

Infrastructure and climate change



One consequence of changes to the UK's climate is an increase in the frequency and magnitude of certain extreme weather events, which can impact UK infrastructure. This POSTnote considers the main risks to economic infrastructure in the UK, current progress in managing these, and barriers to adaptation.

Background

Infrastructure is fundamental to society, the economy and human quality of life.^{1,2} While definitions of infrastructure vary,³⁻⁵ a number of stakeholders (including the UK National Infrastructure Commission) refer to 'economic infrastructure' as the systems that underpin transport, energy, telecoms, water, and waste and flood risk management.⁴ Evidence shows that climate change is increasing the frequency and intensity of certain extreme weather events in the UK, posing a risk to UK infrastructure.^{6,7} Recent examples include the near-collapse of a dam near Whaley Bridge following significant rainfall,⁸ and extensive rail disruption during the July 2019 heatwave.⁹

Two recent reviews have highlighted the need to ensure that UK infrastructure is resilient to climate change:

- In 2019, the Committee on Climate Change (CCC) concluded that no UK infrastructure sectors were reducing risks at an appropriate rate to address possible climate change risks.¹⁰
- In 2018, the National Infrastructure Commission (NIC)¹¹ recommended that the Government should ensure the UK's future resilience to extreme drought and achieve a national standard of flood resilience by 2050.⁴

The NIC is undertaking a study of the UK's economic infrastructure resilience due for publication in Spring 2020.¹² In its 2020 budget, the Government announced £640 billion investment in infrastructure over the next 5 years, including in transport and broadband.¹³ In January, the Government also pledged to publish a National Infrastructure Strategy setting out plans to address the challenges posed by climate change.¹⁴

Overview

- The Committee on Climate Change (CCC) identifies flooding as the most significant weather risk to UK infrastructure, with other risks including droughts and heatwaves.
- Infrastructure interdependencies mean that failure can spread rapidly between sectors.
- The level of planning and implementation of adaptation measures varies between and within sectors, and includes both technical and strategic measures.
- Building resilience requires long-term investment under uncertain conditions, though techniques are available to facilitate effective decision-making under uncertainty.

This POSTnote focuses on the impacts of climate change and extreme weather on the UK's economic infrastructure. It does not include 'social infrastructure' (such as housing, schools and hospitals), though social infrastructure relies on economic infrastructure to function.^{2,14,15} It covers:

- The main climate-related risks facing the UK's economic infrastructure, including risks arising from interdependencies.
- Responsibilities for the resilience of economic infrastructure, including existing policy and legislation.
- Technical and strategic measures being used to improve climate resilience, and challenges to their implementation.

UK climate change and extreme weather

The most recent assessment of how the UK's climate will change in the 21st century is published in the Met Office's 2018 UK Climate Projections (UKCP18).¹⁶ UKCP18 provides projections of climate and extreme weather under different future emissions scenarios (whereby a temperature rise of greater than 4°C above pre-industrial levels typically corresponds to a 'high' emissions scenario, and a warming of less than 2°C corresponds to a 'low' emissions scenario).¹⁶⁻¹⁹ Long-term changes in average climate can reduce the capacity and efficiency of certain infrastructure types,²⁰ while in the short-term, extreme weather events can cause failure and disruption of essential services.²⁰ The predicted frequency and magnitude of many types of extreme weather events increase with higher levels of warming.²¹⁻²³ While extreme cold weather events are set to decrease, the potential benefits to infrastructure from reduced cold-related disruption are outweighed by other risks.^{16,24} The CCC has highlighted that the

main climate-related risks to UK infrastructure during the rest of the century are:²⁴

- **Flooding.** Winters are predicted to get wetter with more high intensity rainfall events, while summers will be dryer with short but heavy rainfall,^{16,18,25} increasing surface water flooding.¹⁸ Sea levels are expected to rise, with increases greater in the south than in the north.¹⁶
- **Water Scarcity.** UKCP18 predicts an increase in the overall risk from drought in the UK, particularly in southern England.¹⁶ According to the NIC (and based on an earlier version of the UKCP),^{26,27} under a medium emissions scenario²⁶ with population growth and no further adaptation, England could have a shortage of 2.7–3.0 billion litres of water a day by 2050.^{4,26}
- **High Temperatures.** All areas of the UK are projected to warm by the end of the 21st century, with South East England experiencing the largest temperature rise. Multi-day heatwaves are projected to become more frequent.^{17,18,28}
- **Wind Storms.** Some UKCP18 projections show modest increases in near-surface wind speeds and the frequency of winter storms after 2050. However, models vary and there is a high degree of uncertainty in wind and storm projections.²⁹
- **Geohazards.** An increase in heavy rainfall and drought is predicted to increase the likelihood of geohazards such as landslides, sinkholes and ground subsidence.³⁰

UK infrastructure

Most UK economic infrastructure (such as telecommunications, energy and water networks) is owned and operated by the private sector.^{12,24} However, much of the transport sector is under public ownership. For example, motorways, some A roads, and permanent railway infrastructure are constructed and maintained by Highways England and Network Rail respectively, both public bodies.^{31,32}

Governance and policy

Infrastructure operators have the ultimate responsibility for the day-to-day resilience of their assets.³¹ However, there is a broad policy, legislative and regulatory framework in place to increase infrastructure resilience and to encourage good practice among operators (Box 1).^{31,33} Advice on infrastructure resilience is also provided by independent bodies including:

- **National Infrastructure Commission (NIC).** Provides impartial, expert advice and recommendations on major long-term infrastructure challenges to Government, including via the National Infrastructure Assessment (NIA) produced once every Parliament.^{4,11}
- **Committee on Climate Change (CCC).** Advises the Government and devolved administrations on climate change risk assessments and adaptation programmes (Box 1).^{34,35}

Interdependence

Infrastructure sectors are highly interdependent, often relying on several others to function reliably.^{36–40} For example, telecoms companies rely on the energy sector to supply their power, while energy providers use telecoms networks for their control systems.³⁸ This means that disruption or failure in one sector can spread to others (known as cascading failures).^{41–44} Interdependence can increase a network's vulnerability and the impact of disruption (Box 2).^{45–47} Understanding of the

interdependencies between infrastructure sectors has improved in recent years.^{41,44,45,47–49} Some research has highlighted that, if managed appropriately, interdependencies can improve the overall resilience of certain infrastructure to climate change.^{39,50}

Box 1: Responsibilities for infrastructure resilience

Government policy

The Cabinet Office has overall responsibility for ensuring the resilience of national infrastructure.¹² It categorises national infrastructure into 13 sectors and designates a lead Government department for each one,³¹ which is responsible for producing annual Sector Security and Resilience Plans (SSRPs) setting out risks to infrastructure and plans to address them.³¹ Lead departments also produce National Policy Statements (NPS) to guide significant infrastructure project decisions and consider climate hazards.^{51,52}

Legislation

- The Climate Change Act 2008 requires production of a climate change risk assessment (CCRA) every 5 years.⁵³ It also requires the production of a 5-yearly National Adaptation Programme (NAP) for England to address these risks.^{54–56} Similar mechanisms exist in the devolved administrations.^{55–57}
- The Climate Change Act also contains an Adaptation Reporting Power (ARP) for Government to invite infrastructure providers (and others) to report on progress they have made towards adapting to climate risks.⁵⁸
- The Flood and Water Management Act 2010 for England and Wales requires the Environment Agency (EA) to prepare a national strategy and sets out responsibilities regarding flood risk.⁵⁹
- The Civil Contingencies Act 2004 specifies responsibilities for local-level emergency preparation and response.⁶⁰

Regulation

Regulators ensure that operators meet Government targets and that legislation is observed.¹² They may require operators to meet specific resilience standards or establish the terms under which investments are made, although exact powers vary between sectors.³¹ Most sectors are economically regulated (excluding most ports and airports).^{12,61} For transport, the Secretary of State sets objectives and investment for roads, objectives for rail, and the overall strategy for airports and ports.¹² Environmental regulators also have certain enforcement powers. For example, the EA can revoke licenses from water companies if abstraction is causing environmental harm.^{62,63}

However, concerns remain regarding the extent to which the full complexity of the interactions between sectors are understood and managed.^{12,24,36–39} The CCC highlights interdependency as a major risk that is exacerbated by climate change, and it remains a challenge in this area.¹⁰ In addition, stakeholders have highlighted that interdependency risks are increasing with greater use of internet connected infrastructure, which relies heavily on the telecoms and energy networks.⁴⁰

Resilience and adaptation

The Cabinet Office defines resilience as the ability of assets and systems to anticipate, absorb, adapt to and recover from disruption.⁶⁴ Infrastructure operators implement resilience strategies that adhere to government guidance and regulations.¹² Approaches to improving infrastructure resilience vary between sectors, but can broadly be categorised as strategic or technical measures.^{65,66}

- **Strategic measures.** Include governance measures such as policies, regulations or management practices that seek to improve the resilience of an infrastructure system.⁶⁶⁻⁷⁰ For example, Network Rail has plans to ensure the availability of emergency equipment and workforce in high-risk flood areas if part of the railway is out of action.⁶⁵
- **Technical measures.** Include traditional engineering approaches such as the building of new infrastructure or modification of existing infrastructure to meet higher standards of resilience.^{65,66} These measures may involve adding redundancy into a system (ensuring alternative equipment is in place for when infrastructure is put under strain or fails),⁷¹ or green engineering measures such as sustainable drainage systems, which use natural features (such as ponds and swales) to reduce flood risk.^{66,72-74}

Box 2. Lancaster flooding in 2015

In December 2015,^{75,76} extremely heavy rain led to a breach in recently upgraded flood defences at Lancaster's major electricity substation, forcing electricity to be switched off. Over 55,000 properties lost power, and since the substation also served local broadband cabinets and mobile base stations, mobile phone coverage and home broadband connectivity was lost. Cash registers and card services also ceased to function. Trains were unable to run and many roads were closed.^{75,76} Power was restored to all properties within 3 days.^{75,76} The Cabinet Office estimated the economic damage to be £1.6 billion.⁷⁷ In response to this and other floods, the Government published a National Flood Resilience Review in 2016, which included more funding for temporary flood defences and plans to improve flood resilience.⁷⁸

The risk to infrastructure from climate change varies between different assets due to characteristics such as age, location and planned lifetime.^{24,67} Older infrastructure, which has not been built to modern specifications, is often more vulnerable to damage from climate change and extreme weather, and is typically more expensive and difficult to adapt.^{75,79}

In 2019 the CCC scored different sectors (including economic infrastructure sectors) as low, medium or high based on quality of planning and progress in managing climate-related risks.¹⁰ The following sections discuss the adaptation measures being implemented across each sector and the scores given to each by the CCC (the flood risk management and solid waste sectors are considered in Box 3).

Transport

The CCC found that the UK's main road and railway networks have good quality plans in place for climate change and weather resilience, with both considering high and low climate change scenarios.^{10,80} For example, Highways England has incorporated a number of climate resilience standards into its design manuals for roads and bridges.⁸¹ However, the CCC says that there is limited evidence that local authority managed roads are prepared for climate risks.¹⁰ Ports and airports also showed mixed degrees of planning.¹⁰ The rail sector has incorporated some technical measures to improve resilience. For example, Network Rail recently spent £250m upgrading 320 km of overhead lines in South East England with wiring that has a higher heat tolerance.⁸² However, the CCC reported that investment in ageing rail infrastructure is currently insufficient

to manage future risks.^{10,24} Some ports have been preparing for climate change (for example by raising quay heights).^{10,24} Airports have tended to be reactive; Gatwick Airport invested in flood prevention measures following flooding in 2013.⁸³

Water

The CCC scored the water sector as high for its quality of planning for climate change.¹⁰ Water providers plan for risks to the UK's water supply from drought and population growth through 5-yearly Water Resource Management Plans (WRMPs).⁸⁴ WRMPs are a statutory requirement set by the Government and describe a company's approach to managing these risks for at least the next 25 years.^{10,85} In addition, Ofwat (the water regulator) assesses the 5-year business plans of water companies, including for climate resilience.⁸⁶

Increasing resilience in the water industry relies on both increasing water supply (for example via new reservoirs and water transfer schemes), and reducing demand and waste.^{10,24} According to the NIC, new reservoirs, water transfer schemes and desalination infrastructure will be required to address the UK's projected water deficit.^{10,12,24} Water companies have undertaken work to reduce demand and leakage, including by running public water efficiency campaigns,¹⁰ and committing to halve leakage by 2050.^{4,26,86,87} In 2019, Ofwat announced £13 billion of investment to improve the resilience of water and wastewater services, including plans to increase flood resilience and decrease dependency on the energy network.^{10,24}

Energy

Ofgem requires that the National Grid Electricity System Operator holds a back-up power reserve equivalent to the size of the largest single source operating on the network at a given time.⁸⁸ In response to outages partially triggered by a lightning strike that affected approximately 1 million customers in August 2019, the Government commissioned an industry review of the requirements for back-up power to the grid.⁸⁸⁻⁹⁰ According to the CCC, the energy industry has a strong understanding and good level of planning for climate change risks.¹⁰ The industry body, the Energy Networks Association, released cross-industry standards for flood protection of grid and major substation assets.^{10,91} The National Flood Resilience Review (NFR, Box 2) also set a target for major substations to be protected against extreme floods by 2021.⁷⁸ Ofgem (the energy regulator) has committed £100 million of investment in flood defences for energy infrastructure.⁷⁸ It also offers financial rewards for electricity and gas companies that meet certain performance targets for resilience work, with penalties for those that do not meet service interruption targets.¹⁰

Telecoms

The CCC rated the quality of the telecoms sector's climate change planning as low, with little planning for either 2°C or 4°C scenarios.¹² TechUK claims that telecoms infrastructure has an inherent level of resilience due to its relatively short asset lifetime and the multiple routes through which telecoms traffic can be delivered.⁹² However, this may not be enough to prevent major disruption,¹² and disruption can sometimes propagate over long distances. For example, in 2015, telecoms disruption in Leeds and York led to loss of landline phone communications to a hospital in Tyneside.^{24,93} While there is no

mandatory overarching resilience strategy for the telecoms sector, Ofcom set industry guidelines for flood planning in 2017.⁷⁸ The guidelines do not consider projected future changes in flood risk, but led to all assets located in high flood-risk areas being fitted with flood resilience measures.¹⁰

Box 3. Other economic infrastructure sectors

Flood risk management

The CCC scores different aspects of flood risk, including river and coastal flood alleviation, coastal erosion risk management and surface water flood alleviation, with each sector receiving mixed scores.¹⁰ In England, the Environment Agency (EA) is responsible for producing the National Flood and Coastal Erosion Risk Management (FCERM) strategy, with delivery of this plan shared between risk management authorities (such as the EA, local authorities, water companies, and highways authorities amongst others).^{94,95} The EA is currently updating its FCERM strategy for the period 2020–2100, with plans for resilience and adaptation to flooding and coastal change for both 2°C and 4°C warming scenarios.⁹⁴ The strategy includes measures such as directing infrastructure developments away from high flood risk areas, and improving building standards to reduce flood damage.⁹⁴ The EA has also proposed to follow the NIC'S recommendation to establish a national standard of flood resilience.⁹⁴ In 2019, the CCC suggested that increasing future risks are likely to necessitate further increases in funding for flood defences.¹⁰ In its 2020 budget, the new Government pledged £5.2 billion of investment in flood defences between 2021 and 2027.¹³

Solid waste infrastructure

Solid waste infrastructure refers to the systems used to dispose of or process waste.⁹⁶ This sector was not assessed by the CCC,¹⁰ and is not included in NIC'S infrastructure resilience study, as extreme weather events have fewer immediate impacts on the services it provides.¹² UK waste management policy does not directly consider climate change adaptation,^{97–99} but the Environment Agency considers flood risks when granting permits for new landfill sites.¹⁰⁰ The CCC has recommended that new waste facilities and future maintenance work should consider climate change resilience measures.²⁴

Barriers to improving resilience

Infrastructure investment

Building resilience requires long-term investment from the public and private sector.^{2,15,66,67,101} It was recently estimated that an additional investment of £0.2–£4.8 billion per year is required to ensure that newly built infrastructure in the UK is climate resilient over the rest of this century.⁶⁷ Measures that improve climate resilience can also deliver co-benefits.^{66,67} For example, improving the resilience of the telecoms network may also increase its cybersecurity,¹⁰² and green engineering measures can help meet climate mitigation targets.^{66,72,103} However, incentivising long-term investment can be challenging, as resilience benefits are typically poorly captured in cost-benefit analyses,⁶⁷ and private sector investment plans tend to focus on short-term returns.^{62,67} Stakeholders have also said that the mismatch in timing between different regulatory cycles and a lack of mechanisms for co-funding between sectors may limit long-term resilience investment.¹² In 2015 the Treasury published guidelines for investment of public funds, which include accounting for climate resilience benefits.²

Uncertainty in levels of risk

Uncertainties in climate projections and modelling mean that changes in weather patterns and the resulting magnitude of the increase in risks to national infrastructure are unclear.^{67,104,105} There are also socio-economic uncertainties, such as the degree of uptake of electric vehicles (and the future level of demand for electricity).^{40,67,106,107} These uncertainties mean that investment decisions and climate change planning can be challenging, and in some cases can lead to concerns about under-or over-investment in resilience.^{66,108,109} Measures that have been developed to tackle this include: decision-making frameworks that account for uncertainty,^{110–112} adaptation options that provide benefits under a range of climate scenarios,^{113–115} and more flexible ways of building infrastructure, for example, by allowing incremental modifications to be made to assets over time as risks change.¹⁰⁴ Such approaches have been used by the EA for the Thames Estuary 2100 plan, which sets out how to manage flood risks across the estuary until the end of the century under a range of climate scenarios.^{116–119}

Design and adaptation standards

Newly built assets must adhere to engineering standards and building codes, which tend to only consider historical weather extremes.^{67,120–122} The CCC has called for these to be updated to reflect climate projections.⁶⁷ Responses to an NIC scoping survey also suggested that inconsistent design standards make it difficult to compare or assess resilience.¹² The British Standards Institution and the International Organization for Standardization recently published the first of a set of standards to guide climate adaptation within organisations.^{123–125}

Interdependency and data sharing

Stakeholders suggest that there is a lack of cross-sector collaboration, limiting providers' understanding of risks arising from interdependencies.^{12,48} The Cabinet Office's National Infrastructure Resilience Council aims to bring together infrastructure providers to coordinate cross-sector resilience work and data sharing,^{67,126} and the UK Collaboratorium for Research on Infrastructure and Cities has launched an online platform (DAFNI) to encourage sharing of infrastructure data between Government, industry and academia.¹²⁷ Despite this, the CCC say that there has been insufficient progress made in reducing interdependency risks, highlighting a lack of coordinated action by Government and operators.¹⁰

Adaptation reporting power

Infrastructure providers may be asked to report to Defra on the progress they have made towards climate adaptation (ARP, Box 1).^{54,58} The latest round of reporting (ARP3), set to close at the end of 2021, involves at least 88 organisations, including public bodies, regulators and infrastructure providers participating on a voluntary basis.^{54,58,128–130} During consultation for this round, 60% of respondents suggested it should remain voluntary to minimise the burden on businesses and prevent the ARP from becoming a tick box exercise.¹³¹ However, some academic stakeholders, the CCC, and others have suggested that the scheme be made mandatory to ensure all relevant organisations consider climate change risks.^{128,132–133}

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