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Adapting to climate change in the infrastructure sectors

Maintaining robust and resilient infrastructure systems in the
energy, transport, water and ICT sectors

Full report



A report for
Adapting to Climate Change Programme
Department for Environment, Food and Rural Affairs

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Glossary

Terminology	Description
Critical National Infrastructure	Infrastructure assets (physical or electronic) that are vital to the continued delivery and integrity of the essential services upon which the UK relies, the loss or compromise of which would lead to severe economic or social consequences or to loss of life (Source: Cabinet Office)
Economic infrastructure	Infrastructure networks and assets in the sectors covered in this report: energy, water, transport (ports, airports, rail and roads) and ICT
Externalities	Benefits and costs which are not reflected in the market price of goods and services.
ICT	Information, Communications and Technology, which includes the mobile communications network, internet and broadband, wireless networks, and other communication media
Interdependencies	Risks or benefits that are interlinked with another party
No regrets adaptation	Adaptation measures that generate benefits regardless of the climate outcome
Private good	Item of consumption that, if used by one person or firm, may not be available for others
Public good	A public good (or service) which may be consumed without reducing the amount available for others, and cannot be withheld from those who do not pay for it.
UK CIP and UKCP09	UK Climate Impacts Programme is a programme set up to assess the impacts of a changing climate. In particular UKCP09 provides future climate projections for land and marine regions, and observed climate data. It is the first UK climate projections to provide probabilistic projections, and incorporate data from an ensemble of climate models.

Important notice

This report has been prepared by PricewaterhouseCoopers LLP for the Department for Environment, Food and Rural Affairs (Defra) in accordance with the terms of our contract RMP5684 and for no other purpose. It was commissioned by Defra in conjunction with the cross-departmental Infrastructure and Adaptation Project (the Project).

The report's findings and recommendations are not endorsed by Government but will be considered by the IAP 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, ICT, transport and water sectors to future climate change impacts.

Executive Summary

Introduction

Sustained, effective operation of the nation's infrastructure in the energy, water, transport and ICT sectors is vitally important to the performance of the UK economy. This report explores the implications of climate change impacts, both for existing infrastructure and for future investment in these sectors, and examines the role of government and regulators in encouraging action on adaptation to climate change, to maintain robust and resilient infrastructure systems.

In this report we refer to the energy, water, transport and ICT sectors as 'infrastructure sectors' and infrastructure networks and assets in these sectors as 'economic infrastructure'¹.

Economic infrastructure typically has a long useful life, with much of the existing infrastructure and planned future investment expected to be in operation for many decades to come. Meanwhile the country faces growing risks from the impacts of climate change as a result of the rapid increase in concentrations in greenhouse gases in the earth's atmosphere.

Climate change is a global phenomenon. However many of the impacts are local. Adaptation action must therefore be tailored to local circumstances, as well as to the strategic importance of the assets concerned. Effective and timely investment planning and decision making within the infrastructure sectors is a critical component of the nation's response to climate change.

Compared to many countries, the UK faces less severe climate impacts, and the UK appears to be amongst the leaders in considering adaptation in the infrastructure sectors. Timely action on adaptation to maintain robust and resilient infrastructure systems will enhance the attractiveness of the UK to inward investment in a low carbon world. It will also generate skills and experience in the UK, which will help UK businesses capitalise on export opportunities as other countries engage in adaptation.

Growing investment requirement

The level of investment in economic infrastructure in the UK is expected to increase in coming decades, in response to socio-economic changes, the need to transition towards a low carbon economy and ageing infrastructure in some sectors. Infrastructure UK estimated in early 2010 that investment averaging £40-50 billion a year in real terms was needed to 2030 and beyond, compared to the annual average of around £30 billion in the last five years².

While much of this new investment is required to meet short-term needs (for example scaling up renewable energy and increasing the capacity of ports), a substantial proportion of new infrastructure is expected to be in use long after 2030, with large parts of the existing economic infrastructure in the UK also still in operation. Within that time frame, global and local climate systems are expected to change, with the resultant climate impacts likely to affect the service delivery and the efficiency of economic infrastructure.

Understanding the extent to which existing infrastructure and new investment in the infrastructure sectors are resilient to the changing climate will be important in determining whether current levels and types of investments are adequate.

¹ Economic infrastructure includes assets within the four sectors in this study classified by Government as 'critical national infrastructure' for the purposes of security and resilience as well as other 'non-critical' assets. Critical national infrastructure also includes assets in other sectors not covered in this study. In considering our findings it is important not to confuse economic infrastructure and critical national infrastructure, although we do comment on the potential to harmonize policy on climate change adaptation, security and resilience in relation to economic infrastructure.

² Strategy for national infrastructure, HM Treasury, Infrastructure UK, March 2010

Government's Infrastructure and Adaptation Project

Adaptation to climate change is an important part of the UK Government's focus on addressing climate change. The Climate Change Act paved the way for the development National Adaptation Programme, based on the results of the National Climate Change Risk Assessment. Within Government departments, Departmental Adaptation Plans are being set out to identify key priorities and actions. Government also promotes adaptation in the private sector through the provision of research and information around climate change impacts by the UK Climate Impacts Programme (UKCIP), and the use of the Adaptation Reporting Power to direct a number of organisations to report on how they are assessing and acting on the risks and opportunities from a changing climate.

The two-year, cross-departmental Infrastructure & Adaptation Project (IAP), chaired by the Department for Transport (DfT) and bringing together all relevant economic infrastructure departments, has commissioned work to identify the risks and operational implications of long-term climate change to infrastructure in the energy, water, transport and ICT sectors. This work has identified a number of risks for each of these sectors, as well as significant cross-sectoral risks across different types of infrastructure, reflecting strong interdependencies between the infrastructure sectors.

The infrastructure sectors range from unregulated competitive markets (ports and power generation) and regulated, private sector monopolies (energy networks and water) to state-procured public goods (motorways). The private sector is deeply involved in the infrastructure sectors, variously as investor, owner, operator, lender, insurer and, importantly, as a major user of economic infrastructure. It therefore has a key role in addressing the risks of climate change and ensuring the resilience of economic infrastructure in the UK.

The nature of climate change risks, however, is that they generate broad social and economic externalities, which the private sector may not always take fully into account. In particular, in the absence of legislative or regulatory intervention, private sector companies may be prepared to live with a level of climate change risk that is unacceptable to society.

This study, commissioned by the Department for Environment, Food and Rural Affairs (Defra) on behalf of the IAP and carried out by PricewaterhouseCoopers LLP (PwC), examines whether the different market, policy and regulatory models in the infrastructure sectors, together with Government policy and legislation more generally, provide adequate incentives (both positive and negative) to infrastructure providers to consider climate resilience across their existing economic infrastructure and future investment in these sectors.

The report's findings and recommendations are not endorsed by Government but will be considered by the IAP 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, ICT, transport and water sectors to future climate change impacts.

Early progress

The results of work to date by Government, regulators and the infrastructure sectors are promising. In particular, there is a strong level of awareness of the potential impacts of climate change on economic infrastructure in the UK, encouraged by a combination of improved scientific and technical knowledge, greater media interest in the issue, and action by Government and by market leaders.

Key milestones have been the publication of the latest set of UK Climate Projections (UKCP09) and the adoption of the Adaptation Reporting Power, by which Government requires key providers of economic infrastructure providers and their regulators to report on the risks faced from climate change and how these risks are being managed and reduced³.

Meanwhile, there is some evidence that investment decisions are beginning to take potential adaptation measures into account. However, experience to date has highlighted a number of important challenges:

- **Information gaps:** Government has played a central role in the provision of information on climate change impacts and risks. This information is a public good, with wide application across society and the economy, and has helped sustain the UK's leading reputation in climate change. Given the broad remit of Government-led research, the information collected and provided through key initiatives (UKCP09, upcoming UK CCRA) tends to be generic or has a wider application, and stakeholders in all of the infrastructure sectors recognised that information currently available is not sufficiently detailed or tailored to their sectors and infrastructure to inform adaptation responses. Efforts by individual companies and by industry collaborations are bridging these information gaps, although the pace at which this is happening differs across sectors.
- **Managing uncertainties:** The most difficult challenge faced by many stakeholders in the infrastructure sectors is the incorporation of uncertainties into the decision making process.
- **Balancing priorities:** Even when climate change risks are considered, building in climate resilience needs to be balanced against other objectives, and with the exception of 'no regrets' or 'quick win' measures, adaptation tends to be lower down the priority list.
- **Short-term regulatory focus:** In regulated sectors, regulators act upon the statutory duties determined by Government. Climate change adaptation is not explicitly prescribed as a statutory duty for many regulators, but is embodied within wider mandates (e.g. protection of short- and long-term consumer interest, security of supply). Regulators are adequately equipped with appropriate levers (including incentives and penalties, standards and regular pricing controls) to deliver these mandates and therefore incentivise adaptation. However, the strong emphasis on short-term value for money, especially against a backdrop of a recovering economy, coupled with uncertainties around the severity of the long-term impacts of climate change, mean that adaptation requirements are not yet being addressed on a systematic basis. Whilst in principle the regulatory framework is broadly fit for purpose in the context of climate resilience, there is a need to strengthen the focus on long-term resilience.
- **Private sector priorities:** In competitive and unregulated sectors such as power generation and ports, adaptation investment faces competition for capital and for management time. Except for very large, long-life assets, or where the risk is particularly significant, adaptation may not always receive sufficient attention at Board level or from shareholders.

³ See <http://www.defra.gov.uk/environment/climate/legislation/reporting.htm> for further details on the Adaptation Reporting Power.

- **Interdependencies:** A key gap identified across all sectors is the lack of priority given to interdependencies. There are strong inter-linkages within and between all the infrastructure sectors, with mutual reliance on transport, energy, water and telecommunications. However the level of understanding of climate risks from these interdependencies was lower than for direct risks to the infrastructure in the sector. Greater collaborative efforts between the infrastructure sectors, regulators and Government are required to address these interdependency issues.

The role of investors and insurers

Compared to climate change mitigation, the market forces driving adaptation action are presently relatively weak.

Leading investors, lenders and insurers are interested in getting a better understanding on how climate risks are being managed by companies, so that they are able to distinguish potential ‘winners’ and ‘losers’. However there is little evidence that climate change risks and adaptation actions are significant drivers of investment activity or of pressure from investors on companies in the infrastructure sectors. This apparent anomaly reflects the difference between typical investment time horizons (which for most investors range from the very short-term to perhaps ten years) and the timeframe over which significant climate impacts are expected to emerge.

Similarly, although insurers tend to have a relatively good understanding of climate change, there appears to be little differentiation in premiums to reflect climate risk. This reflects a number of factors, including the frequency of renewals (typically insurance is let on annual contracts) and information gaps and uncertainties associated with the likely timing and impacts of climate change.

Key recommendations

Figure 1 provides a summary of the strategic recommendations of this study and the role of different stakeholders in implementing them. The recommendations are aimed to be applicable across the economic infrastructure sectors. Government should support and encourage action across all recommendations.

Part 2 of this report also addresses issues specific to a sector, highlights the good practices observed, and identifies areas where these recommendations are applicable and how they would be incorporated.

Roles of different stakeholders in infrastructure adaptation

Government

The Government has had a catalytic effect in raising awareness and encouraging action in infrastructure adaptation, in particular through information provision (e.g. UKCP09) and by exercising the Adaptation Reporting Power. It will be important for Government to continue to encourage adaptation action, and to foster partnership working across sectors and between different stakeholders. Government should also maintain and update existing information provision initiatives (e.g. UKCIP and UK CCRA), and facilitate co-operation across companies and sectors on developing greater or more in-depth understanding of risks.

Regulators

Climate change adaptation is not explicitly prescribed as a statutory duty for many regulators, but is embodied within wider mandates (e.g. protection of short- and long-term consumer interest, security of supply). Regulators are adequately equipped with appropriate levers (including incentives and penalties, standards and regular pricing controls) to deliver these mandates and therefore incentivise adaptation. However these mandates and levers are more explicitly linked to climate change in some sectors (e.g. water and energy) than in others (e.g. telecoms and airports). When

considering the need for adaptation, regulators have to balance long-term resilience against the shorter-term concerns of efficiency and value for money in the delivery of services to customers.

Investors and insurers

Although there is increasing awareness of climate change risks, adaptation to climate change is not yet a significant driver of action in financial services. Climate risks tend to extend well beyond the time horizons that most institutional investors or insurers typically consider. Nevertheless, institutional investors in, and insurers of, infrastructure have a significant stake in timely adaptation and climate resilience. Greater disclosure of risks and actions by companies should help to increase understanding and catalyse action.

Infrastructure operators

As in other sectors, there has been more focus to date in the infrastructure sectors on climate mitigation (i.e. reducing emissions) than on adaptation. Adaptation action in the infrastructure sectors takes many forms, ranging from consideration of physical design and location, changing or managing operational procedures and building or retrofitting additional resilience features, to emergency and contingency planning.

By addressing climate risks, operators should see long-term benefits in more resilient infrastructure, enhanced security of supply and reduced costs, leading ultimately to a lower cost of capital, higher revenues (where customers are willing to pay for reliability and continuity of supply) and sustained long-term returns.

Owners and operators of economic infrastructure need to embed adaptation thinking throughout their organisations, in the same way as climate leaders have embraced climate mitigation, and to work with other infrastructure companies, regulators and Government to address cross-sectoral risks and interdependencies.

Local authorities and local enterprise partnerships

The local nature of many climate impacts underlines the importance of regional or sub-regional adaptation responses. Indeed, local stakeholders may well have a longer-term view on issues that affect them directly than on national issues, because of their commitment to, and dependence on, the local physical and commercial infrastructure.

Local authorities (or Local Enterprise Partnerships (LEP's)) have an important role to play in encouraging and coordinated action at the sub-regional level, bringing together infrastructure operators and other stakeholders to address climate risks at the local level. They may also be able to catalyse funding for cross-sectoral initiatives and to encourage more targeted solutions. Co-ordination and facilitation across these local groups should also encourage action nationally.

Figure 1: Summary of recommendations

This table summarises our strategic recommendations and different roles of the various stakeholders of economic infrastructure in their implementation. Primary responsibilities are highlighted in bold.

Recommendation	Government	Regulators	Infrastructure operators	Investors and insurers	Local bodies (e.g. Local Enterprise Partnerships, local authorities)	Professional institutions and engineering community
Communicate a Government vision for infrastructure adaptation	<ul style="list-style-type: none"> Communicate a clear vision for adapting the nation's infrastructure to climate change and the roles of the private sector, regulators, local bodies and Government 	<ul style="list-style-type: none"> Engage and clarify role for regulators 	<ul style="list-style-type: none"> Engage and clarify role for operators 	<ul style="list-style-type: none"> Engage and clarify role for investors and insurers 	<ul style="list-style-type: none"> Engage and clarify role for local bodies 	<ul style="list-style-type: none"> Engage and clarify role for technical providers and engineering community
Promote cross-sectoral consideration of adaptation and climate resilience	<ul style="list-style-type: none"> Facilitate top-down co-ordination 	<ul style="list-style-type: none"> Regulators to discuss adaptation and interdependencies at cross-regulator working group. 	<ul style="list-style-type: none"> Industry bodies to co-operate on cross-sector interdependencies 		<ul style="list-style-type: none"> Co-ordinate forum for local infrastructure operators, local business and civil society 	<ul style="list-style-type: none"> Promote information sharing on cross-sectoral issues
Align short-term resilience with climate change adaptation	<ul style="list-style-type: none"> Align existing focus on short-term resilience (including work currently being led by Cabinet Office) with long-term climate change adaptation needs 	<ul style="list-style-type: none"> Set out the time frames that the infrastructure providers should be expected to plan against, which could vary depending on the life spans of their assets 	<ul style="list-style-type: none"> Utilise decision pathway approach and real options analysis for long life asset decisions 			
Use existing regulatory levers to address adaptation	<ul style="list-style-type: none"> Monitor the progress on adaptation; in particular consider more explicit levers or mandates on adaptation if the existing mandates and levers available to regulators are not providing the expected results 	<ul style="list-style-type: none"> Ensure consideration of adaptation in the infrastructure planning process Ensure appropriate evidence of adaptation as part of the regulatory review process 	<ul style="list-style-type: none"> Ensure consideration of adaptation in investment and regulatory planning 		<ul style="list-style-type: none"> Ensure consideration of adaptation in the infrastructure planning process 	

Recommendation	Government	Regulators	Infrastructure operators	Investors and insurers	Local bodies (e.g. Local Enterprise Partnerships, local authorities)	Professional institutions and engineering community
Bridge information gaps	<ul style="list-style-type: none"> • Encourage awareness and engagement by the private sector and other stakeholders • Assume co-ordinating and quality assurance roles as appropriate 		<ul style="list-style-type: none"> • Seek ways to lower the costs of information provision, for example through collaboration • Demonstrate leadership by sharing best practices 	<ul style="list-style-type: none"> • Encourage a closer working relationship in sharing information across investors and insurers 	<ul style="list-style-type: none"> • Enable information sharing between local infrastructure providers and local communities / businesses 	<ul style="list-style-type: none"> • Forge a closer working relationship to pool best practices and data
Promote disclosure of climate risks	<ul style="list-style-type: none"> • Require infrastructure owners to disclose risks from climate change through ARP 	<ul style="list-style-type: none"> • Encourage or require companies and infrastructure owners to disclose risks from climate change 		<ul style="list-style-type: none"> • Encourage or require companies and infrastructure owners to disclose risks from climate change 		<ul style="list-style-type: none"> • Forge a closer working relationship to pool best practices and data
Promote good practice through procurement and financing	<ul style="list-style-type: none"> • Promote good practice through public procurement • Government-owned financing institutions to show leadership through their investment approval process 			<ul style="list-style-type: none"> • Lenders and investors that provide financing should encourage best practices on adaptation through their investment approval process 		
Encourage innovative approach to financing cross-sectoral adaptation	<ul style="list-style-type: none"> • Proposed Green Investment Bank to look at catalysing innovative approaches to financing 			<ul style="list-style-type: none"> • Pool funding or use financial instruments to address cross-sector adaptation 	<ul style="list-style-type: none"> • Co-ordinate forum for local infrastructure operators, local business and civil society 	

Summary of strategic recommendations

Communicate a Government vision for infrastructure adaptation

Most of the owners and operators of economic infrastructure in the UK have a good understanding of climate change risks, but lack clarity on how they should respond. Government should develop a clear vision of how and when the nation's economic infrastructure should be adapted to climate change, the role of the different stakeholders in adaptation and the benefits of timely action.

This vision should be communicated to the private sector (including investors and insurers, as well as infrastructure owners and operators), regulators, local authorities and LEPs, as a call to action on adaptation.

Promote cross-sectoral consideration of adaptation and climate resilience

Generally, less progress has been made in addressing cross-sectoral interdependencies and in many cases these are potentially the 'weakest link' in climate resilience. Whilst increased resilience within sectors would help to address this issue, more needs to be done to identify and respond to key interdependencies.

This will necessitate enhanced information sharing and cooperative behaviour within and between sectors, with local authorities or LEPs and regulators. This may require some co-funding of adaptation action.

Align short-term resilience with climate change adaptation

An important challenge on long-term adaptation is the weak alignment of short-term priorities (e.g. efficiency, value for money, balancing immediate resilience needs) with long-term resilience. The Government's long-term vision for adaptation should seek to clarify the timeframes for climate adaptation planning and investment (this may vary from sector to sector and between asset classes). The vision should also align its existing focus on short-term resilience (including the work currently being led by Cabinet Office) with long-term climate change adaptation needs. Regulators need to set out the timeframes that the infrastructure providers should be expected to plan against, which could vary between and within sectors, depending on the life spans of their assets.

Use existing regulatory levers to address adaptation

Economic regulators should ensure that appropriate consideration is given to climate adaptation challenges in the investment planning process. Balancing climate risks with efficiency and value for money concerns may require re-assessment of regulatory and planning time horizons (perhaps using mechanisms such as the water sector Strategic Direction Statement). Regulators should pay particular attention to climate change projections and assumptions and ensure that these are supported by appropriate documentary evidence as part of the regulatory review process.

Other regulators (health, safety) also have mechanisms to encourage or support adaptation. At a local level, major infrastructure projects are also expected to adhere to local planning restrictions, which help promote local resilience.

Bridge information gaps

Government has played a central role in the provision of information on climate change impacts and risks. However, Government cannot be expected to provide the level of granularity required to address all the specific needs of the infrastructure sectors. Government and regulators have an important role, however, in encouraging collaboration, within and between sectors and at local levels, to address information gaps in a cost efficient manner, and the sharing of climate change information for the wider benefit of businesses and the economy.

For their part, infrastructure owners and operators should seek opportunities to reduce information gaps and costs by collaboration with other infrastructure operators, professional institutions and other sectors. Information providers could also help lower costs to operators through collaboration and pooling best practices and methods.

Promote disclosure of climate risks

The Adaptation Reporting Power is already driving greater awareness of climate change risks and adaptation responses in the infrastructure sectors. Government, investors and insurers should all seek to build on this momentum, encouraging the sharing of knowledge and best practice in the infrastructure sectors and more widely. Transparent disclosure of how infrastructure owners and operators in the UK are responding to climate change would enable stakeholders and the public to scrutinise and assess the resilience of their infrastructure.

Promote good practice through procurement and financing

Government should promote good practice in adaptation through public procurement of infrastructure and infrastructure services. Government should also encourage Government-owned financing institutions to show leadership through their investment approval processes. The Green Investment Bank (GIB) plans may provide an opportunity to give more profile to adaptation actions.

Encourage innovative approach to financing cross-sectoral adaptation

Adaptation measures that help reduce climate change risks to several parties may suffer from free-ridership problem, as individual stakeholders may be unwilling to fund their share of the costs of adaptation. Pooling funding from different parties, or using financial instruments that help share the costs and risks, could help catalyse adaptation projects that addresses cross-sector climate change risks. There is scope for innovative approaches to the financing of adaptation and the GIB may be able to play a role in catalysing this.

Structure of the report

This report sets out a number of strategic recommendations to Government, regulators, industry, investors and insurers to provide a roadmap for the UK's infrastructure sectors to help maintaining a robust and resilient economic infrastructure against the impacts of climate change.

Part 1 of the report provides an overall summary of this study. Section 1 summarises our findings while Section 2 presents our key recommendations, focusing on strategic issues common to the four sectors in this study.

Part 2 of the report provides further details for each infrastructure sector and the investor and insurance community. Section 3 summarises the policy and regulatory framework for the UK. Sections 4 to 7 present the key findings and recommendations of our study for each of the four infrastructure sectors – energy, transport, water and ICT. Section 8 focused on the findings and recommendations for the investor and insurance community.

Part 1: Key findings and recommendations

1 Results of desk research and consultations

1.1 Introduction

The need for climate resilience in infrastructure

Sustained, effective operation of the nation's infrastructure in the energy, water, transport and ICT sectors is vitally important to the performance of the UK economy. This report explores the implications of climate change impacts, both for existing infrastructure and for future investment in these sectors, and examines the role of government and regulators in encouraging action on adaptation to climate change, to maintain robust and resilient infrastructure systems.

In this report we refer to the energy, water, transport and ICT sectors as 'infrastructure sectors' and infrastructure networks and assets in these sectors as 'economic infrastructure'⁴.

Economic infrastructure typically has a long useful life, with much of the existing infrastructure and planned future investment expected to be in operation for many decades to come. Meanwhile the country faces growing risks from the impacts of climate change as a result of the rapid increase in concentrations in greenhouse gases in the earth's atmosphere.

Climate change is a global phenomenon. However many of the impacts are local. Adaptation action must therefore be tailored to local circumstances, as well as to the strategic importance of the assets concerned. Effective and timely investment planning and decision making within the infrastructure sectors is a critical component of the nation's response to climate change.

Adaptation and climate risk sharing

The nature of adaptation and the roles of markets and regulation differ widely across the infrastructure system:

Private sector risk-based approach

Some types of adaptation are private goods – the protection of infrastructure for an operator also secures its economic operability. A private sector, risk-based approach to adaptation is often sufficient to ensure resilience. For example, ports operators incorporate weather variables like storminess, precipitation levels and temperature changes into the design of their ports, because these are important drivers of port downtime. Business-led adaptation – driven by prudent risk management or a desire to differentiate against competitors – can ensure the resilience of private-owned infrastructure assets without government intervention. Competitive pressures mean that infrastructure operators that adapt faster than their peers emerge as leaders on service resilience and reliability. However, the downside of relying on a private sector, risk-based approach is that the failure to adapt by laggards could have repercussions across the economy.

Positive externalities from adaptation – public goods and interdependent networks

For other types of infrastructure, adaptation has 'merit good' or 'public good' characteristics, which means that the positive externalities from improved resilience accrue to other parties, rather than, or as well as, the party that bore the costs of adaptation. In the UK, highways and local roads are recognised as public goods and provided by the state (via

⁴ Economic infrastructure includes assets within the four sectors in this study classified by Government as 'critical national infrastructure' for the purposes of security and resilience as well as other 'non-critical' assets. Critical national infrastructure also includes assets in other sectors not covered in this study. In considering our findings it is important not to confuse economic infrastructure and critical national infrastructure, although we do comment on the potential to harmonize policy on climate change adaptation, security and resilience in relation to economic infrastructure.

the Highways Agency and local authorities). By extension, the climate resilience of these public goods will also carry public good characteristics.

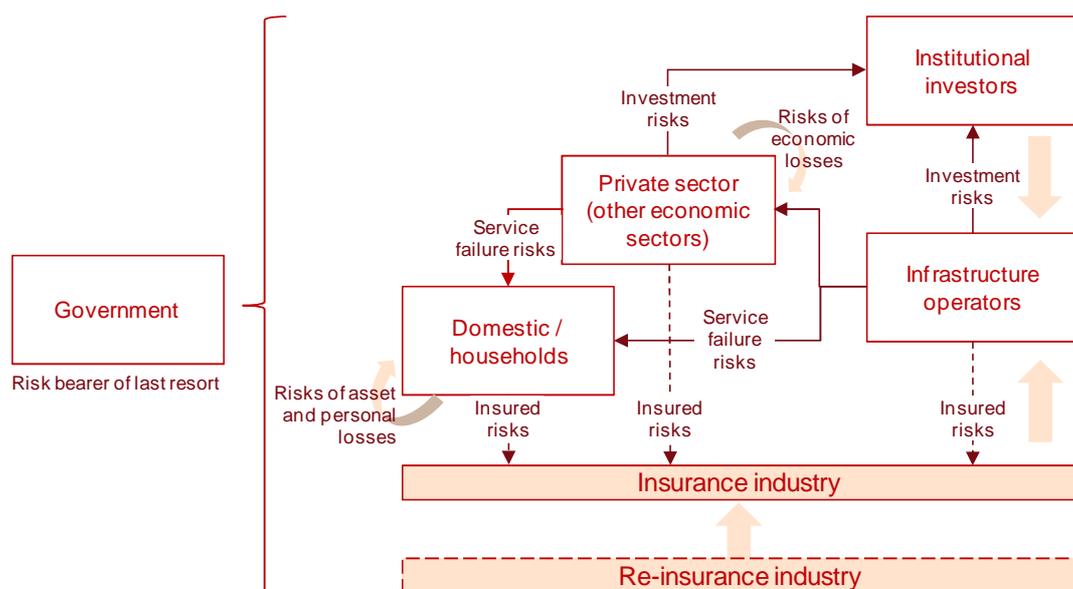
The interlinked or network nature of some economic infrastructure may also mean that while the benefits of a resilient infrastructure are shared by many, the costs of adaptation are often borne by only one party. For example, continuity and security of electricity supplies are important for the whole of the economy, but adaptation of electricity infrastructure needs to be carried out by the power sector. Similarly, train operators and railway track owners might not take into full account the importance of rail connections for freight transport to the ports sector when prioritising adaptation investments.

Sharing climate risk

Adaptation is also a means to reduce the risks of climate change borne by different parties. Figure 2 illustrates generically how the risks of failed or inefficient infrastructure are shared⁵. Infrastructure operators risk economic losses from poorly adapted assets (e.g. loss of revenue, damaged or inefficient assets). At the same time their users (i.e. other infrastructure sectors, the wider economy and domestic users) are exposed to risks of service failure. Investors also bear investment risks both from the economic losses of infrastructure operators and from other investments reliant on this infrastructure. The potential losses may be reduced through insurance, passing on part of these risks to the insurance (and re-insurance) community. Ultimately, however, government may act as a risk bearer of last resort, stepping in to assist with losses suffered in extreme circumstances.

Where the risk of climate change impacts is spread across many stakeholders, market forces (users, investors and insurers) may drive adaptation actions to manage and reduce risks. However, where stakeholder pressure or influence is inadequate in driving adaptation, government or regulators may need to intervene.

Figure 2: Risk of climate change impacts on infrastructure



Source: PwC

⁵ This may vary across sectors. For example, the market structure of a sector is a factor in determining the level of risks that a party is willing and able to accept. Monopolies tend to have a greater capacity to absorb risks of short term financial losses compared to companies in highly competitive sectors.

1.2 Challenges to adaptation and infrastructure resilience

Introduction

We consulted the economic infrastructure sectors through focus group sessions and one-to-one interviews, and invited participants to share and debate their views on the progress and challenges faced on adaptation. These consultations were informed and supplemented by desk research. This section provides a summary of the findings of this work.

Information gaps

The levels of awareness and the extent of information gaps on the impacts of climate change varies across the infrastructure sectors, as well as between stakeholders and companies within each sector.

Broadly, we found that:

- Awareness varies depending on the type of impact or issue faced (see Figure 3);
- An increase in the level of awareness tends to be driven by recent events (especially high impact events);
- Differences in levels of awareness of different risks and impacts is partly explained by their emphasis within existing policy or regulation, e.g. flood risk assessment is common practice during planning applications, so most participants have a high level of understanding of flood risks compared to other climate risks;
- Current information tends to be generic and not sufficiently tailored to an asset or infrastructure to enable adaptation planning; and
- There is low or little appreciation for the need to consider interdependent risks across sectors or networks.

Figure 3: The level of understanding by infrastructure operators and investors on key climate change risks

Issue	Infrastructure operators		Investors	
	General awareness of climate change as an issue	Understanding of specific climate change impacts	General awareness of climate change as an issue	Understanding of specific climate change impacts
High impact events e.g. flood	<ul style="list-style-type: none"> • Strong for most sectors 	<ul style="list-style-type: none"> • Strong for most sectors 	<ul style="list-style-type: none"> • Limited to niche investors⁶ 	<ul style="list-style-type: none"> • Limited to niche investors
Incremental changes in averages e.g. temperature	<ul style="list-style-type: none"> • Moderate 	<ul style="list-style-type: none"> • Weak, growing in some sectors such as energy, roads and rail 	<ul style="list-style-type: none"> • Weak, growing for niche investors 	<ul style="list-style-type: none"> • Weak
Interdependency with other sectors	<ul style="list-style-type: none"> • Weak, although most obvious links such as cooling water for energy or role of ICT were identified 	<ul style="list-style-type: none"> • Weak 	<ul style="list-style-type: none"> • Weak, but growing for investors with portfolio of interlinked assets 	<ul style="list-style-type: none"> • Weak

⁶ 'Niche' investors here refer to institutional investors that have a focus on thematic issues, e.g. pension fund investors focused on infrastructure, investors investing on green or climate change themes.

The most immediate need identified by participants was for information to be tailored better to specific types of infrastructure or to a particular sector. Data provided by the Met Office and UKCIP tends to be generic and often insufficient to inform the required adaptation measure. Further work to bridge these gaps could be relatively costly. Some sectors or companies are proactively addressing this. For example:

- The energy distribution companies are collaborating on deepening their understanding of a range of weather and climate change impacts including the potential impacts on overhead lines and underground cables; and
- Network Rail has commissioned research into climate change impacts on the railways with RSSB⁷.

There appears to be greater collaboration on information gathering in some sectors (e.g. energy) than others (e.g. ports). A lack of consensus or collaborative efforts across companies may mean duplications or inconsistencies in information gathering.

Incorporating long-term adaptation into investment decision making

Participants agree that where a sound business case can be made, measures that adapt an infrastructure to climate change would be implemented. However, infrastructure operators face a number of hurdles before adaptation is considered, and the level of scrutiny could also vary for an internal business case (e.g. by management or board) versus an external business case (e.g. by regulators, investors or lenders).

Figure 4: Challenges for adaptation: efficiency or market failure?

	Challenge for adaptation	Efficient response if	Market failure if
Materiality of risks	<ul style="list-style-type: none"> • Unless the risks have material or significant financial or operational impact operators / investors tend not to respond to the risks 	<ul style="list-style-type: none"> • Adaptation occurs when the benefits of adaptation outweighs the costs • This could mean that operators or investors bear some residual risks by choosing not to take action, because the costs outweighs the benefits 	<ul style="list-style-type: none"> • The positive externalities of adaptation to other parties are not taken into account • The costs and benefits of adaptation cannot be quantified, leading to misinformed judgements • Short-termism or other objectives are given greater weight
Timescale of the project	<ul style="list-style-type: none"> • For longer life assets, need to consider issues or factors that affect their whole life span, whereas assets on maintenance cycles offer potential for retrofit or later adaptation 	<ul style="list-style-type: none"> • The costs of retrofitting or later adaptation is lower than early investment, for example through incremental low-cost measures • Uncertainties in the severity of impacts means that delaying decisions provide opportunity to make more informed decisions 	<ul style="list-style-type: none"> • Full life cost of assets are not considered e.g. because of short-termism, discount rates • Adaptation is ignored because of the complexities involved in dealing with uncertainties, even though methods and tools are available
Uncertainties	<ul style="list-style-type: none"> • Low probability events or events with high levels of uncertainty tend to lead to a lack of response, especially if the impact is not material. 	<ul style="list-style-type: none"> • Uncertainties in the severity of impacts means that delaying decisions provide opportunity to make more informed decisions 	<ul style="list-style-type: none"> • Adaptation is ignored because of the complexities involved in dealing with uncertainties, even though methods and tools are available
Distinction from other sources of interruption / risks	<ul style="list-style-type: none"> • Businesses are more concerned with the impact of an “event”, than the cause, e.g. operational outages in electricity generation could be caused by weather disruptions or by other incidents such as fire or vandalism. 	<ul style="list-style-type: none"> • Climate change does not lead to a deviation from “business-as-usual” so there is no need to change existing practices. 	<ul style="list-style-type: none"> • Systemic risks are not addressed because the impacts are indistinguishable from other causes.

⁷ Tomorrow's Railway and Climate Change Adaptation (TRaCCA), Technical Strategy Advisory Group, Phase 1 report Adapting to extreme climate change published in August 2010

Developing the business case for adaptation

Where potential risks from climate change are identified, an infrastructure operator or investor will assess the need to respond. The decision on whether to take active action depends on a number of factors. Often these factors represent efficiency considerations, but they may also mask a number of possible market failures.

These findings are neither new nor surprising. Business makes judgements on materiality and timescales for every type of risks. Business also frequently deals with uncertainties such as demand and revenue growth. However, the uncertainties around climate change can magnify the modelling and decision making challenges. Infrastructure companies will often be aware of possible ways to manage these uncertainties, such as the decision pathway approach and real options theory, but in practice these are little used because of the complexity involved. Furthermore, until the risks of climate change can be disentangled from other potential sources of 'random' interruptions or risks, companies may be unwilling to model climate change risks as a separate and distinct issue.

The adaptation response required varies by type of assets. Mapping the four factors above highlights how current practices on adaptation vary from 'good practice' (see Figure 5). Different components of an infrastructure could have different life spans, and some decisions may be irreversible. For example, for a new railway (e.g. High Speed One), the route of the railway will be largely unchangeable, and stations, bridges and embankments will be long-life assets often with embedded interdependencies; however the track and signalling equipment are more likely to be replaced or upgraded more regularly. The complexity of a typical infrastructure project means that adaptation responses may need to be looked at from a holistic viewpoint.

Figure 5: Asset type, good practice adaptation and current practice

	Existing assets		New and planned assets	
<p>Long-life span (> 20 years) E.g. power plants, reservoirs and water mains, transport structures</p>	<ul style="list-style-type: none"> • Good practice adaptation 	<ul style="list-style-type: none"> • Use of decision pathway approach to ensure long-term effective resilience through maintenance, repair, retrofit or replacement 	<ul style="list-style-type: none"> • Adaptation needs and response (especially those with greater certainty) can be identified and developed as part of planning application process, with respect to (local) standards and specifications • Use of decision pathway approach can help identify and prioritise long-term challenges and response 	<ul style="list-style-type: none"> • Best practices and well understood issues tend to be incorporated in investment decision (e.g. on flood risks, known weather interruptions) • The investment horizon of investors and operators tends to be a key determinant of the period within which climate change risks are being examined
<p>Short / medium life spans (<20 years) E.g. road surfaces, data centres, overhead lines and long life assets nearing end of life</p>	<ul style="list-style-type: none"> • Good practice adaptation • Current practice 	<ul style="list-style-type: none"> • Incremental adaptation could be incorporated at each replacement cycle • E.g. road resurfacing, upgrade of data centre systems, replacement of new overhead lines • The concept of adaptation at replacement cycles is well understood across all stakeholder groups. Some evidence that this is being looked at, but this study is unable to conclude whether this is consistently carried out across all assets or sectors • E.g. energy sector is examining scope for adapting during replacement of overhead wood poles 		

Evaluating the business case for adaptation

From the perspective of a 'user' or 'approver' of the business case, e.g. a regulator, investor or lender, the uncertainties involved pose a major barrier to adaptation, as the key 'good practices' that are expected from operators also include:

- The appropriate use of an evidence base to support a business case;
- Careful consideration of the adaptation options available, the decisions made and the impact on key priorities e.g. return on investment, value-for-money etc.; and
- Consensus (within the industry, amongst regulators and, as appropriate, with other stakeholders) on the application of this knowledge.

There was broad consensus across the regulatory and investor community in this study that adaptation investments would generally be funded if the issues identified above had been satisfactorily addressed in the business case. This places the burden of justifying an adaptation need on the infrastructure company, and both regulators and investors rely on them to be proactive in adapting to climate change. Regulators and investors perceive that infrastructure companies are the most informed parties on the risks faced, and that they currently lack the ability to judge if adequate action has been taken by operators. As a result, only well-justified business cases for adaptation (e.g. those with high levels of certainty) are being 'approved'.

Short holding periods and lack of long-term certainty in policy and regulation also mean that many investors and insurers have little incentives to intervene directly in how companies in their portfolio respond to the physical risks of climate change. More resilient infrastructure can lower the cost of capital to investors and reduce the risk exposure to insurers; however this is currently unlikely to be priced into investment analysis. The majority of investors and insurers that we spoke to recognise that adaptation is not yet a priority on their agendas, primarily because of their shorter time horizons relative to the likely timeframe for climate risks. In the insurance industry, for example, contracts are typically renewed annually (although many insurers have long standing relationships with the asset owners that they insure).

In the short-term, adaptation may be best considered alongside other drivers for investments, focusing on 'no-regrets' or 'win-win' investments (see case study on United Utilities for an example of this). Regulators and investors are more prepared to support adaptation measures that also generate other benefits.

1.3 A strategic framework to enable adaptation

Principles and summary of recommendations

The key recommendations of this report were developed independently, but were guided by the interaction with stakeholders, and follow a number of principles as highlighted below. These recommendations have also been discussed with Government, subject matter experts on adaptation, sector specialists, and a small selection of companies as part of the consultative process.

Our recommendations are broadly consistent with the recommendations by the Committee of Climate Change, which published its first report of the Adaptation Sub-Committee (ASC) in September 2010, independent to our work.

'Successful' adaptation is determined by best practice processes and systems, rather than outcomes

Adaptation cannot eliminate the impacts of climate change completely. In particular it may be efficient to accept some residual risks. Successful adaptation should promote the following outcomes:

- Ensuring service delivery adapts to meet future needs;
- Reducing the risk to service delivery;
- Reducing the risk to the viability of existing infrastructure, e.g. avoiding the need for costly retrofitting or even re-building/re-location;
- Reducing the risks associated with investment in new (or new types of) long-term infrastructure (and so reducing the risks to financial returns); and
- Enabling infrastructure owners/operators to deliver the wider public good and minimise their own financial risks.

However, we believe it is difficult to judge the success or failure of adaptation through realised outcomes – e.g. service delivery failures could still occur even if the infrastructure system is well-adapted⁸. Judging outcomes may also mean a skew towards reacting to an event, rather than prevention. Therefore, we consider infrastructure adaptation to be 'successful' if market and regulatory systems are in place that:

- Identify and assess long-term climate change risks, including interdependent and systemic risks;
- Incentivise decision making that favours efficient and effective adaptation; and
- Are robust over the long-term, i.e. as and when greater certainty occurs.

'Successful' adaptation also needs to consider interdependencies, based on systems thinking

As the impacts of climate change are increasingly felt, interdependencies will become more important – e.g. service disruptions become more systemic or simultaneous failures become more likely. Appropriate levels of resilience within sectors at a local level will help to ensure resilience across sectors nationally. However collective resilience may be threatened by the weakest links within systems. Gold plating of every type of investments is also likely to be inefficient and unaffordable for consumers. Coordinated responses and coherent planning is therefore important in building collective resilience across the economic infrastructure sectors.

The recommendations therefore aim to address resilience within and across sector by

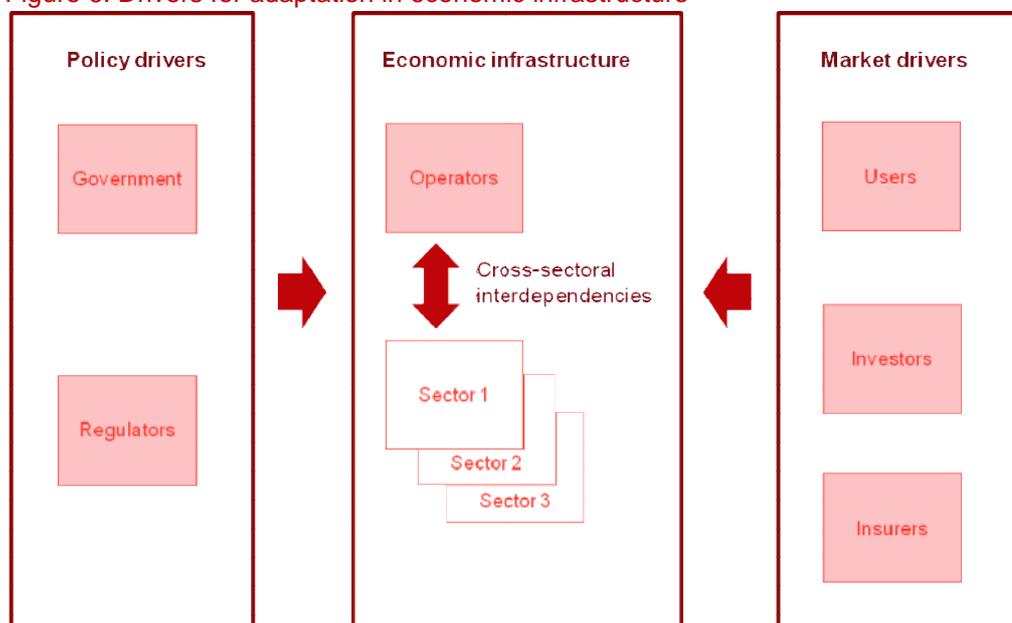
- Building and promoting climate resilience at the sector level and encouraging a systems thinking approach; and
- Forging collaborative and partnership working across sectors and geographies.

⁸ This is the principle-agent problem that economists refer to.

Private sector-led adaptation should be promoted and encouraged by leveraging existing market forces

Infrastructure operators and owners will face significant operational, financial and reputational risks when their infrastructure systems are not well-adapted. It is in their commercial interest to ensure climate resilience and, as markets become more familiar with climate risks and adaptation solutions, market pressure should drive this. The recommendations are therefore aimed at promoting a private sector risk-based approach by removing barriers to adaptation and strengthening the market drivers. The role of Government and regulators should be on catalysing action and sustaining momentum.

Figure 6: Drivers for adaptation in economic infrastructure



Source: PwC

The recommendations build on the approach adopted by the Government in dealing with adaptation, as summarised in a recent response to the Environmental Audit Committee⁹, which we endorse:

- The Government will play its part by giving the necessary lead and enabling other actors to make the most effective decisions;
- Adaptation is a local issue, delivered most effectively with actions tailored to local circumstances and challenges;
- Adaptation of nationally significant infrastructure to the impacts of climate change is important, currently driven by the statutory Reporting Power introduced by the Climate Change Act;
- Adaptation is expensive but failure to adapt risks greater costs – the focus should be on evidence, understanding and concrete action; and
- Government, local authorities, businesses and communities need to collaborate and manage risks and seize opportunities.

⁹ Government response to the conclusions and recommendations of the Environmental Audit Committee: Adapting to Climate Change, Sixth Report of Session 2009-10, August 2010

2 Recommendations

Recommendation 1: Communicate Government's vision for infrastructure adaptation

Most of the owners and operators of economic infrastructure in the UK have a good understanding of climate change risks, but lack clarity on how they should respond.

Government should develop a clear vision of how and when the nation's economic infrastructure should be adapted to climate change, the role of the different stakeholders in adaptation and the benefits of timely action.

This vision should be communicated to the private sector (including investors and insurers, as well as infrastructure owners and operators), regulators, local authorities and LEPs, as a call to action on adaptation.

Challenges and current state

Infrastructure owners and operators, as well as the investment and insurance community, are aware of the increasing priority of adaptation for Government, through a number of regulations and initiatives:

- The Climate Change Act;
- The set-up of the Adaptation Sub-Committee in the Committee of Climate Change;
- Information provision such as the UKCIP and UK CCRA;
- The Adapting to Climate Change programme within Defra;
- The Infrastructure & Adaptation Project (which commissioned this report);
- The use of the Adaptation Reporting Power.

A key challenge identified by stakeholders consulted in this study was the plethora of initiatives but lack of clarity on how different programmes and initiatives are interlinked. Many are also unclear about the Government's long-term policy on infrastructure adaptation and are looking for a clear long term strategy. Some want further specificity, suggesting that Government needs to define the climate scenario that business needs to plan towards, or on the level of resilience to which infrastructure needed to be protected. The draft National Policy Statement (NPS) for ports, for example, is relatively specific, proposing that ports need to look at the 10%, 50% and 90% estimates against the emission scenario the independent Committee on Climate Change suggests we are most closely following¹⁰. Meanwhile there is less prescriptive guidance for other sectors.

It is inherently difficult for Government to prescribe specific climate scenarios or level of resilience for every type of infrastructure¹¹. Each sector has different drivers and challenges, which mean that a 'one-size-fits-all' approach would not work. Nevertheless, there is a need to arrive at a consensus on what successful adaptation would look like, and highlight the importance of overall resilience for the whole economic infrastructure system. The Government needs to provide the 'bigger picture' of how its various policies and initiatives promote adaptation, whilst emphasising the need for the private sector to take action on adaptation and the benefits that this brings. This would provide a clear signal to the private sector about their role in managing and reducing their risks to climate change.

¹⁰ Draft National Policy Statement for Ports, Department for Transport, November 2009

¹¹ However the Adaptation Sub-Committee from the Committee of Climate Change has recommended that Government defines adaptation outcomes and acceptable levels of risks.

Recommendation and practical ideas

The Government needs to define and articulate a clear vision for adaptation and resilience in the nation's infrastructure. The vision could include the following elements:

- Define 'successful' adaptation and the roles of different parties, building on the response to the Environmental Audit Committee;
- Place emphasis on interdependent and systemic risks, e.g. create a greater role for Infrastructure UK to identify and raise awareness on interdependent infrastructure issues, and bring relevant Government departments together through working groups to promote systems thinking (see Recommendation 2);
- Highlight the need for partnership working, the role of local authorities and communities and the financial sector, in particular in dealing with interdependent infrastructure risks, at national and local levels (see Recommendation 2);
- Identify the varying roles of market forces, infrastructure operators, regulators and Government as procurer, and any potential market or regulatory factors where Government intervention may be required (see Recommendations 3, 4 and 7);
- Identify information needs and responsibility for its provision, e.g. the UKCIP could help companies to be better informed on the climate risks and highlight best practices, but the private sector needs to take action to benefit from this support (see Recommendation 5);
- Clarify responsibility for monitoring progress, e.g. the Government could sustain action and momentum, through the Adaptation Reporting Power (ARP), by monitoring overall progress, enabling comparison of performance across industries and companies, and identifying interdependencies (see Recommendation 6); and
- Address the crucial issue of who should pay for adaptation (including intergenerational, inter sectoral and inter regional issues) and how actions on cross-sectoral interdependencies might be financed (see Recommendation 8).

Subsequent recommendations in this report aim to fit within this vision. Government has a role in promoting all these recommendations, but they should be taken forward and driven by different stakeholders in their respective areas. To do so, the vision needs to be widely acceptable, through consensus building, politically and across the private sector.

Effective communication of this vision will help raise awareness amongst the private sector and relevant stakeholders (e.g. local government) on the importance of climate resilience, and will be as important as the vision itself:

- Political consensus need to be achieved across the infrastructure sectors and political parties, and supported by independent bodies such as the Committee of Climate Change;
- Cross-sectoral infrastructure organisations such as Infrastructure UK have a key role to play in encouraging and emphasising the need for adaptation and climate resilience, especially on interdependency issues;
- The vision should be reinforced by the relevant government departments for each sector through incorporation into their strategic paper or long-term plan;
- Ministers and department representatives and relevant departments should help with the dissemination of the vision's messages to the private sector – different stakeholders would require different channels; and
- The vision needs visible support from the private sector e.g. through a list of signatories that indicate support and willingness to act on adaptation.

Recommendation 2: Promote cross-sectoral consideration of adaptation and climate resilience

Generally, less progress has been made in addressing cross-sectoral interdependencies and in many cases these are potentially the 'weakest link' in climate resilience. Whilst increased resilience within sectors would help to address this issue, more needs to be done to identify and respond to key interdependencies.

This will necessitate enhanced information sharing and cooperative behaviour within and between sectors, with local authorities or LEPs and regulators. This may require some co-funding of adaptation action.

Challenges and current state

A key gap identified across all sectors is the lack of priority given to interdependencies. Despite strong inter-linkages within and between the infrastructure networks, many infrastructure operators do not address interdependently issues adequately or consistently.

Both central and local government are working to address this gap. Infrastructure UK was set up to provide a strategic view across all infrastructure sectors, and different Government departments are increasingly working together on adaptation issues. Regional and local forums are also set up to address adaptation needs, e.g. the London Climate Change Partnership, the Three Regions Climate Change Partnership.

Recommendation and practical ideas

As the impacts of climate change are increasingly felt, interdependencies will become more important – e.g. as service disruptions become more systemic or simultaneous failures become more likely. Appropriate levels of resilience within sectors at a local level will help to ensure resilience across sectors nationally, as further discussed in Recommendations 3 – 6. However collective resilience may be threatened by the weakest links within the systems. Gold plating of every type of investments is also likely to be inefficient and unaffordable for consumers. Coordinated responses and coherent planning is therefore important in building collective resilience across the economic infrastructure sectors.

Coordination is required at a cross-sector, national and sub-regional level. Figure 7 illustrates the different types of collaboration that could be forged and the focus areas for collaborative working. There are already partnerships and joint working at the sector level, and existing industry bodies should extend this collaboration across sectors.

Recommendation and practical ideas: Economic regulators

The UK economic regulators should co-ordinate to ensure that climate adaptation challenges are fully considered in the infrastructure investment and maintenance plans of regulated utilities. Regulators already hold a monthly cross-regulatory working group to ensure matters of consistency on key issues that should be approached in a common way. This group provides a platform to enable a consistent approach to adaptation is adopted throughout all regulators.

Recommendation and practical ideas: Local governments and the role of planning

In some sectors, infrastructure is already owned or managed at the regional or local level, e.g. water and local roads. In others, the infrastructure is part of a national network, e.g. highways and telecommunications. In many cases, however, the local nature of the infrastructure and/or projected climate change impacts suggests that a sub-regional approach may be appropriate in most or all sectors. A sub-regional response would require strong sub-regional coordination across local authorities (e.g. via the forthcoming Local Enterprise Partnerships). Local authorities and Local Enterprise Partnerships

could facilitate coordination at the sub-regional level, bringing together infrastructure operators to minimise risk to climate change at that level.

At the local level, the role of planning is also important in ensuring that new infrastructure plans factor in cross-sectoral interdependencies, as well as taking account of the local circumstances. The planning reforms of the current Government which will give greater powers to local councils, communities, neighbourhoods and individuals could encourage closer co-operation and collaboration amongst local infrastructure operators and communities. Local decision making may, however, lead to varying levels of resilience across regions. To avoid this, Local Enterprise Partnerships and local authorities need to interact regularly to share and update best practices.

Figure 7: Cross sector climate change adaptation

Role	Industry bodies	Regulators	Sub-regional bodies
Nature of co-operation	<ul style="list-style-type: none"> • Cross-sector bodies 	<ul style="list-style-type: none"> • Cross-regulator working group 	<ul style="list-style-type: none"> • Forum for local infrastructure operators, local businesses and local authorities
Applicable sectors / organisations	<ul style="list-style-type: none"> • Infrastructure UK • Energy Networks Association • Association of Electricity Producers • Water UK • Intellect • Highways Agency • Network Rail • British Ports Association • UK Major Ports Group 	<ul style="list-style-type: none"> • Ofgem • Ofwat • Ofcom • ORR • CAA 	<ul style="list-style-type: none"> • Local enterprise partnerships • Local authorities
Focus areas	<ul style="list-style-type: none"> • Value chain mapping of key infrastructure and the identification of weak links; • Greater cross-sector communication on existing and planned investments, to enable opportunities and risks to be identified; • Best practice sharing of experience – including dealing with uncertainties, presenting business case to investors or regulators of adaptation needs; • Create structure or mechanism for cross-sector funding on adaptation investments; and • Coordination of emergency planning and disaster management in the event of infrastructure failure. 		

Recommendation 3: Align short-term resilience with climate change adaptation

An important challenge on long-term adaptation is the weak alignment of short-term priorities (e.g. efficiency, value for money, balancing immediate resilience needs) with long-term resilience. The Government's long-term vision for adaptation should seek to clarify the timeframes for climate adaptation planning and investment (this may vary from sector to sector and between asset classes). The vision should also align its existing focus on short-term resilience (including the work currently being led by Cabinet Office) with long-term climate change adaptation needs. Regulators need to set out the timeframes that the infrastructure providers should be expected to plan against, which could vary between and within sectors, depending on the life spans of their assets.

Challenges and current state

Whilst there is a reasonably good understanding of climate risks amongst infrastructure operators, they will generally only take action when there is a strong business case for adaptation. With the required investments on infrastructure particularly over the short-term – at £40-50 billion a year – adaptation needs on new investments need to be prioritised, focusing on those that are required most urgently, and where the business case is strongest.

At the national level, a substantial amount of work has been done by the Cabinet Office¹² to identify the short-term resilience issues for critical national infrastructure (CNI), defined as “those infrastructure assets (physical or electronic) that are vital to the continued delivery and integrity of the essential services upon which the UK relies, the loss or compromise of which would lead to severe economic or social consequences or to loss of life”.

In some sectors (e.g. water, aviation), the short-term-long-term trade-off is partially addressed by aligning 5-year pricing review cycles to a longer term strategic vision. However, these strategic visions tend to look out to a 25-30 year period, while many impacts from climate change are only likely to be felt after this timeframe. There is a need, at least for long-life infrastructure, to adopt a longer timeframe and a whole life approach. Short asset life assets tend to be able to benefit from incremental investments, alleviating the risk of over-adaptation, however regulators and operators need to plan strategically to adapt at the right replacement cycle.

Recommendations and practical ideas: Government

A set of basic principles could help determine and prioritise adaptation needs on new infrastructure:

- Consideration to the reversibility of decisions, given the level of uncertainties, or the potential impact of locked-in investments;
- Focus on areas with greater levels of certainty of climate change science and impacts on the asset; and
- Focus on areas that also have multiple drivers for investments or are interlinked with investment pattern and drivers of other sectors e.g. win-win and no-regrets investments.

To reduce the overall costs to Government and business in responding to resilience issues, the focus of the short-term resilience of CNI needs to be better aligned to long-term adaptation needs, through:

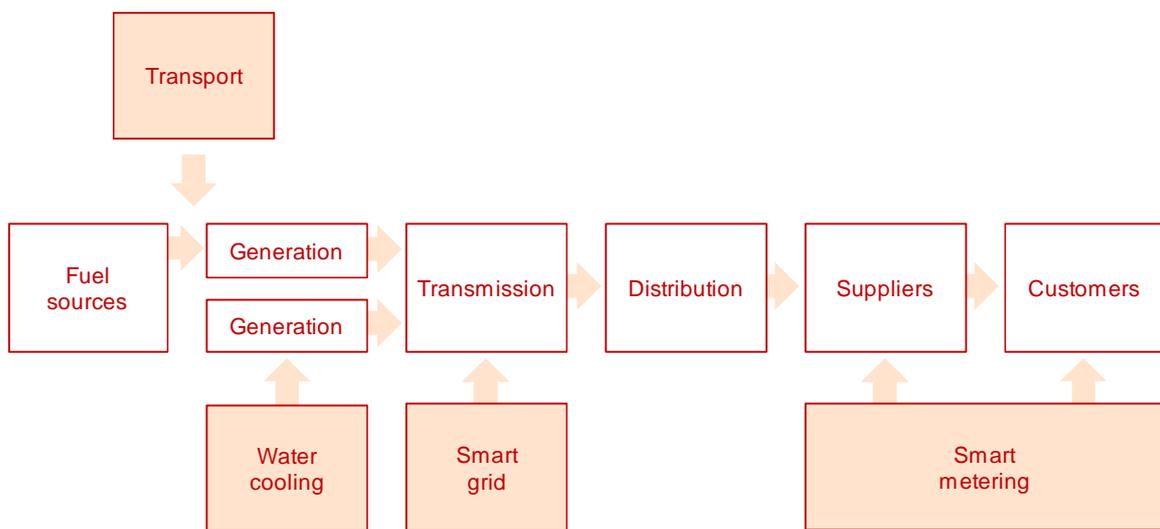
- Extending the scope of the Cabinet Office programmes to include long-term climate change: Much of the work under the CNI resilience programmes already consider natural hazards and events induced by climate change, however

¹² Cabinet Office March 2010: Sector Resilience Plan for Critical Infrastructure

these could be extended to include explicit consideration of long-term climate resilience by addressing key climate change risks (e.g. those identified by the UK CCRA).

- Carrying out value chain or supply chain mapping of key CNI: the Cabinet Office can lead or support the value chain or supply chain mapping of key interdependent issues, working with other government departments.

Figure 8: Illustrative and high level value chain mapping for electricity sector



Mapping key dependencies along the value chain could help identify interdependencies with other sectors as well as potential weak links. Here for example, the sector is dependent on transport for fuel sources, water for cooling, and the ICT sector for effective management of demand and supply. Resilience of the sector also needs to 'flow-through' along the value chain, i.e. from fuel transport to the distribution network.

Recommendations and practical ideas: regulators and industry bodies

For regulated sectors, the relevant regulator should set out the appropriate time horizon within which they would expect companies to consider the impacts of climate change on the infrastructure and align resilience efforts accordingly. This would include setting out a long-term resilience strategy, and ensuring that investment decisions made during each five-year regulatory cycle are compatible with this long-term strategy. For unregulated sectors, this role could be assumed by the relevant Government department or industry body.

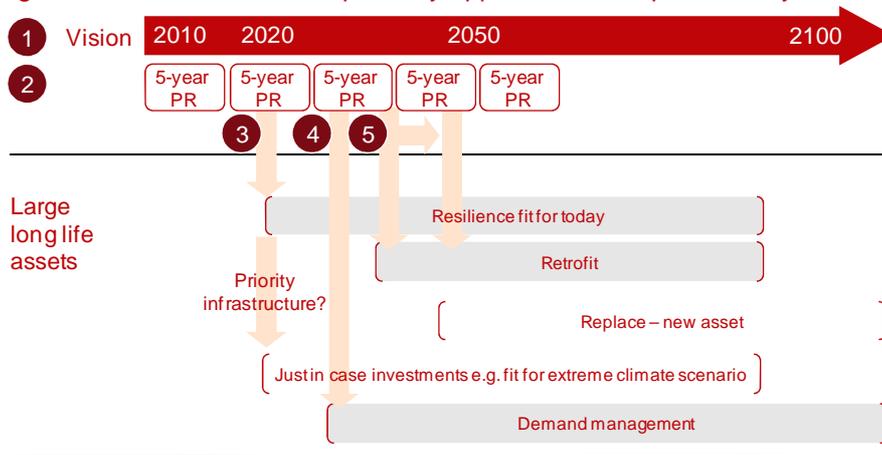
An immediate need is to identify and prioritise adaptation needs for the existing and planned economic infrastructure for the next 5-10 years. Government or regulators could encourage this by:

- Providing guidance on the use of decision pathway or real options analysis in all new, large and long life infrastructure projects on adaptation over the life time of the asset and identify how they fit into a long-term investment plan;
- Promoting value chain or supply chain mapping of key interdependent assets and issues and assess the potential weak links for adaptation or resilience work; and
- Assessing regularly whether existing incentive and penalty structures can remain fit for purpose over the long-term.

Use of decision pathway or real options analysis in all new, large and long life infrastructure projects on adaptation

Figure 9 provides an illustration of the issues that need to be considered by regulated infrastructure operators, and how the decision pathway approach can enable the evaluation of adaptation options and responses. In this illustration we focused on the decision pathway. However, within most regulatory regimes a more robust or quantitative analysis might be required, and so the use of real options valuation might be utilised. Operators in most sectors would need time to learn and make full use of these techniques, especially to incorporate interdependencies. Sharing best practices would help operators address this.

Figure 9: Illustrative decision pathway approach / real options analysis



- 1 The long-term vision would articulate what successful adaptation would look like, and the need for long-term investments to be aligned with this vision.
- 2 The 5-year pricing review (5-yr PR) would provide the key levers and mechanisms to incentivise investment, balanced against other priorities including value for money.
- 3 Large, long life assets should include a decision pathway or real options appraisal. In particular, it should map out key options and decision points, and evaluate the cost effectiveness of different pathways.
 - For example, the level of built-in resilience could depend on the cost of waiting (including the cost of retrofitting or replacement before end of life and the potential of stranded assets), and on whether the infrastructure is critical enough that it requires upfront precautionary investment.
 - Through the analysis, regulators would also be able to identify the decision points (i.e. the relevant pricing review cycle) which would help prioritisation of future work.
- 4 Some adaptation response may be included regardless of the level of built in resilience, e.g. no regrets measures such as demand management measures.
- 5 Decisions could be dependent on other assets: weak links could render some adaptation investments wasteful or ineffective. The decision whether to retrofit or replace an asset could be dependent on resilience in another sector.

Recommendation 4: Use existing regulatory levers to address adaptation

Economic regulators should ensure that appropriate consideration is given to climate adaptation challenges in the investment planning process. Balancing climate risks with efficiency and value for money concerns may require re-assessment of regulatory and planning time horizons (perhaps using mechanisms such as the water sector Strategic Direction Statement). Regulators should pay particular attention to climate change projections and assumptions and ensure that these are supported by appropriate documentary evidence as part of the regulatory review process.

Other regulators (health, safety) also have mechanisms to encourage or support adaptation. At a local level, major infrastructure projects are also expected to adhere to local planning restrictions, which help promote local resilience.

Challenges and current state

Issues raised by regulators and regulated operators during our study include:

- Short-term priorities (e.g. value-for-money) tend to overshadow long-term concerns, driven by concession/licence periods, pricing periods and/or short-term profitability needs (see also previous recommendation);
- There is difficulty in measuring and understanding customer willingness to pay for adaptation, making it difficult to justify value-for-money; and
- In the current economic and fiscal climate, value-for-money and affordability concerns could lead to adaptation measures being de-emphasised, potentially locking-in the exposure of long-term assets to climate change impacts.

However, this study found that in regulated sectors, industry regulators appear to be equipped with appropriate policy levers to incentivise behaviours consistent with economy, efficiency and equity. Regulators act upon their statutory duties determined by Government. Climate change adaptation is not an explicitly prescribed statutory duty for many regulators but is embodied within wider mandates (e.g. protection of short- and long-term consumer interest, security of supply). Regulators are equipped with the required levers (including incentives and penalties, standards and regular pricing controls) to deliver these mandates and therefore incentivise adaptation.

Each sector's regulatory framework is designed to suit the industry, and offers different benefits and risks in relation to adaptation. In particular, the level of policy and regulatory guidance varies widely – within the context of climate change adaptation some sectors may prefer stronger specification, while others may want an industry-led response, which could also depend on whether a sector is price-regulated. Sectors in which price is set through regulation are likely to react to regulators' demand for more adaptation as long as these are factored into the pricing reviews. In light touch sectors, competitive pressures would favour adaptation measures that deliver clear benefits at low costs.

For example, the water companies identify investments within the water resources planning framework with guidance from their regulator. The network companies in the regulated energy sector take a more proactive approach in setting and agreeing the technical standards for their equipment and infrastructure, with little interference from the regulator. The rail regulator interprets broad strategic guidance from the Government (High Level Output Specification (HLOS)) and regulates the industry accordingly to deliver these requirements through more specific levers and interventions. These approaches offer different benefits and risks: more direct regulation may mean that outcomes are more closely scrutinised and therefore more likely to be in the interest of consumers, but this carries the downside risks of Government or regulators not getting them right. An industry-led approach could bring out innovative and tailored solutions, but is likely to be less risk-averse than the Government or regulators.

Recommendations and practical ideas: regulators

The emphasis, therefore, should not be on revising existing regimes or regulatory structures, but on ensuring that climate change impacts and adaptation needs are adequately and consistently taken into account within each regulatory framework, and that those needs are balanced with other competing priorities. The economic regulators considered in this study have access to a number of regulatory levers, as illustrated in Figure 10. Other regulators (health, safety) also have mechanisms to encourage or support adaptation, for example the RSSB is also a key influencer of adaptation in the rail sector as it oversees the long-term safety strategy for the industry. At a local level, major infrastructure projects are also expected to adhere to local planning restrictions, which help promote local resilience.

In the longer term, economic regulators may need to consider the extent to which their existing incentive and penalty structures to preserve levels of service quality remain fit for purpose in the context of climate adaptation challenges. In particular, the extent to which the societal costs of service quality failures are represented in existing regulatory mechanisms should be explored, as should the relative merit of increasing penalties where this is a) appropriate and b) can be done in a way that does not give rise to significant premiums on user charges.

Recommendations and practical ideas: Government

The reports and disclosures requested by the Adaptation Reporting Power (ARP) provide Government with an assessment of the actions taken on adaptation. Government should monitor progress on adaptation and should consider more explicit regulatory levers or mandates if the existing provision is not delivering the expected results.

Figure 10: Regulatory levers relevant to climate change adaptation

Levers	Ofgem	Ofwat	Environment Agency	CAA	ORR	Ofcom
Investment appraisal	<ul style="list-style-type: none"> • Pricing review 	<ul style="list-style-type: none"> • Pricing review • Large capital projects 		<ul style="list-style-type: none"> • Pricing review 	<ul style="list-style-type: none"> • Pricing review 	
Licence conditions and financial penalties (for failure to adapt)	<ul style="list-style-type: none"> • Failure to meet incentives targets (e.g. customer satisfaction). • Potential to fine for legal or licence breaches (e.g. significant service failures). 	<ul style="list-style-type: none"> • Failure to meet incentives targets (e.g. SIM/ OPA). • Potential to fine for legal or licence breaches (e.g. significant service failures) • Customer service standards: compensation for foul flooding, outages and failure to supply 	<ul style="list-style-type: none"> • Licenses water abstraction: may vary or revoke licences where abstraction is causing environmental harm. • Issues drought permits. 	<ul style="list-style-type: none"> • Service quality (e.g. queue length at airports and delay penalties are routinely applied). 	<ul style="list-style-type: none"> • Penalties applied to railway operations, primarily in relation to station quality, revenue collection (to protect against fare evasion) and delays. 	
Standards	<ul style="list-style-type: none"> • Serviceability targets 	<ul style="list-style-type: none"> • SEMD: legal requirement for minimum amount of drinking water per day • Water efficiency and leakages • Water Supply (Water Fittings) Regulations: min. standards for domestic water saving fittings • Security of supply index • Target level of service for hosepipe bans • Serviceability targets • Effluent quality standards (related to flooding) 	<ul style="list-style-type: none"> • Issues water resources planning guidelines. 	<ul style="list-style-type: none"> • Service quality standards are prescribed – e.g. the target delay time that any flight should be subject to (financial penalties are applied if targets are not achieved – capped at a notional maximum). • More recently, the CAA has also adopted a financial responsibility for regulated entities – which has involved setting appropriate standards for debt and financing arrangements. 	<ul style="list-style-type: none"> • Standards are set out governing station quality, revenue collection and the timely operation of rail services. The availability of car parking spaces and CCTV coverage at stations are also articulated in a set of appropriate standards. 	

Levers	Ofgem	Ofwat	Environment Agency	CAA	ORR	Ofcom
Other	<ul style="list-style-type: none"> Ensuring security of supply of energy Failure to meet agreed price control outputs (if any) 	<ul style="list-style-type: none"> Shortfall adjustment for failure to meet agreed price control outputs (if any) Domestic supply obligation and strategic supplies for large users 	<ul style="list-style-type: none"> Advises Government on adequacy of water companies' Water Resource Management Plans. Advises Government on the adequacy of water companies drought plans. 		<ul style="list-style-type: none"> Regulation of Network Rail's stewardship of rail infrastructure Safety regulation 	<ul style="list-style-type: none"> Universal service provision
Scope for greater incorporation of adaptation	<ul style="list-style-type: none"> <i>Closer link between long-term infrastructure resilience and security of supply of energy</i> 	<ul style="list-style-type: none"> <i>Consistent approach for both water and wastewater</i> 	<ul style="list-style-type: none"> <i>Greater alignment with economic regulator and Government</i> 	<ul style="list-style-type: none"> <i>Greater integration of industry issues (airports, aircrafts, navigation etc.)</i> 	<ul style="list-style-type: none"> <i>Potential for adaptation to be part of HLOS</i> 	<ul style="list-style-type: none"> <i>Greater focus on contingency and emergency planning between networks</i>

Recommendation 5: Bridge information gaps

Government has played a central role in the provision of information on climate change impacts and risks. However, cannot be expected to provide the level of granularity required to address all the specific needs of the infrastructure sectors. Government and regulators have an important role, however, in encouraging collaboration, within and between sectors and at local levels, to address information gaps in a cost efficient manner, and the sharing of climate change information for the wider benefit of businesses and the economy.

For their part, infrastructure owners and operators should seek opportunities to reduce information gaps and costs by collaboration with other infrastructure operators, professional institutions and other sectors. Information providers could also help lower costs to operators through collaboration and pooling best practices and methods.

Challenges and current state

Government has played a central role in the provision of information on climate change impacts and risks. This information is a public good, with wide application across society and the economy, and has helped sustain the UK's leading reputation in climate change. Given the broad remit of Government-led research, the information collected and provided through key initiatives (UKCP09, upcoming UK CCRA) tends to be generic or has a wider application, but it provides the basis for infrastructure operators to undertake further information gathering and research.

Some sectors (e.g. water, ports) have invested more heavily in information gathering and research, recognising the need to tailor generic information and climate variables to identifiable impacts on their infrastructure. Others are only beginning to understand the importance of looking at future climate change impacts.

Currently many sectors work with the Met Office and other providers to identify and model specific risks, initiated and led by the sectors or companies. Some of these studies are conducted with little external input, in sectors or areas where in-house analysts and engineers have the relevant skills and capacity. Independently, third parties such as investment analysts, the insurance sector, NGOs, think tanks, the scientific or academic organisations conduct and publish analyses that contribute to the information and knowledge base.

Many operators and investors currently do not look at how climate change could affect interdependent infrastructure.

Recommendations and practical ideas: infrastructure operators

Government cannot be expected to provide the level of granularity required to address all the specific needs of the infrastructure sectors. Infrastructure operators should use Government-led research as a key source to inform their understanding on climate change, but they would need to identify and invest in research on issues specific to their infrastructure or business. Infrastructure owners and operators should seek opportunities to reduce information gaps and costs by collaboration with other infrastructure operators, professional institutions and other sectors.

Open sharing of information and knowledge would speed up the development of understanding on risks and solutions, however this has to be sympathetic to the concerns that operators are unwilling to share information freely after investing significant costs on data collection and research, or that the data may include commercially sensitive information. Infrastructure operators may need to find methods to share their knowledge without compromising commercial sensitivity – for example all companies within a sector could provide the information to an independent third party who could 'sanitise' the information prior to sharing with the sector. If costs of research are high, data could also be 'sold' rather than provided freely by an infrastructure operator.

Recommendations and practical ideas: Government

Government should maintain and update existing information provision initiatives to encourage awareness and engagement by the private sector and other stakeholders, by maintaining and updating existing efforts such as UKCIP.

Government should also encourage and coordinate efforts to address information gaps at the local and cross-sectoral levels, and ensuring that information collection and provision are carried out more efficiently. It also has an important role in ensuring the information provided is relevant and fit for purpose.

This could be done by an independent matching, co-ordination and quality assurance (QA) role, which could be undertaken by Infrastructure UK, Defra or an existing organisation or programme (e.g. UKCIP). Activities could include:

- Identifying commonalities of findings from the different research that can be replicated to other areas;
- Identifying a pool of technical experts and information providers and encouraging best practice sharing;
- Highlighting major gaps, especially on interdependencies;
- Mapping information needs to potential information providers (e.g. professional institutions, technical consultants);
- Bridging co-operation between different technical providers, e.g. where multiple providers can complement each others' skills to deliver research that addresses whole life cycles of an asset; and
- Providing a QA role for research conducted by commercial providers.

This model has been used in the developing world and on broader adaptation issues. Information portals (e.g. AfricaAdapt¹³) and independent organisations (e.g. the Climate Development Knowledge Network by the UK Department for International Development¹⁴) have been set up to facilitate sharing of knowledge and matching knowledge needs to providers. Adaptation on infrastructure might be too specific an issue to emulate these models to their full extent, thus the role could be broadened out to encompass other types of adaptation issues.

Recommendations and practical ideas: Information providers (in-house research teams, investment analysts, the insurance sector, NGOs, think tanks), professional institutions and the engineering community

The community of professional institutions and engineers could also help identify interdependencies and common issues across sectors, as they tend to work across sectors and geographies. Forging a closer working relationship between the different providers of information, technical and engineering solutions could help generate understanding and knowledge that is greater than the sum of its parts, and potentially at lower overall costs to the private sector (or other 'buyers' or users of information).

This could be done by the independent co-ordinator, or in the absence of that, leadership by one or more information providers (especially the investor or insurance community) to build a network of practitioners, identifying how different research complements or feed into one another. This has to be done in a way that encourage knowledge sharing, but also foster healthy competition.

¹³ AfricaAdapt is an independent bilingual network (French/English) focused exclusively on Africa, to facilitate the flow of climate change adaptation knowledge between researchers, policy makers, civil society organisations and communities across the continent.

¹⁴ The Department for International Development (DFID) has set up the Climate Development Knowledge Network to bring existing relevant research and information to developing countries, and funding new priority research and analysis.

Recommendation 6: Promote disclosure of climate risks

The Adaptation Reporting Power is already driving greater awareness of climate change risks and adaptation responses in the infrastructure sectors. Government, investors and insurers should all seek to build on this momentum, encouraging the sharing of knowledge and best practice in the infrastructure sectors and more widely. Transparent disclosure of how infrastructure owners and operators in the UK are responding to climate change would enable stakeholders and the public to scrutinise and assess the resilience of their infrastructure.

Challenges and current state

Infrastructure operators that we consulted during this study acknowledged that market pressure would encourage them to respond to the risks of climate change. However the consensus was that there is a relative lack of real pressure from key economic stakeholders – investors, insurers and customers – to consider long-term risks from failure to adapt to climate change. The insurance community (for example through the Association of British Insurers (ABI)) as well as a small number of leading investors, have voiced concerns around the level of resilience of UK infrastructure and assets, but this is not yet seen as a critical issue by the majority of financial stakeholders.

Investors and insurers also have varying perceptions on the extent to which operators understand their risks. Amongst the few stakeholders that are more heavily engaged on adaptation, there is a consensus that the current level of disclosure on climate change risks faced by companies on their portfolio is inadequate. Several major reporting and disclosure regulations and initiatives around climate change risks and adaptation could go some way to addressing this:

- Adaptation Reporting Power: assessment of the current and predicted risks presented by climate change and a programme of measures to address the risks highlighted;
- Carbon Disclosure Project Investor Project: disclosure of physical and market risks; and
- CDP Water Disclosure: companies that are water-intensive or face particular water-related risk to disclose risks and opportunities in relation to water.

Currently, the focus on adaptation remains weak relative to climate change mitigation. Greater disclosure would raise the awareness of 'mainstream' investors and insurers on the risks of climate change and on how companies within their portfolio understand and respond to those risks. For reputational reasons, companies would also be encouraged to take action if their risks are disclosed publicly.

Recommendations and practical ideas: Government

The Adaptation Reporting Power directs the majority of infrastructure owners in the energy, transport and water sectors to produce reports on the current and future predicted impacts of climate change on their organisation and their proposals for adapting to climate change. The public nature of the reports will allow their key stakeholders to engage and add scrutiny on how adaptation needs are being addressed. The Reporting Power could also encourage major infrastructure companies to consider interdependencies. Over the longer term, the Reporting Power can help maintain the quality and consistency of information provision, and share learnings with other voluntary reporting initiatives such as the CDP.

Recommendations and practical ideas: investors and insurers

Recent experience on carbon and climate risk reporting more generally also suggest that greater disclosure will help increase awareness, address information gaps and identify and prioritise adaptation responses and that peer pressure would encourage companies to follow best practice.

In the corporate sector more generally, the Carbon Disclosure Project (CDP)¹⁵ has been leading the push for greater disclosure. The primary focus is on emissions reporting and mitigation actions, but the information requests also include questions on the physical risks of climate change. ClimateWise, a collaborative insurance initiative through which insurers report and respond to the risks and opportunities relating to climate change, also looks at adaptation (albeit targeted at the insurance sector rather than the companies or infrastructure they insure). In the US, the Securities and Exchange Commission has provided public companies with interpretive guidance on SEC disclosure requirements on climate change, which includes the physical impacts of climate change among other issues.

The rising number of disclosure initiatives could help catalyse companies into taking action, but will also add to the reporting burden (and costs) for companies and could lead to ‘climate change initiatives fatigue’.

Recommendations and practical ideas: use of information

It is therefore important to build on and enhance existing initiatives and avoid unnecessary duplication. Information reported by companies can be used to:

- Identify common risks and adaptation measures;
- Identify interdependencies of companies within the portfolio an investor / insurer;
- Publicise best practices on adaptation both within and across sectors, and “name and shame” of companies that are failing to adapt; and
- Influence companies that fail to report or a reporting company’s decisions on areas that lack action.

Some of these are expected to arise from the publication of the reports in response to the Adaptation Reporting Power, or are already being done through the reported information to the Carbon Disclosure Project.

Figure 11: Information disclosure on climate change adaptation

Role	Government	Voluntary organisations	Investors / Insurers
Examples of initiative / regulation	Adaptation Reporting Power	Carbon Disclosure Project	Direct information requests
Reporters	Selected infrastructure operators and regulators	Voluntary, open for all sectors	Infrastructure operators within portfolio
Potential use of data	Individual scrutiny of company Publicity of best practices on adaptation; or naming and shaming laggards	Analysis of common identified risks and adaptation measures Publicity of best practices on adaptation; or naming and shaming laggards	Individual scrutiny of company Identification of interdependencies of companies within the portfolio
Reinforcing effect	Publicity of best practices on adaptation; or naming and shaming laggards can reinforce pressure to act Monitoring or verification by independent bodies add credibility to the reported information		
Duplicative effect	Potential climate change initiatives fatigue leading to low response Different reporting format or scope could lead to additional costs to companies without corresponding benefits		

¹⁵ See <https://www.cdproject.net/en-US/Programmes/Pages/overview.aspx> for details on CDP.

Recommendation 7: Promote good practice through procurement and financing

Government should promote good practice in adaptation through public procurement of infrastructure and infrastructure services. Government should also encourage Government-owned financing institutions to show leadership through their investment approval processes. The Green Investment Bank (GIB) plans may provide an opportunity to give more profile to adaptation actions.

Challenges and current state

As discussed in the previous recommendation, infrastructure operators are likely to respond to the risks of climate change if demanded by their users or investors. Government, as a key buyer or investor for many types of infrastructure and infrastructure services, needs to lead the market by demanding the consideration of adaptation. A guidance to Government departments, *Adapting Your Procurement*¹⁶, are aimed at helping capital projects to be procured in a way that “ensures they are designed, built and operated to be resilient to climate change over their expected lifetime, e.g. 10 years for a road surface, 50 years for a school and up to, and over, 100 years for infrastructure such as bridges”.

Recommendations and practical ideas: Government and providers of finance

There is a potential for public procurement bodies of infrastructure and infrastructure services, including the proposed Green Investment Bank, to encourage adaptation through the procurement process. Procurement departments regularly incorporate environmental criteria in their decisions, and this process could be expanded to consider adaptation. Lenders and investors could also adopt the same approach.

Adaptation could be encouraged throughout the asset life, for example:

- Decision to finance
 - Incorporate as part of the due diligence process an assessment of the project against specific climate change risks relevant to the infrastructure;
 - Include as a filtering or selection criteria when considering infrastructure project finance the extent to which adaptation has been taken into account;
 - Apply particular focus or preference to infrastructure projects that address cross-sectoral adaptation;
 - Apply different rates (for loans) for well-planned and adapted infrastructure, to account for the greater resilience and lower exposure to risks.
- Ongoing relationship
 - Include as part of the terms and conditions of project finance or during renewal of financing contracts the need to address long-term climate change risks (e.g. demonstrate that climate change is part of the risk register);
 - Require reporting and continual monitoring of climate change risk exposure of infrastructure provider.

¹⁶ See <http://www.defra.gov.uk/environment/climate/programme/government-systems.htm>

Recommendation 8: Encourage innovative approach to financing cross-sectoral adaptation

Adaptation measures that help reduce climate change risks to several parties may suffer from free-ridership problem, as individual stakeholders may be unwilling to fund their share of the costs of adaptation. Pooling funding from different parties, or using financial instruments that help share the costs and risks, could help catalyse adaptation projects that addresses cross-sector climate change risks. There is scope for innovative approaches to the financing of adaptation and the GIB may be able to play a role in catalysing this.

Challenges and current state

Adaptation measures that help reduce climate change risks to several parties may suffer from free-ridership problem, with private sector beneficiaries unwilling to fund their fair share of the costs, leaving the public sector to should the burden. For example, currently many flood defence projects are funded publicly, such as the Thames Barriers. As public funding is increasingly limited, however, more innovative mechanisms need to be used to lever private funding for cross-sectoral adaptation.

Recommendations and practical ideas: Government

Pooling funding from different parties, or using financial instruments that help share the costs and risks, could help catalyse adaptation projects that addresses cross-sector climate change risks.

The role, responsibilities and resource of the proposed Green Investment Bank are likely to be targeted at climate change mitigation, but its investments need also to be compatible with adaptation. In particular the Green Investment Bank could consider the use of financing structures that:

- Use public funding to remove parts of the risks or provide the incentives to fund adaptation projects that would otherwise not have been carried out;
- Lever sufficient private contribution by targeting specific stakeholders, e.g. the insurance community.

Recommendations and practical ideas: financial services industry

The financial services sector could also play a key role in encouraging innovation, leveraging existing risk transfer instruments that also manage risks. Catastrophe bonds or cat-bonds, for example, help transfer risks of losses to investors as a result of a “catastrophic” event. Innovative variations could build in an adaptation element into cat-bonds, or make the rating or pricing cat-bonds better linked to the level of built-in adaptation.

Another example that is being trialled in other areas is a Social Impact Bond – where the Government pays Social Impact Bond investors a return on improved social outcomes, in exchange for the required financing to fund preventative measures. This has been used to fund preventative measures on health and social issues that could then lead to reduced public spending¹⁷. An equivalent Adaptation Impact Bond could generate required financing for adaptation measures, with the savings from reduced damage or service interruption returned to investors.

¹⁷ For example, preventative measures to reduce accidents in the elderly could result in lower hospital admission rates. The savings in the costs of care are returned to investors as returns on the bonds.

Part 2: Sector findings and recommendations

3 UK policy and regulatory framework

3.1 Overview

The policy and regulatory framework governing the provision of infrastructure is complex. It differs between type of infrastructure (e.g. road, rail, ports, ICT) and reflects the different ways in which the infrastructure providers themselves are structured. Where the infrastructure is owned and/or operated by a monopoly provider who has no obvious direct competitor (e.g. airports and water services), these sectors are regulated by an economic regulatory body to ensure best value for consumers and appropriate levels of service quality. Sectors where there is competition (e.g. ports and power generation) are unregulated from a competition perspective, although they remain subject to other regulations and policy directives governing issues such as safety. Usually, however, this type of regulation has no material role in determining investment and asset management strategy – the theory being that operators will act efficiently in a competitive market.

Figure 12: Sectors covered in this study

	Provided by Government	Economic regulation	No economic regulation
Sectors	<ul style="list-style-type: none"> Road 	<ul style="list-style-type: none"> Energy distribution and transmission Water and wastewater Rail Airports Telecommunications 	<ul style="list-style-type: none"> Power generation Ports IT
Market structure	<ul style="list-style-type: none"> Public good 	<ul style="list-style-type: none"> Monopoly or network structure 	<ul style="list-style-type: none"> Competitive industries
Funding sources of infrastructure	<ul style="list-style-type: none"> Government 	<ul style="list-style-type: none"> Private, but determined or influenced by regulators 	<ul style="list-style-type: none"> Private
Implications on adaptation	<ul style="list-style-type: none"> Direct role for government 	<ul style="list-style-type: none"> Potential role for regulators if market forces fail to incentivise adaptation 	<ul style="list-style-type: none"> Reliance on market forces to incentivise adaptation Intervention would take other forms of policy and regulations (rather than through the economic regulator)

The policy and regulatory framework is provided by a combination of:

- Government policy and legislation: the articulation and delivery of policy goals is the responsibility of the relevant Government Department, within an overall legislative context set by Parliament and the EU. Parliamentary scrutiny is provided through Committees such as the Public Accounts Committee and by the National Audit Office. In some sectors (such as transport) a range of local bodies are involved in the delivery and maintenance of infrastructure;
- Regulation:
 - Economic regulators: these govern the operation of the regulated utility providers – in the water (Ofwat), energy (Ofgem), telecommunications (Ofcom) and transport (ORR, CAA) sectors. These regulators have remits to promote the interests of customers through the efficient delivery of infrastructure services and the promotion of service quality. Where levels of service quality are not fit for purpose, regulators typically have the power to impose penalties and incentives on regulated utilities;
 - Other regulatory bodies: A range of other regulatory bodies act to preserve statutory obligations and practices that apply to infrastructure sectors throughout the UK. An example is the Health and Safety Executive, which has a role in ensuring the safe operation of assets;
- Oversight by consumer groups and independent bodies. There are a range of consumer groups and bodies that monitor the infrastructure planning, delivery and maintenance process on behalf of users. Additionally, the

Competition Commission acts as an independent appeals authority for regulatory settlements proposed by economic regulators.

More detail on the policy and regulatory framework for individual sectors is provided in subsequent sections.

3.2 Current challenges to the delivery of resilient infrastructure

Policy makers, regulators and private investors face a range of complexities in addressing adaptation to climate change. These include:

- Information asymmetries: a lack of information or awareness of climate impacts;
- The 'public good' nature of some adaptation measures: where adaptation infrastructure funded by one party benefits all or other sections of the community;
- Behavioural barriers: adaptation decisions are complex, often involve very long time horizons and significant uncertainty. Long-term capital programmes tend to be heavily discounted and financing costs can therefore mean that longer term issues and complexities are not addressed until it becomes business-critical to do so; and
- Adaptive capacity. Some organisations and bodies may lack the ability to respond to climate change because of financial or other constraints.

In addition to these complexities, there are also distributional issues to consider. Climate change is likely to have different impacts across sectors, regions, and social groups, making it difficult to identify beneficiaries and stakeholders. The costs of insufficient resilience are likely to extend well beyond the infrastructure providers themselves because the broader economic and social costs of service quality failures and disruptions are typically not borne in full by them. Meeting the challenges presented by climate change therefore requires a robust policy and regulatory framework – in both its design and its implementation.

It is possible that the costs of trying to prevent all losses could exceed the likely benefits, and efficiency might well be achieved by an outcome that effectively recognises some residual losses. This approach is not inconsistent with the regulatory philosophy that governs UK regulated utilities more generally:

- Effectiveness: regulation and intervention should be effective and correct for a prevailing market or non-market failure. This requires a good understanding (ex ante) of the implications of different barriers and failures and intervention at the most appropriate level to address local, regional, national and international barriers;
- Economic efficiency: the ability of a regulatory instrument to achieve the greatest benefits at the lowest cost, once uncertainty is appropriately incorporated in the decision making;
- Equity or fairness: the distributional impacts of a regulatory instrument. Different measures will have different effects on different sections of society or over different generations. Care should be taken to avoid creating perverse or conflicting incentives.

There is however a series of practical challenges for regulators and policy makers in promoting the delivery of robust, climate-resilient infrastructure. These are considered below.

Uncertainty and risk

There are two important aspects to any adaptation decision: what to do and when to do it. This typically involves comparing the adaptation costs with projected short and long-term benefits. Despite considerable progress in our understanding of the climate system, there will always be an inherent element of uncertainty about the likelihood and

impact of different climate scenarios on society and the environment; and the existence of tipping points, feedback mechanisms and limitations of existing models means that there are a wide range of possible future climatic scenarios.

A common issue for adaptation lies therefore in dealing with uncertainty, and defining the timescale and nature of adaptation responses in the face of a continually changing environment and developments in scientific knowledge.

A variety of approaches have been proposed to support decision-making in the presence of pervasive uncertainty. Approaches that are likely to be relevant here include:

- Identifying and implementing ‘no-regret’ measures that would be justified under all possible future climate scenarios; and ‘win-win’ measures, that reduce the vulnerability to climate change while meeting other policy objectives, including climate change mitigation; and
- Decision pathway approach or Real Options Analysis (ROA), which incorporate flexibility as part of the decision making process (i.e. as an opportunity cost). ROA can be used to look at the value of deferring a decision when:
 - The investment is irreversible or implies large sunk costs;
 - There is uncertainty about the payoffs of the investment;
 - The investment can be delayed; and
 - More information about payoffs becomes available during any waiting period.

Promoting efficient investment

Ultimately, regulators and policy makers both want to promote investment in efficient infrastructure – meaning that investment must be made in a way that represents best value for users/customers. Sometimes this implies a ‘trade off’ between the provision of a fully robust asset and one that remains fit-for-purpose, but more affordable. Regulators and private investors make this trade off within the current regulatory regime on a day-to-day basis and generally seek to ensure that customers are involved to provide a perspective on the balance between quality and value for money.

There are inevitable tensions in this process. Regulators are understandably anxious to avoid the ‘gold plating’ of infrastructure – whereby over-investment is likely – leading to higher customer charges and enhanced returns for infrastructure providers. The decision making process is therefore complex and subject to judgement around the type of infrastructure that delivers ‘best value’.

There are, however, examples of infrastructure being provided on a ‘no regrets’ basis – whereby assets are judged to provide sufficient or alternative benefits regardless of the outcome of the climate scenario. Circumstances such as these are not common-place, and tend to be applied where assets provide benefits that promote social, environmental, or economic objectives. For example, water companies may need to improve or secure water supply in response to potential water scarcity, but they may need to do so anyway as part of compliance with existing environmental legislation or to meet rising demand (see case study on United Utilities).

There are also examples of infrastructure being planned and delivered in a way that considers uncertainty and risk in the decision making process. In particular, the use of decision pathway or ROA to identify risk and risk mitigation measures is a process that is gaining credence amongst regulators and policy makers. The approach supplements the advice given in the HM Treasury’s ‘Green Book’¹⁸. The Green Book guidance has laid out in depth appropriate methodologies for dealing with uncertainties around climate change, with strong preference towards a real options analysis approach.

¹⁸ HM Treasury, ‘The Green Book – Appraisal and Evaluation in Central Government’, TSO

Adopting a decision pathway or having a 'real option' means building in the possibility at a certain period in the lifetime of a project to make a decision without committing to this at the beginning. In practice, the decision pathway approach and ROA incorporate a dynamic learning mechanism which provides the opportunity to phase investments and stage key decisions, to assess the costs and benefits of options at a later stage, for example by:

- Investing now and making follow-up investments later, subject to the progress of the original project (a growth option);
- Abandoning the project if losses outweigh the benefits (an exit option); and
- Waiting and learning before investing (a timing option).

Long-term infrastructure planning is commonly deployed throughout regulated utilities, whereby incremental infrastructure follows a Long-Term Investment Plan (LTIP) which provides a framework for investment over a period of 20-40 years into the future. But the application of this approach in the context of adaptation requirements suffers a number of challenges:

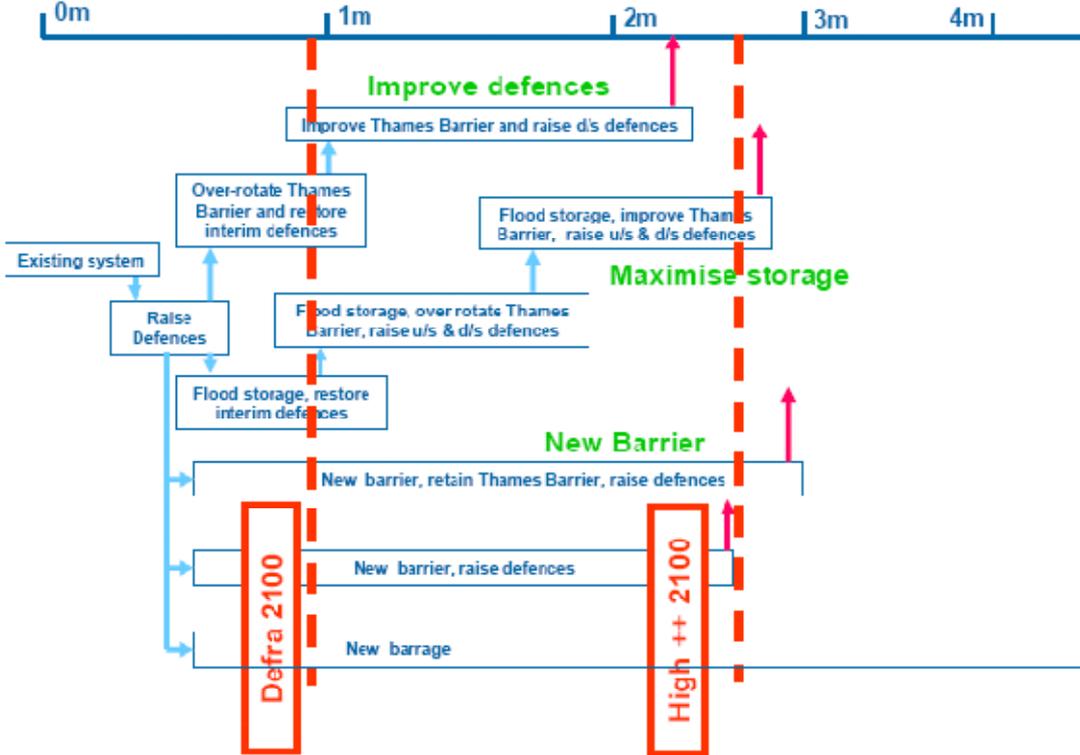
- The stochastic nature of climate patterns: Uncertainty may not be significantly reduced in the future because of the inherently non-linear nature of climate hazards and impacts.
- Irreversibility: Climate change might result in irreversible damage. Due to uncertainty over tipping points (after which climate stresses have irreversible consequences) and low-probability catastrophic events, delaying decisions might lead to irreversible damage.
- Timing: To be effective, the analysis requires a good understanding of when the cut-off points will occur. An inaccurate estimate of these points would ultimately affect the outcomes of the appraisal.
- Costs of information: Gathering information incurs a cost, and given the high level of uncertainty around climate change, significant investment in information gathering does not ensure the complete resolution of uncertainty.

Deploying ROA throughout the long-term planning process represents an opportunity to articulate these risks and uncertainties. This in turn would promote efficiency by internalising adaptation risks and requirements in the development and maintenance of infrastructure.

One example of the application of real options analysis is that of the Thames Estuary 2100 (TE2100) project. The project mapped out a set of decision pathways for a series of infrastructure assets to 2100, laying out available measures or options. This helps to demonstrate interventions that were most attractive now without constraining future options.

Figure 13: Thames Estuary 2100 decision pathway approach

Maximum water level rise:



Note:

Each box represents one or more portfolios of responses

2008 Climate Change Scenarios and implications on options

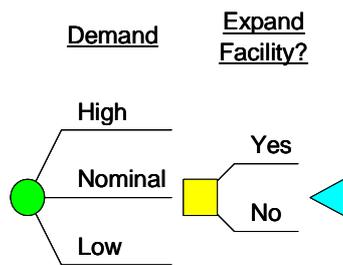
Use of real options modelling

Real options provide more flexibility to an investor by allowing key decisions to be deferred.

In an investment subjected to uncertainty, there is a range of potential outcomes. Investors typically look at the distribution of the outcomes and the expected NPV when making their decisions.

In some types of projects, particularly large, long life span capital projects, not all decisions could be determined before commencement of the project, or the level of uncertainties involved may mean that making early decisions that lock-in specific outcomes could bear an unacceptable level of risks. There could also be a number of decisions that can only be made sequentially. These decisions would collectively determine the outcome of an investment. In the example here, an investor could expand the generation capacity of a power plant at a later stage depending on the level of additional demand, for example from additional cooling and air conditioning needs as a result of warmer summers.

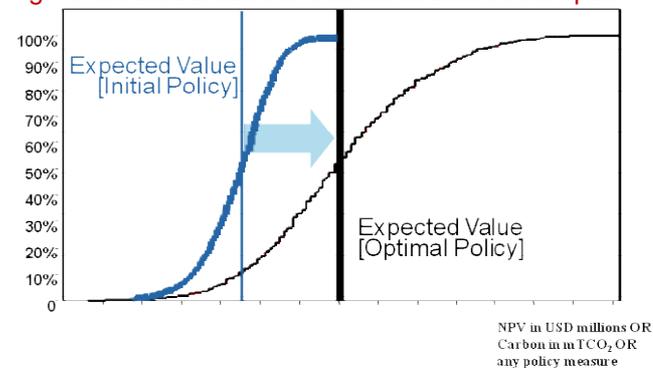
Figure 14: Real options: staging key decisions and modelling uncertainties



Illustrated below is the distribution of net present value under two different options. The first (initial policy) could correspond to a scenario where there is no expansion of generation capacity, and the second corresponds to one where there is an expansion (optimal policy).

The outcomes (i.e. returns to the investors) would still be subject to uncertainties, but ROA allows the modelling of the expected value or outcome given a pathway of decisions relative to a baseline policy. The results show that the being able to expand the facility would yield higher expected value. An investor can use the results to determine at the start of the project whether to build in the potential for capacity expansion, for example by securing spare capacity.

Figure 15: Distribution of outcomes with a real option



Source: PwC

3.3 Ownership models and investment timeframes

UK infrastructure is provided by a range of owners and operators. Some of these are subject to economic regulation (such as some transport providers, energy, water and telecommunications companies), but others (such as privately owned ports) manage and determine their own investment strategies without intervention or independent review. The basis for the absence of economic regulation in key infrastructure sectors is that of the perceived existence of competition. Competition from alternative infrastructure providers should in itself be sufficient to promote efficient investment. An example would be a port which failed to invest adequately in infrastructure that was resilient would be likely to lose business to a competitor who was better prepared.

Ownership models also complicate any cross-sectoral response to adaptation. In the transport sector for example, some infrastructure providers operate on fixed-term concessions (such as High Speed Rail 1 – the company which operates the track between London and the Channel Tunnel) which typically grant the operator rights for a period of 30+ years. With no guarantee of continued rights of operation and revenue collection after this concession period, the operator will inevitably focus on adaptation requirements arising during the time of the concession. However adaptation requirements could imply the need for longer term infrastructure planning.

The timeframe over which concessions are granted is therefore an important consideration in determining whether and how which long-term adaptation challenges can be factored into the infrastructure investment and renewal process.

There are mechanisms available to overcome the transitional problems associated with concessions and similar timeframe restrictions. For example, UK economic regulators set charges on a rolling five-yearly basis¹⁹ but typically require the development and management of assets to be conducted according to a LTIP which extends some years (typically 20+) into the future. Capital expenditure is effectively managed according to the LTIP in a way that is consistent with a longer term strategy, and still funded in 5 yearly packages.

Managing infrastructure according to a long-term plan is essential to deliver the right infrastructure to meet future challenges such as adaptation. It is also an essential element of the funding of the regulated infrastructure. The UK regulatory philosophy remunerates capital expenditure according to standard regulatory depreciation principles – meaning that large scale ('lumpy') capital expenditure is added to a notional asset base, and depreciated over an appropriate timeframe (for example, 100 years+ for some UK airport runways). This is done to avoid issues of inter-generational equity, whereby users of today would pay a disproportionate amount for long-term adaptation infrastructure, should consumer prices be adjusted to pay for capital investment over a single (five yearly) review period.

3.4 Experience in other countries

The challenges posed by climate change are not limited to the UK alone, and other countries and regions have responded in addressing the risks to their infrastructure base. The climate change risk most commonly focussed on is water scarcity and the impact of climate change on coastal regions and cities. Figure 16 provides a number of examples of how other developed economies are responding to the challenges of climate change on infrastructure. Figure 17 provides a summary of the extent to which climate change adaptation has been identified and addressed in national plans as of 2006 (substantial changes across most countries since then) which provides a rough indicator of the relative leaders on adaptation, showing that the UK is relatively advanced in addressing adaptation.

¹⁹ Referred to as a Quinquennial review.

Figure 16: Examples of infrastructure adaptation in other developed economies

Country/region	Examples of institutional change/actions to address climate resilience or adaptation	Examples of adaptation policies and actions undertaken or planned
Australia	<ul style="list-style-type: none"> Infrastructure Australia (responsible for the development and implementation of a strategic blueprint for Australia's future infrastructure needs) identified one of the seven key objectives identified is adaptable and secure water supplies (more adaptable and resilient water systems to cope with climate change) Climate Change Adaptation Infrastructure Project (Australian Homeland Security Research Centre): to advance and disseminate best practice on climate change adaptation in partnership with the private sector, governments, non-government organisations and research community. 	<ul style="list-style-type: none"> Key activities by Climate Change Adaptation Infrastructure Project include developing a standard on Climate Change Adaptation System for Organisations, developing training course on adaptation for electricity networks, railway infrastructure and emergency services for the Department of Climate Change. Water trading in Australia was legislated in the 1980s as a demand side management approach to alleviate emerging water scarcity.
Canada	<ul style="list-style-type: none"> Infrastructure Canada (INFC) Other partners on infrastructure adaptation include federal government departments and agencies: Natural Resources Canada, Environment Canada, Fisheries and Oceans Canada, Transport Canada, Industry Canada, Agriculture and Agri-Food Canada, Parks Canada, Health Canada, the National Research Council, Indian and Northern Affairs, and Public Safety and Emergency Preparedness Canada. 	<ul style="list-style-type: none"> INFC considers adaptation in its various funding programs. E.g. applicants to the Canadian Strategic Infrastructure Fund (CSIF) are required, under the program's policy leveraging framework, to demonstrate how their project addresses climate change impacts and adaptation, and may be required to take certain measures to address these issues. Most CSIF projects, except for some broadband projects, also trigger an environmental assessment under the Canadian Environment Assessment Act
Denmark	<ul style="list-style-type: none"> Cross-Coordination Forum for CC Adaptation (KOK) with Coordination Unit for Research in CC Adaptation (KFT), Information centre (web portal) 	<ul style="list-style-type: none"> Road regulations and railway standards are being/will be reviewed and revised with consideration of expected climate changes. Danish Environmental Protection Agency published guidelines in 2007 giving municipalities new tools for thinking across the municipal sectors and taking climate change into account in connection with construction and operation of sewage systems and sewer renovation. Consideration of change in payment regulations to incentivise alternative surface-water drainage methods
Japan	<ul style="list-style-type: none"> Ministry of Land, Infrastructure, Transport and Tourism is tasked with Japan's adaptation strategies to climate change adaptation with focus on water-related disasters 	<ul style="list-style-type: none"> Issuing series of "Practical guidance on strategic climate change adaptation planning"
New Zealand	<ul style="list-style-type: none"> National Infrastructure Unit (NIU) issued National Infrastructure Plan (March 2010) which acknowledged the impacts of climate change as one of the long-term key trends that need to be addressed 	<ul style="list-style-type: none"> Information provision including: technical manuals, local government planning guidance and case studies of best practices
US	<ul style="list-style-type: none"> Climate Change Adaptation Task Force (set up by the White House Council on Environmental Quality (CEQ), the Office of Science and Technology Policy (OSTP), and the National Oceanic and Atmospheric Administration (NOAA)): includes representatives from more than 20 Federal Agencies to develop Federal recommendations for adapting to climate change impacts both domestically and internationally 	<ul style="list-style-type: none"> State-level adaptation planning in progress (see California as an example)
California	<ul style="list-style-type: none"> An Infrastructure working group analyzed both impacts and strategies for California's infrastructure. 	<ul style="list-style-type: none"> The initial focus on infrastructure was on transportation and energy, including bi-weekly meetings from representatives from Caltrans and the California Energy Commission with other sectors to develop strategies for adaptation, and workshops with stakeholders. Ensuing adaptation focus for the infrastructure sector will expand to include urban landscape, existing and proposed development, and waste systems.

Source: Websites of national infrastructure bodies and national adaptation plans

Figure 17: Coverage of impacts and adaptation in National Communications in OECD countries (2006)

		Climate change impact assessments			Adaptation options and policy responses				
		Historical climatic trends	Climate change scenarios	Impact assessments	Identification of adaptation options	Mention of policies synergistic with adaptation	Establishment of institutional mechanisms for adaptation responses	Formulation of adaptation policies/ modification of existing policies	Explicit incorporation of adaptation in projects
Early stages of impact assessment	Iceland		○	○					
	Portugal	○		○					
	Hungary			○					
	Latvia	●		○	○				
	Liechtenstein		○		○	●			
	Germany		○						○
	Russia			○	○				
Advanced impacts assessment, but slow development of policy responses	Slovenia		○	●					
	Estonia		●	●					
	Mexico	●	●	●					
	Lithuania	●	●	●					
	Japan		●	●					
	Finland	●	●	●	○				
	Poland		●	●	○				
	Romania	●	●	●	○				
	Denmark	●	●	●	○				●
	Korea	●	●	●	○				
	Greece	●	●	○	○				
	Czech Republic		●	●	○				
	Belarus		●	●	●				
	Bulgaria	●	●	●	●				
	Canada		○	○	●				
	Croatia		●	●	●				
	Slovak Republic	●	●	●	●				
	Ukraine		○	●	●				
	Norway		○	●	●	○			
	Sweden		●	●	●	○			
	Belgium		●	●	●	○			
	Ireland	●	●	●	●	●			
	Spain		●	●	●	●			
	Austria		●	●	●	●			
France		●	●	●	●				
Switzerland	●	○	●	○	●				
Italy	●	●	●	●	●				
Moving towards implementing adaptation	Netherlands			○	○		●	●	●
	United States	●	●	●	●	●	●	●	
	New Zealand		●	●	○	○	○	○	
	Australia		●	●	●	○	○	○	
	United Kingdom			○	○	●	●	○	

Legend:

Coverage:

	Extensive discussion
	Some mention/ limited discussion
	No mention or discussion

Quality of discussion:

●	Discussed in detail, i.e. for more than one sector or ecosystem, and/or providing examples of policies implemented, and/or is based on sectoral/national scenarios
○	Discussed in generic terms, i.e. based on IPCC or regional assessments, and/or providing limited details/no examples/only examples of planned measures as opposed to measures implemented
◐	Limited information in NCs, but references to comprehensive national studies

Source: Progress on Adaptation to Climate change in developed countries, an analysis of broad trends, Frédéric Gagnon-Lebrun and Shardul Agrawala, 2006

4 Energy

4.1 Overview

The UK electricity and gas sectors have similar structures, described further below. Broadly, the activities of generation, shipping and supply are competitive, whilst the monopolistic activities of transmission and distribution are regulated. Ofgem is the regulatory authority for gas and electricity. This study covers the power generation sector as well as the transmission and distribution networks for both gas and electricity in the UK.

Electricity

Generation of power is dominated by large centralised power stations supplemented by renewable generation and the England-France interconnector. Small-scale distributed generators tend to feed power directly into the distribution networks rather than the transmission system.

Transmission of the power across Great Britain is via the National Grid in England and Wales and Scottish Transmission system in Scotland. Power is transmitted via c.25,000km of high voltage (400kV / 275kV) cables designed to minimise losses. The transmission systems are operated by the System Operator (SO), National Grid Electricity Transmission plc (NGET). Electricity transmission assets are owned and maintained by regional monopoly Transmission Owners (TOs): NGET for England and Wales, Scottish Power Transmission Limited (SPTL) for southern Scotland, and Scottish Hydro-Electric Transmission Limited (SHETL) for northern Scotland. Distribution of power to domestic and commercial consumers is through 14 regional Distribution Network Operators (“DNOs”) over c.800,000km of overhead and underground cables and step down transformers (132kV and below).

The sale of power to end consumers is carried out by multiple licensed power suppliers across the UK, some of who are independent and some that are part of vertically and/or horizontally integrated companies.

Gas

Producers operate Offshore Facilities in over 100 fields beneath the sea around the British Isles. In addition, Liquefied Natural Gas (LNG) is delivered to specific terminals (e.g. Isle of Grain) by sea. Gas transmission is undertaken via the high pressure National Transmission System (NTS), which is owned and operated by National Grid. The NTS consists of more than 6,600km of pipeline operating at pressures of up to 85 bar. The NTS supplies gas to 40 power stations, a small number of large industrial consumers and the twelve Local Distribution Zones (LDZs), which are organised in eight Distribution Networks (DNs). The DNs contain pipes operating at lower pressure which eventually supply the consumer. Historically the DNs and NTS were in common partnership. In 2006 four of these networks were sold to other companies. Therefore at present distribution companies include National Grid Gas Distribution, Wales and West Utilities, Northern Gas Networks and Scottish and Southern Energy.

4.2 Summary of climate change impacts

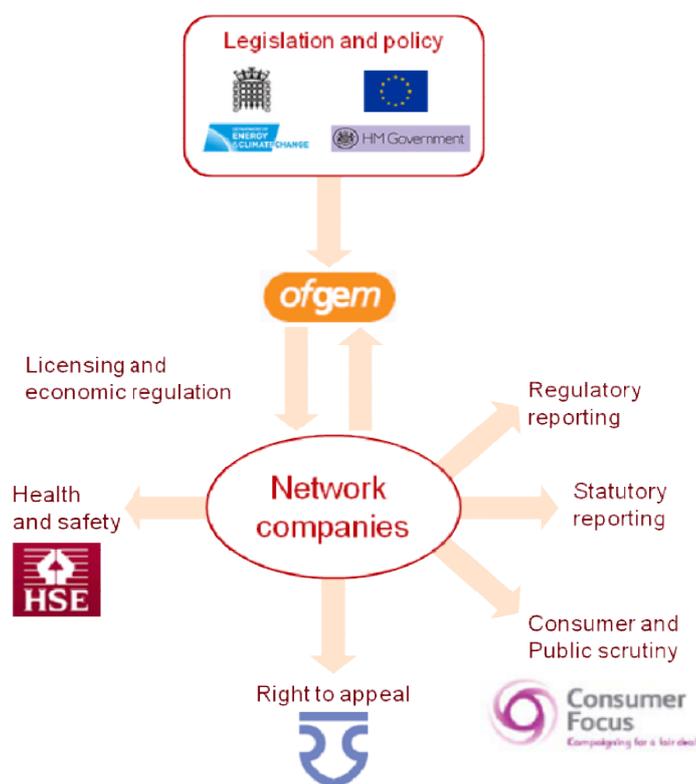
The study by URS conducted as part of the Infrastructure and Adaptation Project has identified a number of potential challenges arising from climate change including vulnerabilities to increases in precipitation, wind intensity and frequency of storms. This section provides a brief summary of those impacts and the key implications on energy infrastructure.

Principal climate change risks	Implications for infrastructure
Fossil fuel generation and nuclear	
<ul style="list-style-type: none"> • 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 • Access to water for cooling 	<ul style="list-style-type: none"> • Nuclear facilities require water cooling and are located close to the coast, making them vulnerable to coastal erosion and flooding from sea level rise. Nuclear site operators for existing sites are required under the terms of their licence to provide a high standard of flood protection (e.g. a one in 10,000-year flood risk) and to provide protection against other possible effects of climate change and extreme weather events. New sites are subject to the Strategic Site Assessment process which includes consideration of flood risk management, tsunami and storm surge and coastal processes. • Long-term flood risk to fossil fuel plant is less pronounced due to greater flexibility in site selection and tends to be considered in the ordinary course of business. • Fossil fuel power plants will need to adapt existing technology to maintain efficiency levels to maximise energy output of combustible material, for example developing additional infrastructure to maintain optimal temperature of combustion. • Generation availability may be limited by shortage of cooling water, temperature of cooling water at inlet or high ambient air temperatures.
Renewable energy	
<ul style="list-style-type: none"> • Loss of efficiency of, and storm damage to, renewable energy sources due to increased storminess 	<ul style="list-style-type: none"> • The design of wind turbines will need to take into consideration the potential damage from extreme weather events. • The electricity grid will need to be enhanced to address increasing variability in both supply and demand patterns. • Wave and tidal energy may also be impacted by increased or more extreme storms. Significant changes in tidal flows could impact (positively or negatively) the economic viability of tidal and wave power generation schemes
Energy distribution	
<ul style="list-style-type: none"> • Reduced capacity of electricity distribution network due to increased temperatures and precipitation / storminess • Flood risk including surface water and fluvial flooding on substations 	<ul style="list-style-type: none"> • Increased temperature presents risks to substations, with reduced ability of distribution networks to cope with the incremental increases in temperature if capacity thresholds are at risk. • Substations are vulnerable to damage from extreme weather events such as flooding, and subject to flood protection standards. Flooding and damage to the grid and primary substations could lead to medium term (weeks to months) loss of supply to large numbers of customers. • The majority of electricity network assets are procured to European or International Standards, which set out ranges of climatic conditions, such as ambient temperatures, ice and wind loads etc. in which the equipment are operational. As a consequence many of the UK assets have the capability to operate at higher temperatures and in more extreme weather, although there may be some impact on performance.
Fuel processing and storage	
<ul style="list-style-type: none"> • Potential for flooding from increased storminess, sea-level rise and storm surges 	<ul style="list-style-type: none"> • Gas, oil and biomass shippers may not be able to dock successfully, leading to short-term fuel availability issues. Similarly, shippers may not be able to load oil and gas from off-shore facilities due to storms at sea. • Greater risk of damage to coastal storage and terminals for oil and gas from increased storm events, and sea level rise.

4.3 Regulatory context and adaptation

The delivery of UK energy policy goals are the responsibility of the Department of Energy and Climate Change (DECC), with the legislative framework provided by the EU and HM Government. Parliamentary scrutiny is provided through bodies such as the Energy and Climate Change Committee, the Public Accounts Committee and the Regulatory Reform Committee.

Figure 18: Regulatory framework for energy network companies



Transmission and Distribution Companies are licensed and regulated by the Gas and Electricity Markets Authority (GEMA) which operates through its executive body Ofgem. They are regulated via price controls, currently set every five years by Ofgem. The price control mechanism defines an allowed level of revenue for each network company across the five year period based on Ofgem's view of the level of expenditure required to operate an efficient network and generate a reasonable level of return to the company's shareholders. The allowed revenue is calculated using a "building block" approach. The building blocks of allowed revenue include operating expenditure, pensions, tax, an allowance for depreciation, and a return on the Regulatory Asset Base. The allowance for capital expenditure is provided ex-ante based on a detailed efficiency and performance review of each company's historical and forecast capital expenditure. The operating cost allowance is set following a normalisation of historical operating costs and consideration of efficiency improvements and upward cost pressures for some elements of operating costs.

Investments which have been deemed efficient by the regulator enter the Regulatory Asset Base (RAB), and the network company earns a return on the RAB (at the WACC set by the regulator), as well as an allowance for depreciation. The

network assets are typically depreciated over 20 years, although there are different approaches adopted across the different networks due to the legacy policy decisions.

Under the current regime, as many assets are likely to last for 20 years or more, ensuring the resilience of these assets should be in the interest of network companies. However, this needs to be balanced against the ability to recover adaptation costs through the RAB – therefore the need to demonstrate that any such investment is cost-effective, efficient and value for money. While adaptation is not an explicit statutory duty, Ofgem’s remit to protect the interest of consumers, both current and future, and ensure the long-term security of supply to the UK should mean that efficient and value for money adaptation solutions that can secure the long-term resilience of network assets are also taken into account.

In addition, network companies are required to publish long-term development statements outlining their investment requirements and likely development of the network. For instance every year National Grid Electricity Transmission publishes a Seven Year Statement and National Grid Gas Transmission publishes a Ten Year Statement and a Long-term Investment Plan. These long-term plans could provide visibility to the regulator, government and wider public on the types and levels of adaptation investment required.

In theory, the regulatory levers currently in place in the network industry have the capability to enable, and indeed require, consideration of adaptation investment needs. A review of the RPI-X regulatory regime currently being carried out in response to significant future challenges also brings an opportunity to consider whether changes are needed to the current regulatory tools and framework to deliver key objectives for Ofgem. As part of this, Project Discovery is an investigation led by Ofgem assessing the future security of supply that can be delivered by the existing market arrangements over the coming decade. Under this workstream, Ofgem is considering a range of potential policy measures to deal with issues such as the scale and timing of investment, uncertainty in future carbon prices, weakness of short-term signals and risks from inconsistencies with international arrangements. One of the many issues under consideration is the extent to which climate change impacts are fully captured. There is widespread recognition that adaptation and infrastructure resilience would need to be considered alongside other long-term challenges rather than in isolation. Thus, the extent to which Project Discovery and potential changes to the regulatory regime reinforce the need to look at long-term challenges and priorities, as well as tighten mechanisms to address them, could also help create focus on climate change adaptation in the regulatory decision making process.

The electricity generation sector is not subject to economic regulation and consequently does not have a specific regime or mechanism through which the response to climate change adaptation can be scrutinised.

4.4 Power generation

Key findings and challenges to adaptation

Awareness around climate change, but still trying to understand specific impacts

There is a good level of understanding of climate change issues in the power generation sector. However the focus of investors and operators to date has been more on mitigation than on adaptation.

The sector is seeking to increase awareness and understanding of adaptation issues. Nonetheless the challenge for companies in the sector is substantial. As highlighted in research by Acclimatise for a group of investors²⁰, the energy generation sector, with large fixed assets and long asset life times, high capital investments as well as operational costs, is vulnerable to the effects of climate change; but as every company has a unique asset profile and, consequently, very

²⁰ Briefing report for Henderson Global Investors, Insight Investment, Railpen Investments and Universities Superannuation Scheme, UK energy generation: Understanding the investment implications of adapting to climate change, October 2009, Acclimatise

different exposure. Ten power generation companies in the UK has been asked to report the current and predicted risks of climate change to their business, and the measures that are being undertaken to address those risks. These reports will contribute towards highlighting the commonalities and differences across the sector, which could help identify key challenges for the sector as a whole.

Difficult to justify “just-in-case” investments

Currently, power generation companies tend to consider risks to their assets and revenues and in relation to new investment decisions on a site-by-site (or project-by-project) basis. Climate change risks would be addressed similarly. However, the extent to which these risks present robust business case for an adaptation response, or to warrant “just-in-case” investments to ensure continued resilience, depends on:

- The materiality of the risks from climate change: for example, generation companies believe that there would need to be a significant reduction in operational efficiency from increased temperature before the financial viability could be substantially affected.
- The timescale of the project: Longer life assets, which tend to be larger capital projects such as new coal or nuclear power stations, are expected to place greater priority on longer term issues such as climate change impacts. But the life of many types of assets (up to 20 years, in some cases up to 40 years) is not generally long enough for climate change risks to be significant.
- The level of uncertainty: Low probability events or events with high levels of uncertainty, especially if the impact is not material, tend to present a weak business case for adaptation.

In particular, weather-related disruptions are typically not modelled explicitly in the financial assessment of investment opportunities. Businesses tend to be concerned with the resulting impact rather than the cause, e.g. operational outages could be caused by weather disruptions or other incidents such as fire or vandalism. Unless these weather-related disruptions are shown to be significantly more frequent or more systemic as a result of climate change, companies will continue to treat these as “random” business interruptions.

Uncertainties around future generation mix

Changes in the generation mix as a result of plant retirements and regulatory and market changes will lead to different, and potentially reduced, adaptation challenges. However uncertainty over the speed of transition to a low carbon economy, as well as technological, market and regulatory uncertainties add to the complexity of determining adaptation responses.

Built-in resilience, but climate change may present systemic risks

While power generation companies are beginning to assess the potential impacts of climate change on their asset portfolios and businesses, more work needs to be done at the industry or national level to explore exposure to systemic risks. More information and analysis is needed, for example, to assess the risks and implications of widespread flooding for the power generation sector and other sectors that depend on it.

The business case for adaptation investment by power generation companies is based on an assessment of private risks, rather than the internalisation of external costs, e.g. to customers or to ‘UK plc’. While there is a potential disjoint between private and social resilience, it is uncertain the extent to which this might affect overall resilience: the supply of electricity, for example, depends not on any single generation plant but on the total generation capacity that is connected to the transmission and distribution network. Thus failure in a single plant is highly unlikely to affect the continuity of supply to the UK energy users, whilst the likelihood of simultaneous multiple plant failures across the UK from extreme weather events (which tend to be localised) is low. However, systemic issues across all power generation plants, e.g. lower efficiency as a result of increased temperatures, may present challenges in ensuring the continuity and security of supply

in the longer term. Adopting a private risk-based approach may be sufficient to ensure resilience from one type of climate change impact but not from another – but this is an area that requires further investigation.

Role of regulation and local planning

Stakeholders consulted as part of this study commented that the societal appetite and willingness to pay to avoid power supply disruption are key factors in determining whether there is a role for the regulator or Government in implementing a minimum level of resilience.

The power sector is not subject to price regulation or explicit obligations to generate electricity, as it operates in a competitive environment. Consequently the economic regulator, Ofgem, does not currently intervene in the way power generation companies address adaptation. Instead externalities such as flood risks are addressed through the local planning process. Because of the increasing focus on flood risk management in the granting of operating licences, companies are more likely to take into account and respond to this issue (see Case study on Drax Heron Plant).

Planning Policy Statement guidance on climate change²¹ considers the role of planning in climate change mitigation and adaptation; however the level of detail on adaptation issues varies significantly, compared to mitigation, which is consistently emphasised throughout the guidance. For example, part of the guidance on renewable and low-carbon energy generation to regional planning bodies recommends that they should:

“not require applicants for energy development to demonstrate either the overall need for renewable energy and its distribution, nor question the energy justification for why a proposal for such development must be sited in a particular location”

The revised draft National Policy Statement on Energy sets out the Government’s energy policy, explains the need for new energy infrastructure, sets out policies which are relevant to more than one type of energy infrastructure with a number of guidelines on climate change adaptation:

“applicants must consider the impacts of climate change when planning the location, design, build, operation and, where appropriate, decommissioning of new energy infrastructure”

“This should cover the estimated lifetime of the new infrastructure.”

“Should a new set of UK Climate Projections become available after the preparation of the ES, the IPC should consider whether they need to request further information from the applicant.”

“Adaptation measures can be required to be implemented at the time of construction where necessary and appropriate to do so.”

Reinforcing the focus on adaptation and incorporating adaptation standards into the planning application process are viewed by those consulted for this study as a straightforward way to encourage adaptation, especially for the new assets with relatively long lives. Consideration would need to be given as to whether such standards should be applied nationally or regionally. The application of national output standards, for example requiring all investments to provide adequate defence against a 1 in 200 year flooding scenario, could disadvantage regions where adaptation costs are high.

²¹ Planning Policy Statement: Planning and Climate Change, Supplement to Planning Policy Statement 1, December 2007, Communities and Local Government

Recommendations for the power generation sector

Bridging information gaps

As highlighted in the recommendations of this study, generation companies should be encouraged to develop a common level of understanding and approach to risk management in relation to the physical risks of climate change across their infrastructure asset base, through:

- Adopting a consistent approach to modelling physical risks across similar assets;
- Identifying key interdependencies and potential interactions within their infrastructure asset base when planning for adaptation; and
- Developing a risk management strategy that spans their asset base, including consideration of asset types, age and useful life, geographies, and capital and operational needs.

The Adaptation Reporting Power which some generation companies are now subject to will help to deliver this. Industry, Government and/or Ofgem could also collaborate to encourage more consistent approaches to modelling climate change impacts, in particular in relation to time horizons, risk tolerance levels and the modelling of uncertainties, through industry-wide studies (with transmission and distribution Network Operators, as well as with other generators), value chain mapping and analysis of weak links in the system.

Local approach to risk assessment

Local agencies play a large role in the planning application process, making many of the important decisions through a consultative process and with guidance from Government and relevant bodies such as the Environment Agency. This local-based approach benefits from flexibility (being able to interpret planning rules according to local circumstances) and the potential to consider interdependencies. However it can add to the administrative burden that companies seeking planning permission face. It could also lead to unreasonable variations in the level of risk tolerance and resilience across the country.

Government has an important role in facilitating co-operation and consistency across local authorities, through encouraging networks of local government that share best practices and information. The Three Regions Climate Change Group is a model where three regions²² grouped together to look at common issues around climate change resilience.

4.5 Power transmission and distribution

Key findings and challenges to adaptation

Substantial collaboration underway to improve understanding

The power transmission and distribution sector recognises that climate change is likely to increase the risks to the resilience of transmission and distribution infrastructure and efforts are already being made to improve the understanding of climate change impacts and risks. For example, the Met Office Hadley Centre has provided tools to evaluate climate change impacts on assets using UKCP09 data and is also undertaking work for electricity network operators to assess the impacts of a range of weather events on equipment fault rates. Other research work is underway in relation to ice accreditation (EU “COST 727” project), impacts of changed precipitation on earthing systems (British Geological Survey) and on overhead line and underground cable ratings (EA Technology). The sector is also establishing a common

²² East of England, South East of England and London

approach to the method of evaluating climate impacts which will have the benefit of establishing a standard assessment protocol.

Despite the progress, there are still information gaps that the sector is looking to resolve. For example, the data from Environment Agency and/or the Scottish Environment Protection Agency (SEPA) which informed the joint working group on flooding, consisting of ENA, Met Office, EA, SEPA, DECC and Ofgem, is considered to be insufficient for the needs of some companies. For example information on flood risk and depth, which is important to the design of defence systems for substations, was not available for all companies. Also, not all sites have sufficient information above and beyond the EA data, such as how their assets would be impacted at different depths of flooding.

Regulatory incentives to ensure resilience and minimise customer interruptions

As a regulated industry, the sector is subject to policy and regulatory pressure to take active steps to ensure the resilience of its infrastructure. The Sector Resilience Plan for Critical Infrastructure set out by the Cabinet Office highlights the extent to which the transmission and distribution sector has been addressing resilience of its assets and infrastructure to flood risks, with the Energy Networks Association leading a panel to improving the resilience of equipment and developing a methodology (ETR 138) for analysing flood risk. The information from this process is expected to feed into price control reviews, helping companies to access additional funding for resilience improvement.

Ofgem also has an incentive regime in place relating to customer interruptions and speed of restoration of supply, albeit with exemption thresholds for exceptional events such as major storms. As storms become more likely and potentially more extreme with climate change, Ofgem may need to re-examine the extent to which these exemptions are consistent with the promotion of climate change adaptation. This could also mean a review on the incentives and penalties as the risk profile changes.

The DECC Energy Emergency Executive also looks at cross-sectoral resilience around managing emergencies, and electricity Network Operators routinely interface with other stakeholders through Local and Regional Resilience Forums. The prioritisation of these resilience activities tends to be based primarily on the materiality of the potential, with a focus on grid and primary substations. From over 1,000 major substations, those at risk have been identified and programmes are underway to upgrade resilience. Other electricity assets are considered lower priority, without a strong business case for incorporating resilience measures. In particular, weather or climate related impacts are relatively small in comparison compared to other faults / issues that could affect continuity or security of supply.

Long life assets: high cost of capital discounts future benefits of adaptation

Through focus groups conducted as part of this study, the sector emphasised the need to consider climate change impacts as one of many potential threats to the economic resilience of the transmission and distribution network. The business case should be looked at through a risk-based and cost-benefit approach, which would be informed through debate with Ofgem. Investment decisions tend to look forward to the next regulatory horizon (e.g. to the next electricity distribution price control period, 2015-2020) but rarely beyond.

A major challenge in the evaluation of adaptation responses is the traditional use of net present value assessment, which tends to weaken the business case for precautionary adaptation investment on long life assets, given the extended timescale over which climate change impacts are expected to arise. In particular, whilst Government may employ a 3% or 3.5% test discount rate, network operators' cost of capital tends to be substantially higher.

Short life assets: "quick win" opportunities by taking advantage of replacement cycles

However, the sector recognises opportunities to incorporate consideration of adaptation in a number of ways. Careful planning aligned with the asset lifecycle and not just focusing on assets with high impact losses may present cost-

effective 'quick win' opportunities. For example, almost half of the wooden poles used to carry power lines will need replacing in the next 10 – 15 years; there may therefore be an opportunity to incorporate features that help these adapt to climate change impacts (e.g. taller or sturdier poles to withstand more frequent or severe storms) at relatively low cost and so avoid the need to replace the poles ahead of the lifespan of the new assets. Through the price control mechanism, the costs of some adaptation responses – such as changing overhead line wooden poles to mitigate sagging and to avoid obstructions or the costs of adding additional assets – are known to the sector, which would facilitate evaluation of adaptation costs.

While there is little scope for speculative spending, there is some flexibility for companies to make investment decisions that could then be incorporated into the subsequent spending review.

Recommendations for the power transmission and distribution sectors

Bridging information gaps

Although the network companies have invested in developing their understanding on climate change risks and measures to adapt to them, and have done so in a collaborative manner, more work is required to bridge information gaps. Network Operators should work together and with the regulator to:

- Adopt a consistent approach to modelling physical risks across similar assets and to the treatment of these as part of the regulatory pricing reviews;
- Achieve consensus on how collective resilience could support security of supply;
- Clarify the levers that Ofgem could or should use to incentivise adaptation; and
- Collaborate with generation companies to understand the impact of weather and climate disruptions to the sector as a whole: for example, by undertaking an extensive value chain mapping and exploring weak links in the system.

Short life assets: prioritising “no regrets” and “quick win”

As companies tend to incorporate measures fit for purpose over the expected life span of their assets, the concept of incremental adaptation is well suited to shorter life assets, as uncertainties are greatly reduced. Addressing adaptation at the design and replacement phases also reduces costs dramatically, presenting better value for money for the consumers.

Network companies need to work with Ofgem to identify assets that are approaching the end of their replacement cycles and evaluate the potential to build in adaptation measures. There is a danger that long-term investment plans and strategies focus on issues and priorities for larger projects. However identifying short life assets, their replacement cycles and potential points for intervention or innovation (e.g. upgrading standards or kits) is equally important.

Long life assets: mapping out the decision pathways

Currently, investment plans and strategies in the transmission and distribution sectors typically have a time horizon of 20 years. Network companies tend to look at whole life costs of assets, but for assets with longer expected life span, the time horizon may not be consistent with longer term adaptation. A long-term strategic view on infrastructure resilience and the inclusion of a decision pathway approach could help fit current 5-year control periods within a longer horizon over the life of the asset.

Case study: Drax Power Limited's Heron Renewable Energy Plant at Immingham

Introduction

Drax Power Limited (Drax) is developing a 300MW dedicated biomass-fired renewable energy plant on a site near the western entrance to the Port of Immingham, as part of Drax's efforts to increase electricity generation from renewable sources and reduce greenhouse gas emissions from power generation. The plant is predicted to deliver a saving of 1,800,000 tonnes of carbon dioxide (CO₂) each year, and to provide enough renewable electricity to power 512,000 homes. Construction is expected to commence in the second quarter of 2011 and the plant to be fully operational in the fourth quarter of 2014.

This new Heron biomass plant has been selected as a case study to help illustrate the important interdependencies between the Port of Immingham and the delivery of the UK's renewable energy targets. As a new-build asset, the plant could be susceptible to climate change over the long-term, but adaptation solutions are already being factored into the design and planning. Drax and Associated British Ports (ABP), the owner and operator of the Port of Immingham, are private sector companies and not subject to economic regulation, although they are subject to other forms of regulation (e.g. planning, environmental, health and safety etc.).

The selection of site

The economic viability of the plant is conditional on good transport links, access to fuel and connection to the electricity transmission network. Drax researched coastal and riverside locations that were within conveying distance of ports across the UK and which also offered access to water for the plant. Importantly, the plant will consume between 1.3 and 2.4 million tonnes of biomass per year (depending on the balance of biomass pellets, chips, straw and energy crops in the feedstock supply) and imported biomass will, at least initially, make up much of the fuel source.

The site, near the western entrance at the Port of Immingham, on land that is designated for commercial and industrial use, has been selected due to the presence of the nearby deepwater port which is capable of taking "appropriately sized and designed ships from national or international sources" and has "the infrastructure to receive and discharge large quantities of biomass". The Port of Immingham is the UK's largest port in terms of tonnage handled. Immingham's prime deep-water location on the River Humber, the UK's busiest trading estuary, provides access to global trade routes and shipping links throughout Europe and North and South America, Africa, Australia, the Middle and Far East. In 2008, the port handled 55 million tonnes of cargo, roughly 10% of all UK sea-borne trade. The Port of Immingham also expects biomass handling to be an increasingly important source of revenue, potentially increasing to 5 million tonnes in 2020 and 7.5 million tonnes in 2030.

In addition, the site has close road and rail links for potential deliveries of indigenous biomass, consistent with Drax's intention to develop the use of indigenous biomass fuels, and for ash transport off site. The plant will be water-cooled, using water from the nearby Humber Estuary, and biomass fuel will be transferred to the site via conveyors from off-loading facilities. Electricity will be exported from the plant on to the National Grid electricity transmission network.

Environmental considerations and climate change impacts of the site

The proposal requires consent from the Department of Energy and Climate Change (DECC), with the Section 36 planning application lodged with DECC in October 2009. Drax also consulted with North Lincolnshire Council, the Environment Agency, Natural England, members of the public and a range of other organisations as part of its application process.

The main environmental consideration was the assessment of the likelihood of flooding at the site in accordance with Planning Policy Statement 25 (PPS25), Development and Flood Risk. The assessment considered the existing flood levels available from the Environment Agency and likely changes due to climate change. As part of its application,

Drax initially looked at risks over the expected commercial life span of the project of 25 years but ,following consultation with DECC, it incorporated consideration of a 75 year timeframe for the impact assessment. As the projected impacts from climate change over a 75-year period are more pronounced than those over a 25-year horizon – for example expected sea level rise and potential breach of flood defences – this has led to greater climate / weather resilience being built in than would otherwise have been incorporated.



This has had implications for the cost of construction and the time required for this, including:

- The material required for the elevation of the project (to provide for greater sea level rises) under a 75-year horizon is approximately 1.5 times that required for a 25 year (an additional 100,000m³), increasing the associated costs from c.£5m to £7-10m:
- The change may also place additional obligations upon Drax to secure appropriate compensatory habitat under the EC birds and habitats directives.
- The increased elevation will reduce the area of the site and necessitate longer site access routes due to the steeper gradient.

Notwithstanding these cost implications, Drax recognised that the additional resilience could also deliver benefits through reduced risks to its site and lower business interruption insurance. However, there is also a strong realisation that the additional resilience does not necessarily ensure security of supply from the new plant, given the level of interdependencies. For example, as the electricity produced by the plant will be exported via an underground electrical connection to the National Grid Killingholme 400 kV substation, downstream connection will still be heavily conditional on the resilience of the substation. Similarly, access to feedstock will be crucial to the operations of the plant.

Access to inputs and dependence on the Port of Immingham

As the Port of Immingham will be the primary route through which imports of biomass will be accessed, an infrastructure corridor has been planned to link the main plant and fuel storage areas to a jetty on the Humber and this will contain cooling water pipelines and conveyors to transport biomass from ships to the main plant area.

The type of feedstock used will determine the design of the system, as more weather sensitive feedstock (such as wood pellets) will require an enclosed conveyor system. As this conveyor system is to be built by Drax but located on ABP's site, it will benefit from the built-in resilience offered by the Port of Immingham, with a 1 in 200 year level of protection against flooding.

For a business such as ABP, with a wide range of infrastructure exposed to the weather and climatic conditions, the downtime associated with weather disruptions could have a significant impact on its finance and profitability. ABP is therefore giving careful consideration to the potential impacts of climate change – including sea level rise, tidal and rain surges and storminess – and introducing adaptation measures to address these impacts across its ports. Drax's conveyor system will therefore benefit from the resilience of the port, without necessarily incurring substantial additional financial costs, as is the case with the biomass plant. At the same time, Drax and other customers of the port will also be vulnerable to the impacts of climate change on the Port of Immingham, but as separate entities are not directly involved in decision related to adaptation within ABP.

ABP is acutely aware of the interdependence of the port and related infrastructure, and recognises the importance of collaborative efforts on resilience with key stakeholders and organisations such as the local authorities and Environment Agency. As a private enterprise, however, commercial and financial viability will be the key driver for investment in building increased resilience into the infrastructure and assets of ABP.

Additional resilience to Drax's feedstock supply is provided through an onsite fuel stock of 5-14 days worth of feedstock supply, plus options for additional off-site stock. This supply buffer was required by financiers of the project, through clauses in the funding term-sheet. Drax is also looking to expand the share of domestic feedstock supply over the longer term, to reduce reliance on international sources.

Concluding remarks and lessons learnt

The Drax Heron plant will rely heavily on the Port of Immingham to deliver feedstock to its operations, both through the receipt of international cargo and through the conveyor belt system that transports the feedstock to its sites. ABP, as the operator of the port, has given active consideration to the impacts of climate change and the adaptation needs of the port, driven by the need to minimise risks to its commercial operation.

Drax is also investing in increased resilience to its plant by planning for a longer time horizon than the current commercial norm, despite additional costs and time for its construction, following consultation with DECC.

The security of supply of electricity, however, could still be subject to interruption from the impacts of climate change if the downstream connection breaks down, highlighting the importance of sustained resilience along the value chain.

Lessons learnt:

- Awareness within ABP and Drax is relatively high for strategic reasons: ABP is in a sector which is exposed to weather disruptions, and Drax has a high geographical concentration of assets. This awareness has been a key driver to bridge information gaps.
- Cross-sectoral interdependencies have not been explicitly considered; but these organisations are starting to be aware of impacts along their value chains, which provide the incentive to act.
- The business case for adaptation is driven by commercial self interest, but external or regulatory pressure is often important in encouraging higher level of resilience.

5 Water and wastewater

5.1 Overview

The UK water sector has a long experience in managing climate variability in the design and operation of long life clean water and waste water assets. The sector is heavily regulated by several bodies, each with different objectives in relation to economic efficiency, the environment and quality of water, wastewater and effluent. One of the main challenges for the sector is therefore co-ordinated action by all of these organisations.

5.2 Summary of climate change impacts

The study by URS conducted as part of the Infrastructure and Adaptation Project has identified a number of potential challenges arising from climate change. This section provides a brief summary of those impacts and the key implications on water and wastewater infrastructure.

Principal climate change risks	Implications for infrastructure
Water supply, treatment and infrastructure	
Reduced security of supply due to changing precipitation patterns and drought.	<ul style="list-style-type: none">• Potential stranded assets due to relocation/ replacement of unsustainable abstractions if original abstraction points are no longer viable, with water stress in aquifers and the surrounding river reach/ catchment.• Replacement assets are likely to be energy intensive, high cost solutions (e.g. reservoir construction, effluent re-use, desalination), especially in Southern England.• Increased drought frequency places greater onus on water companies to create supply networks (rather than demand centres relying on a single source of supply) to lower risks of rota cuts. Investment may be both within company boundaries and between companies, especially in South East England. This will have implications for the costs of water distribution, and energy used to pump water to consumers.• Sudden, heavy rainfall is not a good means of recharging groundwater sources; hence aquifers may deplete even if rainfall is theoretically sufficient to maintain supply.• Potential opportunity for storage of water (reservoirs) during high rainfall for use in periods of low precipitation (e.g. greywater, bankside storage), but likely to be expensive, with scarcity of appropriate sites and potentially difficulty in developing these.• Potential opportunity to increase use of sustainable drainage systems (SuDS) which allow infiltration of groundwater; construction and maintenance costs will need to be considered.• Conflict on use of treated effluent from wastewater to support river flow and biodiversity, versus use for public water supply.• Lack of water availability means that water companies may need more than their licensed quantity of water to serve customers' basic needs, with implications on biodiversity (fish kills, algal blooms etc).
Increased fluvial flooding due to increased precipitation and storm surges.	<ul style="list-style-type: none">• Protecting critical assets (pumping stations, treatment works) situated on floodplains.• Dams and impounding reservoirs may need to be strengthened so that they are resilient to increased rainfall (which causes increased pressure on the dam wall).• Increased soil movement leading to increased bursts and leakage will increase maintenance costs. Companies will need either to increase maintenance or to develop innovations that allow for pipe flexing when soils (especially clay) move due to watering/dewatering or change in temperature.• Increased run-off due to 'flash' rainfall events likely to increase pollution of water sources from agricultural nitrates and phosphates (unless farming practices change), and from urban and non-agricultural sources such as roads, requiring more complex drinking water treatment, or the need for SuDS.• Need to protect against flood water ingress to drinking water pipes, which could contaminate supply.
Other (e.g. temperature increases)	<ul style="list-style-type: none">• Increased temperature might lead to increased frequency of algal blooms in surface water sources and the need to apply additional drinking water treatment processes (which are likely to be energy intensive).• Higher temperatures (rather than lower precipitation) might lead to increased eutrophication, especially if combined with increased nutrient loading from run off, which could increase treatment costs. It could also increase the oxygen demand as the biomass generated decays, which may also lead to taste and odour implications for potable abstractions.

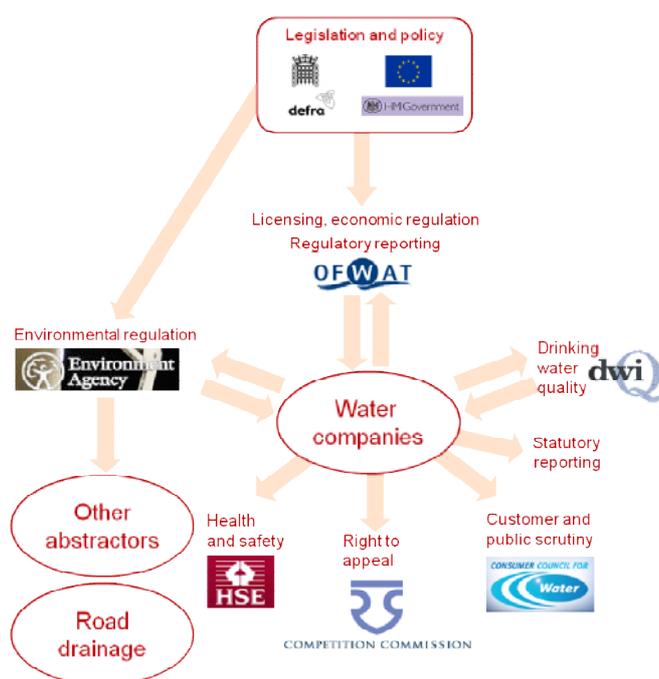
Principal climate change risks	Implications for infrastructure
Wastewater collection, treatment and disposal	
Increased sewer (pluvial) flooding due to increased precipitation and storm surges.	<ul style="list-style-type: none"> • Need to adapt sewerage capacity (especially surface and combined sewers) and treatment assets to cope with widely variable loading factors. • Sewer modelling and understanding the likely impacts of changing system load will require joint working between the sewerage companies, Highways Authorities and Local Authorities to understand the overall impact of surface, foul and combined effluent. • May also require co-operation with private sewer owners, although transfer of private sewers to sewerage companies, proposed for October 2011, will result in more integrated management of the public sewerage system. • Co-operation required between Local Authorities, property developers, and sewerage companies on sustainable drainage systems (SuDS) following the allocation of responsibilities in the Flood and Water Management Act for new developments. • Retrofitting SuDS in houses, public spaces and roads is difficult and costly, but would reduce volume and rate of surface water flowing to sewer, and improve water quality. • Separating combined surface and foul sewers could potentially be very costly. • Need to protect critical assets (pumping stations, treatment works) situated on floodplains. • Increased requirement / load for pumping stations is energy intensive. • Environment Agency 'no deterioration' policy for effluent released to watercourses will mean that the same key standards (e.g. amount of nitrate) will need to be met, irrespective of the volume of effluent, requiring improvements in treatment processes (which are also likely to be energy intensive) and potential need for greater storage at treatment works. • More extreme fluctuations in effluent concentration at wastewater treatment works may require changes to treatment process.
Increased pollution incidents due to changing precipitation patterns and drought.	<ul style="list-style-type: none"> • Potential for increased sewer flooding due to overloaded sewers. • Need to adapt treatment works to treat more concentrated effluent if clean water efficiency reduces demand. Reduced role of effluent as flow support to rivers. • Resilience of underground assets to increased soil movement. Companies will need either to increase maintenance or to develop innovations that allow for pipe flexing when soils (especially clay) move due to dewatering or change in temperature. • Potential for odour nuisance from treatment works and sewers during dry periods. • Increased requirement for retrofitted SuDS to tackle surface water flooding and diffuse urban and road pollution from rainfall runoff.
Increased fluvial flooding due to increased precipitation and storm surges.	<ul style="list-style-type: none"> • Currently, combined sewer overflows (CSOs) discharge into watercourses during storms leading to sewerage litter on banksides and raw foul sewage in the watercourse. This has a potential impact on biodiversity in the water environment. If flooding events become more frequent, CSOs will need to be addressed in a more rigorous way.

5.3 Regulatory context and adaptation

Water and wastewater companies are generally self-contained, regional monopolies. The sector is subject to price regulation by Ofwat, the economic regulator, which conducts five yearly price control reviews. Companies prepare a detailed five year business plan, as well as a high level Strategic Direction Statement (SDS) setting out their long-term plan for the next 25 years. Companies also prepare a 25 year statutory Water Resources Management Plan, setting out the impact of future demand and supply forecasts (including climate change impacts and climate change uncertainty) on the future requirements for water. Companies have used the SDS to highlight, amongst other things, climate change impacts and concerns for the levels of service, asset resilience and the security of supplies. At the time of writing, Ofwat and the Consumer Council for Water, are undergoing a review by Defra, due to be completed in 2011. The review will consider the extent to which the current regulatory arrangements continue to meet challenges faced by climate change and population growth while maintaining affordability for consumers

There is a high level of awareness of climate change in the sector, which was initially driven by the need to produce long-term water resources plans. More recently, legislation such as the Flood and Water Management Act, and independent reviews such as the Pitt Review of flooding, the Cave Review of competition and innovation, and the Walker Review of customer charging, have taken the debate on adaptation issues further. This has meant that the water and wastewater sector is one of the more advanced sectors in dealing with infrastructure resilience to climate change.

Figure 19: Regulatory landscape for water and wastewater sector



5.4 Key findings and challenges to adaptation

Recent events triggered action even with lack of market pressure

In a regulated sector such as water, there is no strong market pressure from investors or other stakeholders for adaptation action. As long as investors see a fair return on capital (which is determined through the pricing review), they will finance the investments required by the sector (which may be driven by immediate needs or by the requirement for longer term resilience). Until there is a clear signal that the sector has failed to address the impacts of climate change, for example if insurance premia rise to unsustainable levels, the majority of investors – particularly those with relatively shorter term horizon – are unlikely to exert pressure on the sector to act on risks management and resilience measures.

However, experience of climate impacts and risks as a result of events not directly linked to climate change, such as the 2007 floods, has prompted action by water and waste water companies to address climate change adaptation.

Strong understanding of impacts but still unclear on how they feed into pricing reviews

The water and wastewater sector is generally well informed on the physical risks of climate change, and has a high level of awareness on the vulnerability of their assets, their location and potential technological solutions. However there are

information gaps in some areas – such as how the impacts vary spatially and the nature of the impacts, e.g. some areas may experience increased frequency of storms, while others experience similar number but more severe storms.

The main challenge for the sector is a lack of consensus on the application of this knowledge for planning and regulatory purposes. The relative timing of the 2009 pricing review and the publication of the UKCP09 data meant that the latest climate science and data will not be incorporated formally into the pricing review process until the next review period. Ofwat took account of this by defining a notified item on climate change and water resources, which gave the water companies time to assess the UKCP09 scenarios and, if necessary, allowed them to go back to Ofwat with further proposals before the next price review. The focus up to the next price review will therefore be for the water sector to agree on a broad methodology, with standards on the use of probabilities and scenario planning, on appropriate investment programme for adaptation for delivery in 2015-20 and beyond.

Sector participants in our research have distinguished between different types of adaptation activities:

- New, large assets (e.g. reservoirs): there is more scope for innovation in new assets, and it is easier to make a business case for high-profile assets;
- New smaller infrastructure (e.g. new sewerage connections): the case for adaptation may be more difficult to make for smaller schemes, although the asset lives are long;
- Existing, smaller infrastructure (e.g. small sewers): retrofitting adaptation solutions tend to be costly and difficult, and so building a business case is more complex; and
- Demand management (for water) or sustainable drainage (for wastewater): as an alternative to civil engineering-based, supply side adaptation.

Long life assets: SDS / planning horizon shorter than asset life spans

A challenge for the water and wastewater sector, particularly for long life assets, is the impact of horizon planning and how this affects the regulatory pricing structure. Some of the adaptation activities involve making high cost investments today to adapt to impacts that may not be realised within the 25 year horizon of the SDS vision. This is an issue inherent in a sector with a long asset life span, and is not specific to climate change adaptation. To some extent the economic regulatory regime has factored in the possibility of incorporating long-term asset investments through assumptions relating to the financing capital investment through return and depreciation.

Fundamental to the concern around time horizon, however, is the extent to which the sector (or its regulator) is able to make the trade-offs between current and future resilience in practice. Ofwat's remit covers both current and future consumers, but in practice when set against the criteria of value for money, Ofwat need to consider the impact on customers' bills and consumers' willingness to pay. However, it is difficult to obtain evidence of future consumers' willingness to pay, and consumers today may also not attach sufficiently high willingness to pay for future resilience. The potential disconnect between consumers who pay today for the investments and those who benefit in future generations means that Ofwat might not have sufficient evidence base to support decisions in favour of adaptation investments.

Water companies are also expected to invest in maintenance of the existing substantial base of assets. Although this expenditure contributes to building resilience over the long-term, it tends to be classified as operating expenditure. This accounting treatment presents a key challenge to timely adaptation action.

Prioritising and phasing adaptation investments

In the context of climate change adaptation, Ofwat's position is that the water and sewerage sectors should:

“...adapt in a phased, responsible and appropriate manner. This means that adaptation plans must be based on sound science and evidence. In some cases, there are significant regional differences in future climate change scenarios, so a range of approaches may be required.”

To a large extent, the periodic nature of the 5 year price review process, within the context of a 25-year SDS approach, lends itself to a phased response to adaptation. In theory this is broadly consistent with prioritising investments using the decision pathway approach, and should lead to the adoption of a strategy which avoids large commitments during periods of uncertainties by offering the flexibility to make deferred decisions. This should offer both protection and value to consumers.

In adopting this approach, the evaluation of business cases during the pricing review becomes an important process in determining the types of investments that are considered and approved. The water sector has relatively more experience than the other sectors on looking at climate change adaptation investments through the regulatory process. Ofwat has published a good practice guide reinforcing the need for business plans on adaptation to “have a sound evidence base, be specific and relate directly to individual circumstances”. This places the burden on water companies to be aware of relevant issues, to set their levels of risk tolerance and to articulate their business case robustly. This is likely to lead to a focus on adaptation measures that have a strong business case, perhaps where there are multiple drivers (see case study on United Utilities).

Role of demand management and standards

Participants from this study also proposed that a greater use of performance standards or other metrics may encourage more effective adaptation. This approach is already being adopted to encourage demand side management; for example, water companies are expected to meet leakage and water efficiency targets. Companies would be made to consider investments and other measures necessary to meet these standards, removing the risks of reliance on the policies of an individual water company.

The challenge then falls onto the regulator to set appropriate standards. In the last pricing review (PR09), Ofwat acknowledged the concerns of some stakeholders that they “were not pressing companies to reduce leakage significantly over 2010-15”. Standards may also constrain innovation in the industry, setting the sector into a compliance mode, rather than promoting innovation (this is also articulated by the Cave review²³ and the Council for Science and Technology²⁴).

Formal long-term framework for wastewater important for adaptation

Stakeholders are also concerned about some specific issues for waste water. While there is a greater focus on climate change adaptation in the supply/demand planning for water resources, this has yet to become a core issue for waste water plans. Water resources planning is also subjected to a long-term statutory process, but waste water and drainage has no formal framework for long-term planning, prompting a need for an overall guiding framework for waste water and drainage needs that all key stakeholders agree to.

Interdependencies acknowledged but yet to formulate joint solutions

The sector is dependent on a number of other key sectors in the delivery of their services. For example, ICT is increasingly important in telemetry systems used to run plants remotely. Access to transport routes is important for the delivery of critical supplies; and the sector is energy-intensive, particularly in water and wastewater treatment and pumping.

²³ Independent Review of Competition and Innovation in Water Markets: Final report, Professor Martin Cave, April 2009

²⁴ Improving innovation in the water industry: 21st century challenges and opportunities, Council for Science & Technology, March 2009

There is little evidence that interdependency issues are being consistently or robustly examined, but existing business continuity plans and other efforts go some way to manage these issues. For example, on energy in particular, the water sector is looking at ways to become more energy efficient as part of their contribution towards a low carbon economy, but these efforts could also reduce the level of dependency on energy and develop greater resilience to the sector. The challenge for the sector is to integrate these issues further and also to consider the impacts of water infrastructure failure onto other sectors.

5.5 Recommendations for the water and wastewater sectors

Joint working across government, regulators and water companies

Collaboration – both within the sector and with other key stakeholders – is crucial in the delivery of adaptation. In particular, there are multiple stakeholders that can influence the adaptation measures for certain asset types. For example, water companies have to deal with any water overflows from watercourses that drain into the sewerage system, and these could increase in frequency as a result of climate change. A possible solution could be to divert the watercourse, which would fall under the responsibility of the Environment Agency. A collaborative effort in addressing issues such as these could result in overall lower costs for both the water companies and society in general.

Bridging information gaps and sharing best practices

The sector is working together well to bridge gaps in information on particular adaptation issues and data relevant to the sector, e.g. flood levels by region. However the sector needs to work more closely with the regulator on adaptation, to establish common and best practice on how adaptation should be incorporated into the regulatory decision making framework.

The water sector's current head start on considering and addressing climate change risks within the regulatory framework could make it a potential model for other sectors and regulators to draw on. The sector could maintain this lead by providing best practice case studies, bridging consensus on issues such as methodology of risk assessment, and demonstrating the use of tools (such as real options analysis) to deal with uncertainties. This would also enable the sector to be prepared to embed adaptation needs in the next pricing review.

Long-term frameworks for water and wastewater

The current 25 year SDS is able to capture the expected life spans of many types of assets; however the sector also has many longer life assets with useful lives extending beyond the SDS. By taking a longer term and whole life cost perspective for these assets, decisions on adaptation can be made taking into account the full costs and benefits over the expected life span of the assets. Ideally this would involve adopting a decision pathway approach and mapping out options over the life of the asset.

Crucially, a long-term planning framework (e.g. the equivalent of the SDS for water) is also required for drainage and/or waste water, where climate change and other long-term challenges will put increasing pressure on waste water treatment capacity.

Climate change considerations

To incorporate the impacts of climate change in the cost-benefit analysis, United Utilities used the UK Climate Projections UKCP02 scenarios, the most recently available at the time. The three main scenarios from UKCP02 were translated into forecast river and reservoir flows using a standard industry methodology. Climate change impacts were incorporated into the company's headroom assessment, again using a standard industry methodology. The forecast impact of climate change on water resources suggested a need for a pipeline with a capacity of 60 million litres. However, in response to the security of supply driver, the pipeline is being built with a capacity of 100 million litres and is expected to remain fit for purpose for the duration of its 100 year asset life.

In the company's view, the long-term impacts of climate change should not be considered in isolation. In this case, adaptation was only one of many drivers for the investment, and security of supply ended up dominating the consideration of the pipeline capacity, with headroom capacity over and beyond that would have been built in if climate change impacts were considered in isolation. Nevertheless, including adaptation along with other drivers in planned infrastructure projects as part of normal business was considered a sensible approach.

Regulatory and planning framework

Under the regulatory framework for the water industry, United Utilities were required to get funding approval from the economic regulator Ofwat, and approval from the Environment Agency and the Drinking Water Inspectorate.

Ofwat provided the greatest scrutiny of the regulators, as the pipeline was replacing a previous scheme and the funding would require money to be re-allocated between the AMP4 and AMP5 pricing reviews. In United Utilities' view, a scheme that was purely driven by climate change adaptation would have been unlikely to receive funding approval. The success of the funding application was down to greater certainty of other drivers, including the EU legislation and the supply security threat caused by closure of aqueducts for cleaning. On the other hand, the Environment Agency was supportive of the pipeline where adaptation is concerned, given a preference towards schemes that transfer water over those involving new abstraction.

Interdependencies with other infrastructure and sectors

The West-East Link pipeline crosses several major infrastructure assets, including three motorways, the West Coast Mainline railway and gas and electricity networks, as well as both rural and urban areas. United Utilities chose to build tunnels for the pipeline where needed, as this provides greater security, is relatively quick to install and increases the ease of obtaining planning permission. It also removes the dependence on other infrastructure, such as bridges.

As part of the planning process, United Utilities consulted with other infrastructure stakeholders to discuss concerns over their assets, although no major issues were identified. In particular, the pipeline also passes through 20 Local Authority areas. To manage the views of so many local government stakeholders, United Utilities convene the group through a Local Authority forum. Discussions were also held with environmental and community groups.

Concluding remarks

The West-East Link pipeline is an example of an infrastructure investment that incorporates climate change adaptation as one of its drivers. The 'no regrets' nature of this adaptation response meant that the risks of climate change could be successfully incorporated as part of a wider risk assessment. Indeed, after modelling the potential impacts of climate change, other drivers were found to supersede the adaptation needs in the design of the pipeline.

In the context of the heavily regulated water industry, United Utilities produced a compelling case to its environment, quality and economic regulators based on multiple investment drivers. The regulatory framework provided challenging but not insurmountable barriers, requiring United Utilities to demonstrate a positive cost-benefit analysis and an economic and practical rationale.

6 Transport

6.1 Overview

The focus of this study on transport is on four sectors: airports, ports, road and rail. Our consultations with stakeholders have focused on national strategic infrastructure that is critical for the functioning of the UK's transport system as a whole. This 'strategic infrastructure'²⁵ is identified by the Department for Transport (DfT) and is made up of a network of 14 national transport corridors connecting the 10 largest conurbations and 17 international gateways and is critical for economic success (see Figure 20 and Figure 21). Many of the findings could of course be extrapolated to the issues presented in planning and delivering infrastructure beyond these transport corridors, although we have not explicitly done so in the course of this study.

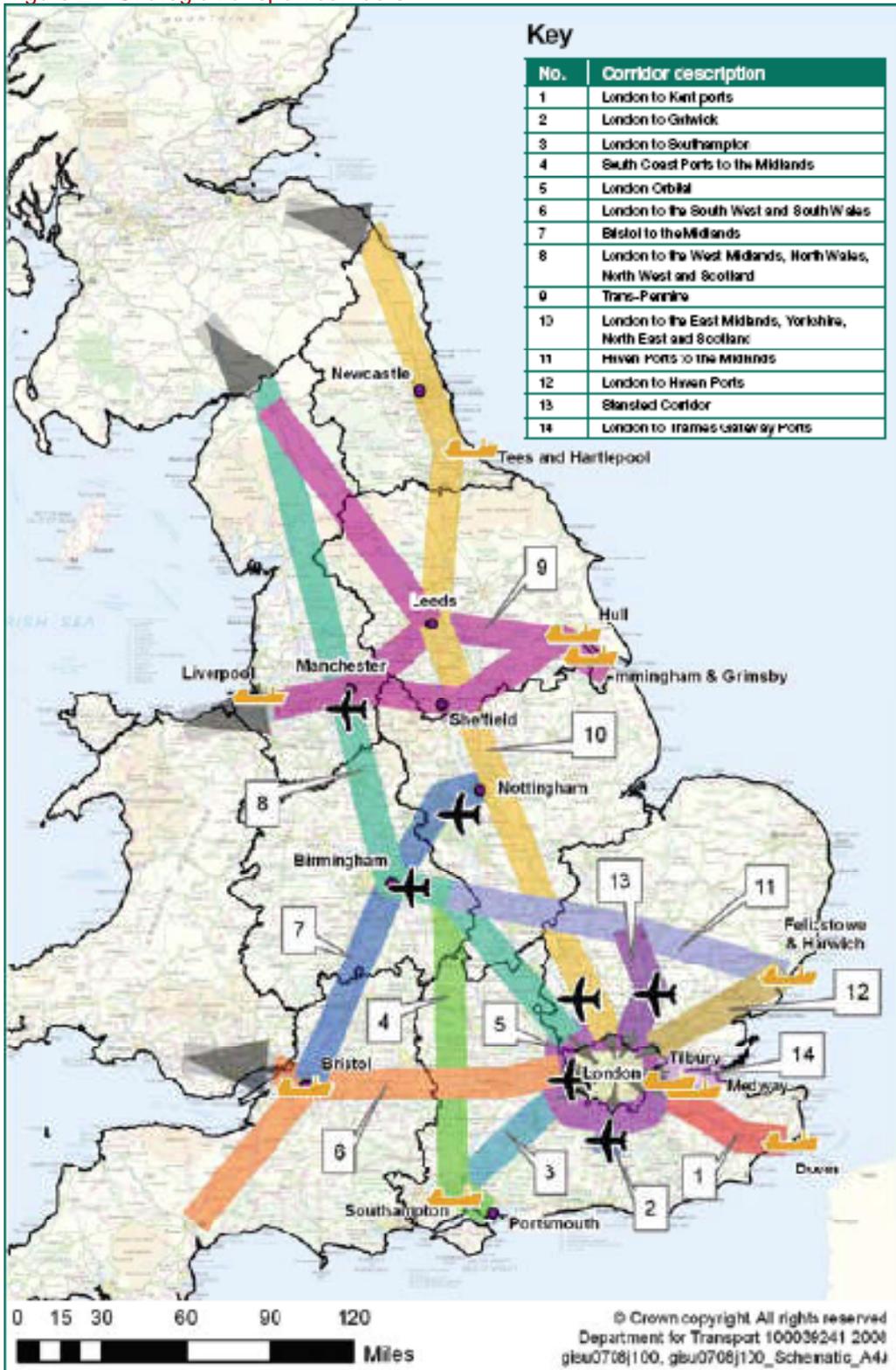
Figure 20: Strategic transport corridors – key infrastructure

Largest urban areas (population, 2008) Source: CLG primary urban area indicators, 2010	Key ports (traffic in million tonnes, 2009) Source: DfT, 2010	Key airports (passenger movements/freight tonnage, 2009) Source: CAA, 2009
<ul style="list-style-type: none">• London (8.89m)• Birmingham (2.31m)• Manchester (1.80m)• Newcastle (0.81m)• Sheffield (0.79m)• Leeds (0.77m)• Liverpool (0.76m)• Bristol (0.68m)• Nottingham (0.63m)• Portsmouth (0.51m)	<ul style="list-style-type: none">• Grimsby & Immingham (54.7)• London (45.4)• Milford Haven (39.3)• Tees & Hartlepool (39.2)• Southampton (37.2)• Forth (36.7)• Liverpool (29.9)• Dover (25.1)• Felixstowe (24.3)• Medway (13.1)	<ul style="list-style-type: none">• Heathrow (65.9m: 1,278k)• Gatwick (32.4m: 75k)• Stansted (19.9m: 183k)• Manchester (18.6m; 103k)• Luton (9.1m; 29k)• Birmingham (9.1m; 13k)• Bristol (5.6m; n/a)

The UK transport sector is dominated by private sector operators. Economic regulation is present only in rail and aviation, but transport regulators also cover safety obligations. The Secretary of State for Transport is responsible for the security and resilience of UK transport systems.

²⁵ See DfT, Delivering a Sustainable Transport System: Main Report, November 2008

Figure 21: Strategic transport corridors



6.2 Summary of climate change impacts

The study by URS conducted as part of the Infrastructure and Adaptation Project has identified a number of potential challenges arising from climate change. This section provides a brief summary of those impacts and the key implications on transport infrastructure across the four sub-sectors for this study.

Principal climate change risks

Implications for infrastructure

Airports

- | | |
|---|---|
| <ul style="list-style-type: none"> • Changing precipitation levels and flooding risks • Increased temperatures • High winds at airport due to increased storminess | <ul style="list-style-type: none"> • Runway and apron drainage facilities could require upgrading as excess surface water could delay aircraft operations • Aircraft flight characteristics are impeded with higher air temperatures, as lift is reduced. This could mean longer delays for airlines and passengers |
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Ports

- | | |
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| <ul style="list-style-type: none"> • High tides / storm surges causing increased sea level at ports • High winds at ports due to increased storminess which leads to buffeting of ships and berths • Sea level rises leading to operational constraints (e.g. berthing, loading/unloading) | <ul style="list-style-type: none"> • Investment in improving the design of harbours (e.g. new breakwaters, harbour walls) • Investment to re-orientate berths to cope with cross winds (berths are typically designed to ensure shipping is aligned to the prevailing wind) • Need improved forecasting of imminent storm surges to reduce the risks • Ports on England's east and south coasts are at highest risk as the greatest rise in sea levels predicted at these locations |
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Roads

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|--|--|
| <ul style="list-style-type: none"> • Flooding from increased precipitation and/or storminess • Scour of bridges due to increased precipitation and/or storminess • Moisture fluctuations in road embankments in south east England from wetter winters and drier summers • Wind speeds and frequencies | <ul style="list-style-type: none"> • Risk to embankments causing unevenness in the road surfaces • Expansion joints from some road bridges could shrink leading to bridge damage from temperature increases • Bridge failures could lead to significant disruption to services and the need for emergency personnel. • Wind is also a key risk on roadside trees/vegetation, blocking roads and can be dangerous for high sided vehicles, especially on high roads and bridges |
|--|--|

Rail

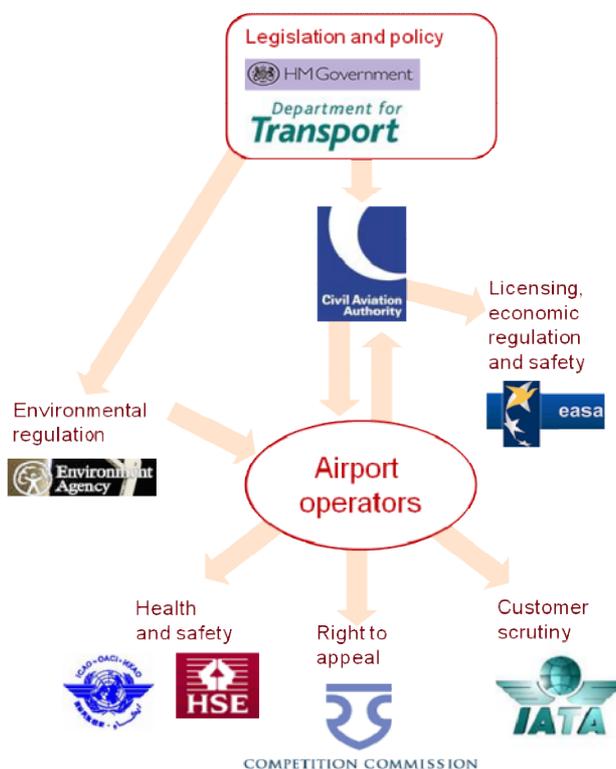
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| <ul style="list-style-type: none"> • Flooding of lines reduces the stability of the sleepers and bridge structures. • Ballast may be washed away by flooding or eroded by precipitation • Rapid succession of cold and warm spells can place stress old and brittle metal lines • Wet leaves on rail lines (from increased precipitation and winds) can short the electrical circuits that provide signalling • High winds interfere with the connection between the overhead lines and the train. | <ul style="list-style-type: none"> • Failure of track and lineside equipment • Bridge failures can completely cut off some rail services • Scour of bridges due to increased precipitation and/or storminess • Buckling of rail tracks and wind damage • Structures may need to be toughened, elevated, or even moved • Trees planted too close to lines can cause a hazard because of windthrow, though when positioned appropriately can protect the infrastructure • Increased heat resulting in reduced window of opportunity to carry out maintenance/renewals work, passenger health and staff working conditions. |
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6.3 Airports

Overview and market context for adaptation

The Department for Transport sets the general themes of airports policy in the UK – mainly through ‘White Papers’ – which establish the strategic direction of development, capacity and the way in which environmental considerations are incorporated into the provision of airport capacity.

Figure 22: Regulatory framework for airports



At the operational level, the airports sector is primarily regulated by the UK Civil Aviation Authority (CAA), who is responsible for the safe operation of all airports used for public transport or flight instruction purposes. Specifically:

- Aerodrome Standards are set out to oversee the safety of aviation activities. All aspects of the aerodrome and its management which have an impact on aeronautical safety are considered;
- For designated airports (London Heathrow, Gatwick and Stansted) – which are regarded as having ‘market power’ (monopoly characteristics) – the CAA also sets the maximum charges (for a five year period) that these airports can levy to users (airlines). These charges are based upon the requirement that only ‘efficient’ capital investment and operational costs at each airport are to be recovered through user charges (airline and passenger charges), in addition to a commercial rate of return earned by the operator. In doing so, the CAA expects users (airlines) to be consulted on all capital investment prior to it being remunerated; and
- For non-designated airports (such as Newcastle, the Scottish Airports), investment policy is determined by the airport operator and airlines. The CAA has no role in determining investment priorities. It does however retain a role in ensuring safe operations (safety regulation).

Whilst the CAA sets charges on a 5 yearly basis, longer term investment planning is common because infrastructure assets are costly (e.g. LHR Terminal 5) and cannot be reasonably borne by single groups of users over a short timeframe. Rather, these assets need to be funded and remunerated over extended periods. Moreover, service quality and capacity issues in aviation infrastructure need to be planned incrementally according to the long-term views of customers, because the nature of the infrastructure itself is 'lumpy' (in the sense that the infrastructure is costly and very significant in scale) and requires considerable planning and occasionally pre-funding prior to delivery.

Other regulatory bodies are also involved in airport operation, such as the Environment Agency and HSE. The International Civil Aviation Organisation (ICAO) sets safety principles – some of which apply to airport operations, and the International Air Transport Association represents the interests of airlines – particularly in airport investment and regulatory matters. TRANSEC (Transport Securities and Contingencies Directorate in DfT) is the security regulator.

Key findings and challenges to adaptation

Lack of consideration of interdependencies

Airport operators respond to a regulatory regime that currently does not explicitly require adaptation to be incorporated in the investment planning cycle, although clearly operators are motivated to ensure that airports are resilient to the extent possible, since revenue is lost should airports not be available for use by airlines. It is however fair to say that no explicit adaptation requirement is placed upon operators by the economic regulator (the Civil Aviation Authority).

In general terms, this study identified a general perception that the impacts of climate change on airports are not explicit. Impacts are likely to be locationally specific, and as such, addressed by operators in different ways and over different timeframes as required. Airlines were also perceived as being relatively resilient to adaptation challenges – because they have experience of operating in a range of climatic extremes and have procedures in place to facilitate continued operations. Specifically, consideration of adaptation issues at airports tends to focus on operational infrastructure – such as heating and cooling needs, or surface water drainage on runways and aprons.

A further observation is that airports may not always consider the impact of climate change on other surface infrastructure that they depend upon, in particular road and rail. As many airports tend to be located some distance outside large conurbations, passengers and freight depend heavily on land transport for access to airports. The resilience of airports in terms of their ability to function in the context of climate risks could therefore be undermined by surface access failures that could inhibit the efficient movement of passengers and freight.

The long-term investment framework is in place, but consideration of adaptation is not always clear

The previous administration's Future of Air Transport White Paper (ATWP) was published in 2003 with the aim of setting a national, strategic policy framework for aviation for the next 30 years. In response many airport operators have produced master plans which tend to have clear links with the ATWP, span a 30 year timeframe, involve a thorough consultation process, and consider the sustainability of the proposals²⁶. Promoting a long planning horizon is again consistent with the recommendations in this report – however Government may need to assess whether 30 years is an appropriate period when adaptation is taken into consideration, or alternatively, if critical infrastructure related issues might need to take a longer term view.

Airport infrastructure typically undergoes regular upgrades, replacement and maintenance, and depending on these cycles adaptation measures could be introduced to incorporate enhanced levels of resilience according to the latest

²⁶ Assessing The Future of Air Transport White Paper as a strategic framework for sustainable airport development, Research conducted by Ipsos MORI and the Institute for Transport Studies on behalf of the Department for Transport

science. The challenge of the timing of adaptation arises when upgrades and replacements happen more regularly as a result of damage from changing weather patterns. Thus, airport operators and regulators could perhaps seek to balance the level and cost of resilience built in against the life span of the next replacement cycle – e.g. if an airport operator resurfaces its runways (roughly every 7-10 years – but will vary with use), the potential adaptation needs over this period would be considered, whereas adaptation impacts beyond 7 years could be phased in during the next resurfacing exercise. To do so, operators need a good understanding of impacts both in the short and longer term.

The Coalition Government's Secretary of State for Transport Philip Hammond announced in July 2010 that a new set of duties would be introduced for the Civil Aviation Authority's (CAA) economic regulation of airports which "will put the interests of passengers unambiguously at the heart of the regime" and that "the CAA's primary duty will be to promote the interests of existing and future passengers". Several features of this proposal bear scope for supporting adaptation and resilience investments:

- Passenger-focussed investment;
- Preparation of plans for continuity of service should an airport operator get into financial difficulties;
- Civil sanctions, including financial penalties, for the CAA to enforce licence conditions, creating a more efficient and responsive enforcement regime;

Although the preparation of plans for continuity of service is aimed at financial resilience, a similar principle could be applied looking at operational and infrastructure resilience. This may or may not be part of the licence conditions, but the ability to enforce e.g. through financial penalties would build credibility for the regulator or Government.

Recommendations for the airports sector

Longer term and more integrated planning

The current 30-year framework is generally suitable for many types of shorter life span infrastructure, but could be insufficient for longer term new assets. The Government and Department for Transport would need to review the need for longer planning horizon for large new infrastructure, e.g. new airports, and emphasise the role of evaluating investments of 15-20 years or more against potential adaptation requirements. This could be done as part of the existing regulatory review cycle, and the regulator (the Civil Aviation Authority) would require regulated airports and National Air Traffic Services to incorporate consideration of adaptation risks and requirements in their investment plans.

A more integrated view of the sector is also required. The consideration of resilience to the aviation sector needs to go beyond airports and include other related infrastructure, e.g. surface access to airports. The current regulatory framework focuses on incentives and penalties for airport related service quality, but the consideration of interdependencies and broader resilience surface access should also be explored. Ultimately, this process should be about incentivising cross-sectoral discussions to ensure a consistent approach to adaptation.

Better sharing of information within sector and within region

Airports could benefit from greater industry collaboration on how the risks of climate change are incorporated in the planning, design, construction and operation of an airport, through greater sharing of information and best practices.

A key challenge to this would be the variability of impacts. As airports are by nature geographically diverse, climate impacts are likely to differ – some collaboration would be possible for more generic impacts, but local issues may best be dealt with locally. Airports may find local forums and other local infrastructure operators provide a more suitable platform to identify local risks and mitigation measures. Interdependencies and collective resilience with land access to airports (roads and rail) should be a key priority for cross-sector collaboration and should be incentivised by the regulator.

6.4 Ports

Overview and market context for adaptation

The UK ports are vital gateways for trade and travel into and out of the country. In 2008 total freight traffic through UK ports was 563 million tonnes, of which over 80% was through the 15 major ports. As an island economy the ports sector makes a significant economic contribution at national, regional and local levels (£445 billion of international trade passed through UK ports in 2008).

The UK ports sector comprises a mix of private and publically owned facilities. Within the top ten largest ports there are examples of both types of ownership, such as Grimsby and Immingham, and Southampton (ABP) and Milford Haven and Dover (both trust ports). Ports are not price regulated, in the sense that airports and utilities are, so the ability of the public sector to actively influence investment plans is less tangible. The UK ports policy allows commercial, trust and municipal port operators to make decisions about where and when to invest in infrastructure investment, although recognising that the ports industry needs to take full account of adverse impacts and benefits, locally and regionally. This approach also recognises the competitive nature of many ports – which in itself should provide a catalyst for efficient investment which responds to adaptation challenges (because ports that anticipate adaptation challenges well, could have a competitive advantage over those that do not).

The trust ports sector is governed by the Modernising Trust Ports policy (updated in 2010). Trust ports are independent statutory bodies, each governed by its own unique, local legislation (Harbour Revision Orders) and controlled by an independent board. Trust ports have no shareholders or owners other than Government, but are accountable to a range of stakeholders including port users, port employees, and the local community.

Typically infrastructure investment decisions in Trust Ports are taken independently by its Board and reflect the need to operate on a commercial basis but also to respond to a range of stakeholder interests (e.g. making an economic contribution locally). There is no policy or regulatory regime that dictates the nature or scale of port infrastructure investment in trust ports. There is no regulatory authority that specifically covers the ports sector. However, bodies such as the General Lighthouse Authorities maintains the safe access to ports through the provision and marking of appropriate routes to enable ships to reach ports. However, Government provides regular published port demand forecasts every five years to help Government and developers assess the prospective national need for capacity in each of the main port traffic sectors.

Key findings and challenges to adaptation

Operating conditions make the ports sector acutely aware of climate change

The ports sector is particularly vulnerable to climate change, being located on the coast and to predicted changes in sea level rise, storm surges and flooding. As a result, the sector is acutely aware of the potential challenges from climate change, and operators have been continuously monitoring data on flooding, wind speed and other climate variables, including the use of UKCP09. Typically this means a heavy reliance on the advice of engineering consultants on climate and weather related issues. A main challenge for the sector, however, is geographical and local modelling. For example, generally the published data is seen to be more useful for southern based ports compared with northern based ports, because of geographical variances in sea level rises – some parts of Scotland are experiencing or expecting sea level falls. There is also a broader concern on the use of data for the sector that outdated evidence is informing investment decisions.

The ports sector is also viewed by commentators as a conservative, risk averse sector so operators are familiar with the concept of “just-in-case” investments, especially to protect high value and premium facilities such as flooding of major automated facilities. With long asset lives (60-100 years for some assets), ports also recognise the benefits in building in climate change adaptation in new infrastructure than trying to retrofit at a later stage.

The response across the sector still varies considerably

However, set within this context, infrastructure and commercial decisions still need to be grounded in robust business cases and respond to the demands of shareholders and the market. Thus, some ports acknowledged that climate change is an area with low recognition in the business planning process, while others reported that climate change is one of many measures of risk / resilience consideration in a port’s risk register. It is also unclear the extent to which climate change adaptation is consistently and robustly considered across the sector. For example, all major ports are required to produce Master plans for the period to 2030, but climate change adaptation issues tend not to be robustly addressed or articulated for many ports. Thus, for example, ports rarely go beyond compliance levels when looking at new infrastructure (e.g. 1:200 levels of flood protection, height of quays dictated by planning regulations). In particular, many ports consulted recognised that the uncertainties involved in a time horizon greater than 25 or 30 years tend to render the business case immaterial (e.g. discounting of benefits accruing in 30 years).

Strong guidance from the draft policy statement provides a good basis for successful adaptation

The draft National Policy Statement (NPS) prepared by the DfT in 2009 for the ports sector looked at a range of issues on the planning of ports, one of which is climate change adaptation²⁷. The draft NPS emphasised the importance of looking at potential impacts from climate change when planning the location, design, build and operation of new port infrastructure. Some guidance around the types of information to be used were also provided, for example:

- Use of the latest set of UK Climate Projections;
- Apply, as a minimum, the emissions scenario that the independent Committee on Climate Change suggests the world is currently most closely following – and the 10%, 50% and 90% estimate ranges;
- Consideration of Environment Agency (EA) Flood Maps and a flood risk assessment (FRA); and
- The high emissions scenario (high impact, low likelihood) should be applied to safety critical elements (e.g. storage of gas, petro-chemicals) which are critical to the safe operation of the port infrastructure

Further specific guidance on the FRA also include amongst other things

- Proportionate to the risk and appropriate to the scale, nature and location of the project;
- Be undertaken by competent expertise;
- Consider both the potential adverse and beneficial effects of flood risk management infrastructure together with the consequences of their failure;
- Consider the vulnerability of those using the site, including arrangements for safe access; and
- Include the assessment of the remaining (residual) risk after risk reduction measures have been taken into account and demonstrate that this is acceptable for the project.

This set of guidance is broadly consistent with many of the recommendations in this report: i.e.

- Provide high level guidance on what successful adaptation would incorporate e.g. in this case the types of scenarios considered; and

²⁷ At the time of writing it is unclear whether the NPS will be used under the new administration.

- Place emphasis on the resilience and adaptation needs of the critical elements of the infrastructure

In particular, by articulating the need to look at high emissions scenario for critical elements the NPS has helped identify what “just in case” investments might look like. What the NPS is less clear on, is the timeframe of the project – as “just in case” adaptation for a project with expected commercial life of 25 years could be very different from one of 75 years (see case study on Drax Heron plant).

Need to balance against efficiency and long-term competitiveness

Participants of this study have argued that retaining the competitiveness of ports is an important consideration and that over-investment would lead to inefficient or uncompetitive outcomes. The “right” level of investments would be vital to retain the confidence of the ports’ customers and investors, and ports as unregulated entities should be allowed to make their own decisions as long as there is consistency in terms of the levels of risk tolerance across sectors – e.g. defining flood risks to 1:200 (EA guidance) or 1:100 levels of protection and timeframe. This could be encouraged through the types of guidance offered in the NPS, as well as improvements in the effective learning and sharing of climate change related risks across the sector.

Recommendations for the ports sector

Encourage the principles recommended in draft National Policy Statement

The approach and guidance on climate change adaptation planning as presented in the draft National Policy Statement provide many of the right principles in evaluating and responding to the risks of climate change. While the future of the National Policy Statement is unclear at the time of writing, to the extent that these guidance are consistent with the needs of the ports sector (i.e. striking a balance between adequate resilience and economic competitiveness) they could form the basic principles for how the ports sector address climate change.

Better sharing of information within sector and within region

As with airports, ports are geographically diverse, with varying climate impacts. A localised approach (on top of necessary sector level co-ordination) could involve local forum and other local infrastructure operators to identify risks and mitigation measures. Again similar to airports, interdependencies with land access to and from ports (roads and rail) are important and collective resilience would need to be considered jointly rather than in isolation.

6.5 Roads

Overview and market context for adaptation

The Secretary of State for Transport retains responsibility for overall Government policy on roads, including determining road policy, setting the strategic framework for new developments and establishing financial parameters.

Road transport is a devolved matter so Scotland, Wales and Northern Ireland largely plan their own road networks. In Scotland, Wales and Northern Ireland, individual agencies reporting to the respective regional assemblies take responsibility for major roads. These are the Scottish Executive in Scotland, which plays a similar role to the HA in England, The Transport Directorate of the Welsh Assembly and the Roads Service in Northern Ireland which is an Executive Agency established within the Department of the Environment for Northern Ireland.

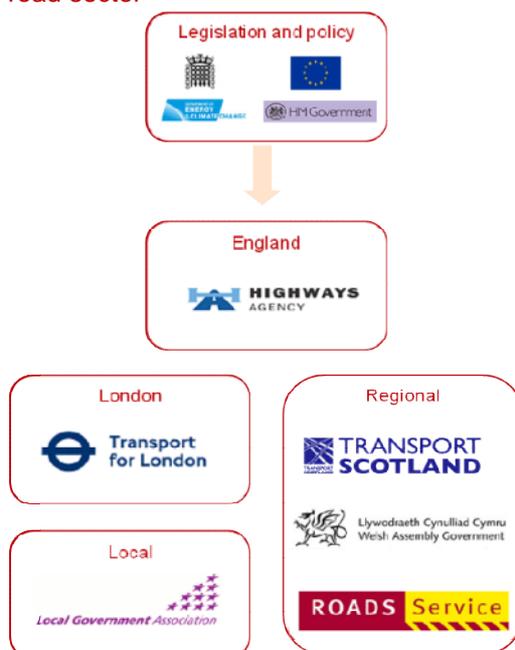
Local authorities in England have the legal duty to maintain local roads, which form 98% of the road network whilst the Highways Agency is responsible for the operation, maintenance, and improvement of England’s strategic road network.

The road network is split into 12 areas, where five year Managing Agent Contracts (MAC) are let to the private sector for maintenance of roads.

In London, Transport for London takes responsibility for a sizeable network of main arterial roads. Its main role is implement the Mayor’s Transport Strategy for London and manage the transport services across the capital for which the Mayor has responsibility. TfL is directed by a management board whose Members are chosen for their understanding of transport matters and appointed by the Mayor of London, who chairs the TfL board.

The local approach to the planning, management and maintenance of roads means that whilst the Highways Agency would be crucial in maintaining the strategic national network, local governments would need to play an active role in incorporating adaptation responses in their local road networks.

Figure 23: Regulatory landscape in the road sector



Key findings and challenges to adaptation

Road infrastructure could benefit from incremental adaptation

While decisions around resilience improvement lie with the Highways Authorities, given that the road network is resurfaced every 8-12 years, this provides the opportunity for the Highways Agency (or Local Authorities) to build in additional resilience to current and short-to-medium term future weather events over the natural repair and maintenance cycles. Areas of greater concern include infrastructure with longer term investment cycles that will still be around beyond 2020, for example structures such as bridges.

The Highways Agency sets the right context for long-term adaptation, but ownership of short-term issues are less clear

In 2009, the Highways Agency developed and published a Climate Change Adaptation Strategy and Framework which forms the basis to which adaptation is considered in the strategic road network. The Framework specified a list of desired outcome as follows:

- Climate change considerations are factored into Highways Agency investment controls and business as usual, including design, construction, maintenance, and operations;
- Early consideration of climate change risks leading to greatly reduced costs over asset life;
- A move away from reliance on historical weather record as basis for standards and specifications;
- Residual climate change risks are assigned appropriate management action; and
- The Highways Agency can demonstrate an effective approach to climate change risk management and fulfil our reporting obligations.

As part of the framework, the strategy has identified over 80 Highways Agency activities that may be affected by climate change. A preliminary appraisal of the risks associated with these vulnerabilities has been undertaken which found that over 60% of assets are expected to be materially affected by current predicted levels of climate change within the relevant asset life or activity time horizon. The Highways Agency developed a methodology to identify and compare options to manage the risks associated with the Highways Agency's vulnerabilities. The methodology provides a tiered approach to assess options and guidance to identify the preferred option. The risk appraisal has also enabled vulnerabilities to be prioritised for attention, based upon several criteria including their potential to disrupt the operation of the Highways Agency network. Once selected, the preferred adaptation solution is translated into an adaptation action plan. The detailed guidance could help inform the sector's investments, where major investments could have very long lead in times of over 10 years.

Despite the large programme of work identified by the Highways Agency, we note that there is a concern that the managed motorways have lower than acceptable levels of resilience. The Institute of Civil Engineers assessed that there is little spare capacity, with an accident or breakdown typically resulting in length queues²⁸. This could potentially be exacerbated by climate change. Thus a large part of ensuring the short to medium term resilience of the road network – as the Highways Agency carries out its adaptation programme – is reduce and manage recovery in the event of extreme weather conditions. The adaptation responses would also need to incorporate the provision of information and advice to motorists about adverse conditions, road closures or alternative routes. This would also mean a greater focus on inter-modal connectivity, to ensure that the overall transport systems could help mitigate the impact on passengers and /or freight. One key priority would be to look at the wider interaction between climate change and traffic demand, commuter patterns, freight patterns and inter-modal connectivity.

Recommendations for the roads sector

Promote understanding of the wider linkages between climate and transport

The Highways Agency and the Department for Transport could conduct or commission further analysis on the wider interaction between climate change and traffic demand, commuter patterns, freight patterns to understand the wider interactions between the climate and the roads network. This exercise could also potentially encompass other modes of transport.

²⁸ ICE, The State of the Nation, Infrastructure 2010

Promote a local focus on local solutions

Local authorities could convene local forum with other local infrastructure operators to examine local solutions to road resilience. The forum could also identify joint funding mechanisms to finance resilience work. For example, the “last mile” of road linkages to specific infrastructure or economically important operations is occasionally privatised – a greater examination of the extent to which this approach could help internalise the externalities of climate change could help generate innovative funding arrangements.

Cross-modal and emergency planning

By improving existing communication channels to road users, Highways Agency and local authorities can help road users manage their journey more effectively during periods of interruptions. For example, real-time communication and information can help manage recovery and emergencies, including providing information about road closures, traffic conditions, alternative routes and early warning systems on adverse weather. While many of the information listed are currently provided e.g. through radio traffic reports, more accurate or localised early warning systems could help reduce the risks to road users.

6.6 Rail

Overview and market context

Regulation plays a key role in delivering UK railway services. The UK rail industry depends on private companies to deliver rail services, supply equipment and provide expertise. Network Rail is the private sector monopoly owner and operator of the national rail network, including track, signalling, bridges, tunnels and stations. Network Rail operates under a network licence. This licence contains a set of conditions under which Network Rail must operate. Its operation is regulated by the Office of the Rail Regulator (ORR).

All participants in the industry are subject to commercial pressures and driven by targets and incentives and the effective functioning of the railways is reliant on co-operative working between different companies and organisations.

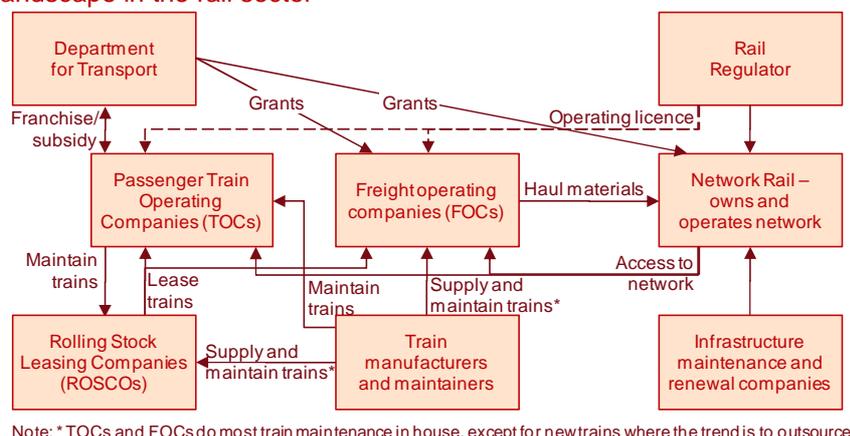
The ORR approves all contracts. Therefore both freight operating companies and train operating companies have regular interaction with the ORR and Network Rail. The role of the ORR is summarised as one of monitoring and where necessary enforcing delivery by the whole industry of its regulatory obligations – safety, performance, efficiency and investment – and encouraging further improvement to meet the needs of customers and improve value. The sector is subject to 5-year control periods (currently in CP4 2009 – 2014) to ensure continuity of planning, delivery and funding.

The Government specifies through the High level Output Specification (HLOS) the key requirements, including:

- Safety: e.g. 3% reduction in risk of death or serious injury to rail workers and passengers;
- Reliability: e.g. punctuality to improve from currently 90% to 92% (long distance/regional) / 93% (London and SE);
- Capacity: sets out level of passenger demand to be met on each of its strategic routes; and
- Other: e.g. 1300 new carriages, major improvements at Reading and Birmingham New Street stations.

The Government also commits its budget through the Statement of Funds Available (SoFA). The current funding commitment extends to £15bn over the period 2009-2014. Within this context, setting the regulatory requirements which shape the way in which this money is spent is an interactive process between Government, Office of the Rail Regulator and Network Rail, to agree the efficient targeting of these funds.

Figure 24: Regulatory landscape in the rail sector



Key findings and challenges to adaptation

Ongoing work to bridge information gaps

A study by Network Rail has been commissioned (Jul 2010) by the rail industry safety board (RSSB) to look at the impacts of climate change on exposed coastal tracks, embankments and bridges over the coming decades. The £750,000 UK-wide investigation is expected to save £1bn over the next 30 years through safety improvement and emergency planning. The project will look at vulnerable coastal lines, the risk of flooding and landslides for cuttings and embankments alongside lines, and the ability of bridges to withstand floods. The new review will also involve designing modelling tools with the Met Office. As well as regular investment by Network Rail, there is a strong dependence on the knowledge and experience of the technical expertise, in particular engineers, to provide the right level of guidance and recommendations. These recommendations would also be weighed in terms of the costs and benefits, and in general participants to this study found that issues with greater certainty tend to be addressed.

The key challenge for the rail sector is the age of the infrastructure, such that many assets predate existing standards or design guidelines which are now deemed compatible with providing resilience. Thus recent and new infrastructure assets are likely to be equipped with best practices and tend to address issues or impacts that are already visible today (e.g. High Speed 1 is built to a very high level of flood risk protection, and utilises landscaping design to avoid the impacts of falling leaves from vegetation). Existing, older infrastructure, on the other hand, would need to rely on repair, maintenance and upgrade to ensure future resilience.

A strong awareness of climate change

As with many other sectors, the key guidance for new assets relate to planning guidance provided, in particular around flood risks. The impact of recent flood events has also led to greater willingness to accept and comply with the guidance. The Adaptation Reporting Power, which affects key rail infrastructure owners, also raised the agenda of climate change adaptation in senior management and board of these organisations.

The inherent network nature, awareness on climate change impact and recent experiences of Network Rail have led to a strong awareness on the need to consider systems thinking and interdependencies, for example the need to protect vulnerable assets as well as those interlinked to them. The need for electrification of the network, as part of the industry's plans to reduce carbon emissions, would also mean a greater dependence on the electricity sector.

A focus on adaptation is compatible with the current regulatory framework

Participants from the rail sector have promoted the model of rail regulation as one conducive to the incorporation of adaptation. In particular, the government sets expectations through the High level Output Specification (HLOS) in collaboration with the sector, which then determines the types and scale of investments required. These principles would then be considered by regulators during their regulatory interactions with operators, including the potential to impose penalties for failing to meet targets or standards. Adaptation, particularly if considered as part of prudent asset management, could be one of many issues for consideration within the HLOS.

Greater inter-modal connectivity could help manage emergency response

The sector has also recognised the importance of disaster management and emergency response. A good example provided by Transport for London (TfL), which is a local government body responsible for most aspects of the transport system in Greater London including rail. The oversight across the different modes meant that TfL has strong capability and focus on the emergency response aspect of resilience – for example including a communications programme that can inform customers and boroughs of alternative transport. This also highlights the importance of the role of communications in emergency and disaster planning, and how ICT could play a role in improving resilience.

A recent example from the volcanic ash cloud from Iceland disrupting the UK's flights – albeit not climate change related – shows how the rail sector is also responsive to disruptions in other sectors and react by offering commuters additional capacity. Greater inter-modal co-ordination and contingency planning could well help to minimise the disruptions caused by weather events and provide continuity of transport services.

Recommendations for the rail sector

Greater focus on network and systems resilience

Network Rail and infrastructure operators are currently improving their understanding of the impacts of climate change and the required response. The industry is configured to look at network risks and systems resilience as a whole, but the focus could also be usefully extended to incorporate interdependencies with other sectors – in particular other transport modes, and potentially energy and ICT.

Local focus on local solutions

As with roads, train operating companies, Network Rail and local authorities could work together through local forum and other local infrastructure operators to examine local solutions, including joint funding mechanisms and opportunities. Local authorities could also increase focus on inter-modal issues to manage and coordinate the overall transport system during periods where one transport mode fails.

7 Information and Communication Technology (ICT)

7.1 Overview

This report considers ICT infrastructure as the whole of the systems and artefacts which enable the transmission, receipt, capture, storage and manipulation of voice and data traffic on and across electronic devices. As such it includes:

- All the infrastructure components of copper and fibre optic cables, exchanges, masts, aerials and antennae;
- System devices (e.g. network switches, routers, wireless access points);
- Data centres, call centres, electronic data interchange, on-line commerce;
- End-user devices (e.g. computers – both portable and desktop, telephones, mobile telephones, PDA and other hand-held devices, SCADA control devices, GPS transmitters/receivers);
- Satellites (taken as outside the scope of this inquiry); and
- Applications (e.g. the programs that enable the infrastructure and devices to function, interact and perform useful functions).

ICT is the only sector of infrastructure that directly connects any one user to any other user across time and space using multiple pathways simultaneously and capable of dynamic re-routing in real time. As such the value of ICT services is the network rather than any of the individual components, and the operation of the network that relies on the whole infrastructure.

ICT performance under stress (and human performance when the technology does fail) can be unpredictable and it is subject to node failure in which damage or compromise of a key element (a node, router, switch or exchange) causes a service failure to multiple users. The increasing trend towards shared infrastructures, outsourced arrangements (including off-site data centres), emergence of 'cloud computing' (where both the data and the application are held remotely from the user) all have great potential to drive greater business efficiency. The greater interconnectivity represents increasing challenges to the resilience of any particular element being able to operate independently when other elements fail.

There is as yet very little work that has explored the potential risks from weather and climate in relation to ICT vulnerabilities, particularly in the context of current and future developments and emerging technologies, and the consequent knock-on to other parts of the infrastructure "system of systems".

7.2 Summary of climate change impacts

The study by AEA Technology conducted as part of the Infrastructure and Adaptation Project has identified a number of potential challenges arising from climate change for the ICT sector, summarised by this section.

Principal climate change risks Implications for infrastructure

Network Exchanges and Data Centers

- | | |
|---|---|
| <ul style="list-style-type: none">• Increased risk of overheating in data centres, exchanges, base stations etc.• Coastal erosion and coastal flooding of infrastructure (e.g. exchanges) in vulnerable areas• Increased flood risk to assets in flood plains or urban areas (increase in flash floods), e.g. data centres, exchanges | <ul style="list-style-type: none">• Availability of services or degradation in quality of service e.g. due to unit or system failure• Reduced business costs to cope with winter demand (e.g. reduced space heating in data centres, exchanges, etc)• Degradation of infrastructure close to coast line, availability of services, repair & recovery times, increasing business costs and health & safety risks• Reduced availability of services, repair and recovery time and increased business cost in flood plain areas• Business costs to maintain internal data centre environment• Increased heat-related health and safety risks to exposed workers (e.g. maintenance engineers, drivers, |
|---|---|
-

Principal climate change risks Implications for infrastructure

staff in exchanges)

- Changes in dehumidification requirements and tolerance ranges of system devices
-

Wireless Infrastructure

- Location / density of wireless masts may become sub-optimal since wireless transmission is dependent upon temperature (refractive index)
 - Impact on quality of radio-frequency propagation if vegetation type changes in response to climate
 - Increased risk of subsidence, reduced stability of foundations and tower structures
 - Changes in storm / wind-loading damage to all above ground transmission infrastructure
 - Lightning strike damage to transmitters during storms
 - Increased saline corrosion of coastal infrastructure e.g. broadcasting towers
 - Reduction in availability and quality of services and increase in business costs due to refractive index
 - Reduced impacts of snowfall on masts, antennae, etc, with less infrastructure degradation, maintenance costs and health & safety risk and improved availability of services
 - Improvement in signal propagation and service quality due to less vegetation
 - Degradation of infrastructure and increasing business costs to repair foundation of infrastructures
 - Degradation of infrastructure, availability of services, repair & recovery time and increasing business costs due to storm damage
 - Degradation of infrastructure, availability of services, quality of service and increasing business costs due to lightning
 - Degradation of infrastructure, availability of services, repair & recovery times, increasing business costs and health & safety risks due to increased saline corrosion
 - Business costs to maintain internal data centre environment
 - Changes in dehumidification requirements and tolerance ranges of system devices
-

Copper and fibre optic cables

- Risk of flooding of low-lying infrastructure, access-holes and underground facilities
 - Increased erosion or flood damage to transport structures which may expose cables / trunk routes
 - Reduced quality of wireless service with higher rainfall rates
 - Changes in corrosion rates
 - Degradation of infrastructure, availability of services, increasing business costs and health & safety risks due to flooding
 - Degradation of infrastructure, availability of services and increasing business costs
 - Degradation in quality of service
 - Reduced availability and quality of services, longer repair & recovery times, increasing business costs and health & safety risks
 - Business costs to maintain internal environment
 - Degradation of infrastructure and increasing business costs
 - Increasing difficulty to repair faults and restore service with increasing volume of adverse weather-related problems
 - Changes in dehumidification requirements and tolerance ranges of system devices
-

7.3 Key findings and challenges to adaptation

Fast paced market with high refresh rates

The high refresh rates and technological changes in the ICT sector mean that the long-term risks from climate change to its infrastructure are not actively considered. Indeed, a substantial proportion of the infrastructure systems described in section 7.1 was not present 15-20 years ago. This makes the consideration of climate change impacts of infrastructure in 20-50 years difficult or impossible for the stakeholders consulted as part of this study, and given that investments rarely extend to this time horizon, the business case for long-term adaptation is inherently weak or non-existent. Long-term climate resilience in the context of a fast paced market therefore needs to focus more on the organisational and sector resilience, i.e. how ICT companies evaluate and manage risks on an ongoing basis.

Focus on emergency response

The focus of providing resilience currently is on emergency response, for example through the National Emergency Plan for the UK Telecoms sector and National Emergency Alert for Telecommunications (NEAT) protocol. These plans and group cover several aspects of emergency response including:

- Information flow during an emergency including identification of network disruption;
- Ensure that information regarding potential or actual emergencies with telecom implications are brought to the attention of the lead government department (currently BIS); and
- Ensure restoration of the network as soon as possible.

The Electronic Communications Resilience and Response Group (EC-RRG) is tasked with promoting the availability of electronic communications infrastructures in the UK, chaired by an industry representative and hosted by BIS. The EC-RRG issued guidelines to telecommunications infrastructure operators on resilience, which includes the following guidance amongst others:

- Telecommunications companies will invest, where practical, in duplicate or triplicate back-ups for their equipment (redundancy) and diverse transmission routings, to ensure that the 'logical' architecture of the service will be more resilient than the simple physical layout. The key is to avoid, wherever possible, 'single points of failure'. Complementary processes of restoration and repair have to be strengthened.
- Essential equipment should not be concentrated, particularly in one building, to the extent that overall network security is jeopardised. Where essential equipment is co-located (for example, at multiprocessor sites), priority should be given to physical separation, such as a fire break, to reduce the possibility of common mode failure.
- Physical design: e.g. underground line plant, buried at a depth where intrusions are unlikely, is preferable to aerial line plant; antenna masts should be designed to withstand likely wind and ice loading.
- Key inputs - power: The power supply to key equipment should not be interrupted in the event of a mains power supply failure. The mains supply should be secure and steps taken to ensure that it is reliable. For major sites, it may be appropriate to acquire diverse feeds of mains supply.

The guidance suggest that to a large extent, many adaptation measures are known to and being applied by the sector, as they are common in response to other types of threats. The challenge that climate change brings is ensuring that the guidance would continue to provide the resilience required as the market evolves. The additional difficulty is in monitoring and evaluating the extent to which infrastructure operators follow the guidance, and whether there is a role for the regulator Ofcom or Government in enforcing or mandating these guidance. Specifically, resilience is currently not a priority for Ofcom, which aims to promote a light touch regulatory environment.

Awareness of interdependencies and potential opportunity to facilitate adaptation

However, there is an overall recognition that many of these infrastructure assets are exposed to weather-related disruption, or key inputs including electrical power. The dependence of many of other sectors on ICT also means that extreme weather events could place strains on the capacity of the networks.

This dependence also represent potential opportunities for the sector, for example bridging information gap, enabling the use of telemetry and remote working, providing early warning systems and real-time feed of information. The market opportunities may lead to a greater awareness of the ICT sector to improve on its resilience.

7.4 Recommendations for the ICT sectors

Focus on emergency response

The ICT sector's core focus, given the high refresh rates of the sector, need to be on the improvement of network and systems resilience, through greater collaboration and support across networks, and improve knowledge sharing of climate / weather related data and their use. The current EC-RRG provides a potential platform to coordinate and manage this cooperative effort, however Government could help ensure that adaptation is actively and adequately considered on its agenda (as there is a real risk that long-term issues could be de-emphasised). It would also need to increase interaction with the energy sector to ensure the security of power supply.

The role of ICT to enhance adaptation

The ICT sector needs to recognise its potential role in enabling and enhancing adaptation. Early warning systems, smart equipment, sophisticated and resilient back-up systems and procedures are some of the opportunities for the sector to capitalise on. Improvements to existing products and systems e.g. the smart grid for the energy sector, telemetry for the water, and real time communication for the transport, could also generate profitable ventures. The ICT sector is starting to take active interest in enabling adaptation, especially in least developed and developing countries where opportunities are greatest. Providing solutions in the economic infrastructure sectors is equally important and should be actively promoted. To capitalise on these opportunities the sector would also need to demonstrate its own resilience to climate change and "walk the talk". This is being observed in the sector's response to the climate change mitigation agenda, where ICT companies are responding quickly to realise opportunities to manage and lower energy use of other sectors, but doing so by demonstrating their own green credentials in energy management.

8 Risks: The role of investors and insurers

8.1 Overview

The risks associated with climate change to an infrastructure asset or project are typically spread across a number of stakeholders, including both investors and insurers:

- **Operators:** service disruption or inefficiencies could lead to higher costs or lower revenue, or there may be a need to incur costs for restoration of services or compensation;
- **Investors:** the level and stability of returns on investments could be affected;
- **Insurers:** damage or interruptions to the insured asset or project could result in a claim;
- **Users:** service delivery could be interrupted or terminated completely and the cost of the service may change significantly;
- **Government and regulators:** government is likely to bear some or all of the cost of disaster management, emergency response or restoration of services.

This section focuses on the role of investors and insurers.

Institutional infrastructure investors have grown in recent years driven by the demand for steady and predictable long-term returns, as well as, in the case of some types of infrastructure, the launch of the government's Private Finance Initiative (PFI) in 1992. The exposure of these investments to impairment from extreme weather events through to lower returns as a result of lower efficiency levels could all be exacerbated by climate change.

Adaptation is particularly critical to the insurance industry as it directly affects their business. In 2007 the summer floods alone caused more than £3bn of insured damage and the total disruption to the economy was far greater.

Infrastructure investors and insurers are thus also key stakeholders to ensure the resilience of infrastructure assets. We have considered both of these groups in this section, recognising that many of the exposures are similar to both groups of players, and therefore the need and types of response required could be identical or complementary.

Institutional investors

There are a wide range of institutional investors in infrastructure including public and private pension funds, superannuation schemes, insurance companies, sovereign wealth funds, and investment and development banks. What all of these investors have in common is that for part of their investment portfolio they are looking for opportunities that can offer a steady or predictable cash flow over the long-term. Infrastructure is an asset that can potentially meet this demand. For what may be regarded as a lower risk investment the investor is willing to accept a lower return on their capital invested compared to other investment classes or sectors.

These investors are investing equity or share capital to the companies owning and operating the infrastructure. They may make this investment directly or by investing in a specialist infrastructure fund. Infrastructure investments can be highly leveraged i.e. with only a small percentage of the total financing being equity, sometimes as low as 10%, with the balance coming from commercial debt²⁹.

However the infrastructure offering is not homogenous and within the sector there can be a range of risk reward propositions. There are in essence six main elements that will help to define more closely where any particular opportunity sits on the risk reward spectrum, these are:

²⁹ This report does not consider the approach of commercial debt providers.

- What stage of development is the asset – ranging from still to be built (and the risks of developing it) to fully developed with an operational track record;
- What is the revenue source – whether publicly funded or user paid;
- What is the revenue profile – is it steady over the long-term, linked to GDP or inflation, regulated, highly unpredictable, seasonal or short-term;
- What is the cost profile – is it largely fixed or flexible to demand/need, is it linked to GDP or inflation, regulated, predictable or unpredictable;
- Whether open to competition or a monopoly; and
- What is the contractual basis – is it a time limited concession type investment or an open ended business albeit potentially open to regulation.

So an infrastructure asset whose revenue is solely dependent on the ‘user pays’ and open to competition, for example an airport, is a different investment proposition to infrastructure that local or national government pays for on the basis that pre-defined requirements are met, such as a hospital. The variety of models is illustrated below.

Figure 25: Funding and financing of infrastructure

		Energy	Telecoms	Transport	Waste	Water
Public capital	User funding	Public industry			Commercial waste operations by Local Authorities	Scottish water
	Taxpayer funding	Conventional capital procurement		Most roads	Municipal waste facilities	Flood and coastal defences
Private finance	PPP / PFI			M25 widening	Municipal waste facilities	Northern Ireland water PFIs
	User funding	Economically regulated private industry	National Grid	BT Openreach	Some airports	England and Wales water supply and sewerage
		Other private industry	Electricity generation	Cable networks	Ports	Commercial waste disposal

Source: Table extracted from HM Treasury and Infrastructure UK, “Strategy for national infrastructure”, March 2010

Recognising the different types of investment opportunities and range of investor risk reward appetite is important as it influences investor appetite and incentive to deal with change including the impact of climate change.

Insurance

The insurance sector, like the institutional investment community, separates the risks (and insurance products and portfolio) around the construction of infrastructure and those from the ongoing operation of infrastructure. In addition, the sector could also be insuring risks around damage to the infrastructure asset itself and on business continuity.

Insurers traditionally based its view of risk on historical records of hazard occurrences, but climate change could mark a shift away from this approach, with fundamentally different risk assessment tools by insurers and the way the sector manages its portfolio risks. In the UK, the sector body the Association of British Insurers (ABI) looked at the impact of climate change scenarios on insurance pricing. The expected impact of climate change (more broadly and not specific to infrastructure) in the UK under a 2°C temperature increase scenario is a required additional insurance capital of £1,065 million for a 200-year flood. Without sufficient capital, the availability of insurance could be reduced.

The insurance sector relies heavily on external information from specialist providers, such as RMS (on quantifying weather-related catastrophe risk) and Aon Benfield (on natural hazards risk) with internal modelling.

8.2 Current practice for incorporating climate change adaptation in investor decisions

Low awareness on climate change risks generally

Given the wide variety of investors active in the infrastructure market and the range of infrastructure investment opportunities it is not surprising that we encountered diverse responses to this study. A number of investors that we approached to contribute to this study declined the opportunity as they were unable to identify the extent to which adaptation is relevant to their investment portfolio. In some cases, this was a consequence of the limited time horizons adopted by the investor – reflecting either the time-limited nature of their investment in an asset (e.g. an operating concession), or a general short-term approach to managing risk (and the associated returns).

Within the group of investors who participated in this study, there were several investors who acknowledged that they were not clear on how the physical risks of climate change could affect their investments in the future. But there were other investors who had ‘climate change’ firmly on their agenda – who are leading the sector in this area.

It is interesting to note that in early 2010 Ceres, the United Nations Office for Partnerships and the United Nations Foundation co-hosted the fourth Investor Summit on Climate Risk attended by more than 520 investors, financial and corporate leaders. Although the focus of the discussion seems to have been largely focused on the transition to a low carbon economy, the need for adaptation to extreme climate risks was discussed.

Common barriers with operators on justifying adaptation

In many ways the investors consulted as part of this study has echoed the views of the sector operators on factoring adaptation into investment decision making, in particular:

- There is potentially a semantic/terminology issue in identifying what is meant by the impacts from climate change, for example of number of respondents commented that climate change is not an investment consideration but they do take account of flooding risks.
- The perceived current lack of detailed information on what the climate might be in the future and the uncertainty this creates makes it difficult to incorporate climate change risks as part of an investment decision. Investors have no sense as to what adaptation might cost and what impact it will have on their investment return. There is also a lack of awareness of what information is available.
- The nature of some of the impacts – very long-term / over 50 years – meant that the net present value (NPV) of a probabilistic impact is likely to be negligible under current financial modelling practices.
- The timing of the impact may be inconsistent with the investors’ time horizon. For example the impact may be predicted to occur beyond the term of the concession or when the investor expects to have exited their investment.

- The degree to which climate change impacts are included in evaluation, whether when making the initial investment or ongoing, is linked to direct experience of the investor, general awareness of the topic, or from specialist advisors. For example recent wide scale flooding in the UK has put flood risk assessments on the agenda for every investor's environmental due diligence. Even the most climate change aware investors are reliant on specialist advisors or the asset company management teams to advise on what adaptation is needed and when.
- Interdependencies of sectors are issues rarely considered in investment decision making.
- They recognise that financial models and figures are not the only determinants in their decisions but non-financial information, in particular on intangible and unquantifiable risks, could help inform decision making. However, this is conditional on companies providing the required information. Investors view the disclosure of risks of climate change vital in informing their decisions, even if they could not be monetarised.

Investors have a significant role to play in encouraging or requiring resilience and adaptation in operators of infrastructure. However this differs depending on a number of factors:

- Assets owners that have longer term visions such as pension funds are more likely to look at adaptation or long-term resilience. Pension funds are also particularly concerned about steady revenues over a long period of time.
- Funds with a shorter term defined life period, often around 10 years, focus on short-term performance, although their exit strategy may consider some long-term issues.
- Asset owners are largely reliant on fund managers delivering a target performance and so may not have direct influence over their portfolio of assets.
- Asset managers who have a more strategic role in the management of their portfolio tend to be more active in influencing change. A comparison against the climate change mitigation agenda suggests that investors or asset managers can be an important driver of change.
- Asset managers with a diverse portfolio (geographically or across sectors) are less likely to focus on resilience of a particular company or asset. However, in some instances, this could highlight interdependencies and promote thinking about resilience of their portfolio as a whole.
- Some "thought leaders" in the sector have done pilot studies and exploratory work in understanding climate change, but the mainstream investors had yet to look at adaptation. The "pace" observed in the climate change mitigation agenda suggests that it could take 3-5 years before an issue becomes mainstream.
- However, "trigger events" often help raise an issue up the agenda for investors, and flooding is a good example where this has happened.

8.3 Current practice for incorporating climate change adaptation in insurance decisions

Lack of consistency in approach to climate change and scepticism from customers

Participants to this study acknowledged that there are currently no consistent and direct dialogues between insurance and the building of infrastructure. The extent to which insurance may provide risk assessment advice may depend on the structure of the client. There is a perception that insurers are "educating" on climate change in order to sell on clients into buying more insurance, or to charge higher premiums.

Common barriers with operators and investors on justifying adaptation

Participants from the insurance community also believed that insurance is not currently a driver for adaptation measures, and conversely the risks of climate change has yet to affect the insurance premium or insurability of an asset significantly.

For some infrastructure operators, as insurance would tend to be across the portfolio of the assets of the company, higher risk assets may be offset by other lower risk assets in the portfolio.

As with the investor community, time horizon is a key determinant of how insurers respond to climate change risks. A key challenge for the sector in looking at adaptation is the length of insurance contracts. This is normally on an annual basis, which creates a mismatch between the annual structure of insurance and the long-term lifecycle of infrastructure assets. Insurers are not likely to increase premium on a year-on-year basis as a result of climate change, as this could be a commercial disadvantage. The exceptions to this are when extreme events occurred, which could trigger a step change. For example, flooding risks have been higher up the agenda since the extensive flooding of 2007.

The role of independent and international expertise

On knowledge sharing and influencing change in a company, participants in this study see insurance brokers having a role to play in sharing the expertise, especially for those that have international presence they are able to share knowledge from other countries with similar climates / more extreme climates. There is also a consensus that there needs to be a body that can “manage” the knowledge, for example collating and analysing risk reports. This is consistent with the needs of investors and the key principles of the disclosure similar – i.e. risk profile of a company and how companies are managing these risks – although there may be subtle differences in the types of information needed by the insurance sector to aid their decision making, for example insurers may be interested in the risks at the asset or geographical level, while investors may be more concerned about resilience at the organisational level.

8.4 Encouraging adaptation

The discussions with investors and insurers about how to ensure the necessary adaptation is made can be summarised into three themes:

- Is climate change adaptation a positive or negative risk?
- What adaptation is needed and when?
- What will it cost and who will pay for it?

Underpinning all of this is where do the risk, and therefore the cost and benefit, for climate change sit.

Is climate change adaptation a positive or negative risk?

Long-term investors can see potential benefits of incorporating climate change adaptation measures into their assets because it will lower overall risks and help the stability of return over the long-term – an important characteristic for infrastructure investment. However this is tempered by the uncertainty about: what adaptation is needed; when the adaptation needs to be made; how much will it cost and who will pay for it. So overall there may be a short-term negative impact (investing under uncertainty) for a long-term positive impact (stable returns).

There may be a distinction between the approach taken by long-term investors and shorter term investors in that shorter term investors may not be concerned with climate change as they do not expect to remain invested in a particular asset when the impacts of climate change are felt. However if they are expected to continue to invest in the same sectors these shorter term investors' interests should be largely aligned with long-term investor, for example if their investment exit is through a sale then they would not want abstract concerns about climate risks and costs diminishing their asset value.

The circumstance where interests may diverge is where an investor holds stakes in a series of concessions or public private partnership type investments and they expect the concession to have finished before climate change adaptation is

needed. For any new concessions that may be impacted by climate change, informed investors will seek to negotiate clear risk allocation for the required adaptation at the time of investment.

In either case if the current investors believe the impact of adapting to climate change has materially negatively impacted the overall investment characteristics of the infrastructure asset class then they may choose to exit the sector or seek a higher return on capital for the greater risk they perceive they are taking which may result in higher charges or use fees.

Similarly in insurance, insurers are primarily most concerned with risks over the period of the insurance contract, but insurers with long-term relationships with their clients and expect to operate in the same market over the long-term are also concerned by longer term risks. In practice, insurers may prefer to allow a gradual appreciation of insurance premium over a succession of contracts as the risks are increasingly priced in (up to a point where an asset becomes uninsurable for a particular insurer, and eventually the industry). Currently operators of infrastructure have yet to have difficulty insuring their assets, although step changes have been observed in recent history where some areas become uninsurable following extreme weather events (the most visible being in Florida, United States where insurers successively pulled out of parts of the state's property insurance market following a series of hurricanes).

What adaptation is needed and when

A strong message from the investors and insurers interviewed for this study is the need to long-term policy clarity – which they believe could drive behavioural change and the focus of efforts. Policy clarity would also drive mainstream investors and insurers to consider an issue that might have otherwise been considered “niche”.

In essence what investors appear to be seeking is for government to set out the climate scenario that the infrastructure needs to be adapted for. As part of this scenario investors might expect the government to highlight any infrastructure it sees as having critical national importance.

Insurers on the other hand, are interested in government taking an active approach to encouraging adaptation. For example, the ABI is pushing greater partnership relationships: including the UK Government, devolved Governments, local authorities, business and individuals.

The difficulty with articulating the risks and climate scenario is that whilst it might create a clear framework for investors to plan any necessary adaptation it creates a number of difficulties for government, namely:

- It is questionable whether the government will ever be in the position to set a single climate change scenario.
- It removes flexibility to adapt in the future or to different scenarios.
- It exposes the government to the difficulties of defining what infrastructure can be deemed critical.

It exposes the government to claims for negligence/compensation should adaptation be made to meet a predefined scenario and actual climate change is different.

Without setting a target scenario, the role for government must be more to do with communicating the latest and most credible science and forecasts of how the climate might change. For example UKCP09 is readily available but its content and key messages are not perceived to be very accessible. The government has a role to help with the education of investors on the issues and help them to start factoring climate change adaptation in to their long-term planning so when the time comes to actually make the changes the challenge and options for change can be well understood. Insurers, which have made more progress in the understanding of risks given the nature of their business, could also forge closer links with infrastructure investors (especially since insurers are also investors) to share this knowledge

The far greater challenge is how to tackle infrastructure interdependencies. Again it seems beyond the expected remit of government to map out all the interdependencies are but it undoubtedly has a role to try and facilitate cross sector working and understanding of any interdependencies.

What will it cost and who will pay for it

Investors are concerned that there may be circumstances where the level of investment needed to carry out the necessary adaptation measures does not make a sufficiently strong business case, whether the up front funding is difficult to arrange or there is insufficient revenue to repay the costs. In many cases, the costs of adaptation (especially adaptation against extreme weather events) may not be recovered, since the benefit to infrastructure operators and investors is a “non-event” and the associated avoided costs. Indeed, operators mitigate against the risk of an event by purchasing insurance. In some sectors, operators are able to pass on this investment on increased resilience and reliability as higher user costs, but this is more unlikely for competitive sectors especially if competitors do not value resilience as highly. This is potentially a greater concern for unregulated sectors where returns are unregulated. This would mean that not all of the necessary adaptation will be made under a market driven approach.

The government’s risk is that without an investment case no adaptation is made to assets regarded as key to the economic growth of the country and such assets are subsequently adversely impacted by climate change. However in many respects the government has already accepted this non investment risk for many other events that may interrupt service or service quality or has chosen to mitigate it through economic regulation.

Investors interviewed felt that if the government is unwilling to completely rely on market forces for all adaptation then the government potentially needs to discriminate between different infrastructure assets and prioritise those that are of greater importance for the economic growth of the country. For example it may be necessary to differentiate between the cost of maintaining a minimum level of protection for any economically important infrastructure and the cost of maintaining a higher level or resilience for these assets. The former costs could be regarded as some form of ‘national asset insurance’ for which government could provide strong incentives to ensure the adaptation is made or to part or fully fund where it is not economically viable to do otherwise. All other costs should be considered and funded alongside any other capital investments. It could be appropriate that any government funded or subsidised adaptation is undertaken at a lower return on capital to the mainstream activity.

At the end of the day, the cost of adaptation is borne by the general public, whether it is through increased user charges or through taxation. Being able to invest cost effectively and potentially spreading the costs over a number of years would help reduce the burden on users and taxpayers.

8.5 Better disclosure on risks

A specific recommendation by this report is encouraging the disclosure of risks associated with climate change. For example, the Carbon Disclosure Project, as part of its reporting requirements on carbon mitigation, has also asked global electricity companies to report on the extent to which they recognise the need for action to build business resilience to manage the risks and capitalise on the opportunities that inevitable climate change brings. Improved disclosure on risks could lead to companies increasing their level of awareness, and also provide the information required by investors to make investment decisions. For example, through analysing the responses in the disclosure CDP, the most frequently mentioned risks and those risks that are being addressed could be identified³⁰ in the electricity sector. This list of risks could then encourage other electricity utilities to examine and assess their own vulnerability.

³⁰ Carbon Disclosure Project Report, Global Electric Utilities Building business resilience to inevitable climate change, The Adaptation Challenge, 2009

Figure 26: The most frequently identified and managed risks identified by electric utility companies

Top 10 risks identified and managed

Distribution grids negatively affected by extreme events
Changing levels of precipitation leading to variable river levels for hydro
Assets compromised by extreme weather events
Increased energy demand for air conditioning and refrigeration in summer
Reduced river flows and efficiency of cooling processes
Wholesale and retail energy prices will remain volatile
Milder winters will result in less demand
Disruptions to offsite utilities (e.g. communications, water, waste treatment etc.)
Changes in sea level and flooding will compromise assets
Changes in wind pattern that could affect the wind energy production

Source: CDP Information Requests 2008, Acclimatise 2009

The ability to compare across companies, through publicly available information, also helps increase external and peer pressure on companies to ensure risks are appropriately managed. Reported information could focus on how assets, companies, business models (assets, cash flows, and strategies) are affected by climate change. This includes understanding how the business or asset operator is responding to the threats of climate change, through appropriate governance and management systems including robust risk identification and assessment processes.

8.6 Recommendations

Articulating a long-term vision and providing information to facilitate infrastructure adaptation

Investors and insurers typically see the role of Government as being one to articulate a long-term vision and provide clear policy signals on the need for adaptation in the delivery and maintenance of infrastructure assets, for example where Government perceive the risks of adaptation to be.

The Government also has a role to help raise awareness within the investor and insurance community of the potential long-term risks posed by climate change. This would also include making information more available and accessible to investors and insurers, for example:

- Review the content, relevance and accessibility of the existing information available on climate change, for example UKCP09 and articulate the direct applicability of this information to infrastructure providers, investors and insurers;
- Promote awareness of available information and consider how it might be promoted and presented to the investor community. For example is it topic Government representatives should seek to talk about at infrastructure investor conferences?
- Facilitate cross sector working to identify infrastructure interdependencies. By way of example, dialogue between investors on risks and adaptation could be promoted through regulatory bodies and informal dialogue as appropriate.

The role of government as a procurer

As Government is a key “buyer” of infrastructure and infrastructure services, for example through public private partnerships, it could also play a role in encouraging new contracting arrangements or contract renewals to consider the need for climate change adaptation. Defra and the Office of Government Commerce (OGC) have produced guidance to help public procurement professionals and their organisations adapt their procurement, to consider the impacts of climate

change for the lifetime of the assets or other goods and services that are being delivered through procurement. In the course of procuring infrastructure goods and services, Government should therefore stipulate the adaptation response that it expects to consider as an integral part of the procurement process.

Greater disclosure of risks and risk management measures

Investors and insurers could encourage companies and infrastructure owners to disclose risks from climate change. Transparent disclosure of how key infrastructure operators in the UK respond to climate change would enable stakeholders and the public to measure and scrutinise the resilience of infrastructure.

As described in the recommendations in this report, it is important that investors and insurers build and enhance current reporting initiatives and avoid duplication. Crucially, information reported need to be seen as being used effectively, so that reporting companies would also see the value of responding to these initiatives. In particular, the information could be used to enable and facilitate adaptation and bridge information gaps. Potential uses include:

- Analysis of the information reported by companies on common identified risks and adaptation measures;
- Identification of interdependencies of companies within the portfolio an investor / insurer to explore role of jointly funded adaptation measures;
- Publicity of best practices on adaptation both within and across sectors, and “name and shame” of companies that are failing to adapt; and
- Individual scrutiny of company to influence decisions on areas that lack action or companies that fail to report.

Improved risk management measures to account for climate change

With greater understanding on the risks to infrastructure investments, investors and insurers need to look at how their portfolio incorporates climate change risks and how these risks are managed. This could include

- Greater focus on how assets, companies, business models (assets, cash flows, and strategies) are affected by climate change. This includes understanding how the business or asset operator is responding to the threats of climate change.
- Factor in climate change adaptation in to all business decisions now so when changes are needed it is not a business ‘shock’.
- Ensure that companies in portfolio have appropriate governance and management systems in place, including robust risk identification and assessment processes

Best practices and opportunities to finance infrastructure and adaptation

Another key challenge in addressing interdependencies in infrastructure is the financing of adaptation needs. Enabling the financing of cross-sector adaptation projects could help to catalyse adaptation action more generally, especially in the unregulated sectors. There is a potential role here for the proposed Green Investment Bank and the investor and insurance community to stimulate innovation in infrastructure investment and to encourage financing for adaptation action, particularly where this requires joint financing.

This could include consideration of specific climate change risks (e.g. action to mitigate impacts from flooding, extreme weather events) or a more generic focus that climate change is being considered (e.g. demonstrate that climate change has been considered as part of risk register). Examples and options of the role that funding providers could play include:

- Decision to finance

- Incorporate the physical long-term risks of climate change as a key risk factor as part of the due diligence process of funding approval;
- Include as a filtering or selection criteria when considering alternative infrastructure projects the extent to which adaptation has been taken into account;
- Apply particular focus or preference to infrastructure projects that are cross-sector in nature and result in lower joint adaptation costs;
- Apply different rates (for loans) for well-planned and adapted infrastructure, to account for the greater resilience and lower exposure to risks.

Project finance or investment criteria

Some types of investment vehicles (particularly themed investment funds) apply screening when choosing their investment. Similarly lenders could subscribe to certain criteria (e.g. those set under the Equator Principles) when assessing projects to be financed.

Negative screening: excluding certain companies or sectors on the basis of certain characteristics or principles (e.g. animal testing, environmental practices, human rights, military involvement, nuclear power). Failure to adapt to climate change may be one of the criteria.

Positive screening: actively selecting or rewarding certain companies committed to “positive” characteristics or principles. In the context of adaptation, positive screening would include greater preference towards companies that are able to demonstrate long-term climate resilience.

- Ongoing relationship
 - Include as part of the terms and conditions of project finance the need to address long-term climate change risks;
 - Require value chain mapping, reporting and continual monitoring of climate change risk exposure of infrastructure provider.

Collaboration between Infrastructure UK and the Green Investment Bank could also explore the role of green financial products to enable joint funding for cross-sectoral adaptation projects (in particular those with public good characteristics), or highlight the need for innovation in the financial services community to enable project finance that could account for cross-sectoral adaptation.

The financial product or financing structure could include some of the following characteristics:

- Effective use of public funds alongside private finance to remove risks or capture the costs of positive externalities created by adaptation: the public funding element helps remove parts of the risks or provide the required incentives to fund adaptation projects that would otherwise not have been carried out.
- Public funding would need to lever sufficient private contribution: by targeting specific stakeholders, e.g. the insurance community, small amount of public funding may be able to lever substantial private funding.

Innovation to extend existing financial instruments and insurance products to adaptation: by making use of and innovating on existing risk management instruments, including for example catastrophe bonds and weather derivatives not just to help transfer risks of a weather event but also to manage some of these risks through adaptation.

9 Annex: Background and approach to this study

9.1 The Infrastructure and Adaptation Project

A two-year, cross-departmental Infrastructure and Adaptation Project (IAP), chaired by the Department for Transport (DfT) and bringing together all relevant economic infrastructure departments, has been tasked by 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 to future climate change impacts. The IAP is due to be completed in spring 2011.

The IAP team focus on four key sectors – energy, transport, water and information, communications and technology (ICT). Each of these sectors faces long-term risks, technically and operationally, from the impacts of climate change, albeit to different extents³¹. Furthermore, the infrastructure system is highly interdependent, which could lead to climate change exacerbating the risk and impact to the UK economy.

PwC has been commissioned as part of the IAP to undertake a study of whether different approaches by infrastructure investors and operators may be needed to facilitate long-term (20+ year) climate change adaptation action across new and existing infrastructure, and to consider how Government, regulators and investors could support this.

9.2 Approach to this study

We conducted the study in three phases:

Phase 1: Mapping the current regulatory framework:

We identified the policy and regulatory issues sector by sector and highlighted cross-cutting policy and regulatory issues which are important in addressing adaptation in investment decisions. We also conducted a literature review to identify key market developments, and we considered possible techniques for assessing the appropriateness of adaptation investment decisions, such as the decision-pathway approach and Real Options Valuation.

Phase 2: Analysis of investment in new/existing infrastructure and role of owner / operators:

The objectives of this phase was to review and understanding the investment decision process of investors, owners and operators for different sectors and assets, together with the regulatory and policy environment which facilitates this investment. We achieved this through two key strands of work:

- Stakeholder engagement: We engaged with stakeholders relevant to the four sectors of this study, including the operators and regulators (where relevant), as well as the investor and insurance community. Two broad topics were considered:
 - Private risk-based approach: identifying information gaps and building the business case
 - Internalising the externalities: role of stakeholders (operators, investors, insurers, regulators and government)
- Use of case studies: We used two case studies of recent and ongoing infrastructure investment decisions to inform our work: the planned Drax Heron biomass plant (energy) and the United Utilities East-West mains link (water). These two case studies are incorporated in the relevant sector sections.

³¹ For example in ICT only a small proportion of its infrastructure base are built for 20 years or more, compared to the other three sectors where this applies to the bulk of their infrastructure.

Phase 3: Development of recommendations:

Based on the findings from Phases 1 and 2, we developed a range of overarching recommendations for opportunities and levers to facilitate long-term climate adaptation action in infrastructure investment, as well as sector-specific recommendations for each of the four sectors covered by our review.

Recommendations addressed the roles of each of the key stakeholder groups, as well as levers to address the key inter-sectoral dependencies across the four sectors.

10 References and Acknowledgements

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