Solid waste management
- Nuclear, coal, oil and gas energy
- Renewable energy generation
- Power systems, transmission and distribution
- Energy demand management

Infrastructure delivers services that support jobs, drive economic growth, increase people's safety and improve quality of life

The UK climate is changing:

Since 1980, average temperatures have increased by 0.8-1°C. All ten of the warmest years on record in the UK have occurred since 1990. 2014 was the warmest years on record in the UK.

Annual average rainfall has not changed significantly since records began in 1766 but there has been some increase in the past few decades. Winter rainfall appears to have increased and there is evidence that more is falling as heavy events in some regions. Summer rainfall has decreased (though the trend is less clear).

During the 20th century, sea level around the UK rose by an average of 1-2mm/year. Over the past decade, however, the rate has increased to over 3mm/year. Peak sea levels during extreme weather events appear to be rising at a similar rate.

Extreme heat waves are expected to increase over the next century.

UK infrastructure is vulnerable to these changes:

Infrastructure in the UK experiences significant impacts as a result of the natural variability of our climate.

Increases in the frequency of severe weather events (e.g. flooding) will lead to increased disruption of infrastructure.

Gradual shifts in long-term trends (e.g. a rise in average temperatures) can reduce the capacity or efficiency of some infrastructure.

These increases and shifts can alter not just the design life of infrastructure but also the effectiveness of the services it provides.

Climate change will interact with, and exacerbate, the impact of other pressures that include population growth and an ageing infrastructure:

Although infrastructure owners and operators are already implementing a number of measures in response to climate change, design and implementation – and the rolling out of new infrastructure – can take many years. It is therefore important to:

Consider the scale of possible change and variability in the UK's future climate in the context of risks to existing and future infrastructure.

Develop flexible solutions that can deal with a wide range of future weather conditions and, where feasible, allow for the introduction of new knowledge and technologies.

Anticipate risks to infrastructure from future climatic and other relevant changes, and start taking appropriate steps now to adapt to them.

Background

Producing this Report Card

This card is an initiative of the LWEC (Living With Environmental Change) partnership. Bringing together UK public sector organisations that fund, carry out and use environmental research and observations, LWEC aims to make sure that decision-makers in government, business and society have the information, knowledge and methods they need in order to adapt to and, where possible, benefit from environmental change. The card was developed with funding and input from the UK Government's Department for Environment, Food and Rural Affairs (Defra), the Environment Agency, LWEC, the Natural Environment Research Council (NERC) and the Engineering and Physical Sciences Research Council (EPSRC).

Both this high-level summary and the technical reports underpinning it have been reviewed by a group of independent experts to assure their quality. The overall process that has produced these deliverables was steered by an expert panel drawn from academia, government and industry.

The source papers for this card are available from the LWEC website.

The UK's infrastructure

UK infrastructure provides services essential to improving quality of life. Key components of this infrastructure include:

55

major airports processing **228 million** passengers each year

2,537

railway stations enabling **1.3 billion** rail journeys each year (figures for Great Britain)

2,200

miles of canal (figure for Great Britain)

245,000

miles of road, with **>6500** miles being the average distance travelled by road per person per year (figures for Great Britain)

52

major ports handling **507 million** tonnes of cargo each year

25,400

miles of flood defences (figure for England only)

Sources: Civil Aviation Authority, Department for Transport National Travel Survey, Office of Rail Regulation, Department for Transport Port and Freight Statistics, Canal and River Trust, Scottish Canals, Environment Agency

Over 100

drinking water reservoirs and over **9000** waste water treatment plants, enabling water use amounting to **145** litres per person per day

15,500

miles of high-voltage overhead power lines, plus almost **500,000** miles of other overhead lines and underground cables (figures for Great Britain)

Over 52,500

mobile phone base stations, delivering more than **134 billion** minutes of call time each year

460

power stations generating **361** Terawatt-hours of electricity

510

licensed landfill sites with a combined capacity of **540 million** cubic metres (figures for England & Wales)

3.5 million

square metres, of data centres, supporting **22.6 million** residential and small business broadband connections

Sources: **Defra, Environment Agency, Department of Energy & Climate Change, Ofgem, Infrastructure UK, Ofcom & DataCentreDynamics, Ofcom**

What has happened to date?

- Central England Temperature (the world's longest series of monthly temperature observations) has risen by 0.9-1°C since 1980. All ten of the warmest years on record in the UK have occurred since 1990. 2014 was the warmest years on record in the UK.
- Average annual rainfall has varied from year to year, and whilst there has been some increase in recent decades there is no clear long-term trend for England and Wales since records began in 1766. Seasonal rainfall is highly variable but winter rainfall appears to have increased. Summer rainfall has decreased but the trend is less clear and recently there have been some wet summers.
- Over the past 50 years, there is evidence that more rain is falling as heavy events during winter [in some regions].
- Sea level around the UK rose by about 1-2mm/year during the 20th century, with the rate of rise varying from decade to decade and increasing to over 3mm/year in the past decade. Peak sea levels during extreme weather events appear to be rising at a similar rate.
- Severe windstorms have become more frequent in the past few decades, although it is not clear whether this is part of a long-term trend.

Sources: **Jenkins et al. (2008); Hanna et al. (2008); Haigh et al. (2010); Donat et al. (2011); Jones et al. (2013); Watts et al. (2013); Christidis et al. (2014). National Climate Information Centre: http://www.metoffice.gov.uk/climate; Central England Temperature dataset: http://www.metoffice.gov.uk/hadobs/**

What could happen in the future?

- **Temperature:** All UK regions are expected to warm – more so in summer than in winter. Changes in average summer temperatures are expected to be greatest in parts of Southern England and least in the Scottish Islands. Winter nights are expected to become milder.
- **Heat waves:** The frequency and intensity of extreme heat waves are expected to increase over this century.
- **Rainfall: Rainfall:** Although annual average rainfall may not change much over the 21st century, regional and seasonal changes may occur. The west of the UK may see winter rainfall increase by up to a third by the end of the century, with small decreases over the Scottish Highlands. There will be an increased chance of summers having lower rainfall, particularly in Southern England, but downpours may become heavier when they occur. Changes in summer rainfall over Scotland are less clear.
- **Sea level:** This will continue to rise around the UK, probably at a faster rate than observed in the last century. This will lead to higher peak sea levels during extreme weather events.
- **Humidity:** Relative humidity may decrease by up to 5-10% during summer, with the greatest reductions in Southern England and smaller reductions further north. In winter, changes could amount to a few percent or less, across the UK.
- **Solar radiation:** This may increase on average across the UK, with the greatest increase expected in Southern England.
- **Fog:** Although there is uncertainty regarding changes in the occurrence of fog, the annual number of 'fog days' is expected to fall by 20-50% with the largest decreases in Northern Britain and North Wales. During winter, there may be an increase of 5-20% in the number of fog days across Southern Britain and the Midlands.
- **Wind:** Changes to atmospheric circulation may shift storm tracks north or south, although changes in wind speeds are uncertain.
- **Lightning:** Increases in the number of 'lightning days' are expected across the whole of the UK during all seasons, although the figures are uncertain.

Note: estimates of changes in fog, wind and lightning generated by climate models are particularly uncertain.

Sources: **Murphy et al. (2009); Boorman et al. (2010a); Christidis et al. (2014); Sexton & Murphy (2010b); Boorman et al., (2010b); Haigh et al., (2010); Kendon et al., (2014)**

Winter 2013-14 and the importance of secure and reliable services

Between December 2013 and January 2014, the UK experienced a succession of extreme weather events that led to significant disruption of infrastructure services in many places. Some communities experienced loss of key services such as lighting, heating and transportation for many weeks. The rapid succession of bad weather events hampered efforts to restore these services.

Initially, most of the weather impacts related to strong winds and the most significant coastal surge that the UK had seen since 1953. Tidal flooding first occurred across the north of the UK and then affected exposed areas further south. High winds also damaged surface infrastructure.

As rainfall continued, a number of rivers (including large catchments such as the Severn and the Thames) started to flood. In early January, strong winds combined with high spring tides and high river flows to produce high water levels and large waves, leading to coastal flooding in the south and west of the country.

In total, there were 12 major storms and these were responsible for: seven fatalities; flooding of 1700 properties across England; loss of power for over 150,000 homes for significant periods of time; closure of Gatwick Airport; disruption of rail/road travel (including the severance of the railway line to West Devon and Cornwall); overtopping and breaching of flood defences; plus general damage to buildings and to infrastructure assets. Although comparable and, in some cases, even more severe individual winter storms have occurred at other times in recent years, this was the stormiest period of weather for at least 20 years and the wettest winter in England and Wales since 1766.

Ensuring our infrastructure is resilient to events like this – and to future changes in climate generally – is clearly of fundamental importance.

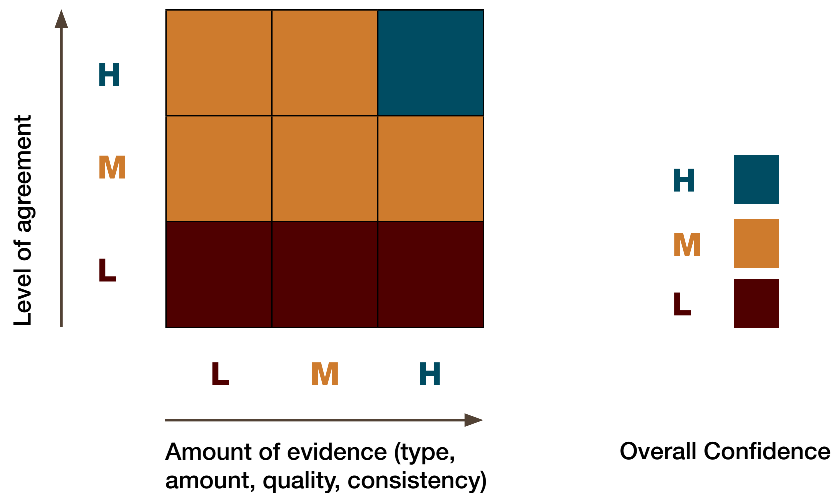
Source: **Met Office and Centre for Ecology and Hydrology (2014)**

Confidence

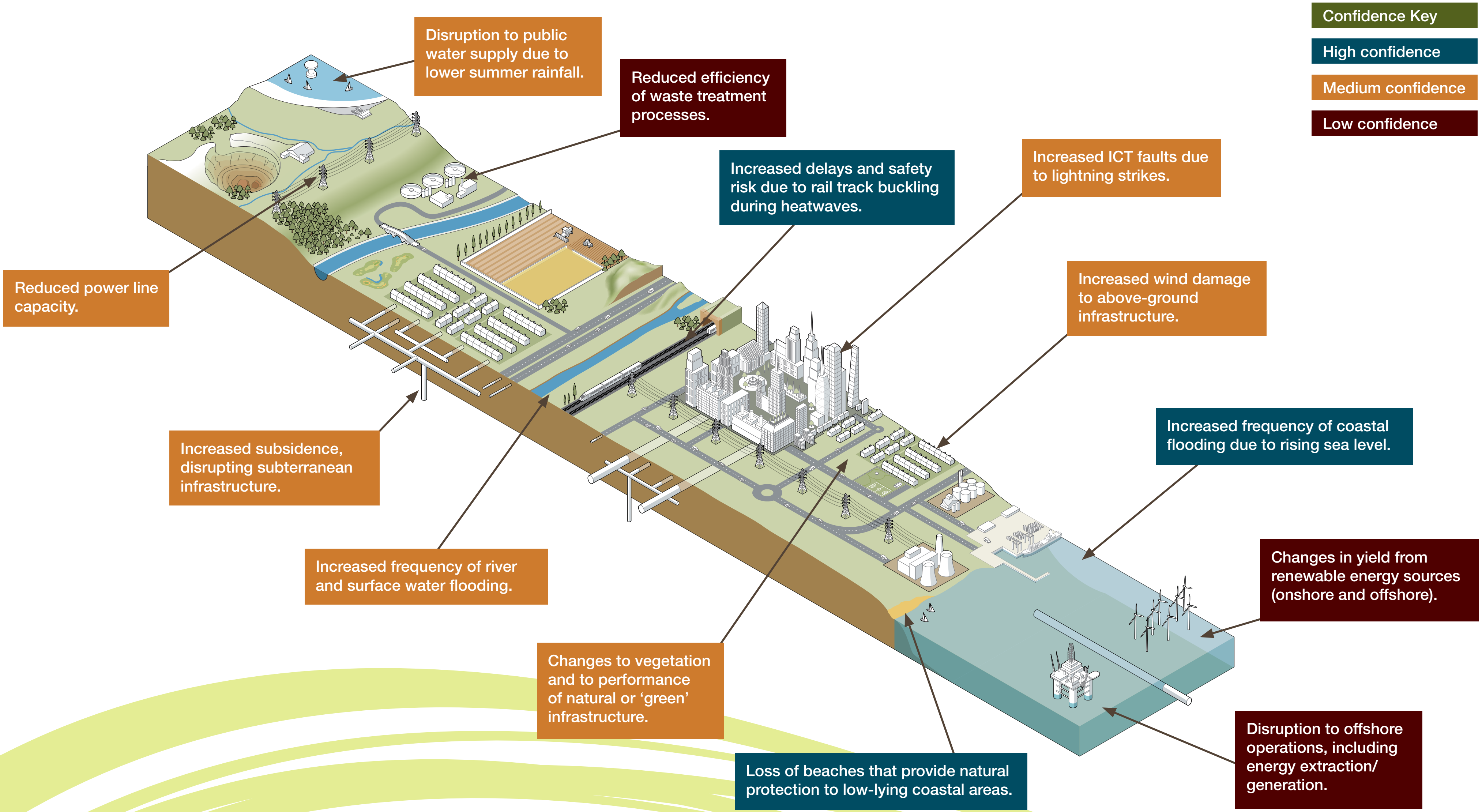
This Report Card assesses scientific evidence regarding the relationship between climate impacts and infrastructure. These assessments (see pages 12-14) should be read in conjunction with the section 'Changes in the UK's Climate' (see pages 6 and 7). The relative significance of the impacts is not considered. This would require analysis of social, economic and environmental implications.

In developing the card, a key objective was to be clear about the level of confidence in the various statements made about the impacts of climate change on UK infrastructure. A confidence level – high, medium or low – has therefore been attached to each assessment. Assigned by scientific experts, this level reflects the degree of scientific agreement in each case as well as the amount of information available. For example, there would be a low confidence level in a conclusion drawn from a few studies that disagreed with each other, but high confidence in cases where many separate investigations reached the same conclusion.

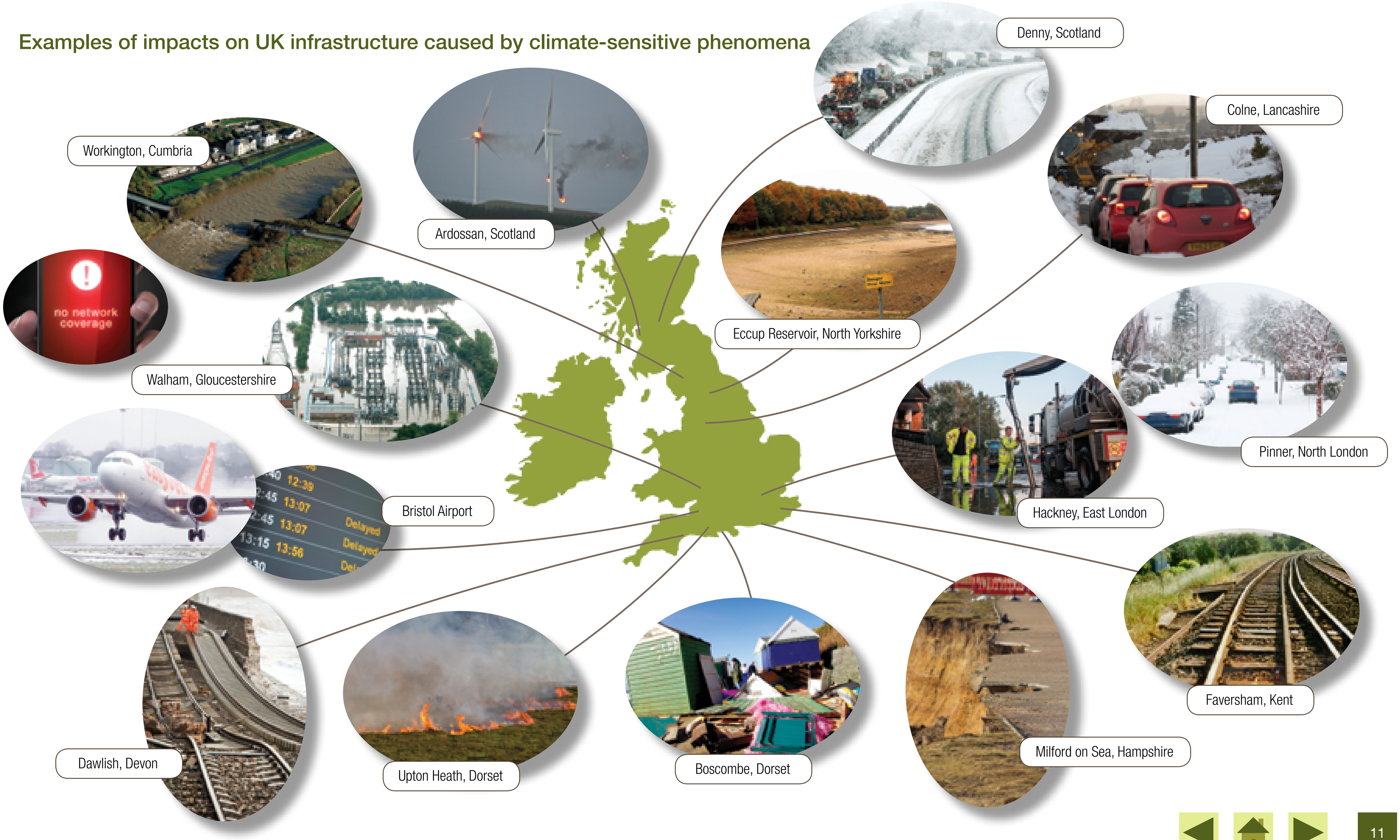
The Report Card has simplified the assessments to provide an overall confidence level of high (H), medium (M) or low (L). Low confidence results are still based on evidence and still reflect expert judgment.



Some examples of how climate change may impact UK infrastructure



Examples of impacts on UK infrastructure caused by climate-sensitive phenomena



High Confidence ■H
Medium Confidence ■M
Low Confidence ■L

The main findings of this Report Card are presented in the following pages. The first column highlights some existing trends and sensitivities relevant to the relationship between infrastructure and climate in the UK. The second column summarises what may happen over the rest of the 21st century.

Sea level rise

Current trends and sensitivities

A large number of infrastructure assets, across all sectors, are already located in the coastal zone. ■H

Some urban areas and their infrastructure are already below average high-water levels. ■H

Saltwater has already intruded into some coastal aquifers, but the cause has usually been over-abstraction of water from those aquifers. ■H

The Thames Barrier has been shut more frequently in recent years as a result of (i) extreme weather events and (ii) changes in the rules governing when it should be closed. ■H

Coastal defences have been breached on a number of occasions since 1953, including during the winter storms of 2013-14. ■H

Protection for some stretches of cliff and low-lying land has been removed where it is considered uneconomic or where there is a need to restore natural processes. ■H

What could happen

Increased likelihood of extreme weather events disrupting coastal infrastructure, in terms of (i) absolute failure of infrastructure assets and (ii) conditions that make their operation unsafe. ■H

Sea level rise over the 21st century further increases the frequency of Thames Barrier closures, ■H whilst low-lying areas become increasingly tide-locked, requiring drainage with pumps to avoid flooding even on sunny days. ■H

Salinity fluctuations, resulting from higher sea levels infiltrating sewerage infrastructure, reduce the effectiveness of sewage treatment. ■M

Increased rates of erosion and reduced protection from natural barriers (e.g. beaches), with subsequent loss of land and/or failure of infrastructure within coastal zones. ■M

Increased saltwater intrusion into some coastal aquifers. ■M

Current trends and sensitivities

Rainfall

A large number of infrastructure assets, across all sectors, are already located in areas susceptible to river or rainwater flooding (with some degree of protection already provided in many cases). ■ **H**

Flooding of infrastructure assets can lead to service disruptions and impacts far beyond the flooded area; for example, flooding of a transport hub can have knock-on implications for the movement of goods and people. ■ **H**

Water abstracted directly from rivers meets the needs of citizens, businesses and infrastructure services (e.g. cooling for power stations). ■ **H**

Extended periods of low rainfall can lead to restrictions and, in a few instances, the failure of public water supplies. ■ **H**

An increase in impermeable surfaces (e.g. concrete driveways) in urban areas disrupts natural processes, increases surface water flows and augments the risk of flooding. ■ **H**

What could happen

Increased frequency of high river flows, resulting in a higher likelihood that flooding will affect infrastructure assets in river floodplains. ■ **M**

Increased frequency of urban drainage capacity being exceeded, resulting in urban flooding and increases in the discharge of pollution into watercourses. ■ **M**

Increased likelihood of droughts, leading to disruption of water supplies and of infrastructure services (e.g. cooling for power stations). ■ **M**

Increased incidence of disruption to earthworks along transport and flood defence corridors, including: shrink/swell around pipework; landslips; undercutting; and bridge scour. ■ **M**

Lower overall rainfall but higher frequency of destructive flash floods in summer, increasing potential disruption to infrastructure. ■ **M**

Decrease in summer hydroelectricity production and increase in winter hydroelectricity production (assuming generating capacity is in place to harness increased water flows). ■ **M**

Reduced supply of water to parts of the canal network. ■ **M**

Reduced quality of wireless communication services because rainfall can disrupt communication signals. ■ **M**

Temperature

Current trends/sensitivities

Railway track buckles and road tarmac can rut and melt during hot weather. ■ **H**

Overhead power and communication lines can sag during hot days with low winds, reducing operational efficiency. ■ **H**

Performance of mechanical and electrical systems (e.g. ICT, flood gates, power generation turbines) is sensitive to temperature. ■ **H**

Maintenance and construction cannot be carried out in very hot or very cold temperatures. ■ **M**

Passengers using public transport experience heat stress on the hottest days. ■ **H**

Demand for services such as water and energy is sensitive to temperature. ■ **H**

What could happen

Increased temperatures and severe heatwaves increase the risk of disruption and of reduced efficiency/safety associated with almost all infrastructure services; e.g. overhead power lines transmit electricity less efficiently in higher temperatures. ■ **H**

Disruptions related to cold, snow and ice decrease, although severe cold spells still occur. ■ **M**

Increased cost of services due to changes in operational and management procedures; e.g. air conditioning to cool workers, night-time working for outdoor jobs, and the relocation of services. ■ **L**

Increase in subsidence affecting infrastructure foundations; increased drying out of engineered slopes due to hot, dry spells, causing damage to flood defences, transport networks, underground cables/pipelines, pylons and telecommunication masts. ■ **M**

Warmer weather encourages more people to walk or cycle, delivering both health and greenhouse gas reduction benefits. ■ **M**

Changes in vegetation along embankment corridors can lead to instability, whilst changes in vegetation in ‘green infrastructure’ used to manage urban flooding can reduce its effectiveness. ■ **M**

Alteration of biological processes and disease vectors related to solid waste and waste water treatment, many of which increase health risks. ■ **L**

Changes in temperature lead to significant shifts in demand and make existing heating and cooling systems less efficient. ■ **L**

Other factors: windstorms, lightning, humidity, solar radiation

Current trends/sensitivities

Strong winds are one of the most significant causes of damage and disruption to all infrastructure services. ■ **H**

High winds lead to bridge closures and pose problems for high-sided vehicles. ■ **H**

Wind can increase the efficiency of overhead power lines by cooling them, but wind turbines cannot operate in very high wind speeds. ■ **H**

Windstorms can disrupt infrastructure systems: (i) directly, by damaging infrastructure assets; (ii) indirectly, by toppling trees or blowing other debris around. ■ **H**

Lightning strikes cause faults in ICT and electrical systems. ■ **H**

Corrosion is more severe in humid environments than in dry ones. ■ **H**

Humidity and solar radiation influence demand for infrastructure services (e.g. energy for heating or cooling). ■ **M**

What could happen

Increased wind damage to all above-ground infrastructure ■ **L** and increased impact due to trees or other debris indirectly damaging on-land infrastructure. ■ **M**

Increased storminess leads to larger waves impacting offshore coastal infrastructure ■ **L** but changes in wave height are less significant for near-shore infrastructure. ■ **M**

Increased failure of wind turbines due to high winds ■ **L** and small changes in average annual wind-power output. ■ **M**

Increased frequency of lightning strike disruption to ICT and electrical infrastructure, with a ‘cascading impact’ on other systems. ■ **M**

Changes in humidity alter leaf-fall and vegetation growth patterns along transport and river corridors and in ‘green infrastructure’. ■ **M**

Increased number of ‘fog days’ in Southern Britain disrupt transport operations, especially at ports. ■ **M**

Summary of potential climate impacts on infrastructure

This table summarises the key links between climate impacts and infrastructure sectors. An ‘x’ denotes that such a link has been identified in the expert technical reports (see pages 12-14). The absence of an ‘x’ signifies that no evidence was found during the review. (For more information, see the reports.) The larger the number of relationships (as shown in the table), the greater the potential for extreme weather events to impact upon multiple infrastructures.

Climate impact

	Sea level rise				Rainfall						Temperature						Other factors				
Infrastructure sector	Damage or disruption from coastal flooding	Tidelocking	Saline intrusion	Coastal erosion	Damage or disruption fom river flooding	Damage or disruption from pluvial flooding	Droughts and low precipitation	Altered capability or efficiency	Biological processes and/or disease	Stability of earthworks	Severe heat	Severe cold, snow and ice	Altered capacity or efficiency	Subsidence and/or dessication	Biological processes and/or disease	Demand for service	Lightning strike	Humidity	Solar radiation	Fog	Storminess and wind damage
Rail transport	x			x	x	x	x	x		x	x	x	x	x		x	x	x			x
Road transport	x			x	x	x		x		x	x	x	x	x		x		x		x	x
Inland waterway transport	x	x			x	x	x			x	x	x	x	x		x					
Ports & marine transport	x	x		x		x					x	x	x							x	x
Potable water	x		x	x	x	x	x	x	x		x	x	x	x	x	x					x
Waste water & sanitation	x	x	x		x	x	x		x		x	x	x	x	x						
Flood & coastal erosion management	x	x		x	x	x				x	x			x	x						x
Information & communication technology	x				x	x	x	x			x	x	x				x	x			x
Solid waste	x			x	x	x	x		x	x	x		x		x						x
Nuclear, coal, oil & gas energy	x			x	x	x	x			x	x	x	x								x
Renewable energy generation	x				x	x	x	x					x						x		x
Power systems, transmission and distribution	x				x	x					x		x				x				x
Energy demand	x				x	x	x				x	x				x			x		

Implications of impacts

Exposure of individuals to loss of services such as heating, communications and water supply will impact economic activity as well as people's health and wellbeing.

Pressures on supply and demand may lead to increased prices.

Infrastructure operators risk loss of revenue from assets that are damaged or that operate with lower efficiency.

Risks to business and industry include increased disruption of the services (e.g. transport and communication links) that they rely on.

Investors and insurers will bear increased risks and losses: (i) directly, from infrastructure within their portfolio; (ii) indirectly, from losses on infrastructure-dependent activities.

Government (and taxpayers) often step in to assist with losses suffered in extreme circumstances.

Adverse environmental impacts can result from infrastructure failure (e.g. when sewers overflow or fuel distribution lines fail).

Choices

Across all infrastructure sectors, a number of actions have already been taken by owners and operators to reduce the impacts of severe weather events and climate change, and to embed climate change issues into investment programmes. The UK Government's first National Adaptation Programme (NAP), published in summer 2013 (Defra, 2013), sets out the roles of government, the private sector and others in meeting the challenge of climate change, including the Government's adaptation policies and actions.

The UK's National Infrastructure Plan (HM Treasury, 2014) sets out over £320 billion planned investment in infrastructure up to 2020-21. To avoid longer-term impacts on people and the economy, it is essential that these investments, as well as the adaptation of existing infrastructure, are considered in the context of the potential impacts highlighted in this Report Card.

There is still considerable uncertainty about the nature and extent of future climate change impacts. Although further research and analysis should reduce this, it is very unlikely to be eliminated. Adaptation of infrastructure will therefore need to be flexible in order to cope with a wide range of possible changes. This will involve a combination of measures that include:

- **Retrofitting** existing infrastructure to be more resilient to changed weather conditions.
- Adding **redundancy** into infrastructure networks in order to provide viable alternatives when some parts of the network fail.
- Building in **flexibility** so that infrastructure assets can be modified in future without incurring excessive cost.
- Designing systems that consider how changes in climate **will alter supply, demand and risks**.
- Identifying **alternative and creative ways of delivering services**, e.g. the use of green spaces to aid flood management.
- **Incentivising reduced demand** for services through behaviour change and the use of more efficient technologies.
- Ensuring infrastructure organisations and professionals have the necessary **skills and capacity** to implement adaptation measures.

Challenges

The evidence presented in the technical reports supporting this card has revealed the limitations in our knowledge of infrastructure performance and failure over long timeframes. **A sustained monitoring and research programme** is required to generate better understanding of how weather and other processes impact on and degrade infrastructure systems.

Modern technology has enabled **services to be conveyed over great distances**, meaning that supply does not have to be local to demand. This has a number of advantages. However, if regions become too imbalanced, it can create instabilities: for example, if regions responsible for supply are abruptly disrupted or if regions rely on a single asset (e.g. the railway line to West Devon and Cornwall).

Governance, regulation and financial appraisal methods usually operate on short timeframes. This does not reflect the long operational lifetime of many infrastructure assets over which changes in climate are to be expected.

Interdependencies between different types of infrastructure are increasingly pervasive. For example, a reliable energy supply depends on the use of ICT for automated control. Many of these interdependencies are sensitive to changes in climate; for example, reduced availability of cooling water for an inland power station can affect its ability to generate electricity.

Increased interdependency, as well as the geographical relationship between supply and demand, can lead to an **impact on one infrastructure component being felt far beyond the location where the original impact was experienced**, posing challenges for operators and responders. Research is improving our understanding of the potential extent and economic costs of these 'cascading impacts' but large uncertainties remain.

A key lesson from the winter storms of 2013-14 is that **engineering design must change**. Consideration of individual events is no longer adequate and future infrastructure design must take into account a much wider set of current and potential future hazards. These include hazards that act in combination, events that are short and intense, and those that persist over many weeks. Developing flexible solutions for physical networks poses challenges for engineers and designers.

Well-intended interventions to manage climate impacts can have unintended consequences or trade-offs elsewhere; for example, protection of coastal communities can starve neighbouring beaches of sand and increase flood and erosion risks. Likewise, infrastructure design and use is often directly related to energy consumption and greenhouse gas emissions; for instance, air conditioning to reduce heat stress requires energy. However, there are also opportunities for synergies; for example, infrastructure for alternative modes of transport provides an opportunity to promote and enable the wider use of low-carbon transport options.

The documents included in the list below are working papers developed specifically to support this Report Card. They include a wide bibliography of published UK research into the past and future impacts of climate change.

Technical reports

1 Rail Transport: John Dora (John Dora Consulting Ltd).

2 Road Transport: Lee Chapman (Birmingham University).

3 Inland Waterway: Port & Marine Transport: Jan Brooke (Jan Brooke Environmental Consultant Ltd.).

4 Potable Water: Steven Wade (UK Met Office).

5 Waste Water & Sanitation: Luiza Campos (UCL), Geoff Darch (Atkins).

6 Flood & Coastal Erosion Management: Paul Sayers (Sayers and Partners) & Richard Dawson (Newcastle University).

7 Information & Communication Technologies: Lisa Horrocks, Neil Walmsley & Sarah Winne (Ricardo-AEA).

8 Solid Waste: Geoff Watson & William Powrie (Southampton University).

9 Nuclear, Coal, Oil & Gas Energy: Edward Byers & Jaime Amezaga (Newcastle University).

10 Renewable Energy Generation: Lucy Cradden, Atul Agarwal, Dougal Burnett & Gareth Harrison (Edinburgh University).

11 Power Systems, Transmission & Distribution: Simon Blake, Peter Davison, David Greenwood & Neal Wade (Newcastle University).

12 Energy Demand: Ruth Wood, Dan Calverley, Steven Glynn, Sarah Mander, Conor Walsh, Jaise Kuriakose, Frances Hill & Mirjam Roeder (Manchester University).

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Watts et al. (2013): LWEC, Climate change and water in the UK - past changes and future prospects.

Peer Reviewers of technical reports

David Jaroszweski (University of Birmingham), Kate Avery (Network Rail), John Thornes (Public Health England), Mike Winter (Dorset County Council), Alberto Uzanni (University of Loughborough), David Whitehead (British Ports Association), Philip Burgess (Association of Inland Navigation Authority), Jin Wang (Liverpool John Moores University), Glenn Watts (Environment Agency), David Butler (University of Exeter), Keith Colquhoun (Thames Water), Owen Tarrant (Environment Agency), Colin Thorne (University of Nottingham), Kevin Paulson (University of Hull), Phil Longhurst (Canfield University), Jan Gronow (Imperial College London), Andy Limbrick (Energy UK), David Howard (CEH Lancaster), Andy Kerr (University of Edinburgh), Martin Mayfield (University of Sheffield), Philip West (Western Power Distribution), Dan Van der Horst (University of Edinburgh), Lucia Elghali (University of Surrey).

Peer review of Report Card

The academic peer review group was chaired by Andrew Watkinson (University of East Anglia) and comprised: Jason Lowe (Met Office) and Andrew Westcott (Institution of Civil Engineers).

Working Group

Chair: Richard Dawson (Newcastle University)

Project Manager: Andrew Onobrakpeya (Environment Agency)

Other Members: Neil Veitch (Environment Agency) Lola Vallejo (Committee on Climate Change), Roger Street (UKCIP), Rob Felstead & Chris White (EPSRC), Robyn Thomas, Gemma Truelove & Susan Ballard (NERC).

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