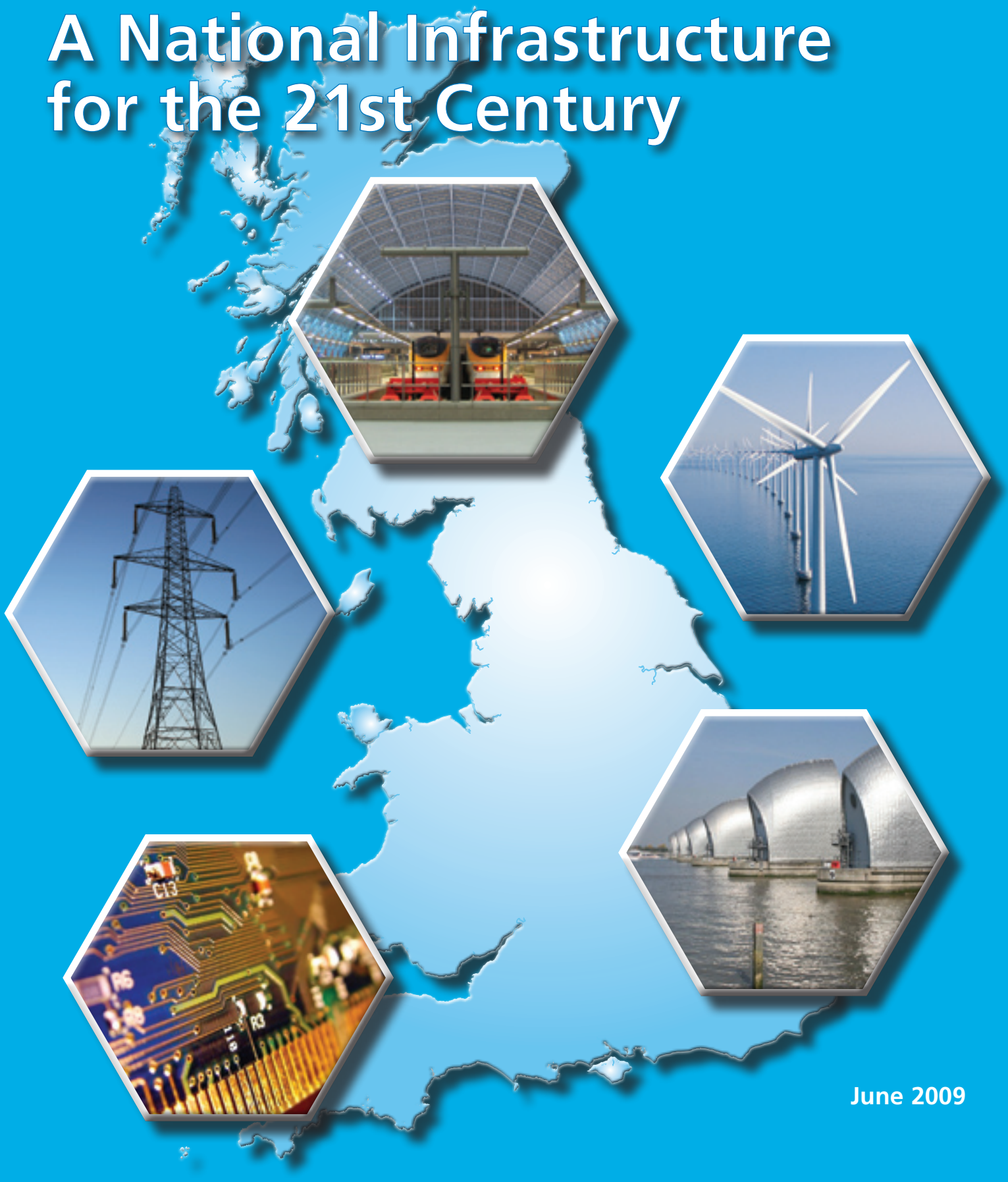
COUNCIL FOR SCIENCE AND TECHNOLOGY

# A National Infrastructure for the 21st Century



June 2009

**THE COUNCIL FOR SCIENCE AND TECHNOLOGY (CST) IS THE UK PRIME MINISTER'S TOP-LEVEL ADVISORY BODY ON SCIENCE AND TECHNOLOGY POLICY ISSUES.**

CST's remit is to advise the Prime Minister and the First Ministers of the devolved administrations on strategic issues that cut across the responsibilities of individual government departments. CST organises its work around five broad themes (research, science and society, education, science and Government, and technology innovation) and takes a medium to long term approach.

CST's recent work profile includes reports on 'Improving innovation in the Water Industry: 21st Century challenges and opportunities' and 'How academia and government can work together'. Previous reports include 'Strategic decision making for technology policy', 'Pathways to the future: the early career of researchers in the UK, 'Nanoscience and Nanotechnologies: A Review of Government's Progress on its Policy Commitments', 'Health Impacts – A Strategy Across Government', A 'Better Use of Personal Information: Opportunities and Risks'; 'An Electricity Supply Strategy for the UK', 'Policy Through Dialogue: informing policies based on science and technology'.

The members of the Council are respected senior figures drawn from across the field of science, engineering and technology. The current membership of the Council:

Professor John Beddington (co-chair)
Professor Geoffrey Boulton
Professor Peter Davies
Professor Dame Janet Finch (co-chair)
Professor Alan Gilbert
Professor Dame Wendy Hall
Dr. Hermann Hauser
Professor Alan Hughes
Dr. Sue Ion
Sir Paul Nurse
Dr. Raj Rajagopal
Dr. Philip Ruffles
Professor Michael Sterling
Professor Kathy Sykes
Sir Mark Walport

**CONTACT**

Council for Science and Technology
Kingsgate House, 66–74 Victoria Street
London SW1E 6SW
+44 (0)203 300 8510
cstinfo@bis.gsi.gov.uk
www.cst.gov.uk

# Contents

# Foreword from the Council for Science and Technology

The Council for Science and technology has undertaken the work for this report at the request of the Prime Minister, and with support from the Treasury, the then Departments for Innovation Universities & Skills (DIUS) and Business, Enterprise & Regulatory Reform (BERR) – now the Department for Business Innovation and Skills (BIS). It has been a major undertaking and the Council has harnessed the skills of a broad range of experts including scientists, engineers, policymakers and other professionals to produce this report. We have deliberately taken a helicopter view of the UK national infrastructure (NI) rather than examine the details of the individual elements. We have reviewed the provision of water, energy supplies along with the transport system and the provision of information and telecommunications technology (ICT). We have focused on the major challenges, with particular emphasis on the key issues relating to the interconnectivity of the different components.

The Council's Infrastructure project group was led by Sir Mark Walport, a member of the Council and Director of the Wellcome Trust, and comprised CST members Professor Geoffrey Boulton, Professor Peter Davies, Professor Dame Wendy Hall, Dr Sue Ion and Professor Michael Sterling. We co-opted Professor Brian Collins, Chief Scientific Advisor to the Department for Transport and the then BERR, as a member of the project group.

The report makes a set of high level recommendations, all of which have been road-tested with stakeholders from Government, business, the regulatory and professional bodies, scientists and engineers and the learned societies. We are especially grateful to all who participated in this project. We are also grateful to the Institution of Civil Engineers and the Wellcome Trust for hosting workshops and other events.

We would like to thank Mark and the members of the project group, officials from the Government Office for Science, Professor Brian Collins and his colleagues - in particular Elizabeth Hogben - who contributed to the successful completion of this report. We also thank AEA Technology for the valuable insights provided by their report *An overview of systemic interactions of the UK National Infrastructure*.

We look forward to working with Government and the devolved administrations in taking forward our recommendations.

Professor John Beddington
Co-chair of CST &
Government Chief Scientific Adviser

Professor Dame Janet Finch
Co-chair of CST

# Executive Summary

A high-quality national infrastructure (NI) is essential for supporting economic growth and productivity, attracting globally-mobile businesses to the UK, and for promoting social well-being. This report addresses the major issues facing the national infrastructure, focusing on communications, energy, transport and water, i.e. those sectors that transport key resources around the UK and provide global links.

An increasingly mobile business community relies on the NI to function and compete effectively in global markets. The effects of serious NI failures on business and public confidence are likely to be far-reaching and long-lasting, with inevitable economic and political consequences if that failure is localised in the UK.

Much of the national infrastructure – railways, roads, energy production and supply, water and sewage works – was constructed in the nineteenth and early twentieth centuries. Their robustness and resilience provided the basis for subsequent economic and population growth far beyond what was envisaged at the time. More recent infrastructure developments in information and communications technologies (ICT) now underpin the operation of the other sectors. The major change over the last 50 years has been the gradual, but ultimately seismic, shift from a series of unconnected structures to an interconnected NI where failure in one part has a direct and damaging knock-on effect in others.

The UK national infrastructure is now a network of networks. It operates within a social context and the interface between the NI and users is crucial. Most of the NI is owned, operated, built and maintained by the private sector, and is mainly embedded in a regulatory framework within a wider government context. Therefore both the private sector and Government have major and complementary roles to play in delivering a 21st century national infrastructure: business primarily in terms of investment, innovation and operating the network; and Government helping to create the climate for investment, and overseeing the NI as a network of networks.

We do not believe that the NI can continue on its current trajectory, for three main reasons:

- it is highly fragmented, both in terms of delivery and governance, which means that:
  - there is no overall vision of what the NI should look like
  - investment in the NI occurs in an *ad hoc* way with the emphasis very much on *replace* and, to a certain extent *renew*, rather than *modernise*
  - responsibilities and accountabilities are silo-ed within Government departments, agencies and regulators, with little coherence or connectivity across the network of networks
  - no-one has the responsibility or accountability for looking across the NI as a whole i.e. across the network of networks
  - there is little or no knowledge of vulnerabilities and risk arising from interdependencies across the NI which means that investment in adequate resilience will always be low priority
  - little or no expenditure occurs on a precautionary basis, instead the approach is to perform heroic acts in times of crisis

- its resilience against systemic failure is significantly weakening through a combination of:
  - ageing infrastructure components
  - greater complexity and interconnectivity between the different infrastructure sectors
  - nearing maximum capacity as a result of increased social and economic pressures
- the significant challenges posed by climate change and socio-demographic changes, which mean that:
  - there is an urgent need for a major change in devising low carbon solutions to meet the 80% target for reducing greenhouse gas emissions by 2050
  - core pieces of infrastructure need to be 'future-proofed' against extreme natural events
  - they need to be able to respond to future demographic, social and life style changes

Despite significant levels of investment by the private sector in recent years, we do not believe market forces by themselves will deliver a resilient NI fit for the 21st century. A partnership between business and Government is needed.

A modern national infrastructure needs to be:

- optimised in terms of cost, low-carbon footprint and service quality
- robust, resilient and adaptable to changing patterns
- innovative across all the sectors, driven by business in partnership with government

The NI needs a skilled workforce, not least in terms of trained engineers and technicians able to design, operate and service it. The responsibility for championing and developing a skilled workforce must be shared by business and Government.

Public engagement and dialogue is needed to understand more clearly people's expectations of the NI.

We recognise the challenges that the current economic environment is creating in terms of investment and understand that this may limit the ability of Government to address the issues identified in the short-term. However, in the current economic situation it is even more important for Government to create sufficient long-term certainty and coherence across the NI landscape. This will enable and maximise the opportunities for sustained private sector investment in circumstances in which global competition for funding will be particularly intense.

Given the need to plan for the long term, it will be important to identify quickly those aspects which will need cross-party support, at least in terms of identifying where the problems lie.

## Recommendations

### *Recommendation 1*

Government needs to appoint a lead body to deliver a clear and consistent vision for the future of the NI in order to create certainty, address both short- and longer-term pressures and changes, and attract investment to the UK.

Government needs to decide where the lead should be. We believe BIS, Treasury and Cabinet Office are all well-placed to act as the focal point within Government, but working with an independent stakeholder group of business and other major players.

The vision should look forward to 2050, clearly setting out the objectives and the rationale for decision-making. The core objective should be both to modernise and coordinate the NI to make it fit for purpose so that it:

- underpins future prosperity, in a world which is adjusting to a new economic order
- averts the danger that the UK will become increasingly unattractive to investment as its infrastructure becomes ever more unreliable
- supports the government's aspirations in relation to targets for mitigating the effects of climate change
- is resilient to the effects of climate change
- supports the quality of life which citizens rightly expect
- is suited to future population changes, including a larger number of older people, changing patterns of migration across Europe, and the likely urban/rural balance in residence patterns
- ensures alignment between the vision and the national policy statements
- acts as a road-map (see recommendation 3)

The vision needs to encompass social factors, such as future residence preferences, and how far it is necessary to plan for any or all of the following:

- more home-based working
- a possible preference for living in smaller towns or rural areas as quality of daily life becomes an important issue for more people, especially with more older people in the population – or alternatively, a move to living at higher population densities in large cities, as a response to economic, work and social pressures
- changes in health care which focus more on individually managed health care and telemedicine, and less reliance on attending health centres or hospitals

The stakes are high. Failure to develop and implement such a vision will mean that the UK falls increasingly behind its competitors, with increasing risks of major infrastructure failures that could have enormous costs to the economy and social well-being.

Government needs to decide where the lead should be. We believe BIS, Treasury and Cabinet Office are all well-placed to act as the focal point within Government. BIS has a leading role in delivering the UK's economic, innovation and skills agendas which underpin, and are underpinned by, the NI. At the same time, Treasury is at the heart of

economic decisions including investment in infrastructure. In deciding where the lead rests, Government will need to recognise that the NI involves a combination of expenditure by (i) private companies; (ii) companies which are themselves regulated; and (iii) Government itself via public expenditure. Whichever department leads will need to work closely with other departments, not least Cabinet Office which has much expertise on civil contingencies, and put in place an independent stakeholder group of business and other major players.

We believe the independent stakeholder body needs the following characteristics: independence, permanence, credibility, and having cross-cutting and other expertise.

### *Recommendation 2*

Government must address urgently the silo-based approach to NI, in particular:

- agree that the lead department, working closely with Cabinet Office and the independent stakeholder group, should take the overall policy lead in co-ordinating across Government, and that the overall objectives should be to:
  - develop mechanisms for achieving a more joined-up approach across Government in order to deliver the vision and prioritise the resilience and interconnectivity issues that need to be tackled
  - improve knowledge-sharing across Government, its agencies, business and the regulators to enable better risk assessment and alignment of regulation with policy objectives, as well as delivering better analysis and ensuring innovative solutions are transferred between the different sectors of the infrastructure
  - implement the provisions of the Planning Act as a matter of urgency

The various parts of the NI operate in silos, with significant fragmentation of responsibilities and accountabilities across Government, its agencies, the regulators, its operators and at a geographic scale. Each sector is regulated separately without regard to interdependencies and with a historic rationale for scope and remit. The tendency to focus on specific infrastructural components rather than on interconnected infrastructural systems leads to financial and operational inefficiencies, a poorer service to citizens and business, and unintended negative consequences. Silos at the level of the individual, as well as at the organisational and legislative levels, need to be cleared away.

A quick win would be for Government to join up more closely the approaches it takes to natural hazards, security and environmental threats, which are all highly inter-related.

There is a need for quick and effective communication, co-ordination and knowledge-sharing at national, regional and local government levels and between Westminster and the devolved administrations to ensure co-ordination and to minimise the potential adverse consequences of the fragmented provision of the national infrastructure. We welcome both the Pitt Review findings that the NI operators, Government and regulators need to work together to foster a collective responsibility for enhancing resilience in line with the National Security Strategy and the concept of a National Plan to drive up resilience by reducing the most substantial risks, to provide appropriate economic incentives and, where necessary, to enable quick action. An efficient planning process is essential for the timely development of the NI.

### *Recommendation 3*

The lead department, working closely with Cabinet Office and the independent stakeholder group, should collaborate with senior business leaders and the regulators to scope out and deliver by 2010 a road map setting out the priority actions in the short-term (5 years) and for the longer-term, that are needed to enhance or maintain the resilience of the NI, paying particular attention to:

- points of weakness, especially vulnerabilities at the interconnections and how best to build in the necessary safeguards and redundancy into the systems to mitigate weak points
- conflicts created by different strategic and legislative frameworks, and understanding the effects of sector-specific interventions on other components of the NI
- stimulating better understanding of the complexity and resilience of the national infrastructure, by commissioning research into scenario planning and modelling NI systems, from physical, economic and social perspectives
- human factors, so that individuals operating in one sector of the NI consider the effects of what they do on other sectors of the NI
- technology and skills needs (see recommendations 5 and 7)

Our report highlights significant deficits in the levels of resilience of the national infrastructure. It also shows up particular 'points-of weakness' where localised failures could trigger a cascade of wider consequences across different sectors or components of the NI.

There is a lack of understanding of the vulnerabilities, particularly where one sector of the NI is dependent on another. Unless addressed, such dependencies can lead to a misplaced level of reliance on other systems that could also have serious consequences e.g. ICT networks which are used to control parts of the NI and which operate through the internet. There needs to be a robust analysis of these interconnections, plus a more pro-active approach to managing the interdependencies.

Modelling and simulation techniques are important ways of enabling complex systems to be understood and manipulated in a virtual environment. It is particularly important that interactions between different components of the NI are modelled in an integrated fashion to ensure that system sensitivities are identified and understood. Such system models are powerful tools for design and planning of infrastructure to ensure that it is optimised to key policy constraints such as minimal energy loss, cost, carbon emissions, efficiency of supply and flexibility to demographic and climate change. Simulation and modelling are areas where the UK has academic strength. There is a need for more investment by business, the regulators and Government in modelling techniques, including supporting the best R&D in modelling techniques within universities. There should also be support for the social sciences to increase understanding of human behavioural interactions with the NI.

### *Recommendation 4*

Government, working closely with the Regulators and the major business stakeholders, should ensure that the remits of regulators are fit for purpose, and in particular whether they:

- provide incentives for modernisation and innovation
- deliver the necessary resilience and interconnectedness within and between the different sectors of the NI
- stimulate innovative solutions where appropriate
- are joined-up in terms of how they work across boundaries between their respective regimes, and at the interconnectivities between different sectors of the NI

We recognise that this work will need to be carried out at a strategic level and avoid creating unnecessary uncertainty

Regulation of national infrastructure is needed because market forces alone may not provide all of the essential features of the NI, for example the appropriate level of security, resilience, interconnectivity and co-ordination between infrastructures, research and development investment and future-proofing.

The current regulatory framework has lasted well over 20 years, and was designed for particular purposes, separately for the individual sectors within the NI. We are not convinced that as it currently stands the regulatory system is optimally designed to meet 21st century challenges e.g. to address the pressing challenges for increased resilience; for reducing carbon footprints; or for encouraging longer-term investments in innovative solutions by business. We acknowledge that some regulators are taking a more proactive approach to addressing this problem, e.g. Ofgem's self-initiated review of energy network regulation. It is important to ensure that the regulatory regime encourages innovative solutions from business. It is important that the regulatory regime underpins policy objectives and that these are aligned across the NI sectors.

The review should address the House of Lords' Select Committee finding that: *"action is necessary to improve regulators' joint working. There needs to be a more structured and formal co-operation between the regulators if it is going to be meaningful".*

### *Recommendation 5*

Government departments, the Regulators, the Research Councils and bodies such as the TSB need to incentivise the infrastructure operators to connect better to the science and engineering base to develop innovative solutions using best technology. To do this, they should come together to address of the following core questions:

- is procurement being used optimally, or indeed at all, to balance low risk/low cost solutions with the need to innovative?
- whether there should be more, or more effective, Innovation Platforms, Knowledge Transfer Networks and other types of collaborative R&D projects between infrastructure operators, academia and the other stakeholders?
- what technologies are available now and are they being exploited effectively within NI?
- what are the barriers to deployment e.g. the need for technology demonstration?
- what are the priority areas for underpinning R&D?
- how to encourage more cross-disciplinary research to clarify the interconnections and interdependencies of infrastructure components, including the human dimensions?
- what scenario planning is needed?
- what roles the professional bodies and learned societies might play?

Meeting the challenges for a 21st century NI will require innovative solutions, drawn from the science base. This will include developments to existing systems, such as moves to active networks and smart metering.

Supporting innovation in key infrastructure sectors by means of direct procurement will create markets for new high-tech businesses in the UK, stimulate innovation throughout the supply chains and act as a mechanism for pulling through R&D from the science and engineering base. The TSB therefore needs to press forward with the Small Business Research Initiative and extend the pilot programmes beyond Health and Defence into other areas of the NI.

Regulators should consider carefully the effectiveness of the mechanisms they have in place to encourage innovation, which should be folded into the overall review of the regulatory regimes highlighted in recommendation 4.

The TSB and the Research Councils need to do more to stimulate collaborative R&D between business and academia in key areas of the NI. Government, business, Research Councils and the TSB, and regulators need to come together to address key issues around technology availability and deployment and the priority areas for R&D including new cross-Council multidisciplinary programmes.

Government should work in collaboration with the research community, technology developers and investors to develop scenarios and potential roadmaps e.g. for the UK low carbon landscape for 2050.

### *Recommendation 6*

Government should put in place ongoing mechanisms for gathering social intelligence for example public engagement and dialogue for key issues on the national infrastructure.

The general business community and the wider public need to understand the challenges that will be faced by NI over the next 30-50 years. It is essential that the long-term provision of national infrastructure be informed by a better understanding of users' needs and expectations. These needs must be factored into all stages of the design, development and operation of infrastructure as strategies and policies develop, regulations evolve and investments are made.

We believe that Government, infrastructure businesses and regulators should put in place mechanisms for public engagement and dialogue on key issues such as:

- the value placed on infrastructure whose provision entails significant investments and costs
- its significant carbon footprint
- future challenges and the role customers can play in helping to address them
- levels of investment in the UK NI
- how tolerant society is to risks resulting from infrastructure failures
- how to achieve the necessary skills sets by attracting people to key industries
- how Government can better act as an intelligent customer

There needs to be a clearer understanding of the social context in which people make decisions, for example to use less water on a routine basis. Such decisions will affect the future resilience of the NI but they are not simply a response to the market, though that clearly plays a part, nor are they simply a series of individual decisions. People are influenced by the behaviour of those around them, by expectations created through the media, by their own commitments, and many other factors which are part of the social fabric. Analysis of this, based on the best social science data available, is essential for effective planning and operation of the NI.

### *Recommendation 7*

The Sector Skills Councils, working with business, BIS and professional bodies urgently need to address the short-term gaps in the skills market needed to deliver a 21st century NI, and provide clear forecasts of the skills needed in the longer-term, and how these can be met. The operators of NI need to identify their needs to ensure they attract, retain and develop the skills of their workforces.

A clear vision of the skills required to operate, maintain, develop and modernise the national infrastructure needs to be developed. The operators of the NI have the central role in driving this forward. Engineering skills across all the major engineering disciplines will be central to delivering a modernised NI, on a major scale not seen in the last 50 years.

The Sector Skills Councils and other bodies representing industry and professions, such as learned societies, professional associations, higher and further education institutes, need to continue working together to provide the Government with this essential information. But the lead must be with the employers themselves, and in a co-ordinated way.

Encouraging the supply of science, technology, engineering and mathematics graduates should continue to be a Government priority. Putting in place more high-level apprenticeships and training and development of technician engineers should be an important component of the skills mix needed. The development of multidisciplinary skills sets to design, install, operate and maintain the NI will be essential.

There is a question of whether a more focused approach to skills training is needed for strategically important sectors such as the low carbon economy, and major infrastructure projects such as nuclear build and retrofitting of low-carbon solutions. There are other skills bottlenecks needing urgent attention, for example in transport planning and operational research.

Social science skills will be essential at many stages of planning and implementing change in the NI. These include:

- researching, and gathering together the findings from existing research, on the social dimensions of modernising the NI
- informing modelling and simulation on a more interconnected NI
- operational management of the NI systems in a way which takes the social dimensions fully into account
- managing public engagement

The skills relevant to the above can be found across a range of social science disciplines: demography, social statistics, anthropology, geography, sociology, social psychology. There needs to be an exercise to identify how generic skills in these disciplines need to be developed to produce a cadre of social scientists suited to working on NI projects and within those industries. The Economic and Social Research Council will have an important role in ensuring that these skills and the relevant research is undertaken to support a modernised national infrastructure.

# Chapter 1: Introduction

CST has undertaken an overview of the major issues facing the national infrastructure. We have focused on identification of the major challenges that are common to each sector of the NI. We have placed particular emphasis on characterizing the key issues relating to the inter-connectedness between the different components of the NI. Our work builds on CST's previous reports on Energy and Water[1], which indicated that there were significant issues to be addressed.

We have:

- examined how the core components of the national infrastructure interconnect; their resilience; and the innovation, science, technology and skills gaps that need to be filled to ensure that the integrated national infrastructure meets the global challenges; and
- made recommendations to Government on specific, high level interventions needed to ensure a modern, integrated, and resilient national infrastructure that will help ensure the future social and economic prosperity of the UK

We have focused on communications, energy, transport and water, i.e. those infrastructures that transport key resources around the UK and provide our global links. We refer to these as the national infrastructure (NI)[2].

Throughout this report we make reference to 'Government': by this we mean government departments, their agencies and non-departmental public bodies; regulators; local government; and, where appropriate, the devolved administrations of Scotland, Wales and Northern Ireland.

In the UK, essential services and systems are known as the national infrastructure (NI). The UK economy depends upon its infrastructure and Government recognises that without these essential services the UK could suffer serious consequences, including severe economic damage, grave social disruption, or even large-scale loss of life[3].

Much of the national infrastructure – railways, roads, energy production and supply, water and sewage works – was constructed in the nineteenth and early twentieth centuries. Their robustness and resilience provided the basis for subsequent economic and population growth far beyond what was envisaged at the time. More recent infrastructure developments in information and communications technologies (ICT) now underpin the operation of the other sectors. The major change over the last 50 years has been the gradual, but ultimately seismic, shift from a series of unconnected structures to an interconnected NI where failure in one part has a direct and damaging knock-on effect in others.

The UK national infrastructure is now a network of networks. It operates within a social context and the interface between the NI and users is crucial. Most of the NI is owned, operated, built and maintained by the private sector, and is embedded in a regulatory framework that fits within a wider Government context. Other parts of the NI are administered directly through government agencies e.g. the Highways Agency.

1 *See: An electricity supply strategy for the UK (2005); Improving innovation in the water industry: 21st century challenges and opportunities (2009) at www.cst.gov.uk*

2 *The five sectors of infrastructure that have not been included (finance, food, government and public services, health and emergency services) are, to a greater or lesser extent, dependent on the others even though they are important. We refer to these as the social and economic infrastructure.*

3 www.cpni.gov.uk

A further complexity is the geographical organisation of different infrastructures which, in some cases, is divided nationally, regionally, locally and between Westminster and the devolved administrations, and in other cases by corporate boundaries. The NI system is therefore highly complex and fragmented. It is funded and delivered in a wide variety of ways (see Annex 1).

A modern infrastructure supports economic growth, attracts globally mobile business to the UK, and promotes social well-being. It gives people and business certainty in their daily lives and confidence that the Government generally is ensuring their well-being and potential for them as individuals, and for UK business to develop and flourish.

## Infrastructure is essential for supporting economic activity and growth…

An increasingly mobile business community relies on the NI, not least ICT and power, to function and compete effectively in global markets. In advanced societies, people take their infrastructure for granted, and indeed, it is the infrastructure that is key to enabling society to advance. The effects of serious NI failures on business and public confidence are likely to be far-reaching and long-lasting, with inevitable political consequences if that failure is localised in the UK.

### UK share of global infrastructure spend

Global infrastructure spend is expected to be £6.4 trillion between 2008–2015. Forecast annual UK strategic infrastructure investment represents ~3% of the global total. Planned infrastructure investment in the UK in 2008-2015 is estimated at £200bn with 65% of funding to come from private sector, 6% from Public Private Partnerships (PPPs) and the remainder from public funds.

Many key investment projects rely on private finance either as direct investment or through mechanisms such as PPPs. In the current economic climate the UK faces stiff competition in securing investment – from private investors and from within Government budgets. In this environment, there needs to be a clear vision from Government about the future and needs for the national infrastructure. This will be essential to persuade the private sector to invest in the NI and, in particular, private sector investors will need long-term certainty in order to judge whether to commit major funds. We have seen a failure of the market to respond in a timely manner to significant shifts in policy e.g. on renewable energy – but the corollary of this is that the market needs to be confident that these policy shifts are sustained.[4]

## … attracting business to the UK…

Businesses looking to invest in the UK will be looking at a range of factors, including a comparison of the UK infrastructure to that in other countries in terms of ability to meet their needs.

Competition for finance will be increasing in the current economic downturn so Government needs to create the best possible conditions to attract investors. This requires them to deliver on the various commitments they have already made: notably in reforming the planning regime for large infrastructure projects.

*4 Figures presented to the Business Council for Britain.*

## … responding to consumer demand…

Some sectors of the NI are more market-led than others. For example, communications are driven by consumer demand for the latest technology resulting in the rapid expansion of mobile phone usage and home computing. Given how much it underpins the rest of the NI, it is crucial to ensure that ICT is developed in a manner that not only meets the needs of the market and the consumer, but also addresses the broader strategic objectives of Government in terms of coherence and resilience. Widespread disruption or failure of these systems would have catastrophic effects. Simply assuming 'the market will provide' may not be enough. Government is aware that digital communications are now critically dependent on timing signals from satellite GPS systems which are susceptible to in-band jamming over a wide area and over which there is no UK control.

## Comparison of Government's role in development of different components of National Infrastructure

**Railway Network**

The Victorian railway network was laid down by private operators with different specifications e.g. different gauge sizes. This resulted in duplication e.g. different companies operating tracks next to each other. Government eventually brought coherence through nationalization. However the nationalised network was highly inefficient and eventually significant cuts in the infrastructure were made following the Beeching review in the 1960's. Although this significantly reduced the burden on the national purse it also led (along with subsequent interventions) to the position we have today of a relatively inefficient system by most European service standards, with inadequate resilience and scope for expansion given 21st century demands.

Privatisation and economic regulation have facilitated increased investment in the rail network in recent times. Government has committed to invest around £15 billions over the next regulatory period. Nevertheless there remains scope for renewed Government intervention to develop an appropriate vision for UK transport strategy more broadly, where economic priorities are set for transport investment across modes, and for planning for resilience of cross-modal transport networks, taking account of engineering as well as economic factors.

**Information and Communications Networks (ICT)**

The telecommunications network was developed by the government owned General Post Office (GPO) before becoming British Telecommunications. It was privatised in the early 1980s and regulated by the then Oftel which also created new companies to stimulate market competition in telecommunications. By contrast, the IT industry and all of the electronics technologies that supported both telecommunications and IT have never been government-owned; nor have they been regulated. Despite the increasing convergence of telecommunications and IT over the last 20 years, telecommunications continues to be regulated whereas IT is open to international market forces. This continues to produce inconsistencies in the treatment of ICT-based services. In addition, the dominance of a few component subsystem suppliers, such as Microsoft, Google, Cisco and Intel, have produced vulnerabilities which may produce risks of cascade failure and/or reduced resilience.

**Electricity Networks**

The first public electricity supplies in this country started in the 1880s. The world's first modern high pressure power station was built at Deptford in 1889 by Sebastian de Ferranti, Chief Engineer at the London Electric Supply Corporation. Up to the 1920s a large number of separate local electricity enterprises were set up. These were often unreliable and inefficient; and the local plant had to track demand. A committee chaired by Viscount Weir recommended interconnecting these local generators to form a National Grid. The first grid was completed in 1935 and gave greater security and much greater average efficiency (up from 8% to 20%).

The industry was nationalised in 1948, eventually creating the CEGB to plan and match demand, which doubled every seven years through to the early 1970s. In the early 1990s the Government privatised the industry except for the nuclear stations, which were themselves privatised in 1996. This break up of a state monopoly together with the creation of a bidding system for wholesale electricity brought about efficiency savings in power generation and hence kept costs lower than they otherwise would have been. However, replacement of a publicly funded "command and control" approach by a multi-owner privately funded system operating in a regulated market has inherent limitations in the ability to deal with the priorities of the 21st century and forms of generation that will be fundamentally different from those in the preceding half century.

We now face a change as profound as that faced by the developers of the initial grid, with much of the capacity to supply once again in the hands of the private sector and a complex situation of how a new grid will be planned and by whom, and how market signals will be made to encourage private companies to make the investments that such a major change will require.

## … promoting social inclusion…

NI is an integral element of daily life, giving people certainty, security and the confidence and the potential for them as individuals, and the UK as a whole, to develop and flourish. As we have already noted, excellent national infrastructure underpins advanced societies. Within these advanced societies excellent policies for national infrastructure can promote well-being and social inclusion, for example developing a strategy for the availability of public Wi-Fi[5]. Alternatively, low quality NI, geographical variation in NI provision and poor accessibility could increase social exclusion of vulnerable sections of the UK population.

*5 Wireless digital networks.*

## Social inclusion and demographics

An overarching vision for the future of UK national infrastructure provides an opportunity to promote well-being and social inclusion alongside contributing to future economic growth, resilience and mitigation of climate change.

For example, research funded by the Department for Transport[6] suggests there are clear connections between transport and social exclusion and that enhancing social mobility requires more physical mobility. Given the current distribution of opportunities, some people need both to be able to travel more and to accept the need to travel more if they are to be socially "included". This may appear to lead to a conflict with the objective of reducing the need to travel in order to reduce overall carbon emissions from transport.

In the ICT sector, the Government Action Plan for Digital Inclusion[7] highlights the strong links between social and digital exclusion – 75 per cent of socially excluded people are also digitally excluded. Part of Digital Britain (the UK's plans to secure the UK's position at the forefront of the digital economy) is aimed at ensuring fairness and access, with universal availability and promotion of skills and media literacy, alongside plans to upgrade and modernise wired, wireless and broadcast infrastructure.

Government forecasts anticipate an extra 5.5 – 6 million households by 2031 (up from 24.2million households in 2006). This expected growth is caused by growth in the population and by the continuing fracture of families. Of these new households, 70%—or some 4 million—are expected to consist of a single person. A quarter will be pensioners. By 2026, 38% of all households are expected to be single person, compared to 23% in 1981. Average household size is projected to continue on its downward trend, reducing from 2.41 in 1997 to 2.15 by 2031. Within these households, the number of over-75s is projected to increase by 50% by 2031, and this group will make up 12% of the population by then.[8]

The growth in households, the behaviour of the occupants and their needs, aspirations and expectations of access and use of infrastructure services, will be a key factor in determining future demands on infrastructure needs. National, regional and local policy on issues such as rural and urban planning, physical, social and economic regeneration and public transport should be closely linked to any overall vision for the future of infrastructure, both in terms of shaping and delivering the vision.

## … and determining how we live in the future.

Decisions about the nature and distribution of the national infrastructure will determine how we live in the UK in the future. The quality and price of different modes of transport will determine how we move around; the distribution of housing and telecommunications will determine how much we need to move around. The location of housing will be determined by the geographical distribution of the key components of the NI. We have a choice – either these matters can be left to markets and to chance, or alternatively Government can promote a national debate and a more structured approach to these huge policy issues. CST recommends the latter, especially since there is a global imperative to tackle climate change.

6 *http://www.dft.gov.uk/pgr/inclusion/se/socialexclusionandtheprovisi3262?page=3#a1002*
7 *http://www.communities.gov.uk/documents/communities/pdf/1001077.pdf*
8 http://www.foresight.gov.uk/Energy/EnergyFinal/Roberts%20paper%20-%20section%2010.pdf

## Digital Britain[9]

The UK is already a digitally enabled and to a significant degree digitally dependent economy and society. Those countries and governments that strategically push forward their digital communications sector will gain substantial and long-lasting competitive advantage.

It [the online world] is moving from conferring advantage on those who are in it to conferring active disadvantage on those who are without. Despite that increasing disadvantage there are several obstacles facing those that are off-line: availability, affordability, capability and relevance. Affordability is addressed in part through the roll-out of the Government's £300m Home Access scheme for low income families.

Universal Service Commitment – more than one in 10 households today cannot enjoy a 2Mbps connection. [The Government intends to] correct this by providing universal service by 2012. The Universal Service Commitment is to be delivered by a mix of technologies: DSL, fibre to the street cabinet, wireless and possibly satellite infill. But the first strains are beginning to show: under-investment in backhaul networks – the so-called middle mile – in fixed networks is becoming increasingly apparent. In mobile, the very success of broadband will increasingly lead to congestion in the existing spectrum. Other countries are investing heavily in upgrading their networks to take advantage of technology change.

Next Generation Final Third project – next generation broadband networks offer […] more revolutionary applications. These will include tele-presence, allowing for much more flexible working patterns, e-healthcare in the home and for small businesses the increasing benefits of access to cloud computing which substantially cuts costs and allows much more rapid product and service innovation.

9 *Excerpts from the Digital Britain Report – June 2009.*

# Chapter 2: The major challenges

There are significant challenges facing the national infrastructure in both the short and the longer-term. We do not believe that the NI can continue on its current trajectory, for three main reasons:

- its resilience against systemic failure is significantly weakening through a combination of:
  - ageing infrastructure components
  - greater complexity and interconnectivity between the different infrastructure sectors
  - nearing maximum capacity as a result of increased social and economic pressures
- the significant challenges posed by climate change and socio-demographic changes, which mean that:
  - there is an urgent need for a major change in devising low carbon solutions to meet the 80% target for reducing greenhouse gas emissions by 2050
  - core pieces of infrastructure need to be 'future-proofed' against extreme natural events
  - they need to be able to respond to future demographic, social and life style changes
- it is highly fragmented, both in terms of delivery and governance (see chapter 3)

It is necessary to improve the resilience of the national infrastructure. The term 'resilience' is most widely used across government in relation to extreme events such as terrorist attacks. In this report we use a broader definition of this term to include the ability to respond to:

a) major unpredictable external events such as large scale flooding, intense heatwaves or terrorist acts

b) progressive changes in external circumstances that push a component of infrastructure beyond a "tipping point" where non-linear internal feedbacks cause major failures in service delivery, with the potential to cascade through to other, coupled infrastructure components. Examples of such slowly changing external drivers include progressive climate change or shifts in the pattern of demand

c) large changes in demand

d) evolution of components of technology that unintentionally create vulnerability in infrastructure components, for example the replacement of multiple bespoke communications systems by mobile communications

e) interaction between external (a and b) and internal (c) processes

## Ageing infrastructure components and capacity issues

There are significant vulnerabilities, capacity limitations and a number of NI components nearing the end of their useful life which need to be renewed in the immediate future. There are particular pinch-points, especially where different NI sectors connect. We are at a critical juncture, where a number of decisions over the next 18 months are needed to underpin the next wave of investment in NI. Due to the relatively long lead times for

planning, designing and building NI components these challenges extend over the next 3–10 years.

Some components of the infrastructure are already at or near maximum capacity or are likely to encounter significant problems meeting demand in the near future.

Updating the NI is not just about short-term solutions. The typical lifespan of NI components is somewhere between 15 and 60 years, so whatever is built today will need to meet the needs of the UK in the longer term e.g. likely future changes in demand created by socio-demographic issues such as a population growth[10]; an increasingly ageing population; and the greater choice people now have in terms of where they live and work.

## Ageing infrastructure components

**Transport**

Bridges, motorways, roads, railroad, airports, subway/tube, ports. Last major investment peak –1975. Estimated dates for renewal – 2015

**Water**

Water mains, sewage treatment, sewer pipes and hydro reservoirs. Water and waste ~ 45 years

**Energy**

Nuclear, electricity, oil and gas, transmission (60 years). Last major investment peak – 1965. Estimated dates for renewal – 2000. UK's electricity transmission system from north to south is close to capacity: there is a need to put in place significant transmission reinforcement, but planning delays have been the major obstacle to date in reinforcing networks between England and Scotland. National Grid are looking to put in place 2 DC sub-sea cables to reinforce the link between Scotland and England. Electricity generation efficiency – commercial drive for efficiency has reduced 'spare' capacity

10 *For example, when Joseph Bazalgette designed the London sewage system, it was on the basis of a population several times the London population at the time.*

## Capacity

### Roads

UK motorways carry 2.5 times more passengers and twice the amount of freight compared to the average of advanced nations[11]. Congestion will add £10bn annually in cost to business by 2025[12]. Capacity problems are expected by 2020-2030 on motorways and trunk roads in the London region, the M1/M6 corridor from South East England to the North West and Yorkshire, and several urban road networks (e.g. Manchester and Leeds).

### Rail

UK has one of the worst on-time arrivals performance in Europe, because of driven by high utilisation of the track network.

There is likely to be substantial overcrowding on the rail network[13] by 2020–2030, in particular the West Coast Mainline railway to Birmingham and Manchester and sections of the East Coast mainline railway to Leeds and Newcastle.

### Airports

Capacity problems are expected by 2020–2030 in airports in South-east England; 3% of all UK flights delayed due to congestion.

### Ports

Prior to the economic downturn capacity problems were expected by 2020-2030 at London and Haven ports. Consideration should be given to limitations in capacity that may arise in the future.

### Energy

Without significant new build by 2016 the UK could have less than 5% capacity margin during peak power demand. The UK needs to renew ~30% of its generation capacity by 2050[14].

## Climate change

Resilience against climate change is the most significant and complex longer-term challenge. The effects of climate change are predicted to cause higher summer and winter temperatures, sea-level rises, a rising intensity of storms, forest fires, droughts, increased flooding, heatwaves and alter resource availability, e.g. of water.[15] The challenges for the current infrastructure are both to adapt to such impacts and to support the radical transition to a low carbon economy.

The Government's National Security Strategy, published in March 2008, recognises climate change as potentially the greatest challenge to global stability and security, given expected world-wide impacts. Effective adaptation is key to mitigating this risk, in relation to infrastructure and other areas.

*11 Average of top 5 EU countries by population plus Canada and Japan.*
*12 Eddington Report.*
*13 High Speed line study for DfT.*
*14 2007 Energy White Paper.*
*15 IPCC report 2007.*

## Direct effects of climate change infrastructure components

One of the limiting factors for the transfer of electricity by overhead transmission lines is their thermal capacity, which is affected by the ambient air temperature. Higher global peak temperatures will reduce those limits and hence the capacity of the network to transfer electricity.

**Impacts on water infrastructure[16]**

- Pipe systems for both drinking water supply and sewage will be more prone to cracking as climate changes lead to greater soil movement as a consequence of wetting and drying cycles
- Water and wastewater treatment works, pumping stations and other network assets on the coast or in flood plains will be at increased risk from flooding, storm damage, coastal erosion and rises in sea levels
- Existing sewage systems were not designed to take climate change into account. This means that more intense rainfall is likely to exceed the capacity of parts of the network and cause local flooding
- Dams will be more prone to siltation resulting from increased soil erosion, and the slippage risk to soil dams from intense rainfall events will also increase.

Mitigating the effects of climate change by increasing renewable energy generation or modal switch in transport demand, will radically impact on demand patterns. This will require increasing capacity in some systems and the development and demonstration of entirely new infrastructures e.g. for hydrogen fuel or carbon capture and storage, or major use of electric/battery propulsion in the transport sector.

## Mitigating climate change – NI requirements

The National Grid will need major investment to enable low carbon distribution networks to be developed[17]. It requires adaptation to deal with volume and intermittency if it is to fully utilise energy from renewable sources.

In additional to electric vehicles impacting on the grid the increased use of ground or air source heat pumps for domestic heating will also have a big effect since the current assumptions about load diversity on the distribution system will no longer be valid. The network will therefore need substantial reinforcement.

We are pleased to note that the bottlenecks in the transmission system are currently being addressed by National Grid, so that new generation e.g. via offshore wind from Scotland and Wales can be connected to England via offshore cables.

16 *How the water industry is adapting to climate change – Water UK Briefing, December 2008.*
17 *CST's report: An electricity supply strategy for the UK (2005).*

## Cleaner Transport

Domestic transport accounts for approximately 25% of UK carbon emissions and road transport is responsible for nearly 95% of these emissions[18]. DfT supports policies aimed to increase the use of cleaner fuels (such as biofuels) and the electrification of road transport but step changes will be needed, electric vehicles could yield substantial reductions in transport carbon emissions, but only if the necessary infrastructure is in place alongside other incentives and R&D investment. For example, electric cars will require large infrastructure changes to the electricity grid with charging points available around the country and domestically.

## Extreme events

There is significant activity across Government and the NI businesses to increase NI resilience by reducing the vulnerability to extreme events and prepare for short-term disruption. The Government has identified extreme events that would have a direct impact on or be caused by disruption of NI, through its National Risk Register[19]. The Civil Contingency Secretariat and the Centre for the Protection of National Infrastructure work across Government and the business sector to reduce vulnerability and mitigate the effects of extreme events and threats.

Although the UK is better positioned than some countries because of disaster rehearsals e.g. Black Start (the National Grid restart from scratch) there is concern that some organisations may not have plans in place to deal with the emergency situations as indicated in the Cabinet Office Civil Contingency Secretariat guidelines.

Government minimises impacts of the loss of essential services through emergency preparedness and contingency planning. It does not prescribe standards of protection or measures of resilience to reduce the vulnerability of the infrastructure to e.g. flooding[20]. A key issue is whether operators are able to identify and reduce vulnerabilities to an acceptable level themselves or whether a degree of Government advice and intervention is needed[21]. We believe Government should set clear standards to reduce vulnerability.

## Extreme weather events

January 2007 severe storms damaged electricity transmission and distribution systems causing power cuts in areas of Surrey, Yorkshire, northern Lincolnshire, Lancashire, south Lake District, Hertfordshire, Bedfordshire, Buckinghamshire, Cheshire and Wales.

February 2009 saw the heaviest snowfall in Britain for 18 years. The disruption to transport networks across the UK is estimated to have cost the economy approximately £1.2 billion, and severely disrupted the provision of other public services critically dependent on transport or staff.

18 *http://www.Department.gov.uk/pgr/statistics/datatablespublications/energyenvironment/tsgbchapter3energyenvi1862.xls*

19 *Government has published a National Risk Register, as part of the National Security Strategy, which sets out an assessment of the likelihood and potential impact of a range of different risks that may directly affect the UK. The National Risk Register is designed to increase awareness of the kinds of risks the UK faces, and encourage individuals and organisations to think about their own preparedness. The register also includes details of what the Government and emergency services are doing to prepare for emergencies. http://www.cabinetoffice.gov.uk/reports/national_risk_register.aspx*

20 *See the Pitt Review page 251.*

21 *Walker (2008) The Governance of the critical national infrastructure, Public Law, 323–352.*

## Major Accidents

April 2007 – a major pumping component at a waste water treatment plant serving 800,000 customers in Edinburgh failed, causing 1,000 litres a second of partially diluted untreated sewage to be pumped into the Firth of Forth.

March 2004 – a fire in a BT cable tunnel put 130,000 land lines out of action, disrupting Derbyshire and Cheshire police communications and Manchester ambulance service. Cash dispensers and retail point-of-sale credit systems were shut down across several counties. These lines were thought to be resilient to single point of failure but the back up systems shared the same ducting space.

## Flooding Summer 2007[22]

Severe rainfall led to 48,000 households and 7,300 businesses being flooded across England.

The June event resulted in 8,600 homes (20,000 people) and 1,300 businesses in Hull being flooded as a result of the city's drainage network being overwhelmed by heavy and prolonged rain. In Sheffield, the Neepsend electricity substation was shut down with the loss of power to 40,000 people. Over 1,000 people were evacuated from villages near the Ulley reservoir dam near Rotherham. This led to the M1 being closed for 40 hours as a precaution.

The July event left 350,000 people without mains water supply for over two weeks. Around 10,000 people were left stranded on the M5 and surrounding roads as drivers were forced to abandon cars, and 500 people were stranded at Gloucester railway station as the railway network failed. Temporary defences were erected at Walham electricity substation, which helped protect the power supply to 500,000 people in Gloucestershire and South Wales. However the Castle Meads electricity substation was shut down whilst temporary defences were put in place, which left 42,000 people without power in Gloucester for up to 24 hours.

Approximately 42,000 hectares of agricultural land across England flooded last summer, slightly over 0.5 per cent of the total area, resulting in total losses estimated at £11.2 million. Government has responded[23].

## Power Failure

In August 2003 a major failure of the National Grid caused the loss of power to parts of the Northeastern and Midwestern United States and Ontario, Canada. A power fluctuation caused over 508 generating units and 265 power plants to shut down leaving an estimated 55 million people without power. In New York the power outage resulted in 3 deaths, 3000 fires from use of candles, 80,000 calls to 911, 300 arrested for looting, shut down cellular coverage and 400 flights cancelled with an estimated cost of over £5 billion.

22 *The Pitt Review – Lessons learned from the 2007 summer floods; 25th June 2008.*
23 *RDAs have currently committed over £11 million in support for businesses affected by the floods. Funding of up to £87 million has been made available by Government departments.*

# Chapter 3: A long term vision for national infrastructure

We do not believe the NI sustainable as currently configured. It is highly fragmented, both in terms of delivery and governance.

This means that:

- there is no overall vision of what the NI should look like
- investment in the NI occurs in an *ad hoc* way with the emphasis very much on *replace* and, to a certain extent *renew*, rather than *modernise*
- responsibilities and accountabilities are silo-ed within Government departments, agencies and regulators, with little coherence or connectivity across the network of networks
- no-one has the responsibility or accountability for looking across the NI as a whole i.e. across the network of networks
- there is little or no knowledge of vulnerabilities and risk arising from interdependencies across the NI which means that investment in adequate resilience will always be low priority
- little or no expenditure occurs on a precautionary basis, instead the approach is to perform heroic acts in times of crisis

Despite significant levels of investment by the private sector in recent years, we do not believe market forces by themselves will deliver a resilient NI fit for the 21st century. A partnership between business and Government is needed.

### *Recommendation 1*

Government needs to appoint a lead body to deliver a clear and consistent vision for the future of the NI in order to create certainty, address both short- and longer-term pressures and changes, and attract investment to the UK.

Government needs to decide where the lead should be. We believe BIS, Treasury and Cabinet Office are all well-placed to act as the focal point within Government, but working with an independent stakeholder group of business and other major players.

The vision should look forward to 2050, clearly setting out the objectives and the rationale for decision making. The core objective should be both to modernise and coordinate the NI to make it fit for purpose so that it:

- underpins future prosperity, in a world which is adjusting to a new economic order
- averts the danger that the UK will become increasingly unattractive to investment as its infrastructure becomes ever more unreliable
- supports the government's aspirations in relation to targets for mitigating the effects of climate change
- is resilient to the effects of climate change
- supports the quality of life which citizens rightly expect

- is suited to future population changes, including a larger number of older people, changing patterns of migration across Europe, and the likely urban/rural balance in residence patterns
- ensures alignment between the vision and the national policy statements
- acts as a road-map (see recommendation 3)
- The vision needs to encompass social factors, such as future residence preferences, and how far it is necessary to plan for any or all of the following:
- more home-based working
- a possible preference for living in smaller towns or rural areas as quality of daily life becomes an important issue for more people, especially with more older people in the population – or alternatively, a move to living at higher population densities in large cities, as a response to economic, work and social pressures
- changes in health care which focus more on individually managed health care and telemedicine, and less reliance on attending health centres or hospitals

The stakes are high. Failure to develop and implement such a vision will mean that the UK falls increasingly behind its competitors, with increasing risks of major infrastructure failures that could have enormous costs to the economy and social well-being.

Government needs to decide where the lead should be. We believe BIS, Treasury and Cabinet Office are all well-placed to act as the focal point within Government. BIS has a leading role in delivering the UK's economic, innovation and skills agendas which underpin, and are underpinned by, the NI. At the same time, Treasury is at the heart of economic decisions including investment in infrastructure. In deciding where the lead rests, Government will need to recognise that the NI involves a combination of expenditure by (i) private companies; (ii) companies which are themselves regulated; and (iii) Government itself via public expenditure. Whichever department leads will need to work closely with other departments, not least Cabinet Office which has much expertise on civil contingencies, and put in place an independent stakeholder group of business and other major players.

We believe the independent stakeholder body needs the following characteristics: independence, permanence, credibility, and having cross-cutting and other expertise.

### *Recommendation 2*

Government must address urgently the silo-based approach to NI, in particular:

- agree that the lead department, working closely with Cabinet Office and the independent stakeholder group, should take the overall policy lead in co-ordinating across Government, and that the overall objectives should be to:
  - develop mechanisms for achieving a more joined-up approach across Government in order to deliver the vision and prioritise the resilience and interconnectivity issues that need to be tackled
  - improve knowledge-sharing across Government, its agencies, business and the regulators to enable better risk assessment and alignment of regulation with policy objectives, as well as delivering better analysis and ensuring innovative solutions are transferred between the different sectors of the infrastructure
  - implement the provisions of the Planning Act as a matter of urgency

The various parts of the NI operate in silos, with significant fragmentation of responsibilities and accountabilities across Government, its agencies, the regulators, its operators and at a geographic scale. Each sector is regulated separately without regard to interdependencies and with a historic rationale for scope and remit. The tendency to focus on specific infrastructural components rather than on interconnected infrastructural systems leads to financial and operational inefficiencies, a poorer service to citizens and business, and unintended negative consequences. Silos at the level of the individual, as well as at the organisational and legislative levels, need to be cleared away.

A quick win would be for Government to join up more closely the approaches it takes to natural hazards, security and environmental threats, which are all highly inter-related.

There is a need for quick and effective communication, co-ordination and knowledge-sharing at national, regional and local government levels and between Westminster and the devolved administrations to ensure co-ordination and to minimise the potential adverse consequences of the fragmented provision of the national infrastructure. We welcome both the Pitt Review findings that the NI operators, Government and regulators need to work together to foster a collective responsibility for enhancing resilience in line with the National Security Strategy and the concept of a National Plan to drive up resilience by reducing the most substantial risks, to provide appropriate economic incentives and, where necessary, to enable quick action. An efficient planning process is essential for the timely development of the NI. In order to create a long-term vision for NI, deliver the investments needed and provide effective response to emergencies Government needs to improve its co-ordination and ensure alignment of policy and regulation on an ongoing basis. Close working between all of the participants in the provision and operation of national infrastructure is essential for the delivery of first-class systems[24]. Relationships must be strengthened between Government, regulators, providers and users, to ensure users' needs are met both now and in the future, as their needs evolve[25].

We welcome the Pitt Review findings that the NI operators, Government and regulators need to work together to foster a collective responsibility for enhancing resilience in line with the National Security Strategy.

The high levels of interconnectivity in terms of systems, demand and strategies require a cross-sectoral approach at all levels of responsibility[26]. We welcome the concept of a National Plan to strengthen resilience by reducing the most substantial risks, provide appropriate economic incentives and, where necessary, act quickly. However, measures will be needed to ensure that implementation is not effectively carried out.

There are two components to this: first, in relation to security threats and natural hazards where we welcome as a first step the formation of the National Hazards Group within the Civil Contingencies Secretariat of the Cabinet Office; and, second, in respect of investment where there is a need for a more co-ordinated approach across Government, the regulators and business to ensure that priority investments happen, at the right times, and in a joined-up way across Government. Better recognition also needs to be given to the UK's vulnerability to fuel supplies in the energy sector and to events initiated as a result of issues arising overseas.

*24 We understand ESRC is funding projects on how agencies and sectors engage and how they might better work together.*
*25 We are aware of the Energy Emergency Executive Committee which brings energy infrastructure businesses together.*
*26 The Pitt Review pointed out that: "the approach taken by Government to mitigating the delivery of essential services from natural hazards has largely been uncoordinated and reactive".*

## How other countries co-ordinate investment in NI

**Korea – Office of National Infrastructure**

A one-stop shop for major projects, accelerating delivery and providing a coordinated front-door for investors

**Canada – National infrastructure framework**

An overall framework, building on the National Policy Statements to provide consistency of infrastructure priorities across sectors and over time

**Australia – Advisory Council**

A council of 12 private and public sector experts headed by Sir Rod Eddington provide the evidence base and perspectives across the infrastructure spectrum

**US – Infrastructure Bank**

A public development bank dedicated to US infrastructure investments – a proposed federally funded bank to provide $50 billion in subsidised debt per year for selected projects

A central requirement for effective co-ordination is effective knowledge-sharing between all the players. Other countries have processes for managing information-sharing.

## Information-sharing

The **US National infrastructure Protection Plan** defines the roles and responsibilities for all levels of US Government and business that need to work together to secure the US's critical infrastructure and key resources

The **Australian Trusted Information Sharing Network for Critical Infrastructure Protection** allows members (including the emergency services) to share security-related information in a protected environment to ensure they are adequately managing risk

The **Dutch Critical Infrastructure Protection project** is designed to prevent disruption against technical failings, overloading, extreme natural phenomena and intentional or unintentional human action. The National Advisory Centre for Critical Infrastructure is a public/private network between government and infrastructure operators who are able to share information on threats, risks and vulnerabilities

In the **UK, the Civil Contingency Secretariat (CCS) and the Centre for the Protection of National Infrastructure (CPNI)**, work across Government and the business sector to reduce vulnerability and mitigate the effects of extreme events and threats. There are also Cabinet Committees set up to deal with particular issues, such as the Cabinet committee for pandemic flu planning, which was established in 2005 to guide the preparations for a potential influenza pandemic. The Committee is chaired by the Secretary of State for Health, and around 20 ministers are members. The Committee has provided drive and focus to the work to deliver a step change in UK planning, and overseen the production and publication of a national framework for preparedness. We are seeing the importance and effectiveness of this at the moment in the context of swine influenza.

An alternative approach would be to set up an inter-agency body to oversee co-ordination of NI, but this would need to be light-touch to avoid unnecessary bureaucracy.

## The Pitt Review – National Resilience Forum (NRF)

The Pitt Review; *Learning lessons from the 2007 floods*, recommends the creation of an inter-agency body to address resilience issues. The National Resilience Forum (NRF), with representatives of local response organisations and Government, would give a multi-agency strategic oversight. The NRF would not be a decision-making body. Government would continue to make decisions and the NRF would help to advise and encourage multi-agency working.

The NRF would deliver:

- high level buy-in and strong affirmation of the Government's commitment to a multi-agency, consensual approach
- a clear signal that the centre of government attaches great importance to the work, prompting action and interest of external bodies
- a public statement of intent through published minutes and collective endorsement of key decisions; and
- a focus for national, regional and local stakeholder groups which do not have a direct link in to Cabinet Committees.

## The Planning Act 2008[27]

The planning process has traditionally been a major blocker to big infrastructure projects. It is essential that the new Planning Act is implemented quickly. This is designed to help prioritise and streamline the regime for major NI projects through the development of National Policy Statements (NPSs). However, these need to be aligned with an understanding of the long-term challenges, interconnections and resilience of NI. In this context, formulation of the National Policy Statements should be framed within the context of advice obtained from independent advisory bodies, such as the National Resilience Forum. The presumption is that the remit of this legislation includes all the necessary infrastructure components; however, there appear to be some anomalies e.g. downstream oil pipelines are included but oil refining and storage facilities are not. Further clarification and possibly expansion of the scope of the infrastructure components covered by the Planning Act would be beneficial.

27 *Pitt Review – Learning the lessons from the 2007 floods.*

## Planning Act 2008

The Government will set out in National Policy Statements the case for nationally significant infrastructure, integrating social, economic and environmental policies. These statements will be subject to thorough public consultation, appraisal of sustainability and Parliamentary scrutiny. Developers will be required to consult local communities and other key stakeholders as they prepare those projects and before they submit an application. Decisions on applications will be made by an independent Infrastructure Planning Commission using streamlined inquiry procedures. Inquiries and decisions would be subject to statutory timetables. It is understood that they would be subject to challenge through the Courts.

## National Policy Statements

### Energy

The Government will publish an overarching national policy statement covering key elements of energy policy relevant to infrastructure provision, such as climate change, security of supply and the energy market, and including information relevant to likely future demand and measures to secure energy efficiency. Energy national policy statements will also be expected to encompass different forms of energy generation such as fossil fuels, renewable energy, electricity networks and gas infrastructure and are currently under development for nuclear power.

### Transport

The Government's aim is to establish a suite of national policy statements that will comprise:

- a statement for aviation incorporating the 2003 Air Transport White Paper (ATWP) in a way which meets proposed policy and statutory requirements for National Policy Statements; the Government is already committed to produce a further progress report between 2009 and 2011, which would provide a good opportunity to designate the ATWP in conjunction with that report
- a statement for ports, possibly incorporating international freight, based on the work already undertaken as part of the ports policy review
- a statement for the strategic national highway and rail networks focusing primarily on the highway network, given that comprehensive plans for the rail network were published earlier this year in the high level output specification (HLOS) and supporting rail White Paper.

These statements will over time be aligned with the overarching transport strategy now under development, reflecting the cross-modal approach recommended by Eddington, in order to ensure a consistent analytical and policy framework. The recent discussion document *Towards a Sustainable Transport System* sets out how the Department proposes to develop this strategy, working with transport users and other stakeholders over the period to 2012.

### Water infrastructure

The Government set out updated policies for water supply and water quality in *Future Water* (2008). This will inform development of a new national policy statement on infrastructure development for water supply and waste water treatment for the period from 2010 to 2035. The national policy statement will also be informed by parallel planning and price review processes such as the Water Resource Management Plans which water companies will produce, and the quinquennial reviews of water company sewerage charges.

### Offshore renewables

The IPC and the Marine Management Organisation proposed under the Marine Bill White Paper will have responsibilities for consents for offshore renewables projects of specific generating capacities. Both will operate in accordance with Government policy in this area whether set out in the relevant NPS or in the Marine Policy Statement.

# Chapter 4: Resilience and interconnectivity

The highly interconnected nature of the NI, set alongside the fragmentation of delivery and governance means that:

- no-one has any responsibility or accountability for looking across the NI as a whole i.e. across the network of networks
- there is little or no knowledge of vulnerabilities and risk arising from interdependencies across the NI which means that investment in adequate resilience will always be low priority
- little or no expenditure occurs on a precautionary basis, instead the approach is to perform heroic acts in times of crisis

Despite significant levels of investment by the private sector in recent years, we do not believe market forces by themselves will deliver a resilient NI fit for the 21st century. A partnership between business and Government is needed.

### *Recommendation 3*

The lead department, working closely with Cabinet Office and the independent stakeholder group, should collaborate with senior business leaders and the regulators to scope out and deliver by 2010 a road map setting out the priority actions in the short-term (5 years) and for the longer-term, that are needed to enhance or maintain the resilience of the NI, paying particular attention to:

- points of weakness, especially vulnerabilities at the interconnections and how best to build in the necessary safeguards and redundancy into the systems to mitigate weak points
- conflicts created by different strategic and legislative frameworks, and understanding the effects of sector-specific interventions on other components of the NI
- stimulating better understanding of the complexity and resilience of the national infrastructure, by commissioning research into scenario planning and modelling NI systems, from physical, economic and social perspectives
- human factors, so that individuals operating in one sector of the NI consider the effects of what they do on other sectors of the NI
- technology and skills needs (see recommendations 5 and 7)

Our report highlights significant deficits in the levels of resilience of the national infrastructure. It also shows up particular 'points-of weakness' where localised failures could trigger a cascade of wider consequences across different sectors or components of the NI.

There is a lack of understanding of the vulnerabilities, particularly where one sector of the NI is dependent on another. Unless addressed, such dependencies can lead to a misplaced level of reliance on other systems that could also have serious consequences e.g. ICT networks which are used to control parts of the NI and which operate through the internet. There needs to be a robust analysis of these interconnections, plus a more pro-active approach to managing the interdependencies.

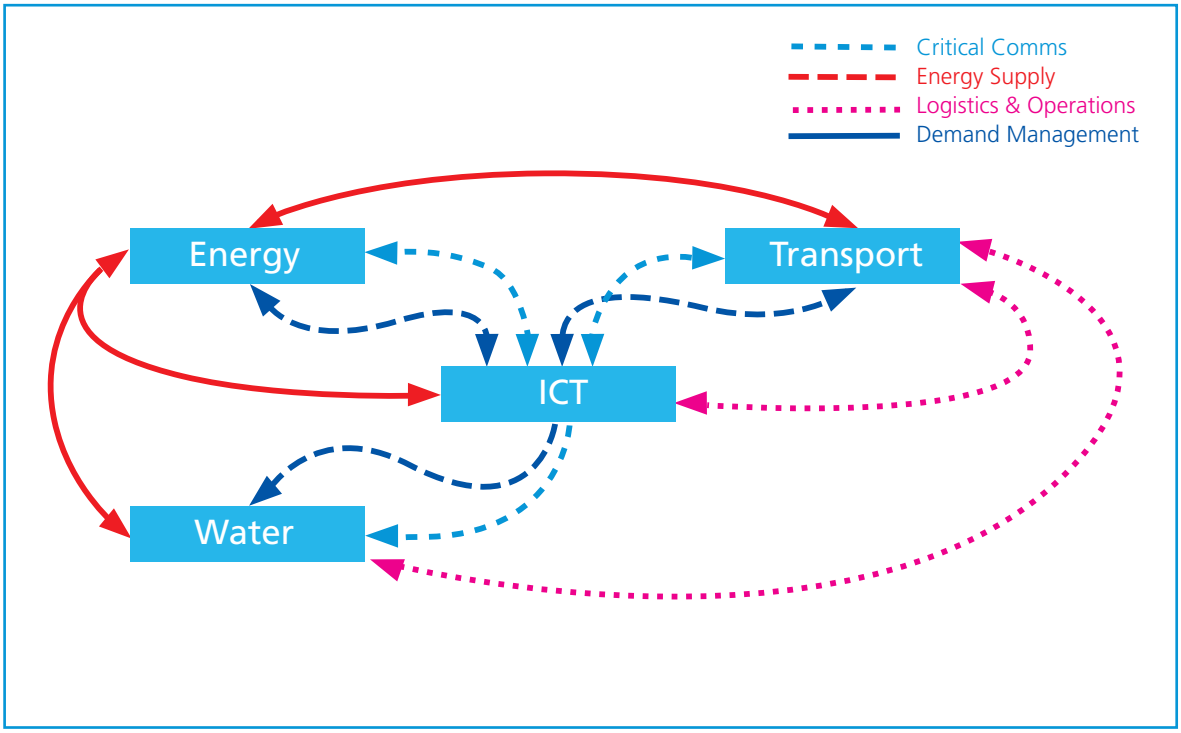
Components of the national infrastructure do not operate in isolation. They are increasingly interdependent, for example they all require power and are increasingly dependent on ICT for control systems, communications and general business operations. Interconnections exist not only between the physical systems but also at the strategic level and in the patterns of demand, e.g. a 'journey' will normally involve more than one form of transport; if a failure occurs in one component passengers will switch modes where possible.

The NI needs to be resilient, not just defined in terms of the ability to respond to extreme events such as terrorist attacks, but in terms of longer-term adaptability to changing patterns of demand; and to changing socio-demographic, economic and environmental circumstances[28]. The complicated ownership pattern of the NI (see earlier) has created a fragmented programme of risk and hazard assessment, regulation and protection, with vulnerabilities at the interfaces.

It is inevitable that increased levels of resilience will add to the costs of the NI, as market-driven and efficiency-led approaches may not place sufficient value on resilience, and a balance will need to be struck between the extent of 'future proofing' against particular types of event in terms of probability and impact. Government, working in conjunction with the owners of the NI and the regulators, needs to satisfy itself that there are the appropriate levels of risk management in place and that these reduce the likelihood of knock-on failures within and between sectors.

Underpinning these challenges is the need to develop innovative solutions and maintain an appropriate skills base to design, build, operate and maintain the NI. These are considered in more depth in later chapters.

***Figure 1 – Interconnections between the different sectors of national infrastructure***




*28 ESRC along with other Research Councils and the Centre for the Protection of National Infrastructure have funded research to examine the impact and growth of recent urban resilience policies.*

Figure 1[29] shows an analysis of individual interconnections (e.g. the different ways in which ICT depends on transport or vice versa). Individual interdependencies are categorized into logistics and operations, demand management, critical communications and energy supply. The dependencies have been ranked in terms of: (i) immediate resilience; (ii) governance issues; and (iii) threat from climate change/contribution to carbon emissions, to give an indication of how fragile or threatened the dependency is, and where there are strengths and opportunities. There are significant differences between NI sectors in the levels of embedded resilience under both normal and stressed situations.

The big messages are:

- ICT is central in supporting all other sectors, particularly for critical communications, but has least reliance on other NI sectors (apart from energy supply on which it is wholly dependent). Some NI sectors use ICT developments to improve demand management; in many sectors it is embedded *e.g.* rail signalling, power station controls. ICT in particular needs to sustain a high level of resilience under highly stressed conditions
- energy supply is critical for operating all sectors but has a high level of dependency on other NI sectors
- transport is critical for logistics and operations, particularly for getting resources (including staff) to the point in the infrastructure where they are to be deployed
- business depends heavily on all aspects on the NI
- there are opportunities to improve efficiencies by exploiting NI interactions[30]

Within each sector of the NI the direct effects of a failure or an extreme event are reasonably well understood and methods to mitigate or adapt have been developed to some extent (although further evidence is required to confirm this in all sectors). However, there is a lack of understanding of the vulnerabilities in the circumstances where a particular NI sector is dependent on another[31]. Unless addressed, such dependencies can lead to a misplaced level of reliance on other systems that could have serious consequences.

## Moves to just-in-time systems

Organisations increasingly adopt just-in-time systems of stock and logistics management and outsource both these activities to improve the efficiency of their operations. This method of management relies heavily on information management and contains an implicit assumption that NI is secure and reliable, e.g. transport system will not cause delays to deliveries and the information system will not fail. Additionally, the fragmentation and privatisation of NI has encouraged competition and efficiency without regard to resilience or agility. This creates two challenges: first, how to plan and build sustainable resilience into NI; and second how to maximise agility without risking systemic failure. Local optimisation may be the enemy of resilient system functionality[32].

There needs to be recognition that mitigating the risks of system failure will mean increased costs to business or consumers or both.

*29 AEAT report to CST April 2009.*
*30 For example in co-location of infrastructure facilities such that systemic benefits may be derived from their interaction – e.g. co-location of waste treatment, water treatment and power-generation facilities.*
*31 For example data transfer from one business to another relies on communications infrastructure owned by a third, and one data packet has neither more nor less priority than another on shared communications facilities.*
*32 Contribution from Professor Jim Norton and Professor Brian Collins.*

## Aligning policy objectives

One of the major challenges facing the future of national infrastructures worldwide is how to handle currently irreconcilable objectives to deliver increased services with decreased carbon footprint. For example, the EU and member states have agreed stringent targets on water quality and reducing carbon footprints with little sense of the impact that regulation in one major area of infrastructure will have on another. This tension between contrary objectives requires the development of solutions based on innovative technology, which provides both an opportunity and a threat to the UK, depending on how well the UK is positioned to innovate and to profit from that innovation.

### Water quality and carbon emissions

Water quality is a key driver for change within the water industry. Increasingly stringent controls on water quality have driven up the energy usage of this sector, it is a major electricity user, accounting for 3% of the total UK electricity demand, and is set to continue increasing its carbon footprint.

Innovative low-carbon technologies, such as pump optimisation techniques, will be an essential part of the solution to reduce carbon emissions of the water industry. At present only about 10% of the water industry's total energy use is from renewable sources and alternative methods of powering the industry need to be identified, for example wind energy.

There needs to be a more joined-up approach across the water and energy sectors to allow water companies to take advantage, within the regulatory regime, of their ability to generate renewable energy and use it to offset energy intensive processes within the sector.

## Cascade Failure

A major risk to NI is the unexpected consequences of cascade failures across sectors because the extent or type of interconnectivity is not well-enough understood[33].

33 *The Defence Science and Technology Laboratory has modelled cascade failures in some sectors to reveal major knock-on effects e.g. flooding causing a cascade of water between water pumping stations and crucial pieces of the energy infrastructure that could quickly impact across large areas of the UK.*

## Cascade Effects

Providing alternative routes leads to efficiency and robustness (e.g. allowing telephone calls to reroute around local hotspots will in general lessen the impact of a traffic/capacity mismatch). A local traffic/capacity mismatch is controllable, but when the spare capacity across the entire network is reduced, it can lead to the system as a whole suddenly hitting its capacity limit. Re-routing to less-than-ideal routes increases incidents, which can lead to cascading failure (e.g. in the past an accident on the M4 would have caused stationary queues on the M4; now it increasingly causes spillage of traffic onto substitute routes, accidents on these routes, further rerouting across wide areas, further accidents etc).

Grouping resources together to achieve efficiency inevitably runs the risk of catastrophic failure. Nevertheless, local knowledge and incentives are important, and decentralising decisions tends to achieve greater rapidity in response. Advances in IT have allowed huge steps forward in decentralised control of networks (first in communication networks like the telephone network and the Internet, now in power and transport networks). It is essential to understand the system at a macroscopic level.

When a network with extensive decentralised control is close to the edge, the spare capacities in different parts of the network become highly correlated, a simple consequence of the network's aggregate capacity becoming saturated.

Linkages between networks are creating a network of networks, with its own fragilities. A power loss that can cause an underground line to fail may cause absence of key workers in another network, etc. Again, the routine application of local decentralised optimizations in search of efficiency and robustness can, paradoxically, lead to a greater risk of cascading failure[34].

## Electricity and ICT dependencies

Energy is critical for supplying power for operating other sectors. ICT is used in demand and flow management as the key to capacity utilisation. Wholesale loss of electrical power can knock out traffic lights leading to traffic chaos and gridlock which impacts on the ability of people to live and work normally and the emergency services' ability to respond. Mobile phone networks will become overloaded and probably fail; domestic heating will fail and water supplies and sewerage services will be affected; petrol pumps, tills and ATMs will fail and TV would stop; electric lights would not work leading to more use of candles and hence greater fire risks.

*34 Contribution from Professor Frank Kelly.*

## Vulnerabilities of ICT infrastructures

There are three computer operating systems (Windows, MacOS or Linux). These are updated automatically creating a significant vulnerability to malicious attack. Increasing dependence on a few systems reduces resilience. They are also significantly vulnerable during the update periods, particularly systems that need to test the impact of updates before roll-out, as the update often identifies system vulnerabilities.

The complexity and interdependence of the key components of the information and communication system are high and growing, and not well understood. Vulnerabilities at the interfaces present real risks of systems failure. Business tends not to have tested and audited resilience strategies. Emphasis on back-up systems has diminished.

Risks of failure increase where ICT network systems are working close to capacity (i.e. above 40%).

## Modelling and simulation

It is important to be able to measure, predict and mitigate the functioning and malfunctioning of complex infrastructure systems. Modelling and simulation techniques are important ways of enabling complex systems to be understood and manipulated in a virtual environment. It is particularly important that interactions between different components of the NI are modelled in an integrated fashion to ensure that system sensitivities are identified and understood. Such system models are powerful tools for design and planning of infrastructure to ensure that it is optimised to key policy constraints such as minimal energy loss, cost, carbon emissions, efficiency of supply and flexibility to demographic and climate change.

The history of modelling the climate system provides an informative guide to optimal approaches to modelling the NI. Rather than model the full details of ocean, atmosphere, biosphere etc, the most instructive early models were those in which these individual systems were 'black boxes' with simplified characteristics, but where the interactions between them were modelled so as to identify the sensitivities of the whole coupled system. Whilst models of individual components of the NI (water, rail, electricity etc) should continue to be developed, it is important that 'interaction' models of the whole system are developed, which should ultimately converge with more detailed, individual system models.

Simulation and modelling are areas where the UK has academic strength. There is a need for more investment by business, the regulators and Government in modelling techniques, including supporting the best R&D in modelling techniques within universities. There should also be support for the social sciences to increase understanding of human behavioural interactions with the NI. This will increase our ability to understand and predict human behaviour in the context of functional and malfunctional infrastructure.

Whilst individual organisations may have data and data systems to assist in optimising their own operation against regulatory expectations, there appears to be limited information and capability in understanding the interactions between sectors and no incentives at present to optimise overall performance of interlinking infrastructure systems[35].

*35 AEAT report to CST April 2009.*

## Modelling Transport and Energy

### Transport

DfT has developed a National Transport Model (NTM) as an analytical and policy-testing tool. There are several detailed models of the Rail infrastructure available, each with a particular focus, e.g. OSLO for electrification, VISION for signalling issues etc. Network.

Rail has models used for train timetabling purposes and there are e.g. specific junction optimisation models[36].

There is no 'whole railway' model; the logistical issues, such as train crewing etc are modelled separately by Train Operating Companies, who generally do not have detailed infrastructure models. Modelling in France and Germany is probably more advanced than in the UK. The UK network is very different from other EU networks and there is little direct interaction.

The Highways Agency is using Intelligent Transport Systems (ITS) to manage networks and vehicles[37].

### Energy

The National Grid has a model of the electricity transmission and distribution networks that allows testing of different scenarios involving changes in location and volume of demand or generation, effects of disasters etc. Models of European networks do exist but are not publicly available. A number of universities e.g. Cardiff have models of the combined gas/electricity networks. The key issue is that the models accurately represent the full range of timescales implicit in the system; few do.

We understand that the Energy Technologies Institute is initiating work to develop a model of the energy infrastructure. There is some modelling of security of electricity supply[38].

### EU Technology Platform – Zero emissions fossil fuel power plants

Modelling of different scenarios for carbon capture and storage demonstration has identified that an optimised demonstration strategy, including for example co-location of different demonstration units, so that they can share one transport and storage site, could reduce costs by 50% and reduce the timescales for full demonstration of the whole process by 5–10 years.

It is unrealistic to expect to develop a model of the infrastructure as a whole, to simulate the operation both of individual infrastructural systems and also their interactions and then optimising in terms of cost, resilience, emissions' levels, patterns of population/activity etc.

*36 These use sophisticated algorithms to work out the best way of giving trains priority over a junction to minimise the overall service delays if, for example, one train arrives out of sequence. Some models do have 'layers' such as electricity demand etc. Some train simulators calculate loading at the grid connection.*

*37 e.g. to implement Active Traffic Management and Managed Motorways schemes on several motorways in the West Midlands.*

*38 For example by Oxera – Non-market value of generation technologies June 2003.*

# Chapter 5: Regulatory regimes

### *Recommendation 4*

Government, working closely with the Regulators and the major business stakeholders, should ensure that the remits of regulators are fit for purpose, and in particular whether they:

- provide incentives for modernisation and innovation
- deliver the necessary resilience and interconnectedness within and between the different sectors of the NI
- stimulate innovative solutions where appropriate
- are joined-up in terms of how they work across boundaries between their respective regimes, and at the interconnectivities between different sectors of the NI

We recognise that this work will need to be carried out at a strategic level and avoid creating unnecessary uncertainty.

Regulation of national infrastructure is needed because market forces alone may not provide all of the essential features of the NI, for example the appropriate level of security, resilience, interconnectivity and co-ordination between infrastructures, research and development investment and future-proofing.

The current regulatory framework has lasted well over 20 years, and was designed for particular purposes, separately for the individual sectors within the NI. We are not convinced that as it currently stands the regulatory system is optimally designed to meet 21st century challenges e.g. to address the pressing challenges for increased resilience; for reducing carbon footprints; or for encouraging longer-term investments in innovative solutions by business. We acknowledge that some regulators are taking a more proactive approach to addressing this problem, e.g. Ofgem's self-initiated review of energy network regulation. It is important to ensure that the regulatory regime encourages innovative solutions from business.It is important that the regulatory regime underpins policy objectives and that these are aligned across the NI sectors.

The review should address the House of Lords' Select Committee finding that: *"action is necessary to improve regulators' joint working. There needs to be a more structured and formal co-operation between the regulators if it is going to be meaningful".*

Regulators were established post-privatisation for some NI sectors to regulate natural monopolies in order to protect consumers and, where appropriate, stimulate competitive markets. The regulatory regime has historically grown in a piecemeal way over the last 25 years as different state-owned monopolies were privatised, and each regulator has a different combination of remits with little regard for interdependencies[39]. Economic regulation allied with the drive for improved efficiency makes good business sense and provides better value; but it does risk driving out spare capacity within the networks[40], with the unintended consequence that resilience is lost, exacerbated by the increasing interconnectedness between infrastructure sectors where failure in one is likely to affect another[41].

*39 e.g. Ofcom which is primarily there to ensure competition within the telecommunications market is maintained; or Ofgem where recent changes have focused its role on regulating energy networks with less emphasis on generation, which is seen as primarily market driven.*
*40 For example, replacing larger numbers of smaller assets with smaller numbers of larger ones.*
*41 For example, resilience improvements in one sector could be completely negated by vulnerabilities in another.*

We are not convinced that as it currently stands the regulatory system is optimally designed to meet 21st century challenges e.g. to address the pressing challenges for increased resilience; for reducing carbon footprints; or for encouraging longer-term investments in innovative solutions by business. We acknowledge that some regulators are taking a more proactive approach to addressing this problem, e.g. Ofgem's self-initiated review of energy network regulation[42]. It is important to ensure that the regulatory regime encourages innovative solutions from business[43]. It is important that the regulatory regime underpins policy objectives and that these are aligned across the NI sectors.

## Regulatory review periods

Regulatory review periods are mismatched with build and life times of major infrastructure projects. This means that the prices could be altered 6-8 times during the lifetime of these assets. For example: the price control review period is 5 years; the lifespan of grid transmission asset is in excess of 30 years; the lifespan of water pipeline assets is 40 years.

## Excerpt from CST's Water Report[44]

**Regulation in the water sector**

We believe the regulatory regime needs to change in two main ways. First: to introduce mechanisms to value and reward innovation through new technology, including innovative low-carbon solutions, which would in themselves create a virtuous circle by helping to stimulate the wider supply chain to develop low-carbon solutions. The system as currently operated does not generally incentivise R&D investments beyond the five-year regulatory review period, although Ofwat does allow overlap projects spanning two price review periods, and so longer-term enabling innovations are being lost. Second: to introduce mechanisms to value and reward water and sewerage companies when they make the necessary longer-term R&D investments into innovative low-carbon solutions, which would in themselves help to create a virtuous circle by stimulating the wider supply chain to develop low carbon solutions.

While many sectors of NI are regulated, some are not[45]. We welcome the Government's acceptance of the need for a specific duty to be placed on economic regulators to build in resilience into the NI[46]. We also welcome Ofgem's own reviews of the future shape of energy markets and their current regulatory regime; we would encourage them to share their findings, as we expect there will be issues of general relevance to other regulators[47]. We are also aware that DfT are currently mid-way through a review of the regulatory framework for airports.

CST welcomes the proposal in the Digital Britain report that *"Government believes that Ofcom's duties should be modernised in two ways. Firstly, Ofcom should have an explicit general duty to encourage investment as a means of furthering the interests of consumers,*

*42 Ofgem's RPI-X@20 project launched in March 2008.*
*43 For example, the CST's Water report found that the five-year price review periods mitigated against investment in longer-term innovative solutions by the water companies.*
*44 Extract from the CST report: Improving innovation in the water industry: 21st century challenges and opportunities*
*45 These are either under the control of Government e.g. the Highways Agency and local authorities, or are wholly private sector e.g. internet service providers.*
*46 Government response to Sir Michael Pitt's review December 2008.*
*47 For example: Ofgem's RPI-X@20 project, which is reviewing its approach to energy network regulation; and Project Discovery on the medium-term outlook for GB markets.*

*alongside its duty to promote competition where appropriate. We also propose to give Ofcom a duty, which is the communications equivalent of the letter from the Governor of the Bank of England, to alert the Government to any significant deficiencies in the coverage, capability and resilience of the UKís communications infrastructure and to report every two years on the state of that infrastructure."*

There is also a broader question of whether issues such as security of supply can be solved by market forces, or whether there is a need for some form of intervention by regulators. There is also a question on whether issues of capacity and headroom can continue to be delivered by the market alone, there are concerns on the energy side about placing too many eggs in too few technology baskets e.g. an over-reliance on offshore wind.

The rate of development and increasing complexity of IT and internet systems, plus Government's and the private sector's very patchy records on IT procurement, suggests that some form of regulatory oversight might be necessary. However, this is a highly complex area, involving the interaction between cyberspace and geography and there is a risk that attempts to regulate externally would either not be achievable and/or would mean that activities which were being regulated would move outside the jurisdiction of any regulatory regime, assuming one could actually be set up and enforced[48].

## The National Grid

Design and development of a UK low carbon distributed network, (the technical architecture), is unlikely to become reality in the timescales required if left to market forces alone. There is an important role for Government in the process, acknowledged in the 2007 White Paper where it states that *"Government's role is to ensure that new market opportunities are identified, that the market and regulatory environment is 'user-friendly' for smaller participants, that potential barriers are identified and addressed and that genuine market failures are resolved."*

We fully support the House of Lords' Select Committee finding that: *"action is necessary to improve regulators' joint working. There needs to be a more structured and formal co-operation between the regulators if it is going to be meaningful."*

48 *Self-regulation does work in certain areas e.g. the posting of child abuse images can be reported to the Internet Watch Foundation who then take action through the ISPs.*

# Chapter 6: Stimulating innovation

A modern national infrastructure needs to be innovative across all the sectors, and that innovation must be driven by business, but Government has a role in specifying a stable, long term framework for the future of the NI which then gives business confidence to invest. It must provide incentives for business to connect to the science and engineering base.

### *Recommendation 5*

Government departments, the Regulators, the Research Councils and bodies such as the TSB need to incentivise the infrastructure operators to connect better to the science and engineering base to develop innovative solutions using best technology. To do this, they should come together to address of the following core questions:

- is procurement being used optimally, or indeed at all, to balance low risk/low cost solutions with the need to innovative?
- whether there should be more, or more effective, Innovation Platforms, Knowledge Transfer Networks and other types of collaborative R&D projects between infrastructure operators, academia and the other stakeholders?
- what technologies are available now and are they being exploited effectively within NI?
- what are the barriers to deployment e.g. the need for technology demonstration?
- what are the priority areas for underpinning R&D?
- how to encourage more cross-disciplinary research to clarify the interconnections and interdependencies of infrastructure components, including the human dimensions?
- what scenario planning is needed?
- what roles the professional bodies and learned societies might play?

Meeting the challenges for a 21st century NI will require innovative solutions, drawn from the science base. This will include developments to existing systems, such as moves to active networks and smart metering.

Supporting innovation in key infrastructure sectors by means of direct procurement will create markets for new high-tech businesses in the UK, stimulate innovation throughout the supply chains and act as a mechanism for pulling through R&D from the science and engineering base. The TSB therefore needs to press forward with the Small Business Research Initiative and extend the pilot programmes beyond Health and Defence into other areas of the NI.

Regulators should consider carefully the effectiveness of the mechanisms they have in place to encourage innovation, which should be folded into the overall review of the regulatory regimes highlighted in recommendation 4.

The TSB and the Research Councils need to do more to stimulate collaborative R&D between business and academia in key areas of the NI: Government, business, Research Councils and the TSB, and regulators need to come together to address key issues around technology

availability and deployment and the priority areas for R&D including new cross-Council multidisciplinary programmes.

Government should work in collaboration with the research community, technology developers and investors to develop scenarios and potential roadmaps e.g. for the UK low carbon landscape for 2050.

## Ofgem's Innovation Funding Initiative (IFI)

This is designed to encourage network businesses to invest in innovation and allows businesses to fund investments in R&D up to 0.5% of their annual regulated revenue. It was introduced in response to the consistent decline, actually approaching zero spend, since the 1990s.

Projects include R&D related to: asset condition monitoring, better ways of modelling network performance, and the development of new equipment. They can embrace technical development, asset management from design through to construction, commissioning, operation, maintenance, and decommissioning. They include environmental challenge issues.

Since the introduction of the scheme there has been a substantial increase in R&D spending by the distribution businesses. In 2007/8, they spent £12.1m on IFI projects, equivalent to 0.33% of their regulated revenue. The IFI scheme for the transmission businesses came into operation in April 2007 with projects of £4.5m, with an intensity (i.e. R&D spend in relation to turnover) of around 0.25%. Ofgem calculates that the net present value of investments made by the distribution businesses in 2007/8 exceeded £50m.

As Research Councils and the TSB develop their forward strategic plans, for example we know that ESRC is publishing its strategy, and cross-cutting programmes, they should consider the innovation and R&D needs of the NI (see Annex 2).

## The UK Research Councils' Energy Programme

This programme is led by EPSRC and is bringing together engineers and scientists from many areas to tackle the research challenges involved in creating new energy technologies, developing and exploiting low carbon energy technologies, reducing energy use and understanding the social and economic implications with funding of £108M in 2008/09.

Much greater recognition needs to be given to the massive increase in costs required to deliver prototypes and demonstrators, as opposed to concepts, before business can be confident in making key investment decisions associated with the NI.

Bodies such as the Energy Technologies Institute and the Energy Research Partnership will have important roles in bringing a step change in applied energy research and development in the UK and internationally, as well as addressing relevant environmental, social and economic issues[49].

*49* http://www.epsrc.ac.uk/ResearchFunding/Programmes/Energy/

## KWR – the Dutch Watercycle Research Institute

"What the Dutch don't know about water, nobody knows" (quote from a German Chief Executive)

The Dutch have an integrated approach to water management and use across the Netherlands, with an emphasis on polder, or collaborative consensual working between the 10 Dutch publicly-owned drinking water companies, the 26 water boards dealing with waste water treatment and water system management, together with the private sector and Government. Investing in water technologies is seen as an integral part of maintaining water quality and efficiency, as well as delivering a smaller energy footprint.

The Dutch water sector can draw on a science base of around 400 million euros, largely in applied research and hydrology. KWR has a research budget of 17 million euros, levied from the water companies, and a staff of between 150 and 180 people. Around 6.5 million of KWR's 17 million euros budget is used to leverage external funding, and there are secondments from the university base into KWR. In addition, TTI Water conducts longer-term research through a virtual institute (TTI Water) which spends around 7 million euros per year. In the Netherlands there are about 100 PhD students engaged in applied R&D related to water technologies.

CST has previously identified a number of key technology areas relevant to infrastructure developments.

## Excerpts from CST's Technology priorities report[50]

**Low carbon distribution networks for electricity supply**: "We must move towards smarter distribution networks if we are to facilitate greater energy efficiency and manage a low carbon future. This must include the associated ICT, software and control systems for active network management. Smart metering will be the key to overall development of this technology, in particular enabling the use of sophisticated dynamic tariffs[51]. Network innovation is unusual in that new technology has to be proven on the live system so network company engagement from an early stage is a prerequisite for success."

**Disaster Mitigation Technology**: "Global impact of disasters is already exceeding $100 millions with potential effects of climate change being measured in the trillions[52]. It requires a range of technologies such as earth monitoring from satellites and earth-based stations together with predictive modelling of surface events and their physical and social consequences, plus engineering-based mitigation systems such as earthquake-proof buildings. CST recommends formation of a Disaster Resilience Knowledge Transfer Network."

The transition towards a more sustainable, low carbon society will require a step-change in the development and deployment of a range of existing and new technologies and infrastructures which are not currently in place. These include centralised supply side options

*50 CST report: Strategic decision-making for technology policy (November 2007).*
*51 Smart and decentralised networks may need specific attention by Ofgem as currently there is a breakpoint in the regulatory frameworks for generation less than 50MW.*
*52 Stern report on the economics of climate change.*

such as carbon capture and storage, infrastructure technologies such as decentralised networks (transport, water etc), cleaner transport and micro-generation.

More scenario planning is needed. Government should work in collaboration with the research community, technology developers and investors to develop scenarios e.g. for the UK low carbon landscape for 2050. These scenarios would enable possible pathways for innovation and technology to be developed and so assist Government, energy, and other businesses and investors to develop their strategies for the long term. Regulators need to ensure they have their own adequate scenario planning exercises in place[53].

Equally as important as R&D investment and technological innovation is the need for both people and the organisations themselves to be innovative[54]: for example ensuring the workforce development in terms of individual and collective skills' levels; and development of clever processes and models which allow organisations to be more responsive and adaptable.

Data management and security are important issues which Government still needs to address to secure maximum benefit from the NI e.g. through the NHS. CST has previously identified the need for development of safeguards for the handling of large amounts of personal or sensitive data in a secure fashion[55].

## Transport Research

DfT's low carbon vehicle agenda is designed to stimulate new technologies to reduce road transport carbon emissions, for example research into biofuels, electric vehicles and (to a lesser extent) hydrogen vehicles. Studies are also being undertaken to consider how aviation, rail and maritime carbon emissions can be reduced[56]. In 2008–09 DfT allocated just under £60M for research activities. EPSRC supports the universities' centre for rail research to help ensure a strong engineering base for railways' systems R&D in the UK, including work on safety, reliability and capacity, reducing environmental footprints.

*53 For example Ofgem's Long-term electricity networks scenarios in response to the Government's 2006 Energy Review.*

*54 ESRC is funding research in these areas. It is also looking at: effects on social and environmental sustainability; public policy options to increase innovation; and the economic, social and managerial factors which enable the UK to capture high value from innovation processes.*

*55 CST report: Better use of personal information: opportunities and risks November 2005.*

*56 http://www.hm-treasury.gov.uk/d/pbr_csr07_king840.pdf*

# Chapter 7: Public engagement and dialogue

### *Recommendation 6*

Government should put in place ongoing mechanisms for gathering social intelligence for example public engagement and dialogue for key issues on the national infrastructure.

As we have shown, the challenges over the next 30–50 years will be profound and potentially disruptive in impact whilst offering significant opportunities for innovation. We need the general business community and the wider public to understand these challenges and to have a place in shaping the long-term vision and road-map. It is therefore essential that the long-term provision of national infrastructure be informed by a better understanding of users' needs. These needs must be factored into all stages of the design, development and operation of infrastructure as strategies and polices develop, regulations evolve and investments are made.

We believe that Government, infrastructure businesses and regulators should put in place mechanisms for public engagement and dialogue on key issues such as:

- the value placed on infrastructure whose provision entails significant investments and costs
- its significant carbon footprint
- future challenges and the role customers can play in helping to address them
- levels of investment in the UK NI
- how tolerant society is to risks resulting from infrastructure failures
- how to achieve the necessary skills sets by attracting people to key industries
- how Government can better act as an intelligent customer

There needs to be a clearer understanding of the social context in which people make decisions, for example to use less water on a routine basis. Such decisions will affect the future resilience of the NI but they are not simply a response to the market, though that clearly plays a part, nor are they simply a series of individual decisions. People are influenced by the behaviour of those around them, by expectations created through the media, by their own commitments, and many other factors which are part of the social fabric. Analysis of this, based on the best social science data available, is essential for effective planning and operation of the NI.

Government, business and the regulators need a better understanding of the acceptable levels of risk and tolerance by both business and consumers to determine the level of resilience that are required in different sectors of the infrastructure. At the same time there needs to be debate around the implications of mitigating the risks of system failure, which are likely to mean increased costs to business or consumers or both. Leadership from Government on public engagement will be crucial to delivering a 21st century NI. Awareness by the general public of vulnerabilities in the NI is low, but reactions are swift and often heated when things go wrong.

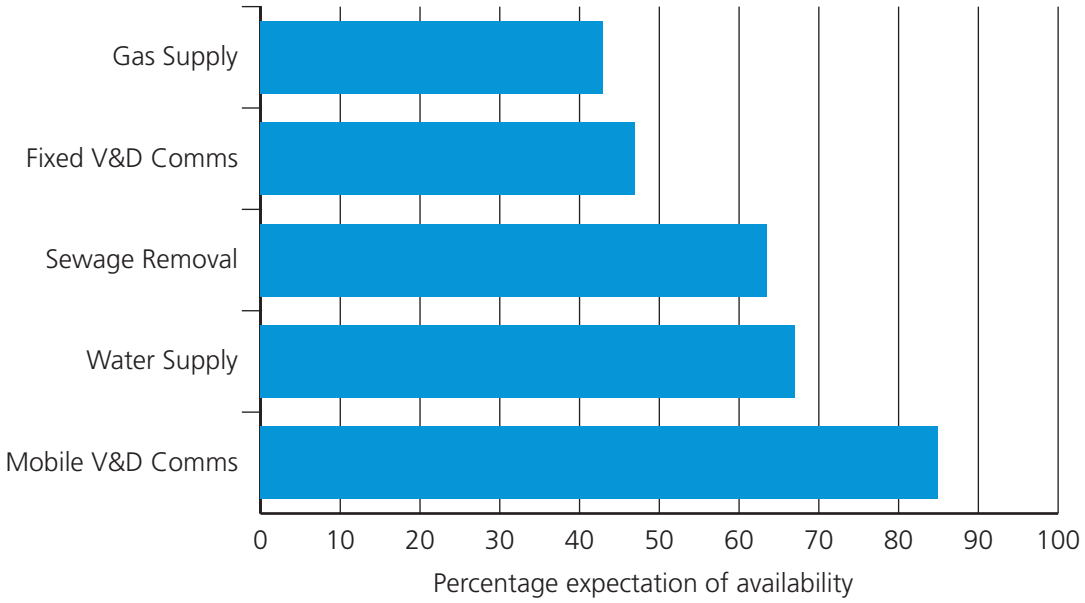
Feedback during the Pitt Review demonstrated that the public needs to be reassured that essential services are resilient to flooding or other civil emergencies.

## Outsourcing of mobile communications[57]

Over the last 10 years businesses have increased their reliance on the mobile phone network to provide critical communications. This network was never designed to be highly resilient and is vulnerable to power outages and traffic overloads. However, the awareness of this vulnerability among the business community is low.

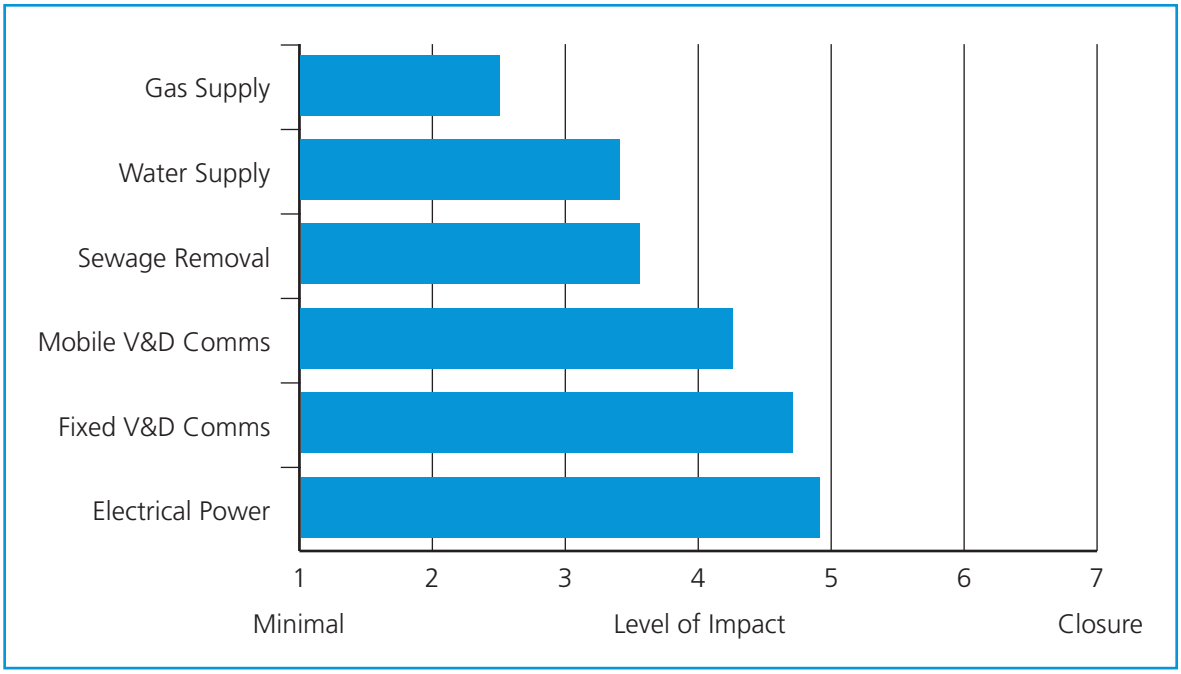
The graph below shows business's expectation of continuing availability of other services during a 12-hour wide area failure of electrical power[58]. This demonstrates that the business sector has a misplaced perception that mobile communications are more resilient than they truly are.

***Figure 2 – Expectation of continuing availability of other services during a 12 hour wide area failure of electrical power***




57 *Jim Norton – The crisis in our critical national infrastructure.*
58 *Institute of Directors – Business operation survey. Research carried out March 2008.*

***Figure 3 – Mean organisational impacts of loss of services for 24 hours during the working week***




Particular areas where CST believes infrastructure provision for the next 50 years will benefit from greater public engagement include investment in the National Grid; nuclear power; gas and oil supply as reliance on overseas supplies increases; fresh and waste water management; and sustainable fit for purpose transport.

# Chapter 8: Skills

The NI needs a skilled workforce, not least in terms of trained engineers and technicians able to design, operate and service it, and the responsibility for championing and developing a skilled workforce must be shared by business and Government.

### *Recommendation 7*

The Sector Skills Councils, working with business, BIS and professional bodies urgently need to address the short-term gaps in the skills market needed to deliver a 21st century NI, and provide clear forecasts of the skills needed in the longer-term, and how these can be met. The operators of NI need to identify their needs to ensure they attract, retain and develop the skills of their workforces.

A clear vision of the skills required to operate, maintain, develop and modernise the national infrastructure needs to be developed. The operators of the NI have the central role in driving this forward. Engineering skills across all the major engineering disciplines will be central to delivering a modernised NI, on a major scale not seen in the last 50 years.

The Sector Skills Councils and other bodies representing industry and professions, such as learned societies, professional associations, higher and further education institutes, need to continue working together to provide the Government and the devolved administrations with this essential information. But the lead must be with the employers themselves, and in a co-ordinated way.

Encouraging the supply of science, technology, engineering and mathematics graduates should continue to be a Government priority. Putting in place more high-level apprenticeships and training and development of technician engineers should be an important component of the skills mix needed. The development of multidisciplinary skills sets to design, install, operate and maintain the NI will be essential.

There is a question of whether a more focused approach to skills training is needed for strategically important sectors such as the low carbon economy, and major infrastructure projects such as nuclear build and retrofitting of low-carbon solutions. There are other skills bottlenecks needing urgent attention, for example in transport planning and operational research. The economic and Social Research Council will have an important role in ensuring that these skills and the relevant research is undertaken to support a modernised national infrastructure.

Social science skills will be essential at many stages of planning and implementing change in the NI. These include:

- researching, and gathering together the findings from existing research, on the social dimensions of modernising the NI
- informing modelling and simulation on a more interconnected NI
- operational management of the NI systems in a way which takes the social dimensions fully into account
- managing public engagement

The skills relevant to the above can be found across a range of social science disciplines: demography, social statistics, anthropology, geography, sociology, social psychology. There needs to be an exercise to identify how generic skills in these disciplines need to be developed to produce a cadre of social scientists suited to working on NI projects and within those industries. The Economic and Social Research Council will have an important role in ensuring that these skills and the relevant research is undertaken to support a modernised national infrastructure.

## Registered Engineers and Technicians

The total number of registered engineers and technicians has declined from 263,999 in 1997[59] to 239,303 in 2007 (a fall of approximately 10%)[60].

Approximately half of all registered engineers (CEngs, IEngs and Eng Techs) are either already past retirement age or will reach legal retirement age within 10 years[61]. National Grid estimate that 33% of its UK Transmission engineering workforce will retire over the next 10–15 years[62]. The Engineering and Technology Board, publishers of Engineering UK, describe this situation as a demographic time bomb.

A SEMTA[63] commissioned labour market survey in 2007[64] of 5,129 employers in engineering sectors in Great Britain found that 11% of all employers interviewed had experienced some hard-to-fill vacancies within the last 12 months, although greater recruitment difficulties were reported in Marine (20%) and Aerospace (16%). The main reasons cited for recruitment difficulties were a lack of applicants with the required qualifications and skills and a lack of applicants with required work experience.

Businesses that operate the NI, and their supply chains, also have crucial roles to play, and not least in terms of 'employer training'. The employer recognition programme[65], developed by the then Department for Innovation Universities and Skills in 2007, allows accredited employers (awarding organisations) to gain national recognition for in-house training and employees receive a formal qualification under the Qualifications and Credit Framework. We are pleased to note that Network Rail is an awarding organisation under this programme. There is a strong demand for experienced engineers but a deficit in businesses willing to invest in individuals to take them from qualified to competent.

*59 Engineering UK 2007.*
*60 Engineering UK 2008.*
*61 Engineering UK 2008.*
*62 taken from the IUSS Commons Select Committee report Engineering: turning ideas into reality.*
*63 the Sector Skills Council for science, engineering and manufacturing technologies.*
*64 2006 Labour Market Survey of the GB Engineering Sectors, SEMTA.*
*65 Also referred to as the 'recognition of employer and provider training programme' or 'accredited employer training'.*

## Nuclear Engineering

The post-war civil nuclear investment programmes, (power stations and reprocessing facilities), on the back of the development of nuclear defence capabilities meant that the UK had a world-class engineering capability from the 1950s onwards, plus world-class university research in nuclear technologies.

Concerns over long-term storage of nuclear waste, plus the availability of cheap and plentiful North Sea gas supplies led to the 'dash for gas' in the 1980s; nuclear engineering investment dropped significantly as the CEGB was privatised and the UKAEA's mission was restricted to decommissioning and R&D programmes were cut. The lack of nuclear build and little research funding in the UK meant there was little appetite for undergraduates to enrol on nuclear engineering or similar courses.

Global warming and the need to reduce carbon emissions have led to nuclear generation being firmly back on the agenda. There are 10 nuclear sites currently operating within the UK delivering about 15% of the UK's electricity, but by 2020 there will only be three; Heysham, Torness and Sizewell B. By 2025 there will only be Sizewell B. Therefore replacement power stations will need to come on-stream quickly. This will require experienced engineers and a good supply chain. It will need to be done alongside legacy waste management, maintaining defence capability and the many other civil and other engineering projects either underway or coming on-stream. It will be against a background of increasing demand around the world for nuclear build[66].The competition for engineers will be therefore be significant and planning needs to begin now if we are to avoid needing to put in place an heroic eleventh-hour rescue operation.

66 *Currently 43 new reactors are under construction,106 are being planned, and 266 proposed; see www.world-nuclear.org/info/reactors.hmtl*

# Annex 1: Funding and delivery mechanisms for UK national infrastructure

The NI is funded and delivered in a variety of ways. For example:

- commercially-driven, user-paid infrastructure e.g. unregulated airport and ports where it is for the developer to decide what and when infrastructure is built. Any development is then paid for by consumers (but prices are not regulated because competition exists)
- commercially-driven, user-paid but price-regulated infrastructure with a stronger role for Government. Regulated airports are an example. Government supports investment in additional capacity but this is a commercial decision for the airport operator (and where prices are regulated to protect from monopoly power). The energy sector also largely follows this model but prices are set by the market or through Government intervention.
- price-regulated businesses where independent regulators play a stronger role in determining the level and nature of investment. For example water, where the regulator has an input into the nature of the investment programme but infrastructure investment is funded by users.
- price-regulated business that is funded by the taxpayer and users e.g. Network Rail. This is a model where the business is funded both by users and taxpayers where the DfT have a central role in setting out the outputs it wants from the railways and the level of funding to achieve that. The regulator sets efficiency targets and prices for the company.
- publicly-decided and publicly-funded infrastructure e.g. roads. Government decides where they should go, when they should be built and pays for them. This may include some private finance but ultimately government rather than users pay. Clearly Government enjoys much greater control over this infrastructure, but it is only a small part of the overall picture.

# Annex 2: Cross-cutting Research Council programmes

**Energy Programme** – an EPSRC-led programme to tackle the research challenges involved in creating new energy technologies and understanding the social and economic implications.

£108M has been committed in 2008/09 – aims to position the UK to meet its energy and environmental targets and policy goals by supporting world-class research and postgraduate training to develop and exploit low carbon energy technologies and to reduce energy use.
**http://www.epsrc.ac.uk/ResearchFunding/Programmes/Energy/**

**Living with Environmental Change (LWEC)** – NERC-led programme aims to make infrastructure, the built environment and transport systems resilient to environmental change, and develop more sustainable, less energy-intensive systems and approaches that are socially acceptable, economically advantageous and more environmentally harmonious.
**http://www.nerc.ac.uk/research/programmes/lwec/**

**Global Uncertainties Research Programme (GURP)** – an RCUK-led programme on five global phenomena – conflict, crime, environmental degradation, poverty and terrorism and their implications in terms of security or insecurity.

**Lifelong Health & Wellbeing**

**Digital Economy** – EPSRC led
**http://www.epsrc.ac.uk/ResearchFunding/Programmes/DE/default.htm**

**Nanoscience** – from engineering to application – EPSRC led
**http://www.epsrc.ac.uk/ResearchFunding/Programmes/Nano/default.htm**

# Annex 3: Organisations and Individuals contacted by CST

CST would like to thank all those individuals and organisations who gave their time in support of this project. Inevitably we cannot name every individual we spoke to in the course of the project, but we are extremely grateful for all the input we received.

## Academia

| Individual | Organisation |
|---|---|
| Prof. Frank Kelly | Cambridge University |
| Prof. Gordon Mackerron | Sussex University |
| Prof. Janusz Bailek | Edinburgh University |
| Prof. Jim Macdonald | University of Strathclyde |
| Prof. Jon Crowcroft | Cambridge University |
| Prof. Nick Jenkins | Cardiff University |
| Prof. Roger Kemp | Lancaster University |

## Government

| Organisation | Individual |
|---|---|
| Cabinet Office | Bruce Mann |
| | David Brown |
| | Mark Harris |
| | John Tesh |
| | David Murphy |
| | Matt Barber |
| | Steve Marsh |
| Centre for the Protection of National Infrastructure | Roger Cumming |
| | Joe Bradbury |
| | Dr Nicholas Moiseiwitsch |
| Defence Science & Technology Laboratory | Bryn Hughes |
| | Michael Corcoran |
| Department for Business, Innovation and Skills | Simon Fraser |
| | Vicky Pryce |
| | Philip Rutnam |
| | Brian Titley |
| | David Hendon |
| | Fiona Clarke |
| | Dr Gordon Cole |
| | Elizabeth Hogben |
| | Giles Hall |
| | Matt Bowhill |
| Department for Communities & Local Government | Prof. Michael Kelly |

| | |
|---|---|
| Department for Environment, Food & Rural Affairs | Prof. Robert Watson |
| | Matthew Crossman |
| | Will Lochhead |
| | Daniel Instone |
| Department for Transport | John Collins |
| Department of Energy & Climate Change | Willy Rickett |
| | Andy Roberts |
| | Michael Rutter |
| | Giles Scott |
| | Neil Feinson |
| | Paul McIntyre |
| Government Office for Science | Energy and environment issues group |
| | Foresight |
| | Horizon Scanning Centre |
| HM Treasury | Lewis Neal |
| | Nikunj Khutti |
| Ministry of Defence | George Brander |
| Office of Government Commerce | Julie Pendergast |
| Scotland Office | Alisdair McIntosh |
| Wales Office | John Williams |

## Industry/other

| Organisation | Individual | Role |
|---|---|---|
| Bailey Energy | David Frise | General Manager |
| Biotechnology & Biosciences Research Council | Prof. Douglas Kell | Chief Executive |
| British Computer Society | Dr Louise Bennet | Chair of Strategic Security Forum |
| BT | Mark Hughes | Security Director |
| Business Council for Britain | | |
| Civil Aviation Authority | Chris Jesnick | Chief Operating Officer |
| Design Council | Neil Gilbert | Programme leader – design development |
| Economic & Social Research Council | Prof. Ian Diamond | Chief Executive |
| Engineering & Physical Sciences Research Council | Prof. David Delpy | Chief Executive |
| Institute of Civil Engineers | Tom Foulkes | Director |
| | Andrew Cruddington | Senior policy manager |
| | Beth Bear | Senior policy analyst |

| | | |
|---|---|---|
| Institution of Engineering & Technology | Chris Earnshaw | President |
| | Mike Hayward | Board member |
| | Paul Davies | Head of Policy |
| | Yvonne Hubner | Principal policy adviser |
| Institution of highways and transport | Scott Dyball | Technical & external affairs officer |
| Jaguar & Landrover Research | Nigel Clarke | Manager of advanced chassis research |
| Martyn Thomas Associates | Martyn Thomas | |
| McKinsey Consultants | Andrew Macmillan | |
| Medical Research Council | Prof. Leszek Borysiew | Chief Executive |
| National Grid | Duncan Rimmer | |
| | Steve Holliday | Chief Executive |
| Natural Environment Research Council | Prof. Alan Thorpe | Chief Executive |
| Ofcom | Peter Ingram | Chief Technology Officer |
| | Clive Carter | Principle Strategy & Market Developments |
| | Gareth Davies | Competition Policy Director |
| Office of Rail Regulation | Michael Lee | Director of access, planning and performance |
| | John Larkinson | Deputy director of access, planning and performance |
| Ofgem | Gareth Evans | Head of Profession – Engineering and technical adviser |
| | Steve Smith | Managing Director of Networks |
| Ofwat | Regina Finn | Chief Executive |
| | George Day | Director Network Regulation |
| Research Councils UK | Claire Graves | Chief Executive |
| Royal Academy of Engineering | Philip Greenish | Chief Executive |
| Royal Commission on Environmental Pollution | Tom Eddy | Secretary |
| Scottish Power and National Grid | Colin Gibson | Former Director |
| Technology Strategy Board | Graeme Spittle | Chairman |
| | Iain Gray | Chief Executive |
| | David Way | |
| | Paul Lewis | |
| Telefonica O2 Europe Plc. | Mike Short | Vice President – Research and development |
| The Foundation for Science & Technology | Dougal Goodman | Chief Executive |
| UK Energy Research partnership | Jonathan Radcliffe | |
| UK Petroleum Industry Association | Nick Vandervell | Communications Adviser |
| UKERC | John Loughhead | Executive Director |