

Developing resilience standards in UK infrastructure

NATIONAL
INFRASTRUCTURE
COMMISSION

Better infrastructure for all

September 2024

Our remit

The Commission provides government with impartial, expert advice on major long term infrastructure challenges.

The Commission's objectives are to:

- support sustainable economic growth across all regions of the UK
- improve competitiveness
- improve quality of life
- support climate resilience and the transition to net zero carbon emissions by 2050.

In fulfilling our purpose and objectives, we:

- **set a long term agenda** – identifying the UK's major economic infrastructure needs, and the pathways to address them
- **develop fresh approaches and ideas** – basing our independent policy recommendations on rigorous analysis
- **focus on driving change** – building consensus on our policy recommendations, and monitoring government progress on their delivery.

A fuller description of the Commission's remit can be found on our website at nic.org.uk/about/what-we-do/. This includes a table of devolved administration responsibilities by infrastructure sector.

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Foreword

The problem with resilience is we only truly realise it's important when things go wrong.

When a container ship blocked the Suez Canal for six days in 2021, up to \$10 billion worth of trade was stranded and knock-on delays to everyday supplies lasted for months.

When a heavy storm struck the coastal track in Devon ten years ago, Cornwall's only rail link to the rest of the country was severed for eight weeks.

And more recently, when hot weather last summer led to water shortages in parts of Kent and Sussex, several schools were forced to close at short notice.

Pre-empting and mitigating for such incidents requires a fresh approach to resilience. One that values resilience properly before incidents occur.

The logical starting point is to agree an objective set of resilience standards that citizens can expect from key infrastructure services, such as the service levels available in different scenarios and the speed of recovery from major incidents.

Deciding upon the right standards involves looking at the costs of meeting them, as well as the impacts for everyone of having standards that are not rigorous enough.

This is not straightforward and requires extensive analysis of these different factors, particularly where there are interdependencies between different sectors.

Given this complexity, the inevitable trade-offs to be considered and the importance of proper enforcement, government is the only place where such decisions can be settled.

This report offers one input into this process, setting out where the Commission has identified current gaps in resilience standards and some ideas on how government could address these.

It is a timely moment for government to act, as it considers priorities for a new national infrastructure strategy, informed by the Commission's second *National Infrastructure Assessment*.

Without clear standards across relevant sectors, the billions of pounds of investment in new assets envisaged in our Assessment could be built in ways that we end up regretting – and so taxpayers or billpayers face extra costs to pay for emergency measures when things go wrong.

The process of setting standards is made even more urgent by the pressures of a changing climate and increased weather extremes – one of the biggest threats to infrastructure resilience.



We will never be able to fully adapt to every risk from climate change.

But our proposals seek to at least provide the public with greater transparency – and consistency – in what to expect from everyday services when major shocks occur.

The Commission stands ready to support departments to make this a reality.

Professor Jim Hall FREng

Commissioner

Executive summary

The UK's economic infrastructure has, for the most part, proved resilient to shocks and stresses over recent years. However, infrastructure service disruptions over the last couple of years have demonstrated the potential for widespread failures including knock on effects such as school closures.¹ Infrastructure systems face a range of threats, including cyber or terrorist attacks. This report focuses on measurable threats – climate change, a lack of capacity or redundancy in systems, and the impact of an aging asset base – which can be addressed by setting resilience standards. In the second National Infrastructure Assessment the Commission recommended that government should publish resilience standards for the digital and telecoms, energy, transport and water sectors by 2025. This report sets out how government can implement this recommendation.

Investing now in the resilience of infrastructure services is critical. A changing climate will lead to new threats – extreme heat buckling rails, drought related subsidence bursting pipes, and increased flood risk. Infrastructure services are also adapting to limit carbon emissions – changing the nature of risks such as the electrification of transport and household heating increasing the consequences of failure of the electricity system. Finally, the second *National Infrastructure Assessment* set out a programme of investment required to deliver net zero and enable growth across regions. It will be cheaper to ensure these systems are resilient as this investment is made – but to do so requires knowing the standard of resilience expected.

The Commission recommended that government should publish an initial set of resilience standards by 2025 so that around £400 billion of investment decisions due in the next five years can factor in these targets. This will enable operators to begin to build resilience towards the desired levels into their systems and to plan for future climate change. It will also enable system designers to take advantage of the uptick in investment in systems for other reasons – achieving net zero and supporting growth – to achieve these targets. It is much more efficient to build in resilience from the outset than to rely on costly retrofits.

The report considers three kinds of standard:

- **Customer outcome standards:** Service quality and reliability outcomes for customers – such as average length of service outages in a year.
- **System performance standards:** standards a system is required to meet – such as being able to deliver a service even after the failure of the biggest asset within a system.
- **System recovery standards:** Expected service recovery times after a service outage and the level of backup services which must be supplied to consumers in the event of an outage.

The report does not consider technical asset standards due to the number of assets and standards within infrastructure systems, but the Commission recognises the importance of these standards for supporting system level resilience.

Setting standards requires trade-offs. High level customer outcome standards give infrastructure operators the flexibility to decide how to deliver their services. However, they are lagging indicators, because current system performance is not an indicator of how systems will perform in future. This can be resolved by stress testing systems against certain scenarios or by setting system performance standards, such as specifying levels of redundancy. This may provide greater certainty about the underlying resilience of systems, but increasing output requirements may reduce the scope for operators to find efficiencies in delivering their services. As a result, choosing which standards to set involves trade-offs between a set of resilience goals and costs. In making these trade-offs, government should consider the system of standards. While individual standards may be affordable on their own, they may add incremental costs to the system. Government must therefore prioritise the standards it wishes to set.

The Commission has investigated potential gaps in existing service standards to support a first round of standard setting by 2025. Stakeholders were engaged through a series of workshops across the digital and telecoms, energy, transport and water sectors, supported by a literature review to understand the existing standards landscape. The Commission confirmed that in many cases measures which could serve as resilience standards already exist, with some notable gaps, in both standards and in stress testing to ensure systems meet the standards that are in place. Gaps the Commission has identified are outlined in the table below.

Resilience gaps

<p>Inter-dependencies</p>	<p>Stress testing: In the second National Infrastructure Assessment, the Commission recommended that a system be put in place for cross sector stress tests which addresses interdependencies and the risk of cascade failures – a failure in one sector leading to service failures in another.</p>
<p>Digital and Telecoms</p>	<p>Resilience guidelines for private networks serving critical national infrastructure: Government should consider whether further action is needed to ensure that the private telecoms networks serving critical national infrastructure do not lead to failures in the services they support.</p> <p>Review consumer information for public networks: Ofcom provides service information for consumers to help them understand the reliability of networks. This should be reviewed to ensure information on network resilience is accessible to consumers.</p>

<p>Energy</p>	<p>Energy supply resilience: Government should understand how future changes to the energy system will affect the ability of that system to meet energy demand and deliver a resilient service for consumers including in extreme supply and demand scenarios. Government should set a baseline expectation of levels of demand the system should be expected to meet in specific stress test scenarios. This demand could be met by measures such as a strategic energy reserve. Government should also require infrastructure operators to have a clearer understanding of how future climate risks to the generation, transmission and distribution systems might threaten services for consumers.</p> <p>Forward looking asset health standard considering climate change related deterioration: The energy transmission and distribution systems have a network asset risk metric which considers the future deterioration of the network to consider appropriate levels of maintenance. This metric should incorporate climate change driven deterioration in asset health.</p>
<p>Transport</p>	<p>Forward looking asset health standard considering climate change related deterioration: For the strategic road network, local roads and the rail network, there should be a forward looking asset health metric which factors in risk from future threats, including climate change. This would assess the likely remaining life of transport assets, such as road drainage and the probability of its failure over a given time, to ensure resilience is not threatened by a failure to address threats or invest in long term maintenance.</p> <p>Key route resilience: Government should set out a high level cross modal key route strategy for the strategic road and rail network, indicating broad levels of resilience for key routes and nodes where alternative transport modes are not feasible, enabling operators to cost these levels of resilience. This would be supplemented by advice against travel on some routes when the network faces extreme conditions that it is not designed to be resilient against.</p>

<p>Water</p>	<p>Peak demand: Government should consider a standard setting out the volume of water that water companies’ systems are required to be able to treat, store and put into supply over the course of a short peak demand period– as opposed to long term drought storage for which a standard already exists.</p> <p>Single source of supply: Government should consider a standard on the number of consumers reliant on a single asset for supplying their water.</p> <p>Forward looking asset health standard considering climate change related deterioration: The sector needs a forward looking asset health metric which assesses the likely remaining life of assets, and the probability of failure over time, to ensure that resilience is not threatened by a failure to invest in long term maintenance or to address future threats.</p> <p>One in 50 year storm risk reduction target: Ofwat has guidance for companies on reporting on the percentage of customers at risk from a one in 50 year storm event – an event with a two per cent annual probability. Government should consider setting a desired risk reduction target in line with the Commission’s recommendation for a single joint target for surface water flood risk reduction.²</p>
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Government has recently committed to reviewing its approach to national resilience.³ As part of this, government should explore the above gaps and consider if there are others when publishing its first round of resilience standards for economic infrastructure.

Publishing resilience standards in each sector will not only support future resilience planning. It will also enable each sector to understand levels of resilience in other sectors to help manage interdependency risks. Government departments should set standards for each sector, with the method and timetable depending on the different regulatory structures in each. Cabinet Office can then play a coordinating role in ensuring that cross sector interdependency risks, such as the reliance of digital and telecoms, transport, and water networks on power, are managed effectively.

Background

Resilient infrastructure can continue to provide the services business and communities rely on despite short term shocks. Resilience often requires additional investment which may cost money in the short term but avoid costly impacts during shocks. The Commission's analysis has previously demonstrated that the cost of proactively building additional water supply capacity would be significantly less expensive than emergency measures in the event of a severe drought.⁴ However, many service shocks are infrequent, and while the cost of intervention is immediately evident, future benefits are uncertain. Both the public and private sectors are likely to underinvest in infrastructure resilience unless the government sets expectations across regulatory and spending cycles, and through standards which have public backing. This will limit the impact of shocks and support recovery, so disruption from events does not lead to major harm.

Setting out clear resilience standards will also help businesses and consumers to plan. If clear standards are in place, then consumers and businesses can understand the degree to which they might need to plan for their own resilience, such as through storing water on the premises or using alternate routes to make journeys. It will also enable government to advise on what levels of individual resilience might be appropriate for households and businesses.

In its second *National Infrastructure Assessment* the Commission recommended that government should publish resilience standards for the digital and telecoms, energy, transport, and water sectors by the end of 2025 (see box below). This report sets out how government can progress this recommendation.

National Infrastructure Assessment resilience recommendation

By 2025, government should:

- Following advice from regulators, publish a full set of outcome based resilience standards for digital, energy, transport and water services, committing to future reviews every five years
- Require regulators to ensure their determinations in future regulatory settlements are consistent with operators meeting these resilience standards in the short and longer term
- Require regulators to put in place a system for cross sector stress testing which addresses interdependencies and the risk of cascade failures.

What are resilience standards?

Standards in infrastructure operate at different levels, from the outcome based resilience standards the Commission has recommended to detailed technical standards for specific assets. There are four broad categories of standards:

- 1. Customer outcome standards:** These standards are based on the quality of service received by customers. Regulatory performance incentives on levels of service can be regarded as a type of standard. For example, water supply interruptions above three hours are both measurable and are regarded as having a material impact on customers, and so the total duration of any interruptions above three hours is subject to regulatory incentives and penalties.⁵
- 2. System performance standards:** These standards dictate how the system is expected to perform in certain circumstances, but only indirectly link to customer experience. For example, in the energy sector there are codes specifying the level of resilience required in the electricity transmission system. In the water sector, the Drinking Water Inspectorate's Compliance Risk Index score measures the risk arising from specified treated water compliance failures.⁶
- 3. Technical asset standards:** System assets are also required to meet specific technical standards which dictate their tolerance to different events, including changes in the surrounding climate. For example, rails in the UK are designed to a stress free temperature of 27°C. If they experience temperature significantly above this, rail buckling can lead to service disruption.⁷ These standards also cover how assets are used – such as thermal ratings for overhead lines.
- 4. Recovery standards:** These standards set out what is expected in the event of a service failure, both in terms of restoration of service and in terms of support services to customers while the service is down. Consumers are entitled to compensation if their water supply is not restored within a 12 hour period, implying a standard for water companies to restore supply within that time. While supplies are down, customers are entitled to at least ten litres of water per person per day within 24 hours. By contrast, for digital services, customers registered with companies signed up to Ofcom's automatic compensation scheme are entitled to compensation if a fault is not resolved within two full working days.⁸

In this report the standards the Commission is referring to are customer outcome standards, underlying system performance standards for proactively designing resilient networks, and recovery standards. Technical asset standards are out of scope, though the Commission recognises that they will play a key role in ensuring asset systems achieve service level resilience standards.

The case for action

Future resilience is critically important because as the third Climate Change Risk Assessment highlighted, a changing climate will lead to new threats to infrastructure services.⁹ Extreme heat could create problems for rail networks, drought related subsidence could damage underground water pipes and rail embankments, and increased flood risk could threaten most services.

In its second *National Infrastructure Assessment* the Commission found that no infrastructure operators had yet publicly set out the costs of making the delivery of their services resilient to climate change. Infrastructure operators need to understand the standard of resilience they are expected to provide in order to design and cost future resilience.

The resilience of the UK's infrastructure services is also evolving due to technological change and because of the need to transition to net zero carbon emissions by 2050. Increasingly, infrastructure services are dependent on telecoms infrastructure for control and monitoring and so the consequences of these systems failing are becoming more severe. Equally, the transition to net zero is driving an increasing reliance on the electricity system for heating homes and powering transport, also adding to the consequences of the system's failure.

Finally, resilience will be less costly if it is designed into systems which are already investing for other reasons. For several decades sectors such as energy transmission and distribution, transport and water have operated as mature systems maintaining a steady state and managing incremental growth. But the second *National Infrastructure Assessment* highlighted that to deliver net zero, enable growth across regions, and to support resilience to a changing climate, this status quo is not sustainable. The UK will need to start building infrastructure networks at scale to ensure we can transmit enough electricity to power electric cars and heat pumps, have enough water to support a growing number of homes and improve mobility in congested cities.

To support the government in developing resilience standards, the Commission has conducted a literature review to understand current potential gaps in standards that government may wish to fill. It has also engaged stakeholders in a series of sector specific roundtables in the digital and telecoms, energy, transport and water sectors to understand how government can take this recommendation forward. The report sets out some indicative resilience gaps the Commission has identified, core principles for setting resilience standards and next steps for government.

The challenge of setting resilience standards

Resilience standards can be challenging to set. Firstly, a patchwork of resilience standards already exists across the digital and telecoms, energy, transport and water sectors. The Commission has reviewed these standards set out in Annex 1. Government will need to consider these gaps and identify priority areas for a first round of standard setting and determine whether existing standards need to be updated. The Commission has recommended that standards should be reviewed every five years to address changes in the threat environment, in the technology available to address them, and in public attitudes to disruption.

This means that there is potential for systems to become more resilient over time as new standards are added in each review period or as existing standards are strengthened. Five year reviews are also an opportunity to consider which are the most high priority standards within the system based on the government's risk appetite – how it decides to approach the trade-off between additional resilience and affordability.

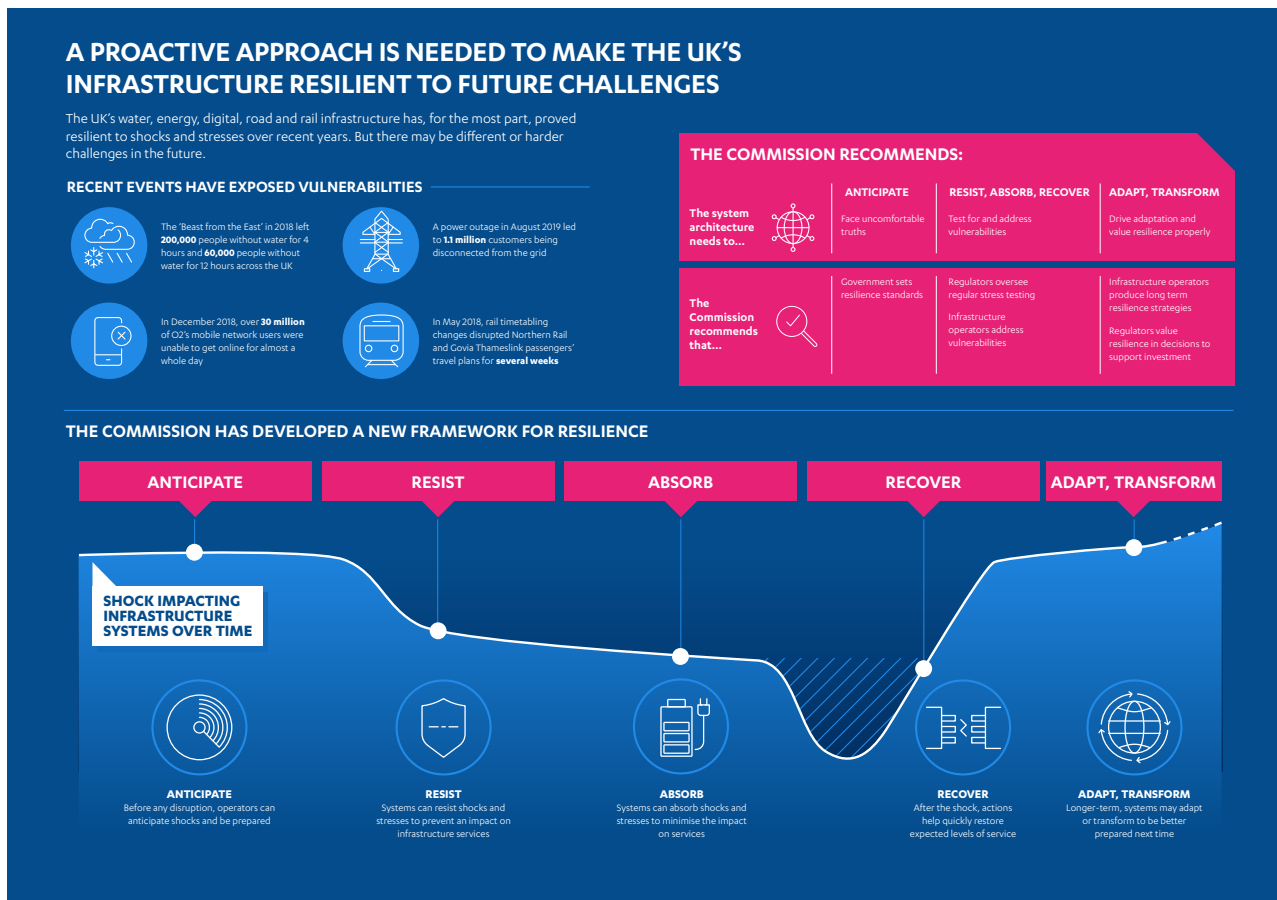
A second challenge to standard setting is identifying a 'first mover'. Government is reluctant to set a resilience standard without understanding the costs of that standard. But infrastructure operators argue that they cannot cost resilience until they understand what the target level of resilience is. Setting standards is therefore necessarily iterative as providers must draw up a menu of costed options which government should ultimately choose from. A blueprint for this is the Commission's identification of a drought resilience standard. The Commission identified the costs and benefits of several drought resilience options. It then recommended that water companies should be asked to plan for a drought with a 0.2 per cent annual probability because proactive resilience – managing leakage and demand and building new supply infrastructure - would cost roughly half as much as reactive measures. Since then, the water industry has assessed options and proposed costed programmes for achieving this standard.

There is a trade-off for government in setting service standards. Setting a high level customer outcome standard gives consumers an understanding of the level of service they should expect, while giving infrastructure operators the flexibility to deliver that standard in the most efficient way possible. However, this approach makes it hard to measure whether desired levels of resilience have been achieved because for long life infrastructure assets system performance is a lagging indicator. For example, short term performance can be maintained by reducing redundancy in a system, such as reducing the number of water mains supplying an area from two to one. This would not lead to an immediate change in outcomes for consumers, but overall resilience would be reduced. To resolve this, regulators can require network operators to maintain specified levels of redundancy in their systems, or specify stress tests to explore the underlying resilience of systems. However, increasing output requirements, in terms of specific infrastructure interventions, can remove the flexibility for system operators to innovate when delivering system outcomes. The question for government is how far innovation and efficiency should be valued over standardised and more predictable system resilience.

Finally, there is also a potential trade-off between stringent requirements to maintain services at all costs and the need to restore systems as quickly as possible if service is lost. For example, if a very high level of resilience is too expensive, it may be preferable to focus efforts on restoring service swiftly in the event of an outage and to rely on emergency measures in the meantime. For example, having teams available to clear routes of debris left by flood waters or landslips can ensure the rapid recovery of transport networks. As the Commission's resilience framework (Figure 1, below) highlights operators should have recovery strategies in place as well as maintaining required levels of service resilience, as 100 per cent resilience is rarely if ever achievable or cost effective. Additionally, if systems propose to rely on emergency measures, such as the provision of bottled water in the event of water system outages, these must be tested with the public to ensure they are tolerable and preferable to proactive resilience.

Figure 1: Resilience requires anticipating threats, and adapting through a combination of resisting or absorbing threats, recovery strategies and transforming systems

National Infrastructure Commission Resilience Framework



Source: National Infrastructure Commission

Principles for setting resilience standards

Stakeholders across all sectors reported common principles that departments should consider when setting resilience standards:

- **Common scenarios:** It is not sufficient for government to set a common resilience standard across a sector. This must be underpinned by common planning scenarios across all infrastructure sectors, such as climate change and population growth scenarios, to ensure standards are truly consistent. For example, the rail industry has recently agreed a set of common scenarios for planning across the sector. Regulators should also collaborate on collective challenges, such as on developing forward looking asset health metrics.
- **Make trade-offs:** Resilience standards often reflect a trade-off between the cost of achieving greater resilience and the benefits of avoided losses. It is in theory possible to optimise this trade-off for every single asset and system, but that is time consuming, so setting standards that will be safe and not excessively costly in most situations makes sense. Nonetheless in special cases it may be necessary to explicitly examine the trade-off.
- **Don't let the perfect be the enemy of the good:** Standard setting will be an iterative process. There will always be uncertainties and data gaps in setting service levels, so standard setting should be based on best estimations and what can be known at that point in time. As more information comes to light, for example, as the future trajectory of system changes due to the net zero transition become clearer, standards can be reviewed at the next cyclical review point.
- **Consider the widest range of possible impacts including interdependencies:** Standards should consider risks beyond the failure of individual infrastructure systems. A failure in the electricity system may cause failures in digital and telecoms, transport systems and/or water and wastewater.
- **Use a wide range of methods to understand consumer views:** A wide range of methods should be used to understand consumer views to make standards politically sustainable.¹⁰
- **Different approaches for new build compared to retrofitting:** The cost of building in resilience in new or renewed infrastructure may be a lot less than the cost of retrofit. Different approaches should therefore be taken for each – asset design standards can be set to determine the resilience of new build and some renewed infrastructure, while risk based prioritisation should be used to plan a sequence of retrofit interventions within an overall budget for existing assets. Government should recognise that in long life infrastructure systems, the risks posed by existing infrastructure are far greater. As the second National Infrastructure Assessment set out, on current rates of replacement 88 per cent of existing water mains and 85 per cent of rail assets could still be in place by 2055, so prioritising retrofit options is a larger factor when considering system resilience.¹¹

- **Consider standards collectively:** Government must ensure that when introducing new standards the collective cost impact of the system of standards is taken into account when considering the trade-off between resilience goals and costs.
- **Phase the introduction of standards:** It may not be possible to achieve desired levels of resilience at speed given the relatively long lives of infrastructure assets. These standards may need to be phased in over a specified period of time, especially if they are designed to address emerging threats like projected levels of climate change. Different infrastructure operators may need different timelines for introducing standards to reflect the different starting positions of their asset bases.

Resilience gaps

The Commission undertook a literature review and four sector specific roundtables to identify possible gaps in resilience standards in the digital and telecoms, energy, transport and water sectors. The Commission found a series of sector specific gaps which individual government departments should consider addressing in a first round of standard setting. The roundtables also highlighted a more general concern about interdependency risks.

Managing interdependencies

In the second *National Infrastructure Assessment*, the Commission recommended that a system should be put in place for cross sector stress testing which addresses interdependencies and the risk of cascade failures. Stress testing, through simulating how systems might react to shocks and stresses, can help infrastructure operators identify and address vulnerabilities in advance of an event. It can also help infrastructure operators test decision making processes, preparing operators for disruptions other than those in the scenarios set out in the stress tests. To ensure the stress tests address vulnerabilities, regulators should set out scenarios and scope for stress tests – providing guidance for developing bespoke tests where necessary – and oversee them, scrutinising outcomes and requiring operators to develop and implement plans to remedy any vulnerabilities identified. To ensure these stress tests are carried out as effectively as possible, in its 2020 report the Commission called for the UK Regulators Network to promote sharing of best practice in stress testing across relevant regulators, including learning lessons from the financial sector and other stress testing already in operation.¹²

While each sector needs to take action to manage its own risks, in some cases a systems approach may be more efficient. The Climate Resilience Demonstrator has been exploring how information sharing about risks facing all sectors in a geographical area could lead to more efficient common solutions.¹³ For example, a communally funded flood defence covering digital and telecoms services, energy and water networks, may be more affordable than individual defences for all three kinds of assets. Greater data sharing must be enabled and encouraged to allow these kinds of efficient investments to emerge and they must be fundable by each sector's regulatory system. Regulators should work together to overcome potential challenges caused by differing timelines for regulatory reviews and budget setting in each sector.

Greater sharing of data will also enable more strategic decisions about which services might need to be restored first in the event of a service outage in one sector – such as a power cut – to limit the impact of cascade failures. This action is in addition to addressing sector specific challenges set out below.

Digital and telecoms sector

Public telecoms networks – including fixed broadband and landline and mobile services – are subject to a different model of regulation than the private and public regulated asset bases in the energy, transport and water sectors. Ofcom provides guidance to service providers on the approach that it would normally expect them to take to ensure service security and resilience. Service providers can adopt different solutions but are required to justify this approach in the event of a service outage. This guidance sets out relatively detailed expectations on the level of redundancy required in systems and on how to account for flood risk to core sites.

No standards are set for service levels. Instead Ofcom provides consumers with information about provider service levels such as the number of faults per 1,000 customers per month and the median average download speed by connection type. Additionally, most providers are signed up to the automatic compensation scheme in the event of long duration service outages, which should incentivise companies to recover services rapidly. Government should consider whether it wishes to set target customer outcome standards in addition to Ofcom’s existing resilience guidance for networks.

However, Ofcom should review its information for consumers on service levels provided by networks to ensure its information on resilience is adequate and accessible. For example, Ofcom has a requirement for customers dependent on a landline to be able to contact 999 for at least an hour in the event of a power cut.¹⁴ But customers who are dependent on mobile services may find themselves unable to contact 999 if their mobile service goes down and they are using a mobile provider that has not enabled voice over WiFi calling as a back up. Consumers may struggle to understand these differences in service provision when choosing a provider unless information is accessible.

Private networks

Other infrastructure networks – energy, transport and water – use private telecoms networks for some services. Private telecoms networks are not subject to Ofcom’s guidance, and this could create resilience challenges where these networks serve critical national infrastructure. Some stakeholders have suggested that these networks may not need to meet the same resilience requirements as public networks because private customers are already very resilience focused and so the market will drive resilience, and that stringent requirements might stifle innovation. However, there are several reasons why private telecoms networks may need to be subject to clear standards where they serve critical national infrastructure:

- **Increasing reliance on digital solutions:** The consequences of failure of private telecoms networks are becoming more severe as more use cases are built into other infrastructure networks. For example, some water companies are building digital sensors into their sewer network as part of schemes to extract further capacity from the existing network by reconfiguring it to optimise the system for forecast storms. If this system were to fail before a storm, not only would the sewer system not be optimised for a flood, but the flood would likely be worse because the water company had invested in a digital solution instead of expanding sewer capacity.¹⁵ Similarly, in the energy sector, as the electricity distribution system becomes more complex and volatile, digitisation is increasingly required to operate the system reliably and efficiently.¹⁶
- **Variable resilience outcomes:** If resilience is left to the market then there could be considerable differences in levels of resilience between providers as a level of resilience would be dependent at least in part on the skills and expertise of individual contract negotiators. This could create variability which may only be revealed in the event of service failure.
- **Investment in regulated asset bases:** Even if individual contract negotiators are skilled in setting out resilience requirements, in sectors with a public or private regulated asset base (energy, transport and water) without a clear standard to meet they may not be able to make the case for this investment to regulators in price or spending period reviews.

There are a number of options for ensuring the resilience of private telecoms networks, set out below:

- **Retain current regulatory model:** Infrastructure operators are held to account for their current outcome based resilience standards regardless of whether service failures are caused by their own infrastructure or by private telecoms networks they use.
- **Government, following advice from regulators, specifies levels of resilience:** Sector regulators could specify levels of resilience they require telecoms networks used by infrastructure operators to meet.
- **Reform Ofcom's remit:** Change Ofcom's remit so it has the ability to regulate private telecoms networks for critical national infrastructure.

In this report the Commission has not been able to assess the scale of current and future threats to resilient services caused by a reliance on private telecoms networks, or the relative benefits of the above options for addressing them. Government should consider these options as it considers future resilience standards.

The increased use of digital systems in critical infrastructure systems does not just require the resilience of private telecoms networks, it also requires that the digital systems making use of the information from these networks is resilient. For example, water companies will need to develop software and hardware to deal with an exponential increase in data from customers as households transition from bi-annual meter readings to hourly data collected by smart meters.

For the overall system to deliver its intended service, these systems, alongside the telecoms networks supporting them, will need to be resilient. Departments, following advice from regulators, should monitor possible threats to services created by reliance on these systems to consider whether clearer or more stringent resilience standards are required.

Next steps for the Department for Science, Innovation and Technology

Ofcom has recently consulted on resilience guidelines for public digital and telecoms networks in the UK.¹⁷ The regulator should seek to review this guidance on a five yearly basis, with a next review in 2028, and government should consider at that point whether changes in levels of dependency on public networks necessitates the setting of customer outcome resilience standards. Any standards may require improvements in the metrics that Ofcom currently use to measure and communicate network performance. Ofcom should keep its information for consumers on these measures of service reliability and resilience under review to ensure it is adequate and accessible to enable consumers to make an informed choice.

Next steps for government

For private networks it will ultimately be for government to determine whether the increasing reliance on private networks for critical national infrastructure requires a change in how private networks are regulated. This should be considered as part of five yearly reviews of resilience standards.

Energy sector

In the energy sector the Commission noted that there was already a set of resilience standards covering the ability of the system to transmit and distribute energy through a mixture of legislation and regulation. These standards include requirements for system redundancy, expected levels of system availability and service recovery times. All of these standards will enable or incentivise resilience in the face of events which damage or disable transmission and distribution assets. However, stakeholders agreed that there was no clear understanding of the system's long term resilience, particularly in terms of its ability to reliably meet electricity demand.

A version of supply standards exists for the gas sector. For gas transmission and distribution the network is required to be designed to be able to withstand the failure of its single biggest asset and still deliver a peak day's demand in a winter with a five per cent chance of occurring in any given year – or a one in twenty year winter.¹⁸ A draft system performance standard has also now been produced for gas supply. This will require the National Energy System Operator to assess whether the gas supply will be sufficient to meet demand in defined weather events such as a seven, 11 or 15 day cold snap.¹⁹ There is also an existing measure for the electricity system – loss of load expectation – which is defined as the number of hours per year in which supply is expected to be unable to meet demand under normal operation of the system.²⁰ But this metric is based on an average weather year and does not stress test against extreme conditions such as a wind and solar drought in winter when demand is highest.

In the future it will be more challenging to understand the system's capacity to supply electricity. There are multiple forms of electricity supply, each with its own risks. For example, the system as a whole will need to cope with a wind drought where a large proportion of wind turbines are not generating. Uncertainties about the future make-up of the system also add to the challenge as consumers increasingly feed into the network as well as draw from it. Consumers feeding domestically generated renewable energy or electric vehicle battery storage into the grid increase the number of unknown variables and while this could make the system more resilient, it increases the challenge of understanding the system's underlying level of resilience. Uncertainties also arise because different parts of the system are governed by a patchwork of different licences, standards and expectations and no one part of the system has an overarching understanding of how these fit together to deliver overall system resilience.

There are multiple means of building resilience into the system. Government could further strengthen system capacity through the Capacity Market to provide generation at times of system stress, and use the Demand Flexibility Service to incentivise demand reduction. This is broadly how the system is managed today, but government could choose to go further – for example, by developing a strategic energy reserve to deal with severe scenarios, as the Commission recommended in its second *National Infrastructure Assessment*.²¹ This would provide a long term store of energy, though it would still require accompanying generation capacity to ensure the required electricity can be generated. These approaches may or may not be augmented by an overarching electricity supply customer outcome standard, but whichever solution government adopts, it should meet the below tests raised by stakeholders at the Commission's energy sector resilience roundtable:

- **Be measurable:** The National Energy System Operator should compare demand scenarios with available sources of supply.
- **Consider probabilistic scenarios:** The National Energy System Operator should be able to assess whether the system will be able to cope with scenarios such as wind drought with a specified annual probability.
- **Stress test against a range of future energy generation scenarios:** The future makeup of the electricity system is unclear, particularly the take up of domestic renewables and flexibility, such as vehicle to grid. The system operator should consider a range of scenarios and assess the supply and demand balance against a reasonable worst case.
- **Consider the system as a whole:** Generation, transmission and distribution must be considered together to avoid a situation where, for example, enough electricity is generated but cannot be transmitted due to resilience failings in the transmission or distribution network.
- **Make use of existing measures:** Any resilience measure or standard should make use of existing measures. For example, generators with Environment Agency issued permits are already required to develop climate change risk assessments to help them address future resilience threats. Equally, reporting under the Task Force on Climate Related Financial Disclosures requires scenario planning which could help build understanding of the sector's resilience.

- **The need to differentiate the new normal from extremes:** Energy system service restoration targets are already subject to conditions in the case of extreme weather events. With a changing climate, Ofgem will need to review its extreme weather trigger thresholds to set out what constitutes ‘new normal’ weather where services are expected to function as normal, and what constitutes a climate extreme where service may be less reliable or take longer to restore.

In addition to understanding the impact of climate extremes on the system’s ability to generate and transmit energy, investment in the transmission and distribution system must factor in changes in the climate which might affect asset lives, and therefore maintenance expenditure. Ofgem’s existing Network Asset Risk Metric considers the existing health of assets in the system and the likely efficient funding required to maintain system performance. This metric should incorporate threats to the system from increased deterioration due to chronic stresses caused by changing climate conditions. Distribution and transmission systems should also be stress tested against acute threats including flooding.

Next steps for the Department for Energy Security and Net Zero, Ofgem and the National Energy System Operator

Across the energy transmission and distribution systems, the Department for Energy Security and Net Zero should consider how existing measures of future asset health can adequately factor in changes in climate related threats. Across the generation, transmission and distribution systems, the department should consider the existing standards landscape to consider whether an additional future energy supply system performance standard is required to ensure resilient supplies. Indicative timelines for this activity for each sector are set out below.

Electricity distribution

Ofgem will need to consider whether existing resilience standards for electricity distribution are appropriate as part of the price control process that will begin later this year. Work on resilience should be carried forward in the next electricity distribution price control. Distribution Network Operators should explore what action would be required to maintain their existing service levels in the climate resilience strategies they are required to submit as part of that price control. The Commission will also consider resilience as part of its current study on the electricity distribution network and will work with Ofgem and the Department to ensure recommendations in this area can effectively inform the process.

Electricity transmission and gas transmission and distribution

As the price control for the period 2026-31 is already well advanced for electricity transmission and gas transmission and distribution, the Commission recommends that any additional resilience standards could be factored into the following price control (2031-36), with reopeners enabling earlier investment if desirable.

- **December 2025:** Ofgem and the Department should identify gaps in levels of service where resilience standards would be appropriate.
- **December 2027:** Companies submit evidence on indicative costs of different levels of resilience, including factoring in climate resilience.
- **December 2028:** Ofgem publish 2031-36 price control methodology consultation, and government decide appropriate resilience levels for any new standards for that price control.
- **July 2030:** Draft determinations give an initial view on funding for resilience in the 2031-36 price control.

Electricity generation

As highlighted above, electricity generation could present new challenges in future as the system's complexity grows. The National Energy System Operator will be conducting annual risk assessments to set out risks to the system in 1-5 years, 5-10 years and in more than ten years. While it will not be possible to do so in time for the first risk assessment in summer 2025, in future years the National Energy System Operator should quantitatively assess future risks to supply, with government taking action to ensure appropriate levels of resilience are designed into the system as it evolves. The Commission's second *National Infrastructure Assessment* has supported this process by modelling future flexibility needs and recommending the development of 60GW of short duration flexibility and 30TWh of persistent flexible generation by 2035.²²

Transport sector

Transport is a critical enabler for the wider economy, ensuring workers can travel to their workplaces and ultimately keeping other critical services such as schools and hospitals open. Yet, as a sector, transport has the fewest resilience standards and measures of the sectors the Commission considered.

The analysis at Annex 1 suggests resilience gaps for National Highways because there are no targets for structural condition, technology availability, drainage resilience or the geotechnical condition of assets. While there are sometimes detailed requirements for new assets, such as a requirement for drainage design for new roads to be resilient to floods with a one per cent annual probability, this does not apply to existing assets.²³ With climate change, it is also likely that the probability of severe flooding will increase, potentially requiring upgrades to drainage even for those roads originally designed to that standard.

In the local roads sector, the position is worse because there is now not only no required condition score for local roads, but there is also no consistent measurement metric.²⁴ This means it is not possible to compare the condition of local roads in different local authority areas.

For the national rail network there are metrics which consider future asset condition, such as the Composite Reliability Index and the Common Safety Indicators, but these do not consider how future threats such as climate change may alter the future sustainability of the asset base.²⁵

There is currently no target for expected service recovery times, above and beyond overarching punctuality and reliability metrics which will be more affected the longer services are not recovered.

Ports in the UK operate through three main models: privately owned ports, ports which are run by trusts, and ports which are owned by Local Authorities. All of these ports are subject to safety regulations.²⁶ Closures of port services can be driven by a range of factors including adverse weather conditions and vessel groundings. Many ports compete for custom, incentivising resilience, because if one port is closed, some shipping can be diverted to another port. However, as preparations for leaving the EU demonstrated, some ports, such as the Port of Dover, are key and irreplaceable nodes in the UK's transport system. Government should establish a comprehensive list of such key sites and the resilience they are expected to provide. In some instances, major wharves are also safeguarded by the Secretary of State for Housing Communities and Local Government for the purposes of water-borne freight handling. Major wharves should be considered as part of the key sites review.²⁷

In the airport sector all airports offering commercial services are required to have a safety licence. These include requirements for back up power to keep runway lights on to enable planes to land in emergencies. Both Heathrow and Gatwick are subject to economic licences reviewed by the Civil Aviation Authority and these licenses include resilience conditions. The Civil Aviation Authority also regulates the two arms of air traffic control – control towers at airports which are competitive services, and high air traffic control which is an economic monopoly run by NATS (formerly the National Air Traffic Services). The latter is subject to an economic licence which includes resilience requirements.²⁸ As with road, rail and ports, government should establish a key route and node strategy which indicates if and where it might require specified levels of resilience for priority routes or airports.

Overall, there are two major potential gaps across the sector:

- **Forward looking asset health standard:** In both the road and rail sectors, resilience is in part a facet of overall asset health. Neither the road nor rail sectors have a comprehensive, consistent, or forward looking measure of asset health which incorporates future threats such as climate change. Without a target for this, it is difficult to see how government can determine whether the levels of funding it is allocating for maintenance are sustainable in the long term without creating a cliff edge backlog of asset maintenance.
- **Resilience of key nodes:** Some journeys are critical because they are inherently single modal or enable critical services. Equally, as with the energy and water networks, the transport network is in some locations dense and in others sparse. This is driven, in the road and rail sectors, by factors such as population density and the geographical challenges of building out the network. The result is that some journeys are relatively replaceable, as with journeys over Hammersmith Bridge, which has been closed to motor traffic since 2019, but which lies in a dense part of the network where traffic can divert to Chiswick or Putney two miles away to cross the Thames. But the consequences of failure of the QE2 bridge are far more severe, as anyone wishing to cross the Thames from Essex or Kent would need to divert through the already congested Blackwall Tunnel 19 miles upstream.

Government should explore whether key nodes and routes in the UK's road, rail, port and airport transport network should have different service levels – such as being kept open even in extreme weather scenarios. It should also set out trigger scenarios whereby for some routes action changes from maintaining services to advising against travel. Past studies have called for this and the government set out an initial view of key routes.²⁹ Government also identified some routes during the Covid-19 pandemic.³⁰ This could be a starting point for an overarching and wider review of key route resilience.

In the transport sector resilience roundtable, stakeholders highlighted the following considerations when drawing up future resilience standards:

- **The need to fund data collection:** In the transport sector some assets, such as rail embankments, can be almost 200 years old, with little data about how they were constructed. Further funding is required to understand the condition of some of these assets as well as how they respond to climate extremes before the level of resilience systems can offer can be understood.
- **The need to differentiate the new normal from extremes:** Service reliability on the rail network in particular already has exclusions for extreme weather, such as heavy snowfall, where it might be unsafe to encourage passengers to travel unless necessary. With a changing climate, decisions will have to be taken about what constitutes 'new normal' weather, and what is a climate extreme where it is allowable to limit service provision. These should be informed by the potential for risks to passenger safety such as needing to 'detrain' passengers from stranded trains.
- **Funding needs long term focus:** Stakeholders reported that to be funded, schemes often need to demonstrate that they can deliver outputs in one to two years. As projects aimed at strengthening resilience rely on probabilistic events occurring, their benefits may not materialise in the short term and, as a result, they can be overlooked for funding. However, building in resilience can be cheaper in the long run if the alternative is expensive rebuilds in the event of weather hazards materialising.
- **Resilience must be cross-modal:** A resilience strategy should consider the multi-modal nature of transport and ensure that if, for example, a rail or road route needs to close, there is an alternative route or mode of transport available, especially for essential workers. Any strategy should also encompass all required uses of the road, rail, port and airport networks, including freight. In developing this strategy government should manage tensions between infrastructure in public ownership which can access government support, and privately owned and operated infrastructure which cannot. It must also manage tensions between different modes which can be in competition for both passengers and freight.
- **Communicating resilience gaps:** Information on key nodes in the UK's transport system is potentially sensitive as publicly setting out critical points could make them more vulnerable to attack from malign actors. Government will need to strike a balance between communicating a level of service the public can expect and protecting sensitive information.

Next steps for the Department for Transport

Government should explore filling the gaps the Commission has identified relating to forward looking asset health and a high level resilience strategy for key nodes and routes. Operators report that if they had a high level view, for example setting out that a particular railway line should be almost always operational, while a different specified route can be expected to shut down once a year, they would be able to develop and cost solutions to deliver this. This would then enable government to review these costs and determine whether the overall level of resilience proposed is appropriate. While this review may not be publishable in full due to the security implications of publicly identifying key routes, the Department should consider how it can communicate levels of resilience users can expect from the transport network.

Timelines for filling these gaps are set out below.

National Highways

Highways investment is driven by the Road Investment Strategy. The next strategy, the third covering 2025-30, is due to be announced shortly. National Highways should develop forward looking asset health metrics to inform their maintenance strategy in this road period and planning for the next strategy, covering 2030-35. A high level timetable for planning is set out below:

- **December 2025:** National Highways and regulators agree gaps in standards they wish to address in Road Investment Strategy 4, providing advice to government for a final decision. Government should support this with a high level steer on which routes should be subject to which expected levels of resilience.
- **March 2027:** National Highways submits evidence to regulators on indicative costs of different levels of resilience, including climate resilience.
- **September 2028:** Government selects a desired level of resilience which can then begin to be factored into investment decisions. Investment may need to be delivered over several strategy periods.
- **2029:** Final decision on Road Investment Strategy 4 investment.

Network Rail

Strategic rail investment will be driven by the next control period, which commences in 2029. If government sets out a high level strategic direction, Network Rail can advise how much this might cost and how long this might take to be designed into its systems.

- **December 2025:** Network Rail and regulators agree gaps in standards they wish to address, submitting advice to government for a final decision. Government should support this with a high level steer on which routes should be subject to which expected levels of resilience.
- **2026-28:** Network Rail sets out the cost of the high level steer on resilience levels, including climate resilience and the timelines required to achieve them. The appropriate timeline may span several control periods depending on the quantum of investment required.

- **2028:** Government takes a final decision on control period eight investment, including determining whether its proposed level of investment is appropriate. Government may also begin the process of revising its high level resilience strategy for control period nine.
- **April 2029:** Control period eight investment commences.

Ports and airports

By the end of 2025, to the same timeframe as a high level strategy for strategic roads and rail, government should identify key nodes in the UK's port and airport networks and set out high level expectations for service resilience. Government should also consider whether the existing governance frameworks are sufficient to support the implementation of desired levels of resilience.

Local roads

The workshops found that no expected levels of resilience exist for local roads and that there is no consistent metric for comparing the condition of local roads between authorities. In its second *National Infrastructure Assessment*, the Commission recommended that government devolve five year transport budgets to local authorities in time for the next spending review. The next multi year spending review will run for at least three years from 2026-29.³¹ Government should devolve funding in this spending review and, in the longer term, develop a consistent metric for measuring the condition of local roads and set out a high level ambition for a target level of resilience, set out in Local Transport Plan Guidance. In 2023, 20 per cent of local authorities did not share data with the Department for Transport on the proportion of A Roads that should be considered for maintenance.³² The Department will need to increase its understanding to assess the extent of any maintenance backlog and the timeframe needed to both bridge this backlog and achieve desired levels of resilience.

Transport in Mayoral Combined Authorities

In its second *National Infrastructure Assessment*, the Commission confirmed its belief that local transport decisions are best taken at local level. In this report the Commission has not been able to analyse the resilience requirements of regional transport bodies under Mayoral Combined Authorities such as Transport for Greater Manchester. However, in order to ensure their services are resilient, regional transport bodies should be clear about the levels of resilience they are targeting, and that this factors in the levels of resilience set out for the strategic road and rail network above.

Water sector

There is already a set of resilience standards covering the water sector through a mixture of legislation and regulation. However, stakeholders in the water sector workshop agreed that there were notable gaps in expected resilience to peak water demand and in water resource system redundancy.

Both of these areas would ultimately lead to water companies receiving regulatory penalties through the Outcome Delivery Incentive for customer supply interruptions but relying on this has disadvantages:

- 1. This is a lagging measure:** By the time these resilience failings become regular enough issues to affect Outcome Delivery Incentives, it could be costly to build in proactive resilience. Without forward looking resilience measures it is possible that water companies will be incentivised towards investments which maintain services short term at the expense of long term resilience.
- 2. Investment case:** Without measurable resilience standards it will be challenging for companies to build further resilience into their systems. Without a clear target to aim for, the need for resilience spend could be challenged by regulators trying to manage upward pressure on bills.
- 3. Consumer tolerance:** If the alternative to proactive water supply resilience is to supply customers with bottled water in the event of an outage, this needs to be tested with customers to ensure they would not instead be willing to pay any additional cost of building greater resilience into systems rather than facing this inconvenience.
- 4. Lost opportunity for efficient investment:** No new major reservoirs have been built in the last thirty years, but the development of twenty new water resource schemes, including nine new reservoirs is funded in Ofwat's draft determinations for Price Review 24.³³ This investment will also require additions to the overall supply network to support moving water around the system from these new schemes. If effectively planned and phased in, supply resilience could be delivered as an additional benefit of this investment at less additional cost than if delivered as a standalone investment programme.

All resilience standards require careful scoping and planning to ensure they do not incentivise unnecessary or poor value for money investments. Below are some considerations for the Department for Environment, Food and Rural Affairs in setting resilience standards for the resilience gaps the Commission has identified.

Peak water demand

Water resource systems rely on treatment works treating water continuously, but consumers do not use water at the same volume across a week because usage often looks different on a weekday compared to a weekend and in the daytime compared to the middle of the night. Treated water is therefore stored in service reservoirs so it is available to be put into supply when it is needed. If demand outstrips supply over a long hot period, as was seen in summer 2022, then it is possible that service reservoirs will run out of water and treatment works will not be able to treat and store enough water to supply households.

The ultimate result is consumer loss of water supply. This creates the real risk that while the Commission's estimated £21 billion programme of investment in long term drought resilience will deliver enough raw water to meet needs over a dry summer, water companies may not be able to treat and put this water into supply fast enough to meet daily or weekly demand.³⁴

When setting a resilience standard to address this problem the department should consider:

- **Timing:** The standard should be phased in so it can be delivered alongside investment in long term drought resilience.
- **Relationship with demand management:** Water companies have a key role to play in the Environment Act target to reduce water demand to 110 litres per person per day by 2050 and to reduce non-household demand by 15 per cent.³⁵ Any peak standard should consider how it factors in activity to flatten overall demand and how the embrace of digital technologies might potentially support the movement of demand peaks in different supply areas. It should also consider the possibility of future demand side responses such as enabling interruptible supplies for business customers in exchange for tariff reductions.
- **Consider demography:** The metric would need to consider differing levels of peak demand for areas with houses with gardens compared to areas with flats.
- **Creating new resilience risks:** A balance should be struck between action to meet peak demand and avoiding causing new problems. Too much water in the supply system so that supply reservoir turnover decreases too much could lead to stagnation threatening drinking water quality.

Single source of supply

There is also a risk that there is insufficient redundancy in the water supply system. In some areas properties rely on a single supply asset and if this fails all of the households supplied will lose access to clean water. This risk may be obscured in the short term. For example, the number of mains serving an area may be reduced from two to one due to cuts in maintenance, meaning an area is vulnerable to single asset failure, but this would not immediately lead to customer supply interruptions. Any standard should consider the system as a whole, from water source to treated water discharged from taps at sub Water Resource Zone level.

When setting a resilience standard to address this problem, the department should consider setting limits on the level of resilience expected. In some areas, such as isolated hamlets, it may not be practical or affordable to develop more than one source of supply. This could be addressed by setting a population cap, by saying for example that no group of more than a set number of houses should be supplied by a single source of supply. The exact cap will need to be determined by cost modelling and discussion between regulators and water companies. Alternatively, companies could undertake risk modelling to understand the probability and consequences of failure from single sources of supply.

Infrastructure operators should also consider single sources of failure caused by system interdependencies when planning to address single sources of supply – such as two sources of supply which rely on the same electricity substation.

Forward looking asset health standard for water and wastewater assets

As the Commission highlighted in its Chair's letter to the economic regulator, Ofwat, in 2023, currently the metrics used to assess long term system resilience – mains repairs, unplanned outages, and sewer collapses – are lagging indicators. While they provide information about the condition of assets today, they do not on their own give insight into the future condition of assets because their only data point is the point of failure. At present there does not appear to be a comprehensive and consistent understanding of asset condition across the sector and how this may change in future. A more complete view of asset health in the sector would support a multi-asset management period view of the investment required to maintain asset health and, consequently, service performance and reliability.³⁶

Sewer flooding

The Commission identified a gap in resilience standards for wastewater services relating to the risk of sewer flooding. Ofwat has an Outcome Delivery Incentive for companies to reduce the risk of properties suffering internal sewer flooding. Alongside this, Ofwat issues reporting guidelines, though without targets, on the number of properties at risk of flooding from a storm event with a two per cent annual probability – or a one in 50 year storm.³⁷ This metric is forward looking and designing to a target risk reduction level would improve system resilience to future threats rather than only addressing current system issues. The target would be to reduce the number of properties at risk of being affected, and consequently the number of properties actually affected would reduce over time.

Interventions which reduce the risk of storm related sewer flooding can also help to address the risk of surface water flooding, which has the same cause – heavy rainfall overwhelming the drainage network. The Commission has previously recommended that the government set a long term target for reducing the number of properties at high and medium risk of surface water flooding. It also called for upper tier local authorities, water and wastewater companies and, where relevant, internal drainage boards, to produce joint costed plans to reduce risk.³⁸ Any metric used to apply a service standard for storm relate sewer flooding should factor in these targets.

The other area where resilience failings have been highlighted – storm overflow discharges – is currently subject to a target of reducing spills to ten a year.³⁹ While this target may be subject to review, the presence of measurable targets, regardless of the level at which they are set, enables clarity about the desired level of resilience.

Further considerations

There are further considerations which are applicable to all of the resilience gaps highlighted above.

- **Different starting positions:** As there has been no clear resilience target to date, different companies will require different levels of investment and different target dates to achieve a new resilience standard.

- **Common metric:** Any metric should be common across all companies to avoid the risk of a resilience postcode lottery. This would give consumers and businesses across the country clarity about what level of resilience they can expect. The level of the standard may vary depending on the risk being addressed. For example, reducing sewer flooding in some areas will be more costly than in others.
- **Relationship with Outcome Delivery Incentives:** These standards would help companies achieve an Outcome Delivery Incentive – mains bursts – which is currently standardised across all companies in England. The resilience target should therefore also be standardised to avoid giving some companies an unfair advantage in outperforming this incentive.
- **Consider the system as a whole:** Whole systems – such as raw water storage, transport and treatment and clean water distribution - must be considered together to avoid a situation where, for example, enough water can be stored, but cannot be treated and circulated.
- **Consider what is being incentivised:** Standards should where possible avoid incentivising specific behaviours – such as building additional unnecessary redundancy into systems – when other forms of resilience such as enhanced reliability and robustness of existing assets may be more efficient.
- **Consumer preference:** Setting standards will ultimately be a political decision but it should be informed by centrally coordinated investigation of consumer preferences using a range of methodologies as different methods can yield very different results.⁴⁰
- **The need to differentiate the new normal from extremes:** With a changing climate, decisions will have to be taken about what constitutes ‘new normal’ weather under which systems are expected to function as normal, and what is a climate extreme where it is allowable to limit service provision. This will include updating return periods as the climate changes so that, for example, due to climate change a storm with a two per cent annual probability in 2050 will be more severe than a storm with a two percent annual probability in 2025.

Next steps for the Department for Environment, Food and Rural Affairs

In the water sector, the setting of resilience standards will be too late to influence the 2024 Price Review, so standard setting should be done over the next asset management period to target investment for Price Review 2029 and influence earlier system planning by water companies. The Commission proposes four stages to developing and implementing those resilience standards:

1. **December 2025:** The Department for Environment, Food and Rural Affairs, Ofwat, the Environment Agency and the Drinking Water Inspectorate should collectively identify gaps where resilience standards would be appropriate. As a starting point the department should consider the gaps the Commission has highlighted above.
2. **December 2026:** Water companies submit evidence on indicative costs of different levels of resilience, including factoring in climate resilience. Regulators would supplement this with centralised consistent analysis of consumer views to avoid resilience varying by region.

- 3. December 2027:** Ofwat finalises Price Review 29 methodology incorporating the government's target resilience standards. Ultimately, selecting a level of resilience is a political choice which must be in the hands of government. Government may or may not wish to override the cost/benefit analyses it receives because it believes the importance of resilience goes beyond cost. While the level of service is a choice for government, in order to ensure stability of delivery, this choice should not be revisited once made until the next price review cycle.
- 4. 2028-29:** The selected level of resilience should be factored into the price control cycle.

Next steps for Cabinet Office

This report has set out issues for government to consider on a sector by sector basis, with a view to enabling the consideration of interdependency risks once sectoral level resilience is revealed. Once these interdependencies are identified it will be for Cabinet Office, as the government body with overall responsibility for resilience, to support departments in identifying how these can be managed.⁴¹ For example, a water treatment works which does not have a resilient electricity supply – because it is supplied by only one source – may find it cheaper to invest in additional back up generation as the cost of additional supply would be too expensive or too carbon intensive. But if several critical infrastructure facilities are located in the same place, it may be more cost effective or less carbon intensive to build a new line rather than expect them all to rely on additional back up generation. As noted above, tools such as the Climate Resilience Demonstrator have shown how data sharing can enable more efficient collective systems level resilience investment.

To support the sharing of information Cabinet Office should consider how it can enable greater data sharing between sectors to avoid individual operators having to engage in lengthy legal discussions on the implications of sharing data.

The below timetable sets out how Cabinet Office could support the management of interdependency risks to ensure efficient and resilient outcomes over the next standard setting cycle:

- 1. End of 2025:** Cabinet Office collates and publishes resilience standards for the digital and telecoms, energy, transport and water sectors.
- 2. End of 2027:** Cabinet Office sets out tools and principles for managing interdependency risks across all sectors. This could include making available funding for tools such as the Climate Resilience Demonstrator to spatially map resilience threats and inform collective decision making.
- 3. End of 2030:** Where necessary, Cabinet Office collates and publishes updated resilience standards produced by departments which include deeper consideration of interdependency risks.

Glossary

Capacity market	The Capacity Market ensures security of electricity supply by providing a payment for reliable sources of capacity
Cascade failure	The failure of one infrastructure system – such as water supply – triggered by failures in other parts of the system – such as electricity supply.
Climate Resilience Demonstrator	A climate change adaptation digital twin project that looks at the impact of flooding on energy, water and telecoms networks.
Demand Flexibility Service	The Demand Flexibility Service aims to incentivise domestic consumers and industrial and commercial users to voluntarily reduce or flex their demand.
Digital and telecoms sector	Fixed and mobile telephony and broadband services provided by telecoms infrastructure
Forward looking and lagging metrics	Forward looking metrics measure likely system performance into the future, while lagging metrics measure actual system performance today, but not the ability of a system to maintain that performance into the future.
Infrastructure operators	All those owning and operating infrastructure services, systems or assets.
Inter-dependencies	In the context of an infrastructure system, interdependencies are other infrastructure services that one system relies on to provide its own service.
Metrics	Metrics are means of measuring service performance or quality.
Outcome based service standard/target	Standards or thresholds that are used to express the quality and/or availability of an infrastructure service than an infrastructure provider should aim for.
Outcome Delivery Incentive	An incentive mechanism used by Ofwat to reward water companies for achieving certain target service levels, and to penalise them for failure to achieve them.
Peak demand	The highest level of demand in a system over a short period of time.
Recovery standard	A standard specifying what is expected in the event of a service failure, both in terms of restoration of service and in terms of support services to customers while the service is down.

Redundancy	Additional capacity within a system which means a service can continue to run despite the failure of an individual asset
Return periods	The annual probability of an event occurring, such as a drought which has an annual probability of ‘returning’ once every 500 years – or has a 0.2 per cent annual probability.
Stress testing	Testing a representation or simulation of a system to reveal its performance under certain conditions or to reveal the conditions that could lead to failure.
System performance standard	A standard that an infrastructure system is expected to meet which may not relate directly to customer experience. For example, a requirement for a system to continue to function in the event of a failure of its largest asset is a redundancy focused system performance standard.
Vulnerability	In the context of infrastructure systems, a vulnerability is a characteristic of the system or weakness in the system that has the potential to lead to partial or full failure of the system.
Water Resource Zone	An area within which the sources of water and distribution of water to meet demand is largely self contained.

Annex 1 - Existing resilience standards

The Commission’s report on resilience standards highlights a number of potential gaps in resilience standards that government may want to address in a first round of standard setting. However, a range of customer outcome, system performance and recovery standards already exist across the digital and telecoms, energy, transport and water sectors. The table below sets out these standards. For the Commission’s purpose a standard is a measured level of service provided to customers, a measured expected level of system performance, a measured speed of service recovery after an outage or required level of service during recovery.

Sector	Customer outcome standard	System performance standards	Recovery standards
Digital & telecoms	None	<p>In the telecoms sector, these standard are expected ways of delivering a service. Providers can deviate from this, but would be expected to explain why in the event of a service outage:</p> <p>Redundancy: Ofcom set out redundancy requirements – for example having street cabinets connected to more than one ‘parent’ to avoid single points of failure.⁴³</p> <p>Power back up – core sites: Ofcom expects core sites in networks to have five days of back up power in the event of a power outage.⁴⁵</p>	<p>Compensation for outages: Services signed up to the automatic compensation scheme are required to compensate customers for service outages longer than two working days.⁴²</p> <p>999 calls for landline customers in a power cut: Landline service providers should ensure customers can contact 999 for at least one hour in a power cut.⁴⁴</p>

Sector	Customer outcome standard	System performance standards	Recovery standards
		<p>Power back up – active cabinets: ‘active’ street cabinets – which rely on an electricity supply from the grid - are expected to either be phased out in three - five years or to have four hours of back up generation.</p> <p>Flood risk: Ofcom expects core sites to either be located outside the Environment Agency’s Extended Flood Outline or to be able to divert services to another site in the event of a flood.⁴⁶</p>	
<p>Energy</p>	<p>Electricity transmission – service availability: National Grid Electricity Transmission currently has a target of not more than 147 megawatt hours of electricity not being supplied due to network reliability annually.⁴⁷</p>	<p>Electricity transmission – voltage and frequency: The transmission network operates to safety standards – voltage should not be 10 per cent above or below expected voltage for high voltage lines and 6 per cent for low voltage lines and frequency should not vary by more than 1 per cent from expected frequency.⁴⁸</p>	<p>Gas and electricity distribution – target time for service restoration: Electricity providers have a 12 hour time limit for restoring supplies in normal weather, rising to 24 or 48 hours in extreme events. Gas distribution companies have 24 hours to restore supply before compensation is payable.</p>

Sector	Customer outcome standard	System performance standards	Recovery standards
	<p>Electricity distribution – supply outages: Household and non-household customers without power for at least three hours on more than four occasions are entitled to compensation.⁴⁹</p> <p>Gas distribution – service availability: Companies have a target for the maximum amount of time service is unavailable due to unplanned outages.⁵²</p> <p>Gas transmission and distribution - safety: Companies have a target for the percentage of uncontrolled gas escapes dealt with in one hour and controlled within two hours.⁵⁵</p> <p>Heat networks: The previous government recently consulted on introducing standards for heat networks, including on security of supply.⁵⁷</p>	<p>Gas transmission and distribution - peak demand: The network is expected to be able to deliver the volume of gas required to meet peak demand in a winter with a 5 per cent annual probability, despite the failure of the single largest system asset.⁵⁰</p> <p>Electricity Distribution – flood risk: Substations serving more than 10,000 domestic or business customers who cannot be diverted to be another supply must be resilient to a flood with a 0.1 per cent annual probability.⁵³</p> <p>Electricity transmission - redundancy: The electricity transmission system is required to have minimum standards of system redundancy – including that no loss of power should occur as a result of the failure of any single asset.⁵⁶</p>	<p>Gas and electricity distribution and heat networks – priority services register: Gas and electricity distribution companies are required to maintain a priority services register of vulnerable customers and offer services tailored to need while supply is unavailable.⁵¹</p> <p>Electricity system restoration: The electricity system as a whole is required to be able to restore 60 per cent of regional capacity within 24 hours, and 100 per cent of UK electricity demand within five days.⁵⁴</p>

Sector	Customer outcome standard	System performance standards	Recovery standards
Transport	<p>Strategic road network – roadwork delays: National Highways have a target to keep roadworks related delays below a certain impact score measured in weighted lane meter days.⁵⁸</p> <p>National rail – punctuality: The rail network has a punctuality target measured by the percentage of stops arrived at more than one minute after scheduled arrival.</p> <p>National rail - reliability: The rail network has a target for the percentage of trains not running all or part of their journey. Within this Network Rail has a Composite Reliability Index with regulatory penalties for service affecting failures.⁶¹</p> <p>National rail – service in adverse weather: Network Rail have different service expectations in adverse cold weather, where punctuality may be affected, and extreme cold weather, where the priority is getting customers home over running a normal timetable.⁶²</p>	<p>Strategic road network – pavement condition: National Highways have a target for 95 per cent of the network’s pavement to require no further investigation.⁵⁹</p>	<p>Strategic road network – recovery after incidents: National Highways has a target for 86 per cent of incidents affecting traffic flow to be cleared within one hour.⁶⁰</p>

Sector	Customer outcome standard	System performance standards	Recovery standards
Water and waste-water	<p>Water supply interruptions: Water companies have targets for reducing the duration of planned and unplanned supply interruptions above three hours and separate targets for unplanned supply interruptions. The unplanned outage standard varies between companies.⁶³</p> <p>Drinking water quality: Water companies have targets to reduce the risk of non compliant water entering supply measured by the Compliance Risk Index.⁶⁷</p> <p>Sewer flooding: Water and wastewater companies have targets for reducing the number of internal sewer flooding incidents per 10,000 connections. This does not vary between companies.⁷⁰</p> <p>Pollution incidents: Water and wastewater companies have a target for reducing the number of pollution incidents per 10,000km of sewer.⁷³</p>	<p>Mains repairs: Water companies are given targets to reduce the number of required mains repairs.⁶⁴</p> <p>Cutting leakage: Water companies are given targets to reduce the amount of water lost to leakage.⁶⁵</p> <p>Safety of raised reservoirs: Water companies have to meet compliance standards to ensure the safety of raised reservoirs.⁶⁸</p> <p>Drought resilience: Water companies are required to plan future water resources to ensure resilience to a drought with a 0.2 per cent annual probability.⁷¹</p>	<p>Compensation for lost supply: household customers have a right to payments if their supply is not restored within 12 hours, or 24 hours in the event of a mains burst.⁶⁶</p> <p>Water supply during a service outage: household customers must be supplied with ten litres of water per person per day in the event of a supply outage.⁶⁹</p> <p>Priority services register: Water companies must maintain a priority service register with bespoke services based on need for registered vulnerable customers in the event of a supply interruption.⁷²</p>

Sector	Customer outcome standard	System performance standards	Recovery standards
	<p>Wastewater treatment works compliance: Water and wastewater companies have targets to ensure their discharged wastewater complies with Environment Agency permits. The level of treatment required depends on the population equivalent served by the works and the water body it is being discharged into.⁷⁴</p>	<p>Sewer collapses: Water and wastewater companies are given targets to reduce the number of sewer collapses per 1,000km of sewer.⁷⁵</p> <p>Combined sewer overflow spills: By 2050 water and wastewater companies are expected to reduce storm overflow spills to no more than an average of ten spills per year.⁷⁶</p>	

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