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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

Summary report



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

For further information please contact:

Richard Gledhill 020 7804 5026 richard.gledhill@uk.pwc.com

Lit Ping Low 020 7804 0345 lit.ping.low@uk.pwc.com

www.pwc.com

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.

Summary of the report

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.

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.

Sector summary: Power generation

Key findings

There is a good level of understanding of climate change issues in the power generation sector. 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.

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. 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. Adopting a private risk-based approach may be sufficient to ensure resilience from one type of climate change impact but not from another, more work needs to be done at the industry or national level to explore exposure to systemic risks.

Changes in the generation mix as a result of plant retirements and regulatory and market changes will lead to different 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.

The power sector is not subject to price regulation or explicit obligations to generate electricity, as it operates in a competitive environment. Instead externalities such as flood risks are addressed through the local planning process. 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.

Recommendations for the power generation sector

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 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.

Sector summary: Power transmission and distribution

Key findings

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. The sector is also establishing a common 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.

As a regulated industry, the sector is subject to policy and regulatory pressure to take active steps to ensure the resilience of its infrastructure – such as the Sector Resilience Plan for Critical Infrastructure set out by the Cabinet Office; Ofgem's incentive regime relating to customer interruptions and speed of restoration of supply; DECC Energy Emergency Executive on cross-sectoral resilience around managing emergencies.

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. 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. 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 sector

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.

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. 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.

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.

Sector summary: Water and wastewater

Key findings

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. The water and wastewater sector is generally well informed on the physical risks of climate change. The main challenge for the sector is a lack of consensus on the application of this knowledge for planning and regulatory purposes.

Some of the adaptation activities involve making high cost investments today to adapt to impacts that may not be realised within the typical 25 year horizon it plans for. To a large extent, the periodic nature of the 5 year price review process, within the context of a 25-year horizon, lends itself to a phased response to adaptation. In theory this is broadly consistent with prioritising investments, 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. 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. 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. Thus Ofwat might not have sufficient evidence base to support decisions in favour of adaptation.

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.

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 e.g. leakage and water efficiency targets. The challenge then falls onto the regulator to set appropriate standards. Also, standards may constrain innovation in the industry, setting the sector into a compliance mode, rather than promoting innovation.

Stakeholders are 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.

Recommendations for the water and wastewater sector

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. A collaborative effort in addressing issues such as these could result in overall lower costs for both the water companies and society in general.

The sector is working together well to bridge gaps in information on particular adaptation issues and data relevant to the sector. 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.

Sector summary: Transport

Airports: Key findings

Airport operators respond to a regulatory regime that currently does not explicitly require adaptation to be incorporated in the investment planning cycle, although 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.

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. Airports may not always consider the impact of climate change on other surface infrastructure that they depend upon, in particular road and rail.

In response to the previous administration's Future of Air Transport White Paper (ATWP) many airport operators have produced master plans which span a 30 year timeframe, involve a thorough consultation process, and consider the sustainability of the proposals. Airport infrastructure also 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 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.

The Coalition Government 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.

Recommendations for the airports sector

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.

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.

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.

Ports: Key findings

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. There is also a broader concern on the use of data for the sector that outdated evidence is informing investment decisions.

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.

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 adaptation. 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.

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.

Recommendations for the ports sector

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.

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.

Roads: Key findings

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.

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. As part of the framework, the strategy has identified over 80 Highways Agency activities that may be affected by climate change. 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, 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 queues. 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.

Recommendations for the road sector

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.

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.

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.

Rail: Key findings

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 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. Existing, older infrastructure, on the other hand, would need to rely on repair, maintenance and upgrade to ensure future resilience.

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.

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. Adaptation, particularly if considered as part of prudent asset management, could be one of many issues for consideration within the HLOS.

The sector has also recognised the importance of disaster management and emergency response. 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

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.

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

Sector summary: Information & Communication Technology

Key findings

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. 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.

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. 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.

Guidance from the EC-RRG 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.

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.

Recommendations for the ICT sector

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 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. 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.

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