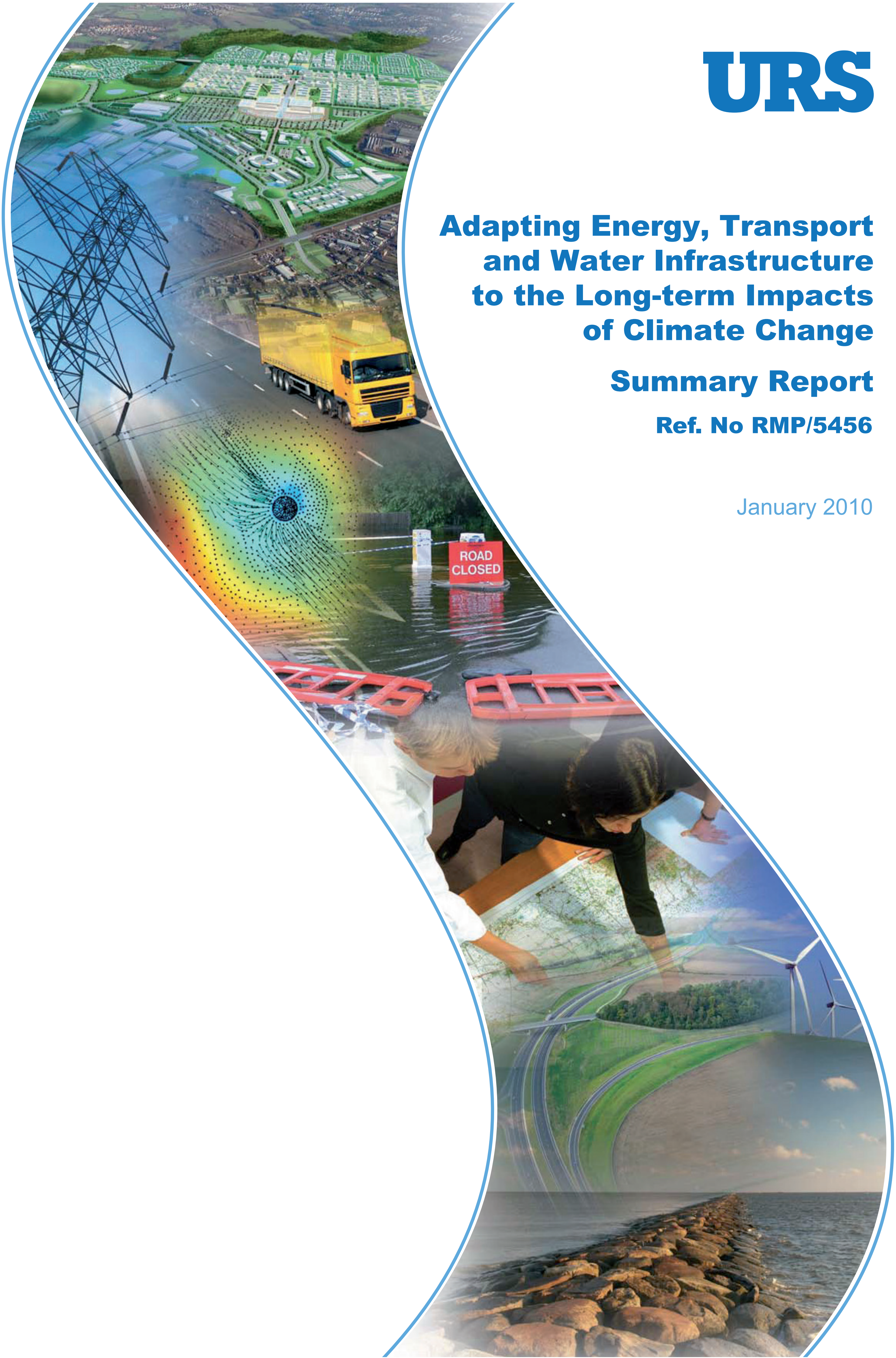
URS



Adapting Energy, Transport and Water Infrastructure to the Long-term Impacts of Climate Change

Summary Report

Ref. No RMP/5456

January 2010

Adapting Energy, Transport and Water Infrastructure to the Long-term Impacts of Climate Change

Summary Report

This is an independent report commissioned by the cross-departmental Infrastructure and Adaptation project.

Its findings and recommendations are not endorsed by Government but will be considered by the project as part of its two year programme of work to identify and examine strategic solutions to improve the long-term resilience of new and existing infrastructure in the energy, transport and water sectors to future climate change impacts.

Summary report

This report sets out the case for adapting infrastructure in the energy, transport and water sectors so that new and existing infrastructure is able to operate effectively in a long-term changing climate.

The report focuses on the long-term impacts of climate change (2030s to 2100) to the infrastructure in the three sectors, setting out:

- **The long-term risks from climate change to the infrastructure, both technically and operationally.**
- **The need to consider the interdependency risks of the infrastructure system and how this can be exacerbated by long-term climate change.**
- **The need for all infrastructure to consider the long-term impacts of climate change in its design, build and operation.**
- **The adaptation options available as well as the barriers that could prevent action.**
- **Suggested recommendations to the Infrastructure and Adaptation project as part of its two year programme of work.**

This three month study provides a more thorough understanding of the above issues. It provides a robust starting point for more detailed work on infrastructure and adaptation to be taken forward by the Infrastructure and Adaptation project and others. For example, industry and academia might take forward possible work on understanding possible thresholds/trigger points that infrastructure might have to the impacts of climate change.

Introduction and context

The UK Climate Projections (UKCP09) [1] published in June 2009 sets out the projected impacts of climate change across the UK to the end of this century. The main trends will be hotter and drier summers, warmer and wetter winters, rising sea levels and more severe and frequent extreme weather events such as floods, storms and heat waves.

How infrastructure has already been affected by climate change
• In November 2009 severe flooding in Cumbria resulted in a number of road bridges collapsing leaving utility cables visible and without support and a community split in two. The same flooding also impacted the West Cumbria Railway Line[2].   • During the summer of 2007, a series of severe floods occurred across the UK. Intense periods of heavy rainfall meant that half a million people were left without either water or electricity and transport networks were brought to a standstill. In Gloucestershire the loss of the Mythe water treatment works left 140,000 houses without mains

1 The Climate Change Act 2008. Available from: http://www.opsi.gov.uk/acts/acts2008/ukpga_20080027_en_1
2 Cumbria County Council website, Latest Flood Updates on News in Cumbria. Available from: http://www.cumbria.gov.uk/floods/floodsnews.asp. Accessed: 16th December 2009.

water supply for up to two weeks, while up to 10,000 people were left trapped on the M5, and commuters were left stranded on the rail network[3].

- In the summer of 2006, road surfaces in regions including Cumbria and Durham softened due to a heat wave[4].
- During the heat wave of 2003, many of France's nuclear power stations were unable to operate at their design capacity due to a change in temperature of the river water used for cooling, which resulted in some being shut down entirely. This occurred at a time when electricity demand was particularly high due to an increase in the use of air conditioning. Consequently a large part of continental Europe suffered blackouts[5]

Given the long-term challenge of adaptation, it is an increasing concern for Government, business and infrastructure operators. This is underlined by new statutory adaptation provisions– the Adaptation Reporting Power and UK Climate Change Risk Assessment – within the Climate Change Act[6].

As the country's infrastructure is already, and will be increasingly, affected by the impacts of climate change, long-term responses will be needed to ensure more resilient and robust infrastructure. The Domestic Adaptation Programme Board, which oversees the cross-Government Adapting to Climate Change (ACC) programme, has prioritised 'infrastructure' as a cross-departmental priority. It is also recognised that effective adaptation of infrastructure will minimise potential long term disruption and costs to the UK economy.

Each of the three sectors that form the subject of the study are complex in terms of their various components of infrastructure, the various parties involved and interdependencies across the sectors and with the ICT sector. The study focuses on national infrastructure (i.e. motorways rather than local roads) relevant to the three sectors.

This report is to the cross-departmental Infrastructure & Adaptation project[7] as part of the ACC Programme. URS Corporation Limited (URS) was commissioned by the Department for Environment, Food and Rural Affairs (Defra) on 11 September 2009 to report to the Infrastructure and Adaptation project:

- Technical risks and operational implications of long-term climate change to infrastructure in the energy, transport and water sectors;[8]
- Interdependency risks across the sectors from long-term climate change (and role of Information and Communications Technologies (ICT)); and,
- Barriers to, and options for, increasing long term adaptation action across the three sectors to improve the infrastructure's long-term resilience to climate change impacts.

---

3 Environment Agency, Review of 2007 Summer Floods, December 2007. Available from: http://publications.environment-agency.gov.uk/pdf/GEHO1107BNMI-e-e.pdf

4 Local Government Association (LGA), "Winter gritting lorries placed on summer standby", 18th July 2006. Available from: http://www.lga.gov.uk/lga/core/page.do?pageId=45277. Accessed: 16th December 2009

5 G.Thuma (GRS) et al, Experience with the influence of both high summer air cooling water temperature and low river levels on the safety and availabilty of German and French NPP. Available from: http://www.eurosafe-forum.org/files/pe_76_24_1_1_01_paper_weatherconditions_en_thu_big_final_031104.pdf

6 Department for Environment, Food and Rural Affairs, Adapting to Climate Change: Ensuring Progress in Key Sectors - 2009 Strategy for exercising the Adaptation Reporting Power and list of priority reporting authorities, November 2009, http://www.defra.gov.uk/environment/climate/legislation/reporting.htm

7 The two year Infrastructure and Adaptation project has been set up as part of the cross-Government Adapting to Climate Change Programme, to identify and examine strategic solutions to 'improve the long term resilience of new and existing infrastructure in the energy, transport and water sectors to future climate change impacts'.

8 In the context of this project, infrastructure has been defined as a physical asset central to the function of each of the three sectors.

Methodology

The study comprised a number of joined-up tasks: project planning; information assimilation (literature review and stakeholder engagement); analysis and assessment; and reporting.

The study assessed the vulnerability of infrastructure to the projected climate impacts in the 2030s, 2050s and 2080s and evaluated the nature and significance of the key technical risks and operational implications. This assessment considered how climate change could affect both supply of and demand for services delivered through the infrastructure.

Appropriate adaptation options as well as potential barriers to implementation have been identified throughout all stages.

A series of conclusions and recommendations have been developed, focused on how to overcome the barriers and how to increase the long-term resilience of infrastructure to the long-term impacts of climate change.

Stakeholder engagement

Stakeholder engagement within and across sectors has been invaluable to the study, providing important technical and operational insights across the sectors. The consultation process covered a range of stakeholders including owners and operators of infrastructure assets, contractors, research institutions, policy makers and regulators. It included a workshop bringing together the three sectors with Government officials and URS.

From the engagement process, it is evident that there is increasing awareness and understanding of the need to adapt to climate change within each of the sectors. However, this has not generally led to adaptation action, with the focus remaining on mitigation of climate change impacts or short-term contingency planning. Most adaptation actions are focused on risks from extreme weather events such as flooding and storms rather than the gradual changes in climate that are also predicted (e.g. temperature and rainfall changes and sea level rise).

A key message from stakeholders is that there is a reluctance to plan for the long-term impacts of climate change due to perceived uncertainty associated with the impacts of climate change and the financial risks involved. In addition, although UKCP09 is widely known, some companies are still finding it difficult to take on board its range of probabilities and uncertainties and to apply the projections to their own specific operations.

Therefore interpretation of UKCP09 is often too simplistic - rather than using a multi-variable approach, investment decisions are based on headline figures from UKCP09. In many cases, the lack of consideration of long-term impacts of climate change in relevant regulatory frameworks means that businesses find it difficult to justify the financial investment considering the uncertainty and potentially long payback periods.

Organisations engaged included:

Anglian Water plc Association of British Ports Association of Electricity Producers Automobile Association Birmingham International Airport British Airports Authority British Dam Society British Energy BP Carbon Disclosure Project (CDP) Centrica Chartered Institute of Water and Environmental Management (CIWEM) Consumer Council for Water Dorset County Council Dover Harbour Board Drax Group plc E.ON EDF Energy	Energy Networks Association Environment Agency Health and Safety Executive (HSE) Highways Agency Institution of Highways & Transportation International Power Leeds University Climate Change Centre Manchester Airport National Grid Network Rail Office of the Gas and Electricity Markets (Ofgem) Powerfuel RAC Foundation Renewable Energy Association Road Haulage Association RWE npower Scottish Power Skanska	Southern Energy Severn Trent plc Society for Motor Manufacturers and Traders Stagecoach Surrey County Council Thames Water Utilities Ltd Transport for London UKCIP UK Energy Research Partnership UK Water Industry Research (UKWIR) United Utilities plc Water Service Regulation Authority (Ofwat) Water UK Climate Change Focus Group (CCFG) Waterwise Warwickshire County Council

The risks from climate change to the energy, transport and water sectors

To improve understanding of the long-term risks to the infrastructure in the three sectors from climate change, an assessment was undertaken to test how the projected changes in the climate might impact the infrastructure.

This assessment focused on the impact of climate change on the functionality of infrastructure enabling the identification of vulnerable infrastructure. This allowed key technical and operational risks to be identified in each sector.

Energy

Key vulnerabilities in the energy sector are those associated with an increased intensity of precipitation, possible changes in wind, increased frequency of storms and higher temperatures all of which are likely to become significant to the sector by the 2050s.

Pressing issues identified include transformer thresholds being exceeded, generation efficiencies being affected and coastal infrastructure being at particular risk. All areas of energy infrastructure will, however, need to respond to pressures by the 2080s.

Energy infrastructure operators generally have a pragmatic response to vulnerability and risk. Whilst it is apparent that energy infrastructure is vulnerable to climate change, it is felt that infrastructure has a significant degree of resilience to change. In addition, technically it will be feasible to deal with adaptation issues over short, medium and long-term periods. Energy infrastructure around the world maintains output in a variety of different climates such as those that will be experienced in the UK. This experience can be readily transferred.

The forthcoming new build in energy infrastructure, particularly generation, provides a significant opportunity to design in adaptation measures. The typical design and operational life of key infrastructure components are in excess of 25-30 years (and 100 years for nuclear energy). This new build must incorporate adaptation in its design and build and not wait for significant disruption or failure which would have severe economic, social and environmental consequences.

In most instances, energy transportation and distribution systems will require reinforcement, e.g. retrofitted cooling approaches, but not a complete overhaul. In addition, there is a need for the sector to be able to respond to changing demands for energy, e.g. peak demands in summer to cope with increased cooling requirements and therefore new climatology and demand data will be required. Key risks identified are:

Infrastructure components	Key risks
Fuel processing facilities/ storage of fuel/ transport of fuel	Flooding of fuel supply infrastructure due to increased storminess and sea level rise/ sea surges.
Power generation (fossil, nuclear and renewables)	Flooding of fossil fuel and nuclear power plants due to increased precipitation and sea level rise. Loss of efficiency of fossil fuel power plants due to increased temperatures. Loss of efficiency of, and storm damage to, renewable energy sources due to increased storminess.
Energy distribution systems	Reduced capacity of distribution network due to increased temperatures and precipitation/ storminess.

Transport

The transport sector, comprising road, rail, ports and aviation, is particularly vulnerable to increases in frequency and intensity of storms and flooding. All transport operators contacted referred to recent incidents such as the floods in summer 2007 and gales in January 2007 when technical deficiencies caused significant disruption to services.

Transport operators are less concerned by the predicted gradual climate change in, for example temperature, and pointed to overseas experience where many solutions are available, for example the temperature resilient paving needed for roads. Work by the Highways Agency and rail industry has already been undertaken which has looked at the design life of certain elements of road and rail infrastructure, current design codes and future projected climate change. However, adaptation understanding in the ports and aviation subsectors are less advanced. It is apparent that where national guidance has already been introduced, for example Planning Policy Statement 25 "Development and Flood Risk"[9], operators are more advanced in planning to adapt to climate change. Key risks are:

Infrastructure components	Key risks
Roads	Flooding from increased precipitation and/or storminess. Scour of bridges due to increased precipitation and/ or storminess. Moisture fluctuation in road embankments in south east England due to wetter winters and drier summers.
Rail	Flooding from increased precipitation and/or storminess. Scour of bridges due to increased precipitation and/ or storminess. Moisture fluctuation in embankments in south east England due to wetter winters and drier summers. Overheating of underground trains due to increased temperatures.
Ports	High tides/ storm surges causing increased sea level at ports. High winds at ports due to increased storminess.
Airports	High winds at airports due to increased storminess.

Water

Key vulnerabilities to the water sector are associated with changing precipitation patterns. The impacts from changing precipitation patterns will be both gradual and sudden. Over time a shift in winter precipitation will reduce the availability of water in some regions while increasing the availability in others. More intense and frequent rain events pose an increased risk of fluvial flooding damaging infrastructure. These rain events could potentially overwhelm drainage leading to both pluvial sewer flooding and an increase in the number of discharge events at combined sewer overflows thereby having a negative impact on the environment. Changing precipitation patterns will also impact the amount of water available for dilution in surface waters receiving

[9] Communities and Local Government, Planning Policy Statement 25: Development and Flood Risk, December 2006, http://www.communities.gov.uk/publications/planningandbuilding/pps25floodrisk

treated wastewater effluent. A decrease in dilution capacity for the protection of the environment will have significant impacts on the level of treatment required at wastewater treatment plants.

Water utilities currently prepare Water Resources Management Plans with a 25 year forecast that consider aspects such as population change, climate change and investment projections. Action on climate adaptation is therefore already occurring which includes considering long-term issues as well as short-term resilience planning. Key risks are:

Infrastructure components	Key risks
Water supply, treatment and infrastructure	Reduced security of supply due to changing precipitation patterns and periods of drought. Increased fluvial flooding due to increased precipitation and storm surges.
Wastewater collection, treatment and disposal	Increased sewer (pluvial) flooding due to increased precipitation and storm surges. Increased fluvial flooding due to increased precipitation and storm surges. Increased pollution incidents due to changing precipitation patterns and periods of drought.

Interdependency

An important finding of the study is that the infrastructure system is highly interconnected. There are interconnections between the infrastructure components both within and between the three sectors and with the ICT sector. In addition, parts of our infrastructure (e.g. gas supplies) are dependent on infrastructure in other countries. Climate change impacts beyond the UK may also impact functionality. Where these interconnections are associated with the supply or receipt of a service on which the receiving sector is reliant and an impact on this supply could be critical, these have been termed 'interdependencies'.

The study identifies two specific types of interdependencies which could have far greater impacts on infrastructure functionality than individual failures:

Cascade failures referring to a series of linked impacts or failures (see examples of cascade failure).

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 (see Humberside case study on page 7).

Examples of cascade failure
The flooding events in Cumbria in November 2009 highlight the impact of cascade failure through the interconnection of bridges and telecommunications. This meant communications were cut at a time when they were particularly needed. The situation could have been exacerbated if the bridges had been used as a connecting structure for the water mains supply - the bridge failure could have resulted in damage or complete failure to the water pipeline resulting in a total loss of clean water to the local community. Transport can also be affected by failure in the water sector. A section of the M1 near Sheffield was closed in June 2007 for 36 hours as a precaution against the possible failure of the nearby Ulley reservoir. Large quantities of rainfall led to high volumes of water flowing over the spillway, scouring and cracking on the slope of the reservoir's dam. The engineers advised that this could lead to dam failure and the motorway was shut as it lies in the inundation path. Had the dam failed this would have been an example of cascade failure.

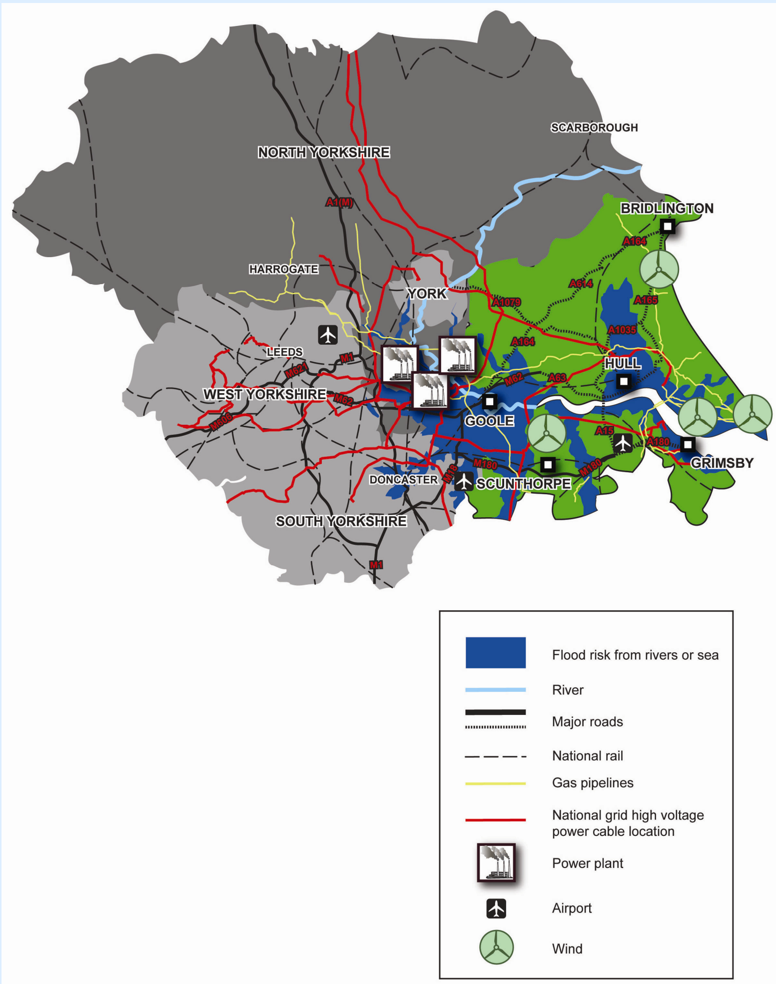
Humberside case study

Humberside is supported by a vast network of energy, water and transport infrastructure, either side of the estuary. This densely populated region, could be severely affected by projected changes in rainfall, sea level and temperature. Due to heavy pluvial impacts and its coastal location, it has already demonstrated a vulnerability to flooding, resulting in significant costs across the region. Intense rainfall led to severe floods in June 2000 which caused over £150 million of damage. Flooding in 2007 caused widespread disruption right across the region, and in Hull the floods led to damage to 7208 residential properties and over 1300 businesses. Water levels close to the main coal fired electricity generators in the region were all high, particularly for Ferrybridge coal fired power station. A number of factors contribute to making the region particularly vulnerable to the impacts of extreme weather events:

- Flood plains - by Goole and Hull are vulnerable to freshwater and tidal flooding.
- Coastal location – vulnerable to sea level rise, tidal flooding and coastal erosion.
- Low elevation: 90% of the area around Hull lies below high tide level.

The incidence of extreme weather events could, in future, impact key infrastructure with more severe consequences occurring where different elements of infrastructure converge, such as:

- Road and transport infrastructure: M62 and M180 with smaller A-roads link the major centres. A network of rail connections exists between Leeds, York, Hull and the East Coast. Flooding of these could result in thousands of stranded travellers and significant transport delays.
- Gas pipelines: The gas landing station near Hull is supported by a large network of pipelines with significant onward supply to adjacent regions. Coastal flooding and erosion could disrupt supplies.
- Power stations: with a combined a capacity of 14GW including three major coal fired power stations: Ferrybridge, Eggborough and Drax. Humberside also has 160MW renewable power and 1200 MW CHP capacity. Together these comprise 17% of the UK's electricity generation capacity. Loss of generation capacity or damage electrical transmission systems from flooding would result in a significant loss of power affecting the region. As over 10% of the power is exported, significant impacts would be felt across the UK.



Water supply for the three main power stations is taken from river water. Water supply in the Goole area is sourced primarily from groundwater reserves. Reduced summer rainfall, increased agricultural needs and a growing population could mean a greater pressure for this resource. This could be further aggravated by the potential incursion of seawater due to a rising sea level.

In the long term, it is likely that there will be a shift from an energy mix to a more diverse, decentralized energy network relying on a range of renewable technologies such as wind, tidal and biomass. Planning permission exists for a biomass plant near Drax shortly to be followed by two others. Sea storms have the potential to disrupt the landing of biomass imports. A scenario of biomass and gas both of which are imported could present high risks in terms of security of supply.

Source: Prof. Coultard et al. The June 2007 Floods in Hull, August 2007. http://www.coulthard.org.uk/downloads/floodsinhull1.pdf

New infrastructure

The impacts of climate change present a long-term problem and we need to ensure that new infrastructure, often with a life-time of 50-100 years (or more), is resilient to long-term climate change. Whilst the detailed technical solutions vary considerably, all new infrastructure in all sectors needs to consider the long-term impacts of climate change for design, build and operation. Ensuring new infrastructure is able to adapt to long-term climate change, will require:

- Identification of the likely impact of the long-term climate change impacts on the new infrastructure and examining and designing the possible acceptable minimum level of resilience.
- Understanding whether new advice on design and/or construction of the infrastructure is needed.
- New legislation and/or regulation to ensure this happens and that the interdependencies are properly identified and addressed for the design life of the infrastructure.
- Possible new financial controls and undertakings to ensure any operating costs to adapt to climate change are able to be funded. This should be for the duration of the life of the infrastructure.

Adaptation options

It is clear that in response to the long-term risk to infrastructure from the impacts of climate change, adaptation options will be required. These will need to include technical, operational, repair, retrofit, replacement options as well as wider cultural, financial and regulatory options.

Given the time constraints on the project, the net benefit of each option was qualitatively assessed considering the possible benefits versus the main potential barriers or challenges. Options with a national, irreversible, gradual and long-term impact were considered to potentially have a higher net impact than those with a local, reversible, gradual and short-term impact.

Example adaptation options	
• More frequent and improved inspections of all infrastructure. • Further assessment of infrastructure resilience in particular understanding thresholds to climate changes. • Prioritisation of remedial works for high risk locations, e.g. regional convergences. • Incorporation of adaptation considerations into design and build of all new infrastructure. • Increased use of water recycling to reduce risk of reduced water availability. • Retrofit and strengthen of infrastructure where appropriate	• Increasing capacity and structural stability of storage, e.g. gas storage. • Separation of combined sewer systems to reduce impact of increased flooding. • Further engineered flood protection for existing infrastructure in particular coastal infrastructure • Location of new infrastructure away from the flood zone. • Proactive management of energy use to decrease demand on supply especially in the summer. • Control of surface water runoff using SUDS.

Barriers and implications

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

Investment	How to ensure that investment in adaptation is incorporated into new infrastructure investment and/or refurbishment of existing infrastructure?
Policy, Standards and Design	How to ensure that policy, standards and design for new and existing infrastructure ensures that the long-term impacts of climate change are considered?
Business Operations	How to incorporate the issue of resilience of climate change into operational business decisions so that monitoring and planning for the impacts become part of core business operations?
Interdependencies	How to identify key interdependencies and vulnerabilities within and between the three infrastructure sectors so that appropriate and robust cross sector solutions can be developed?
Knowledge and Awareness	How to ensure 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?
Societal Expectations	How to manage the expectations and demands of society to enable greater appreciation of the strains that climate change may put on infrastructure and key services (e.g. water and energy supply)?

Maximising availability of investment

There is a clear need for investment in adaptation measures to be available at the right time for both new infrastructure and/or technologies and for improvements to existing infrastructure. Designing and constructing more resilient new infrastructure is likely to have associated financial implications therefore, determining what is the “right time” for the investment to adapt existing infrastructure is critical.

This is likely to vary widely so a key challenge is making the case for investment ‘now’, when the impact may not be seen until decades later (i.e. investing in extra capacity/flexibility to allow for adaptation to occur rather than expensive retrofit or in the worst case, abandoning of the infrastructure).

Traditional investment appraisal processes for projects seek to identify robust and relatively short term returns on investment. For example regulators assessing the effectiveness of public spending need to demonstrate value for money to the customer, i.e. balancing effective service delivery and minimising price increases. The Green Book developed to enable economic assessment of the social costs and benefits of policies, projects and programmes provides a possible approach.[10]

[10] The Green Book www.hm.treasury.gov.uk/data-greenbook-index.htm

Potential solutions need to reflect the different business and investment models within and across the three key infrastructure sectors. It is recognised that the design life for much of the infrastructure in the three sectors is medium to long-term and that consideration needs to be given now for infrastructure that will still be operational well beyond 2050. If appropriate measures for incorporating adaptation considerations into infrastructure investment are not taken in the short term, significant risks of climate change on infrastructure may occur in the future resulting in disruption and failure with considerable economic impact.

Any approach needs to recognise that investing in preventative action rather than reactionary basis is a challenge; as return on investment cannot be guaranteed.

The timescales for 'payback' of investments in new or replacement infrastructure must allow for the potential impacts of future climate change to be considered and accounted for. This needs to be reflected in the decision making processes of both regulators and private investors for infrastructure.

Developing policy, standards and design

A general lack of consistency in approaches to long-term climate change adaptation is identified both across and within the three key infrastructure sectors. This can be attributed to a lack of over-arching national, sector and regional specific standards for the design of new, and retrofit of existing, infrastructure with respect to climate change adaptation.

Policy, standards and design need to take account of new infrastructure, retrofit of existing infrastructure (e.g. existing bridge) for increased resilience to climate change impacts and retrofit for improvement to the infrastructure itself (e.g. end of life of plant, increasing capacity etc). It is recognised though that there will not be a single solution that applies to all three, rather there will need to be a suite of solutions but usefully found in one single document/strategy.

There is also a lack of information on how to consider the interdependencies with other sectors when assessing infrastructure investment. As interdependencies between sectors are critical for functionality, a systematic process for evaluating and assessing interdependencies and potential supply and demand issues to the impacts of climate change will be vital. Consideration, where relevant, of dependency for supply on other countries is required.

The current planning system provides a number of mechanisms that could form the basis to ensure that appropriate considerations of climate change resilience occurs in the planning stage such as:

- The draft National Policy Statements for the energy and ports sector issued in November 2009[11],[12].
- The existing Planning Policy Statement (PPS) on Climate Change[13] (supplement of PPS1) that sets out how planning by regional planning bodies (preparation of Regional Spatial Strategies) and planning authorities (preparation of Local Development Documents) should take into account the unavoidable consequences of climate change.

However, specific guidance on systematic review of planning applications at a regional and local level for climate adaptation is needed to provide additional coverage of this issue, especially interdependencies. Any

[11] Department for Energy and Climate Change, Draft National Policy Statement for energy infrastructure, November 2009, https://www.energynpsconsultation.decc.gov.uk/
[12] Department for Transport, Draft National Policy Statement for Ports, November 2009, http://www.dft.gov.uk/consultations/open/portsnps/
[13] Communities and Local Government, Planning Policy Statement: Planning and Climate Change - Supplement to Planning Policy Statement 1, December 2007, http://www.communities.gov.uk/publications/planningandbuilding/ppsclimatechange

such guidance at a planning application level would need to clearly define for both project developers and planners what “appropriate” climate adaptation provisions might be.

Integrating solutions into the planning process, however, will not capture all infrastructure construction. This is particularly important for sectors where the focus of investment is expected to be on upgrades and maintenance (e.g. much of the water and transport sector) rather than new build. Ensuring that the appropriate requirements and specifications are reflected in standards will be important.

The engineering profession and infrastructure owners have a key responsibility and role to ensure that these standards are appropriate for the long-term projected climate change so that existing infrastructure is able to adapt.

However, without greater understanding of trigger points for certain climate change parameters there may be a significant knowledge gap associated with developing such standards.

Changing operational practices

Existing business structures and systems tend to focus on timescales of 6-12 years, limiting long-term operational planning. There needs to be a clear incentive for long-term operational planning to be integrated into existing business processes. Tackling this issue requires action and commitment at all levels of organisations, as well as across a number of internal disciplines. This is not something that an organisation’s climate change or environmental team can address alone.

Consequently, climate change adaptation needs to build on existing resilience work and should be integrated into many business processes including project appraisal processes; design standards and requirements; system monitoring and maintenance planning; risk management; supply chain management; procurement of services; and, emergency and contingency planning.

The Adaptation Reporting Power under the Climate Change Act 2008[14] gives the Government authority to ask public sector organisations and statutory undertakers to assess the risks that climate change poses to them, the actions they are going to take in response to these and report on the findings of this assessment. This will enable the organisations covered by this regulation to examine their risks adequately, including those to their buildings, staff, services and operations, supply lines, customers and stakeholders or regulatory functions.

However, not all organisations that manage and operate infrastructure in these sectors are covered by these regulations. Alternative mechanisms of driving change are also required.

Inter- and intra- sector solution planning

There is not enough recognition of interdependency; that all three of the sectors are wholly reliant on each other operationally, and that ICT is integral to all sectors and should be considered a shared resource. This means that connections and opportunities for the sectors to work together in a mutually beneficial way to adapt to climate change are often missed. Interconnections need to be considered both horizontally (between and within sectors) and vertically (i.e. between national, regional and local levels), recognising that the levels of knowledge regarding climate change and adaptation vary significantly between sectors and levels.

[14] Department for Environment, Food and Rural Affairs, Adapting to Climate Change: Ensuring Progress in Key Sectors - 2009 Strategy for exercising the Adaptation Reporting Power and list of priority reporting authorities, November 2009, http://www.defra/gov.uk/enviornmental/climate/leigslation/reportimng.htm

There is a need to develop an improved level of understanding of each of the individual sectors and a route map of dependencies between them. The cross sector engagement that started in the November workshop, that formed part of the project should continue.

Improving knowledge and awareness

Key to increasing the long term resilience of infrastructure is understanding what is needed. There needs to be greater understanding of UKCP09, and of the tipping points and interrelations between sectors. Engineering and design codes typically define performance standards or tolerances; and engineers are then practiced at developing designs and specifications that met these clear standards.

The probabilistic approach used in UKCP09 has been developed by the climate change professionals to allow engineers to compare sensitivity of infrastructure to key thresholds enabling a risk based decision to be made. This approach is different from that which designers and operators are used to.

In developing solutions, it is also important to refer to and use experiences of others. Many aspects of the projected future climate for the UK, are already experienced elsewhere in the developed world. Therefore designers and operators are already managing to design, operate and maintain infrastructure that can function in these climate conditions. These experiences should be used.

In addition, there is a need for public and private infrastructure owners to assess the vulnerability of their assets to climate change and assess the risks of failure / loss of service so they can prioritise investment decisions to the highest risk sites. This should build upon any work being done to assess the existing resilience of infrastructure to current natural hazards.

Societal expectations

There is a need to increase the public's understanding of how climate change impacts may affect infrastructure and the supply of essential services as well as how societal behavioural change can assist in reducing the impact of climate change in the long-term. As part of this work, challenging society's expectation that resources may not always be readily available will be important. A reduction in demand for certain services (e.g. energy) can form part of the adaptation response.

Conclusions

The study has identified a large number of conclusions that can be broken down into: issues for a sector and cross sector level; knowledge; and implementation of appropriate solutions.

Sector and cross sector level:

- Existing infrastructure in the UK has been engineered and built for our past or current climate All sectors have considerable vulnerability to climate change in the long term although certain elements of infrastructure or functionality can be identified as being more so.

- There is a lack of understanding whether the infrastructure is vulnerable to specific climate thresholds or climate trigger points. Companies find it difficult to act until they know these and the likely conditions at the end of an assets life.

- The energy, transport and water sectors have complex and varying business and financial models that have been developed for their own sector's interests.

- Costs associated with adapting to climate change are complex, reflecting this complexity and the wide range of infrastructure components, their ages, interdependencies, design life and possible adaptation options.

- There is a lack of long-term foresight in all sectors for the period between 2030- 2100, although there is some evidence of consideration in this timescale (e.g. in the water industry). Current business and economic planning models tend to focus on the next 10-15 years, yet the design life of infrastructure ranges from 10 to over 120 years and much of the UK's existing infrastructure is considerably older than these design lives (e.g. parts of the rail network).

- The three sectors are interdependent but individually sectors are not proactive in recognising and tackling this. Identifying and understanding the specific links and using these to tackle interdependency will be of mutual benefit.

- Solutions need to encompass both new and existing infrastructure. Within the transport and water sectors, the majority of investment is for upgrades, whilst in the energy sector we are moving into a period when significant investment is on new build.

- Whilst the options to tackle technical risks are varied; the barriers are common. Focus at a national level on interventions which remove or reduce these barriers and constraints will have widespread benefits.

- Societal expectations are high. Customers do not expect interruptions to supply, restrictions on use or loss of quality yet demand low costs. It is recognised that this is not necessarily the case in other countries that are faced with resource shortage that may be replicated in this country due to long-term climate change.

Improved understanding:

- Knowledge of trigger points for failure or disruption associated with gradual climate change is lacking. Without this knowledge it is difficult to identify when investment will be required and to predict the increased level of protection therefore additional investment that might be needed in the future

- There is a lack of consistent knowledge across the sectors of the scientific understanding of climate change and the range of adaptation options available.

- Although UKCP09 is widely known, some companies are still finding it difficult to take on board its range of probabilities and uncertainties and to apply the projections to their own specific operations.

- Within some organisations there is a reluctance to plan for the long term (50-80 years) due to the perceived uncertainty associated with the impacts of climate change.

- Public understanding and appreciation of the challenges that climate change poses on infrastructure and operation of essential services, and the level of adaptation required is minimal.

Implementation of appropriate solutions:

- To ensure new infrastructure, often with a life-time of 50-100 years (or more), is resilient to long-term climate change, we need to ensure that when commissioning new infrastructure the long-term impacts are always considered in its design and build.

- The inherent uncertainty in predicting our future climate does not promote action. Inaction is however, not an economic option. Failure has considerable impact on functionality of the UK infrastructure and retrofit measures can be highly expensive. Integrating climate change into business risk assessment frameworks is an option.

- Investment, both in terms of the amount allocated and its availability is a major barrier. Investment for long term resilience does not meet the current requirements for short term customer value for money or shareholder or investor return on investment.

- Increased regulation focussing on the long term adaptation to climate change will be required in all sectors, particularly those which are competitive markets.

- Consideration of climate change adaptation is lagging behind climate change mitigation in many sectors. Increased incentives are required for climate change adaptation.

Recommendations

URS has developed a series of recommendations to the cross-departmental Infrastructure and Adaptation project. These recommendations will feed into the project's two-year programme of work; the project is due to be completed by March 2011 and will report into the Domestic Adaptation Programme Board.

Consequently, these recommendations should be seen as independent, not endorsed by Government, and which will be considered as part of the Infrastructure and Adaptation project's wider programme of work.

The recommendations are focused on overcoming the key barriers identified and, if implemented, will help increase the long-term resilience of infrastructure in the energy, transport and water sectors to the impacts of climate change.

Financial

- More research into mapping and comparing the business and investment models used to finance each element of infrastructure in the three sectors is required to understand the various models that need to be considered for intervention and how to embed adaptation within these models.
- Mechanisms (e.g. financial bonds) need to be developed to ensure that the responsibilities for costs associated with future maintenance or upgrades to adapt to climate change are clearly defined and that funds are available over the lifetime of the

	asset to support appropriate adaptation measures. • Without some form of indemnity, private sector operators will be unable to justify to shareholders the cost of adaptation where the benefits are unknown. The Infrastructure and Adaptation project's work should commission further work to examine how such costs could be underwritten and the issue of risk (including responsibility for risk) better understood.
Policy and Regulatory	• Responsibility for infrastructure is split between public and private organisations, as well as national, regional and local governance. The Infrastructure and Adaptation project should consider how best adaptation can be embedded as a result and what type of interventions are required (rather than a one size fits all approach). • The current regulatory framework and other policy and guidance does not support long-term consideration and investment to adapt to climate change. The Infrastructure and Adaptation project should focus on how regulation and other frameworks could support long-term adaptation action in the sectors.
Technical & Operational	• Increased knowledge of infrastructure operational thresholds is required. A programme of research within each infrastructure sector, working with academia, is required to enable a robust understanding of these thresholds and possible trigger points. • Increased understanding in business and professional bodies of how to use the range of probabilities and uncertainties contained within UKCP09 to enable businesses to apply the projections to their own specific operations. • New infrastructure should be designed and built so that it can be readily adapted. Industry, Government, engineers and planners need to work together to understand better how to do this on a consistent basis across all sectors. This should also consider ICT and interdependencies. • To increase information sharing, in particular of technical and operational risks and appropriate adaptation measures, the Infrastructure and Adaptation project, in partnership with infrastructure organisations, industry bodies and regulators, should set up a cross sector forum. • Increased understanding on the impact of climate change on infrastructure interdependencies is needed. The Infrastructure and Adaptation project, working with industry, academia and engineers needs to implement a programme of work that looks to test how climate change might increase infrastructure interdependencies, in particular in relation to increasing the threat of cascade failure. As part of this work, options to reduce the vulnerability of the infrastructure system as a whole to climate change needs to be developed. • As climate science continues to evolve and more data becomes available – in particular on wind and storms – industry needs to review the technical and operational risks from climate change on a regular (i.e. 3-5 years) basis to ensure infrastructure is resilient to long-term climate change.
Societal	• Industry, working with the relevant lead Government department and regulator, needs to implement a communication programme to:

  - Raise awareness of how climate change may affect infrastructure and delivery of essential services and their functionality.
  - Demonstrate how behavioural change can help reduce the impacts by reducing pressure on infrastructure/service demand.
- Outside of the engineering and environmental disciplines, general awareness of the need to invest in adaptation measures is lacking. The Infrastructure and Adaptation project, working with engineers, industry and the finance sector, should develop a programme of engagement to address this.